

# Technical Sessions

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## TS-1

## California-Federal Bay-Delta Program: The Most Comprehensive Ecosystem Restoration Program in the USA—Political Issues

**Chair: Lester Snow—Executive Director CALFED Bay-Delta Program, Sacramento, CA • USA**

### INTRODUCTION— OVERVIEW OF THE CALFED BAY-DELTA PROGRAM AND THE ERP

**Lester Snow**

CALFED Bay-Delta Program, Sacramento, CA • USA

### WHY A HEALTHY ECOSYSTEM IS INTEGRAL TO SOLVING MANY OF THE BAY-DELTA WATER SUPPLY RELIABILITY PROBLEMS

**Mary Nichols**

California Resources Agency, Sacramento, CA • USA

Secretary Nichols will comment on the role of ecosystem restoration in the resolution of California's long standing water use conflicts. She will also discuss the benefits of an inclusive planning process and the State-Federal partnership.

### THE TRADE-OFFS NECESSARY FOR GATHERING SUPPORT FOR THE ERP FROM WATER USERS AND ENVIRONMENTAL COMMUNITIES

**Tom Graff**

Senior Attorney, Environmental Defense Fund, Oakland, CA • USA

The environmental community has advocated the restoration of the Bay-Delta environment for decades. After 150 years of decay, CALFED's Ecosystem Restoration Program holds great promise to restore balance to the ecosystem. The balance we seek is considerably more than the traditional mitigation for the latest round of environmental insults. What we want is a restoration, or at least substantial rehabilitation, of the system. We agree with CALFED's apparent decision - to focus on the reestablishment of ecosystem processes and functions as the basis of its program. There are elements of the program that need to be strengthened in the planning process, there are guarantees and assurances that must come out of the negotiations, and there are funding issues that must be resolved in the political process before we can declare the Restoration Program a success. The Restoration Program is weak on measurable objectives. While we accept that there will always be scientific uncertainties, we insist that the goals and objectives of the program are quantified to the extent possible. We want to know what is in this grand deal for the environment. We do not expect to see the Restoration Program replace the laws and regulations that currently protect this fragile environment, although we too would like to limit our need to rely on litigation and regulation to achieve our objectives. The political process must assure the funds to bring about restoration, but this will eventually require a substantial fee associated with the use and depletion of Delta natural resources as well as funds from public treasury. Finally, as we move forward to establish a restored environment to its rightful place as an essential element of a vibrant state economy,

we want to make sure that environmental restoration is sustained. The Restoration Program should not be a basis on which to build new unjustified dams and canals. Water conservation, the elimination of water subsidies, and a vigorous water transfer market must be put into place to protect our rivers. Sensible land use and growth management policies have to go hand in hand with habitat restoration. Sound environmental policies coupled with sound economic policies hold the greatest promise for meeting CALFED's multiple objectives.

### CALIFORNIA AGRICULTURE'S DEPENDENCE ON A RELIABLE WATER SUPPLY AND EFFECTS OF ITS INTERRUPTION ON AGRIBUSINESS

**Brenda Jahns Southwick**

California Farm Bureau Federation, Sacramento, CA • USA

California's Central Valley farm community is watching the development of CALFED's Environmental Restoration Program with great interest and a modicum of hope. On the one hand, we see the opportunity to benefit as a partner in improved land stewardship. On the other hand, we are concerned with what appears to be a cavalier attitude toward agriculture being forced to bear an unreasonable societal cost. This result would be contrary to CALFED's adopted principle that there will be no significant redirected negative impacts in the Bay-Delta or other regions of California. Perhaps the most significant benefit we could derive from participating in the Ecosystem Restoration Program is regulatory relief. If the Program performs as predicted, we would expect less conflict between our ability to farm and the regulatory constraints of the Endangered Species Act and similar laws. If this conflict avoidance or resolution cannot be achieved, CALFED will be a resource drain rather than a gain. Second, regulatory certainty is critical to the success of CALFED. We need to be able to work with regulatory agencies in a timely fashion to implement environmental rules and constraints while recognizing the nature-driven requirements of the land and the plants and trees that make up our resource base. We would prefer to be active participants in managing for regulatory mandates as part of our business plan rather than merely reacting to an unexpected administrative or legal ruling. CALFED needs to take a grassroots approach, bottom up rather than top down, and embrace local participation in restoration projects because farmers have technical expertise as well as intimate knowledge of long-term environmental conditions and changes that occur seasonally. Perhaps more importantly, farms make up the existing environment and we want to be treated as partners equal to habitat. Also, CALFED needs to be methodical – massive changes in habitat and resource reallocations may not achieve desired

results. Both regulators and the regulated need flexibility to be creative, to be receptive to changing needs and to not do massive harm. The third outcome critical to a successful Ecosystem Restoration Program is a more reliable water supply. Interruptions in water deliveries always hit agriculture the hardest. We need more water and we want to recapture water supplies loaned to meet environmental regulatory requirements. Further, our present primary concern is that we not lose what we have a legal right to now. Water supply reliability rationally includes development of the operational flexibility in surface and groundwater storage and water transfer programs to meet habitat, agricultural and other needs via use of existing and new supplies. The Environmental Water Account must give CALFED managers the ability to deal with fishery problems and biological surprises without taking water destined for farms in the Central Valley. Finally, the large-scale land use changes with associated water reallocation proposed in the Ecosystem Restoration Plan will permanently diminish the agricultural resource and will do so at a rate and scale exceeding that attributable to urban sprawl. Although CALFED has promised to focus first on existing public land, we know from experience that is not enough to fulfill its ambitious agenda. Large scale and localized conversions from the agricultural environment to habitat, even when it involves willing sellers (a touchy subject), will force fundamental adverse environmental and socio-economic impacts, including loss of critical mass to maintain economic viability. The consequences of those impacts portend profound changes to the California farm community. We have to find a way to protect the water infrastructure that is the foundation of California's booming economy. We also must find a way to protect the most unique and valuable agricultural resources in the world – California land and water. CALFED's biggest achievement would be to allow us to do that as equal partners.

## URBAN ECONOMIC IMPACTS RESULTING FROM AN ECOSYSTEM IN A STATE OF DECLINE

### Pete Rhoads

Metropolitan Water District of Southern California,  
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The reliability of water supplies exported from the Delta and the quality of those supplies are paramount issues for urban water agencies, including the Metropolitan Water District of Southern California. The experience of the early 1990's demonstrated that uncertainties imposed by the Endangered Species Act and the decline of the Delta aquatic ecosystem could directly reduce the reliability of urban supplies. In water quality terms, the quality of existing urban water supplies from the Delta is not optimal and improvements are essential. From one viewpoint, economic health and ecosystem health are closely related and that support for ecosystem improvements will ultimately benefit urban water supply objectives. If the ecosystem isn't healthy, water supply reliability and the economy will also suffer. This perspective has guided urban water community support for ecosystem restoration to date. One of the toughest end-game dilemmas, however, concerns support for the substantial costs for ecosystem restoration. Given practical limitations and ratepayer patience, where should urban water community support be focused to best meet the objectives of enhanced water supply reliability and quality? What is the best balance of source water quality versus treatment? What is necessary to get broad stakeholder support for continuing ecosystem enhancement? Do the potential benefits of ecosystem restoration balance the costs for urban water interests?

## TS-2

### California-Federal Bay-Delta Program: The Most Comprehensive Ecosystem Restoration Program in the USA—Scientific and Technical Issues

**Chair: Dick Daniel—Ecosystem Restoration Program—CALFED Bay-Delta Program, Sacramento, CA • USA**

#### THE ROLE OF EXPERIMENTAL RESEARCH, MONITORING, AND MODELING IN SUPPORT OF ECOSYSTEM RESTORATION

##### Nicholas G. Aumen

Lake Park, FL • USA

Complex and untested ecosystem restoration projects require a solid underpinning of science to increase the certainty with which restoration management decisions are made. Ecosystem restoration in south Florida now is proceeding on a scale unequaled anywhere else. Approximately \$2 billion dollars over the next eight years are committed for: restoration of one-third of the original Kissimmee River channel; reduction of phosphorus levels in agricultural runoff into Lake Okeechobee; construction of more than 16,000 ha of wet-

lands to remove phosphorus from agricultural runoff entering the Everglades; and other restoration projects. In addition, the U.S. Army Corps of Engineers has submitted a hydrological restoration plan, known as the "Restudy", to Congress, with a projected \$7.8 billion dollar price tag over the next 20 years. This restoration plan calls for re-plumbing of south Florida's extensive canal system to provide increased environmental benefits, while still providing water supplies and flood protection to a rapidly expanding population. High-quality science in support of restoration must be carefully planned using a structured, decision analysis framework, including input from managers, scientists, and the public. Research must be directed clearly toward the overall management goals, and should include appropriate levels of long-term data collection, experimental research, and predictive modeling. Scientists must participate in ensuring that research results are used

appropriately. Peer review of science at all phases, but especially through publication of research results in technical venues, guarantees the quality of the science and withstands the challenges, whether in the legal or public arenas, that might arise to good decision making.

#### APPLIED SCIENCE AND ADAPTIVE MANAGEMENT– THE CALFED EXAMPLE

**L.H. Smith<sup>1</sup>** and L.H. Winternitz<sup>2</sup>

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Results of applied science studies are important to policy development and management of natural resources, but political windows of opportunity are often shorter than the time periods necessary for science programs to produce new information and understanding. Furthermore, synthesizing available scientific understanding to address a management question and communicating results to policy makers is probably more art than science. Active adaptive management can improve the use of science in management and policymaking, but can conflict with resource management and regulatory policies, which are often designed to avoid perceived risks. CALFED, a collaborative attempt to find a comprehensive resolution to ecological and water management problems of the Sacramento and San Joaquin River basins and their estuary, has embraced the concept of adaptive management and has produced an initial design of an applied science (monitoring and focused research) program. One of CALFED's challenges in refining the science program is to develop and implement adaptive management experiments that evaluate potential rehabilitation actions. Potential water quality and ecosystem experiments illustrate the possibilities and limitations of implementing adaptive experiments.

#### IS ADAPTIVE MANAGEMENT REALLY GOING TO BE PART OF THE CALFED ECOSYSTEM RESTORATION PROGRAM?

**W.J. Kimmerer**

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The most striking contrast between the CALFED Ecosystem Restoration Program and the other CALFED programs is the degree of confidence in the outcomes. Although the success of actions to shore up levees, improve water quality, etc., can be reasonably predicted, there is little agreement or understanding about what actions will improve conditions in the ecosystem. This situation lends itself to adaptive management, in which uncertainty in expected outcomes is acknowledged, and dealt with through practices that maximize learning with each action taken. However, several potential impediments may hinder the application of adaptive management in the CALFED ERP. The first impediment is a lack of agreement about what adaptive management is, and about what can actually be learned through an adaptive program. The second is that adaptive management is antithetical to the cultures of most agencies, including CALFED: these agencies are tasked with solving problems, and are

expected to know how to do it before starting. The third, related impediment is the conflict between adaptive management and both ESA regulations and the other goals of CALFED, notably the need to provide assurances of water supply reliability and water quality. ERP can take one of two courses: use adaptive management as a buzz-phrase while taking actions that seem reasonable, and tacking on post-hoc monitoring programs; or insist on acknowledging the high degree of unpredictability inherent in the ecosystem, and determine bounds within which adaptive management can really be done while minimizing conflicts with other programs. The first course has been taken so far.

#### ADAPTIVE RESTORATION: A STRATEGIC APPROACH FOR INTEGRATING RESEARCH INTO RESTORATION PROJECTS

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At San Diego Bay, a project designed to mitigate damages due to highway and flood channel construction evolved into a model adaptive management program based on restoration research (i.e., adaptive restoration). For ~10 years, the California Department of Transportation and the US Army Corps of Engineers (mitigators), the US Fish and Wildlife Service (resource agency and regulator), and the Pacific Estuarine Research Laboratory (monitors and researchers) worked together to evaluate the results of ecosystem monitoring and to identify shortcomings of habitat designed for endangered species. Multiple attempts to improve habitat based on field research were followed by the prediction that some mitigation standards would not be achieved for  $\geq 40$  years. Once it was clear that habitat for the light-footed clapper rail could not be provided in a timely manner, the Fish and Wildlife Service set an alternative requirement (removal of fill from another, nearby wetland). A similar adaptive restoration approach is now being used at Tijuana Estuary. Two restoration sites have scientific experiments built into their designs: (1) The 0.7-ha Tidal Linkage has one-half of its marsh plain devoted to an experiment that will show how many of the native salt marsh species need to be planted to achieve desired ecosystem functions. (2) The 8-ha Model Marsh is designed to compare ecosystem functioning in replicate areas with and without tidal flushing. Key to these projects are having a resident research group, long-term research funding, and managers who facilitate scientific involvement. The outcome will be answers to questions that are needed to proceed with the full 200-ha restoration program at this National Estuarine Research Reserve.

## DEVELOPING ESSENTIAL ECOLOGICAL INDICATORS FOR THE SAN FRANCISCO BAY/DELTA/RIVER SYSTEM

Terry F. Young and **Rodney M. Fujita**  
Environmental Defense Fund, Oakland, CA • USA

Every professional who has researched, monitored, or regulated portions of the San Francisco Bay-Delta-River system has been asked the question, “How healthy is this ecosystem?” In order to provide an easily understandable, yet scientifically valid answer to that question, the Environmental Defense Fund convened a panel of nationally-recognized scientists to develop a set of Essential Ecological Indicators. In order to accomplish the task of collapsing a lot of fairly complicated information into a few indicators, the panel considered it important to use a methodical framework to capture the complete array of structural, functional, and compositional elements of ecological integrity. The panel chose not to include stressors, which require a separate set of indicators. Ecosystem attributes and processes in large estuarine ecosystems such as the San Francisco Bay-Delta-River system fall into six categories: habitat quality (including water quality); geomorphology; hydrology; energy and nutrient flows; native biota; and disturbance. Panel members then selected indicators for each category, in part by referring to the more detailed and comprehensive set of indicators that had been proposed as part of the “CALFED” program. The draft Essential Ecological Indicators are the following:

- The number of habitat types, characteristic of the pre-1850 system, that are still represented by a certain number of viable patches
  - The proportion of major habitat types relative to their historic proportions
  - An index of water quality that reflects exposure to important types of contaminants
  - An index of river health that reflects whether the river can meander, flood on occasion, and carry sediment like a natural river
  - An index of marsh health that reflects whether the marsh is complex and growing
  - The proximity of current water flows to pre-disturbance flows
  - An additional flow indicator (still to be defined) that captures the importance of maintaining a natural pattern of variability of flows and salinity
  - An index of productivity in the Bay and Delta
  - An index of native fish species
  - An index of bird species
  - An index of riparian and wetland vegetation
  - An index of species that are habitat specialists
  - An index of native species that have been decimated or extirpated in this system
  - Percent of abundance or biomass of fish, bird, vegetation, and habitat specialists that is comprised of exotic species.
- Many of these indicators will be normalized to reference conditions. The EEIs can potentially become a valuable tool for adaptive management.

## TS-3 **Appropriate Use of the Concept of *Ecosystem Health* in Environmental Management**

**Chair: Robert T. Lackey—US Environmental Protection Agency, Corvallis, OR • USA**

### INTRODUCTION

#### **Robert T. Lackey**

National Health and Environmental Effects Research Laboratory, US Environmental Protection Agency, Corvallis, OR • USA

Effectively resolving complex ecological policy problems or managing most natural resource systems may require something beyond traditional “command and control” or “maximum sustained yield” approaches. Normative science has emerged as a cornerstone of some of the most serious alternatives to traditional environmental or natural resource management. From a suite of alternatives using normative science (i.e., ecosystem management, community based environmental protection, bioregional management, ecological sustainability, ecological integrity, etc.), I use the concept of ecosystem health as an example of a possible alternative approaches to natural resource and environmental management. Increasingly, ecosystem health is heralded as a concept that will help clarify, evaluate, and implement 21st century ecological policy. It is the publicly-asserted cornerstone of many natural resource and environmental manage-

ment programs. As the concept has matured beyond vague explanations, it has become increasingly contentious because it is normative—it embodies a set of inherent values. At the core of debates over the utility of ecosystem health is a struggle over which societal values and preferences will take precedence. The foundation of the concept is the metaphor of human health, but this simple metaphor is both a strength and a weakness. The metaphor provides a simple intellectual framework for describing complex ecological policy issues in everyday terms. It falters, however, in failing to capture the most contentious elements of ecological policy debates—the decisive role played by competing individual and societal values and preferences. In spite of its helpful service in illustrating complex and important policy issues, implementing the concept of ecosystem health is prone to improper use by allowing, if not encouraging, scientists and others of the “professional elite” to select which societal preferences will be sanctioned in ecological policy. Whether current constructs of ecosystem health can be modified sufficiently to overcome inherent weaknesses remains to be seen. Normative science, with its tacitly derived value and preference character, provides little to resolve divisive natural resource or environmental management problems.

## ECOSYSTEM HEALTH: A FLAWED BASIS FOR GOVERNMENT REGULATION AND LAND MANAGEMENT

**Allan K. Fitzsimmons**

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The concept of ecosystem health is ill-fated as a basis for government land use management policies. The idea remains vague. It lacks agreed upon definitions and norms that make it difficult to operationalize. Where one observer of the landscape sees a sick ecosystem, a second viewer may see a wheat field. The spatial units—ecosystems—whose health would be protected are ad hoc mental constructs for which the idea of health has no substantive meaning. More fundamentally, after more than half a century of trying, scholars are unable answer basic geographic questions regarding ecosystems that are prerequisites to using them for land management purposes. We do not know, for example, where one ecosystem begins and another ends in space or time. How can decision makers fashion rational land management policies from an unclear concept superimposed on nebulous areas with no fixed address? Given these frailties one cannot reasonably expect that use of the ecosystem health concept will result in cogent land use regulations or balanced environmental protection policies.

## MEASURING ECOLOGICAL PARAMETERS FOR THE PREDICTION OF SUSTAINABILITY

**Wayne G. Landis<sup>1</sup>** and **John F. McLaughlin<sup>1&2</sup>**

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Ecosystem health is at best a poor metaphor for the description of the non-equilibrium dynamics characteristic of ecological systems. Point descriptions of status typically used to measure health are similarly misleading. We have taken a novel approach using an assessment hyperplane. Our goal is to predict the probability that an ecological system remains within in the hyperplane over a specified time interval. The assessment hyperplane is a multivariate space defined by cultural values, societal laws and physical/ecological constraints. Sustainability of an ecological system is defined as the trajectory of the system remaining in the assessment hyperplane throughout the assessment period. Three types of indicators are relevant to sustainability: variance in system response, the probability of leaving the assessment space, and the probability of re-entering the assessment space. The formulation of indicators must recognize that ecological systems are dynamically complex and composed of both deterministic and stochastic components. As has been demonstrated in laboratory and field experiments, the best indicators of impact change over time. Hence, a single variable cannot accurately predict both current and future

system status. We provide six requirements for developing a useful set of indicators: (1) Selection criteria must emphasize accuracy in predicting system status relative to the assessment hyperplane. (2) Indicator selection should use a variety of methods with different assumptions about system structure and function, to avoid problems of information loss with indices and projections. (3) Impacts to complex systems are best measured using different variables at different points in time. Indicator selection should consider temporal variation in indicator accuracy. (4) Selection and use of indicators should consider the dual deterministic and stochastic nature of ecological systems. (5) The stochastic components should be considered explicitly, for they can affect system dynamics qualitatively. (6) When many organisms disperse among sites in a system, prediction accuracy requires knowledge about spatial processes. In this case, indicator selection and use must consider the spatial configuration of those sites.

## UNDERSTANDING THE POLITICS OF ECOLOGICAL REGULATION: APPROPRIATE USE OF THE CONCEPT OF ECOSYSTEM HEALTH

**John Freemuth,**

Andrus Center for Public Policy, Dept. of Political  
Science, Boise State University, Boise, ID • USA

It is apparent that we have entered an era of the “paradigm bazaar,” as new terms continue to be suggested as frameworks for managing environmental and natural resource systems throughout the world. As one example, U. S. federal land and environmental managers trumpet “ecosystem management” as the new approach to environmental and natural resource management in this country. In a similar vein, our conference meets to discuss “ecosystem health”. Both terms have intuitive, emotional, and rational appeal. Yet, as experience with ecosystem management will suggest, ecosystem health is fraught with a number of conceptual difficulties that remain to be worked out. Ecosystem health can imply the regime of the professional expert, who will present a one-way dialogue with the citizen who must be “educated”. Put more bluntly, the health metaphor can suggest the physician, who once again, knows best how to take care of the sick patient without interference from the layman. Environmental management in the United States, however, takes place in a pluralistic and multiple-value driven democratic system of governance. Environmental managers are an important voice in this system, but they are not the only voice. The success of the ecosystem health paradigm, then, will depend on how the approach can and must be embedded in that democratic culture of governance and decision-making in order to be successful. Failure to so embed ecosystem health may doom it to policy failure.

## TS-4

**The Global Ecological Integrity Project: Understanding and Implementing Ecosystem Health****Chair: Tony McMichael—London School of Hygiene and Tropical Medicine, London • UK****THE ETHICS OF ECOLOGICAL INTEGRITY AND ECOSYSTEM HEALTH: THE INTERFACE****Laura Westra**Environmental Studies, Sarah Lawrence College,  
Bronxville, NY • USA

Our group has studied the role of ecological and biological integrity in natural systems, in support of all life, but also in support of the health of human and non-human animals and ecosystems. My own contribution to the project has focused on the ethical implications of the contributions of the scientists involved in the project. I have argued that traditional moral theories are necessary in order to assess the impacts of environmental disintegrity to which we are exposed, but they are not sufficient to prescribe appropriate action. I argue that we need to adopt a radical new position, inspired by the holism of Aldo Leopold, and I propose the “ethics of integrity” as the best candidate for that role. I support this claim through arguments arising from the group’s research, and I incorporate the recommendations of the “Global Integrity Project” as representative of this radical approach.

**PROTECTING ECOLOGICAL HEALTH: THE 21ST CENTURY PRIORITY****James R. Karr**Professor of Fisheries and Zoology and Adjunct  
Professor of Environmental Health and Public  
Affairs, University of Washington, Seattle, WA • USA

Human society faces health challenges on many fronts. The paramount health challenge of the 21st century will likely be the degradation of earth’s living systems (ecosystems) and the resultant loss of goods and services that are critical to the success of human society. That loss, *biotic impoverishment*, is visible today in three major forms: indirect depletion of living systems through degradation of the chemical and physical environment; direct depletion of non-human living systems; and direct depletion of human systems. This broad sweep illustrates the magnitude of current environmental challenges and the connections between human success and living systems. It also provides an opportunity to exercise the ingenuity that has brought us this far. The concept of health is a powerful tool because it provides a short-hand for good condition and is grounded in science yet it speaks to citizens. When combined with a concept such as biological integrity (the biological context and condition that is the product of evolutionary and biogeographic processes at a place where human influence has been minimal), living systems provide benchmark, guide, and

goal for public policy. Ultimately, the loss of living systems, the loss of ecological health, means the loss of our own basis for existence. People need, want, and deserve to understand these issues. To prevent the loss of ecological health, we must institute widespread and comprehensive biological monitoring to track trends in ecological health just as we monitor trends in human health and in the health of local, regional, and national economies. Success in this arena depends on our ability to identify measurable biological attributes that provide reliable and relevant signal about the biological effects of human activities. We must also improve our ability to communicate status and trends in living systems to citizens and policy makers, including the direct connection between human actions and those trends. Effective communication can transform biological monitoring from a scientific exercise into an effective tool for environmental decision making. Are scientists with knowledge of these issues fulfilling their responsibilities if they do not facilitate that communication? Should they be labeled with the often pejorative “advocate” if they do facilitate it?

**ECOLOGICAL INTEGRITY AND MATERIAL GROWTH: IRREDUCIBLE CONFLICT?****William E. Rees**Director, School of Community and Regional Planning,  
University of British Columbia, Vancouver, BC • CANADA

Ecosystems change naturally over time so how can we (and why should we) distinguish ‘normal’ ecosystems development from human-induced ecological change? Under what conditions can exploited ecosystems be said to have ‘integrity’ or even health? This paper addresses these questions from the perspective of basic human ecology. I show that there is an unavoidable conflict between maintaining ecological integrity and material economic growth. Humans are large social mammals who live in groups. We have correspondingly large energy and material demands, even under pre-industrial conditions. Thus all human groups alter their supporting ecosystems, reducing the biodiversity of their immediate habitats and significantly perturbing a much larger area. We are a true ‘patch disturbance’ species. Material consumption by people living in high-income countries is already perhaps two orders of magnitude above pre-industrial levels. Impoverished people everywhere have similarly rising aspirations. However, since material economic production/consumption is really human ecology, and the economy is an dependent subsystem of the ecosphere, there is no prospect of extending industrial-world material standards to an expected nine or ten billion people while maintaining ecosystems integrity. Energy/material flows appropriated from the ecosphere for humans are irreversibly unavailable for use by other species or to maintain ecosystems structure and function. Pollution takes a



further toll. Continuous expansion of the human enterprise therefore inevitably reduces the diversity, biomass, and resilience of exploited ecosystems. To maintain ecosystems integrity – or even health – requires that we move toward a steady-state economy and find ways other than material growth to eliminate chronic poverty. We can reach 1000m), medium to high genetic diversity within populations ( $0.150 < H < 0.250$ ), very high out-crossing rate ( $t > 0.90$ ) and a tendency to absence of spatial structure. These parameters can change relatively fast after anthropic disturbance. The selection of indicator species for monitoring ecosystem health, must take into account the response to anthropic disturbance. Rare tropical tree species are very sensitive to anthropic disturbance, some times showing a very drastic population fluctuation, or inbreeding increase. Ecological and genetic parameters that express these changes may be used to monitor forest management and conservation.

## MEASURING THE IMPACT OF ECOLOGICAL DISINTEGRITY ON HUMAN HEALTH

**Colin Soskolne**

Dept. of Public Health Sciences, University of Alberta, Edmonton, AB • CANADA

We have conducted a correlational analysis examining associations between broad measures of ecosystem health and the current health status of human populations involving 203 countries around the world. This study revealed that likely owing to world trade, the health of human populations (as measured in life expectancy), percent low birth weight, infant mortality) improves as ecological capital is lost. Two serious questions emerge from such a finding: 1) for how long can the health of human societies be sustained while continuing to draw down ecological capital from other regions of the world? 2) Are the measures used from among those available the most sensitive and specific to assess human health impacts from declines in environmental integrity? This paper identifies the problems in this area of investigation within the context of the literature and suggests future avenues for research. An emphasis on the latter's practicality for anticipating human health impacts will be stressed throughout. Multidisciplinary collaborations needed to develop appropriate measures are identified.

## TS-5

### Greater Addo National Park: A South African Case Study of the Opportunities Provided by a Healthy Ecosystem

**Chair: Walt Whitford**—US Environmental Protection Agency, New Mexico State University, NM • USA

#### THE THREAT OF DESERTIFICATION TO ECOSYSTEM HEALTH AND SERVICES IN THE THICKET BIOME, EASTERN CAPE, SOUTH AFRICA

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The Thicket Biome in South Africa is characterised by dense evergreen, low-growing thicket vegetation which historically supported a high diversity and abundance of indigenous herbivores. The dominant form of landuse is through pastoralism, based largely on domestic goats. However goat browsing leads to severe vegetation degradation, characterised by loss of phytomass, loss of plant species (particularly palatable species), replacement of perennial plant species with annual plants and invasion by unpalatable, alien plant species. This is accompanied by extensive soil erosion and alteration of soil chemistry. All these changes lead to a loss of secondary productivity. Our current understanding is that this degradation through overgrazing is irreversible, and hence can be classified as desertification.

Not only does overgrazing lead to a loss of productivity, but other ecosystem services are lost, including carbon sequestration, retention of soil resources, maintenance of biodiversity, etc. The loss of ecosystem health also leads to a loss of options for sustainable use of natural resources, and it is therefore critical that alternative land use options be developed.

#### A BIODIVERSITY HOTSPOT: OPPORTUNITIES AND THREATS IN THE EASTERN CAPE, SOUTH AFRICA

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South Africa is recognised as the third most biologically diverse country in the world, and its Eastern Cape Province includes examples of all seven of the terrestrial biomes that occur. The region around Addo represents a convergence zone of this biodiversity, with six biomes interdigitating over a

few tens of kilometres. This landscape scale of biodiversity is also reflected at the alpha scale, with the Nama-karoo, forest, savanna, grassland, thicket and fynbos biomes all supporting a high diversity of plants and animals (including the large mammals for which Africa is famous). There is a relatively high degree of endemism, although this is not symmetrical across all taxa. This plant diversity is recognised by the IUCN as a global hotspot of biodiversity, the “Albany” hotspot. Being coastal, this regional diversity includes the marine province, which includes sandy and rocky shores as well as offshore islands supporting a diversity of seabirds. This region therefore represents an opportunity for the conservation of biodiversity of global significance. In addition this biodiversity represents an opportunity for the development of a major nature-based tourism industry.

#### TOWARDS ECOLOGICAL AND ECONOMIC SUSTAINABILITY OF ALTERNATIVE LANDUSES IN THE EASTERN CAPE SOUTH AFRICA: CONSERVATION FOR THE PEOPLE

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Pastoralism with domestic herbivores, the dominant form of landuse in the Thicket Biome, leads to irreversible degradation of the natural forage resource upon which it based and hence is neither ecologically nor economically sustainable. This indicates the need for the evaluation of alternative forms viz. game ranching and conservation/ecotourism, of landuse which may maintain ecosystem health. Game ranching, based on venison production and sporthunting of indigenous herbivores, is ecologically sustainable but provides a lower income (albeit sustainable) than pastoralism. Despite this limitation there appears to be shift towards game ranching, or a combination of game ranching and pastoralism, as a viable form of landuse. Conservation/ecotourism is ecologically sustainable and economically lucrative, generating considerably more income than a comparable sized pastoralism operation. It also provides significantly more employment, at higher income levels than pastoralism, and there are major ripple effects of employment arising from the tourism trade. In addition, conservation/ecotourism generates significant regional and national economic activity on a broader scale through the expenditure on travel by tourists. Thus conservation and the associated tourism industry appear to provide the best socioeconomic opportunities in the Thicket Biome.

#### THE GREATER ADDO NATIONAL PARK: A REGIONAL AND NATIONAL CONSERVATION AND DEVELOPMENT OPPORTUNITY

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In South Africa there is growing acceptance that ecotourism/conservation, as a recognised form of land-use based on healthy ecosystems, can play a major role in promoting development and community upliftment in the Thicket Biome. The Greater Addo National Park proposal sees the amalgamation of two existing conservation areas to form a viable regional and national development and conservation initiative. The proposal is based on 11 recognised criteria and on national and international legislation and treaties. It is fully motivated on the basis of sound conservation, ecotourism and economic principles, perspectives and information. The proposed 398 000 ha park will include 341 000 ha terrestrial and 57 000 ha marine zones, including offshore islands. It will be the third largest, and geomorphologically and biotically the most diverse, conservation area in South Africa. It will be unique through the inclusion of representative areas of six of the seven terrestrial biomes which occur in South Africa, thereby providing resilience in the face of global climate change. The park will maintain an extensive suite of terrestrial and marine biodiversity (species, ecosystem processes and landscapes), including a number of large and charismatic species, and will provide a refuge from desertification processes in the area. It is ideally suited to ecotourism, having a wide range of attractions, good tourism infrastructure and malaria-free status. The park will contribute towards human well-being through the provision of ecosystem services and employment opportunities, and by stimulating sustainable economic activity. A number of issues relating to the establishment, management and socioeconomic potential of the proposed park are discussed.

**Chair: Catherine Toft—Dept. of Evolution and Ecology, University of California, Davis, CA • USA**

**INVENTORY, MAPPING, AND MONITORING OF COSTA RICA'S BIODIVERSITY: POSSIBLE SOLUTIONS FOR MANAGING ECOSYSTEM HEALTH**

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In 1998 the Costa Rican ECOMAPAS Project initiated the mapping of Costa Rica's ecosystems and subsequent monitoring of ecosystem health. This Netherlands funded Project is a joint effort of Costa Rica's National Biodiversity Institute (INBio) and the National Conservation Areas System (SINAC) of the Ministry of Environment and Energy (MINAE). In accordance with INBio and SINAC's mission of saving, knowing and sustainably using tropical biodiversity, and as a follow-up of the 1998 approved national Biodiversity Law, the ECOMAPAS Project contributes in an advanced and innovative manner to the development of knowledge and wise use of Costa Rica's ecosystems. During a first two-year phase, five Conservation Areas (i.e. recognized territorial regions including protected wildlife areas as well as both agricultural and urban areas) covering over 60 % of the country's territory, are ecologically mapped at a detailed scale of 1:50,000. The selected Conservation Areas are: Arenal (ACA), Tempisque (ACT), La Amistad-Caribe (ACLAC), La Amistad-Pacífico (ACLAP), and Osa (ACOSA). Megadiverse protected areas to be mapped include the UNESCO recognized La Amistad (Talamanca) Biosphere Reserve, which is both a World Heritage Site and a Center of Plant Diversity. Interpretation of recent aerial photographs (scale 1:25,000 to 1:40,000), field-based ground-truthing and INBio's species-per-area data base form the basis for the mapping process. GIS-based landscape-ecological maps will integrate different biophysical thematic layers, as well as protected areas and species distributions. The ecological GIS will serve as a basic decision-support tool for efficient planning of ecosystem inventory activities and sound ecosystem management of protected areas and surrounding buffer zones. As soon as the tailor-made and user-friendly GIS systems are developed on a Conservation Area basis, they will be installed and maintained at the decentralized SINAC/MINAE regional offices in the five previously selected Conservation Areas. SINAC and INBio personnel will be trained to manage these GIS's efficiently and effectively, for the benefit of the Conservation Areas' ecosystem health. For it is the availability of a monitoring and evaluation GIS tool, integrating ecological and geographic information, such as proposed by ECOMAPAS, on which the future success of decision-making in ecosystem management, monitoring and restoration strongly depends.

**IDENTIFICATION AND MONITORING IN THE CONTEXT OF THE NATIONAL BIODIVERSITY STRATEGY**

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In accordance with the United Nations Convention on Biological Diversity (CBD), each country should develop national strategies and action plans for the conservation and sustainable use of the biodiversity in areas within the limits of its national jurisdiction, in the context of the different levels accepted by the CBD : ecosystems, species, and genetic resources. As a contracting party of the CBD, Uruguay started in early 1998 a multisectorial and participative process to develop his national biodiversity strategy with the financial support of the GEF, the participation of UNDP as implementing agency and the National Environment Division (DINAMA) as leading agency. Uruguay, located in the Southern Cone of South America, between Brasil and Argentina has a temperate climate with grasslands as a predominant ecosystem and also important areas of wetlands, gallery forest, ridge forest, palm groves and coastal and lagoon ecosystems. One of the first steps in the process of the national strategy was gathering existing information about the uruguayan biodiversity and the identification and monitoring of the activities that can cause adverse impacts to the national ecosystems, species and genetic resources. The process mentioned above must be oriented to policy-making and management in order to reach an effective action to the implementation of the CBD. The results of the monitoring are also important to include them in others sectorial plans and national policies with different levels of relationship with the biodiversity issue (environmental regulations, agriculture programmes, research policies, etc). Several constrains were identified during the strategies process related to the topic of the biodiversity identification and monitoring, for instance : lack of financial resources ; need of coordination between institutions (including public sector, private sector and research institutions), gaps in trained personnel and capacity building programmes, requirements to international cooperation, etc.

## MANAGEMENT AND CONSERVATION OF TROPICAL FORESTS WITH EMPHASIS ON RARE TREE SPECIES IN BRAZIL

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Tropical Forests are known by the high diversity of species (100 to 300 tree species / ha) and intricate ecological interactions, what makes conservation and management very complex. This richness of species includes several patterns of abundance and spatial distribution. We are giving special attention to population density of tree species, because this characteristic is strong related to several ecological traits, like pollination and seed dispersal patterns, role in the succession, and natural regeneration. Common tree species or species that occur at high population densities generally have high regeneration capacity (reverse J population curve), being very favorable to be included in sustainable management projects. Rare tree species that can occur in a very low population density as 1 tree/ha to 1 tree/50ha have long distance pollinators and seed dispensers and a scarce natural regeneration. This kind of species has density and distance dependent mortality and requires small gaps for regeneration. For these reasons, these species are not suitable for sustainable management programs. On the other hand, they are adequate indicators of tropical forest health. In primary forests, Tropical tree species studied in Brazil present long distance gene flow (e.g. pollen flow can reach 1000m), medium to high genetic diversity within populations ( $0.150 < H < 0.250$ ), very high outcrossing rate ( $t > 0.90$ ) and a tendency to absence of spatial structure. These parameters can change relatively fast after anthropic disturbance. The selection of indicator species for monitoring ecosystem health, must take into account the response to anthropic disturbance. Rare tropical tree species are very sensitive to anthropic disturbance, some times showing a very drastic population fluctuation, or inbreeding increase. Ecological and genetic parameters that express these changes may be used to monitor forest management and conservation.

## USING FLORISTIC DATABASES TO MAP BIODIVERSITY AND AS TOOL FOR CONSERVATION

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An immensely valuable source of information on the distribution of biological diversity is found in biological collections. In particular, herbarium specimens and their labels contain detailed historic records that can be converted into databases and used for quantitative biogeographic analyses. As a case study, we created a database for columnar cacti in Mexico (Cactaceae, Tribe Pachycereeae), and a second database for the whole cactus family in Argentina. The records were then converted into biogeographic maps that show patterns resulting from the distribution of these species. In particular, we mapped (a) species richness, and (b) species turnover, and regressed these values against mapped environmental predictors such as temperature, topography, or rainfall. We also mapped the distribution of endemism, by giving each species a weight inverse to the size of their biogeographic area. Finally, we analyzed and mapped areas of similar species content, to highlight areas of uniform floristic content, or “cactological regions.” The regression models showed that a few simple statistical variables were capable of predicting the distribution and occurrence of high-diversity spots. It was also found that different life-forms have different patterns of biodiversity, and that these patterns can be related to environmental factors that limit the life-form growth. From an applied point of view, the resulting maps could be contrasted against the distribution of protected areas, and recommendations related to conservation policies and priorities could be derived from this study. It is concluded that biological collections can be used as tools of great importance for the monitoring and management of biological diversity in the wild.

## TS-7 The Role of Culture and Tradition in Ecosystem Health Management: Case Studies from Developing Countries and Others

**Chair: Alexander Harcourt—Dept. of Anthropology, University of California, Davis, CA • USA**

### ATTITUDES AND THEIR INFLUENCE ON NATURE VALUATION AND MANAGEMENT IN RELATION TO SUSTAINABLE DEVELOPEMENT

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The paper will analyse important aspects of attitudes towards the functions of nature. Then we will try to indicate what else is needed to valuate within the framework of attitudes these functions in relation to ecosystem management. The paper will be based on the analysis of information from four countries: Benin, Bhutan, Costa Rica, and The Netherlands.

## INTEGRATED VECTOR MANAGEMENT FOR MALARIA CONTROL: AN AFRICAN PERSPECTIVE

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Malaria continues to be a major cause of mortality and morbidity in many countries of Africa. The disease is so common and dreaded that among many communities, any sign of fever evokes *a priori* diagnosis for malaria. Within the African context, past attempts at high-tech solutions administered through vertical control programmes have not been sustainable in most countries. Increased resistance by malaria parasites to chloroquine, the most commonly available curative drug, has left large populations without an affordable alternative. Similarly, resistance by mosquitoes to residual insecticides including DDT has been an important obstacle, environmental concerns notwithstanding. Yet, it is becoming increasingly evident that amidst all the despondency, the future for malaria control may lie in simple, community-based environmental management approaches. Suffice to say that more than 90% of malaria is attributable to environmental factors which can be feasibly addressed to create the desired situation of improved health and well-being. Against this background, the International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya, has in its Malaria Programme re-visited the concept of integrated vector management (IVM), based on current knowledge about malaria vector behaviour and ecology. Components of the IVM strategy being developed by ICIPE include the use of agro-ecosystem management for minimising mosquito breeding, and the diversion of hungry mosquitoes to alternate hosts, particularly cattle. Ethno-botanical products, house screening and naturally occurring semio-chemicals are also being evaluated as components of a “push-pull” strategy aimed at reducing human–vector contact. Majority of people in Africa live in rural areas, within a setting of subsistence agriculture and keeping of livestock. The ICIPE IVM approach deliberately targets these two traditional economic activities in order to enhance communities’ participation. As part of the IVM strategy, a pilot project is also being developed on the use of drama, music and song for the delivery of the relevant information in a culturally-friendly way.

## GAMBLING FOR SUSTAINABILITY–LOCAL INSTITUTIONS FOR PASTURE MANAGEMENT IN BHUTAN

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Each summer, on the 18th of the 7th lunar month of the Bhutanese calendar, the pastoral communities of the villages of Gechukha, Chumpa and Chempa in North-western Bhutan assemble at their community shrine. The gathering is a scene of daylong prayer sponsored by the community. Supernatural influence is invoked for favourable outcomes. This day long ritual is just a prelude to the actual business, a brief, statistical affair, which takes place in the evening. Die are cast to allocate the communal pastures to groups herders for the coming year. The group with the highest score gets first choice, the second highest, second choice and so forth. Until they meet again, one year later, each herder will be dependant on the allotted pastures to provide his or her yaks with sufficient feed. Viewed as rules of the game, a local institute of the type mentioned above, is crucial for equitable access to one of the major resources in agro-pastoral communities because it provides a mechanism for the allocation and division of pastures among herders. But this institution is also important for the many other functions it plays. A tentative outline of these can be made: First, an institution is very often eco-specific and therefore it may reflect sustainable uses of resources within that eco-niche. This could also mean that the institution can express accumulated indigenous knowledge about sustainable resource use within that eco-niche.

- Second an institution since it is correlated to an eco-niche is adaptive over eco-niches. Institutional diversity and ecological diversity therefore go hand in hand.
- Third an institution defined as ‘rules of the game’ regulates the behaviour of the individual members of an organization, be it formal or informal. In this sense an institution acts as coordinator of collective activities and obligations of the membership of that community or organization.

My intention in this presentation is to explore briefly these three aspects of local institutions with references primarily to pasture distribution rules in Bhutan.

## TS-8

## The Rio Colorado Delta Area: A Case Study of Water Use Issues

Chair: Juan-Vincent Palerm–MEXUS, University of California, Riverside, CA • USA

## ECOSYSTEM HEALTH FROM THE NATURAL RESOURCE AND BIODIVERSITY PERSPECTIVE

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## PHYSICAL AND BIOLOGICAL LINKAGES BETWEEN THE UPPER AND LOWER COLORADO DELTA

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Human intervention has led to almost total elimination of water and sediment discharge into the Colorado River delta. During 1979-87, 1993 and 1998-99, water releases became necessary due to abnormal snowmelts in the upper basin of the river. In spite of the great ecological impact caused by the construction of dams, life is abundant in the estuary even during the long periods without surface freshwater input. Due to sediment resuspension, the water in the estuary looks brownish and the Secchi disk disappears under few cm. Macro and microalgae are abundant in the estuary, possibly because of turbulence and low tides allowing for enough light for a healthy growth. Phytoplankton chlorophyll *a* often reaches values  $>5 \text{ mg m}^{-3}$ . Highest recorded zooplankton biomass, as dry organic weight per  $\text{m}^{-3}$ , is  $154 \text{ mg m}^{-3}$ , with calanoid copepods as the most abundant taxonomic group. These values are as high as those of healthy estuaries and coastal lagoons. Dolphins are seen often inside the estuary. Salinity and nutrient values at the internal extreme of the inverse-estuary evidence a significant fresh groundwater flow from the river. High  $\text{NO}_3$  values in the delta are due to groundwater input as a result of the application of fertilizers in the agricultural areas. There is a significant relationship between the shrimp catch landed in San Felipe during 1975-97, and the Colorado River flow at the Mexico-US border. The base catch in the absence of flow into the Upper Gulf is  $\sim 200 \text{ tons year}^{-1}$ , and it increases to  $\sim 600 \text{ tons year}^{-1}$  or greater following years of freshwater input. Analysis of DDT and its metabolites in clams sampled from the estuary in 1973 show that as an average total DDT (the sum of: opDDT, ppDDT, opDDD, ppDDD, opDDE, and ppDDE) was 0.067 ppm ( $\text{mg g}^{-1}$  dry weight). More than ten years later, in 1985-86, total DDT concentrations were much lower (0.005-0.011 ppm) compared to those reported for the specimens sampled in 1973, and only ppDDE was found. Given the persistence of the organochlorinated pesticides in the environment, their presence in 1985-86 was due to their use in the past. These values of chlorinated hydrocarbons are well below the action levels proposed by the U. S. National Academy of Sciences as a danger to the environment.

## A REGIONAL PERSPECTIVE FOR MIGRATORY WILDLIFE RESOURCES OF THE COLORADO RIVER DELTA REGION

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Biodiversity conservation of highly mobile organisms, as exemplified by migratory birds, is increasingly and correctly demanding that resource managers adopt region-wide, large-scale views and approaches that include all aspects of the environmental requirements of these resources. Migratory wildlife are especially sensitive regarding connectivity issues that involve both temporal aspects (varying annual cycle needs) and spacial aspects (adequate breeding areas, migratory corridors/stopovers, and wintering habitat) in their requirements. The Rio Colorado Delta area was described by early biological explorers as a region containing the greatest biological diversity in the entire southwestern US; but today it is an area that may be one of the most ecologically degraded ecosystems in North America. And, the Rio Colorado Delta region is a prime example illustrating the ideas often expressed by environmentalists, that in the biological sense, «the whole is greater than its parts»; or in the management context, «think regionally and act locally (in many places).» The Rio Colorado Delta region encompasses a major past and present link in an ecological chain stretching from the North American Arctic into Central Mexico, encompassing three countries, Canada, the US, and Mexico. In this region, as elsewhere, there is need for a large-scale, international approach that maintains the connectivity between its parts. Perhaps historically in the southern Pacific Flyway and in a region where water resources are scarce and demanded-for by many competing interests, these ideals have seldom been met by resource managers, who often reluctantly and frustratingly find themselves at the low-end of the political powerstructure. Degraded habitats in many areas of the Colorado Delta region now occupy, often through unlikely historical events, critical links in a much longer web of ever more distantly connected and less-suitable habitats along the corridors of this «flyway.» The entire regional system is long overdue for wildlife habitat restoration and for a regional/international effort to bring this about. Threats to the Colorado Delta system or parts of it are many and they are getting worse; and they vary with specific location and the type of resource involved. There will be no simple or immediate solutions. Planning for the mitigation of natural resource problems in this region will have to be integrated across the US/Mexico border and must include international support across the border into Mexico.

## WILDLIFE DISEASE AS AN INDICATOR FOR ECOSYSTEM HEALTH

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During recent years, a popular concept has emerged that ecosystem health is measurable in the context of human values and can be defined by certain indices. Wildlife mortality from disease agents, whether infectious or chemical, may be considered as one such indicator of ecosystem health. Some disease agents, such as microbes and parasites, are normal and even essential components of ecosystems. These agents may act to maintain normal ecosystem function by altering or balancing populations of animals. However, increasing losses from certain diseases, such as avian botulism and algal toxicoses, and catastrophic mortality events in wildlife may be an indication of major perturbations in environmental conditions or human-induced acceleration of natural ecosystem changes. We view some wildlife mortality events as a reflection of declining ecosystem health that may negatively impact wildlife conservation and biodiversity. The motivation to manage wildlife disease is a value judgement focused on reversing the affects of disease on some valued component of the ecosystem or to restore conditions to a desired level of ecosystem status. We contend that standards regarding specific diseases can be established as an important measurement for ecosystem health and management, such as their frequency of occurrence, the magnitude of losses, their spatial and temporal patterns of occurrence, and when possible, environmental conditions that promote outbreaks. Recent mortality events involving fish and birds at the Salton Sea of California and avian botulism in general are used to illustrate these concepts. The environmental conditions that facilitate avian botulism outbreaks are described as the type of standards that could be applied for guiding ecosystem management.

## INTERNATIONAL ASPECTS OF ECOSYSTEM CONTAMINATION PROBLEMS IN WILDLIFE OF THE COLORADO DELTA REGION

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The Colorado Delta region once comprised what are now mostly agricultural areas in the United States (Imperial and Yuma districts) and Mexico (Mexicali and San Luis districts), and two below sea level depressions, the Salton Sea and Laguna Salada. Currently, most of the water from the Colorado River is used for irrigation in Mexico and only remnants of the former Colorado Delta region remain. The Cienega de Santa Clara and the Rio Hardy wetlands provide important habitat for many resident and migratory birds. The Colorado Delta is affected by multiple contaminant stressors, including agricultural pesticides and heavy metals from agriculture and other anthropogenic activities.

Recent wildlife mortalities in the upper Gulf of California and Salton Sea areas could be linked to contaminant increases in the region, although disease outbreaks also may have played a major role. The earlier documented contaminant studies in biota of the Colorado Delta were conducted in the 1970s on aquatic invertebrates and fish from irrigation canals and drainages in the Mexicali Valley. Some of the most detailed studies of the impacts of contaminants on wildlife of the lower Colorado Delta were carried out in the 1980s, particularly on birds. More recently, contaminant studies have been conducted in the Cienega de Santa Clara, a particularly important wetland of the Delta. Current efforts are focused on evaluating contaminant threats to wildlife of the Rio Hardy and Colorado Delta in general. Because most water reaching the Delta is used first for agriculture in Mexico and the United States, it is likely that birds using wetlands in the Colorado Delta are exposed to significant amounts of pesticides and other contaminants, the impacts of which need to be documented.

## RESTORATION ALTERNATIVES FOR THE NATURAL RESOURCES OF THE LOWER COLORADO RIVER DELTA, MEXICO

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The delta of the Colorado River covers 780,000 hectares (ha) in the United States and Mexico, encompassing two below-sea-level depressions, Salton Sea and Laguna Salada, and most of the Imperial, Mexicali, Yuma and San Luis irrigation districts. Approximately 1.5 million people live in the Mexico portion of the delta alone. Although most of the delta has been converted from natural habitat to agricultural and urban uses, 60,000 ha of riparian, wetland and salt marsh habitat still exists in the lower delta. This natural area is largely contained within a levee system designed to protect adjacent fields from flooding, and it represents a wildlife corridor extending from the U.S.-Mexico border to the Sea of Cortez. Part of the flood plain is within the Biosphere Reserve of the Upper Gulf of California and Delta of the Colorado River. Most of the delta habitats are supported by water from the United States: the riparian corridor receives pulse flood flows of surplus Colorado River water during wet years on the watershed; and Cienega de Santa Clara marsh in the southeastern part of the delta receives agricultural drainage water from the Wellton Mohawk irrigation district in Arizona. Other wetland and riparian habitats in the delta are supported by agricultural return flows originating in Mexico. The delta contains the most extensive remaining willow thickets, cottonwood-willow gallery forests, and emergent marsh systems in the lower Colorado River ecoregion. The habitats support migratory and resident waterfowl and contain large populations of endangered species, including Yuma clapper rails, desert pupfish, willow flycatchers (recently documented) and, in the marine zone, vaquita porpoises and totoaba fish. Restoration and protection of

the lower delta habitats will require binational cooperation and should be based on the principles of sustainability and equity: 1) the primary management goal must be to provide for a healthy ecosystem and to protect human health; 2) water management decisions should be grounded in

scientific understanding of the regional ecology; 3) the delta habitats should be viewed as a binational resource, dependant upon U.S. water supplies but serving as a species reservoir for the entire lower Colorado River ecosystem, benefiting the natural environment in both the U.S. and Mexico.

## TS-9

### Managing for Ecosystem Health across Political Boundaries

**Chair: Deborah Rogers—Genetic Resources Conservation Program, Division of Agriculture and Natural Resources, University of California, Davis, CA • USA**

#### NATURE POLICY ASSESSMENT IN THE NETHERLANDS: CROSSING POLICY BORDERS FOR STRATEGIC SURVEYING AND ASSESSING POLICY PROGRESS

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The last two years Dutch nature policy has been regularly assessed by reports of the Nature Policy Assessment Office. This office points out the actual state of landscapes and habitats, assesses the impact of current national policies and surveys strategically the opportunities for and threats to nature. In The Netherlands ecosystem health is affected by a great variety of conditioning factors, particularly environmental and water quality, spatial impact, site and population management. These factors are largely determined by the actual use of ecosystems for nature protection, agriculture, recreation, fisheries, housing, timber production, etc. The degree of use is highly influenced by economic development, demography and technology. These findings imply that strategic surveys with regard to the development of ecosystem health must be ultimately based on forecasts of economic, technological and demographic developments and must integrate the impacts of conditioning factors. Moreover, they should deal with various spatial and temporal scales. We developed techniques to assess the progress in policy related to nature and conditioning factors, as well as the policies related to the use of ecosystems. We demonstrated that policy makers hardly define justifiable objectives and targets and that they have problems to integrate various fields of policy (nature protection, water and environmental management, physical planning). Furthermore, we found evidence that, even if real policy targets have been defined, the implementation of national policies to regional authorities is sometimes problematic because of the lack of public acceptance and of coherence of various policy tools. In consequence, we conclude that a major challenge for policy makers is to cross over political boundaries and for researchers to bridge over disciplinary gaps.

#### CONTROL OF NATURAL RESOURCE DEGRADATION TO RESTORE ECOSYSTEM HEALTH AND TO HELP SECURE PEACE IN THE MIDDLE EAST

**Scott Christiansen**  
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Since 1996 Egypt, Israel, Jordan, the Palestinian Authority and Tunisia have been engaged in an Initiative to Control Natural Resource Degradation that focuses to a large extent on the rehabilitation of degraded dryland ecosystems. The project takes place in the Working Group for the Environment of the Multilateral Middle East Peace Talks. The pilot schemes, all in areas of 80-300 mm mean annual rainfall (southern Tunisia; northwest coast of Egypt and the Sinai; the Negev of Israel; the Eastern Slopes of the West Bank; and Wadi Araba in Jordan) involve applied research methods delivered using a participatory approach in community settings. The project concentrates on the themes of (1) income generation from fruit, nut and fuelwood species of trees, medicinal and herbal plants; (2) development of adapted native biodiversity for grazing and conservation; (3) water harvesting and run-off farming; and (4) use of recycled wastewater blended with saline water. The countries divide responsibilities for the themes so that each takes a lead in a particular topic with the Palestinians being the focal point for building of technical capacity and environmental institutions.

#### ECOSYSTEM HEALTH IN THE GREAT LAKES AS A POLICY CASE-HISTORY

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During the first part of this century, water quality in the Great Lakes basin deteriorated despite the signing in 1909 of the Boundary Waters Treaty and a binational policy decision not to cause transboundary pollution to the injury of health and property. The first Great Lakes Water Quality Agreement was negotiated in 1972 and was mainly concerned with control of phosphorus to counter widespread eutrophication. The concentrations of persistent toxic substances peaked in the late 1960s and researchers documented the severe effects on the reproduction and development of fish eating birds and ranch mink fed



Great Lakes fish. The 1978 renegotiation reoriented the Agreement to the virtual elimination of discharges of persistent toxic substances. Though concentrations of many persistent toxic substances started to decline in the mid-1970s because of the implementation of pollution prevention measures by industry and governments, recent declines have been almost imperceptible. Future improvements to restore ecosystem health will depend on costly remedial work which to date has been underfunded because of official regulatory scepticism. Researchers at recent workshops have adopted a methodology for inferring causality, and thereby explored this widespread scepticism about the causal relations between exposures to persistent toxic substances and effects on human health. Similarly, there is a broad divergence of opinion about persistent toxic substances as the cause of the declines and extirpation of various fish stocks, and about the predictions of restoration of these populations with implementation of the pollution provisions of the remedial action plans.

#### LAW AND ECOSYSTEM HEALTH: A COMPARATIVE ANALYSIS OF THE EFFECTIVENESS OF RIPARIAN ZONE REGULATIONS IN ARIZONA AND COSTA RICA

**Bernardo Aguilar**, Ligia Umaña, and Ariana Salvo  
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Effective sustainability requires a dynamic balance between social, economic and ecological aspects of development. Laws

establish links that allow the adaptation between these dimensions. Legal evolution depends on the nature of social institutions. If society lacks awareness of the sustainable way to regulate its areas of connection with the biosphere, the legal framework can become an obstacle to achieve ecosystem health. We illustrate this problem through a comparative analysis of riparian zone legal protection between Costa Rica and Arizona. For different reasons these areas play a key role in the socio-ecological balance of the two States. Yet, their legal protection differs widely. Costa Rican regulations establish an obligation to every land owner of preserving a minimal forest cover around rivers, streams, lakes, springs and other water bodies. Despite lax enforcement and conflicts with the Costa Rican Constitution, the effectiveness of the regulations seems to prove their usefulness. In U.S. and Arizonian Law, unlike wetlands and water bodies, riparian zones are not specifically regulated. Further, because they are frequently well oxygenated, they do not fall into the legal category of wetlands. Therefore, outside National Parks and other protected areas, these fragile open ecosystems are not legally protected. If both areas depend highly on their riparian resources, why is there such difference in regulation? To illustrate the possible effects of the adoption of such policies in Arizona, we present a simple graphic simulation for the riparian areas in the Willow and Watson Lake micro watersheds in Yavapai County. The contrast in legal protection may be correlated with differences in the political ecology of both regions. Thus, an effective proposal for such legal reform would require a much deeper process of analysis.

## TS-10

### Effects of Agriculture on Ecosystem and Human Health

**Chair: Marc B. Schenker**—Dept. of Epidemiology and Preventive Medicine, School of Medicine, University of California, Davis, CA • USA

#### INTRODUCTION

##### **Marc B. Schenker**

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#### THE NORTH AMERICAN AGRICULTURAL SYSTEM-ECOSYSTEM AND HEALTH IMPACTS

##### **Paul D. Gunderson**

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Agriculture in North America has evolved across time into distinctly separate sectors which offer severely contrasting views of long-term sustainability. The human health impacts of these sectors also varies; many impacts have emerged in the absence of explicit attempts to engineer unhealthy exposures out of the agricultural work site. Health impacts do occur to agricultural workforces as well as other population sectors such as consumers or rural/suburban neighbors. Health impacts include most of the

body's systems, and can span entire communities. Some such as musculo-skeletal disease may primarily impact individual workers, others such as asthma or infectious disease affect entire classes of people. The evolution of North American agriculture has caused change in the virulence of human disease and its dispersion among human populations. Long term, a systematic approach is needed to model potential human health impacts of systemic change in agricultural production systems.

#### INFECTIOUS DISEASE HAZARDS TO HUMAN POPULATIONS

##### **Dean O. Cliver**

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The national Food Safety Initiative of May 1997 refers repeatedly to "manure management" and implies that the use of animal manure in vegetable crop production constitutes a

hazard to consumer health. If this is true, those who work in vegetable-growing fields to which manure is applied must be at greater risk. The concern is with zoonotic infectious agents, such as *Escherichia coli* O157:H7, *Salmonella* spp., and *Cryptosporidium parvum*. These are shed, under certain circumstances, in the manure of food animals. The effects of various treatments and storage of manure on the infectivity of zoonotic bacteria and protozoa are under study; methods that destroy infectivity are known, but not widely used. People infected with such agents may experience mild to severe intestinal illness and will shed the agents in their feces. Surveys, using various methods of fecal sampling, are needed to determine the incidence of such infections among field workers, as related to occupational exposure. Control groups for such studies should include people who work in fields to which no manure is applied and those who work directly with food animals and their manure.

#### PM10 AND THE AGRICULTURAL ECOSYSTEM

##### **Robert G. Flocchini**

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In recent years, the presence of particulate matter suspended and transported in the atmosphere and its potential impact on human and environmental has been given great attention. Airborne soil dust particles (< 10 microns) can be the largest fraction of microscopic particulate matter transported in air.

In humans, these particles, especially at the smaller end of the spectrum, have been shown to be inhaled and captured in the lungs. The full ramifications are yet unknown. Many processes occurring in the rural environment suspend particulate material. These processes include wind erosion, traffic on unpaved roads, construction operations, and agricultural activities. These activities have to be compared to activities relevant to the urban environment. Yet the contribution to the suspended and transportable fraction of airborne dust from rural activities has been poorly characterized with the result that the data available to regulatory agencies needed to estimate the impact of these particulates has been historically of limited use. Agriculture is a known non point-source of particulates. Recent research efforts, funded by the United States Department of Agriculture, have measured dust fluxes from the harvesting of almonds, walnuts, cotton, and figs in California's San Joaquin valley. The data were collected on a variety of soils. Preliminary results indicate that most of the harvest emissions are in the size range from 2.5 to 10 microns. The results also show significant reduction in particulate loading downwind of the harvest site. The need for the agricultural community to continue to document the type, size and elemental composition of these emissions will be addressed.

#### PESTICIDE EPIDEMIOLOGY AND ECOLOGY

##### **Michael O'Malley**

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*Abstract not available.*

## TS-11

### **Eradication Revisited: Thoughts on Appropriate Response to Exotic Invasive Species**

**Chair: James R. Carey—Dept. of Entomology, University of California, Davis, CA • USA**

#### ERADICATION CRITERIA: INSIGHTS FROM MEDFLY PROGRAMS

##### **James R. Carey**

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Eradication is defined as "the purposeful reduction in the prevalence of a specific pest to the point of continued absence within a specified area by means of a time-limited campaign." The essential difference between control and eradication is the economic advantage of the later over the former—the cost of a time-limited capital investment as against the ever recurring costs of control measures. Eradication of exotic pests is possible from a biological and technical point of view, but whether it is feasible depends on a number of biological, ecological, social and operational factors. Using eradication programs on the medfly and other fruit fly species in California as models, I will outline six

preconditions for launching an eradication campaign, propose criteria for declaring eradication, and discuss biological and political problems with the overall concept.

#### ERADICATION REVISITED: THOUGHTS ON APPROPRIATE RESPONSE TO EXOTIC INVASIVE SPECIES

##### **Judith H. Myers**

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Eradication is the removal of every potentially reproducing individual of a species from an area which will not be reinvaded by other members of the species. Eradication is a word which should be used with caution because it implies that humans have the technical ability and finances to achieve this goal. The fact that eradication programs are often designed by a small group of specialists who then must convince most members of society

that the costs of the program and its the potential side effects are worth assuming, can result in dictatorial behavior by the specialists and apprehension and mistrust by the public. There are few examples of successful eradication of biological organisms even though it is often the stated goal of programs designed in response to introduced or “invasive” species. A better approach is the prevention of introductions through regulations of imports of plants and animals or materials which may harbor exotic organisms. However, often commercial pressures override rationale regulations. I will consider if there are characteristics of introduced species which may cause some to be susceptible to eradication. In general I feel that we should not use the word eradication and should adopt the attitude that since this goal is rarely achieved, costs and benefits should be evaluated based on partial success and the possible need for continued management.

#### WHY NOT ERADICATION?

##### **Daniel Simberloff**

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Eradication of non-indigenous species has a bad name, largely because it is seen as a pipe dream and because certain highly publicized unsuccessful eradication attempts have had disastrous non-target impacts. Another reason for disenchantment with eradication is that the term has been used colloquially to mean simply partial removal and control at a low level rather than the strict definition of total elimination. However, many eradications have been complete successes, with highly invasive species totally removed from a region. Although some successful eradications have been from small, circumscribed areas, others have been from extensive regions. Successes are not restricted to highly visible vertebrates – insects, snails, plants, and even microorganisms have been eradicated, although certain species’ traits (e.g., a seed bank in the soil, self-fertilization) make eradication far more difficult. The biggest impediment is the absence of an effective early-warning system and rapid, coordinated response mechanism. If invaders were more quickly detected and personnel were immediately deployed to attempt eradication, there is little doubt that successes would be far more frequent. If the same methods would be used in an eradication attempt as in a long-term maintenance control program, there is little inherent conflict between the two approaches. On the other hand, when different methods would be employed (e.g., chemicals for eradication, biological control for maintenance at an acceptable level), the potential exists for major disputes, to the detriment of effective management.

#### ERADICATION OF INTRODUCED MARINE PESTS

##### **Armand M. Kuris**

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Over the past decade, the extent and impact of introduced marine species has become increasingly recognized as a major ecological problem. We have considerable information on the mechanisms of introduction and research on their impacts is underway. Prevention of further arrivals is generally considered the best strategy. However, once detected, the options are less obvious. Detection of introduced species in the marine environment is more difficult than in terrestrial and freshwater habitats. Consequently, detected pests are almost always established pests. The detection of an introduced marine species was met with defeatism. Nothing could be done, so no control measures were even attempted. This led to a fatalistic perspective “that we will just have to learn to live with them...” Recently, based on modeling of diseases in fisheries, and an analysis of pest control strategies in terrestrial and freshwater systems, biological control of introduced marine pests has been proposed and is under active investigation in France, California and Australia. The recognition that there was at least a theoretical window of opportunity to control introduced marine pests quickly led to consideration of other approaches, including eradication. Two major eradication attempts have been conducted. Eradication has apparently been achieved against an established population, at Cayucos, California, of at least 2.5 million South African sabellid worms that infested mollusc shells. This effort was theoretically based, and required study of the basis for susceptibility among California hosts. The second attempt has just been undertaken at Darwin Harbor, Northern Territory, Australia against a Caribbean brackish-water mussel. The afflicted part of the harbor was isolated and chlorinated. It is too early to tell whether this attempt was fully successful, but initial results are promising. Efforts to eradicate marine exotics will have to contend with the scale of recruitment of marine organisms. But, at least the approach is under consideration and investigation.

## TS-12

**The Prairie Ecosystem Study: A Major Interdisciplinary Study of Sustainability and Ecosystem Health in the Great Plains of Canada (PECOS)****Chair: Darwin Anderson—Dept. of Soil Science, University of Saskatchewan, Saskatoon, SK • CANADA****THE PRAIRIE ECOSYSTEM STUDY: ISSUES OF INTERDISCIPLINARITY, SCALE AND SUSTAINABILITY****Darwin W. Anderson**Dept. of Soil Science, University of Saskatchewan,  
Saskatoon, SK • CANADA

The prairie ecosystem study (PECOS) is a major interdisciplinary study of sustainability and ecosystem health in the semi-arid prairie ecoregion of the Canadian part of the Great Plains. PECOS was funded by the Eco-Research Program, part of Environment Canada's Green Plan to foster interdisciplinary research on major Canadian ecosystems. PECOS involved more than forty professors from the universities of Saskatchewan and Regina, and included 29 graduate research projects. Issues of scale are an integral part of ecosystem studies. Researchers work at different levels of detail, sampling only a short portion of long temporal scales. Research done at various scales can be inter-related based on the concept of integrative or hierarchical levels. Sustainability itself has strong elements of scale, and can be regarded as the interaction of three interacting dynamics: those of scale, information and energy. Agroecosystems are likely to be sustainable when they combine at appropriate scales, the right balance of energy use, and content of information, including biological (as in diversity), cultural, and (by necessity) technological information.

**TEMPORAL AND SPATIAL DIMENSIONS OF AGRICULTURAL CHANGE IN THE PECOS AREA****Lisa L. Dale-Burnett**Canadian Plains Research Center, University of Regina,  
Regina, SK • CANADA

The PECOS area has been farmed for less than one hundred years. In this short period, change has been a constant: for farmers, rural communities and the natural environment. Over half of the land has been cropped, average farm size has increased from approximately 320 to 1,000 acres, and tractors have replaced ox teams. In order to evaluate the current sustainability of the prairie ecosystem, it is helpful to study its past. By examining how past agricultural inhabitants lived on the land, and by delving into the reasons for their actions, the changing state of the physical environment and the actions of current residents can be understood in context. This paper explores the spatial and temporal dimensions of agricultural change between 1900 and 1961 in part of the semi-arid prairie ecoregion of southwestern Saskatchewan, Canada. Agricultural change can be presented at a number of spatial scales, from the individual farm unit to the national scale. Temporal scale also plays an important role in the examination of change through time.

Historical sources, for example, are available on various temporal scales: agricultural censuses are available every five years, whereas, interviews with farmers can provide insight into the daily round of farm practices. The actions and adaptations of past inhabitants of the study area can also be explored on various human levels (e.g., the individual, the rural community, the provincial community). The scale or level at which agricultural change is viewed is an important consideration in the study of sustainability of the semi-arid prairie ecosystem.

**HEALTH AND WELL BEING IN A CHANGING ENVIRONMENT: PERCEPTIONS OF A RURAL SENIOR SASKATCHEWAN POPULATION****Gail Remus, Mary MacDonald, Heather Thompson**  
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Saskatoon, SK • CANADA

Concerns about the capacity of the prairie ecosystems to sustain agricultural and other land use practices as well as concern about the health and well-being of those living in rural communities have acquired a new urgency. A rural population within Saskatchewan was randomly surveyed to determine perceptions of health and well being. One thousand subjects were interviewed and stratified according to rural/urban location, gender and rural municipality. This survey was undertaken as part of an interdisciplinary research project funded by the Tri-Council Green Plan program. The larger study titled Sustainability of the Semi-Arid Prairie Ecosystem, involved researchers from disciplines such as soil science, agriculture economics, sociology, biology, nursing and philosophy. This presentation will address the aspects of the study related to health and well being of seniors within the study area. Participants were asked to describe their state of health, satisfaction with life, as well as their outlook on their future. Family and community supports, living arrangements and retirement plans were also explored. A better understanding of these aspects will assist workers in planning health promotion programs for seniors living in a rural area.

**PRAIRIE ECOSYSTEM STUDY (PECOS)\*: FROM COMMUNITY TO CHEMICAL ELEMENTS****Helen H. McDuffie, K.M. Semchuk, M.F.O. Crossley,**  
A. Senthilselvan, A.M. Rosenberg, L. Hagel, M. Masley,  
D.L. Ledingham, P. Hanke, R. Kerrich, A.J. Cessna, D.G. Irvine,  
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An evaluation of the sustainability of the Prairie Ecosystem including the land, the biota and the people was a primary objective of PECOS. In order to further our understanding of

potential human health risks associated with pesticide exposure, we selected a defined, rural geographical area and, in cooperation with the residents, we designed and undertook a study (1) to characterize human environmental and occupational exposure to pesticides by questionnaires and by analysis of blood samples, (2) to assess pulmonary function using spirometry (3) to examine neuropsychological and cognitive function using a battery of tests, (4) to evaluate the frequency of autoimmunity as measured by antinuclear antibody titers, (5) to assess the determinants of injury in this rural population and (6) to analyse the concentrations of 44 chemical elements in drinking water samples. Injury patterns and drinking water quality were each assessed once. All other tests were completed in winter (Feb/March 1996) and repeated immediately following early summer herbicide applications. While environmental and occupational pesticide exposure data obtained by questionnaire is the conceptual link among the biological and environmental measurements, the interaction among members of the various disciplines lead to challenges of the conventional wisdom inherent in each specialty.

(\*Ecosystem Research Program Tricouncil Secretariat of Canada).

#### ECOSYSTEM LEVEL FUNCTIONAL CHANGES IN BREEDING BIRD GUILDS IN THE MIXED GRASSLANDS SINCE AGRICULTURAL SETTLEMENT

**Todd A. Radenbaugh**

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This paper examines temporal patterns in breeding birds on the Mixed Grassland ecoregion of Saskatchewan. Since the early 1900s, humans have impacted the Prairies and significantly changed ecosystem structure through the reallocation of energy, space, and habitat away from native systems. Since the dynamics of ecosystems are scale-dependent, here the impacts of agriculture on broad-scale patterns and processes were explored to investigate implications for the region's ecology, evolution and management. To measure human impacts, analysis of breeding bird guilds was conducted over the past 100 years. Results indicate that the introduction of agriculture has altered ecosystem level functions in bird guilds on the Prairies. Further, the conversion of the Prairies into human-dominated systems is having major influences on the hierarchical structure of grasslands. One major change is the creation of new ecospace that is altering broad-scale biotic interactions, as measured by the responses of bird guilds. Presently, humans constitute a major component of the prairie ecosystem. Therefore, overall ecosystem function and health must be addressed in the wider context to include human society and infrastructures.

#### SUSTAINABILITY USING AN INTEGRATED MODEL

**Kenneth Belcher**

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In order to evaluate the sustainability of complex systems, such as an agroecosystem, the research procedure must make explicit the dynamics within and between system components. In addition, the characterization of sustainability as a long-term goal implies the need for a predictive research framework. This paper describes the development of a computer simulation model that dynamically integrates the economic and ecological components of an agroecosystem. The model is comprised of two primary components: (1) a soils component that simulates soil quality and crop growth parameters; and (2) an economic component that simulates land use and cropping decisions. The model components are self-standing but dynamically linked in order to simulate co-evolutionary changes in target agroecosystems. Adopting a strong sustainability criteria, the integrated model is used to evaluate the sustainability of target agroecosystems and the trade-off between economic and environmental sustainability, based on changes in selected agri-environmental indicators. Discussion will focus on the effect of biophysical constraints on agro-ecosystem sustainability in south-western Saskatchewan and the implication of these constraints for policy development.

#### THE PRAIRIE ECOSYSTEM STUDY: HEALTH OF THE LAND

**Darwin W. Anderson**

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The prairie ecosystem study (PECOS) is a major interdisciplinary study of sustainability and ecosystem health in the semi-arid prairie ecoregion of the Canadian part of the Great Plains. Research on the land and the biota was the focus of twelve graduate research projects, all cross-disciplinary to some degree, and at various scales or levels of detail. The present state of small parts of the ecosystem, such as soil aggregation and the nature of the pore space between aggregates are a function of both the nature of the minerals and organic materials making up aggregates, and land use, particularly practices that influence soil organic matter. Agriculture has direct effects on land, and influences adjacent ecosystems such as wetlands, and the diversity of species that live there. Far-ranging species such as ferruginous and Swainson's hawks, despite reduced populations and fragmentation of habitats, have a high degree of genetic diversity; their future is likely to be influenced mainly by social and economic decisions that influence land use. Rare plants, some of them endangered, benefit from the great spatial heterogeneity of the landscape, and are likely to be threatened by a variety of direct and indirect human activities that destroy or modify habitats. The trace element composition of soil and water shows the influence of human activities such as atmospheric deposition of pollutants from metal smelting, from distant places far removed in time.

## TS-13

**Challenges to Measuring Progress: Sustainable Development in Mining****Chair: Mark Burgham—Natural Resources Canada, Ottawa, ON • CANADA****MEASURING PROGRESS TOWARDS SUSTAINABLE DEVELOPMENT IN THE METAL INDUSTRY IN CANADA****Mark Burgham**

Senior Policy Advisor, Mineral and Metal Policy Branch, Minerals and Metals Sector, Natural Resources Canada, Ottawa, ON • CANADA

Measuring progress on sustainable development represents a major challenge for industry, government and other stakeholders. In its Minerals and Metals Policy, the Government of Canada committed to meet the goal of sustainable development by taking into account environmental, social and economic considerations as early as possible in its decisions. The Policy identified the development of sustainability indicators as a priority. To this end, Natural Resources Canada has begun a multi-party process to delineate common values and objectives that relate to the metals industry. The author reports on progress of this work and sets out key issues surrounding the development of indicators for minerals and metals.

**ISSUES OF SCALE IN THE SELECTION AND INTERPRETATION OF INDICATORS OF SUSTAINABILITY FOR MINERAL RESOURCES****Deborah J. Shields<sup>1</sup> and S.V. Solar<sup>2</sup>**<sup>1</sup>USDA Forest Service, Rocky Mountain Research Station, 240 W. Prospect St., Ft. Collins, CO • USA<sup>2</sup> Slovenian Geological Survey, Ljubljana • SLOVENIA

This paper investigates a number of the questions associated with the use of sustainability indicators for energy and mineral resources at multiple spatial scales. The United States Forest Service has committed to implementing sustainable resource management on all National Forest System (NFS) lands by 2003. The criteria and indicators of sustainability (C & I), published in the Santiago Declaration, will provide the framework for investigating and reporting on ecosystem and social system condition and trend. These C&I were developed for and are applicable only to temperate and boreal forest ecosystems at the national scale; other ecosystems, resources, and spatio-temporal scales were not addressed during the Montreal Process. Thus the existing indicator set will need to be extended to reflect both the Agency's multiple use mandate and the diversity of natural systems present on NFS lands. Because there is no natural scale at which all systems should be analyzed, efforts are under way to develop sustainability indicators for nonrenewable resources at the continental or mezo-scale, national, and forest management unit scales. The degree to

which indicators defined on and measured at one scale can be applied at other spatial scales will need to be determined, as will the appropriateness and statistical validity of data aggregation and dis-aggregation. The factors controlling socio-economic and biophysical systems are typically scale dependent, suggesting that the key to developing scale-appropriate indicators is understanding those factors. Moreover, both the spatial extent of impacts and the methods for addressing scale can differ between the ecological and socio-economic contexts, suggesting that single scale analysis is inadequate for resource management decision support.

**INDUSTRIAL ECOLOGY AND MATERIAL FLOW ACCOUNTING: MEASURING THE SUSTAINABILITY OF MINING****Eric Rodenburg**

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Industrial ecology and material flow accounting are the essential frameworks for observing and measuring the sustainability of industrial processes, including mining. Industrial Ecology is the science of sustainability. To understand the potential effect of economic activities on the environment, we must understand the materials that are mobilized in support of those activities. Mining is just one facet of our industrial ecology. Industrial ecology is the study of material and energy flows within the economy — including their extraction from nature and the return of products, emissions, and wastes to nature. Industrial Ecology aims for a closed loop economic system or (in the interim) at least one that does not overwhelm natural systems' abilities to assimilate waste, emissions, and extractions, and landscape modifications. When looking at the sustainability of mining we want to evaluate the material and energy flows associated with that mining, the disposal of wastes, the processing of ores and consequent releases, the emissions and releases associated with the use of that commodity as a feedstock and as embodied in final products, and the character and mode of disposal in its ultimate fate. We want to look at the whole system to characterize the sustainability of particular activities — including mining activities. To do this we must understand both the quantity and character of materials mobilized to support those activities.

## ADDRESSING GAPS IN ECOSYSTEM HEALTH ASSESSMENT: THE CASE OF MINERAL RESOURCES

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The issue of ecosystem health is closely linked to sustainability. At the most basic level, a healthy ecosystem requires conditions that are sustainable. Sustainability has been defined as a system's ability to maintain structure and function indefinitely. This definition is applicable to a variety of complex systems ranging from cells to ecosystems as well as economic systems. Indicators facilitate the assessment of

ecosystem health. The selection of indicators is based on an integrated approach involving a combination of biophysical, socio-economic and human health parameters. In the context of minerals, there are very few parameters developed to assess ecosystem health. One parameter that has been proposed as an indicator of threat to ecosystem integrity is the depletion rate of mineral reserves. Indicators of reduced threats to ecosystem integrity include increasing output of production per unit of non-renewable resources; increasing recycling efforts as well as declining use of resources. The study of mineral resource flows in the Langat Basin has delineated several potential indicators that will be useful to the assessment of ecosystem health. These indicators can be divided into the categories of availability of mineral reserves and resources, which include rates of mineral sterilisation; extraction of minerals, which include hidden flow parameters; and utilisation of minerals, including recycling.

## TS-14

### Environmental Impacts of a Motor Fuel Additive: Methyl Tertiary Butyl Ether (MTBE) Case Study

**Chair: Daniel P.Y. Chang**—Dept. of Civil Environmental Engineering,  
University of California, Davis • USA

#### GROUND-WATER ISSUES ASSOCIATED WITH THE USE OF MTBE AND OTHER OXYGENATES IN GASOLINE

**John S. Zogorski** and Michael J. Moran  
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Under mandates of the Clean Air Act Amendments of 1990, oxygenates such as methyl tert-butyl ether (MTBE) must be added to gasoline in some areas of the United States (U.S.) to reduce ozone formation and carbon monoxide emissions. Today MTBE is the most commonly used oxygenate and in some areas MTBE is also used as an octane enhancer. The large-scale use of MTBE and its physical and chemical properties have resulted in its detection in many ground-water systems. Low concentrations (< 20 ug/L) of MTBE have been detected frequently in ambient ground water in areas of the U.S. where substantial amounts of MTBE are used (> 5% by volume in gasoline). Some of this ground water is used for domestic and public water supplies. The frequencies of detection of MTBE in ambient ground water are 20.6% in areas that use substantial amounts of the compound and 2.0% in areas that do not use substantial amounts of MTBE (< 5% by volume in gasoline). On the basis of limited monitoring data, public water supplies have been affected by low concentrations of MTBE with a frequency of detection of 6.9%. MTBE in ground water can come from a variety of point and non point sources. Low concentrations may have a point or non point source. High concentrations (> 20 ug/L) generally are associated with point sources such as gasoline stations or pipelines; however, high concentrations can result from certain non point sources. High concentrations of MTBE have been reported in ground water used for some domestic and public water supplies. In some cases, treatment of the water

has been necessary to remove the MTBE or the wells had to be removed from service. At some sites, MTBE has migrated much farther than other common gasoline components and those long travel distances increase the probability that MTBE will be detected in a drinking-water well and that treatment may be required. In addition, the occurrence of MTBE in ground-water systems raises important water-quality issues including:

- (1) What concentration of MTBE is acceptable in ground water used for drinking water?
- (2) How well do drinking-water monitoring programs in the U.S. address chemicals that are of concern primarily because of their taste and odor?
- (3) What is the appropriate mix of drinking-water monitoring for oxygenates, wellhead protection, and education of local water resource planners and managers?
- (4) What is the perspective of the hydrogeologic and water quality communities on the large-scale use of oxygenates in gasoline?

#### MTBE THREATS TO GROUND WATER QUALITY: REAL OR IMAGINED?

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A compilation of statewide groundwater data on MTBE detects in the vicinity of leaking underground fuel tanks (LUFTs) and in public supply wells provides important insights regarding impacts of MTBE on California groundwater. State agency data (September 1998) indicate that of the 5,738 gasoline LUFT sites that impact groundwater, at

least 3,180 (55 percent) have MTBE detects at levels greater than 0.5 to 20 mg/L. The actual number of LUFT sites with MTBE detects in groundwater may be much larger mainly because of incomplete site characterizations and sites which were closed before MTBE impacts were assessed. Even though MTBE introduction into the environment was very recent with respect to time scales of groundwater migration, as of September 1998, 35 of 2,988 (1.2 percent) public drinking water wells that were tested already reported MTBE detects. Nearly all of the 35 detects are in wells completed at substantial depths or with substantial screened intervals, virtually ruling out low-level, atmospheric MTBE sources as causes of the detects and strongly implicating high-concentration point sources, mainly LUFT sites, as the most likely sources. Three-dimensional analytical and numerical modeling analyses indicate that MTBE plumes will grow at much faster rates than petroleum hydrocarbon plumes (e.g., benzene) because of much lower tendency to sorb and biodegrade. Absent aggressive remediation or containment, lengths of MTBE plumes will have grown to approximately 3 to 4 times greater than 1995 benzene plumes, with the largest MTBE plumes exceeding 2,000 ft (600 m) in length. Further, the modeling analysis indicates that vertical migration can be expected to extend significantly deeper than the shallow monitoring well networks that typify LUFT site investigations. Indeed, observed MTBE LUFT impacts in the Tahoe Basin appear to verify these predictions. As of September 1998, 29 of 43 active gasoline LUFT sites in the Basin had MTBE detects in groundwater. The plumes are already laterally (>250 to >1,500 ft; >76 to >460 m) and vertically (80 ft; 24 m) extensive, and 11 public supply wells had been contaminated or threatened. The Tahoe Basin aquifer systems are in alluvial deposits that are by no means a typical of California, although grain sizes are somewhat coarser and hydraulic conductivities therefore tend to be higher than, for example, deposits in the Central Valley.

#### THE EUROPEAN PERSPECTIVE TO MTBE AS AN OXYGENATE IN FUELS

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A European perspective on the use and fate of Methyl tertiary-butyl ether (MTBE) as a fuel oxygenate is discussed. Beginning in the late 70s and up to the mid 80s MTBE was introduced in gasolines in European countries as a replacement for lead to raise octane levels. Today MTBE is added to gasoline also to increase the oxygen content to improve combustion and air quality (carbon monoxide, ozone). According to a European regulation the maximum concentration of MTBE in gasoline is 15 vol.-%. However, unlike in the US no minimum oxygen concentration is required for gasolines in Europe. In EU-Europe per year approximately 120 Mio tons of gasoline are sold containing approximately 2.5 Mio tons of MTBE. Future EU regulations will demand a

reduction of benzene and overall aromatics contents of gasoline which is expected to result in an increased use of MTBE. For decision-makers this situation poses a political dilemma where the reduction of one unwanted compound in gasoline can be the cause for an increased use of another unwanted compound. Regarding the fate of MTBE in the environment only very limited data are available for Europe. Recently, a number of reports have been prepared by national environmental protection agencies. In Denmark MTBE was found in groundwater in concentrations below 1 mg/l in many regions while in the proximity of gasoline stations concentrations up to a few hundred mg/l of MTBE were measured. Using reports of the Danish EPA as an example, measurements of MTBE in ground water, evaluation of health hazards, and future policies are discussed.

#### BIOLOGICAL TREATMENT OF MTBE IN BIOREACTORS AND *IN SITU*

**K.M. Scow**<sup>1</sup>, J. Hanson<sup>1</sup>, J. Eweis<sup>2</sup>, C. Ackerman<sup>1</sup>,  
W. Wright<sup>2</sup>, E. Schroeder<sup>2</sup>, and D. Chang<sup>2</sup>

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The gasoline additive, methyl tertiary butyl ether (MTBE), has become a widespread pollutant in many aquifers and surface waters. MTBE is very mobile, not easily treated by conventional remediation methods, and appears relatively resistant to biodegradation processes in the environment. Biological removal of MTBE, however, has been demonstrated in a number of engineered treatment systems. Effective removal of MTBE in the air phase was demonstrated in both a pilot scale biofilter and in full scale biofilters operating at a gasoline soil vapor extraction site in Richmond California and at the Los Angeles County Sanitation Districts Joint Water Pollution Control Plant in Carson, California. A trickling filter bioreactor was effective at removing high concentrations of MTBE from the water phase. From the full scale biofilter in LA, we isolated a bacterial strain (PM1) able to use MTBE as its sole carbon and energy source under aerobic conditions. PM1 can mineralize high concentrations MTBE to carbon dioxide within a period of several days in laboratory cultures. When inoculated into sediment samples from MTBE-contaminated groundwater plumes at Port Hueneme and Vandenberg AFB in California, PM1 rapidly degraded MTBE and did so with repeated additions of MTBE. Nutrient additions were not necessary to support degradation except at very high MTBE concentrations. Field trials involving inoculation of PM1 into contaminated groundwater at Port Hueneme and Vandenberg will begin later this year.



## COST-BENEFIT CONSIDERATIONS FOR THE INTRODUCTION OF GASOLINE ADDITIVES SUCH AS MTBE

**A.A. Keller**

Bren School of Environmental Science and Management,  
University of California, Santa Barbara, CA • USA

The introduction of gasoline additives to address air pollution, such as MTBE, has to be carefully evaluated to take into consideration all the costs and benefits associated with the policy decision. The recent experience in the US, and in particular in California, indicates that there are significant costs associated with these additives, when the entire health and environmental impact is assessed. MTBE is highly soluble, and thus transfers easily to groundwater and surface water bodies, either as a result of gasoline leaks or spills. It presents possible

health concerns and definitely affects the taste and odor quality of the water. Thus, the air quality benefits achieved by better combustion of the improved gasoline formulation may be superceded by water treatment costs. In addition, there are several other cost categories that have to taken into consideration in such policy decisions, such as monitoring costs, ecological damages, and restrictions on recreational activities. Complicating the policy making process, one has to take into account the fact that air quality benefits decrease with time, since vehicle technologies are improving, such that the reduction in emissions is not necessarily only due to the gasoline additive, but also to other factors. The current work presents an analysis of the situation in California, as well as a discussion on the aspects of the cost-benefit analysis which may differ for situations such as Mexico City, Beijing or other cities with rather different air pollution levels and vehicle technologies.

## TS-15

### Transportation Corridors and Ecosystem Health

**Chair: Mike Johnson—Dept. of Civil and Environmental Engineering, University of California, Davis, CA • USA**

#### THE ECOSYSTEM IMPACTS OF HIGHWAY CORRIDORS

**Bonnie Harper-Lore**

Federal Highway Administration,  
US Dept. of Transportation, St. Paul, MN • USA

The construction and maintenance of highway corridors have many environmental impacts. Highways crisscross the nation in an attempt to guarantee our mobility, our national safety, and our commerce. The economic and social good resulting cannot be overvalued. As these highway corridors divide the landscape, however, often the ecologic good is compromised. These impacts devalue both the human and natural environment. The long-term costs include: fragmentation of habitat and migration routes, dispersal of pest species, and reduction of biodiversity. Short-term costs are more obvious. They include: Construction and maintenance disturbances that lead to sedimentation, expansion of weeds, compaction of soils, and so on. Borrow pits used for construction reduce resources, and often become artificial wetlands. Visual impacts of large roadcuts, destruction of vegetation, and the like occur. The balance of nature is thrown off by mitigation efforts, wetland creations, planting of monocultures, roadside maintenance practices, etc. These impacts or costs to the environment are well known. Thanks to the 1969 National Environmental Policy Act (NEPA), these impacts must be avoided and minimized. This paper will explain the roadside rights-of-way view of the impacts and what State Departments of Transportation across the nation are doing beyond the NEPA requirements; and what remains to be done.

#### THE EFFECTS OF ROADS ON MOUNTAIN LION (*FELIS CON COLOR*) IN CALIFORNIA

**Melissa M. Grigione<sup>1</sup>** and Michael Johnson<sup>2</sup>

<sup>1</sup>Defenders of Wildlife, Washington, DC • USA

<sup>2</sup>University of California, Davis, CA • USA

This presentation gives a brief review of the effects of roads on several carnivore species in general and then uses the mountain lion in California as a case study on how roads influence space-use for this species in three areas of the state. The study uses radio-telemetry data and GIS technology to determine the effects of roads on mountain lion home range size and home range overlap in the Coastal Range mountains (both the Diablo Range in northern California and the Santa Ana mountains in southern California) and the Sierra Nevada mountains. It appears that roads have a greater impact on populations inhabiting the Coastal Range mountains than in the Sierra Nevada. Possible explanations for this are: lower road densities in the Sierra Nevada mountains (perhaps below some minimum threshold for mountain lions); vast ecological differences between the two areas not associated with road densities; and differences in movement patterns between mountain lions populations inhabiting the two areas. This study makes recommendations about the usefulness of GIS road density data in ecological studies pertaining to carnivores and what scales are most relevant for this type of work.

## ENVIRONMENTAL IMPACTS OF MOBILITY AND URBAN POLICY OPTIONS: A CASE STUDY FOR THE BRUSSELS-CAPITAL REGION

Paul Safonov<sup>1&2</sup>, Vincent Favrel<sup>2</sup>, and Walter Hecq<sup>2</sup>

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<sup>2</sup>Center for Economic and Social Studies on the Environment, Free University of Brussels, Brussels • BELGIUM

The paper tackles the ecological aspects of mobility induced by major regional policy options such as offices relocation and expansion, transport and other urban policies for the case study of Brussels-Capital region. A system of models is being developed, including: 1) Forecasts of population and employment dynamics, in accordance to different economic and urban policies. 2) A mobility model, providing scenarios of traffic intensity and its spatial distribution in the region. 3) A model linking mobility and emissions of air pollutants, calculating also external costs of transportation. Recommendations for improvement of the policy making regional and urban planning, in order to reduce the ecological pressure, are discussed.

## ECOLOGICAL IMPACTS OF AN INTRODUCED FUNGUS THAT HAS SPREAD ALONG TOURISM CORRIDORS IN THE STIRLING RANGE NATIONAL PARK, SOUTH WESTERN AUSTRALIA

David Newsome

School of Environmental Science,  
Murdoch University, Murdoch, WA • AUSTRALIA

The Stirling Range National Park lies within the south west Botanical Province of Western Australia, which is an acknowledged center of biodiversity and endemism of international significance. It is an important conservation reserve, genetic resource and nature based tourism destination. The mountain scenery and diverse array of wildflowers attract up to 100,000 visitors a year. Biologically the park contains a diverse flora, with 1500 plant species, which includes 82 endemics and constitutes 20% of the flora of Western Australia. The health of the Stirling Range ecosystem is being compromised by the spread of an exotic fungus (*Phytophthora cinnamomi*) accidentally introduced when the road network was expanded through the national park. The fungus has since been spread along roads and fire-control corridors by infected soil being carried on the wheels of vehicles. More recently it has become apparent that walkers, by carrying infected soil on their boots, have spread the disease along mountain pathways. In south western Australia up to 2000 of the indigenous plants are susceptible to the pathogen. Ecosystem response to the infection has resulted in reduced biodiversity and altered structural composition of the plant communities. Widespread loss of dominant or keystone plant species is likely to impact on dependent faunal populations. This study highlights the role of exotic organisms in degrading ecosystem health and the need for active management in tourism centered protected areas.

## TS-16 Human Communities and Ecosystem Health: Comparing Perspectives and Making Connections

### AGRO-ECOSYSTEM HEALTH IN HONDURAS: LIVESTOCK AND HUMAN HEALTH PERSPECTIVES

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Small-scale livestock production is essential to the livelihoods of semi-subsistence farmers in the Tascalapa watershed of Honduras. This agro-ecosystem health project explored the interactions among human, animal and ecological health as related to livestock production using both epidemiological and participatory methods. The integrated research team of veterinarians, socialologists and local Honduran agronomists co-operated with farmers and local committees to identify the resources and constraints which could contribute to the development of sustainable farm management strategies.

### COMPARING PERSPECTIVES ON ECOSYSTEM HEALTH: A CASE STUDY FROM SOUTH EASTERN AUSTRALIA

Jacqueline de Chazal and Ian R. Noble

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Three perspectives on "Ecosystem Health" are contrasted in relation to remnant forest patches located in an agricultural landscape in South Eastern Australia. The first perspective understands 'health' in terms of increases in forest patch size, a commonly held idea in conservation biology. The second perspective uses a survey of opinions on bushland 'health' given by rural landholders, environmental management professionals and members of community based environment groups in the study region. The third perspective applies Rapport's *et al.* (1985) indicators of 'ecosystem distress syndrome' to a biological field study of remnant forest

patches. The relationships between remnant forest patches ordered in terms of increases in patch size; according to the social survey results; and according to Rapport's *et al.* indicators will be discussed. Practical outcomes for assessing ecosystem health in terms of the above perspectives will be described.

#### RELATING INDICATORS OF ECOLOGICAL HEALTH AND INTEGRITY TO ASSESS RISKS TO SUSTAINABLE AGRICULTURE AND NATIVE BIOTA

**Minghua Zhang**<sup>1</sup>, K. Shawn Smallwood<sup>2&3</sup>, and Paul Grant<sup>4</sup>

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Human activities in Yolo County have contaminated environmental media with nitrates, pesticides, and other pollutants that pose risks to agricultural goals and native biota, and certain activities have changed the structure and extent of integral parts of the landscape that affect ecosystem functionality. We applied the ecological indicators approach to assess the conditions of groundwater, surface water, and assemblages of biota within Yolo County. Indicators of ecological health are composed of available data that are carefully integrated to inform of the risks posed by chemical contaminants. Indicators of ecological integrity inform of the degree to which functional parts of the landscape are intact. We explored how these indicators might interact and affect each other on a common landscape, both in a real sense and in presenting map products to policy-makers. We also sought to identify those natural resources and locations within the County that are most sensitive or vulnerable to past and ongoing land uses, and that may pose the most serious consequences to sustainable agriculture and other planning goals. For these purposes, we used GIS, Mathematica, ecological indicators, and appropriate statistics. We also worked with the Davis Visioning Group to implement our results by providing policy-makers and the public with map-based risks to the agricultural production system and native biota.

#### LAND USE CHANGES DUE TO URBANIZATION FOR THE MID-ATLANTIC INTEGRATED ASSESSMENT REGION

**Ron Matheny** and Keith Endres

US Environmental Protection Agency, Landscape Characterization Branch MD-56, Research Triangle Park, NC • USA

This study assesses possible land coverage impacts of increased population development for the Mid Atlantic Integrated Assessment (MAIA) region as measured through the increase in population and economic activity projections for the years 2000 AD, and 2010 AD, and 2020 AD. It projects possible reductions in acres of agriculture, forest, and wetlands and increases in urbanization as indicated by the 15 categories of the Multi-Resolution Land Characterization data set. This assists in determining land cover areas that may be vulnerable to ecological insult from urbanization. The method used for this analysis is cell-based. A diversity matrix is developed which is weighted for each cell in the MAIA region using the Multi-Resolution Land Characterization by the contiguous cells' land use and distance from existing infrastructure. The method first assigns a score to each cell which represents the number of contiguous urban cells for each of three urban classifications (low intensity residential, high intensity residential, and high intensity commercial/industrial/transportation). Next, each cell is weighted by its Euclidean distance from urban infrastructure (such as roads, pipe lines, cities, etc.). Areas such as Federal and state land and military bases are then excluded as is water (lakes, bays, streams and rivers). Population rejections are derived from the 1998 complete economic and Demographic Data Source by Woods & Poole Economics. Since the MRL uses 3 classifications for urban land use, total employment in 12 economic sectors and the number of households by income are used to determine the acres needed for each urban classification. Three scenarios are used for each projection. The base scenario assumes that household acreage needs and sector needs remain constant. The "smart growth" scenario varies household acreage needs and sector needs. The third scenario reduces household acreage and keeps sector needs constant.

## TS-17

**Managing for Ecosystem Health in National Parks and Equivalent Reserves****Chair: Michael Soukup—Natural Resources and Science, National Park Service, Washington, DC • USA**

## ECOLOGICAL INTEGRITY AS AN IDEAL MEASURE FOR THE HEALTH OF AN ECOSYSTEM

**John D. Varley**Yellowstone Center for Resources, National Park Service,  
Yellowstone National Park, WY • USA*Abstract not available*

## THE ECONOMICS OF EVERGLADE RESTORATION: MISSING PIECE

**Richard Weisskoff**School of International Studies, University of Miami,  
Coral Gables, FL • USA

The restoration of the Florida Everglades is the largest restoration in the world today, having already appropriated more than \$1 billion and preparing a \$7.8 billion proposal to the U.S. Congress on July 1, 1999. The plan for Everglades Restoration, however, fails to consider the impact of the improved activity that it will bring to an already fast-growing region. The restoration will allow the acceleration of cattle-raising and sugar-growing north of the Everglades National Park and the continuing urban sprawl on the east and west coasts. Tourism is also increasing at 3% per year and would be even greater with restoration. This paper reports the

results of testing the continuing and accelerating growth patterns using a regional economic growth model of South Florida. We trace the impacts of ecosystem restoration on major activities in the region over the next 35 years. We find that the current trends add up to an incredible load of economic activity, plus the new activity made possible with ecosystem restoration adds to the already high stresses on the environment. All these feedbacks of the growing economy and its changes have been ignored by the Army Corps' Restudy which forms the blueprint for the present restoration.

## YELLOWSTONE CASE STUDY

**Michael V. Finley**National Park Service, Yellowstone National Park,  
WY • USA*Abstract not available*

## WRANGELL-ST. ELIAS CASE HISTORY

**Jonathan Jarvis**National Park Service, Wrangell-St. Elias National Park,  
AK • USA*Abstract not available*

## TS-18

**Collaborative Approaches towards Managing for Ecosystem Health: The Role of Nongovernmental Organizations****Chair: Rita Schmidt Sudman, Executive Director, Water Education Foundation, Sacramento, CA • USA**

## MANAGED MARINE AREAS IN CALIFORNIA

**Karen Garrison**Natural Resources Defense Council  
Oakland, CA • USA*Abstract not available*

## THE ROLE OF THE PROTECTED AREAS SYSTEM OF CUBA IN MANAGING FOR ECOSYSTEM HEALTH: THE CASE OF CIDA-WWF-CNAP PROJECT "CONSERVATION AND SUSTAINABLE DEVELOPMENT IN ZAPATA SWAMP"

**Antonio Perera<sup>1</sup>, J.L. Gerhartz<sup>2</sup>, and E. Agnew<sup>3</sup>**<sup>1&2</sup> Centro Nacional de Areas Protegidas,  
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In the last five centuries natural forests in Cuba were reduced at 14% of their original area, while natural ecosystems were confined to less than 20% of the total surface of the country. In the last years the development of the National System of Protected Areas (NSPA), has followed the approach of creating

huge multiple-use protected areas located in the main natural regions that encompass around 2 400 000 ha, where a more careful and detailed land use planning process takes place. These multiple-use protected areas are the frame of 80 more restricted core areas, i.e. national parks, ecological reserves and so on, that summarize around 732 000 ha. This approach has represented one of the main tools to preserve ecological integrity and ecosystem health in especially sensitive ecoregions. The paper analyzes the recent development of the NSPAs and the role of WWF Country Plan for Cuba as a support for the consolidation of an integrated approach to ecosystem management. This approach facilitates the insertion of protected areas in a broader scope that permit to work in the frame of large ecosystems, contributing to their stability and health. We focus on the WWF Canada-CIDA-CNAP Project Conservation and Sustainable Development in Zapata Swamp, devoted to the people and biodiversity richness of that wetland of more than 500 000 ha, the most important of the West Indies.

#### HUMANE VALUES AS A BASIS FOR ECOSYSTEM HEALTH

**John W. Grandy**

Wildlife Programs, The Humane Society of the United States, Gaithersburg, MD • USA

Restoring and maintaining the health of ecosystems will require good science and a public that deeply values healthy ecosystems. The Humane Society of the United States

(HSUS) believes that humane values can and should form the basis both for public sentiment toward the environment and for the science that supports and advances those public concerns. Three major HSUS programs address these issues. First, our urban wildlife protection program encourages public tolerance for and appreciation of our wild neighbors, disseminating practical techniques for the humane resolution of backyard wildlife conflicts and the creation of natural habitats for wildlife in urban spaces. Second, our wildlife immunocontraception research program seeks to develop new technologies for the humane, non-lethal control of wildlife populations, while promoting public dialogue on the potential for humane stewardship of wildlife and our environment. Finally, the HSUS Wildlife Land Trust offers landowners who adhere to principles of humane stewardship the opportunity to protect their lands for wildlife in perpetuity.

*Title and abstract unavailable*

**Rita Schmidt Sudman**

Water Education Foundation, Sacramento, CA • USA

## TS-19 Climate Change and Ecosystem Health

**Chair: Stephen Schneider—Dept. of Biological Sciences, Stanford University, Palo Alto, CA • USA**

#### CAN ECOSYSTEMS ADAPT TO 21ST CENTURY CLIMATE?

**Stephen H. Schneider**

Department of Biological Sciences, Stanford University, Stanford, CA • USA

It is a scientific truism that climate determines ecological niches, and it is increasingly obvious that life also modifies climate. This mutual interaction, which I have described with the metaphor of “the coevolution of climate and life,” has taken on particular poignancy in the past several decades as the likelihood that human use of the atmosphere as an unpriced sewer is modifying the chemical composition with potential consequences of significance on both climate and life. Moreover, the fragmentation of habitats combined with potentially unprecedentedly rapid human induced climate changes raises the prospect of significant disruption to biological communities that in turn are relevant to human welfare. Large uncertainties attend every aspect of the logical chain from human disturbances to the environment, to climatic responses, to

impacts on nature and society, and to costs of mitigation of human disturbances. Fortunately, the emerging meta-discipline of “integrated assessment” is beginning to approach this vast problem in a quantitative way. Some of the conclusions from such studies will be presented.

#### CLIMATE CHANGE AND HIGHLAND ECOSYSTEMS IN COSTA RICA

**Alan Pounds**

Monteverde Cloud Forest Preserve, Puentarenas • COSTA RICA

Evidence from Costa Rica’s Monteverde Cloud Forest indicates that increases in tropical air and sea surface temperatures since the mid-1970s have altered regional hydrology and, consequently, natural communities. Highland ecosystems in general and tropical mountains in particular are especially vulnerable to large-scale warming, in part because it is amplified at high elevations relative to sea level. The

amplification, due largely to an increase in atmospheric moisture and a resultant shift towards moist adiabatic lapse rates, may be most pronounced in the tropics, where oceanic warming is most systematic. Because of this warming, tropical freezing heights have shifted upwards, and glaciers on high tropical mountains are rapidly melting. The patterns at Monteverde suggest that relative humidity surfaces, and thus cloud formation heights, have likewise shifted upwards. Dry-season mist frequency, which is negatively correlated with sea surfaces temperatures in the equatorial Pacific, has declined dramatically over recent decades. Associated with the decline is a constellation of demographic changes that have altered communities of birds, reptiles, and amphibians in the area. The most dramatic change was the disappearance of 20 of 50 frog and toad species from a 30-km<sup>2</sup> study area following a period of reduced mist frequency in 1987.

#### CLIMATE CHANGE, BIRDS AND ECOSYSTEMS: WHY SHOULD WE CARE?

**Jeff Price**, Director of Climate Change Impact Studies,  
American Bird Conservancy, Boulder, CO • USA

Nations Intergovernmental Panel on Climate Change projects an increase in global mean temperatures of 1-3.5° C by the year 2100. How will this climate change affect birds? Models of changes in the breeding distributions of North American birds predict that most species will undergo some shift in their ranges. In parts of northern Minnesota and southern Ontario, this could lead to an avifauna with up to 16 fewer species of wood warblers than currently occur. In Michigan, there could be a gross loss of greater than 50% of the neotropical migrants (including greater than 75% of the warblers). Unless all of the components of the ecosystem change at the same rate, an unlikely prospect, this potential disruption of the ecosystem could lead to major impacts on forest health. For example, the loss of insectivorous birds that feed on spruce budworms could lead to outbreaks of increased severity and frequency. I will present maps showing the distributional changes predicted by one climate change model and various sensitivity analyses as well as review the evidence that some changes are already occurring. This includes preliminary results showing that the average latitude of occurrence of some species of North American birds has shifted northward by almost 100 km in the last 20 years. I will also discuss how these potential changes in bird distributions could affect local economies (forestry and tourism) and other models of climate change (e.g., vegetation models).

#### HISTORICAL STUDIES OF SPECIES' RESPONSES TO CLIMATE CHANGE: PROMISE AND PITFALLS

**Rafe Sagarin**

Dept. of Ecology, Evaluation, and Marine Biology,  
University of California, Santa Barbara, CA and Hopkins  
Marine Station, Pacific Grove, CA • USA

Traditional tools of experimental ecology will be largely inadequate in detecting species and community responses to global climate change. Instead, historically-based research, which combines extensive observations of natural systems with a wide array of historical data records can be used to support the connection between changes in biological systems and changes in physical parameters. Most of the small, but growing number of observational studies that attempt to relate biological changes to climate change have used the historical method to varying degrees of success. I use two long-term studies of possibly climate-related changes to intertidal invertebrate and plant populations in central California to illustrate both the promise and pitfalls of historically-based studies. In one study, we showed that southern invertebrate species have become more abundant and northern species have become less abundant since 1930. In the second study, we showed that an important alga, *Endocladia muricata* has shifted to a lower tidal height since 1960. Both findings occurred during periods of warming sea temperatures and are consistent with simple predictions of species' responses to climate warming. Nevertheless, the unavoidably limited spatial scale and temporal gaps in these studies illustrate some of the weaknesses likely to be encountered in historical scientific research. Other historical studies lack in a third area, which is taxonomic coverage. Also apparent is the difficulty in confidently identifying mechanisms responsible for observed changes. This gap will likely be filled with experimental studies that focus on potential impacts of climate change on individuals, populations, and communities. On the positive side, these studies illustrate the importance of long-term data sets, scientific refugia, and permanent study plots in establishing a strong correlation between biological and climatic change.

## TS-20

**Maintaining and Restoring Forest Ecosystem Health: Case Studies from Europe, Australia, and North America****Chair: Bruce Wilcox—Center for Conservation, Research and Training, University of Hawaii, HI • USA****RESTORING NATURALNESS IN SECONDARY FOREST ECOSYSTEMS TO ENHANCE THEIR ECOLOGICAL STABILITY****Peter Brang**

Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf • SWITZERLAND

The ability of a forest ecosystem to fulfill multiple human needs depends on its condition and dynamics, both of which are related to its naturalness. Many forest ecosystems in Switzerland and elsewhere in central Europe are in far from a natural condition as they have been extensively used by humans for centuries. Key components, structures and processes of these forests have been severely altered, and partly impaired. Restoration of impaired ecosystem properties to a more natural state is being increasingly advocated. However, the full restoration of natural forest ecosystem dynamics often leads to unwanted fluctuations in the delivery of products and services to humans, and forest management therefore aims at enhancing ecosystem stability. It is consequently unclear to what extent the naturalness of secondary forest ecosystems should be restored. The conceptual framework of ecological stability properties provides a useful approach to address this question. It includes the basic concepts of resistance – i.e. the ability of an ecosystem to remain unchanged in spite of the presence of a disturbing agent – and resilience – the ability of an ecosystem to return to a reference state (or to reference dynamics) after a disturbance. Forest ecosystem dynamics, including response patterns to human and natural disturbances, can be described in terms of resistance and resilience. Ecosystem restoration is likely to change resistance and resilience of ecosystem components and processes. Understanding the dynamics of forest ecosystems of varying naturalness enables a human disturbance regime with an optimum in ecosystem resistance, resilience, naturalness, and output of products and services to be introduced.

**THE PRECAUTIONARY PRINCIPLE AND ECOSYSTEM HEALTH: A CASE STUDY FROM THE JARRAH FOREST, SOUTH-WESTERN AUSTRALIA****Michael C. Calver**

School of Biological Sciences and Biotechnology, Murdoch University, Murdoch, WA • AUSTRALIA

Maintaining a healthy ecosystem does not preclude economic use of ecosystem components and such use may be an essential part of maintaining healthy human communities within the ecosystem. The precautionary principle is one mechanism for assessing which economic uses or developments are least likely to degrade ecosystem health. It argues

that: “Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by: (i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and (ii) an assessment of the risk-weighted consequences of various options” (*The Intergovernmental Agreement on the Environment*, May 1992, quoted in Deville and Harding 1997, “Applying the precautionary principle”, Federation Press, Sydney, p.13). However, scientific suspicion of the precautionary principle is based largely on confusion as to procedures for incorporating scientific data into a philosophical-political process. Here we take published guidelines on applying the precautionary principle and illustrate how they allow scientific input to the question of whether or not current multiple-use forestry takes a precautionary approach to maintaining ecosystem health in the jarrah forest of Western Australia. The scientific input involved (i) identification of outcomes in similar situations elsewhere in Australia, (ii) selection of indicator species/processes for monitoring based on predictions made on the basis of (i) above and published accounts of processes and indicator species’ biology, and (iii) a prescription for monitoring/experimentation that includes a quantitative requirement for a probability of detecting impacts based on statistical power analysis. On the standards suggested, contemporary management falls short of a quantitative definition of precaution that involves adherence to measurable standards and cannot provide a strong assurance that it will maintain ecosystem health.

**THE SIERRA NEVADA FRAMEWORK FOR CONSERVATION AND COLLABORATION: A CASE STUDY IN MAINTAINING AND RESTORING ECOSYSTEM HEALTH****Hal Salwasser**

USDA Forest Service, Pacific Southwest Research Station, Berkeley, CA • USA

The Sierra Nevada Range of California, nearly 21,000,000 acres of jagged snowy mountains (8.75 mil. ha), contains more than 4,000 lakes and the headwaters of California’s two largest river systems and 22 other smaller systems. The range hosts more than 3,500 species of native plants, 50% of the state’s plant diversity and about 400 species of vertebrate animals, including more than 650,000 of one particular species, *Homo sapiens*. This latter species has transformed the indigenous ecosystems of the Sierra through occupancy and land uses spanning at least 10,000 years. Since the early 1900s, about 62% of the Sierra Nevada have been protected

in public ownership as national parks, national forests, and other public lands. The single largest ownership is the National Forest System, 10 national forests that comprise 41% of the Range. For thousands of years the Sierra was the subsistence habitat for indigenous people. Later it was the source of the Gold Rush of 1849, then a treasure of forage for large herds of cattle and sheep in the late 1800s and early 1900s, then the source of water and hydropower for farms and cities beginning in the mid 1900s, then a source of timber for a growing population in the late-1900s. Now, the principal resource values in the Sierra derive from its water, outdoor recreation, biological diversity and setting for thousands of residences in the urbanizing forest. The different resource values and their implications have driven the management of land and resources in the Sierra since humans first appeared. Changes in these values have fueled controversy and conflict, beginning in the late. Current resource debates swirl around old forests, water, biodiversity (chiefly in the form several mammal, birds, amphibian and fish species), invasive species, wildland fire and forest fuels and the impacts of encroaching humanity in the lower elevation zones. Attempts since the 1980s to reconcile different views and interests as they affect national forest management have been only partially successful. Now, a large, regional scale planning process is underway to address conflicting values and bring both the body of scientific knowledge about the Sierra and citizens who live in or are affected by what happens in the Sierra into a stronger role in shaping conservation plans. This process is known as the Sierra Nevada Framework for Conservation and Collaboration. This presentation will report on the impetus, approach, progress and prospects for the Framework as guidance for sustaining desired ecosystem conditions in the Sierra.

## FOREST BIODIVERSITY MANAGEMENT IN ARMENIA: ISSUES AND DELIBERATIONS

**Karen Ter-Ghazaryan**

Forest Research and Experimental Centre,  
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Armenia is a small (area slightly less than Maryland state) mountainous country located in the southernmost part of the former USSR. Biodiversity in Armenia is particularly rich and specific. The country is situated at the meeting zone of the Caucasian, Iranian and Mediterranean flora regions. Due to this location and the diversity of climate, altitude differences, sharp fluctuations of relief and soil variability, are flora, plant associations and fauna extremely rich and diverse. High rate of biodiversity can be applied also to forest areas, which extend from 700 to 2,600 m a.s.l. Notwithstanding that forest areas occupy only 11% of the land territory, they give shelter to more than half of the total country's biodiversity. The role of forestry and forests for preservation of many endangered species cannot be overemphasized, although detailed surveys are lacking. For instance, broad-leaved deciduous forests support both specific flora and fauna. Many species are completely dependent on forests for their existence.

Following major problems can be mentioned.

- lack of adequate and up-dated information about forest biodiversity status
- insufficient cooperation between concerned ministries and authorities
- poor enforcement, monitoring and control of biodiversity
- lack of trained staff.

The environmental assets found in forests can be very sensitive to various forestry operations, logging and other management activities. It is therefore essential that management methods are adapted to existing natural

conditions and environmental resources, and that larger consideration is taken with respect to these factors.

## TS-21 Landscape Health Assessment: Using Remote Imagery, Geospatial Information, and Landscape Fragmentation I

**Chair: G.P. Patil—Dept. of Statistics, Pennsylvania State University, University Park, PA • USA**

### LANDSCAPE HEALTH ASSESSMENT USING REMOTE IMAGERY, GEOSPATIAL INFORMATION, AND LANDSCAPE FRAGMENTATION

**G. P. Patil**

Center for Statistical Ecology and Environmental Statistics,  
Pennsylvania State University, University Park,  
PA • USA

It is exciting to see that it looks now feasible to do landscape health assessment using remote imagery and landscape fragmentation. Using various technologies, it is now possible to provide snapshots of landscapes indicative of various features of interest pertaining to human societies,

plant and animal communities, aquatic networks, etc. This information can be represented in various kinds of multicolor maps that depict political, natural, methodological, or other features. These multicolor maps provide a basis for comparative assessments of regions within a policy making and implementation context. It is also possible to extract meaningful profiles of management units, such as watersheds, that can be calibrated and compared in order to assess and manage watersheds of a region. These current developments are part of the environmental and ecological information superhighway and are at the cutting edge of regional policy research with remote imagery and geospatial information. When a natural landscape is cast as a categorical raster map, a multiresolution characterization of spatial pattern can be obtained whereby the entropy



is computed for a finer resolution map, conditioned on the values of a coarser resolution map. After application to a sequence of rescaled maps which have increasingly degraded resolution, the conditional entropy is plotted as a function of measurement scale (resolution), thus resulting in a multi-resolution profile of fragmentation patterns. For neutral landscapes that are simulated by multiresolution stochastic generating models, we present a method to directly compute conditional entropy profiles. Such profiles can provide benchmarks for comparing results obtained from raster maps of actual landscapes that are classified from satellite images. Results show that characteristic landscape types give rise to characteristic features of these fragmentation (conditional entropy) profiles.

#### LANDSCAPE PATTERN CORRELATES OF STREAM CONDITION: A MULTI-WATERSHED STUDY FROM THE UNITED STATES MID-ATLANTIC REGION

**K. Bruce Jones**<sup>1</sup>, Anne C. Neale<sup>1</sup>, James D. Wickham<sup>2</sup>, Timothy G. Wade<sup>1</sup>, Kurt H. Ritters<sup>3</sup>, Robert V. O'Neill<sup>4</sup>, and Rick N. VanRemortel<sup>5</sup>

<sup>1</sup>US Environmental Protection Agency, Las Vegas, NV • USA

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Human-induced changes in landscape pattern across watersheds are known to affect stream conditions, including water chemistry, habitat, and biota. However, studies to date have produced mixed results - the importance of individual landscape features has varied considerably. Generally, these studies have been limited to a few watersheds with very different biophysical settings, which may explain variable responses of stream water chemistry and biota to certain landscape features. Taking advantage of a new set of landscape indicators, and a robust stream database generated by the Environmental Monitoring and Assessment Program, we analyzed quantitative relationships between stream conditions and 20 landscape indicators on 590 watersheds across the mid-Atlantic Region of the United States. These watersheds represented a wide range of biophysical and human-use gradients across the Region. In this paper, we report results of this comprehensive study.

#### ECHELON SCREENING OF REMOTELY SENSED CHANGE INDICATOR

**Wayne L. Myers**

School of Forest Resources & Envir. Resources  
Research Institute, Pennsylvania State University,  
University Park, PA • USA

Detecting and mapping landscape change is crucial for monitoring ecosystem health on regional scales. Preliminary indications of change can be obtained expeditiously from remotely sensed spectral data acquired by sensors carried on satellites.

Technical difficulties arise in screening images consisting of change indicators because fine-scale noise is often prevalent and different types of changes vary in the strength of their expression. Treating a change image as a surface and determining its topological structure in terms of echelons can facilitate screening for areas of change to be further investigated by more definitive but less economical methods. Echelons provide a view of surface organization as hierarchical hillforms with peaks being first-order components. Initial extraction of first-order echelons gives a basis for noise suppression without smearing of information. The relative nature of echelons enables flagging of spatially coherent changes that are subtle as well as changes having high spectral contrast.

#### GRASSLAND BIRD COMMUNITIES AND ENVIRONMENTAL HEALTH: THE ROLE OF LANDSCAPE FEATURES

**Douglas H. Johnson**<sup>1</sup>, Sharon F. Browder<sup>2</sup>, and Maiken Winter<sup>3</sup>

<sup>1</sup>US Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND • USA

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Grasslands are North America's most disturbed ecosystem (Samson and Knopf 1994). Nearly all eastern prairies have been converted to annual crop production. Western prairies frequently suffer from overgrazing, invasive plants, and other impacts far different from the natural disturbances under which they evolved (Johnson 1996). Associated with the loss, degradation, and fragmentation of grasslands, populations of birds dependent on prairies typically have declined. Recent research has demonstrated a reciprocal relationship between the landscape health of grassland ecosystems and the breeding bird communities those ecosystems support. First, a variety of landscape features have been demonstrated to influence the population size and reproductive success of birds that use grasslands (Johnson and Winter 1999). And second, metrics based on the composition of bird communities have been shown to reflect the health of grassland landscapes (Browder et al. in prep.). These relationships provide important links between what can be sensed remotely and the actual ecological integrity of the area. In this paper we survey the recent findings that support these conclusions, and suggest ways in which the relationships can be employed both for monitoring environmental health and for managing grassland landscapes.

## REGIONAL VULNERABILITY ASSESSMENT: A CONCEPTUAL APPROACH

**Elizabeth R. Smith**

US Environmental Protection Agency, National Exposure  
Research Laboratory, Research Triangle Park, NC • USA

EPA's Regional Vulnerability Assessment (ReVA) project is developing and testing an approach to conducting comparative ecological risk assessments at the regional scale. It seeks an objective and quantifiable answer to answer the question, "What are the greatest threats accompanying socioeconomic growth in a region and which ecosystems are most vulnerable?" ReVA builds on the environmental

monitoring base developed by the Environmental Monitoring and Assessment Program (EMAP), and incorporates the latest developments in remote sensing, landscape ecology, multimedia modeling, and ecological risk assessment. ReVA also relies on socioeconomic research to develop internally consistent scenarios against which to compare risks from future population growth and concomitant changes in land use and pollutant generation. The research is being conducted in concert with EPA Region 3 as part of the Mid-Atlantic Integrated Assessment (MAIA). This resulting methodology will be a critical aid to state and local governments and regional planning bodies in developing efficient and effective strategies for community-based environmental protection.

## TS-22 Management Strategies Employed in the Restoration of Coastal and Marine Ecosystems

**Chair: Jonna Mazet—Wildlife Health Center, University of California, Davis, CA • USA**

### COOPERATIVE RESEARCH IN SUPPORT OF POPULATION RECOVERY: THE CASE OF THE SOUTH- ERN SEA OTTER

James Estes<sup>1</sup>, **Jonna Mazet**<sup>2</sup>, David Jessup<sup>3</sup>, and Andrew Johnson<sup>4</sup>

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The southern sea otter population is threatened, and recent surveying indicates that the numbers are declining rather than recovering. The California Sea Otter Research Group is a team of scientists representing many disciplines who have formed a partnership among their multiple public agencies and private organizations in order to provide the research necessary to implement management strategies for the recovery of this fragile population. This collaborative approach is an excellent example of a grass roots effort by researchers to build a scientific team capable of addressing the complex issues surrounding the potential extinction of this keystone species in an attempt to prevent the possibly devastating impacts that its loss could have on the California marine ecosystem. Each researcher in this partnership is dedicated to southern sea otter conservation and population recovery and brings to the group a unique scientific perspective and expertise that could not be gathered by any one organization or governmental agency. It is only through this type of collaboration that research which will allow implementation of a strategic plan for population recovery can be produced. Additionally, this creative partnership has resulted in a formidable collection of resources for education, public relations, and political influence.

### NATURAL RESOURCES MANAGEMENT FOR ECOSYS- TEM HEALTH: MANGROVE REHABILITATION AND RESTORATION IN VIET NAM

**Nguyen Hoang Tri**<sup>1</sup>, Phan Nguyen Hong<sup>1</sup>, W. Neil Adger<sup>2</sup>, and P. Mick Kelly<sup>3</sup>

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This paper examine one strategy of ecosystem management widely practiced in coastal Vietnam, namely mangrove rehabilitation and restoration, undertaken to enhance and restore local environments as well as to benefit local population. It may provide a dual, 'win-win' benefits in improving the livelihood of local resource users, enhancing species and functional diversity of ecosystems as well as enhancing sea defenses. The strategy, therefore, represents a precautionary approach to improve the ecosystem health. This paper quantifies the economic benefits of mangrove rehabilitation undertaken, inter alia, to enhance sea defense system in three coastal districts of northern Vietnam. The results of the analysis shows that the mangrove rehabilitation can be desirable from an economic perspective based solely on the direct use benefits by local communities. Such activities have even higher benefit cost ratios with the inclusion of the indirect benefits resulting from the avoided maintenance cost for the sea dike system which the mangrove stand protect from coastal storm surges.

## MULTI-MODELING APPROACHES TO REGIONAL ECOLOGICAL ASSESSMENT: ATLSS, THE EVERGLADES, AND THE ENDANGERED CAPE SABLE SEASIDE SPARROW

Donald L. DeAngelis<sup>1</sup>, Louis J. Gross<sup>1</sup>, and M. Philip Nott<sup>2</sup>

<sup>1</sup>The Institute for Environmental Modeling, University of Tennessee, Knoxville, TN • USA

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There is a great need for tools to aid analysis of the environmental impacts at regional extents of alternative management scenarios, and the ability to link these tools to social assessment including economics. We argue that an appropriate methodology for such a tool is multimodeling. This involves a mixture of modeling approaches based upon the inherent temporal resolution and spatial extent of various trophic components, linked together by spatially-explicit information on underlying environmental (e.g. water, soil structure, etc.), biotic (e.g. vegetation), and anthropogenic factors (e.g. land-use). We describe our ongoing effort to develop and apply a

multimodel to aid in restoration planning in South Florida. The ATLSS (Across Trophic Level System Simulation) project, involves analyzing the ecological impacts of hydrologic planning across the Everglades, but is based on an underlying structure that can be applied to many different regions. The approaches currently involved include spatially-explicit species indices, compartment analysis, differential equations for structured populations and communities, and individual-based models. Linking models which operate at very different spatial and temporal resolutions has been a major challenge, requiring a variety of spatial interpolation methods, and careful design of model interfaces and linkages with remote sensing data and GIS. Such multimodeling efforts are an essential tool to link together disparate data sets, aid monitoring programs, and produce relative assessments of the ecological impacts at landscape-levels of spatially-explicit management plans. We will provide an overview of the project and then focus on a particular endangered species (the Cape Sable Seaside Sparrow) and how the ATLSS project has aided in assessing the impacts of alternative hydrologic plans on this species.

## TS-23

### Human Health Costs of Ecological Degradation

**Chair: David Rapport—International Society for Ecosystem Health, University of Guelph, ON • CANADA**

#### CONTROLLING AIR POLLUTION: IS THE PAIN WORTH THE GAIN?

**R. T. Burnett**

Environmental Health Directorate, Health Canada,  
Ottawa, ON • CANADA

Epidemiological studies, conducted in several countries, have consistently demonstrated associations between ambient concentrations of ambient air pollution and adverse health outcomes, including pre-mature mortality, cardio-respiratory hospitalizations, emergency department visits for respiratory diseases, asthma attacks, respiratory symptoms, and restricted activity. These associations have prompted regulatory agencies in several countries, including Canada, to either revise current air pollution standards or establish new guidelines. Recent epidemiological research in Canada linking air quality and health is reviewed. Economic approaches to evaluating costs and health benefits of controlling air pollutants are discussed, and their use is illustrated in evaluating the consequences of reducing the sulphur content of gasoline. Ongoing epidemiological research on the health effects of air pollution is outlined.

#### SCENARIO-BASED HEALTH RISK ASSESSMENTS: METHODOLOGICAL CHALLENGES

**A.J. McMichael**

London School of Hygiene and Tropical Medicine,  
London • UK

In a stable world, not undergoing fundamental changes in the conditions of life, epidemiologists can comfortably assume that the future (of disease risks and aetiological relationships) will resemble the past. We can therefore use our painstakingly acquired estimates of dose-response relationships and of microorganism transmission dynamics, for specific physico-chemical and infective agents, to estimate the current or future population burden of disease in relation to current or immediately foreseeable exposures. This, for physico-chemical agents, is the essence of “quantitative risk assessment”. However, we no longer live in such a world. Scientists in various other disciplines have identified emerging largescale environmental changes, with incipient disruption of global biophysical systems (e.g., the climate system) and ecological systems (e.g., the productivity of agroecosystems and ocean fisheries, and the geographic range and seasonal variations in vertebrate and arthropod populations involved in the transmission of various infectious diseases). The task for epidemiologists thus changes. We must apply current, and often limited, knowledge and theory to the modelling of future ranges of likely health outcomes. The purpose and limitations of

modelling must be understood; the compounding of uncertainties (statistical, parametric and structural) must be coped with; and decisions must be made about how far to seek to simulate the future real world. (Our experimental traditions caution us against seeking comprehensive “horizontal integration” of environmental and ecological trends with changes in the social, economic, technological and demographic realms.)

#### INTEGRATED RESEARCH ON HEALTH EFFECTS OF GLOBAL CLIMATE CHANGE

##### J.A. Patz

Johns Hopkins School of Hygiene and Public Health,  
Baltimore, MD • USA

Preliminary results will be presented from a series of research projects underway at Johns Hopkins and collaborating institutions to conduct an integrated health risk assessment of climate change. These include: 1) Heat-related mortality in the US; 2) Hantavirus, El Niño and risk predictions from satellite remote sensing; 3) Malaria and soil moisture modeling, Kenya; 4) Dengue fever, simulation models and climate downscaling ; 5) Water-borne cryptosporidiosis, extreme precipitation and runoff modeling; and 6) Cholera epidemics in Peru and coastal marine ecology. Background information for these research initiatives are as follows: 1) mortality rates in the US are highest in the winter, however, determining cause of death is important to conducting a comparative study between summer versus winter mortality; 2) El Niño driven flooding in the American SW, enhances vegetative food sources for deer mice, the mammalian vector for Hantavirus; 3) the malaria parasite requires temperatures above 16° C to develop and weather determines mosquito breeding sites and biting rates; 4) warmer temperatures shorten dengue virus development, further potentiating disease transmission; 5) drinking water contamination by *Cryptosporidium* could be affected by changes in water run-off in high risk agriculture-intensive watersheds; and 6) *Vibrio cholera* has been associated with marine zooplankton by R. Colwell and colleagues. Blooms from warmer sea surface temperatures accompanying El Niño, may contribute to causing epidemics. Many of these case study analyses are highly integrated involving climate change simulation downscaling and hydrological and ecological modeling, which in combination constitute the driving forces for the public health outcomes. Historical validation studies will also be presented. In the case of water-borne diseases, we have conducted a historical spatial and temporal analysis of all US water-borne

disease outbreaks from 1940 to 1994, to determine correlations with local rainfall. This study’s results will be incorporated into an integrated risk assessment of climate change that combines an agricultural GIS, hydrologic run-off and climate modeling to examine cryptosporidiosis risk under future climate change scenarios for the Susquehanna River Basin and Chesapeake Bay drainage areas. Data on US water-borne disease outbreaks were obtained from the Environmental Protection Agency (EPA). Precipitation data for the analysis were provided by the National Climate Data Center (NCDC). In the case of dengue fever validation and modeling studies, data and models of the US Department of Agriculture (USDA) were utilized. Funding support for these studies is from EPA’s Office of Research & Development and from the Office of Policy.

#### HUMAN HEALTH COSTS OF ECOLOGICAL DEGRADATION

##### M. Raizenne

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Environmental degradation will result in adaptive responses in populations. Adaptive public health responses to environmental degradation have traditionally been “prescriptive and acutely responsive” to events and situations. Relatively little attention has been given to systematically developing strategies that quantitatively include environmental health adaptation and mal-adaptation scenarios. Adaptive public and population health strategies to global climate change are increasingly being recognized as important components in developing mitigation strategies to combat global warming and its associated impacts. The precautionary principle is increasingly being recognized as a valuable element in decision-making on environmental issues. There are, however, significant direct and indirect costs associated with implementing strategies based on the precautionary principle as it relates to human health impacts. The “Avaluation” of health is increasingly being considered in the development of public and environmental policy. The methods, approach and assumptions to valuing health impacts of environmental factors are complex and controversial. Further, it is debatable if it is appropriate to use health valuation methods to project the impacts of environmental degradation. In this session, a science-based risk management framework will be presented. The framework will outline considerations for integrating human health issues and health valuation into a climate change risk management approach. Further, the use of health valuation impacts will be demonstrated as applied to air pollution.

## TS-24

**Landscape Health Assessment Using Remote Imagery, Geospatial Information and Landscape Fragmentation II****Chair: G.P. Patil—Department of Statistics, Pennsylvania State University, University Park, PA • USA****RISK AND THREATS TO HUMAN HEALTH DUE TO COLLAPSE OF ECOSYSTEM HEALTH****Ashbindu Singh<sup>1</sup>** and Lada Kochtcheeva<sup>2</sup><sup>1</sup>United Nations Environmental Programme, Environmental Information and Assessment Program-North America EROS Data Center, Sioux Falls, SD • USA<sup>2</sup>The Evergreen State College, Olympia, WA • USA

This paper reviews ways in which environmental conditions, and, in particular, ecosystem health deterioration, affects human health. It represents the integration and assessment of environmental data sets to provide a scientific explanation to maintain the ecological safety of life. Different approaches and determinant factors to evaluate risk and threats to human health are considered. The paper attempts to demonstrate well-established links between environmental changes due to the collapse of ecosystem and influence on the health of population, as well as an analysis of these global, national, and regional trends, which provide a serious ground for decision-making process in the design and implementation of environmental policy.

**PREDICTABILITY OF BIRD COMMUNITY-BASED ECOLOGICAL INTEGRITY, USING LANDSCAPE MEASUREMENTS****Glen D. Johnson**

Private Consultant, Lakeville, PA • USA

A fundamental premise of landscape ecology is that finer-scaled local ecological integrity is directly influenced by larger-scaled land use patterns. Therefore, characterizing landscape patterns that are mapped from satellite imagery may provide valuable covariate information about average integrity “on the ground”. This conjecture was evaluated in Pennsylvania for 102 watersheds where land cover patterns were represented by an eight-category raster map that was based on 30-meter resolution LANDSAT TM images. For each watershed, a suite of conventional landscape variables was obtained (McGarigal and Marks, 1995), along with a “conditional entropy profile”, which is a new technique for quantifying landscape fragmentation pattern over multiple measurement resolutions (Johnson, Myers, Patil and Taillie, 1998; Johnson and Patil, 1998). Ecological integrity for each watershed was assessed from data in the Pennsylvania Breeding Bird Atlas (Brauning, 1992), first based on songbird guilds only, then based on a much larger set of guilds that incorporated all species in the database. The relationship between (abiotic) landscape measurements and assessed bird community-based ecological integrity was evaluated using a combination of cluster analysis, regression modeling and graphing conditional entropy profiles. Results

indicate that landscape measurements alone, as a combination of land cover proportions and spatial pattern variables, can do a very reasonable job of discriminating watersheds with respect to ecological integrity. It still remains elusive, however, to identify those watersheds that are at a critical transition towards the worst ecological integrity.

**A LANDSCAPE APPROACH TO ECOLOGICAL INTEGRITY AND PLANNING: THE MAP OF THE ITALIAN NATURE****Giovanni Zurlini<sup>1</sup>**, O. Rossi<sup>2</sup>, and V. Amadio<sup>3</sup><sup>1</sup>National Research Council and Dept. of Environmental Sciences • ITALY<sup>2</sup>Dept. of Environmental Sciences, Parma • ITALY<sup>3</sup>Italian Ministry of Environment • ITALY

The Map of Italian Nature project started on demand of the national law n. 394 (1991) in order to define the status of the environment as regards “natural values” and territorial “fragility”. An overview of the on-going project activities and procedures for the first million ha is given together with some illustrative results. The primary intent of the project is to generate digital thematic maps as Gis coverages at multiple scaling regions of the existing biodiversity components like species and habitats most threatened with extinction and reduction by which evaluate natural values and ecological fragility. Project focused in this phase on the most threatend structural components of biological integrity and developed simple evaluation procedures for natural values and ecological fragility at multiple scaling regions. Basic data produced concern mosaics of contiguous CORINE habitat patches supported by satellite, airborne (photos and multispectral images) and terrain data, that are also used as a “coarse filter” approach to biodiversity protection to complement protection of individual species at risk. Ecological fragility is estimated either through simple conceptual model relating ecological fragility to ecological sensitivity and human disturbance or as displayed fragility, inferred from habitat loss as observed by change detection analyses of CORINE mosaics. Boundary fractal analysis of CORINE biotopes mosaics is used within the Map of Italian Nature project to quantify the complexity of patch size and shape relationships as well as to identify fractal scaling behaviour of mosaic patterns.

**MAPPING WATERSHED HEALTH****Karen Klima**

Office of Water, US EPA, Washington, DC • USA

*Abstract not available*

## COMPARISON OF MEASURES TO ASSESS ECOSYSTEM DEGRADATION USING REMOTE IMAGERY

**Karen Boomer**

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Ecosystem stress is abstractly defined by parameters such as water quality, air quality, or proportion of area devoted to human-related uses. These parameters are costly to measure for a large region, such as the State of Pennsylvania. One measure of stress is the degree of fragmented land uses, which is visible over large geographic extents with satellite imagery. A new approach to quantifying landscape fragmentation is to measure the entropy, or degree of dissimilarity, that is introduced when the scale of measurement increases twofold for a given area. The parameter of interest is the dominance of specific land uses. This measure of conditional entropy is compared to traditional metrics using multivariate statistical techniques. Watersheds with similar conditional entropies are said to represent a similar degree of fragmentation. The most similar watersheds are clustered together. As a result, areas of high, medium and low fragmentation are identified within Pennsylvania. Using traditional metrics in FRAGSTATS also produces clusters of high, medium, and low stress areas. The objective is to understand how land use changes can be used to identify ecological stress.

## RECENT CHANGES (1930S-1990S) IN SPATIAL PATTERNS OF INTERIOR NORTHWEST FORESTS, USA

**Paul F. Hessburg**, B.G. Smith, R.B. Salter, R.D. Ottmar, and E. Alvarado

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We characterized recent historical and current vegetation composition and structure of a representative sample of subwatersheds on all ownerships within the interior Columbia

River basin and portions of the Klamath and Great Basins. For each selected subwatershed, we constructed historical and current vegetation maps from remotely-sensed 1932-66 and 1981-93 aerial photos, respectively. Using the raw vegetation attributes, we classified and attributed cover types, structural classes, and potential vegetation types to individual patches within subwatersheds. We characterized change in vegetation spatial patterns using a suite of class and landscape metrics, and a spatial pattern analysis program. We then translated change in vegetation patterns to change in patterns of vulnerability to wildfires, smoke production, and 21 major forest pathogen and insect disturbances. Results of change analyses were reported for province-scale ecological reporting units (ERUs). Here, we highlight significant findings and discuss management implications. Twentieth century management activities significantly altered spatial patterns of physiognomies, cover types and structural conditions, and vulnerabilities to fire, insect, and pathogen disturbances. Forest land cover expanded in several ERUs, and woodland area expanded in most. Shrubland area declined most of all physiognomic conditions due to cropland expansion, conversion to semi- and nonnative herblands, and expansion of forests and woodlands. Shifts from early to late seral conifer species were evident in forests of most ERUs; patch sizes of forest cover types are now generally smaller, and current land cover is more fragmented. Landscape area in old multistory, old single story, and stand initiation forest structures declined with compensating increases in area and connectivity of dense, multilayered, intermediate forest structures. Patches with medium and large trees, regardless of their structural affiliation are currently less abundant on the landscape. Finally, forests of the basin are now more contagiously dominated by shade-tolerant conifers, and exhibit elevated fuel loads and severe fire behavior attributes indicating expanded future roles of certain defoliators, bark beetles, root diseases, and stand replacement fires. Although well intentioned, 20<sup>th</sup>-century management practices did not account for landscape-scale patterns of living and dead vegetation that enable forest ecosystems to maintain their structure and organization through time, or for the disturbances that create and maintain them. Improved understanding of change in vegetation spatial patterns, causative factors, and links with disturbance processes will assist managers and policymakers in making informed decisions about how to address important ecosystem health issues.

## TS-25

### Managing Ecosystems to Mitigate the Health Impact of Mining Activities

**Chair: Jean Lebel—International Development Research Center, Ottawa, Ontario • CANADA**

#### A CONCEPTUAL FRAMEWORK FOR IDENTIFYING ISSUES AND INDICATORS TO TRACK HUMAN HEALTH AND WELL BEING IN A MINING REGION: REPORTING FROM AN INDIAN CASE STUDY

**Ligia M. Noronha**

Tata Energy Research Institute, New Delhi • INDIA

The exercise of developing a framework of environmental performance indicators and sustainability markers in minerals development in order to be useful and relevant needs to have

a multi-stakeholder perspective and be transdisciplinary. This presentation discusses the development of this framework and the case study upon which it is based. The methodology involved: 1) the use of the data base and the findings of a case study that employed an Area-wide environmental quality management approach. This study combined spatial data obtained from aerial photographs and remote sensing products, environmental data, and statistical data obtained from mine level questionnaires and socio-economic surveys in the mining belt of Goa. The various data sets were integrated using Geographical Information Systems tools. (2) The

understanding of impacts to human health and well being using an ecosystem approach in the sense that all domains that affect or are affected by mining activity are studied, such as the biophysical, the socio-political-cultural and the economic domain. (3) Defining human well being through decomposing it into its constituents (such as health and freedom) and determinants (such as income, conflict resolution mechanisms, clean air, etc.) (4) Adopting a multi-stakeholder perspective– the government, the mining company and the community –to identify issues of relevance in each domain. (5) Using a causal framework, the Pressure-State-Response framework adapted and expanded to include exposure, effects and impacts to humans for each issue of relevance identified by the stakeholders.

#### INTEGRATING HUMAN HEALTH INTO AN ECOSYSTEM APPROACH: A MODEL FOR STUDYING THE IMPACT OF MINING ACTIVITIES

##### **Donna Mergler**

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The ecosystem approach to human health is an innovative conceptual model which incorporates human health into the dynamic interrelations of ecosystem analyses. The ecosystem approach to human health is an innovative conceptual model which incorporates human health into the dynamic interrelations of ecosystem analyses. In this model, humans are not solely the drivers and disrupters of the ecosystem or the passive objects of environmental destruction, but in continuous interaction with the changing environmental, social and economic conditions. In this dynamic process, positive and negative factors contribute to current and future well-being, not only of the present, but also for coming generations. Health and well-being are, in turn, determinants of social, economic and cultural sustainable and equitable development. Adequately applied to environmental and health impact studies, the ecosystem approach can be a useful tool for attaining sustainable and equitable development. Indeed, human health and its consequences are most often omitted from environmental and cost/benefit impact studies. Here, we propose a means of integrating the human populations into the ecosystem analysis, using mining activities as an example. With mining development and activities in the center, human populations form 4 widening concentric circles, representing workers, the local community, remote communities and the general population. The spheres are not completely closed since the activities of one can affect the others both positively and negatively, influencing their respective health status. The effects of the interaction between these groups and the changes brought about by mining activities is analyzed for both positive and negative impacts on health and well-being.

#### ECOSYSTEM APPROACHES TO INDIGENOUS ISSUES REGARDING HEALTH AND WELL BEING IN THE CONTEXT OF MINING: THE CASE OF THE WAYUU AND EL CERREJON COAL MINING DEVELOPMENT

##### **Cristina Echevarria**

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Indigenous conceptions of health and wellbeing are intrinsically ecosystemic. In contrast with western peoples, Indigenous Peoples see themselves as part of a complex world peopled by other beings that have spirit and intent. This defines a particular ethical position of indigenous peoples with respect to other beings in the universe, in the sense that wellbeing will depend, not only on the health and “quality of life” (as in WHOQOL-100) of the individuals and human communities (epidemiological perspective), but on the vitality and standing (vigencia) of the systems of reciprocity between humans (social systems of regulation and control, traditional social support networks based on kinship, etc.) and between humans and non-humans (integrality and vitality of traditional knowledge on the local environment, cultural systems of management of the environment, ritual interchange of favours between this world and “the other world” (spirit world), etc.). The paper will also look at five nuclear issues as the basis of human and ecosystemic wellbeing from the perspective of indigenous peoples: identity, territory, autonomy, participation and self development. These will be analyzed in the context of the case study mentioned above. The presentation intends to show that issues arising from mining in indigenous territories are best understood and managed from an integral (holistic) approach that mirrors indigenous conceptions of wellbeing, and on the basis of these five nuclear issues.

#### ECOSYSTEM APPROACHES TO HUMAN HEALTH RESEARCH IN THE CONTEXT OF MINING IN THE DEVELOPING WORLD: THE ROLE OF THE INTERNATIONAL DEVELOPMENT RESEARCH CENTRE (IDRC)

##### **Jean Lebel**

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There is a great potential for improving human health through better natural resource management, a concept that deserves wider recognition. This potential is based on the fact that in nature the well-being of people cannot be separated from their physical environment, which provides all species, including humans, with a home, and both sustenance and hazards. The presentation will describe the role that IDRC is playing in the developing world in trying to understand the links between the state of the ecosystem and the human health and well-being in the context of mining activities.

## ECOSYSTEM APPROACHES TO RESEARCHING HUMAN HEALTH AND QUALITY OF LIFE IN MINERALS DEVELOPMENT

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Recent Canadian and UK health policy and health research literature advocates an expanded understanding to human health and quality of life promotion that moves beyond a biomedical approach to health services and interventions. The MERN/INER/TERI research initiative supported by IDRC explores this expanded notion of human health, wellbeing, and quality of life. This paper will explore a holistic approach to the ecosystem effects of mining and the implications that ecosystems - plant and animal (including human) species - pose for minerals development. It begins by outlining an approach to understanding ecosystem health in the broader context of sustainable development and discusses the concept of the transformation of natural capital into overall net increases of natural, produced, human and social capital. It also discusses the equity of the

distribution of this increased wealth and the environmental and social responsibility attached to the transformation process itself. This holistic approach integrates an understanding of human health and quality of life with a complex set of social and cultural conditions, incorporating historical and economic processes. Many mining companies limit their approaches to human health and quality of life effects of mining to biomedical concepts of health, thus focusing primarily on biomedical interventions and services. This approach does not address three broad health and quality of life questions. The first is the question of allocating responsibility for health and quality of life interventions and impacts to various stakeholder groups, e.g. the individual, community, company or government. The second is the question of assessing from the outset potential human health and quality of life effects on different stakeholder groups affected by mining and putting in place preventative rather than curative solutions; and, the third is the question of assessing and monitoring the extent to which minerals development projects contribute to, or detract from, the health and quality of life of local individuals and communities. The paper concludes with a consideration of how the World Health Organisation's "Quality of Life" evaluation tools and research approaches may be adapted specifically to minerals development projects as a framework for answering these questions.

## TS-26

### Ecology of Infectious Diseases

**Chair: Compton J. Tucker—National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD • USA**

#### SOUTHERN OSCILLATION INDEX, SEA SURFACE TEMPERATURE, AND SATELLITE VEGETATION INDEX INDICATORS TO FORECAST RIFT VALLEY FEVER EPIZOOTICS/EPIDEMICS IN KENYA

Kenneth J. Linthicum, Assaf Anyamba, **Compton J. Tucker**, Patrick W. Kelley, Monica F. Myers, and Clarence J. Peters  
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Rift Valley Fever (RVF), a viral disease first described in Kenya in 1931 affects domestic animals and humans throughout sub-saharan Africa and results in widespread livestock losses and frequent human mortality. All known Rift Valley fever virus activity in East Africa from 1950 to May, 1998, is documented to have followed periods of abnormally high rainfall. Pacific and Indian Ocean sea surface temperature anomalies, coupled with satellite normalized difference vegetation index data, enabled a >1-5 month prediction of Rift Valley fever outbreaks in East Africa. Concurrent near-real time monitoring with satellite normalized difference vegetation data identified actual affected areas. A predictive model was developed, using a variety of climatological and meteorological parameters. The ability to forecast regional RVF virus activity in Kenya 2-5

months before outbreaks makes possible implementation of control strategies in time to lessen or prevent animal and human diseases. Effective controls include vaccination of domestic animals, and pretreatment of mosquito habitats adjacent to domestic animal herds and human habitations.

#### EPIDEMIC EARLY WARNING: UNTANGLING INTRINSIC AND EXTRINSIC CAUSES OF DENGUE EPIDEMICS

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Dengue hemorrhagic fever (DHF) case data, population census data and meteorological data for Bangkok (1966-1994) were analyzed to investigate long-term and season trends of DHF incidence in Thailand's capital. Pathfinder Advanced Very High resolution radiometer (AVHRR) Land (PAL) data from July 1981 to September, 1994 were also processed to provide monthly values for the normalized difference vegetation index (NDVI), Price (1983) split-window land surface temperature (LST) and the channel 3 middle-infrared signal (MIR). A statistical model is presented which predicts four months in advance, with an accuracy of  $\pm 100$  cases per month. The analysis identifies a



number of component cycles which may be extrinsic to DHF transmission (e.g., long-term climatic cycles and short-term weather cycles associated with the annual pattern of temperature/precipitation etc.), or intrinsic to the vector-host-disease association (involving susceptible/infected; immune human hosts and vector mosquitoes). The model predicts the DHF data set with remarkable accuracy. It can be projected into the future using 1) the past long-term trend in case numbers, 2) future predictions of the long-term cycles (i.e. with periods >1 year) and 3) season i.e. within year) predictions based on the average monthly climatic conditions for Bangkok. Using this approach, the model predicts case numbers to the end of the year 2004. This paper discusses the issues associated with the development of biological and process-based modeling approaches to predict DHF cases and issues associated with implementation of a statistical approach.

#### THE USE OF SATELLITE-GENERATED METEOROLOGICAL DATA TO PREDICE MOSQUITO-BORNE ENCEPHALITIS TRANSMISSION: PRELIMINARY STUDIES

**William K Reisen**

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Every year mosquito-borne encephalitis virus are responsible for numerous cases of human illness in North America and throughout the world. Transmission is usually sporadic, without a clearly defined epidemic focus. For example, in 1991 there were 5 confirmed cases of eastern equine Encephalitis (EEE) virus reported in Florida, but these cases were from 3 different counties. During other years, however, virus transmission is explosive, causing human epidemics that are extensive and widespread. In 1975, there were 1,815 clinical cases and 108 deaths due to St. Louis encephalitis (SLE) virus reported in humans from the central USA and southern Canada. There is strong evidence, especially from California and Florida, that epidemic SLE virus transmission is triggered and driven by specific meteorological events. If true, this means that variables such as surface temperature, precipitation, snow melt and standing water can be traced and used to predict the relative risk of annual encephalitis epidemics in specific areas. This paper presents the initial findings from of the California segment of a national study examining the environmental links to encephalitis epidemiology. The study incorporates the existence of excellent historical data set of mosquito-borne encephalitis virus transmission events across North America. In addition, it is making use of excellent regional meteorological data sets, making it possible to link known, regional periods of virus transmission with weather conditions prior to and during epidemic transmission. Once the meteorological conditions that predispose a region epidemic virus transmission are known, it will be possible to incorporate real-time meteorological data into

a predictive model to assess and forecast epidemic risk. The role of temperature and precipitation in virus transmission dynamics is explored comparing ecological conditions in the San Joaquin and Coachella Valleys. Significant associations among snow pack in the southern Sierra Nevadas, impaired run-off of the Kern River and mosquito abundance provide a useful model for forecasting the risk of western equine encephalomyelitis virus activity in the southern San Joaquin Valley that may be extrapolative to the entire Central Valley.

#### CLIMATE-BASED MODELS FOR PREDICTING MALARIA TRANSMISSION IN AFRICA

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Malaria is the world's most important parasitic disease. It accounts for between one and two million deaths globally each year, with the vast majority of these occurring among young African children. But even in Africa the intensity of malaria transmission can vary enormously from place to place and over time, and this has important implications in terms of the choice of control strategy (if any) to adopt in a given locality and, more generally, in targeting scarce resources to areas of most concern. Perhaps nowhere is this issue more relevant than in highland areas, where unstable transmission, coupled with low levels of functional immunity in local populations, can combine to produce devastating malaria epidemics. While it is well known that timely intervention in such cases can significantly reduce levels of morbidity and mortality, national malaria control programmes are rarely able to respond quickly enough to make any difference. One of the main reasons for this is that it has not so far been possible to identify those geographical areas which are most at risk from epidemics on a year to year basis, and to thereby provide a focus for epidemic surveillance. To address these concerns the MARA (Mapping Malaria Risk in Africa) collaboration has been exploring a number of ways to predict the risk of malaria transmission using relatively simple climate-based models. The emphasis to date has been on developing spatial models of risk, both in terms of defining areas of different endemicities and, more specifically, deriving maps of epidemic risk in highland areas. This paper describes the approach used in this exercise and in the subsequent validation of the spatial models. It also outlines plans, currently being designed in conjunction with a number of national malaria control programmes, to carry out prospective malaria surveillance in East Africa in order to evaluate a range of operational epidemic early warning strategies.

## TS-27

**Tools and Approaches for Ecorisk Assessment: Watershed Scales**

**Chair: Llewelyn Williams—US Environmental Protection Agency, National Exposure Research Laboratory, Las Vegas, NV • USA**

DEVELOPMENT OF A TERRESTRIAL INDEX OF ECOLOGICAL INTEGRITY (TIEI) – A NEW TOOL FOR ECOSYSTEM MANAGEMENT

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Multiple levels of information are needed to make decisions about complex systems. Examples are the Consumer Price Index, the Dow-Jones Industrial Index, and the Index of Leading Economic Indicators where values of the economic variables are compared to a standardized year or base period. In the human health field, physicians rely on multiple measures from a single sampling point (1 person) and the pattern from all the measurements is used to make some judgement about the health of the individual or to point to a certain disease. Following this assessment, a treatment is specified. Multiple biological indexes calculated from ambient biological data can provide a similar integrated approach for “diagnosing” ecosystem health or integrity. The ideal metric for ecosystem integrity will incorporate multiple dimensions of biological systems. There are a number of interactions, ecological processes and stressors that impact ecosystem integrity. For example, impacting the population of one species may have effects on its predator or prey species. Changes in environmental conditions (such as temperature, moisture, and light) may exceed the tolerance range of species in the ecosystem thereby favoring one population or community over another. The disturbance of “preserves” or “corridors” between preserves could change the habitat available to a population and could eliminate the intermingling of reproductive individuals necessary for species to survive. The Index of Biotic Integrity (IBI), developed by Karr, has been adopted by many States as an indicator of aquatic habitat quality. However, water quality is dependant on the total of all activities that occur within a watershed. A terrestrial index of ecological integrity (TIEI) gives decision makers another tool to help with management decisions in watershed assessments which will lead to further improvements in water quality. This presentation discusses the background of the development of the TIEI, how the measures were selected and how the various measurements or indicators are combined into an index.

RESEARCH SUB-TASK: ANALYSIS OF LANDSCAPE AND WATER QUALITY IN THE NEW YORK CATSKILL-DELAWARE WATERSHED 1973-1988

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The primary goal of this study is to improve risk assessment through the development of methods and tools for characterization of landscape and water resource change. Exploring the relationship between landscape pattern and water quality in the Catskill-Delaware basins will improve understanding of environmental risk and help maintain New York City’s drinking water supply system. Currently the city is trying to decrease the threat to its quality of water through the development and implementation of a long-range watershed protection program. Under the agreement, the State Department of Environmental Conservation issued a permit to acquire land through outright purchase and conservation easement. Landscape indicators believed to impact drinking water quality were calculated for all sub-basins in the Delaware/Catskill watershed using land cover derived from 1989/1991 landsat TM imagery. All available water quality data was collected for streams and reservoirs in the Catskill-Delaware Basins from 1986-1994. The main source for chemical and physical water quality parameters was the EPA’s storage and retrieval data base (STORET). The New York State Dept of Conservation supplied a separate database containing benthic measurements from 1986 to 1997. Correlations were conducted at the scale of the sub-basin between landscape indicators and water quality parameters. There were negative correlations between forest and the water quality parameters chloride, pH, silica, and nitrate nitrogen. Urban and crop land use patterns, particularly on steep slopes and within the riparian area, had weak positive correlations with chloride and nitrate nitrogen, while pasture tended to be more strongly related to pH and silica levels. A step-wise regression analysis was conducted on 25 sampling stations for which the proportion of forest, urban, pasture, and crops had been calculated 100 and 500 meter upstream of the site. The interactions between landscape indicators were found to be more important in predicting water quality than any single land use type. These results suggest that maintaining the quality of New York City’s water supply will require evaluation of multiple landscape indicators in order to target areas in need of protection or restoration.

## FLOOD PLAIN RIVER ECOLOGICAL HEALTH: DEFINING TERMS ON THE UPPER MISSISSIPPI RIVER

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In order to achieve a balance between economic and ecological values on the Upper Mississippi River the goals of each river interest must be weighed against each other. For six decades the economic goal of the river has been tied to barge transportation, and it has been consistently met by maintenance of the 9-ft navigation channel. But a long-term goal for natural resources management on the Upper Mississippi River has been elusive. River ecological health is a valuable and understandable goal. However, whether this term is accepted and used or not depends on how it is defined, and how the definition relates to the mission and objectives of the management agencies responsible for achieving it. What standards of water quality equate to ecological health? How much natural, connected floodplain habitat is enough? What features of the annual hydrograph are critical to ecological health? Which assemblages of species, resident or migratorial, do we accept as being desirable or mandatory? Managers, scientists, and the public have begun defining river ecological health using a collaborative process that will generate a vision for the river in enough quantitative detail to make it happen. The term ecological health was used in the report "Ecological Status and Trends of the Upper Mississippi River System". An initial set of six broad narrative criteria were proposed to describe the primary features of river health. The criteria include: presence of viable populations of native species and their habitats; ability of the system to recover from disturbance; sustainability; capacity of the system to function as part of a healthy basin; annual floodplain connectivity; and the ability of infrequent flow events to maintain the fluvial nature of the system. The criteria were proposed to help establish acceptable and desirable standards within the river community and to serve as tentative targets for the development of relevant and quantifiable metrics by the scientific community. The process of community consensus-building will be initiated during public workshops supported by conservation and environmental groups and a habitat needs assessment by federal and state agencies. The formulation of quantifiable metrics associated with each of the above criteria will be a task of the Long Term Resource Monitoring Program, working in conjunction with the Environmental Protection Agency Office of Biocriteria. Progress along both tracks will help establish the scientifically supportable and socially acceptable definition of river ecological health required to set practical and substantial management objectives for each river reach.

## SENSITIVE ANALYSIS OF THE APPLICATION OF CHEMICAL EXPOSURE CRITERIA FOR COMPARING SITES AND WATERSHEDS

**Florence Fulk, S.M. Cormier, and E.L.C. Lin**

US Environmental Protection Agency, National Exposure  
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A methodology was developed for deriving quantitative exposure criteria useful for comparing a site or watershed to a reference condition. The prototype method used indicators of exposures to oil contamination and combustion by products, naphthalene and benzo[a] pyrene metabolites, sampled from white suckers and common carp in the eastern Cornbelt Plains Ecoregion of Ohio. Sites were selected by two sampling schemes. First, through second order stream sites were selected by an intensified probability-based design developed by the Environmental Monitoring and Assessment Program (EMAP). For larger stream, reference sites were selected by Ohio EPA ecologists. Numerical exposure criteria were determined by an empirical approach, the 95th percentile derived from ranked data. Binomial probabilities based on the number of fish exceeding the exposure criteria at a site and the number of fish sampled at a site were used to determine contamination. The percentile selected to represent the exposure criteria, i.e., 90th, 95th, 99th, and the level of significance in determining contamination at a site, i.e., 1% vs 5%, may impact the final assessment. An analysis of the sensitivity of the final assessment to the selection of percentile and level of significance was conducted. Correlation of the contaminated sites with NPDES discharges and levels of contaminants in the water and sediment were used to confirm the presence of contamination at the designated sites.

## USING A KNOWLEDGE BASE TO ASSESS THE EF- FECTS OF STRESSORS AND STREAM ECOLOGICAL INTEGRITY

**Lester Yuan**

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We demonstrate the applicability of using a knowledge-based decision support system to assess the effects of human activities upon the ecological integrity of the streams draining a given watershed. A knowledge base provides a systematic means of representing expert knowledge, and once programmed, the knowledge base can then be applied to problems that may be too large or too unwieldy for a single person to address. The Ecosystem Management Decision Support System (USDA Forest Service) provides a starting framework, integrating a GIS-based user interface with a fuzzy logic inference engine. We have designed an inference network that qualitatively links catchment-scale, riparian-scale, and local habitat characteristics with stream ecological integrity. To calibrate the system, remotely sensed

land use data are used as inputs at the catchment scale, while field observations of habitat quality are used for inputs at local spatial scales. Output predictions of stream condition

are then compared to field measurements of biotic integrity. The performance of the knowledge base is evaluated with data from catchments not used in the calibration process.

## TS-28

### Tools and Approaches for Ecorisk Assessment: Regional and National Scales

**Chair: Llewelyn Williams—US Environmental Protection Agency, National Exposure Research Laboratory, Las Vegas, NV • USA**

US EPA'S ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM (EMAP): THE WESTERN INITIATIVE – FROM RESEARCH TO APPLICATION

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For several years the US Environmental Protection Agency (EPA) has undertaken research in biological monitoring at regional scales with known statistical confidence. The cornerstone of this research is a program called “EMAP” – the Environmental Monitoring and Assessment Program. Based on a random statistical probability sampling protocol, and a research foundation driven by the use of environmental indicators, EMAP is attempting to move from *research to application* at large, regional scales. The first major pilot demonstration of EMAP was in the Mid-Atlantic region of the United States. Using lessons learned from this effort, EMAP is now implementing the “Western Initiative” – an ambitious effort covering twelve States and three EPA Regions. With an ultimate goal of changing the way environmental decisions can be made– i.e., stressing an assessment-driven objective of providing sound biological information that is useful to scientists, decision makers, and the general public–EMAP seeks to allow the use of many heretofore only “theoretical” management initiatives. For example, with biological data of known statistical confidence, initiatives such as: ‘management for results;’ ‘provision of information, not just data;’ ‘achieving the greatest bang for the environmental buck;’ and *producing scientifically sound assessments that are politically and socially relevant* – are all becoming realities. The goal of an assessment-driven monitoring program that can truly make a difference in how environmental decisions are made is a lofty one. EMAP, however, is in the process of making that goal a reality. The Western Pilot (or “EMAP-West”), will assess stream condition from a biological perspective for twelve Western states, producing a “snapshot” of the biotic condition of these resources over a four-year sampling period. Further, an ambitious assessment of estuarine condition of the western U.S. near-coastal environments is being undertaken, as well as sampling of riparian condition and a complementary West-wide Landscape Characterization effort. Though EMAP has experienced budgetary and management changes over its short 10-year history, many of its original visions are becoming a reality. The Western Pilot may well be the most ambi-

tious–yet most fruitful–U.S. effort of its kind. This demonstration will help to bring to fruition years of research and the aspirations of a multitude of scientists, environmental managers and policy makers.

PREDICTION OF SOIL SALINITY RISK BY DIGITAL TERRAIN MODELLING IN THE PRAIRIE ECOZONE, CANADA

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Soil salinisation is a hard problem for the Prairie Ecozone in Canada. Digital terrain modelling can be used to improve prediction of soil salinity risk. We present a new approach linking regular methods for prediction of soil salinisation and techniques of digital terrain modelling. A predictive map of salinity risk for three prairie provinces of Canada (Manitoba, Saskatchewan and Alberta) is obtained by the approach developed. Possibilities of the approach are discussed.

REGIONAL VULNERABILITY ASSESSMENT:  
CREATING A CONTEXT FOR EVALUATING STREAM  
ACIDIFICATION

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US Environmental Protection Agency's (USEPA) Regional Vulnerability Assessment (ReVA) program is designed to identify ecosystems that are likely to vary beyond the range of natural variability and thereby experience reduced ecological integrity as a result of natural and human-induced stressors. ReVA makes use of remotely sensed and other data suitable for analysis using GIS to locate particular areas where ecosystems may be exposed to the impact of single and multiple stressors. The immediate focus for ReVA is the mid-Atlantic region where several biological assessments have recently been performed including the USEPA's Environmental Monitoring and Assess-

ment Program (EMAP). EMAP results from the Mid-Atlantic Highland Area (MAHA) expressed as a percentage of total stream miles include; 1) <1% of streams were acidic due to mine drainage, 2) <4% were acidic due to acid deposition, 3) 14% were impacted by mine drainage, 4) 24% had poor riparian habitat quality, and 5) 17% had poor in-stream habitat quality. Applying the EMAP data for the purposes of ReVA requires identifying which of the stream miles with poor riparian habitat and in-stream habitat quality were related to mining activity. This is accomplished by overlaying the EMAP sampling locations on mine sites identified using Thematic Mapper (TM) satellite imagery taken from 1989-1993 as well as mine sites identified in other projects and relating the riparian and in-stream condition to the presence or absence of mines. A framework is then presented that demonstrates how to identify factors potentially interacting with mining including acid deposition, issues related to agricultural land use, and hydrologic alterations. This framework is used to develop a model that accounts for the interactions among the identified factors. The model is then applied to projected locations of future mining activity to serve as a case study for ReVA.

#### ASSESSING FISH TISSUE CONTAMINATION ON A REGIONAL SCALE

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The selection of target fish species for assessing the extent of fish tissue contaminants is a critical consideration in regional stream surveys such as the Environmental Monitoring and Assessment Program (EMAP). The ideal species would be widely distributed and common, bioaccumulate chemicals of concern and be consumed by piscivorous wildlife. In first- to third- order streams, small, short-lived forage fish [minnows (F. Cyprinidae), darters (F. Percidae), and sculpins (F. Cottidae)] are more widely distributed and found in greater numbers than species whose adults grow to large size [suckers (F. Catostomidae), trout (F. Salmonidae), bass and sunfish (F. Centrarchidae) and carp (F. Cyprinidae)]. The small forage fish are less mobile, often occur in larger numbers, and generally have smaller home ranges than the bigger fish. Thus, small forage fish usually provide a sufficient sample for chemical analysis and may represent an approximation of the "site average" of accumulated tissue contaminants. Analysis of fish collections from the 1993-94 Mid-Atlantic Highlands Assessment (MAHA) showed that small forage fish were more widely distributed than larger species. Regional assessments of fish tissue contaminants were made for Chlordane, DDT & Metabolites (DDT), Dieldrin, Endrin, Hexachlorobenzene, Mercury, and Polychlorinated Biphenyls (PCBs). Using the percent of stream miles exceeding the wildlife effects thresholds as a basis

for comparison, regional assessments based on small, forage fish were not significantly different from regional assessments using large fish. Small, short-lived fish may, therefore, be an excellent choice as target species for conducting Regional fish tissue studies and wildlife problem formulations.

#### KURSK REGIONAL AUTOMATED SYSTEM ON LAND AGRO-ECOLOGICAL ASSESSMENT

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The possibilities of Kursk region sustainable development are crucially limited now due to strong spatial varying and temporary transforming the agronomy economical and ecological environment here. Specialized automated land evaluation systems are growing in importance for identifying critical ecological problems and for determining rational versions of land-use taking into attention not only current money benefit but more long-term ecological consequences. The developing Kursk regional *Automated System on Land AgroEcological Assessment (ASLAEA)* estimates soil-cover quality by calculating individual partial phase variables, pooling parameters of functional diagnostic groups, and integrating indices in homogeneous and heterogeneous plots. The varying combination of main soil characteristics and qualities can be taken into account for assessment soil fertility, variability, workability and trafficability, phytosanitary state, contamination level and land ecological buffering capacity. Particular evaluations have been determined from the logistic or model equations, which are valid in the range from critical to optimum values of parameters. The reference of every parameter for logistic equation lists: optimum and critical values of parameter, its influence index and degradation crisis rate. In a general way, they are specific features of main regional-genetic soil types/ subtypes (*Russian taxonomy groups*) and landscapes. The possibilities of ASLAEA have been successfully used for the analysis of soil cover agroecological problems in case of farm fields in different districts of Kursk region and of polluted garden and kitchen garden lands in Kursk City. Now ASLAEA is connected with regional soil-ecological GIS, which includes general and soil-ecological information for all main farms in Kursk region. Special regional institutions became interested in its use as kind of decision support system. Acknowledgments: this research was partially supported by the Russian Foundation for Basic Researches Grant 98-04-49059.

## TS-29

**Managing a Multiply-Stressed Lake Ecosystem at Clear Lake, California: A Holistic Ecosystem Approach****Chair: Tom Suchanek—Dept. of Wildlife, Fish, and Conservation Biology, University of California, Davis, CA • USA**

MANAGING A MULTIPLY-STRESSED ECOSYSTEM AT CLEAR LAKE, CALIFORNIA: A HOLISTIC ECOSYSTEM APPROACH

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Multiple management objectives are especially challenging in a system subjected to numerous ecological stresses. Clear Lake (California) is an ancient, shallow, highly productive lake with rich habitats for migrating waterfowl and fish-eating birds and mammals. Local residents also use its abundant resources for recreation, water supply and active sport and commercial fisheries. Yet it also has a well documented history of anthropogenic stresses. It has lost over 85% of its wetlands (resulting in hyper-eutrophication and abundant noxious cyanobacterial blooms), is highly contaminated with mercury (and other contaminants), was the first site to identify the deleterious effects of large concentrations of organochlorine pesticides on bird populations (popularized in Rachel Carson's *Silent Spring*), has had 65% of its native fish fauna replaced by alien species and is the location of a USEPA Superfund hazardous waste site. As such, it represents an excellent laboratory ecosystem to study the effects of multiple stresses and their management. Ultimately, our ability to understand and manage ecosystems will benefit greatly from studies of systems like Clear Lake.

MICROBIAL PROCESSES AND METHYLATION OF MERCURY IN SEDIMENTS OF CLEAR LAKE, CA

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Due to historical contamination with inorganic mercury (Hg) from a point source (Sulphur Bank Mercury Mine), the sediments of Clear Lake, CA, show a tremendous range in concentrations of total mercury (totHg). Microbially mediated processes responsible for transformation of Hg(II) ions into methylmercury (meHg) — the form amplified by food chains — were studied across this Hg gradient. Relative to most freshwater lakes, Clear Lake is eutrophic and has an active sulfur cycle. These facts focused our initial attention on anoxic sediment processes, especially those of sulfate-reducing bacteria, which have been implicated by others as the principal methylators of Hg in estuarine sediments. Over the course of a full year, sediments from sampling sites throughout Clear Lake were repeatedly analyzed for sulfate reduction rates and rates of Hg methylation potential. In spite of frequent positive correlations observed between these two processes over time for most sites, specific inhibitor data indicated that sulfate-reducers were responsible for less than 40% of the methylation potential. Although methylation potential could sometimes be observed for unsupplemented sediments, the process was strongly stimulated by added divalent Hg and was much less sensitive to the totHg content of sediments. Intact sediment cores from throughout the lake were incubated to observe rates of meHg efflux under conditions mimicking those in situ. The sediment having the most active efflux was characterized by high organic content and porewater with both the lowest pH and highest concentration of sulfate observed. It appears that the eutrophic nature of Clear Lake interacts synergistically with prevailing currents and impacts from the Sulphur Bank Mine to amplify meHg production at this site.

## TRANS-GILL AND DIETARY UPTAKE OF METHYL MERCURY BY THE SACRAMENTO BLACKFISH, A PLANTIVOROUS FRESH WATER FISH

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The Clear Lake (California) ecosystem has been subjected to multiple stresses, including the mercury loading problem associated with the Sulphur Bank Mine, a USEPA Superfund site. The consumption of commercially harvested Sacramento blackfish (*Orthodon microlepidotus*), a planktivorous cyprinid native to Clear Lake, provides a route of potential methylmercury (MeHg) exposure to humans. We exposed the gills of adult Sacramento blackfish to Me<sup>203</sup>Hg at a Clear Lake MeHg concentration (1.4 ng/L) using a McKim-type fish respirometer. Mean (±SE) Me<sup>203</sup>Hg extraction efficiency, uptake rate, and uptake rate constant were 35.7 ± 3.5%, 9.2 ± 1.6 ng/h/kg, and 7.7 ± 1.5 L/h/kg, respectively. Dissolved organic carbon additions decreased MeHg extraction efficiencies and uptake rate constants by 78% and 73% (2 mg C/L) or 85% and 82% (5 mg C/L), respectively. Because respiratory variables remained unchanged, DOC-linked decreases in Me<sup>203</sup>Hg uptake argue for strong interactions between DOC and Me<sup>203</sup>Hg. Methyl<sup>203</sup>Hg levels in fish gills, kidney, and spleen from 2 and 5 mg C/L treatments were significantly lower than control values. In addition, we fed juvenile blackfish diets incorporating four levels of MeHg to measure dietary uptake rates. Ongoing determinations of their Hg body burdens and food consumption rates will allow comparisons of MeHg dietary uptake rates with the trans-gill uptake rates. Multiple uptake pathways should be considered in ecosystem-level Hg transport and fate models. Research was supported by the UC Ecotoxicology Program, a USEPA RARE grant, and the UC Davis Center for Ecological Health Research.

## CONTAMINANTS IN CLEAR LAKE GREBES AND OSPREY: PAST AND PRESENT TRENDS OF MERCURY AND ORGANOCHLORINES

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In 1956, Hunt and Bischoff reported high levels of contamination in western grebes by p,p'-DDD, an insecticide used then to control the Clear Lake gnat. Their study was one of the first to document the phenomenon of bioaccumulation of organochlorines in wildlife; and it helped initiate a worldwide effort to document and eliminate negative ecological impacts from insecticides and other potential contaminants. Mercury levels at in the lake are also suspected to have been elevated at that time, but no previous studies had documented this. Other researchers at Clear Lake in the 1960s documented severe

population declines in Clear Lake grebes, mostly associated with the uses of DDD, but also possibly associated with a closely related insecticide used on the watersheds of Clear Lake, p,p'-DDT. Our research began in 1991 with a goal of updating the Clear Lake grebe and osprey status, to document and update contaminant residues found in present-day Clear Lake populations, and to more fully document and explain the levels and effects of mercury, both today and in the past. Our early work with western (*Aechmophorus occidentalis*) and Clark's grebes (*A. clarkii*) has shown that they still suffer some eggshell thinning (related to the persistence of the DDT metabolite, DDE) and their mercury residues are below (but approaching) levels where sublethal effects would be predicted from laboratory and field studies. Yet, mercury residues today are lower (by about 1/3) of what they were in the 1960s. Residues of DDD are present today at 2-3 orders of magnitude less in both fish and grebes compared to what they were in the 1960s. We have found that occasional, severe disturbance by boats has limited reproductive output in Clear Lake grebes in several seasons (1994, 1995, and 1997) but when this has been minimized, grebe production has approached normal levels (compared to reference sites at Tulelake and Eagle Lake in northern California). Osprey, although mostly gone from Clear Lake during the days of intensive organochlorine use, have recently increased at Clear Lake and are currently reproducing normally. Osprey still have elevated mercury levels compared to other reference areas (northern California, Idaho, and Baja California), but apparently these are not high enough at Clear Lake to affect their populations. Overall, conditions at Clear Lake for osprey, grebes, and most other species of birdlife have improved since the 1960s. Because this is a high-use/multiple-use area, careful management to avoid disturbances to sensitive wildlife at sensitive stages, continued work to understand and remediate various sources of pollution, and adequate habitat protection and enhancement should be continued.

## MERCURY BIOACCUMULATION IN THE CACHE CREEK WATERSHED AND DOWNSTREAM, IN RELATION TO ABANDONED MINES AND CLEAR LAKE OUTFLOW

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We have utilized native benthic macroinvertebrates and fishes as indicators of biologically available mercury throughout the upper Cache Creek watershed and downstream. In this presentation, we will discuss prevailing trends in relative mercury bioaccumulation and transport to the downstream Sacramento-San Joaquin Delta and San Francisco Bay, in relation to historic mining sources and Clear Lake outflows. Biotic mercury was low in most of the Clear Lake tributaries and in other Cache Creek tributaries that did not contain historic mercury mining activity. However, dramatic spike concentrations of mercury were present in aquatic biota near abandoned mercury mines. Every significantly elevated set of data was associated with a known

mercury mine source or a stream that drained a mercury mining zone. Samples from the main stem of Cache Creek were elevated well above background levels throughout the stretch between Clear Lake and the Delta. A seasonal pattern was indicated, with abandoned mines supplying large volumes of mercury to downstream during winter floods but with Clear Lake outflows dominating mercury bioaccumulation within the creek itself throughout the spring-fall season of primary biological activity and growth.

Results suggest that much of the large bulk load of mercury transported by Cache Creek may be relatively inert biologically. However, abandoned mercury mines and Clear Lake are clearly sources of a fraction of mercury that is highly bioavailable. Ongoing and future research (to be discussed) seeks to identify those mercury source fractions which may be disproportionately important to mercury methylation and subsequent movement into the food chain—throughout the region and downstream.

## TS-30

### Moving Beyond the Conflict at Lake Tahoe

**Chair: Dennis Rolston—Dept. of Land, Air, and Water Resources, University of California, Davis, CA • USA**

FOUR DECADES OF ENVIRONMENTAL CHANGE IN THE LAKE TAHOE BASIN: LESSONS FOR MANAGING ECOSYSTEM HEALTH

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At Lake Tahoe in the Sierra Nevada mountains of North America, it has been necessary to consider the health of the lake in the context of the entire watershed. This includes, contributing tributaries as well as atmospheric and ground-water effects. The continuous record of primary productivity indicates a steady 5.0% annual increase since 1959 with significant interannual variability related to the annual depth of mixing. Periods of colder temperatures occur about every fourth year and are characterized by complete mixing to the bottom and higher productivity. Since 1959 the average transparency has decreased at about 0.25 meters per year, with temporary improvement during years of incomplete mixing. During this period, the lake has changed from a western-North American, nitrogen-limited system to one that is highly phosphorus-sensitive. The change is largely attributed to atmospheric nitrogen loading from within and outside the basin. Tahoe has also undergone extreme biological perturbation through the introduction of exotic species, including most recently Eurasian watermilfoil, and *Mysis relicta*, the opossum shrimp, which has eliminated the once-abundant cladoceran population. The host of environmental stresses on aquatic ecosystems worldwide, and so evident at Lake Tahoe, has necessitated a more rapid conversion of basic limnological studies into management decisions. So much damage has already been done that restoration-oriented research is of increasing importance. A multidisciplinary approach is essential for developing effective water management strategies. The prospect of global climate change has underscored the importance of collection and careful analysis of long-term data.

THE ROLE OF SCIENTIFIC RESEARCH AND MONITORING IN WATERSHED MANAGEMENT STRATEGY

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Lake and watershed management are linked through hydrologic inputs of nutrients and sediments to downstream waterbodies. Management efforts require cooperation between varied partners, and the importance of a sound, science-based knowledge of ecosystem dynamics and environmental response is critical when designing and evaluating restoration strategies. Central to watershed management is a comprehensive understanding of (1) hydrologic, atmospheric and ecological processes and their interactions, (2) real-time assessment of environmental conditions, (3) response to anthropogenic and natural disturbance, and the ability to (4) predict environmental improvement based on various management strategies. Investigations by University of California-Davis scientists at Lake Tahoe, a large and deep oligotrophic lake in the western United States, underscores the important contribution of long-term monitoring and process-oriented research in efforts to balance environmental protection and economic sustainability. Scientific findings at both lakes have provided the information needed to implement a variety of major policy decisions. For example, a recently completed loading budget for phosphorus indicated that of the total annual 46 metric tons of phosphorus entering the lake during a typical year, 27% came from atmospheric deposition to the lake surface, 29% was associated with stream flow, and the largest contribution came from urban areas which drain directly to the lake. Groundwater inflow accounted for less than 10%. Restoration should give priority to those areas which make the greatest contribution to the nutrient loading budget. Other examples discussed include, streambank erosion, BMP effectiveness, and water clarity modeling.



## A PALEOLIMNOLOGICAL RECONSTRUCTION OF BASELINE CONDITIONS AND ECOSYSTEM RESPONSE TO ANTHROPOGENIC DISTURBANCE IN THE TAHOE BASIN

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Ultra-oligotrophic Lake Tahoe is one of the largest, deepest, and clearest subalpine lakes in the world. Unfortunately, both atmospheric pollution and urban development currently threaten the pristine quality of this unique environmental resource. While routine monitoring of water quality characteristics in this lake has continued for over 30 years, these data can not address the impact from historical perturbations, such as clear-cut logging of virgin timber in the late 1800s. Paleolimnological techniques, on the other hand, provide a scientific basis for assessing the pre-disturbance baseline conditions and for understanding system response to historical disturbances. In Lake Tahoe the sediment chronologies reconstructed from event related markers,  $^{14}\text{C}$  dates, and  $^{210}\text{Pb}$  dating indicate that logging era sedimentation rates increased approximately seven to twelve fold over pre-disturbance rates. During the period of recent urbanization, by contrast, sedimentation rates appear to have been about four times higher than during the pre-disturbance period. During the interval between these two disturbance events, mass sedimentation rates were substantially lower, which indicates that watershed erosion decreased rapidly after clear-cut logging ended. Since diatoms dominate the composition of Lake Tahoe phytoplankton, biogenic silica was used as an indicator of historical primary production. The sediment concentrations of biogenic silica decreased at onset of both disturbance events, presumably from dilution with terrigenous material, as indicated by increasing concentrations of titanium. The flux of biogenic silica, however, actually increased with mass sedimentation rates, indicating that primary production responded to enhanced nutrient input from watershed disturbance. Notably, during the intervening period of watershed recovery and second growth forest, concentrations of biogenic silica decreased and the reconstructed rates of primary production are only slightly greater than baseline rates. This suggests that Lake Tahoe responds at a decadal scale to reductions in nutrient input, despite its long hydraulic retention of about 650 years.

## THE STATE OF AIR QUALITY AND MODELING AND ITS ROLE IN ECOSYSTEM MANAGEMENT AT LAKE TAHOE

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Lake Tahoe is a large fresh water lake at an elevation of 1,898 meters on the border between the states of California and Nevada in North America. The unique, cold, deep lake and surrounding area is in a air basin defined by high mountains with a dramatic vertical relief. The close proximity of the basin to upwind urban areas and the widespread availability of recreational opportunities both provide a source of transported

air pollution and bring a high concentration of visitors to the basin. Due to the topography and location, the Lake Tahoe air basin has three major meteorological regimes, the summer daytime westerly winds, the summer nighttime inversion and a persistent wintertime stagnant inversion. These meteorological regimes transport and then trap pollutants near the lake surface. Recent measurements of Lake Tahoe indicate a loss of lake clarity which is significantly coupled to an atmospheric source of both nutrients and fine particles. Due to the uniqueness of the Lake Tahoe basin, an air quality model specific to this region was developed as part of the Lake Tahoe Watershed Assessment program. The Lake Tahoe Airshed Model (LTAM) is a heuristic eulerian model designed to provide predictive capabilities for management of the basin. Pollution sources including automobiles and forest fires (both wildfires and prescribed fires) are input into the model, and transport and deposition across the basin are predicted. A description of and results from the model for specific scenarios will be presented. Furthermore, recent atmospheric measurements in the basin during local pollution events and their potential connection to degraded lake clarity will be discussed.

## AN ASSESSMENT OF FOREST CONDITIONS IN THE LAKE TAHOE BASIN

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Fire exclusion and extensive logging have modified forest species composition and structure of lower montane forest ecosystems in the Lake Tahoe Basin over the past 150 years. Old-growth conifer forest in the basin has declined from 55% to 4% of the entire forested area, and both understory and overstory tree densities have increased dramatically throughout basin forests. In association with a recent drought, highly visible levels of tree mortality in the Lake Tahoe basin began in the mid-1980s and by the early 1990s mortality was estimated to have reached 300 million board feet over 50,000 ha. Based on our 1997 and 1998 ground surveys, overall cumulative tree mortality in the lower montane zone ranges from 6% to 41% in 31 sampled stands with mean mortality of 22% for both late-seral/old growth and seral stands. While much of this tree mortality can be indirectly attributed to short-term effects of drought and long-term effects of fire suppression and logging, epidemic levels of several bark beetle species were the most important proximal causes of tree death. A number of native pathogens (e.g., dwarf mistletoe, root diseases) have also contributed to tree mortality. Additional threats to tree health in the Lake Tahoe Basin include air pollution, introduced pathogens (e.g., white pine blister rust), and the potential for catastrophic fire due to the presence of increased fuel loads.

Restoration of basin forests could potentially focus on stand thinning and prescribed fire; however, the long-term impacts of these treatments are not explicitly known.

#### PAST HUMAN LAND USE AND ENVIRONMENTAL CONDITIONS IN THE LAKE TAHOE BASIN

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Paleoenvironmental, archaeological, ethnographic and historic documentation are applied to ecosystems management by setting a baseline of reference conditions to determine (1) how present conditions differ from past conditions, (2) the reasons for that difference, and (3) what sustainable conditions may be possible for the future. Human beings have been a component of the Lake Tahoe Basin ecosystem for at least 8000 years. At Tahoe, human land disturbances were initiated by millennia of low-intensity

land management by the Washoe Indians and their prehistoric predecessors. Within a century's time, indigenous practices were replaced by profound resource exploitation by incoming Euro-american populations that logged, grazed and developed the land. Within the last few decades, agency regulation has struggled to control explosive community growth induced by millions of tourists who visit the Lake Tahoe Basin each year. To provide context to contemporary land management attempts to restore the Lake Tahoe ecosystem, historic human disturbances in the Lake Tahoe Basin are briefly surveyed. To illustrate how these data sets are used as independent and corroborative tools to achieve a nexus between historic conditions and contemporary research/monitoring/adaptive management, select examples of applications of these data sets are presented. While it is acknowledged that the incorporation of historical data into truly multi-disciplinary environmental planning efforts treads untested ground, in the context of ecosystem management in the Lake Tahoe Basin, these lines of inquiry reveal the considerable extent to which cultural and environmental history can effectively guide future management.

## TS-31

### Indicators of Ecosystem Health: Development, Selection, and Use

**Chairs: William S. Fisher—US Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL • USA**

**Ralph G. Stahl, Jr.—DuPont Corporation, Wilmington, DE • USA**

#### THE DEVELOPMENT AND USE OF ECOHEALTH INDICATORS TO MEASURE PROGRESS UNDER THE GREAT LAKES QUALITY AGREEMENT

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Since 1972, Canada and the United States have been working to restore the biological, chemical and physical integrity of the waters of the Great Lakes Basin ecosystem. How does one measure and report on the successes and failures of such an undertaking? The Great Lakes Water Quality Agreement (1987) calls for the development of ecosystem health indicators. The governments have been working since the late 1980s on indicators, but a concerted effort, through the State of the Lakes Ecosystem Conferences and through Lakewide Management Plans, has produced a candidate list of 92 indicators that are being circulated for comment. It is expected that over the next 5-10 years, a suite of indicators will be adopted that will allow an assessment of the state of the Great Lakes Basin ecosystem, and smaller geographic units to be made. This paper presents some of the concepts, process and candidate indicators being developed.

#### ENVIRONMENTAL INDICATORS FOR MONITORING ECOSYSTEM HEALTH

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The goal of Minnesota's Environmental Indicators Initiative (EII) in Minnesota is to provide integrated, ecosystem-based information on the state of the environment, using a comprehensive set of science-based, environmental indicators in a long-term monitoring program. The audience for environmental information includes decision makers at all levels of organization, from statewide policy makers and environmental regulators to local conservation districts and citizens. In response to this diversity of information needs, the EII developed conceptual models (of human-environment interactions and of ecosystem integrity) to facilitate the development of menus of appropriate indicators. EII models are consistent with those of the Organization for Economic Cooperation and Development and Environment Canada and are designed to help educate indicator users about ecosystems and help ensure that indicators address their information needs. The model of human-environment interactions organizes environmental information into categories of human activities, environmental condition, the flow of benefits, and societal strategies for sustaining healthy environments. This framework allows citizens and resource professionals to articulate and prioritize environmental management goals (the ecosystem goods and services that they wish to sustain) and specify the environmental conditions that are necessary to sustain the flow of

those benefits. It is then possible to identify what human activities are responsible for altering those environmental conditions and to develop effective strategies that address problems. Use of the framework avoids many of the pitfalls associated with public discussions of complex environmental issues. The model of ecosystem integrity serves primarily as a checklist to ensure that any comprehensive set of indicators will allow assessment of an ecosystem as a whole. Ecosystem integrity is characteristic of ecosystems in which biological productivity, diversity, nutrient cycling, and natural disturbance regimes vary within natural ranges. One example of the successful use of EII models resulted in a detailed description of the factors influencing environmental conditions within a Minnesota watershed and the selection of indicators for surface waters to be used in a comprehensive monitoring program.

#### DEVELOPMENT OF REGIONAL INDICATORS OF SALMON HABITAT IN THE PACIFIC NORTHWEST

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Environmental agencies from 4 US states, one Canadian province and the federal governments of both countries collaborated in a voluntary effort to identify effective indicators associated with salmonid fish habitat. The directors of the 7 participating agencies charged a team to develop, if possible, regional indicators related to issues for which the agencies had responsibility. The indicator team selected a set of indicators using a collaborative input and review process that involved both scientists and policy makers. The effort resulted in a “small but powerful” set of salmon habitat indicators for voluntary use by agencies. The dozen-plus indicators address water quality, water quantity, land use/land cover, and stream habitat. Some indicators are currently operational, while others require further development or generation of additional data. Stream habitat indicators are receiving further evaluation for potential use as an index.

#### WETLANDS RESTORATION: COMPREHENSIVE MANAGEMENT FOR ESTUARINE ECOSYSTEM HEALTH

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Wetlands restoration is commonly undertaken for focused management objectives, usually direct mitigation for unavoidable wetland losses. However, the science has progressed substantially in recent years, and wetlands restoration now offers tools to meet more comprehensive environmental management goals. Because tidal wetlands are integral to healthy estuarine and coastal environments, restoration activities can contribute substantially to the ecological value of these crucial areas. In the Delaware Estuary, a large-scale wetland restoration

program was implemented. A key objective of this program was to enhance production of estuarine and coastal fish and shellfish species. In successfully meeting this objective, the overall health of the estuary, including habitat for birds and wildlife, coastal stability, and landscape functions were greatly improved. This has substantially increased ecological value of the estuary as a whole, and contributed to improved human use values, including recreation, education and research. This paper presents the scientific and regulatory foundation of the restoration program, documents success in meeting the main objective of enhanced fish and shellfish production, and illustrates the powerful contributions of the restored areas to the overall health of the estuary and adjacent coastal ecosystems.

#### EPA OFFICE OF RESEARCH AND DEVELOPMENT: GUIDELINES FOR TECHNICAL EVALUATION OF ECOLOGICAL INDICATORS

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EPA's Office of Research and Development (ORD) has prepared fifteen technical guidelines to evaluate the suitability of an ecological indicator in a monitoring program. The guidelines were fashioned to provide a consistent framework for indicator review and to provide direction for research on indicator development. They are proposed for use in characterizing the strengths and weaknesses of indicators within the context of their intended application and may be used to compare different indicators proposed for a similar purpose. The guidelines are not intended to serve as 'indicator criteria' since different programs vary in their objectives and may be willing to overlook some deficiencies in order to capture a critical strength. The fifteen guidelines are organized within four evaluation phases, originally described for indicator development in the Environmental Monitoring and Assessment Program (EMAP) (1) conceptual relevance, (2) feasibility of implementation, (3) response variability, and (4) interpretation and utility. In addition to the fifteen guidelines, the *Evaluation Guidelines* document includes examples of three different EMAP indicators presented to demonstrate the types of information relevant to each guideline. The examples include a direct chemical measurement (dissolved oxygen), an estuarine benthic community index and a fish community index of biotic integrity.

## TS-32

## Addressing Threats to the Health of Coastal and Near-Coastal Ecosystems

**Chair: Jim Giattina**—Gulf of Mexico Program Office, National Aeronautics and Space Administration, Stennis Space Center, MS • USA

#### HYPOXIA IN THE GULF OF MEXICO: THE CHALLENGE BEFORE US

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Although Progress has been made, eutrophication of freshwater, estuarine, and marine ecosystems continues to threaten the ecological integrity, safe use, and the economic productivity of inland and coastal waters of the United States. In some of these waters, conditions of hypoxia and anoxia may develop. In contrast to many other marine pollution problems, coastal eutrophication has been in ascendancy during the later half of the twentieth century. Given growth and development projections in many coastal areas, additional steps will be necessary to restore and maintain an acceptable nutrient balance in surface water systems.

#### A LANDSCAPE ECOLOGY ASSESSMENT OF THE TENSAS RIVER BASIN, MISSISSIPPI RIVER DELTA REGION, GULF OF MEXICO

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The Tensas River Basin is a target watershed of several U.S. Environmental Protection Agency environmental studies including the Nonpoint Source Management Program and the Gulf of Mexico Program. The Nonpoint Source Management Program has identified watersheds in Louisiana which have been impaired by nonpoint pollution and where land use practices contribute to these pollutant problems. This program identified specifically what types of best management practices need to be implemented to improve environmental conditions. Using the existing data and with the cooperation of landowners, the Tensas River Basin offered a unique opportunity to implement best management practices that could help reduce the concentration of sediment, excess nutrients, or pesticides leaving the Basin. The nutrients leaving the Tensas River Basin, combined with other Mississippi Valley watersheds, are of concern to the Gulf of Mexico Program because research has shown that excess nutrients cause hypoxia (<2 mg/l oxygen) in the bottom waters of the Gulf of Mexico. This condition represents a threat to the coastal marine ecosystem and fisheries in this region of the Gulf. The landscape analysis methods described in this presentation will show how to

use these methods to assess the impact of human land use practices that are being implemented to improve environmental quality. In years past, the freshwater marshes, stream bank areas, and bottomland swamps of the Tensas River Basin were under strong development pressures. Large portions of forest near streams and in backwater swamp areas were converted to agriculture. This loss of forested areas interfered with the interaction of forested wetlands with soil and water that removes pollution before it enters streams, lakes, and estuaries. Wetland forests also absorb peak flows during floods and release the water more slowly, reducing damage to downstream farms and cities. Preserving or restoring wetland forests have other economic benefits such as wetland-based recreation, including hunting and harvesting wetland plants. The people who live within the Tensas River Basin realize that the vegetation along a stream and in backswamp areas can influence the condition of both the stream bank and the water in the stream. Restoration efforts began in the early 1990s. A group of landscape ecological indicators were applied to biophysical data cut to the Tensas River Basin. Remotely sensed data were used for change detection assessment. With these methods, we were able to look at land use practices over the past twenty years in the Tensas River Basin of Louisiana. A simple land use classification was applied to multispectral scanner (MSS) data from 1972 to 1991. After analyses, potential forested wetland restoration sites were identified and target areas of ecological concern.

#### MONITORING MARINE ECOSYSTEM HEALTH IN CENTRAL CALIFORNIA

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Nationwide resource agencies are attempting to move toward the management of ecosystems and away from management of individual species. In 1998 the California Department of Fish and Game (CDFG), an agency that traditionally has managed the harvest of fish and shellfish resources, was charged by the California Legislature with managing marine resources on an ecosystem basis, and established a new Marine Region

headquartered in Monterey, CA. New CDFG programs; and cooperative state, federal, university and private partnerships are making it possible to monitor the health of marine ecosystems, and hopefully better manage these ecosystems. Marine ecosystem health is a relatively new and ill defined concept. It is generally agreed, however, that healthy ecosystems are those that : 1) do not have obvious environmental degradation, frequent pollution events or serious anthropogenic effects due to over harvest. 2) do not have a high frequency of new or emerging diseases/intoxications with negative implications for human and wildlife health. 3) have stable, or at least not declining, species abundance and diversity. 4) do not have frequent dieoffs or similar stochastic events, particularly those involving "indicator" or "keystone" species. We have recently investigated five events that may have implications for the health of California's central coast marine ecosystems. These were: In August of 1997, approximately 400 common murres (*Uria aalge*) were found dead in a relatively confined area of the Monterey Bay National Marine Sanctuary. They died during a "red tide" event of apparent brevetoxicosis (paralytic shellfish poisoning), as evidenced by compatible lesions and specific staining of tissues with antibrevetoxin immunoperoxidase reagents. These are the first such cases on the Pacific coast and in seabirds. In retrospect similar dieoffs may have occurred several times in the last ten years. In October and November of 1997 500 marine birds, predominately western grebes (*Aechmophorus occidentalis*), common loons (*Gavia immer*), and surf scoters (*Melanitta perspicillata*) stranded due to a combination of physical fouling and acute stress due to fish oil exposure, bacteremia (*Salmonellosis*), and migration related debilitation. No responsible party was sited for this pollution event and about 50% of birds were eventually released. Over a three month period in the winter of 1997-98 a significant percentage of the common murre population off California's central coast died as the result of oil and tar contamination. Over 500 live birds, 94% of which were common murres, and over 650 dead birds were recovered. Although there was no point source for the petroleum identified, it was from outside California and appears to emanate from shipping sources. Events of this type have occurred repeatedly in California over the last 5-10 years, and may have serious population level effects. In May and June of 1998 seventy California sea lions (*Zalophus californicus*) and one Northern fur seal (*Callorhinus ursinus*) stranded in an area from San Luis Obispo to San Mateo Counties, 52 died. All had similar neurologic signs and behavioral changes including lack of fear and awareness of humans, ataxia, muscle tremors, opisthotonus, seizures and characteristic rubbing of the back of the head. A bloom of *Pseudo-nitzschia australis* was

determined to be occurring along the California coast at that time and domoic acid was detected in serum, urine and feces of sea lions as well as in anchovies. The only previous similar amnesic shellfish poisoning event occurred in 1990 in Monterey Bay and involved brown pelicans (*Pelicanus occidentalis*) and cormorants (*Phalacrocorax spp*) and effected shellfish as far north as the state of Washington. Since 1996 the southern sea otter (*Enhydra lutris nereis*) population has steadily declined by at least 12%, apparently due primarily to increased mortality in prime age adult animals. This decline preceded and has spanned both the El Nino and La Nina oceanic cycles. Approximately 40% of mortalities are due to infectious diseases and parasites. One of these is an apparently new and emerging disease, two have human health implications and may be related to runoff or non-point source pollution. Metallic and organohalene contaminants and malnutrition due to preferred prey species scarcity may also be factors in this decline. Based on the definitions given of health ecosystems, the described dieoffs may indicate declining marine ecosystem health. Conversely they may reflect improved diagnostic capabilities, better cooperation and increased monitoring and interest in marine animal mortality events. Or both of these may be occurring simultaneously. Diagnosis of two of these dieoffs was made possible by very new diagnostic technologies and two events were detected in part by a volunteer beach monitoring program within a portion the Monterey Bay National Marine Sanctuary. Monitoring the health of marine ecosystems is a relatively new concept. But, marine birds and mammals may serve as monitors of short, medium and longer term disturbances that reflect changes in the health of marine environments. Oil spills and depletion of fisheries are obviously anthropogenic and usually result in short to medium duration changes. Larger scale changes in prey species, ocean nutrient or other cycles, whether due to chronic non-point source pollution, or global warming, may cause changes of longer duration or periodic events such as toxic algal blooms. Mortality events involving different species at various trophic levels have been used as a measure of the health of the Gulf of Mexico and Atlantic Ocean. As our programs for monitoring mortalities continue, we are trying to move towards management practices that could preserve and improve the health in California's most sensitive marine ecosystems.

# TS-33 Measuring Forest Ecosystem and Natural Capital: National to Global

## TOWARDS A P-S-R INDICATOR APPROACH FOR FOREST ECOSYSTEM HEALTH AND NATURAL CAPITAL

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Indicators are essential to assess the efficacy of environmental and natural resources management action and policies, and more generally to evaluate progress toward sustainability. The concept of ecosystem health, like that of sustainability, significantly challenges indicator development as a result of the transdisciplinary nature of the concept. This paper discusses the concepts of health and sustainability as they pertain to forest ecosystems, and the challenges to their measurement. It provides a brief overview of the existing approaches being used to develop indicators in terms of both how scientifically meaningful and policy-relevant they are. It addresses the problem of geographic scale (local to global), focusing in particular on indicator approaches applicable to biodiversity at the regional ecosystem level, incorporating ecosystem health and related concepts, and using land-unit-based descriptors.

## ECOLOGICAL INDICATORS OF SUSTAINABLE FOREST MANAGEMENT: THE CANADIAN EXPERIENCE

**Harry Hirvonen**

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In 1993, the Canadian Council of Forest Ministers (CCFM) embarked on an initiative to define measure and report on the forest values Canadians want to sustain and enhance. This initiative culminated in the development of six criteria of sustainable forest management. These criteria comprise 22 elements and 83 indicators. Of these, four criteria are 'ecological' and the other two social and economic. Analyses are currently under way to assess the viability and practicality of these indicators. Should some indicators be deleted, improved or replaced by more appropriate ones. Other issues to emerge are related to scale of application and method of presentation to the public. The first Criteria and Indicators report released in 1997 was a clinical outline of the complete set of indicators. The 'sustainability' component was missing. The next CCFM report due for release in 2000 discusses, for the six criteria, a smaller, more viable set of indicators with emphasis on applicability for sustainability. This paper looks specifically at the four ecological criteria and associated elements and indicators in this exercise.

## FOREST HEALTH MONITORING IN THE USA: WEST COAST PERSPECTIVE

**Sally Campbell**

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Forest Health Monitoring (FHM) is a cooperative, multi-agency program in the United States. The goals of this relatively new program are to monitor, assess, and report on the long-term status, changes, and trends in the health of the nation's forested ecosystems. FHM is comprised of four inter-related activities: detection, evaluation, intensive site ecosystem monitoring, and research on monitoring techniques. The detection activity covers all forested lands and has two components: a network of permanent plots on which measurements are made each year; and a survey component which includes a variety of surveys to monitor effects by insects, diseases, and other forest stressors. A set of forest health indicators is measured on the permanent plots including tree crown condition; tree damage, growth, regeneration, and mortality; ozone injury to bioindicator plants; soil condition; plant diversity; and lichen communities. FHM indicators were selected on the basis of their ability to reflect societal values of concern and to estimate condition of forest ecosystems in a quantifiable and unambiguous way. Current challenges to the FHM program include integration of FHM data with other data sets, quality control, continuing development of new and refinement of existing indicators, and timely reporting. Baseline plot data has been collected in California, Oregon, and Washington; remeasurement data is currently being collected. Permanent plots will be installed in Hawaii this fall and in Alaska next year (2000). Some highlights of West Coast monitoring include 1998 ozone damage monitoring; development of a lichen gradient model; lichen monitoring and analysis on National Forests in Oregon and Washington; evaluation of several unique insect and disease situations; implementing a quality control program for aerial surveys; and a comparison of FHM and other plot datasets (FIA) to characterize old growth in California.

## INTRODUCTION

**A.F. McCalla**, World Bank, Washington, DC • USA

## RELATIONSHIP BETWEEN ECOSYSTEM HEALTH AND ECONOMIC DEVELOPMENT: RURAL VISION TO ACTION

**J.R. Anderson**

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The importance of agricultural and rural development in broader economic development in the less-developed world has long been recognized in the World Bank and by its many partners in the development effort, not the least being the governments of the many countries that are still highly dependent on the contributions made by their rural sectors. Over the nearly five decades of active experience in such work, much was learned about how to do (and in some cases not to do) effective rural development work. But even so, by the 1990s, there was growing recognition that all was not going as well as it should and could be. Several institutional changes (including some key senior personnel changes) in the Bank in the mid-1990s led to a major rethink of Rural Development. First, there was a reaffirmation that poverty alleviation was indeed the central objective in all Bank effort, an aspect that had not been necessarily a feature of all project interventions in the sector. The new *Vision* that was articulated also highlighted the necessity for ensuring that what gains could be made in agricultural and rural growth should be widely shared in the communities (including those in rural areas themselves). Beyond just economic progress, the traditional Bank concern for advancing greater food security at all levels, from household, to national and thence to global, was not to be forgotten. But for the purpose of the present discussion of ecosystem health and development, it was the fourth leg of the new rural *Vision* that joined these center-stage strategic concerns, namely a commitment to foster sustainable natural resource management, that is perhaps of greatest relevance. The mechanisms adopted for putting this *Vision into Action*, and the problems encountered and progress made thus far, are the substance of this paper

## AGRICULTURAL BIODIVERSITY: A KEY ELEMENT OF ECOSYSTEM HEALTH AND SUSTAINABLE FOOD SECURITY

**Lori Ann Thrupp**

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Agricultural biodiversity is critical for food security throughout the world. How can the erosion of this valuable agrobiodiversity be halted? And how can it effectively be conserved and enhanced? This paper highlights key principles, policies, and practices for the sustainable use, conservation and enhancement of agrobiodiversity to assure sustained food

security. After clarifying the serious threats from the world-wide loss of agrobiodiversity, the speaker will present practical guidelines and lessons for biodiversity management in farming systems and in landscapes. Such strategies build upon valuable local experiences and knowledge, and they also take advantage of recent scientific findings in agroecology and ecosystem health. The presentation will stress the need to adopt an agroecosystems approach, beyond a focus on genetic resources alone—to implement such methods as integrated ecological pest and soil management. Also needed are reforms of conflicting agricultural policies that promote monocultural industrial farming models and uniform technology packages. This analysis shows the vital connection between biodiversity and sustainable food security.

## EVOLVING OPPORTUNITIES TO INTEGRATE MANAGEMENT OF AGRICULTURAL LANDSCAPES AND ECOSYSTEM HEALTH: SUSTAINABILITY AS OPPORTUNITY.

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The intimate connections between economic growth and ecosystem health are no longer in dispute. Global populations are now of such magnitude that for the first time in history how we manage the land can impact directly on the ecological services that support life on this planet. Agriculture has historically been a major contributor to environmental degradation, but under improved systems of land management, it could be a major partner in the environmental solution. Land management decisions by individual farmers have implications for many environmental goods and services, such as impacting on *habitats* for fauna and flora, on a variety of *ecological services*, and on *amenity* or aesthetic values. Many of the environmental benefits associated with sustainable land management will accrue locally and nationally, while others are more clearly global, or at least ‘supra-national’ in scope, such as climate regulation, conservation of genetic resources with potential value in plant breeding or pharmaceuticals, international tourism, and transboundary water-mediated effects. Improved local and global ecosystem health will depend on the collective decisions of millions of individual farmers world-wide. However, farmers make decisions in the context of their local interests and the opportunities available to them. There exists an innate conservation ethic in most of the agricultural community, and this needs to be mobilized within an enabling policy environment that gives equal attention to economic growth and maintenance of environmental quality.

This, however, will not be achieved under business as usual, but rather under improved systems of management which will ensure more flexible and resilient farming systems, and farmers who are better attuned to capture opportunities as

these become available. This new approach is called "Sustainability as Opportunity", and some principles are discussed in the paper.

## TS-35

### Indicators of the Health of Marine Ecosystems

**Chair: Robert Costanza—Director of the University of Maryland Institute for Ecological Economics, College Park, MD • USA**

#### WATER QUALITY AND MICROFAUNA ALONG THE EAST COAST OF INDIA

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In the marine environment, plankters have long been recognised as an important integral part of the marine ecosystem. While there is considerable information on pollution effects on plankters in the coastal zone, no attempt is made to study faunal biodiversity in the surface waters off Chennai coast. A study of diversity of zooplankton communities during one annual cycle was carried out in East Coast of Chennai city. Maximum abundance (23,450 ind/m<sup>3</sup>) of zooplankton community were captured during premonsoon and minimum (1,150 ind/m<sup>3</sup>) during monsoon seasons. Total zooplanktons were represented by 50 taxa and the rotifers represented by one and two species respectively. The shannon-weiner diversity index ( $H'$ ) of zooplankton showed maximum (2.514) during summer season and minimum (0.832) during monsoon season. Thus the availability of microphage in the coastal waters mainly depend on seasonal influence and the quality of the habitat.

#### ANTARCTIC WILDLIFE AS INDICATORS OF ECOSYSTEM HEALTH

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The Antarctic Treaty, adopted in 1959, was designed to address sovereignty issues, scientific research, and concerns regarding military use of the Antarctic continent. Parties to the Treaty have since turned their attention to protection of the environment, as evidenced most recently by the 1991 Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol), which entered into force in January 1998. Activities are to be planned and conducted so as to limit adverse impacts on the Antarctic environment and dependent and associated ecosystems, on weather patterns and water quality, and on populations of fauna and flora. The Protocol also calls for assessment of impacts and early detection of unforeseen events via monitoring of activities. Additional international agreements and domestic

legislation have established frameworks for implementing the Antarctic Treaty and the Madrid Protocol. Of special concern are introductions of non-indigenous flora and fauna, either intentional (e.g., sledge dogs, ponies) or unintentional (e.g., microbial contamination via human sewage and garbage). Health assessments and infectious disease and contaminant surveys of penguins and seals are being used as a monitoring tool for Antarctic ecosystem health. Serological evidence for exposure of Antarctic penguins to the poultry disease IBDV (infectious bursal disease virus) and presence of antibiotic-resistant bacteria in sewage outfalls from Antarctic stations have caused concern among Treaty signatories and in 1998 a workshop on diseases of Antarctic wildlife was convened to develop risk assessment, prevention, response, and monitoring strategies.

#### A PHOENIX RISING: THE ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM AND THE COASTAL 2000 NATIONAL SURVEY

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The purpose of the Environmental Monitoring and Assessment Program-Coastal Resources is to estimate the current status, extent, changes, and trends in ecological indicators of the condition of the nation's coastal resources (intertidal, subtidal, and offshore) on a regional and national basis. Based on EMAP monitoring activities from 1990-1995 approximately 70% of the nation's estuarine waters were sampled focusing on suites of measurements describing the benthic community, the fish community, water quality, levels of sediment and tissue contamination, sediment toxicity, and SAV extent/condition. Estuarine monitoring was based on a probability-based sampling design implemented over a 60-day window during July-September in selected years. The results of monitoring show that 25% 4% of the sediments of the nation has degraded biological conditions while 29% 4% of the area showed degraded conditions in relation to human uses of the resource (e.g., water clarity, tissue contaminants, and the presence of marine debris). Biological degradation is characterized by significantly less than expected number of benthic species and diversity, high numbers of pollution-tolerant species, and low numbers of pollution-sensitive species, incidence of fish pathologies, and increased



levels of selected biomarkers in target fish species. Human use degradation is characterized as decreased water and sediment quality, potential for decreased consumptive use, and incidence of characteristics limiting non-consumptive use. These estimates are based on 100% of the estuarine resources spanning from Cape Henry, VA to Brownsville, TX. In 2000, EPA/ORD will conduct Coastal-2000, a national survey of estuarine condition. While Coastal-2000 will be probabilistically based, its implementation will be through state-level infrastructure and be designed to address not only national and regional issues but state-level issues as well.

#### AN EXPLORATORY APPROACH TO ASSESSING THE INFLUENCE OF ENVIRONMENTAL FACTORS ON FISH COMMUNITY DISTRIBUTION AND HEALTH

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The Chesapeake Bay is one of the most productive systems in the world. It supports a variety of aquatic resources of flora and fauna. However, for the past 350 years and especially in the last two to three decades, there has been substantial deterioration of the natural resources. Many species of submerged aquatic

vegetation and benthic invertebrates have been extirpated. Commercial harvests of fish, crab and shell fish have also declined. The cause of this ecological phenomenon is unknown, although it may be related to nutrient enrichment. To restore the Bay area and to conserve the fish resources, the causal relationships between the environmental stressors and the distribution and health of the fish communities must be understood. This research project adopts an integrated methodology involving the use of multi-variate ordination, statistical, and geographical information systems (GIS) techniques to explore the intricate effects of various environmental factors on fish. Multi-variate ordination techniques are useful exploratory tools to help elucidate latent environmental relationships and to define specific biocriteria. GIS is an analytical technique for identifying spatial relationships. In this project, a non-metric multi-dimensional scaling ordination technique was employed in conjunction with other statistical techniques and ArcView GIS to reveal the relationships between a suite of environmental factors (including in-stream habitat characteristics and neighboring land use) and nitrate levels and fish conditions (such as the Index of Biological Integrity, % of abnormalities, the presence and absence values of fish species) in the riverine system. The results showed that land use is significantly related to nutrient loading, and each is related to the distribution and health of the fish communities.

## TS-36 Agroecology: Integrating Agricultural Production with Ecosystem Health

**Chair: Terrell P. Salmon—Dept. of Wildlife, Fish, and Conservation Biology, University of California, Davis, CA • USA**

#### AN AGROECOLOGICAL FRAMEWORK TO ACHIEVE ECOLOGICAL HEALTH IN AGROECOSYSTEMS

**Miguel A. Altieri**

University of California, Berkeley, CA • USA

Agroecology is the scientific discipline that provides the basic ecological principles for how to study, design and manage agroecosystems that are both productive and natural resource conserving, and are also culturally sensitive, socially just and economically viable. Agroecology provides the guidelines to restore and enhance the resiliency, sustainability and health of agroecosystems. Biotic constraints stressing agroecosystems are understood as imbalances, therefore the goal of the agroecological treatment is to recover balance and enhance the “immunity” of the agricultural system. Biodiversification is the primary technique to evoke self-regulation and sustainability. However, ecological health and sustainability is not possible without preserving the cultural diversity that nurtures local agricultures. In addition to a proper balance of crops, soils, nutrients, arthropods, etc. stable production must take place in the context of a social organization that protects the integrity of natural resources and encourages the harmonious interaction of humans, the agroecosystem and the overall environment.

#### RESTORING HABITAT AND WATERSHED FUNCTION TO SACRAMENTO VALLEY FARMLAND

**John H. Anderson**

Hedgerow Farms, Winters, CA • USA

Intensive farming practices in the Sacramento Valley have essentially eliminated wildlife habitat and ecosystem functions on the majority of farmland. Most farmers routinely keep non-farmed areas devoid of vegetation through a costly and labor-intensive combination of tillage and herbicides. Most of the major drainages that served historically as riparian corridors for wildlife have been channelized and stripped of vegetation. In addition to eliminating wildlife habitat and biodiversity, this so-called “clean-farming” has exacerbated soil erosion, sediment deposition, and flooding. It also locks farmers into a never-ending cycle of seasonal weed abatement. Left alone for even a short period, traditionally clean farmed areas become a complex of non-native invasive weeds that are unacceptable to farmers and that can choke water delivery systems. Hedgerow Farms, in cooperation with the Yolo County Resource Conservation District and other government agencies, has

demonstrated the use of on-farm vegetation practices that completely reverse the concept of “clean farming”. Rather than eliminating vegetation, we have restored an cultivated native California vegetation on roadsides, irrigation canals, drainage ditches, field borders, and along a natural riparian corridor. Every non-farmed area is a complex of native plants (including perennial grasses, sedges, rushes, forbs, shrubs, vines and trees) that competitively suppress invasive weeds while providing a biologically diverse community of plants and animals. Today, Hedgerow Farms supports multiple, interconnected corridors that have eliminated erosion, reduced the need for tillage and herbicides, and may even be assimilating agricultural nutrient run-off. The benefits to wildlife are tremendous. Over 100 species of birds have been recorded on the property. Reptile and amphibian populations have made dramatic recoveries. A myriad of beneficial insects and spiders inhabit the diverse vegetation complexes.

#### FALLOW LAND PATCHES AND ECOSYSTEM HEALTH IN AN AGROECOSYSTEM

**John Hopkins**

Fallow Land Project, Centers of Water and Wildland Resources, University of California, Davis, CA • USA

California’s Central Valley is the world’s foremost agricultural area. In most locations there is little or no natural wildlife habitat remaining. Valley farmers make little use of existing government programs for habitat conservation and restoration. This study examines the constraints and potential for development of a network of small habitat patches and strips, including field and stream borders and areas with poor soils. Current constraints include (1) a large price difference per acre between returns on crops and government fiscal incentives for habitat restoration, (2) a variety of farm practices, (3) farmers’ concerns over government regulations, and (4) a lack of knowledge about existing conservation programs. Conservation projects started by a few farmers show the potential for providing more habitat, especially streamside vegetation, small patches of native grasses, small wetlands and hedgerows. Broad adoption of these practices would provide major benefits for many wildlife species, improve ecosystem health in the Valley, and provide a variety of benefits to farm operations. A number of changes are needed in farmland habitat conservation policies, financing and implementation activities in order to achieve widespread adoption of these techniques. Most importantly, habitat protection and restoration must provide a greater economic return per acre. Farmers need safeguards from additional regulatory burdens in case their new habitat patches attract endangered species of wildlife. Greater availability of technical assistance, demonstration programs and promotion by local agricultural interests such as Resource Conservation Districts is essential for achieving a network of habitat patches.

#### REDUCED DISTURBANCE AGROECOSYSTEMS IN CALIFORNIA

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Despite a 300% increase in conservation tillage (CT) production in the Midwest during the past decade, less than 0.3% of annual row crop acreage in California’s Central Valley is currently farmed using CT practices. Preplant tillage operations typically account for 18–25% of overall production costs for annual crops grown in this region. An average of about 9 to 11 tillage-related passes are routinely done during the fall-spring period to *prepare* the soil for summer cropping. These passes represent not only considerable energy, equipment and labor costs, but recent research indicates that tillage reduces soil organic matter (SOM) and emits considerable respirable dust as well. Because SOM is widely regarded as an important attribute of good soil quality and long-term productivity, interest has been growing over the last several years in developing alternative production systems that reduce costs while at the same time improve the soil resource through greater carbon sequestration. This paper presents very recent work in managed agroecosystems in California’s Central Valley to develop CT production systems for processing tomatoes, cantaloupes and corn. Changes in soil quality indicator properties, soil water storage and weed management that may result from CT systems relative to conventionally managed systems will be described.

#### INSTALLATION OF INSECTARY HEDGEROWS ON FARMS: MANAGEMENT PRACTICES AND COSTS

**Mary J. Kimball**<sup>1</sup> and Rachael Long<sup>2</sup>

<sup>1</sup>Yolo County Resource Conservation District, Woodland, CA • USA

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Four “insectary” type hedgerows were planted in Yolo County in 1996 on large-scale rotational field crop farms. Establishment practices and costs were documented at each site for two years, resulting in the first “model guidelines” for hedgerow installation and maintenance on farms in California. Although hedgerows take time and money to establish, their numerous benefits (wildlife habitat, increased biodiversity, beneficial insect habitat, weed control/pesticide reduction, erosion control, nutrient leaching, dust/chemical buffer) can potentially offset these costs.

MULTIPLE STRESSORS IN THE SACRAMENTO RIVER  
WATERSHED**David Hinton**

Laboratory of Aquatic Toxicology, Dept. of Anatomy,  
Physiology and Cell Biology, School of Veterinary Medicine,  
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Aquatic biota in the Sacramento river watershed are stressed by diversion of river flows, by historical mining resulting in cadmium, copper, zinc and mercury, and more recent contamination by agricultural and urban chemical runoff. In addition the proposed redirection of drainage of saline waters-containing selenium—from the western slope of the San Joaquin River into the Delta formed by the confluence of the Sacramento-and the San Joaquin Rivers could add to the stress on resident organism. These combined stressors have led to deterioration in surface water quality and aquatic habitat. The potential interaction of these stressors, coupled invasions of foreign species and the export of juvenile fish into aqueducts, have driven several species of fish to near extinction in the systems. Effects of historical contamination by heavy metals are potentially exacerbated by presence of organophosphate pesticides, at concentrations exceeding National Academy of Sciences recommendations, throughout the lower watershed and the San Francisco Bay. The Asian clam, *Potamocorbula amurensis*, an introduced nonindigenous species has apparently become a preferred food item of the sturgeon, *Acipenser transmontanus*, an important sport and aquaculture species. Since this introduction, sturgeon body burdens for selenium have increased dramatically and analytical chemistry of *P. amurensis* indicates these organism are effective bioaccumulators of selenium. This review examines potential ecotoxicity associated with multiple stressors in the watershed. Data from field monitoring, laboratory assays from ambient water, and ecotoxicologic investigations are reviewed. Potential designs for multiple stressor investigations are discussed. The information presented on this watershed illustrates the challenge to investigators seeking to evaluate multiple stressor effects on riverine and estuarine organisms.

THE EFFECT OF LIVESTOCK ON STREAM HEALTH:  
AN AGROECOSYSTEM HEALTH APPROACH**Dominique Charron**

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Guelph, ON • CANADA

An epidemiological approach is taken to model indicators of livestock production, stream health and farm economic health in the Laurentian Great Lakes Basin. Risk factors such as livestock density and pasture acreage, net farm income and debt are mapped in relation to biotic indicators of stream health in over 100 watersheds and analysed using a GIS.

IRRIGATED AGRICULTURE AND WATER QUALITY IN  
THE UPPER KLAMATH BASIN**Stephen Kaffka**

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University of California, Davis, CA • USA

Crop irrigation may impair surface water quality in the Upper Klamath Basin. Salt and P mass balance transfers among components of the watershed are presented. The effects of irrigation on water quality are discussed.

ASSESSING RANGELANDS FROM DIFFERENT  
PERSPECTIVES**Hugh Pringle**

Research School of Biological Sciences, Australian  
National University, Canberra, ACT • AUSTRALIA

Two types of rangeland landscapes were assessed along grazing gradients according to aspects of i) biodiversity, ii) landscape pattern and process and iii) range condition. Grazing impacts varied according to both landscape and the perspective underlying assessments. These differences have substantial implications for environmental assessment and management of rangelands.

## TS-38

**Grazing Animals and the Protection of Rangelands in California****Chair: Al Medvitz–Farmer/Rancher, Rio Vista, CA • USA****RECONSTRUCTING THE RANCH: SOCIAL AND POLITICAL ASPECTS OF PROTECTING RANGELANDS IN CALIFORNIA****Sally Kirk Fairfax**

College of Natural Resources, University of California, Berkeley, CA • USA

This paper presents protection of ranching in California as reflecting two kinds of external pressure: a “ranching wears a black hat” pressure to regulate ranching’s putative environmentally destructive elements under statutes such as state and federal water pollution control regulations and endangered species protection, and “ranching wears a white hat” pressures to protect the open space values of ranching from urban sprawl. Both pressures represent challenges and opportunities for the ranching community which is divided along several predictable lines: ranch as family heritage, ranch as bank account. This paper will pursue these tensions through pertinent literature and discussion of key current disputes, such as the pending “Woolsey Bill.” It concludes that the durability of ranching as a life style/open space opportunity for ranchers and communities requires considerable adjustment of ranch practices and ownership towards emerging urban expectations for open space and quasi-rural amenities.

**A RANCHER’S EYE VIEW OF ENVIRONMENTAL COLLABORATION ON GRAZING LAND****Richard and Burrows Hamilton**

Hamilton Brothers Ranch, Rio Vista, CA • USA

The Hamilton Family has owned and leased land in the Dixon Range, also known as the Jepson Prairie in California, since the late nineteenth century. Since that time the use of strategic grazing management with sheep has been used to manage undesirable weeds and grasses (yellow star thistle, foxtail, ripgut brome, wild oats) and preserve sensitive vernal pool ecology with an abundance in variety of natural wild flowers and native grasses. In the early 1980’s the Hamiltons leased neighboring land from The Nature Conservancy (TNC) with whom they developed a sheep grazing plan that would achieve the goals of TNC in the preservation of native grasses. More recently this partnership has been continued with California Department of Fish and Game and the Solano County Farmland and Open Space Foundation. This presentation will discuss the nature of the conditions necessary to form and maintain a cooperative relationship between ranchers and public and private agencies in the enhancement of grazing land habitat.

**CALIFORNIA GRAZING LANDS: SCIENCE POLICY AND THE RANCHER****Jack Hanson**

Rancher/AgResource Solutions, Susanville, CA • USA

Rangelands in California are an irreplaceable natural resource. These lands constitute the largest remaining blocks of open space in the state, provide valuable habitat for a diverse population of wildlife and native plants, and provide watershed for a growing population. Many ranchers believe that grazing of domestic livestock in an environmentally responsible and sustainable manner is one the most benign human economic uses of these great expanses. Increasing public awareness of the natural values of rangelands and of the critical part they play in maintaining the quality of life in California has led to increased pressure on those who graze livestock to continue to aggressively seek and adopt the most environmentally responsible method of plying their trade. But livestock production is an economic activity as well as a social and technical one. Economic considerations are an important aspect of applying “the best available science” to rangeland management. This presentation will explore the natural values of the rangeland and range science as perceived by ranchers who apply that science and put these lands to economic use. The discussion will combine science with economics and political science and add in a bit of philosophy, sociology and history.

**RANGELAND AND GRAZING ECOLOGY IN CALIFORNIA****Lynn Huntsinger**

Dept. of Environmental Science, Policy, and Management, University of California, Berkeley, CA • USA

A review of studies of California rangeland grazing ecology provides opportunity to examine some pervasive tales about the relationship between livestock grazing and California’s Mediterranean grasslands. The support or lack thereof for long held assumptions about the pre-contact composition of California’s grasslands and their fate with settlement, the influence of grazing on California rangeland water quality, and the role of grazing systems in the management and restoration of California grasslands is discussed. Some thoughts on the ecology of urban grazing conclude the presentation.

**CALIFORNIA GRAZING LANDS: WHITHER THEY GO?****Albert G. Medvitz**

Farmer/Rancher, Rio Vista, CA • USA

Grazing lands in California are those allocated to the provision of range for domesticated ruminants, most prominently cattle

and sheep. This talk will describe the historic trends of population growth, land use, and agricultural change as they pertain to changing patterns of livestock production and the use of rangelands in California. The ecological characteristics of grazing lands in California not only have changed over time, but also vary dramatically across the climatic and geographical regions of the state. Reference will be made to interactions between livestock production and habitat maintenance and to conflicts and dilemmas surrounding the continuing production of livestock on California lands.

#### PROTECTING BIODIVERSITY ON GRAZED RANGELANDS IN CALIFORNIA

##### **Richard J. Reiner**

The Nature Conservancy, Lassen Foothills Project,  
Red Bluff, CA • USA

Grasslands in the Central Valley originally covered 22 million acres. Most were lost to cultivation and cities with about 1% remaining today. Analysis of California's Coast Ranges, Central Valley, and Sierra Foothill regions by The Nature Conservancy (TNC) indicates that the remaining grasslands are mostly on large, privately owned ranches. Even though they are heavily

infested with non-native species, they contain significant native species, diversity. Grasslands require periodic disturbance from herbivory and fire to remain healthy, and if these natural processes are eliminated native species diversity declines. TNC is developing conservation strategies, such as the purchase of conservation easements, which will prevent large private ranches from being subdivided. In 1998, TNC established easements on over 100 square miles of grasslands. The easements allow the properties to be grazed but include management restrictions that promote native species diversity. Several case studies are examined where grasslands are being protected in conjunction with ongoing livestock operations. At Jepson Prairie, sheep grazing and prescribed fire are used as treatments to reduce weeds and increase native plant species diversity. Medusahead (*Taeniatherum caput-medusae*), a target weed, was completely eliminated for one growing season in a pasture that was burned in early spring 1995. Advances in management practices and conservation strategies improve the chances that California's grassland biodiversity can be protected into the future.

## TS-39

### **Ecosystem Health in Malaysia: A Case Study of the Langat Basin**

**Chair: Nick Lerche—California Regional Primate Research Center, University of California, Davis, CA • USA**

#### POPULATION GROWTH AND ECOSYSTEM HEALTH: THE CASE OF THE LANGAT BASIN

##### **Mohd. Nordin Hj. Hasan** and Rospidah Ghazali

Institute for Environment and Development (LESTARI),  
Universiti Kebangsaan Malaysia, Selangor • MALAYSIA

The rate of population growth in the Langat Basin is at present one of the highest in the country. Estimated to be 3.7% during the period 1970 to 1980, it increased to 4.8% during the following decade (1980 - 1991). The national population growth rate during the period 1980 - 1991 was estimated to be 3.2%. Most of the growth in population in the basin is concentrated in the district of Hulu Langat, where the rate of growth of 3.5% recorded during the 1970s (1970 to 1980), more than doubled to 7.7% during the period 1980 to 1991. The district of Kuala Langat maintained a low rate of growth and two other districts recorded negative population growth. The population in the Basin is projected to reach 1.85 million by the year 2001 when in 1991 it had only 666,129 people. Concomitant with this growth is the rapid growth of urban centres, housing and industrial estates within the Basin. Federal government policies also promoted the rapid development of basic infrastructure such as roads and highways as well as railway links between major urban centres. In addition several "megaprojects" such as the new Kuala Lumpur International Airport, the multimedia super corridor and the new administrative capital of Putra Jaya, is

anticipated to spurn further growth of the population of the Basin. The health of the Langat Basin ecosystem is anticipated to experience further stress in the near future as the impact of the rapid population growth and attendant changes begin to exert their influence on ecosystem resilience. Indications of early failure by the ecosystem in the Basin to sustain the population are outlined and discussed.

#### MANUFACTURING INDUSTRIES AND ECOSYSTEM HEALTH: THE CASE OF THE LANGAT BASIN, MALAYSIA

##### **Ahmad Fariz Mohamed** and Mohd. Nordin Hj. Hasan

Institute for Environment and Development (LESTARI),  
Universiti Kebangsaan Malaysia, Selangor • MALAYSIA

A study was conducted to determine the implications of industrial development in the basin of the Langat River Basin (area: 2937.9 km<sup>2</sup>) on the health of its ecosystem. The study is part of a meso-scale study, which also examined the potential effects of population growth, mineral extraction, forest habitats loss and river water pollution on the health of the Basin ecosystem. Literature on government policies and strategies on the development of industries in the Basin was reviewed and data on capital investments to make the development possible were obtained. The location of

industrial estates was inventorised and mapped according to types, and breaches of environmental regulations by the industries were documented. Data were obtained from Federal, State and Local government agencies, as well as from the Federation of Malaysian Manufacturers (FMM). Results of this study show that there are 30 industrial estates, with a total of 239 factories located within the Basin. Almost 80% of these are located along rivers. Most were concentrated in the middle of the basin area where the infrastructure was well developed and populations densities were high. Most factories (164/239) were located in the district of Hulu Langat and these included almost all the textile, fabrics and button factories, factories producing electrical and electronic appliances, and those producing industrial and engineering products. Capital investments to develop industrial production in the Langat Basin from 1991 to 1998 totaled RM6.4 billion. There has been a gradual decline in the quality of water in the Langat River. The Department of Environment's water quality index for the river declined in value from 73 in 1988, to 58 in 1997 (0-59 highly polluted; 81-100 clean). In 1998 extraction of river water for processing into potable water was disrupted many times because of high levels of harmful pollutants such as ammoniacal nitrogen, and low flows because of an extended drought period. Of the 55 pollution-related court cases heard over the period 1989 to 1995, 13 were on water pollution. Water supply in the Basin was seriously disrupted in the latter half of 1998 and the state government spent more than RM 55 million to provide alternative sources of potable water for the population during the drought. The study suggests that the development of industries in the Langat Basin, did not take into account the necessity to view the Basin as an ecosystem. This has severely impaired the ecosystem's health.

#### GEOHAZARDS: A VITAL COMPONENT TO DIAGNOSE THE HEALTH OF ECOSYSTEMS

Ibrahim Komoo, **J.J. Pereira**, and W.I. Muhiyuddin  
Institute for Environment and Development (LESTARI),  
Universiti Kebangsaan Malaysia, Selangor • MALAYSIA

Geohazards are hazards of geological, hydrological or geomorphological nature, which poses a threat to humans and their activities. Geohazards in the Langat Basin include phenomena such as landslides, erosion, flood and flash floods, which cause surficial changes that contribute to the physical degradation of land, damage to property and threaten human well-being. The concept of ecosystem health is a useful tool to assess the conditions and quality of the land in terms of its ecological, social and economic domains. Geohazards have disrupted the delicate balance of ecosystem health in the Langat Basin. The widespread occurrences of erosion have resulted in siltation of rivers and subsequent deterioration of its water quality. Landslides have threatened the safety of humans, caused damage to property and increased the cost of maintenance of urban areas. Floods and flash floods have damaged property and caused inconvenience due to disruption of traffic and delays.

Clearly, geohazards have threatened the integrity of ecosystem health in the Langat Basin, both within the context of ecology and well being of the community. An assessment of geohazard impacts have been conducted and selected indicators are proposed for an integrated assessment of ecosystem health with respect to geohazards. In addition, the issue of geohazards risk assessment is addressed, within the framework of ecosystem health.

#### RIVER WATER QUALITY ASSESSMENT AND ECOSYSTEM HEALTH: LANGAT RIVER BASIN, SELANGOR, MALAYSIA

M.A. Yusuf<sup>1</sup>, **Mohd. Nordin Hj. Hasan**<sup>1</sup>, and M. Pauzi<sup>2</sup>  
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Selangor • MALAYSIA

Preserving the health of rivers is a major concern in sustainable development. The Langat River Basin is the focus of much recent development. Other than being a major hub of manufacturing in the state of Selangor, several mega-projects such as the new federal government administrative capital of Putra Jaya, the multimedia super corridor (MSC), Cyber Jaya, and the Kuala Lumpur International Airport are all located in the Basin. Rapid development in the Basin threatens the quality in its rivers. Other than its crucial role in the ecology of the Basin, the rivers contribute substantially to industrial, agricultural and potable water supply within the Basin as well as in the highly urbanised Klang Valley. The Basin suffered major fluctuations in water quality and availability during the extreme draught episode of 1998. Accidental spillage and random discharge of pollutants by industries located along the major rivers exacerbated the drops in water quality. The water quality of Langat Basin rivers was monitored for a period of 12 months starting in May 1998 and ending in April 1999. Samples were collected monthly from 14 monitoring stations located along the river and its tributaries. River water was analysed for 28 parameters. The results were compared where possible to values given in the Interim Water Quality Standards for Malaysia (INWQS) with respect to meeting the needs of aquatic life, potable water supply, recreation and irrigation. The Water Quality Index of the DOE was used to classify stretches of the river according to its river classification scheme. Preliminary analyses suggest that the main pollutants in the rivers of the Basin are organic load, sediment, ammoniacal-nitrogen, phosphate-phosphorous, O & G, phenol, Fe, Pb & Cd. All values obtained for these parameters were higher than the INWQS threshold level. More than 10 water quality parameters exceeded the INWQS threshold level for the support the aquatic life. Parts of the Langat River and Batang Nilai River would be classified as Class IV rivers (very highly polluted) while other parts of the river and its tributaries the Semenyih River, Batang Labu River and Labu would fall as Class III (polluted) and Class II (slightly polluted) rivers. The aquatic ecosystem of Langat River Basin is thus generally not very healthy. Any further deterioration of the quality of its river water will adversely affect the ability of the rivers to provide a clean supply water for domestic, industrial, agricultural and other uses as well as to provide vital services necessary to the health of the Basin's ecosystem.

## FOREST AREAS AND WILDLIFE DIVERSITY IN THE LANGAT BASIN: INDICATORS FOR ASSESSING LANGAT BASIN ECOSYSTEM HEALTH

**Saiful Arif Abdullah**

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Universiti Kebangsaan Malaysia, Selangor • MALAYSIA

Forests cover maps in the Langat Basin inventoried by the Forestry Department of Peninsular Malaysia in 1971/72, 1981/82 and 1991/92 were digitised according to forest status (primary and secondary) and types, to examine changes in area, status and types. The diversity of mammals in the Basin and their conservation status were also examined based on data published in the literature, other articles and technical reports. Data on mammals in the Basin were also obtained from records of Department of Wildlife and National Parks (DWNP). Results show that in three decades (1971/72, 1981/82 and 1991/92) the total area under forest in the Langat Basin had been reduced by 27%. In 1991/92 the forested areas represented only 27.6% (803.8 km<sup>2</sup>) of the total land area of the Basin. There are three major forest types in the Langat Basin: dipterocarp, peat swamp and mangrove forests. Between the period of 1971 and 1992 the total area of dipterocarp forests had decline by about 10.9%. During the period, the total area of peat swamp forests had decline by about 62.3% whereas the total area of mangrove forests (approximately 216 km<sup>2</sup>) remained about the same. In five decades (1950 to 1990) a total of 140 species of mammals from 28 families and 11 orders have been reported in the Basin. Of this, 12.1% (17 species) were big mammals and approximately 88% (123 species) were small mammals. The Department of Wildlife and National Parks classified threatened species into five categories; endangered, vulnerable, rare, insufficiently known and intermediate. Based on this classification, 19.3% or 27 species of all mammalian

species reported to occur in the Basin are as threatened. Of the 27 species, 13 are fall into insufficiently known and 10 are classified as rare. Only three species are classified as vulnerable and none into endangered and intermediate categories. Habitat preferences for each species (excluding bats) were classified into 4 categories; forests (primary and tall secondary forests), forest or can survive in plantation, scrubs and garden areas, urban or settled areas and aquatic. Results show that nearly 55% (45 species) of mammalian species (excluding bats) in the Basin are confined to forest areas (primary and secondary tall forests) whereas 24 species (29.3%) live in forest but can survive in plantations, scrubs and garden areas. Only 3 species, house shrew (*Suncus murinus*), polynesian little rat (*Rattus exulens*) and house rat (*Rattus rattus*) are primarily inhabit urban or settled areas whereas another 4 species prefer to live in aquatic habitats such as forest streams, rivers and estuaries of large rivers. Just over a quarter of the land area in the Langat Basin remained under natural forests at the beginning of the present decade, the largest tract being the dipterocarp forests of the Basin's watershed to its northeast. This forest is contiguous with forests of the hinterland of Peninsular Malaysia and halong the Main Range and harbours most of the mammalian wildlife species found in the Peninsular. It is also a critical watershed for the Basin and must be preserved for the health of the Basin ecosystem. Overall mammalian wildlife diversity in the Basin remains high. However, distribution of wildlife is patchy. Much of the lowland peat-swamp forests as well as the coastal mangrove forests have been cleared for development. The peat-swamp forests play a vital role in the hydrological balance of the Basin and coastal mangroves protect the coastline from erosion. The health of the coastal plain ecosystem of the Basin can be severely threatened if these natural forest areas are not conserved.

## TS-40

### Securing Everybody's Quality of Life Within the Means of Nature

**Chair: Richard Norgaard**—Energy and Resources Group, University of California, Berkeley, CA • USA

**FUTURE-FRIENDLINESS IN ACTION: A TOOLKIT TO HELP PREPARE THE QUANTUM LEAP TOWARDS SUSTAINABILITY**

**Mathis Wackernagel**

Redefining Progress, San Francisco, CA • USA

In order to live, people consume what nature offers. So, every one of us has an impact on our planet. This is not bad as long as we don't take more from the Earth than it has to offer. But do we? This is what the "ecological footprint" measures: how much nature we consume. The tool documents how much bio-productive land and water we occupy to produce our resources and to absorb our waste. It shows the area required to support our current lifestyle. At the same time, everybody wants to live well. Is it possible to secure everybody's quality of life within the means of nature? To find out, the "sustainability barometer"

explores peoples' satisfaction with society, their municipality, and their personal life, thereby complementing the ecological footprint which compares human consumption to the biosphere's capacity to regenerate itself. In essence, satisfaction barometer and the ecological footprint cover the socio-economic and the ecological imperatives for sustainability. This contribution explains the "future-friendly" toolkit with these two assessment tools and shows how they can be applied for building and tracking progress towards sustainability.

## ECOLOGICAL FOOTPRINTS OF BENIN, BHUTAN, COSTA RICA, AND THE NETHERLANDS

**Delft P. Van Vuuren**, E. Smeets, and H.A.M de Kruijf  
National Institute of Public Health and the Environment • THE NETHERLANDS

Since the introduction of the concept of ‘sustainable development’, there has been an ongoing search for indicators that could support decision-making in the context of this concept. Institutes in Benin, Bhutan, Costa Rica and the Netherlands have been collaborating on the issue of sustainable development indicators. Over the last years, the Ecological Footprint (EF) has received much attention as a potential sustainable development indicator. In the context of the collaboration, the EF concept has been applied in order to review the EF concept and to get insight in trends in resource use related to consumption over time (in 1980, 1987 and 1994). The results of the assessment are discussed and the experiences are used to discuss the current potential and limitations of the EF as a sustainable development indicator. The originally defined methodology has been slightly adapted: 1) the report focuses on individual components of the EF (land and carbon dioxide emissions) instead of focuses on the aggregated EF and 2) the land use calculations are based on local yields instead of global average yields. Although per capita and total land use highly differs among the four countries, available data suggests increasing land use in all four countries while per capita land use decreases. The EF for carbon dioxide emissions increases for all four countries both per capita and in absolute terms. Differences in productivity, aggregation (of different resources) and multi-functional land use have been shown to be important obstacles in EF application – depending on the assessment objective. However, despite the obstacles, the study concludes that the EF has been successful in providing an interesting basis for discussion on environmental effects of consumption patterns - including those outside the national borders - and for the equity issue concerning resource use.

## QUALITY OF LIFE AND ECOSYSTEM HEALTH: EXPLORING THE CONNECTION

**Alan Ewert**  
Dept. of Recreation and Park Administration,  
Indiana University, Bloomington, IN • USA

At an increasing rate, the public is expressing its concern over the relationship between the ecosystems they are part of, and the quality of their lives. This concern has historically been centered on the impact that humans have on ecosystems. More recently, this concern has shifted to the ecosystem’s effect on human characteristics such as health-related issues and cathartic responses. The purpose of this presentation is to explore the connection between ecosystem health and quality of life issues. For example, does a

damaged or dysfunctional ecosystem (or components of it) provide vectors that serve to impair human health and other quality of life indicators? In another example, does a lack of wildlands and wilderness areas provide a serious defacement of the human condition? In addition to exploring these and related issues, this presentation discusses how direct involvement with a “healthy” natural environment can enhance quality of life perceptions. The presentation concludes with the treatise that ecosystem management is suspect if it fails to include concern for human health and other quality of life issues. Thus, any discussion on ecosystem health must include an allowance for the relationship between the physical and organic ecosystem and the human condition.

## NATURAL CAPITAL DIFFERENTIATION AS A BASIS FOR ENVIRONMENTAL POLICY AND INSTITUTIONS

**Cecilia Collados**  
City and Regional Planning, University of California,  
Berkeley, CA • USA

This model relates the quality of life of a region and the use this region gives to its natural capital. Natural capital contributes to the quality of life of a region in two complementary ways: first, by directly providing environmental services that cannot be imported, and second, by supplying the natural resources that, through a human controlled production process, become valuable to humans. By characterizing natural capital according to its ability to produce life-supporting environmental services, by its substitutability, and by its possible reconstruction, a stricter definition of sustainability is presented, which provides the basis for a sustainable regional development planning model. Institutions act as an interface in the decision process to use natural capital in a market economy. Four points of intersection of the institutional framework with the proposed model have been identified. These are the “environmental policy points”. One of these points is investigated empirically by studying how recently created environmental institutions in Chile recognize different qualities of natural capital, and how this recognition has contributed to the achievement of sustainability. The research compares the Chilean approval process for construction of two dams in the Bio-Bío River. One dam was approved without the new legislation, the other following the new law. The test results indicate that in the Chilean case, the recognition of different kinds of natural capital by the new institutions has been moderate, and that this recognition has shown only a minor effect on the actual use of critical natural capital.



# TS-41 Ecosystem Responses to Recent Environmental Changes

USE OF LONG-TERM FIELD TRIAL AND MONITORING DATA SETS IN FORESTRY TO MODEL ECOSYSTEM RESPONSES TO ENVIRONMENTAL (CLIMATE) CHANGE

**Csaba Matyas**

Institute of Environmental Sciences,  
Faculty of Forestry, University Sopron,  
Sopron • HUNGARY

Replicated common garden tests in forestry offer interesting insights on adaptive strategies of long-lived organisms with regard to long-term changes in environment. Changes in competitive ability can be modelled also from forest health monitoring datasets. Case studies to be dealt with are ponderosa pine forests of the Sierra Nevada in California and Hungarian oak forests close to the aridity limit.

THE IMPACT OF CLIMATE CHANGE ON THE ECOSYSTEMS OF SMALL ISLAND STATES

**William C.G. Burns**

Pacific Institute for Studies in Development,  
Environment and Security, Oakland, CA • USA

The most dire (and earliest) implications of climate change may be visited upon small island nations in the form of inundation of low-lying coastal areas, loss of mangrove and coral ecosystems, a diminution of species diversity and a substantial increase in violent weather events, e.g. hurricane and typhoons. While the spatial coarseness of climate models still precludes definitive conclusions in this context, there is mounting evidence that climate change will have profound, social, economic and environmental impacts on small island nations. This presentation will both assess the current scientific evidence and suggest means for small island nations to cope with climate change in the next century.

MODELING ASSESSMENT OF THE BIOLOGICAL AND ECONOMIC IMPACT OF INCREASES UV RADIATION ON LOBLOLLY PINE IN THE MID-ATLANTIC STATES

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The assessment of the economic impact of an ecological stressor within a geographic region requires knowledge of the distribution of vulnerable “receptors” within the region, determination of appropriate spatial and temporal resolution of the stressor, and information about the exposure/effect relationship. Increases in the surface flux of solar ultraviolet radiation (UV) due to decreasing stratospheric ozone are a stressor for numerous plant species, including the commercially important loblolly pine (*Pinus taeda* L.). Using a 4-digit Hydrologic Unit Code (HUC) spatial resolution framework for the Mid Atlantic states, current estimated UV radiation levels and hypothetically increased levels, were analyzed monthly under a diminishing stratospheric ozone scenario. Broadband and spectral radiative transfer models were used to calculate monthly averages of current and case scenario daytime UV energy, incident at spatially-representative points within the HUC polygons in the region. The extent of species range and biomass of loblolly pine was estimated for the Mid-Atlantic area from U.S. Forest Service Forest Inventory and Analysis data. An empirical exposure/effect function was then applied to approximate biomass reduction and economic impact in this single-stressor perturbation scenario. The economic impact of environmental degradation provides additional justification for stewardship that imposes regulation and increases in operational costs. This study suggests that the productivity of Mid-Atlantic forest ecosystems may be significantly adversely affected by increases in solar UV. Such economic losses must be considered in the cost/benefit analysis of regulations designed to protect stratospheric ozone.





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