The EMAP Symposium on Western Ecological Systems:

Status, Issues, and New Approaches

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EMAP Overview: Objectives, Approaches and Achievements

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Management for the future sustainability and integrity of our ecological resources requires concepts and tools for measuring status and trends in these resources at multiple spatial and temporal scales and multiple levels of biological organization. Key elements of this process are ecologically meaningful indicators and cost-effective monitoring designs. The Environmental Monitoring and Assessment Program (EMAP) strives to develop the scientific capacity to measure the current condition of our environmental resources and assess trends in their condition. These concepts and methods are being developed and adapted for monitoring efforts in different ecoregions of the country. Most recently the EMAP approach has been successfully used by EPA's ORD, Region III and the States of the Mid-Atlantic. We have produced a Landscape Atlas, a State of the Estuaries report, and a State of the Streams report for the Mid-Atlantic region of the US. We are currently moving to the assessment phase in the Mid-Atlantic and adapting the tools and indicators developed for use in the West. In the Western Environmental Monitoring and Assessment Program (WEMAP), we will test our current indicators and technology for applicability in western ecosystems and develop new methodologies for dealing with uniquely western systems. For WEMAP we plan to develop monitoring designs for use by EPA, the states, and the tribes that will allow assessments at each partner's level and will combine to provide regional assessments. We are also initiating a coastal monitoring program in the west with our partners. Subsequently, we will expand this coastal monitoring to the rest of the nations' estuaries. This will form the basis for a National Estuarine Report Card with baseline conditions and trend analyses. I invite all interested parties to participate in these collaborative efforts and partnerships. With your help, we will remove data gaps and allow unequivocal assessment of the health of the nation's resources.

Managing Multiple Competing Objectives for State Water Quality Monitoring Programs

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The Clean Water Act requires states to develop information about the physical, chemical and biological integrity of state waters and to support standards review. The emphasis on environmental indicators and the Government Performance Reporting Act, raise expectations for extensive state monitoring efforts.

The daily water quality management decisions increasingly must be based upon substantial water quality monitoring and assessment data. Presently, the greatest demand for monitoring resources is coming from the TMDL ligation with aggressive time frames. In the past, many management decisions were based as much on policy considerations as on data and analysis. Now such water quality management decisions must be based on detailed monitoring studies.

Each type of monitoring consumes resources and provides information which is not of value for other purposes. For instance, probabilistic monitoring is of little value in answering specific water-body questions. Watershed-based synoptic monitoring is often needed to answer basic questions for UAAs, site-specific standards, and TMDL development. Because of litigation, it is this type of monitoring that dominates the competition for resources in Colorado.

Conducting statewide monitoring to meet the diverse information goals has been difficult and frustrating for Colorado. We recently received special state appropriations for watershed-scale monitoring and to address the emerging TMDL crisis. We have been forced to optimize the use of our remaining monitoring resources to accomplish any other purposes.

Fortunately, there are other agencies and private entities in Colorado conducting monitoring activities. We are establishing a broad-based Water Quality Monitoring Council to form partnerships and coordinate multilateral monitoring efforts.

Keywords: monitoring, water quality management decision making, monitoring plan design

Ecological Management on Indian Lands

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"Indian Country" in the United States encompasses millions of acres that are controlled by over 500 sovereign Indian Tribes. Conditions on reservations range from degraded environments to some of the last pristine areas in the country. Some tribes have aggressively taken control of their resources and have actively managed and protected tribal lands. However, lack of resources has precluded many tribes from taking such action.

The Confederated Salish and Kootenai Tribes of the Flathead Reservation have developed a large and sophisticated database of environmental attributes contained in a Geographic Information System (GIS). Utilizing ARC/INFO software, the Tribes have developed spatial databases that cover a wide array of environmental factors. The Tribal GIS staff uses these thematic layers to perform spatial analyses and create cartographic and tabular outputs.

Information generated from the Tribes' GIS has been used to develop a variety of land-use planning documents and to conduct project-specific environmental analyses. For example, the Tribes have used the GIS database to designate and analyze conditions within twelve Flathead Reservation watersheds, and are currently working on a written assessment of conditions within each watershed. GIS was used to assist in the development of a comprehensive resource management plan and a forest management plan. Other documents in the planning stages include a water quality management plan, a nonpoint source assessment and management plan, and a wetland conservation plan, and these documents will utilize GIS products generated in-house.

Keywords: GIS, watershed assessment, Indian Tribes, ARC/INFO

Saving the Best of the West: Designing and Conserving Networks of Conservation Areas

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Recent assessments have documented large numbers of species and ecosystems at risk in the United States and throughout the world. Past conservation efforts have often focused on listed endangered species, or the ad hoc establishment of parks and nature reserves, resulting in uneven conservation of biodiversity and limited knowledge of what it will take to get the job done. Conservation scientists are now attempting to design networks of complementary reserves with the goal of conserving representative examples of all the biodiversity in the region. These priority-setting efforts are creating an achievable vision of the appropriate scale of conservation. The Nature Conservancy has completed several ecoregional-scale conservation plans. These assessments have resulted in new conservation decisions by TNC and the recent establishment of several large conservation areas.

Keywords: biodiversity conservation, reserve networks, endangered species

Science and the Management of Western Ecosystems

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The western United States is home to numerous diverse and biologically unique ecosystems. From the Olympic Peninsula and the Greater Yellowstone, to the Colorado Plateau, Mojave Desert, and Pacific coastal systems, the American West offers a remarkably diverse biological and physical landscape. Yet all of these systems are facing unprecedented pressures due to population growth, development of the landscape, short-sighted exploitation of resources, and other activities.

The Greater Yellowstone Ecosystem serves as a useful case study of how the pressures of human activities are rapidly changing western ecosystems. Population growth in the twenty counties surrounding Yellowstone and Grand Teton National Parks is among the highest in the nation. Once contiguous habitat is being fragmented by roads, housing developments, and deforestation. Invasive plants and animals are significantly altering the biological composition of the ecosystem. And new pressures are being placed on air and water resources.

Although a wide range of environmental research and monitoring goes on throughout the West, these multidisciplinary efforts are not well integrated, and information on the status and trends of these ecosystems is lacking. In addition, science and resource management are often not closely coupled. Consequently, the public and policy-makers are not as aware as they should be of the stresses on these systems and the long-term implications of the decline in ecosystem integrity for quality of life and economic growth.

Adaptive management programs that closely link science and management offer an opportunity to address natural resource issues more effectively. Strong research and monitoring programs are critical to the success of adaptive management efforts. I will discuss western ecosystems, the stresses that are modifying them, and potential ways to better couple research and monitoring with resources management.

Concurrent Session 1

Overview of Fresh Water Programs and Regional EMAP

Aquatic and Riparian Effectiveness Monitoring for the Northwest Forest Plan

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The Aquatic and Riparian Effectiveness Monitoring Program for the Northwest Forest Plan is presently being developed by an interagency team of scientists and technical staff. It is intended to evaluate how successful the Aquatic Conservation Strategy (the Strategy) is in restoring the ecological health of watersheds and their aquatic ecosystems. It will determine present watershed condition, track trends in this condition over time, and report on the Strategy's effectiveness across the region. A conceptual model provides a framework for indicator selection relevant for describing watershed condition. Indicator information will be evaluated using a decision support system, whose components and relations are developed by provincial expert panels with local knowledge of system functions. The product will be a histogram of watershed conditions defined as a probability of each watershed being in a functional state, and, by tracking individual indicator values and representing them as a function of a reference condition. An initial pilot test of these concepts has been completed and results demonstrate promise with this approach. This program proposal is in preparation for scientific and agency peer review, and once completed, will be presented to agency executives for their consideration.

Keywords: Northwest Forest Plan, aquatic, monitoring, watershed condition, indicators

Assessing the Ecological Condition of Streams and Rivers in Oregon from Probability Survey Data

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To assess the ecological condition of streams and rivers in Oregon, we sampled 146 sites in summer 1997 as part of EPA's EMAP Project. Sample sites were selected using a using a systematic, randomized sample design from the digitized blue-line network on 1:100,000 scale USGS topographic maps. Sample data can thus be used to infer the status of the 60,100 km of accessible flowing stream/river length in Oregon.. Sites were sampled for indicators of fish and macroinvertebrate assemblages, water temperature, physical habitat, bacteria, fish tissue mercury and water quality. We developed protocols for sampling streams and rivers for fish and found that the optimum sampling effort for each was 40 and 80 times the mean wetted channel width. Salmonids were found in 71% of the stream length in Oregon and cutthroat trout and rainbow trout were the most ubiquitous species in the state. Fish indices of biotic integrity developed for the Willamette Valley and coldwater ecoregions of the state suggest widespread degradation in biointegrity. Mercury concentrations in fish tissue of primary species was between 0.002 and 0.1 ug/g at almost all sites with a median concentration of 0.019 ug/g posing a potential threat to piscivorus vertebrates. Bacterial counts were generally low throughout the state (means; total coliforms=132 CFU/100 mL, fecal coliforms=20 CFU/100 mL). Continually recording temperature monitors were placed in 90 of the study sites. In this subpopulation, 48% of the stream length exceeded the state temperature criteria.

Keywords: indicators, temperature, mercury, fish index of biotic integrity, bacteria, river sampling, bioassessment, biomonitoring

Monitoring Aquatic Systems in the Sierra Nevada

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Monitoring has been identified as the critical link for dealing with uncertainty in adaptive management of large geographic areas. The Sierra Nevada Framework is developing the natural resource agenda for the Forest Service in the Sierra Nevada which includes 10 national forests; this activity involves the Pacific Southwest Region and Research Station in conjunction with agency and public partners. The Framework includes development of a strategy for long-term, multiscale monitoring and evaluation of ecosystem conditions. We address the monitoring design for the aquatic component that includes streams, lakes, riparian, and meadow ecosystems. These ecosystems are the most altered and impaired in the Sierra Nevada.

A conceptual model of ecosystem processes was developed around holospheres for atmosphere, lithosphere, hydrosphere, biosphere, and cultural/social. Within each sphere, characterized processes where used to identify potential attributes (indicators) to be measured. Attributes were then prioritized by a set of criteria: response time, direct measure, signal to noise ratio, ability to interpret, and standardized monitoring methodology and available data in the Sierra Nevada. A core set of attributes is being selected with respect to the objectives of an aquatic conservation strategy that focuses on water quality, population viability, structural diversity of plant communities, special habitats, connectivity, watershed condition, patterns of streamflow, sediment regime, stream channel and shoreline physical condition, and floodplain rejuvenation. A limited amount of data on aquatic systems exists for the Sierra Nevada, thus a pilot data collection effort occurred in 1997 to help guide our monitoring design.

Keywords: Sierra Nevada, monitoring, indicators, aquatic ecosystems

Integrated Population and Habitat Monitoring for the Oregon Plan for Salmon and Watersheds

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The Oregon Plan for Salmon and Watersheds (OPSW) is a cooperative effort by State and Federal agencies, landowners, and local organizations to implement salmon recovery, habitat protection, and restoration of watersheds. Hundreds of new and expanded restoration measures have been implemented to support these goals. The OPSW has increased levels of monitoring designed to assess stream habitat conditions, salmon abundance, juvenile salmon production, and water quality at coastwide, salmon Evolutionarily Significant Unit, and river basin scales. Additional monitoring is applied to local assessments and restoration actions, such a water quality management plans. A multi-agency Monitoring Team was established to provide integration of state, federal, and watershed council monitoring activities, develop standardized monitoring protocols for data collection and analysis, and to evaluate overall effectiveness of restoration measures: all organized under a Conceptual Framework that identifies the key monitoring questions and indicators of system performance. Key monitoring activities are linked through an EMAP based rotating panel design that strikes a balance between status evaluation and trend detection. Working with Corvallis EPA/EMAP staff, the Monitoring Team made changes in coho salmon abundance, juvenile salmon distribution and abundance, and stream habitat assessment protocols to link these activities under a common, unbiased, sampling framework. Application of this sampling framework during the 1998 field season has resulted in improved resolution of habitat/salmon population issues. Coho salmon population levels continue to be low coastwide, yet we found significant differences between Gene Conservation Group areas related to differences in ocean productivity. We also found that differences in stream habitat quality between federally managed forest lands and industrial timberlands was slight. Stream habitat quality was significantly lower in areas with mixed timber production and agricultural land uses. These finding will help the OPSW prioritize funding for restoration efforts on these lands.

Keywords: natural resource assessment, salmon, Oregon Plan for Salmon and Watersheds, integrated monitoring designs

Extrapolation from MAIA Surface Water Monitoring to Western Monitoring and Assessment Programs

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The MAIA program is an integrated environmental assessment program being conducted by USEPA, Region III, and USEPA's Office of Research and Development, in partnership with other Federal and State agencies.

Objectives of the MAIA program are to build partnerships and get all stakeholders involved in helping to (1) identify questions needed for assessing major ecological resource areas, such as ground water, surface water, forests, estuaries, wetlands, and landscapes; (2) characterize the health of each resource area, based upon exposure and effect information; (3) identify possible associations with stressors, including landscape attributes, that may explain impaired conditions for both specific resources and the overall ecosystem; (4) target geographic areas and critical resources for protection and restoration; and (5) monitor environmental management progress.

Our experience with partners uncovered certain key principles of effective watershed management. They were (1) agreement on geologic boundaries and or units of assessment; (2) conduct an assessment of their biological condition of resources; (3) target management to real impairment based upon the biological assessments including TMDL, nutrients and habitat restoration; (4) have watershed approach be holistic or segment by segment based upon nature of problem; (5) have five-year rotation to monitoring and to assessments to allow time for change of environment and for progress from management action; (6) buy-in stakeholders so assessment and monitoring plans use all available resources and innovative options; (7) success will be more cost-effective monitoring and management fixes.

Successful State partnering involves early buy in well before products are developed. MAIA's emphasis on aquatic biology and habitat is a departure from the water quality standards/TMDL mentality and requires open dialogue with state biologists who must educate their managers on the importance of habitat preservation and restoration as the new wave of management of their aquatic resources.

An Overview of Region 8's R-EMAP Activities

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EPA Region 8, as part of its Regional Environmental Monitoring and Assessment Program (R-EMAP), has supported two probability surveys using the EMAP design and indicators. State and Federal biomonitoring programs in the Interior West are not well supported or developed, and there are significant data and information gaps. R-EMAP studies provide a valuable opportunity for determining reference conditions, evaluating biological, physical habitat and chemical indicators, and developing multimetric and multivariate tools for assessment of biological integrity and associations with physical and chemical stressors. Results can be used to support multiple EPA programs including biological criteria, monitoring and assessment, 305(b), and evaluating the effectiveness of pollution control, reclamation and restoration activities.

In 1993 through 1995, a R-EMAP probability survey was conducted in headwater streams in the mineral belt of the Southern Rocky Mountains in Colorado. Of concern is the release of heavy metals from abandoned hard-rock mines. Results show that macroinvertebrates are useful for evaluating biological integrity, and that impairment is due to toxic metals as well as physical habitat stressors. The study also supported development of a Rocky Mountain Biotic Index. In 1999 and 2000, a R-EMAP probability survey will be conducted in plains streams in eastern Montana. Of concern are nonpoint source pollution and habitat impairment due to grazing, agriculture, and channelization. This study will support development of reference conditions and multimetric indices. Montana's R-EMAP study will be integrated into the EMAP Western Pilot, as part of Region 8's focus on the Upper Missouri River basin.

Keywords: biomonitoring, reference conditions, multimetric indices, biological integrity, stream survey, Colorado Rocky Mountains, Montana eastern plains

Aquatic Bioassessment in U.S. EPA Region 9

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USEPA Region IX is supporting various bioassessment programs in Arizona, California, Hawaii and Nevada. USEPA Region IX is establishing a REMAP project to assist Arizona with the development of a rotational random monitoring program that will include bioassessment. In Arizona, related biological programs include a regional reference approach for macroinvertebrate bioassessments; ecoregion approach testing and adoption of an alternate regional classification system; and development of warm-water and cold-water indices of biological integrity. The indices are projected to be used in the ADEQ 1999 305(b) water quality assessment report. In California, an Index of Biological Integrity (IBI) has been developed for the Russian River Watershed using resources from the CWA 319 program. A regional IBI is under development for the San Diego area. Resources from the USEPA Biocriteria Program are being used to support the California Aquatic Bioassessment Workgroup (CABW) in conjunction with the California Department of Fish & Game (CDFG), and to support the Hawaii Department of Health (DoH) Bioassessment Program to refine biological metrics. In Nevada, REMAP resources are being used to create a baseline of aquatic information for the Humboldt River watershed. In addition, the REMAP resources are being used to collect aquatic data on the Muddy and Virgin river watersheds in southern Nevada, and the Walker River watershed in the Eastern Sierras. USEPA Region IX is presently working with the Nevada Division of Environmental Protection (NDEP) to establish a Nevada Aquatic Bioassessment Workgroup. Also, reference conditions for the Truckee River in Northern Nevada are being proposed.

Keywords: bioassessment, biocriteria, Index of Biological Integrity (IBI), USEPA Region IX

Ecological Assessment: How EMAP Fits into a State Monitoring Program

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Monitoring and assessment provide the foundation for sound water quality management. An effective management program, that can ensure the beneficial uses of the water are provided and protected, is based upon an accurate understanding of waterbody health conditions. Monitoring programs should provide information on the status and the spatial and temporal trends of waterbody health.

The Oregon Department of Environmental Quality (ODEQ) waterbody monitoring includes habitat and biological as well as the traditional physical and chemical parameters. The ODEQ monitoring program contains many elements, each of which is designed to provide data to answer specific questions. Spatial and temporal scales for monitoring objectives are not always the same. Many monitoring objectives are often specific to a location or activity. One of the primary objectives of ODEQ water monitoring is to be able to determine, on a regional basis, waterbody status and trends. ODEQ has conducted Regional Environmental Monitoring and Assessment Programs (REMAP) projects at the scale of the ecoregion (Coastal) and watershed (Upper Deschutes Basin). These projects have proven very successful in providing information that can be validly extrapolated to describe conditions and levels of impairment at the regional scale. The EMAP probabilistic sampling approach has been adopted by the state as the basis for many of the monitoring programs established under the Oregon Plan for Salmon and Watersheds.

Keywords: monitoring and assessment, beneficial uses, waterbody health, status and trends, REMAP, regional scale, probabilistic sampling, Oregon Plan for Salmon and Watersheds

Concurrent Session 2

Landscape Ecology and Intensive Monitoring Sites

A Landscape Assessment of the Western United States: The EMAP Western Pilot

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The Environmental Monitoring and Assessment Program (EMAP) has initiated a set of pilot studies that will lead to assessments of stream, coastal water, estuary, and landscape conditions across an 11State area of the western United States. The overall goal of the landscape component of this pilot is to conduct a west-wide landscape assessment that evaluates spatial variability in risks to aquatic resource conditions based on landscape conditions. The landscape assessments generated from this project should provide a cost-effective way for environmental managers to target those areas where aquatic resources are at greatest risk from a range of landscape-level stressors. New spatial data, including land cover data being generated by the Multi-Resolution Land Characteristics (MRLC) consortium, permit an unprecedented opportunity to analyze landscape conditions at regional scales. However, numerous technical and logistical issues must be addressed to achieve this broad goal, including the assembly of primary landscape data across the western US, evaluation of existing and new landscape indicators based on their ability to explain variation in aquatic resource variability, and development of multi-indicator assessment protocols. This paper highlights a four-phased approach to resolve key issues and to achieve a western US landscape assessment by the end of 2003.

Keywords: landscape ecology, regional assessments, EMAP, landscape indicators, watershed assessments

Journey into Economic Ecology: An Explorer's Diary

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Economic ecology is an exciting new field that considers human society and the ecological system as a single, integrated unit. The field holds tremendous potential for altering our viewpoint on the interface between humans and ecosystems. The new approach will be exemplified by an analysis of economic impacts of malaria control in tropical agriculture and by an attempt to evaluate the total global goods and services provided by the natural world. Perhaps the most important development in the field deals with the potential for catastrophic, nonlinear change when society is viewed as an interactive component of the ecosystem. This possibility opens new challenges for any program attempting to monitor and assess environmental change. In particular, this viewpoint requires a significantly different approach than used to monitor and assess small, incremental changes under an assumption of stable recovery to an equilibrium condition. The paper will suggest the possible program changes that might be required. The analysis will be based on an analogy with the differences between monitoring and estimating tomorrow's weather and monitoring to estimate the risk of severe storms.

Keywords: economics, catastrophe theory, risk assessment, nonlinear systems

Landscape Variables and the Ranking of Water Quality Condition: Results for a Semi-arid Region of Australia

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Development of sustainable agriculture calls for measurement and predictions about how specific land practices, new innovations or restoration programs affect the underlying ecological resource base. The research needs to be spatially explicit, so that anthropogenic and natural stressors can be related to changes in ecological resources at a range of scales. A means to assess change is to use indicators of landscape or watershed condition. This approach requires good quality spatial data and an understanding of the key ecological processes. Good quality data is the main limitation. The data limitation can be tackled by establishing a relevant minimum set of indicators from readily available data sets to define landscape condition and trends in broad terms (excellent to poor; getting better or worse). Using this knowledge, 'hot-spots' that require more detailed attention can be identified. Available spatial data includes MSS and TM satellite imagery, digital elevation models, and rainfall data. The development of a range of themes, and simple combinations of themes, has allowed us to identify areas prone to erosion, salinization, inappropriate agricultural practices, and sediment movement into rivers and streams. One application demonstrates a strong correlation between landscape indicators (% area forested, forested areas >50ha, road density, riparian zone intactness, % agriculture on steep slopes, hypsometric integral), and measures of stream water quality (electrical conductivity, salt load, species of macroinvertebrates). The second uses the same spatial data set to evaluate the effectiveness of major community based restoration programs aimed at improving landscape condition or stream quality.

Keywords: landscape condition, watershed condition, indicators of condition and trend, macroinvertebrates, sustainability, salinization, effectiveness of restoration programs

Monitoring Australian Rangeland Sites Using Landscape Function Indicators and Robust Ground and Remote Techniques

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In rangelands, monitoring is critical for achieving a balance in production and conservation goals. In savannas of northern Australia, monitoring has detected a tip in the balance to excessive utilization of many rangelands by cattle. This tip was caused by a surge in live cattle exports to Southeast Asia. How big is the imbalance? Will it swing back? Will native rangeland plants and animals recover? Answers require the use of robust and sensitive monitoring techniques. The aim is to know what to monitor, and where and when. To detect changes in rangeland production and conservation caused by impacts of livestock, indicators linking these disturbances to landscape function are needed, that is, attributes which indicate how well landscapes are capturing, concentrating, and utilizing scarce water, nutrient, and organic resources. Field studies in Australia and the USA document that simple vegetation patch and soil surface condition measures can be used as indicators of the 'state of health' of landscape function. For example, field-based grazing gradient studies demonstrate that landscapes with many small, but wide, vegetation patches effectively function to capture runoff water and sediments, whereas landscapes with few patches do not -- they are dysfunctional. The use of ground-based photo-points and aerial videography are proving to be robust and sensitive techniques for monitoring vegetation and soil patches along grazing gradients, especially if monitoring is focused on 'points of inflection'. Ideally, the time to monitor is when there is maximum differentiation in vegetation patches and soils. Annual monitoring is a minimum if both production and conservation goals are to be achieved in the long-term.

Keywords: monitoring techniques, rangelands, savannas, Australia, remote sensing, photo-points, aerial videography, landscape ecology, landscape function, ecological indicators

Development of the Coastal Intensive Site Network (CISNet)

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The U.S. Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), and National Aeronautics and Space Administration (NASA) have joined in partnership to establish pilot sites for the development of a network known as the Coastal Intensive Site Network (CISNet). CISNet is composed of intensive, long-term monitoring and research sites around the U.S. marine and Great Lakes coasts. In this partnership EPA and NOAA are funding research and monitoring programs at pilot sites that utilize ecological indicators and investigate the ecological effects of environmental stressors. NASA is funding research aimed at developing a remote sensing capability that will augment or enhance in situ research and monitoring programs selected by EPA and NOAA under this announcement. CISNet has three objectives: (1) to develop a sound scientific basis for understanding ecological responses to anthropogenic stresses in coastal environments, including the interaction of exposure, environment/climate, and biological/ecological factors in the response, and the spatial and temporal nature of these interactions; (2) to demonstrate the usefulness of a set of intensively monitored sites for examining short-term variability in long-term trend behavior in the relationships between changes in environmental stressors, including anthropogenic and natural stresses, and ecological response; and (3) to provide intensively monitored sites for development and evaluation of indicators of change in coastal systems. A 1998 Announcement of Opportunity (AO) was prepared and competed through EPA's STAR Program. The breadth and scope of the selected projects is outlined in the presentation and can be found on the Internet at *www.epa.gov/ncerqa.*

Keywords: monitoring, Research, CISNet, Environmental Stressors

Index Sites for Understanding and Monitoring Terrestrial Ecological Effects (PRIMEnet); and Forest Ecosystem Indicators: Monitoring, Assessment, and Prediction (FEIMAP)

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PRIMEnet:

The current lack of a national scale monitoring capability for interconnected environmental properties and integrated, location-specific monitoring should be carried out at a network of permanent locations, Index Sites, where a specific suite of abiotic and biotic indicators are routinely measured using standard methods, coupled with appropriate effects research, and used to interpret the results of issue- or resource-specific information collected by inventories, remote sensing, and regional or national surveys. The U.S. EPA and the National Park Service jointly established a network of sites utilizing 14 National Parks (PRIMEnet). The parks represent a range of ecosystems and each have consistent long-term monitoring of climate, air quality, and UV radiation. The sites are available to conduct research and additional site-specific monitoring programs, to establish the status of the environmental resources of the United States, to track the changes in that status over the long term (decades), and to investigate the mechanisms by which these changes occur.

FEIMAP:

Forest Ecosystems' Indicators are needed to assess responses to anthropogenic stressors, detecting and quantifying changes in forest health, linking changes to stressors, and to provide "early warning" measures of loss of Forest Ecosystems integrity and sustainability.

We will be collecting climatic, edaphic, and ecological data from "intensive" field sites and controlled chamber experiments to: a) develop spatial databases on land cover/land use and elevation maps; and b) build and parameterize various site models (e.g. biogeochemical cycling and GAP models) and landscape models (e.g., C, N, and water quality). Initially, data will be collected along an elevation gradient in the western Cascades of Oregon and used to parameterize the MBL-General Ecosystems Model (GEM) which will be used to assess how environmental changes (e.g., temperature, soil moisture) affect biomass production and storage, and cycling of Carbon and Nitrogen. Sensitive "key processes" (e.g., Carbon and Nitrogen cycling in rhizopheres) will also be studied. Other sites in the western Cascade region and in the Olympic National Park (a PRIMEnet "Index Site") will be used to check the performance of the models and candidate Forest Ecosystem Indicators.

Keywords: monitoring, index sites, UV radiation, national parks, forests, indicators, models, stressors, carbon and nitrogen recycling

Application of Ecological Classification and Predictive Vegetation Modeling to Broad-Level Assessments of Ecosystem Health

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Worldwide concern for the conservation and management of intact ecosystems has prompted many international workshops, conferences, and agreements, all intended to develop and refine criteria and indicators for assessing ecosystem health. Many of the indicators of ecosystem health specified by such efforts involve measures of current landscape conditions relative to some pre-established set of natural reference conditions. Ecological classifications of potential and existing vegetation patterns are of particular importance to assessments of ecosystem health for at least two reasons: 1) they provide a useful framework for summarizing resource information from disparate sources, and 2) they can be mapped across large areas by using techniques that integrate remote sensing, geographic information systems, and ecological modeling. In this paper, we describe methods for mapping potential and existing vegetation in rangeland environments based on previous research conducted within a mixed grass prairie ecosystem of western North Dakota, the Little Missouri National Grasslands. We also illustrate how the intersection of these thematic layers can be used to derive indices of rangeland health and resource condition.

Keywords: ecological classification, landscape ecology, rangeland health, remote sensing, GIS

Concurrent Session 3

Western Regional Assessments of Coastal and Estuarine Environmental Quality

Assessment of Benthic Infauna on the Mainland Shelf of Southern California

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Benthic infauna were sampled from 251 Southern California Bight continental shelf sites in the summer of 1994 to assess biological condition of the sediment. Sample sites were selected using a stratified random design, with the primary strata being depth zone, geography, and proximity to point and non-point discharges. Benthic infaunal condition was assessed using the Benthic Response Index (BRI), and by comparing dominant taxa and community parameters (e.g., number of taxa) of the sampling strata most likely to be influenced by point and non-point discharges with those for the SCB as a whole. Ninety-one percent of sediments in the SCB were found to contain healthy benthic communities. Most stations with altered benthos were located near river mouths, in Santa Monica Bay, or on the Palos Verdes Shelf. Deviations from reference condition, where observed, were mostly small and limited to minor changes in species composition, rather than decline in diversity or loss of abundance.

Keywords: benthic infauna, southern California, sediment quality, regional assessment

A Regional Microbiological Survey of the Southern California Bight Shoreline

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A regional microbiological survey of the Southern California Bight (SCB) shoreline, from Point Conception south to Ensenada, Mexico, was conducted during the summer of 1998 by 33 agencies. Water quality status of the SCB shoreline was assessed by calculating the percentage of shoreline-mile-days exceeding bacterial indicator thresholds for total and fecal coliforms, and enterococcus. The SCB was divided into six strata (high and low use sandy beaches, high and low use rocky shoreline, perennial and ephemeral freshwater outlets) where 307 sites were positioned using a stratified random sampling approach. Weekly samples were collected over a 5 week period beginning August 1998, and tested for indicator bacteria using standard methods normally employed by participating labs (multiple tube fermentation, membrane filtration, Colilert® and Enterolert®). All labs and volunteer groups met testing criteria established through intercalibration performance tests, and QC-check samples distributed during the survey.

Nearly 95% of the shoreline-mile days met bacterial water quality thresholds, indicating good water quality throughout the SCB during the sampling period. Usually only a single threshold was exceeded at a site, mainly for Enterococcus. Freshwater outlets (mostly storm drains) had the poorest water quality where 60% of the shoreline-mile days exceeded thresholds, usually for multiple indicators. Mexican beaches had almost ten times as many threshold exceedances compared with those in the U.S., and the magnitude of exceedances tended to be greater. A second survey during the 1999 wet weather period is being conducted.

Keywords: regional survey, recreational waters, bacterial indicators, total and fecal coliforms, enterococcus

Ten Years of Experience with the Puget Sound Ambient Monitoring Program: Results and Status

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The Puget Sound Ambient Monitoring Program (PSAMP) was initiated in 1989 as a multiple-agency, multi-disciplinary program intended to fill existing data gaps and assess the overall health of Puget Sound. Since 1989, PSAMP has characterized water quality problems, sediment contamination and benthic community structures, shellfish health, fish health, changes in selected marine bird and mammal populations and tissue contamination, and nearshore habitat impacts. Based on data from PSAMP and other monitoring programs, Puget Sound appears impacted by declining or depressed populations of many key species, toxic contamination near most urban embayments with evidence of bioaccumulation in fish and other species, nutrient enrichment in many closed or terminal embayments, and extensive shoreline modification from human construction. The PSAMP program has evolved significantly since its inception. Following a major program review in 1995, the program was re-organized around a two-tiered management structure and most monitoring components were better focused on a smaller and more well-defined set of objectives. Sampling designs have been improved to optimize for either temporal or spatial trends, and there has been a continuing effort to improve and expand the integration of PSAMP components with other monitoring efforts.

Keywords: Puget Sound, PSAMP, water quality, sediment contamination, shellfish, fish health

A Tale of Three Bays with Respect to Environmental Monitoring and Wastewater Management: Southern California Bight, San Francisco Bay and Puget Sound

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To be most effective, West Coast EMAP programs should be designed to resolve uncertainties about future alternative and controversial contaminant management actions in the Southern California Bight, San Francisco Bay and Puget Sound. Time series and past monitoring data, including use of dated sediment cores, mussel watch programs and input monitoring data, confirms that pre-treatment and source control programs have been largely responsible for rapidly declining concentrations of chemical contaminants in all three regions during the past 20 to 40 years. The data also indicate treatment strategies that provided no benefit. Taken together, past data lead to EMAP-testable hypotheses on management actions, including unconventional and controversial ones, which will provide the most future benefit.

EMAP should be designed to (1) compare sources, (2) confirm the rates of contaminant decrease and biological recovery, (3) identify the relevant forms of problem contaminants, (4) confirm the appropriateness of specific effluent, water and sediment quality guidelines and (5) place in context the recent decline of fisheries in the face of improved water quality. EMAP design should not be constrained by conventional or current regulations, but address questions such as: Is it possible that Puget Sound harbor seal populations are reproducing at high rates because their PCB loads are not toxic? Why aren't PAH concentrations in Puget Sound shellfish so high despite numerous control actions? Is it really necessary to limit inputs of nutrients and BOD to Pacific coastal waters (can we replace the nutriment removed by overfishing and climate change)? Why can't effluent concentration-based criteria (including toxicity) be replaced, wholesale, with mass loading criteria (thereby relieving penalties for water conservation)? Why can't sludges, biosolids and stormwater runoff can be responsibly discharged to well-flushed coastal waters (thereby reducing threats to watersheds)?

EMAP and other regional assessment programs should raise these kinds of questions in the context of each area's Dynamic Planning Process (National Research Council, 1993). Each program should be designed to test specific action alternatives and produce comparable cross-media information that leads to the optimum path for recovery and protection in each coastal area including its impacted watershed.

Keywords: wastewater management, multi-media environmental problems, environmental management, hypotheses, criteria

Geophysical and Geological Monitoring of Hawaiian Ocean Disposal Sites with Multibeam Sonar and Bottom Sampling

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Geologic mapping using multibeam sonar and bottom sampling provides valuable information and insights into the anthropogenic impacts to urban ocean settings. This is particularly true when these tools are used to monitor the effects of ocean disposal of dredged material. The Hawaiian Islands have five ocean disposal sites that have been acoustically mapped, sampled, and analyzed for contaminants of concern as part of cooperative disposal site monitoring studies conducted by the US Geological Survey, the US Environmental Protection Agency, and the US Army Corps of Engineers. The studies have primarily focused on the seafloor off of Honolulu in Mamala Bay, which has been used as a repository of dredged material for over a century. The results acquired show the effectiveness of high-resolution geologic mapping and integrated assessment for monitoring ocean disposal sites.

High-resolution multibeam sonar was used to collect and produce bathymetric and backscatter images revealing spectacular details of the seafloor in and around the five Hawaiian disposal sites. The multibeam data are accurately georeferenced in real time for precise location of all imaged features, and have a +/- 1-m spatial accuracy and < 1% depth accuracy.

The shaded-relief, backscatter, and perspective-view images of the seafloor clearly show deposits created disposal activities, drowned reef complexes, volcanic features, and bedforms. Bedforms are also visible on bottom photographs, and documents the occurrence of active sediment transport within the disposal sites. The multibeam imagery depicts two principal types of sea-floor material: low-backscatter natural sediment and high backscatter drowned carbonate reefs and dredged-material deposits. The disposal sites appear as isolated, circular to subcircular overprints formed by individual disposal drops. The overprints coalesce to a nearly continuous, high-backscatter blanket over the sites.

Bottom sampling reveals that high-backscatter dredged material is a heterogeneous mixture of cohesive, gray mud that is mixed with particles ranging in size from sand to cobble-sized clasts of reef material. In contrast, low backscatter natural sediment is tan-colored, muddy carbonate sand. Chemical analyses of the dredged material and natural sediment show that generally contaminant levels are low. Relatively higher concentrations of some contaminants exist, but these are not clearly associated with either with dredged material or natural sediment.

Keywords: geologic mapping, ocean disposal site, site monitoring, multibeam sonar, shaded-relief and perspective views, backscatter imagery

Regional Monitoring in San Francisco Bay: Synthesis and Key Issues

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The San Francisco Estuary Regional Monitoring Program (RMP) began in 1993 and is sponsored by 74 local, state, and federal agencies and companies through their discharge or Bay use permits. The RMP focuses on monitoring water, sediment, toxicity, bivalve and fish tissues in the Bay. It also includes pilot studies that test new monitoring components and special studies that focused on understanding relationships among monitoring components, and with estuary processes. Several major environmental issues have been identified: 1) PCBs and mercury are often above water quality criteria and often occur in fish tissues above EPA screening values. Concentrations do not appear to be decreasing suggesting continuing inputs. 2) Aquatic toxicity usually occurs following runoff events that transport contaminants into the Bay. Dissolved pesticides (diazinon and chlorpyrifos) have been identified as a frequent cause, but other contaminants also appear to be important. 3) Sediment toxicity occurs throughout the Bay, and has been related to specific contaminants (chlordanes, PAHs) at some locations. However, mixtures of contaminants are probably most important. The benthos in the Bay are affected by contamination at a few "toxic hot spots", but seasonal changes in freshwater inflows, sediment type, and invasions of exotic species generally have the greatest influence on the benthos at "reference" locations.

Keywords: regional monitoring, water, sediment, tissues, toxicity, benthos, pesticides, mercury, PCB.

U. S. Geological Survey Research in San Francisco Bay and Delta

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The USGS maintains a broad, long-term program of interdisciplinary studies of the San Francisco Bay estuary. These programs (Toxic Substances Hydrology Program, National Research Program, Coastal and Marine Geologic Surveys Program, Federal/State Cooperative Program, Global Change Program) emphasize studies of the processes and rates at which water, sediments, contaminants, and biota interact, and developing conceptual and numerical models of these interactions. USGS studies are directed toward both increasing understanding of fundamental processes and providing new information and insight into current and potential issues pertaining to waste disposal, water flow management, wetland restoration, exotic species, and harbor/channel dredging. The focus of specific ongoing field and modeling studies include atmosphere-watershed connections; water, salt, and sediment transport; bioavailability and effects of trace contaminants (metals and pesticides); biogeochemical processes mediated by microorganisms; rates of sediment and contaminant accumulation; movement and equilibrium of sedimentary features; subsurface navigation hazards; sea level rise; habitat value of managed wetlands; and ecological impacts of exotic species. Many of the studies are carried out in cooperation with, and with funding from other Federal, State, and local agencies. Information about these studies, a bibliography of USGS studies in San Francisco Bay, and access to nearly three decades of USGS measurements of water quality along a 90-mile transect spanning the length of the estuary, are available on the Internet at *http://sfbay.wr.usgs.gov/access*.

Keywords: San Francisco Bay, USGS, interdisciplinary research, water quality, water flow, salt transport, sediment transport, contaminant effects, exotic species, Internet

Interagency Programs in California Central Valley and Delta

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The Interagency Ecological Program (IEP) is a collaboration of three state and six federal agencies conducting monitoring and focused scientific studies in the Sacramento-San Joaquin Delta and San Francisco Bay Estuary. The IEP started in 1961 as a cooperative endeavor between the California Departments of Fish and Game and Water Resources. Historically the function of this program was to investigate the impacts of the State Water Project (SWP) and Federal Central Valley Project (CVP) on the fishery resources in the Sacramento-San Joaquin delta. In 1980 the geographic range was expanded to include the San Pablo, Central and South San Francisco bays. The 1999 IEP Program is comprised of 64 separate elements of which 21 are monitoring and 43 are focused scientific studies with a budget of $14.1 million. Monitoring program elements provide a long term measurements on a variety of currents and tides, water quality, benthic, phytoplankton, zooplankton, macroinvertebrates and fish. Focused scientific studies include 3-D and 2-D hydrodynamic models, investigations into the role and function of shallow water habitat, expanded threatened and endangered species work, evaluation of fish screens and agricultural diversions, continued work with sturgeon and striped bass, and determination of the impacts of exotic species.

Keywords: Sacramento-San Joaquin Delta, San Francisco Bay estuary, monitoring, threatened and endangered species, water project impacts

Near-Border Chemical Monitoring of Sediments in Mexican Waters

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This study probably represents the first concerted effort to look at the complex issues of exchange of chemicals on coastal waters at the Western Mexico-USA border. Its origin, is partially a consequence of the signing by Mexico and the US of the UN Global Program of Action to Protect the Marine Environment from Land-Based Activities. The CEC group has served as catalyst for the application of this program to the NAFTA nations. Our work represents a small part of a program that will be looking at, the health of the Southern California Bight.

The program, including the Mexican part, has utilized a similar set of analytical tools and a coordinated effort. For most parameters, we participated in intercalibration exercises that took place to insure comparability between measurements. At the same time, collection dates for most parameters were done simultaneously.

Our participation includes most chemical pollutants in sediments, such as trace metals, persistent organic pollutants, hydrocarbons and LAB's. It also includes benthic fauna and microbiology monitoring along the coast. The water chemistry was another component of the program, which included mostly CTD measurements and discrete sampling for calibration against other standard methodologies. In this way, a double check procedure according to established reference methods, was insured.

Three strata were selected on Mexican waters. The stratum closer to Tijuana is expected to show the largest pollution problems followed by the Todos Santos Bay strata and a third strata in the middle, is presumed to be pristine due to scattered population centers. Preliminary analysis of the data and comparisons between strata will be presented.

Keywords: Mexican Monitoring program, sediment chemistry, Southern California Bight, persistent organic pollutants, trace metals

Status of Monitoring for Marine Environmental Quality in Alaska

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The Alaska Department of Environmental Conservation's water quality program focuses resources on identifying and restoring impaired coastal waterbodies while protecting marine waters through its permitting process. With almost 36,000 miles of marine coastline, Alaska's subsistence and cash economies are dependent upon the well being of the marine ecosystem. Alaska relies upon partnerships with federal agencies, university programs, private sector resources and state agency coordination to monitor and report data necessary to manage the restoration and protection programs.

Issues affecting the marine environment are raised by communities, development interests, and site-specific monitoring programs through Alaska's Coastal Management Program. The State's university community determines priorities where marine environmental quality issues are integrated into an annual statewide comprehensive marine monitoring plan. The plan focuses coordination of both federal and university resources to conduct the majority of marine environmental data gathering activities. Logistical support is provided by State agencies where a specific interest is served. Supplemental data are gathered through permitted facilities' marine monitoring programs.

Comprehensive regional monitoring is emerging in Alaska. Several distinct marine regions exist, making a single comprehensive marine monitoring program for the state impractical. A more effective approach for marine monitoring in Alaska allows the different regions to develop their own regional programs. Statewide coordination among federal, university, state and local efforts at the regional level provides indicators on the overall health of the marine ecosystem and provides information for regional resource managers. A few regional marine monitoring programs are in place or in the organizational stage.

Keywords: Alaska, marine monitoring, environmental quality, marine ecosystem, protection and restoration

Concurrent Session 4

Mountains and Forest Ecological Systems

Forest Inventory and Analysis: Overview of Activity in the Western Forests and Monitoring Approaches

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The Forest Service's Forest Inventory and Analysis (FIA) program maintains a nation wide inventory of forest lands. The Pacific Resource Inventory Monitoring, and Evaluation (PRIME) program is charged with doing multi-resource forest inventories in the Pacific coast states. The PRIME program covers all lands outside of the National Forest system, with the exception of Alaska, where the program inventories all lands. At present the PRIME program is on about a ten year cycle in California, Oregon, and Washington. Alaska is still completing their first complete cycle.

The inventory utilizes a large primary sample of photo-interpreted points based on a .85 mile grid, and a secondary sample of field visited plots on a 3.5 mile grid. This scale results in about 10,000 field visited plots in California, Oregon, and Washington. Each plot consists of a cluster of four subplots distributed over approximately a hectare of land. The data collected at each site includes tree parameters, coarse woody debris, snags, understory vegetation, and site identifying attributes.

Compilation and analyses of the above data produces forest resource statistics such as amount and distribution of wood volume, change in forest resources, distribution of insects and disease, wildlife habitat information, and estimates of the distribution of coarse woody debris. Future research efforts will include spatial analyses of non-woody forest products, diversity of understory vegetation and it's relation to forest parameters, coarse woody debris estimates for California's oak woodlands, effect of the spruce budworm outbreak on growth and mortality in eastern Oregon, and many other topics.

Keywords: forest inventory, multi-resource, forest statistics

Forest Health Monitoring Program - Conceptual Approach, Analyses, and Reporting on Forest Health

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Forest Health Monitoring is a national program designed to determine the status, changes, and trends in indicators of forest health on an annual basis. The Forest Health Monitoring (FHM) program identifies important forest health and sustainability issues, selects appropriate data from FHM and FIA ground plots and surveys, aerial surveys, and other biotic and abiotic data sources, and develops analytical and reporting approaches to address selected issues. Analyses of forest health is addressed on a national scale and an expanded analyses including socio-economic factors to address the health of forests in the Mid-Atlantic Integrated Assessment. Issues common to both reports include productivity (growth), diversity (ecosystem and species), vitality (air pollution, invasive species, tree condition, storms, biological indicators of key processes, and insects and diseases), and carbon sequestration (tree).

This paper identifies conceptual approaches, analytical methods, and temporal and spatial change of stressors and forest indicators at the spatial scale of Bailey's ecoregion sections. Forest ecosystems in 24 States are stressed to various degrees by urbanization, air pollution, invasive plant species, native and invasive insects and diseases, and climate- and weather-related events. These stressors are more severe in the Northeast and Lake States areas. Some of the forest ecosections in these 24 States are in relatively good health and at relatively low levels of risk due to air pollution, degradation of softwoods or hardwoods, high mortality, or unexpected low growth. There are many other ecosections that show moderate levels of risk due to several factors. Some ecosections in the Northeast, Great Lakes States, and California are at relatively high risk based on the presence of multiple abiotic stressors and biotic indicators of degrading condition. Whether or not there is a causal relationship between these stressors and diminished forest condition is not known at this time.

Keywords: forest vitality, productivity, diversity, Santiago Declaration, criteria and indicators, crown condition, invasive vegetation, forest health, indicators, insects and disease, monitoring, sustainability

The National Park Service Inventory and Monitoring Program

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The National Park Service has initiated a program designed to implement natural resource inventory and monitoring on a programmatic basis throughout the Agency. Program goals are to: 1) complete basic inventory datasets in approximately 260 natural resource parks, and 2) implement a network of experimental monitoring programs to test alternative monitoring strategies at various spatial scales.

Baseline inventories being completed for parks include: natural resource bibliographies, surveys of vascular plants, vertebrates, threatened and endangered species, and other species of management concern, base cartographic information, geology and soils maps, water resource inventories, air quality information, and basic precipitation and meteorological information. A twelfth data set, vegetation maps, is being completed by the U.S. Geological Survey.

Prototype monitoring programs representing 10 major biomes are being implemented to serve as models for other parks. The USGS conducts monitoring R&D activities. Monitoring programs are operational at Channel Islands, Shenandoah, and Great Smoky Mountains National Parks. Other programs are under development at Denali and Virgin Islands National Parks, Cape Cod National Seashore and a cluster of six midwestern prairie parks. Monitoring programs are developed to meet individual park management needs. Therefore, ecosystem components, stressors, and indicators being monitoring vary by park.

Policies, standards, and database applications to store and distribute data to NPS units and cooperators and to catalog and archive data for future access are being implemented. The program will also provide centralized access to protocols.

Keywords: natural resource management, national parks, baseline inventories, long-term ecological monitoring

Assessing the Sustainability of the Forest Resources of Coastal Oregon: The Coastal Landscape Analysis and Modeling Study (CLAMS)

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The development of forest policies to sustain biological diversity while providing for other social and economic values of forests and watersheds is a major challenge for policymakers and managers. In the Pacific Northwest, the conflict over balancing ecological, economic, and social demands on forests paralyzed forest management on federal lands during the late 1980s and early 1990s. It also introduced considerable uncertainty in management of private lands. These controversies led to major new forest policies in the region for federal and state lands and modification of forest policies for private forest lands.

The policies that now exist in western Oregon were put in place without the benefit of simulations of likely landscape condition, outputs, and effects associated with the policies for different ownerships. Rather, they were based on a mixture of intuition and subjective judgment, focusing largely on one ownership at a time, and without the ability to consider explicitly the landscape dynamics caused by forest succession, activities across ownerships and natural disturbance forces, such as fire, floods, and landslides.

We believe that future policy making in western Oregon could be improved by a better understanding of the cumulative implications of these recently established policies across the landscape and considering all owners. Key questions that policymakers might ask include: What level of biodiversity will be provided? What are the likely timber outputs? Where are the major risks? What are the implications of alternative policies? What policies contribute simultaneously to ecological, economic, and social goals?

To help answer these questions, we are currently focusing on coastal Oregon from Coos Bay north to the Washington border, a heavily forested area containing Oregon's most productive forests and streams and a broad mixture of federal, state, and private owners Our work here is part of the Coastal Landscape Analysis and Modeling Study (CLAMS) - a cooperative project of the PNW Station, OSU College of Forestry, and the Oregon State Department of Forestry led by Tom Spies of the PNW Station.

The central policy goal in CLAMS is to develop and evaluate concepts and tools to understand the patterns and dynamics of provincial ecosystems of the Coast Range and to analyze the aggregate ecological, economic, and social implications of the policies of the different landowners there. This objective is primarily being met by working with teams of scientists of different specialties to build and apply dynamic, spatial models that simulate forested landscapes, the condition of fish and wildlife habitat within these landscapes, and the economic and social outcomes and outputs that they will produce.

An Integrated Ecosystem Assessment of the Columbia Basin

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Driven by the need to replace interim direction, address recent species listings as threatened or endangered under the Endangered Species Act, and break the gridlock of implementing actions, the Forest Service and the Bureau of Land Management initiated an effort to develop a scientifically-sound, ecosystem-based strategy for the lands they administer in the Interior Columbia Basin. The effort included an integrated assessment of 145 million acres in seven states describing the Basin's current conditions and risks associated with different management strategies. The assessment provides the foundation for EISs outlining management direction for 72 million acres of FS and BLM administered lands. The process included a framework for ecosystem management, ecosystem component (social, economic, landscape, terrestrial, and aquatic) assessments, and broad-scale estimates of ecological integrity and socioeconomic resiliency.

Twenty percent of the Basin is currently rated as having high ecological integrity and 60% rated low. Whereas 65 percent of the area was rated as having low socioeconomic resiliency, 66 percent of the people live in counties with high socioeconomic resiliency. Humans dramatically impacted the ecosystems within the Basin, but key components for ecosystem restoration remain. Differences within the Basin dictate that a one-size-fits-all approach to management will not be effective. The absence of management will result in substantial changes in resource conditions. While scientific and technical unknowns remain, the greatest obstacle to ecosystem management in the Basin is the lack of agreement about human values.

Keywords: integration, ecological integrity, socioeconomic resiliency, ecosystem assessment, Columbia Basin, ecosystem management

Monitoring Ecosystems in the Sierra Nevada: The Conceptual Model Foundation

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Large-scale monitoring requires a framework for understanding relationships between components and processes of an ecosystem, and the human activities that affect them. We created a conceptual model to serve as such a framework to monitor the integrity of ecosystems on Forest Service lands in the Sierra Nevada mountains of California. The Ecosystem Process Conceptual Model is centered on ecosystem processes, considers humans as part of ecosystems, and directly serves monitoring as an objective, structured, hierarchical tool for selecting biological, physical, and cultural attributes to monitor. The model has three levels: 1) an ecosystem model that identifies 5 spheres (e.g., biosphere), 2) sphere submodels that identify 4 to 8 key ecosystem processes in each sphere that govern material, energy, or information transfer (e.g., photosynthesis), and 3) key process submodels that identify the 'essential elements' that are required for the process to act, the human activities "affectors" that have negative and positive effects on the elements, and the 'consequences' of affectors acting on essential elements. However, a strong conceptual model alone is not enough to avoid the common pitfalls of large-scale monitoring efforts. We discuss the context of adaptive management, where the application of monitoring is specified, including monitoring objectives, resources available for implementation, and decisions to be informed. We promote a balance of status and trend (retrospective) and cause and effect (predictive) monitoring to best meet the information needs of land managers and serve the objectives of adaptive management.

Keywords: large-scale monitoring, ecosystem process conceptual model, adaptive management

Ecosystem Models as Tools in Assessing Mountain Protected Areas

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Mountain ecosystems increasingly are stressed with greater demand for their resources and stronger external forcing factors, including global climate change. Although all ecosystems are challenging to understand, mountain ecosystems have steep environmental gradients and greater levels of ecological heterogeneity than spatially less complex terrain.

We developed an integrated program of ecosystem modeling and extensive field studies to: (1) quantitatively estimate the major ecological processes of northern Rocky Mountain landscapes and (2) examine landscape-level responses to stressors. The ability to predict ecosystem dynamics under future scenarios should support better management of mountain resources.

Our research was focused on Glacier National Park, a 4,078 km^2 wilderness in the northern Rocky Mountains surrounded by national forests and other wildernesses. To model ecosystem processes, we further developed and tested the Regional Hydro-Ecological Simulation System (RHESSys). RHESSys combines remote sensing, ecological modeling, and geographic information system technologies to produce spatially-explicit estimates of various processes such as evapotranspiration and hydrologic outflows. A topographically sensitive routing routine was incorporated to better distribute water dynamically through mountain watersheds. This improved estimates of stream discharge and provided insights into the sensitivity of the model to scaling issues.

FIREBGC, a combined gap-phase succession model and forest biogeochemistry model, estimates stand-level dynamics, accumulated carbon, and tree regeneration, growth and mortality. FIREBGC also explicitly modeled the successional response of the landscape to forest fires. Together, RHESSys and FIREBGC can reasonably predict the structure and composition of mountain forest communities and the daily rates of ecosystem processes at various spatial scales.

Keywords: ecological modeling, forest processes, disturbance regimes, spatial scales, fire ecology, watershed monitoring, global climate change

Modeling Nitrogen Accumulation and Retention in Pacific Northwest Forests

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Observation of increased atmospheric deposition of nitrogen to terrestrial ecosystems and increased nitrogen in streams and estuaries has prompted calls for a better understanding of how nitrogen moves from forested catchments into surface waters to provide a basis for scientifically defensible regulations on anthropogenic nitrogen. The EPA's Western Ecology Division is conducting an integrated field research and modeling program to better understand and predict nitrogen accumulation and retention in forested watersheds of the Pacific Northwest. The field research is being conducted across regional gradients in climate, soil and vegetation and aims to quantify the magnitude and forms (inorganic and organic) of nitrogen loss from catchments in relation to these factors. A process-based model of carbon, nitrogen and water dynamics in terrestrial ecosystems (MBL-GEM) will be used to: 1) provide a synthesis of the empirical data, 2) test hypotheses about the plant and soil processes controlling nitrogen retention, and 3) predict changes in nitrogen retention in response to natural and anthropogenic stressors. Initially the model will be used to address several key questions: What processes control the rate of nitrogen accumulation in soil and vegetation during succession? What is the role of nitrogen fixation as N input, its magnitude relative to atmospheric deposition, and what is its contribution to nitrogen loss to surface waters? How is nitrogen accumulation and retention affected by changes in CO_2, climate and nitrogen deposition? How does the pattern of nitrogen accumulation and retention change under various disturbance regimes or management practices, including nitrogen fertilization?

Monitoring Air Quality in Mountains: Designing an Effective Network

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Measuring air quality in mountains presents special challenges due to topographical complexity and lack of continuity with urban-based analyzers. Therefore, a quantitatively robust yet parsimonious monitoring network in mountainous regions requires special attention to relevant spatial and temporal scales of measurement and inference. Public agencies are interested in collecting air quality in mountains primarily to: (1) determine if some threshold has been exceeded (e.g., for regulatory purposes), and (2) identify temporal trends (e.g., to protect natural resources). The design of monitoring networks should focus on these objectives. A short-term, multi-scale assessment to quantify spatial variability in air quality is a valuable asset in designing a network, in conjunction with an evaluation of existing data and simulation-model output. A recent assessment in Washington quantified spatial variability in tropospheric ozone distribution ranging from a single watershed to the western third of the state. Spatial and temporal coherence in ozone exposure, modified by predictable elevational relationships, extends from urban areas to the crest of the Cascade Range. This suggests that a sparse network of permanent analyzers is sufficient at all spatial scales, with the option of periodic intensive measurements to validate network design. It is imperative that agencies cooperate in the design of monitoring networks in mountainous regions to optimize data collection and financial efficiencies.

Keywords: air pollution, air quality, monitoring network, mountainous regions, multi-scale assessment, spatial and temporal scales, tropospheric ozone

Concurrent Session 5

Statistics and Information Management Issues

Development and Implementation of Integrated Monitoring Designs

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Federal and state organizations have implemented environmental and natural resource inventory and monitoring programs for over fifty years. Historically, the programs were narrowly focused to meet legislative requirements. Typically, monitoring was restricted to a single natural resource, such as forest, agricultural land, large rivers, estuaries, or lakes. Monitoring requirements were narrowly focused, restricting measurements to cover a single topic, such as timber production, water column quality, lake eutrophication, or contaminants in benthic macroinvertebrates. No longer is it acceptable to maintain such a narrow focus. Even if a monitoring program focuses on a single natural resource, multiple ecological endpoints now must be considered in the development of a monitoring design. Ecosystem management approaches are making it imperative to integrate across all natural resources when developing monitoring programs. These changes are leading the monitoring design community to re-think the inventory and monitoring design process. First, increased emphasis is necessary on definitions of the target population and its elements. Second, measurements to address near-term specific assessment questions must be balanced against long-term unanticipated questions, possibly from an ecosystems perspective. Third, advances in survey design theory have enabled inventory and monitoring programs to become more scientifically defensible and efficient. The challenge is to design an inventory and monitoring program that is efficient in the short-term and yet is flexible in the long-term.

Keywords: monitoring programs, survey design, target population, ecosystems management

Integrating Sampling Strategies for Accuracy Assessment of Land Cover Maps with Environmental Monitoring Programs

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Land cover is an important geographic attribute used in many management applications and research problems pertaining to natural resources. Mapping land cover via remotely sensed data is one of the most practical methods for obtaining land-cover information over broad regional scales at relatively frequent time intervals. Assessing the accuracy of the land-cover classifications is necessary to determine the adequacy of the map for a particular user's objectives. Typically accuracy is determined by comparing the classifications provided by the map to the "true" land cover at a sample of ground locations. The cost of obtaining this "reference sample" is often prohibitive. Consequently, integrating accuracy assessment sampling with existing monitoring programs offers a potential cost-savings benefit. The feasibility of incorporating land-cover accuracy assessment into existing monitoring programs is explored focusing on three major components of accuracy assessment: 1) the sampling design used to select the reference sample; 2) the response design used to determine the true land cover at a sample location; and 3) the analysis and estimation procedures used to produce accuracy estimates and accompanying standard errors.

Keywords: fuzzy classification, multiple frame estimation, photointerpretation, probability sampling

Northwest Forest Plan Assessment and Monitoring Framework

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Conflicting issues in the northwest forests surrounding timber harvest and species viability culminated in national attention and the establishment of the Northwest Forest Plan (NFP) in 1994. The plan, based on a scientific assessment, was adopted by the federal agencies and provides a regional management strategy for the over 20 million acres of federal lands within the range of the Northern Spotted Owl. Further the plan incorporates an adaptive management model that includes actions, monitoring, evaluation and change. Among large scale regional initiatives, the NFP implementation is unique with prescriptive standards and guidelines and a requirement for information on a regional scale. A quantitative monitoring approach to the regional population of management actions was required by the NFP. This paper presents the framework developed for the NFP regional monitoring strategy. Monitoring is being conducted to determine compliance with the standards and guidelines (implementation), to establish the status and trends (effectiveness), and to evaluate the cause and effect relationships (validation). The paper presents a summary of experiences in designing and implementing monitoring in an interagency, regional program. Initial successes and issues provide insights into the NFP implementation and the role of monitoring in adaptive management.

Keywords: regional monitoring, implementation monitoring, effectiveness monitoring, validation monitoring, design framework, interagency implementation, adaptive management

Toward a General Inventory and Monitoring Protocol for the USDA Forest Service: Recent Pilot Study for the Northern Region

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Ecosystem health and restoration are essential to the recovery of endangered and threatened species, the wildness of the Northern Region, clean water, and the array of goods and services required by the diverse publics vested in public land management. Through the Northern Region Strategic Ecological System Inventory, Analysis, and Monitoring project, the Inventory and Monitoring Institute provides advice and assistance to re-engineer protocols from past commodity-focused inventories to integrated approaches respecting key ecological principles. The Northern Region of the USDA Forest Service has initiated a pilot project to design and test a defensible database of biogeochemical land base estimates that can be used to periodically assess ecological systems and monitor change in those systems over time. The project scope, activities, and products are described from initial information needs analyses through inventory design for grassland and forest vegetation modules of the inventory. Through knowledge engineering sessions with NETWEAVER software the project team identified over 30 key questions that represent generally needed information that characterizes vegetation in space and through time within the Northern Region. The core data elements were identified and designs have been developed for vegetation mapping using remotely sensed and ancillary data; and a planned field inventory for the pilot area in northern Idaho. Analyses, preliminary findings, and approaches for coordinating this pilot project with national commitments to monitoring for sustainable management of forest resources are presented.

Keywords: inventory, monitoring, ecology, forest, Forest Service, ecological principles, sustainability, sustainable management, forest resources, Montreal Criteria and Indicators

Inventorying Environmental Monitoring Programs for the Mid-Atlantic Integrated Assessment (MAIA)

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To improve understanding of ecological condition in the mid-Atlantic, the U.S. Environmental Protection Agency (EPA/ORD/MAIA) worked with the MAIA federal partners to produce an interactive, spatial inventory of 128 federal environmental data collection activities in the Mid-Atlantic Region. For each program, the inventory displays a map of sampling locations, lists of measurements, and design and administrative information. It also features user-defined queries, resulting in customized maps that satisfy each criteria. The inventory is being used by the MAIA Team to identify data that may be used in ongoing and future ecological assessments in the mid-Atlantic region; to identify existing field data that may be used to interpret and assess the accuracy of satellite imagery (in support of the interagency Multi-Resolution Land Characteristics (MRLC) Consortium); and to identify opportunities for linking large-scale survey information and remote sending data with ecological process research at a network of multi-resource, intensive monitoring sites (in support of the White House Committee on the Environment and Natural Resources (CENR)).The information populating the inventory was collected in personal interviews with federal monitoring program managers, using a survey questionnaire. The questionnaire was developed in consultation with monitoring scientists from multiple agencies and resource backgrounds. The information needs of the White House Committee on the Environment and Natural Resources (CENR) and the interagency Multi-Resolution Land Characteristics (MRLC) Consortium were also incorporated. The questionnaire was designed to be as short as possible, yet convey sufficient detail on data and sampling methodology for a user to determine if any included programs would help to fulfill environmental analysis or assessment needs. The personal interviews ensured that all questions were understood and answered fully.

Keywords: mid-Atlantic, MAIA, inventory; monitoring programs, ecological assessment

Designing Environmental Monitoring Databases for Statistical Analyses

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Databases designed for statistical analyses have characteristics that distinguish them from databases intended for general use. EMAP uses a probabilistic sampling design to collect data to produce statistical assessments of environmental conditions. In addition to supporting the statistical analyses, these data are later made publicly available as summary databases on the EMAP web site for a general audience. As do writers, database designers should target the expected audience. Analytical databases designed to support statistical analyses usually have restricted scope: in time, in geographic extent, and especially in data types and contents, often limited to a particular scientific discipline. Primary users may be the same people who designed the study, who are familiar with both the methods and the data, and who do not need robust metadata, which are so essential for general purpose databases. Built-in interface, viewing, and analysis tools may not be needed if the data are loaded to software packages that include these things. Often the analytical database is designed in more of a horizontal than a vertical format to ease loading to statistical analysis software packages. These databases may include information on the statistical design such as the inclusion probability of given data points. All replicates and other data used to estimate sample variance are included. The analytical database may be a subset of study data and data from other sources. These design issues are illustrated using an analytical database for estuaries that supports environmental assessments in a broad region such as the EMAP Western Geographic Study.

Keywords: information management, database design, statistical analyses

Concurrent Session 6

Great Plains and Ecological Systems

Linking Assessments of Rangeland Ecosystem Health to Management Decisions

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Rangeland Health is the foremost issue in the management of rangelands. While the application of technology to measure biophysical attributes of ecosystems has advanced greatly in the past two decades, our ability to synthesize and, most importantly, put information into a decision-making context has not kept pace. Although we possess a variety of techniques for collecting, organizing and classifying biophysical information at a variety of scales to make inferences about ecosystem health, we remain at a loss to measure or communicate information about rangeland health or to respond with changes in management.

First, we lack a robust definition of rangeland health that includes humans. There is a need to differentiate among values (the qualities which stakeholders consider worthwhile), criteria (the assessment endpoints which provide dimensions for values) and indicators (things that can be measured) to improve the process of rangeland ecosystem health. Expanding our views of rangeland ecosystem health beyond the biophysical into the interactions of humans and their environment remains a large challenge, both conceptually and practically. Secondly, we are still relatively ill-equipped to measure the driving forces of rangeland ecosystems at real world scales. To date, most assessments are the result of extrapolation of point data by agglomeration and fail to account for the large-scale nature of rangeland ecosystems. Integrating principles of landscape ecology can contribute significantly to our assessments. Finally, we have poorly developed links between assessment information and response decisions at local, regional and national scales. Better general models of rangeland ecosystem dynamics (including humans) can help improve the quality of decisions.

In Search of a Workable Assessment Strategy

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The mission of the Bureau of Land Management is to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations. In practice, this requires a "workable" strategy for determining existing health and for tracking changes that occur over time. So, what makes for a "workable" strategy?

There are three essential characteristics to any such strategy-it must be relevant, it must be affordable, and it must be credible. A relevant strategy is one that provides answers to the pertinent questions routinely faced by public land managers. An affordable strategy is one that can be maintained through normal fluctuations in staffing and funding. A credible strategy is defensible on scientific grounds as well as understandable to the general public.

Keywords: natural resources assessment, public land management, environmental health, environmental indicators, environmental monitoring

Modeling Hydrologic Response to Landscape Change in Semi-Arid Regions

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Arid and semi-arid regions constitute a large part of the western United States. These regions are characterized by larger relative extremes in components of the hydrologic cycle than in humid climates. They include: 1) low annual precipitation but high-intensity storms with significant spatial variability, 2) high evaporation potential, 3) low annual runoff but short-term high volume runoff, and 4) runoff losses in ephemeral channels. Moreover, these regions are especially prone to erosion. Hydrologic models must be able to account for these factors if they are to be used to assess the impacts of landscape change on hydrologic response.

A review of hydrologic models was conducted to assess their applicability to model runoff and erosion response for semi-arid regions undergoing landscape change over a wide range of basin scales. The landscape change data to be employed is a ten class land cover system derived from Landsat imagery over a 20 year time span (Kepner et al., this meeting). Based on this review two models (SWAT and KINEROS), applicable for different ranges of time and space scales, were selected for further analysis. A critical issue that must be addressed to utilize the NALC derived data is the estimation of hydrologic and erosion model parameters from the land cover classes. This issue and the relative sensitivity of the models to land cover change for an example in southeastern Arizona will be presented. Future directions and additional challenges for multi-scale assessment of hydrologic impacts of landscape change on western rangelands will also be discussed.

Keywords: hydrologic modeling, runoff, erosion, semi-arid regions, landscape change, multi-scale process models

Assessing Amphibian Metapopulation Status in Arid Environments

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Amphibians are common denizens of aquatic habitats throughout the arid West, and changes in amphibian populations or communities may reflect ecosystem changes in either the aquatic or terrestrial environment. However, like many organisms, amphibians are often thought to have a metapopulation structure, with large fluctuations in numbers and presence/absence at individual sites. Consequently, monitoring of individual populations may provide a limited picture of the long-term prospects for a species' persistence in an area.

Monitoring metapopulations, rather than individual populations, may present simplifications as well as challenges. For example, the determination of a species' presence/absence (patch occupancy), rather than population size, may be adequate to detect changes in status of a metapopulation in an area, but knowledge will be needed for relationships between such factors as patch size, isolation, and quality relative to patch occupancy. As an example, we have investigated such relationships for a common toad *Bufo punctatus* inhabiting small wetland patches in the Mojave Desert that are highly dispersed due to climatic drying. One hundred forty-seven potential habitat patches (primarily springs) were identified and surveyed for habitat characteristics and occupancy by the species. Metrics for patch size were developed based on extent of water and riparian vegetation, and patch isolation metrics were based on inter-site distances via networks of connecting drainage channels. Preliminary analyses indicate that metrics for patch isolation are inversely related to patch occupancy, whereas metrics for patch size are not. These findings support the notion that amphibian monitoring programs should include isolated as well as highly-connected sites.

Keywords: amphibian, *Bufo punctatus*, habitat fragmentation, metapopulation, monitoring, patch isolation, patch occupancy

New Approaches for Sampling and Modeling Native and Exotic Species

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We demonstrate new multi-phase, multi-scale approaches for sampling and modeling native and exotic plant species at local, regional, and national scales. The primary attributes of the design include: working as an interdisciplinary team, multi-phase data from satellite imagery and aerial photography, stratified random sampling in common and rare habitat types, unbiased survey locations, use of expert taxonomists, and automated data management. There are three main steps in this approach. First, we tested and refined new multi-phase, multi-scale vegetation sampling techniques to identify hot spots of diversity, important rare habitats, and for the early detection of invasive plant species. Second, we developed a suite of predictive modeling tools to: (1) rapidly assess current patterns of native and exotic species;
(2) determine which habitats, communities, and ecosystems are most vulnerable to invasion by exotic species; and (3) predict the spread and potential effects of invasive species. Finally, we advanced information management, data sharing, and outreach capabilities using new technology. The techniques are being applied in the Central Grasslands, Rocky Mountains, and Colorado Plateau, primarily on Department of Interior lands, and on USDA Forest Service lands as part of the Forest Health Monitoring Program. The methods also have been adopted by the Smithsonian Institution's Biodiversity Program, Parks Canada, and others. This approach also has been used to assess the impacts of grazing and fire on public lands, and to assess butterfly (pollinator) and bird diversity.

Keywords: multi-scale sampling, exotic invasive species, predictive spatial modeling, integrated approaches to environmental assessments

Assessing and Monitoring the Health of Western Rangeland Watersheds

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The most important function of watersheds in the western U. S. is the capacity of the watersheds to retain soil and water thereby providing stability in hydrologic head and minimizing stream sediment loads. Long-term soil and water retention varies directly with cover and life history characteristics of vegetation. Data on cover and species composition were collected on 129 sites in an area of the Rio Grande drainage of south-central New Mexico previously assessed by classification of AVHRR imagery. Previous research showed that an index of unvegetated soil (bare patch size and percent of ground without vegetative cover) was the most robust indicator of the soil and water retention function. At sites with less than 25% grass cover and on sites with more than 15% shrub cover there were significant relationships between percent bare soil and mean bare patch size ($p < 0.05$). Several other indicators of ecosystem health were related to mean bare patch size: perennial plant species richness $r = 0.6$, $p < 0.0001$), percent cover of increaser species $r = 0.5$, $p < 0.0001$) and percent cover of forage useable by livestock $r = 0.62$, $p < 0.0001$). There was no relationship between bare patch size and cover of species that are toxic to livestock. In order to assess the ability of western rangeland watersheds to retain soil and water using remote sensing it will be necessary to detect and estimate sizes of bare patches ranging between at least 0.5 meters in diameter to several meters in diameter.

Keywords: oil and water retention, bare patch size, percent bare soil, grass, shrub, remote sensing

Concurrent Session 7

Pacific Coastal and Outer Continental Shelf Assessments: Implications for Management

Monitoring in NOAA's Research Reserves and Marine Sanctuaries

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Resource monitoring in NOAA's Estuarine Research Reserves and National Marine Sanctuaries supports protected area management, specifically with respect to balancing coastal and ocean use and long-term resource protection. The programs track the effects of natural and anthropogenic stressors, trends in environmental condition indicators, and the efficacy of management actions.

Research Reserves initiated a tripartite national monitoring program that will include abiotic, habitat and landuse change elements. The goal is to characterize temporal and spatial variability and document estuarine changes. In 1996, water quality monitoring began at 22 Reserves using automated dataloggers measuring temperature, salinity, dissolved oxygen, pH and depth at 30 minute intervals. In 1999, continuous chlorophyll-a flourescent measurements will be piloted, with large-scale habitat mapping activities planned for 2000 and 2001. All of these activities will be integrated locally, regionally and nationally using a geographic information database system.

Monitoring in the five west coast marine sanctuaries generally serves site specific needs and is not currently intended to be regional or national in scope. Design elements common among most of the sanctuaries, however, include evaluation of water quality and marine mammals, the use of volunteers in data acquisition, and cooperative partnerships with local and state governmental agencies or academia. Other monitoring elements at specific sites include sediment contamination and toxicity, phytoplankton, seabirds, benthic flora and fauna, fish censuses, beachcast organisms, spill reporting, and vessel traffic. Planned future efforts include development of regional and national aspects of monitoring among all 12 of the national marine sanctuaries, standardized measurement of a few specific, relevant parameters (e.g., temperature, productivity), and increased quality of data and information management.

Keywords: environmental monitoring, estuarine research reserves, marine sanctuaries

The Minerals Management Service's Environmental Studies Program: Perspectives on the Silver Anniversary in the Pacific Region

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The Minerals Management Service Environmental Studies Program started in 1973 with the goal of providing scientific information needed for Federal offshore oil and gas leasing, exploration, and development decisions. The program in the Pacific OCS Region, extending from the United States - Canada border in the north to the United States - Mexico border in the south, has supported research in diverse disciplines from air quality studies to social sciences. More than 150 research efforts have been supported and a rich set of information has been made available about ocean resources and processes. The program has evolved and today is focused in southern California in an area of active offshore oil and gas production. This paper describes some of the pioneering research supported and unique data generated during the past 25 years, much of which is not likely to be duplicated, and suggests areas for future needed research in the coastal marine environment.

Keywords: physical oceanography, marine ecology, monitoring, marine mammals, seabirds

Mapping and Evaluating Changing Sediment Contamination Conditions: Los Angeles Margin, California

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We performed assessments of two offshore areas near greater Los Angeles to understand the distribution and character of contaminated sediment and to predict the natural recovery of the sediment from contamination. The first study determined that a 9-million-cubic-meter body of effluent-affected sediment exists on the margin south of the Palos Verdes Peninsula, and that virtually the entire deposit is contaminated with DDT and PCBs. Environmental monitoring and sediment transport modeling showed that, if no remediation actions are taken, contamination levels in this body will remain near their present values well into the next century.

The second study is within Santa Monica Bay, a body of water to the west of Los Angeles that receives surface runoff, sewage, and industrial drainage. Recent surveys have shown that more than 95% of the area in the Bay has contaminants at concentrations exceeding the threshold at which biological effects begin to occur. In collaboration with local agencies, we are investigating how levels of contamination have changed over the period during which Los Angeles has been industrialized (approx. 1900 to the present). We obtained a set of 26 box core samples at station locations defined using a stratified, random design. We dated sediment samples using short-half life radioisotopes (^{210}Pb) to define five time lines extending back over the last 100 years. We then tested sediment from each of these time lines for a variety of contaminants. Analysis of these data show that, although surface sediment in the bay is still contaminated, contamination levels in the past (1970s and 1980s) were even greater. Overall, conditions of sediment contamination in the Bay are improving. In addition to our mapping work, sediment data are being combined with currents and bottom boundary layer information to better understand patterns and rates of sediment and contaminant transport in the Bay.

Keywords: Palos Verdes Peninsula, Santa Monica Bay, continental margin, sediment contamination, environmental monitoring, sediment transport modeling, natural recovery, ^{210}Pb age dating

NOAA's National Status and Trends (NS&T) Program's Sediment Quality Assessments

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As part of its monitoring program for marine environmental quality, NOAA conducts regional surveys in selected bays and estuaries of the U.S. Sediment quality assessments in which analyses of chemical contamination, toxicity, and benthic community alterations are performed, are major components of these surveys. During 1991 through 1997, sediment quality assessments were completed in 25 areas, including estuaries and bays of the Atlantic, Gulf of Mexico, and Pacific coasts. Along the Pacific coast, surveys were conducted in cooperation with the states of California and Washington. One of the major objectives of the surveys is to estimate the spatial (or surficial) extent of chemical contamination and toxicity as measures of the severity of contamination problems in sediments. Several toxicity tests are performed on samples to provide a suite of acute and sublethal endpoints. Samples are collected at randomly-chosen stations within selected strata. In a nationwide compilation of data, approximately 6% of the area sampled was toxic in acute toxicity tests performed with adult amphipods. However, toxicity was much more pervasive in the northeastern estuaries (38%) and southern California bays (35%) than in the southeast (3%) and Puget Sound (0%) in these tests. Data from NOAA's surveys agree very well with those from EMAP surveys of some of the same regions.

Keywords: sediment contamination, toxicity, environmental quality, benthic effects, sediment quality guidelines

Recommendations for the Use of Fish in Coastal Surveys

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The National Benthic Surveillance Project was a large scale, long term monitoring effort which examined fish health in the nearshore coastal areas of the United States. More than 75 sites were included in the sampling design, along the West, East, and Gulf coasts of the United States. The aim of this work was to quantitatively determine the linkages between chemical contaminants in surficial sediments and toxicopathic diseases in benthic fish. The results of this large scale monitoring project showed that there are consistent chemical risk factors associated with the development of hepatic diseases in feral fish, and most notable was the association between levels of polycyclic aromatic hydrocarbons and the presence of necrotic, preneoplastic, and neoplastic lesions. Moreover, subsequent analyses of these large data sets are showing that it is possible to determine threshold levels of contamination, above which there are increasing prevalences of disease, and below which there is no apparent increase in disease prevalences. The threshold levels determined by these "real world" data are generally substantially lower than existing sediment quality criteria. These studies demonstrate the utility of large, consistent datasets for establishing indicators of habitat quality. Additional endpoints which can be utilized in coastal monitoring of fish health include, reproduction, growth, and disease resistance. This presentation will highlight the advantages of using fish species, and indicators of health in these commercially important resources, in current and future monitoring efforts. Moreover, with more marine and anadromous fish stocks proposed for listing under the Endangered Species Act, monitoring of the health of these resources takes on added significance.

Keywords: monitoring, fish, chemical contaminants, polycyclic aromatic hydrocarbons, cancer, reproduction, growth, disease resistance, sediment quality, habitat

CalCOFI: Lessons from a 50-year Time Series

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The California Cooperative Oceanographic Fisheries Investigations (CalCOFI) program has conducted fishery-oceanography surveys in the coastal waters of California since 1949. The present survey plan includes quarterly sampling at 66 stations in a 94,000 square mile grid extending from the US-Mexico boarder to Pt. Conception and out 360 miles. The CalCOFI time series is a valuable resource for detecting and understanding change in environmental structure. The existence of some such baseline is essential for detecting trends and for separating anthropogenic change from natural variability. The dominant trends seen in the 50-year CalCOFI time series are on meso and large spatial scales (tens to thousands of kilometers) and low-frequency (interannual to decadal). Trends in biological structure are strongly correlated with trends in physical structure. This suggests that the major changes in ecosystem structure are caused by large-scale fluctuations in the physical structure of the environment. The fraction of these trends which can be attributed to natural cycles (which will presumably reverse) and to anthropogenic global change (which may not reverse on the same time scales) remains an important open question. Evaluating large-scale and long-term trends is important for understanding local and regional environmental processes because they can only be evaluated when the long-term trends are accounted for. It is also important to learn whether the lessons learned from studies of the more offshore waters of the California Current apply to the inshore region and the land-ocean interface where environmental stresses are greater.

Keywords: Plankton, California Current, climate change, time-series, CalCOFI

Collaborative Data Gathering: the Southern California Wetlands Inventory

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The California State Coastal Conservancy in collaboration with the California Coastal Commission and U.S. Fish and Wildlife Service developed a database of maps and texts summarizing recent data on biological and physical conditions at 41 of Southern California's coastal wetlands. The Southern California Coastal Wetlands Inventory was designed with guidance from local resource managers to be a widely accessible tool for wetlands conservation planning in the region. For each of the 41 sites, the Inventory includes a map depicting the historical extent of wetlands and a map showing recent distributions of habitat type. The inventory also includes data for each site on current and historic land use, watershed hydrology, water quality, soils, wetland habitats, threatened and endangered species, restoration and enhancement activities, and annotated bibliography. The data is stored in a relational database that allows users to perform detailed searches. As the next step, the Coastal Conservancy and the Southern California Wetlands Clearinghouse plan to set-up a system whereby local agencies and conservancy groups will take responsibility for keeping the inventory data up-to-date for their local wetland.

Keywords: wetlands planning, wetlands restoration, natural resource data management, Southern California Wetlands Clearinghouse

The Impact of Land Use on Stormwater Quality in a Large Urban Watershed

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The Santa Monica Watershed is 1072 km^2 and is largely urbanized, serving more than 10 million people in the greater Los Angeles area. The Ballona Creek watershed, is one of the two largest subwatersheds, and is the most urbanized. It drains western Los Angeles from near shore areas to downtown. The discharge from Ballona Creek have been implicated in major problems, such as chronic aquatic toxicity, accumulation of hazardous sediments at the creek mouth and large discharges of trash.

The author and his research team have developed GIS-based models that estimate stormwater quality as a function of land use and rainfall rates. These models have been calibrated for several rainfall events on Ballona creek and generally predict total mass emissions within 50%. These models have been used to determine the impacts of changes in land use, such as conversion of open land to commercial or residential, and application of best management practices (BMP). The model has also been used to find high opportunity sites for BMP application and to compare the emission rates of stormwater to point sources, such as the Hyperion Treatment Plant.

This presentation will show the results of various simulations to show the impacts of growth, BMP application, and the need to concentrate on stormwater discharges, as opposed to further improvement (post secondary treatment) of wastewaters.

Keywords: stormwater, GIS, modeling, landuse, Los Angeles

Human and Ecological Impacts of Contaminants in the U.S. Arctic

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Recent reports have exacerbated concerns about the extent and adverse effects of anthropogenic contamination in the US Arctic. Many Alaskan natives are apprehensive about the quality of their traditional food resources and the health of the ecosystems on which they rely for subsistence.

Activities of anthropogenic radionuclides in the sediment and biota are very low. Consumption of caribou meat adds a very small radiation dose (0.0045 mSv) to the average annual dose received from natural, background radiation and other sources (3.6 mSv). Consumption of subsistence foods derived from marine food chains produces a much smaller, nearly negligible, radiation dose. Global fallout appears to be the only significant source of radionuclides.

Considerable scientific data exist for assessing environmental impacts of petroleum exploration and development. Information products, such as oil spill trajectory models and coastal sensitivity indices, are available to determine the relative vulnerability of shorelines and biota. Levels of polycyclic aromatic hydrocarbons (PAHs) in the environment and biota are generally low but vary considerably. The sum of resolved PAHs in the Beaufort Sea sediment is usually an order of magnitude higher than in the Chukchi or eastern Bering sea. Such high levels may be attributed to different sources, such as peat from eroded coastlines, and inland oil seeps.

Data on other groups of contaminants, such as pesticides, and UV-radiation are few and not adequate to describe regional or temporal patterns. The presence of certain metals, notably cadmium, in food chains leading to high tissue burdens in marine birds and mammals may be an important ecological issue in the region.

Keywords: arctic, radionuclides, contaminants, polycylic aromatic hydrocarbons, cadmium, ultraviolet radiation

Assessment of Risk to Human Health from Chemical Contaminants in California Coastal Fishes

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Human health risk assessment of chemical contaminants in coastal fishes usually requires studies designed to provide site-specific data relevant for risk assessment. A matrix of factors (i.e., catch statistics, site data) should be considered to identify sites and fish species for sampling and analysis. Identification of target populations may aid study design by indicating high use sites and/or preferred fish species. A few localized studies have been conducted in California coastal fishes (Monterey Bay, LA area, SF Bay) and in some cases fish consumption advisories have been issued based on risk assessment. To date, DDTs, PCBs, and methylmercury have been present at levels of health concern in some areas.

Once an adequate database of contaminants in fish is established for an area, advisory tissue concentrations for chemicals of concern can guide development of focused monitoring of target and/or indicator species. Such an approach was used to design the comprehensive monitoring plan for the Santa Monica Bay Restoration Project. Actual fish tissue levels of DDTs and PCBs and advisory tissue concentrations were utilized to guide sampling design.

The recently initiated Coastal Fish Contaminant Study is focused on obtaining contaminant data on coastal fishes for health assessment. These data will greatly expand the current database on contaminants in coastal fish and is critical in guiding the development of effective risk management and risk communication actions as well as establishing the effectiveness of control actions (e.g., mitigation). The results can also guide development of a monitoring plan as described for Santa Monica Bay.

Keywords: human health risk assessment, fish consumption advisories, advisory tissue concentrations, monitoring study design, DDTs, PCBs, Santa Monica Bay Restoration Project

Concurrent Session 8

Development and Application of Ecological Indicators for the Western Ecological Systems

Application of Indicators in Ecological Risk Assessment

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One of the stated goals of the Environmental Monitoring and Assessment Program (EMAP) is to support ecological risk assessment (ERA). This paper will discuss the needs of ERA and the ways in which the indicators generated by EMAP and similar monitoring programs may meet those needs. ERAs provide support for decision making under uncertainty, while EMAPs primary goal has been to elucidate status and trends in environmental condition. ERAs address ongoing or future effects on valued environmental properties termed assessment endpoints. EMAP presents changes in indicators. Indicators, by definition, are not the valued properties themselves but rather indicate that something else may have changed. The thing that is indicated is often vaguely defined and its importance to decision making is unclear. The lack of linkage to assessment endpoints results in part from EMAP's concern with identifying indicators that lend themselves to long-term regional monitoring and in part from the lack of policy guidance concerning what specific environmental properties are worth protecting. ERA is also characterized by a concern for establishing the level of exposure and the relationship of exposure to response so that effects can be estimated or causes can be identified. EMAP has been concerned with identifying potential causal relationships through correlations of indicators, but the results are more suggestive than conclusionary. As a result, they support retrospective hazard identification rather than predictive or retrospective risk assessment. Ways to bridge these and other gaps between EMAP and ERA will be discussed.

Keywords: risk assessment, indicators, endpoints, EMAP

Attaining Environmental Goals: Biological Monitoring and Assessment in Theory and Practice

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Models guide work in basic and applied ecology, including efforts to protect environmental quality. Models—whether conceptual, physical, or mathematical—can be wrong when they focus on inappropriate endpoints (number of permits issued) or when they fail to incorporate critical parts or processes within living systems. Fiscal and environmental resources are wasted when models or theories are used without adequate testing to guide public policy. Too often the demand for theoretical models leads us to ignore biological common sense; too often scientists and managers focus on statistical significance rather than magnitude of effect and its biological meaning.

By examining the behavior of specific attributes of living systems (taxonomic composition, trophic structure, health of individuals) along disturbance gradients, we can improve our understanding of the responses of living systems to human activities. Ambient biological monitoring focuses our attention on the most integrative endpoint (biological condition) and allows us to assess the extent to which our policies protect ecological health. Biological monitoring has evolved rapidly during the twentieth century as knowledge has changed, and human-imposed stresses have become more complex and pervasive. Multimetric biological indexes (e.g., index of biological integrity: IBI) integrate experience and knowledge derived from earlier monitoring approaches. Development of effective multimetric indexes involves five major activities: (1) classify sites to define homogeneous sets; (2) select reliable and relevant signals about the biological effects of human activities; (3) develop sampling protocols to measure those signals; (4) define analytical procedures to extract and understand relevant patterns; and (5) communicate the results to citizens and policymakers.

Critical 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. They may also be used to compare different indicators proposed for a similar purpose. Deficiencies found during evaluation of an indicator can be used to identify areas for further research. 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 of an indicator. 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. The guidelines will be published in a forthcoming EPA technical document, "Evaluation Guidelines for Ecological Indicators." In addition to describing the fifteen guidelines, the document includes examples of three different EMAP indicators presented in the format and sequence of the guidelines. The examples include a direct chemical measurement (dissolved oxygen), an estuarine benthic community index and a fish community index of biotic integrity. The purpose of the examples is to demonstrate the types of information that can be provided to address each guideline.

Keywords: ecological indicators, ecological monitoring, ecological assessment, indicator evaluation, Environmental Monitoring and Assessment Program (EMAP)

Investigating the Linkages Between Chemical, Biochemical and Ecological Indicators of Ecosystem Health in San Pablo Bay, California

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San Pablo Bay, California, is subject to several major environmental stressors, including sediment loads, heavy metal and pesticide residues, industrial waste from the San Francisco Bay Area (including several oil refineries), and chemical waste from the Mare Island Naval Shipyard (now closed).

As part of a CISNet project, an extensive set of potential indicators, based on chemical, biochemical and ecological variables, will be developed. Supercritical fluid extractability and aqueous desorption potential will relate sediment-borne contaminant fluxes to toxicity. Monitoring protein damage, lysosomal destabilization, metabolic alterations and tissue damage in two benthic species should indicate sub-lethal exposure to chemicals in the environment. Ecological stress indicators include composition of benthic assemblages, contaminant bioaccumulation in fish tissue, and reproductive success of birds.

Understanding fluxes and variations in stressors within the system at a range of timescales is key to linking the indicators, optimizing a long term monitoring network, and using the indicators as predictors of change. To achieve this, 12 monitoring stations have been established to provide water, suspended sediment and surficial sediment samples. These will be analyzed for a suite of trace metal and organic compounds. Continuous measurements of current flow, salinity, temperature, and optical backscatter will enable calculation of fluxes.

To assist with the technical evaluation of indicators, EPA is developing evaluation guidelines. This paper seeks to address, (1) the extent to which the evaluation guidelines are satisfied in the proposed study, and (2) the extent to which the indicator development we propose is not reflected in the evaluation guidelines.

Keywords: CISNet, indicators, San Pablo Bay, contaminant flux, ecological stress

Assessing Ecological Health: Defining Terrestrial Indicators

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Protection of ecological health is founded on understanding of biological responses to human activities. Established in 1943 to produce nuclear material, Hanford Nuclear Reservation is an ideal place to test our understanding of biological responses. Hanford contains severely contaminated sites with physical disturbances and areas of healthy native shrub-steppe vegetation. Invertebrates, terrestrial vegetation, and microbiotic soil crusts were sampled in 1997 at 13 sites and 19 sites in 1998 to identify biological attributes (metrics) that responded along gradients of disturbance. We investigated 56 attributes of terrestrial invertebrate assemblages using 1997 data; 28 distinguished between minimally and severely disturbed sites. Only 7 would be expected by chance. Ten attributes gave consistent responses to disturbance in 1998. Several taxa richness attributes changed consistently along disturbance gradients: total number of invertebrate families and number of Diptera, Acarina, Tenebrionidae (Coleoptera), parasitoid, decomposer, and predator taxa. Dominance increased with disturbance. For terrestrial vegetation, total taxa and shrub taxa richness, shrub and lichen cover, and relative abundance of native forbs decreased with increasing disturbance. Proportion of alien taxa and density of forbs (especially alien annuals) increased. Based on knowledge of these patterns, we applied analytical procedures and concepts developed for aquatic systems to develop terrestrial indexes of biological integrity to guide cleanup and restoration programs at Hanford.

Keywords: ecological health, biological indicators, disturbance, multimetric indexes, vegetation, microbiotic soil crusts, invertebrates

Long Term Data Acquisition for Evaluating Change in the Lake Tahoe Subalpine Ecosystem

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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 the contributing tributaries, as well as atmospheric and groundwater effects. The continuous record of primary productivity at Tahoe indicates a steady 5.0% annual increase since 1959 with a great deal of interannual variability related most significantly to the annual depth of mixing. Since 1959 the average transparency has decreased at about 0.3 meters per year, with temporary improvements during years of incomplete mixing. We are currently developing a predictive water quality model for Lake Tahoe, taking advantage of the long-term data set. The host of environmental stresses on aquatic ecosystems worldwide and so evident at Tahoe has necessitated a more rapid conversion of basic limnological studies into management decisions. A multidisciplinary approach is essential for developing effective water management strategies for increasingly complex environmental problems. So much damage has already been done that restoration oriented research is of increasing importance. The prospect of global climate change has underscored the importance of the collection and careful analysis of long-term data in order to better understand and better manage surface waters everywhere. In the past, many policy decisions by regulatory agencies have been based on scanty short-term data that are sometimes lacking methodologically and subject to superficial interpretation. Modern ecologists and limnologists have a responsibility to help meet this global challenge for better management of increasingly apportioned surface and ground water supplies. Strong environmental science must be at the forefront in developing better management practices and providing science-based decisions as we face the ever mounting demands for water, a most essential and limited resource.

Keywords: Lake Tahoe, long-term data set, environmental stresses, primary productivity, lake transparency, interannual variability, water management strategies, aquatic ecosystems

Contributed Talks Concurrent Session 1

Regional Vulnerability Assessment (ReVA) Program

An Overview of EPA's Regional Vulnerability Assessment (ReVA) Program

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Regional Vulnerability Assessment (ReVA) is an approach to place-based ecological risk assessment that is currently under development by ORD. The pilot assessment will be done for the Mid-Atlantic region and builds on data collected for EMAP. ReVA is being developed to identify those ecosystems most vulnerable to being lost in the next 5 to 50 years and to elucidate which stressors cause the greatest risk to ecosystem goods and services. The goal here is not exact predictions, but a first-cut early warning system to identify and prioritize the undesirable environmental changes we should expect over the next few decades. As such, ReVA represents a new risk paradigm for EPA that will require innovative approaches to combine existing knowledge, focus new research, and synthesize many types of information into a meaningful assessment designed to inform environmental decision-makers about future environmental risk.

To develop the regional assessment will involve four interacting functions. First, data on stressors and effects from many sources must be placed into the spatial context and synthesized using the capabilities of Geographic Information Systems (GIS). Second, a core research component must fill critical gaps in our ability to apply the data at the landscape and regional scale and to understand how socio-economic drivers affect environmental condition. Third, an assessment component must keep the project grounded in the real world by actually applying the data and risk assessment techniques to specific regions. Finally, the data and analytical tools must be transferred into the hands of regional managers. This final step is critical to assuring that the results of the research can be applied to continuing regional assessments.

Keywords: regional vulnerability, comparative risk assessment, place-based risk assessment, early warning, integrated assessment

Alternative Futures Analysis in the Willamette Basin, Oregon

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Alternative futures analysis is an assessment approach that synthesizes scientific information in a format useful to community decision-makers. We are working with the Willamette Valley Livability Forum, a group of representative stakeholders established by the Governor. The assessment addresses four basic questions: (1) How have humans altered the landscape over the last 150 years? (2) How might human activities and management decisions alter the landscape in the future? (3) What are the likely ecological and socioeconomic consequences of these possible futures? (4) What types of human activities and management actions, in what areas or ecosystem types, are likely to have the greatest effects. The effects of three alternative future scenarios will be evaluated on four endpoints: terrestrial biodiversity, ecological condition of streams, habitat complexity in the Willamette River, and socio-economic impacts of competing demands for water. Four features characterize our assessment approach and make it particularly well suited to support community decision-making. First, there is no a priori judgment about what is "good" or "bad" but rather an objective evaluation of the likely consequences of a range of alternative scenarios. Second, the assessment deals with all aspects of human interactions with their environment. Third, the assessment is spatially explicit. Where an action occurs can be just as important as what occurs. Finally, the assessment evaluates effects on multiple, diverse ecological endpoints, so that linkages and trade-offs are evident. We will describe ongoing analyses in the Willamette Basin and provide example results from a prototype assessment.

Keywords: alternative futures, environmental assessment, community-based environmental protection, watershed approach

Modeling Land Use Change as an Ecological Stressor

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The EPA Office of Research and Development (ORD) is addressing the question, "Where will projected land-use change most threaten ecological resources within an EPA region?" ORD is conducting a demonstration project in the mid-Atlantic region that employs a multiple-scale framework to identify: 1) county aggregations and 2) specific watersheds where projected growth and land-use conversion pose significant threats to sensitive ecological resources. Results will be presented from a combination of region-wide modeling techniques developed in-house and with the Departments of Agriculture and Interior. Synthesis of these results will identify multiple-county aggregations most likely to undergo significant land-use change. When overlaid with large-scale ecological resources of concern, these subregions will illustrate community risk management priorities for EPA Regions II, III, and IV. They will also provide the focus for more intensive research, serving as test areas for the application and integration of higher-resolution, spatially explicit models developed within ORD, EPA Program Offices, and the academic community. Collaborative application of these models under selected economic and policy scenarios will lead to local development profiles across a range of resolutions and certainty. ORD will use the detailed development profiles that emerge to drive exposure and effects models, arriving at ecological vulnerability profiles at the eight-digit watershed scale. Vulnerability profiles will include ecological resources directly displaced by land-use conversion, and those indirectly impacted by increased quantity and toxicity of runoff and air pollution. Research methods are expected to be transferable to any geographic area where requisite data are available.

Keywords: land-use change, land-use models, ecological vulnerability, risk management

A Multi-Scale Approach to Biodiversity Assessment

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We describe a biodiversity research program developed under the leadership of U.S. EPA and the USDA Forest Service using the name Biodiversity Research Consortium. This program has asked three questions: (1) why is biodiversity spatially distributed the way it is, (2) how can the most important places for conservation of biodiversity be identified, and (3) how will changes, caused by humans, in the landscapes of important places affect biodiversity. Through these questions the research program has had a multi-scale view of the interaction between the science of biodiversity analyses and decision-making. For the implementation of research efforts, the program has defined biodiversity as aggregations of species of higher organisms: vertebrate animals, trees, and butterflies. For larger areas, such as continents, nations, or regions, analyses have studied environmental mechanisms influencing the distribution of species. Also in larger areas, analyses have identified places that contain significant biodiversity components, for example, a set of species that is complementary to those in other places. For smaller areas such as landscapes, selected for their importance in the larger area, analyses have examined the possible effects of future changes, natural or anthropogenic, on species habitats. In sample studies from Pennsylvania and Oregon, this research effort has made findings about specific places, mechanisms, and groups of organisms that affect biodiversity.

Keywords: biodiversity, assessment, multi-scale

Quantifying the Regional Effects of Mine Drainage on Stream Ecological Condition in the Colorado Rockies from Probability Survey Data

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Runoff from both active and inactive metal mining has contaminated waters and sediments in the Southern Rockies Ecoregion. In 1994 and 1995, as part of its Regional Environmental Monitoring and Assessment Program (REMAP), the U.S. EPA conducted a probability survey of wadeable streams in the mineral belt portion of the Southern Rockies in Colorado. Over the two summers of the study, samples were successfully collected from 73 probability sites (representing 6,630 km of streams) and 13 hand-picked sites for indicators of fish and macroinvertebrate assemblages, physical habitat, and sediment and water chemistry and toxicity. Using stream chemistry, sites were classified into Least Disturbed, Mixed Impacts, and Mine Drainage Impacted Chemical Classes. The study area had roughly equal stream lengths in each of the three classes. Overall, an estimated 1,844 km (28%) of stream length had a sulfate signature of mine drainage, 438 km (7%) exceeded state Zn criteria and 376 km (6%) had water toxic to the test organisms. Sites with elevated metals and toxicity were concentrated in the mine drainage chemical class. Water column toxicity tests (48 hour fat head minnow and Ceriodaphnia survival) were better indicators of mine drainage stress than sediment toxicity test (seven day *Hyalella azteca* survival). Also, stream macroinvertebrate assemblages were more sensitive to mine drainage stressors than fish assemblages. The synoptic survey data gathered in the REMAP project provides a useful framework and baseline for assessing the extent of mine drainage impacts in the Colorado Rockies.

Keywords: mine drainage effects, Colorado Rockies, stream survey, toxicity tests, bioassessment, biomonitoring

The Extent of Mine Drainage into Streams of the Central Appalachian and Rocky Mountain Regions

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Runoff and drainage from active and inactive mines are contaminating streams throughout the United States with acidic and metal contaminated waters and sediments. The extent of mining impacts on streams of the coal bearing region of the Central Appalachians and the metal bearing regions of the Rocky Mountains were assessed by three approaches. First, chemistry data from streams sampled by the USEPA's Environmental Monitoring and Assessment Program (EMAP) and Regional EMAP (REMAP) were used to classify streams based on acid neutralizing capacity (ANC), sulfate (SO_4^{-2}), metals, and chloride (Cl^-) concentrations of the water. High sulfate and metal concentrations served as excellent indicators of mine drainage impacts in the watersheds. In the second approach, we determined the extent of mining activity within each U.S. Geological Survey 8-digit hydrologic catalog unit within the study regions and its proximity to streams based on classified thematic mapper (TM) satellite imagery and the USEPA's River Reach File Version 3 (RF3) data. Our third approach, using biological data collected from the EMAP and REMAP streams, looked at the correlation of these data with the stream chemical classification, and estimated the extent of mining impact based on biotic indices and microbial respiration. The stream chemistry approach estimated that about 9% of the stream length in the regions were impacted by mine drainage. The TM approach estimated that 7% of the stream length in the regions were vulnerable to mining impacts. The stream biota indicated that the extent of mining impacts to streams might be as high as 50% of the stream length in the regions.

Keywords: Appalachian streams, biotic indices, EMAP, mining impacts, REMAP, Rocky Mountains streams, thematic mapper imagery

Contributed Talks Concurrent Session 2

Landscape Session

Small Area Estimation for Natural Resources Surveys Using NRI and NFS Data

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The Natural Resources Conservation Service (NRCS) and the Forest Service (FS) of the USDA conduct national natural resources surveys, respectively for the NRCS the Natural Resources Inventory (NRI) and for the FS the Forest Inventory and Analysis (FIA) and special management surveys on National Forest Land in the West (NFS). Using spatial models we use Bayesian predictive inference for the NRI and classical predictive inference for the NFS data base to predict, respectively, percent of a county or hydrological basin that is seriously eroded and percent of dead trees for each non-sampled hectare in a hydrologic basin.

Covariates available include land use, land class, soil quality, rainfall, soil erodibility, slope length and steepness, forest type, etc. We plan to provide reliable standard errors of individual predictions. We also propose standards for verifying the predictions in follow-up work. This is essential for the critical management issues involved.

Keywords: bayesian and classical methods, management, NFS, NRI, number of dead trees, prediction verification, reliable variance estimation, small area estimation

Monitoring of Inter-Annual Variability Reveals Sources of Mercury Contamination In Clear Lake, California

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Mercury (Hg) contamination in the aquatic ecosystem of Clear Lake, California has been documented since the 1970s when fishes were found to have elevated levels of toxic methyl mercury (meHg). Mining practices at the Sulphur Bank Mercury Mine (active intermittently from 1872-1957), along the shoreline of Clear Lake, included the bulldozing of waste rock and overburden ore into the shallow nearshore regions of the lake and the creation of steeply sloped piles of waste rock at the water's edge. This process, plus erosion of the waste rock piles, resulted in an estimated 100 metric tons of Hg in Clear Lake. A monitoring program to assess Hg in Clear Lake has been conducted since 1992, and continuously from 1994. Drought conditions in California had persisted for about 7 years prior to 1992, when the U.S. EPA remediated the steeply sloped eroding waste rock piles, which appeared to significantly reduce sediment Hg concentrations. During the winter of 1994-95, a white flocculent material was observed in the immediate vicinity of the Sulphur Bank mine, leading to the discovery of ongoing acid mine drainage (AMD) (low pH fluids high in Hg and extremely high in sulfate), which has been observed every year since. Presently the AMD is believed to be the most likely major source of meHg production in Clear Lake. The discovery of this source of meHg production in Clear Lake, which will significantly influence the remediation process, was realized only with diligent ongoing monitoring.

Keywords: mercury, mining, monitoring, aquatic, acid mine drainage, floc, Clear Lake, remediation

Integration of Genotoxicity, Population Genetics and Ecological Risk Assessment: Kangaroo Rats Exposed to Radionuclide Contamination at a Nuclear Weapon Test Facility

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This study was conducted to integrate genotoxicity and population genetic data in order to examine their use in ecological risk assessments. We present data on radionuclide contamination in populations of Merriam's kangaroo rats (*Dipodomys merriami*) collected from the Nevada Test Site. Samples from animals taken from two reference and two atomic blast sites were used to determine chromosomal damage (genotoxic effects) using the micronucleus and flow cytometric analyses. Determination of population genetic structure was performed using mitochondrial DNA (mtDNA). The genotoxicity assays revealed no significant differences between the contaminated and reference sites. The mtDNA analysis indicated significantly less variation in one of the contaminated sites than in one of the reference sites and one of the reference sites was genetically distinct from the two contaminated sites. We reanalyzed the genotoxicity data by considering animals to be residents if they possessed mtDNA haplotypes unique to either reference or contaminated sites, or migrants if they possessed haplotypes that were shared among sites. It was found that residents from one the contaminated sites had increased genetic damage compared to residents from the reference areas and migrants from the contaminated areas. Finally, we used a phylogenetic analysis, combined with a distributional analysis, of the mtDNA haplotypes to reconstruct the possible migration history of the populations. This showed that molecular analyses of gene flow and migration patterns could be used to understand better the possible contaminant effects of environmental exposure, including uncovering hidden effects that were not previously apparent.

Keywords: population genetics, genotoxicity, biomarkers, ecological risk assessment, radiation, wildlife

Montane Meadows as Indicators of Environmental Change

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The sensitivity of montane meadows to variations in temperature and moisture suggests that they can function as excellent indicators of environmental change. Given the rich biodiversity of montane meadows, significant changes in plant and animal diversity may occur as meadow vegetation responds to changes in temperature or moisture availability. We used a time series of satellite multispectral imagery for monitoring the extent, condition, and spatial pattern of montane meadows on a seasonal and interannual time scale. Spectrally-based, spatially-explicit models were developed for six meadow types representing a moisture gradient from xeric to hydric in the Yellowstone Ecosystem. We hypothesized that ranges of variability in spectral and environmental parameters existed for each meadow type ("reference states") and that the degree of variability in each meadow type would define the probability of a meadow to shift to a new state under changing environmental conditions. Highly stable states occurred in large meadows at the extremes of the moisture gradient (sedge meadows and sagebrush flats). Conversely, mesic meadows, and small hydric meadows showed the greatest seasonal and interannual variability in spectral response. Field sampling in each of the meadow types was conducted for plants, birds, and butterflies. Mesic meadows supported the highest plant and butterfly diversity whereas hydric meadows supported the richest bird diversity and a community of specialized plants and butterflies adapted to this extreme environment. Because of their sensitivity to environmental conditions and specialized flora and fauna, mesic meadows and small hydric meadows are therefore excellent candidates as indicators of environmental change.

Keywords: remote sensing, biodiversity, multitemporal, Yellowstone National Park, Grand Teton National Park

A Remote Sensing-Based Method for Retrospective Ecological Risk Assessment of Rangelands Subject to Grazing and Military Land Use

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Satellite remote sensing (RS) is currently used by federal land management agencies more for research than as a part of monitoring and assessment protocols. From the early 1950s, federal monitoring protocols were based on traditional conceptual models of ecosystem functioning. Recently, these protocols have been changed to accommodate contemporary concepts of scale, multiple stable states, and thresholds. These paradigm shifts have provided an opportunity to enhance these protocols with scale-dependent technologies like RS and Geographic Information Systems (GIS).

We used an ecological risk assessment framework in conjunction with a definition of rangeland degradation to develop and apply a RS-based method for assessment of rangelands subject to grazing and military land-uses. Rangeland degradation was defined as a change in plant species composition; a decrease in plant productivity; a reduction in soil quality; accelerated soil erosion; and a change in landscape composition and pattern. RS-based measurement indicators were derived from these assessment endpoints using RS and GIS procedures. Analysis of these indices occurred within a GIS which contained 27 years of historical Landsat satellite imagery and site bio-physical and administrative data. The assessment occurred at multiple scales including landscape and administrative (individual paddock/training) scales.

This method is being applied to two sites within the Intermountain/Great Basin Cold Desert (Camp Williams, Utah and Deseret Land & Livestock Ranch, Utah) and one within the Chihuahuan Hot Desert (Ft. Bliss, Texas). The developed GIS database from each site will allow validation of future landscape conditions predicted by spatially-explicit simulation models.

Keywords: remote sensing, Ecological Risk Assessment, rangeland degradation, assessment endpoints, remote sensing-based measurement indicators

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A Landscape Approach for Detecting and Evaluating Change in a Semi-Arid Environment

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Vegetation change in the American West has been a subject of concern throughout the twentieth century. Although many of the changes have been recorded qualitatively through the use of comparative photography and historical reports, little quantitative information has been available on the regional or watershed scale. It is currently possible to measure change over large areas and determine trends in ecological and hydrological condition using advanced space-based technologies. Specifically, this process is being tested in a community-based watershed in southeast Arizona and northeast Sonora, Mexico using a system of landscape pattern measurements derived from satellite remote sensing, spatial statistics, process modeling, and geographic information systems technology. These technologies provide the basis for developing landscape composition and pattern indicators as sensitive measures of large-scale environmental change and thus may provide an effective and economical method for evaluating watershed condition related to disturbance from human and natural stresses.

The project utilizes the database from the North American Landscape Characterization (NALC) project which incorporates triplicate Landsat Multi-Spectral Scanner (MSS) imagery from the early 1970s, mid 1980s, and the 1990s that has been remapped and projected to UTM coordinates at 60-meter resolution. Landscape composition and pattern metrics have been generated from digital land cover maps derived from the NALC images and compared across a nearly 20-year period.

Preliminary results about changes in land cover for the study period indicate that extensive, highly connected grassland and desert scrub areas are the most vulnerable ecosystems to fragmentation and actual loss due to encroachment of xerophytic mesquite woodland. In the study period, grasslands and desertscrub not only decreased in extent but also became more fragmented. That is, the number of grassland and desertscrub patches increased and their average patch sizes decreased. In stark contrast, the mesquite woodland patches increased in size, number, and connectivity. These changes have important impact for the hydrology of the region, since the energy and water balance characteristics for these cover types are significantly different. The process demonstrates a simple procedure to document changes and determine ecosystem vulnerabilities through the use of change detection and indicator development, especially in regard to traditional degradation processes that have occurred throughout the western rangelands involving changes of vegetative cover and acceleration of water and wind erosion.

Keywords: landscape characterization, landscape ecology, landscape indicators, change detection, remote sensing, rangeland condition, semi-arid watershed

Contributed Talks Concurrent Session 3

Aquatic Resources Session I

EMAP - A Retrospective

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EPA's Environmental Monitoring and Assessment Program (EMAP) was designed to periodically assess and quantify, with known confidence, the condition of all the Nation's ecosystems. EMAP's mission was to be strategic, so that progress toward environmental goals could be tracked, and research and remediation resources could be most wisely targeted. Unlike tactical monitoring that focuses on measuring local pollutant concentrations associated with an entity subject to controls, or long-term field research that seeks to test hypotheses about cause and effect, strategic monitoring requires a statistical survey approach relying on biotic indicators. It is too early to assess the extent to which this approach will prove feasible, but a retrospective look at how the original approach came to be tried, and how institutional and social issues affected the program, might be helpful in fashioning environmental monitoring programs in the future. This retrospective is timely in light of the Government Performance and Results Act.

This work has been funded wholly by the United States Environmental Protection Agency. It has been subjected to Agency review and approved for publication.

Assessing Vulnerability of Streamflow to Changes in Land Cover at Regional Scales: Hydrological Modeling Studies in the Interior Columbia Basin

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Streamflow is a fundamental component of water quality: changes in the timing and the quantity of streamflow affects the introduction and transport of sediment and nutrients, stream temperature, and channel morphology and habitat. Changes in vegetative land cover affects streamflow via the processes of evapotranspiration, snow accumulation and snowmelt, soil moisture, and runoff. As an initial framework for assessing regional vulnerability to streamflow changes associated with changes in land cover, this study modeled changes in vegetation within the interior Columbia Basin (690,000 km^2.) over the last century. Two land cover scenarios were used: a reconstruction of historical vegetation, circa 1900; and current vegetation as estimated from AVHRR data for 1990. Simulations were performed using the Variable Infiltration Capacity (VIC) hydrological model, applied at one-quarter degree spatial resolution (approximately 500 km^2) using hydrometeorological data for 1979-1989, and the 1900 and 1990 vegetation scenarios. Simulated daily hydrographs of naturalized streamflow (i.e., reservoir effects removed) were aggregated to monthly totals and compared for 17 tributaries. Two ongoing companion studies are extending this comparative hydrologic framework. The first is downscaling the VIC model to one-eighth degree spatial resolution (approximately 150 km^2) to assess the historic range in streamflow variability associated with changes in vegetative cover due to succession, fire, and forest pathogens. The second study uses fully distributed modeling (30-meter grid) to assess how specific patterns of vegetation change (e.g., through timber harvest) and placement of roads and culverts affect streamflow for representative watersheds of approximately 200-300 km^2.

Keywords: hydrological modeling, streamflow, vegetation, land cover, regional vulnerability

Characterizing Two Small Subbasins in the North Coast Gene Conservation Area, Oregon

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A fine-grained statistically robust probability sample of stream segments is used to characterize and compare conditions of two small (< 20,000 ha) subbasins of the Tillamook watershed, north coastal Oregon. The Tillamook and Kilchis subbasins are of approximately equal size, but differ in terms of geomorphology and (consequently) land use. Logging rates are an order of magnitude higher in the low-gradient Tillamook subbasin, and dairy farming is much more extensive.

A total of 67 wadeable ÷ non-wadeable sites were identified for sampling from a sampling universe consisting of the River Reach File 3 (blue lines on 1:100,000 maps). Potential intraseasonal or interannual differences are addressed by replicate (early vs. late field season) sampling of the same three sites each of the two field seasons. Sampling includes physical habitat, and periphyton, benthic macroinvertebrate, and fish assemblages. Field protocols generally follow those of the EPA EMAP program.

Early results from the 1998 field season are presented (21 wadeable sites). As expected, physical habitant factors varied between the two subbasins. Eleven fish species and four amphibian species were encountered. Three fish species were unique to each subbasin, and two amphibian species were united to the low-gradient, highly manipulated subbasin. Comparisons between our findings and those of regional scale (i.e., coarser-grained) probability samples for coastal Oregon will be discussed.

Keywords: Tillamook, North Coast Gene Conservation Area, scale, periphyton, benthic macroinvertebrates, fish assemblages

Characteristics of Fish Assemblages and Related Environmental Variables for Streams of the Upper Snake River Basin, Idaho and Western Wyoming

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Fish assemblages and environmental variables were evaluated for 30 first- through seventh-order streams in the upper Snake River Basin, Idaho and western Wyoming. Data was collected as part of the National Water-Quality Assessment Program to characterize aquatic biota and associated habitats in surface water. Sampling sites represented major stream types in the basin--large river, agricultural, and least-disturbed reference streams and springs in forested and (or) rangeland watersheds. Twenty-four environmental variables representing various spatial scales, from watershed characteristics to instream habitat and physicochemical measures, were used to examine relations with fish assemblages. Twenty-six fish species in the families *Catostomidae, Centrarchidae, Cottidae, Cyprinidae, Ictaluridae, Percidae, and Salmonidae* were collected.

Detrended correspondence analysis and canonical correspondence analysis differentiated fish assemblages on the basis of site type and showed that fish assemblages were most strongly correlated with percent agricultural and forest land uses, stream width, watershed size, and elevation. Fish assemblages did not correspond to the four major ecoregions in the basin. Percent substrate fines, percent embeddedness, and specific conductance typically were higher for streams influenced by agricultural land use than for reference streams in forested and (or) rangeland watersheds. Percent omnivores and percent common carp were higher for large river and agricultural sites than for reference stream and spring sites.

The introduction of intolerant salmonid species throughout the basin confounds the use of introduced species as a measure of environmental disturbance. Analysis of fish metrics identified some large river and agricultural sites in the lower part of the basin that did not support viable coldwater fish assemblages. These sites characteristically were dominated by tolerant, warm water adapted species.

Keywords: fish assemblages, environmental variables, index of biotic integrity, multivariate analysis, fish metrics

Ecohydrologic Assessment in Coastal Streams of Central California: Salmonid Instream-Flow Needs, Sandbar Dynamics and Lotic Classification

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I reviewed hydrologic, climatic, oceanographic, fisheries, and sandbar data just north and south of San Francisco Bay, to establish instream-flow needs for anadromous salmonids and examine associations among environmental and salmonid variables. Particular focus was given to the effects of environmental factors on the dynamics of sandbar formation and salmonid migrations at stream mouths. The results showed that flows needed for maintenance of physical conditions in lagoons, including adequate depth and openness to the sea, were usually lower than that needed for maintenance of salinity/circulation dynamics and younger life stages of coho salmon and steelhead trout. Notably, flows needed for adult salmonids were typically much higher than other instream-flow needs. Factor analyses on physicochemical variables at an interannual resolution yielded clear hydrologic, wind, thermal, and coastal-upwelling axes. Similar patterns were seen at a monthly resolution, although some disassociation among hydrologic variables occurred and may have resulted from different time lags of response. Neither sandbar nor salmonid-migration dynamics south of San Francisco Bay were well associated with hydrologic variables at an interannual scale, but flows used by immigrating coho in Lagunitas Creek were significantly related to flow availability. At a monthly scale, sandbar dynamics were well correlated with hydrologic and thermal variables, reflecting the greater probability of sandbar formation during warmer, drier seasons. I found further strong interannual relations between instream flows and precipitation via log-log linear equations, the regression parameters showing some correspondence with univariate measures of stream flow variability. Stream flow variability was not strongly related to rainfall variability or the presence of dams and coho, however, likely because various natural and anthropogenic factors determined flow patterns and coho viability. Hence, protection of salmonid stocks on the central California coast will require an integrated, habitat-based program of instream-flow, water quality, cover, and estuarine management, rather than focus on hatchery and other technological solutions.

Keywords: environmental analysis, hydrologic variability, coastal lagoons, coho salmon, steelhead trout, watershed classification and management

Responses of Physical, Chemical, and Biological Indicators of Water Quality to a Gradient of Agricultural Land Use in the Yakima River Basin, Washington

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As part of the U.S. Geological Survey's National Water Quality Assessment (NAWQA) Program the relation between physical and chemical factors and biological indicators of water quality in the Yakima River Basin, Washington, were examined during 1990. Multivariate analyses (ordinations) indicated that elevation was the dominant factor affecting the distribution of biota in the Yakima River Basin; agricultural intensity and stream size were of secondary importance. Study-specific multimetric indices were developed to characterize agricultural intensity and the condition of fish, invertebrate, and algal communities. After accounting for elevation, community condition declined rapidly as agricultural intensity increased. The response of invertebrate and algal community condition to agriculture suggested a threshold response; rapid declines occurred at relatively low levels of agricultural intensity with little response at mid to high levels of agricultural intensity. This pattern of response is significant in the design of monitoring studies and the implementation of mitigation efforts within the Yakima River Basin. For example, mitigation at sites with high agricultural intensity may not be cost effective when compared to mitigation efforts at sites where the level of agricultural intensity is close to the impairment threshold. Based on these results, more detailed studies are being conducted in the NAWQA Program to evaluate physical, chemical, and biological responses along gradients of agricultural and urban land use and to compare these responses among differing environmental settings across the United States.

Keywords: bioassessment, gradient analysis, Yakima River, Washington, multivariate analysis, multimetric analysis, biological condition, agriculture

Contributed Talks Concurrent Session 4

Aquatic Resources Session II

Erosion and Sedimentation Assessment and Management Alternative Evaluation for an Ephemeral Watershed

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An erosion and sedimentation assessment was conducted in California's Panoche/Silver Creek Watershed to evaluate soil erosion and transport, and to determine influencing factors. Erosion features, land use, and vegetative cover conditions were inventoried and mapped in the field. These data were then integrated with output from a geographic information system (GIS) and from the Agricultural Non-Point Source Model (AGNPS) to simulate hydrologic and erosion processes. Best management practices (BMPs) for management of sediment production and reduction of sediment loads were developed and evaluated with the model. The model indicated that revegetation in selected areas and modifications of grazing practices in the highly erodible upland and sparsely vegetated riparian areas, would reduce erosion from upland sources and provide a riparian buffer to reduce the transport of sediment into streams. However, the model also projected that these BMPs would result in a small change in total sediment yield from the watershed relative to the large amount of sediment produced by streambank and streambed erosion during storm events. Construction of runoff detention facilities in the upper watershed was evaluated to address streambank and streambed erosion. Analysis showed that small runoff detention facilities would reduce peak flood flow rates and lower flood stages, decreasing sediment production. Therefore, a BMP scenario combining permanent runoff detention facilities in the upper watershed with re-establishment of a vegetative riparian buffer, and reduction of upland soil erosion by revegetation and modified grazing practices would provide a major benefit in terms of reducing total sediment yield from the watershed.

Keywords: watershed assessment, watershed management, GIS, Agricultural Non-Point Source Model, best management practices, erosion, sedimentation, ephemeral streams

Ecological Considerations for Development of Monitoring Programs for High-Elevation Lakes in the Western USA: Assessing Impacts of Introduced Species and Other Human Disturbances

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High-elevation lakes are broadly distributed across mountainous regions of the western USA. Although, as a group, most high lakes would be considered oligotrophic or poorly productive, there is substantial physical and chemical diversity among these ecosystems that is related to local and regional variation in geology, climatic conditions, topography (e.g., elevation, position relative to the crest of mountain ranges), and lake size. High lakes are potentially sensitive to a variety of human activities, including introduction of non-native species and actions that can increase nutrient loading such as timber harvest and cultural eutrophication. Monitoring programs to assess human impacts such as non-native fish introductions and evaluate recovery should be based on an understanding of how impacts vary with chemical and physical characteristics of lakes. Some types of lakes may be at high risk from a particular human disturbance and other kinds of lakes may be at lower risk. A lake classification system that orders lakes according to chemical and physical characteristics, when coupled with an understanding of how different lake classes respond to human actions, could serve as a basis for establishing a high-lakes monitoring program. For most monitoring of high lakes, multiple trophic levels will need to be assessed to provide understanding of impacts and recovery. To illustrate these ideas we discuss results of our long-term research program on impacts of introduced trout on native biota in high-elevation lakes in North Cascades National Park Service Complex, Washington, USA.

Keywords: high-elevation lakes, impacts of non-native species, lake classification, risk assessment

Determining an Index of Biological Integrity for First to Third Order Russian River Tributary Streams

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A first attempt at establishing an Index of Biological Integrity for the Russian River (RRIBI) was developed from 208 benthic macroinvertebrate samples collected using the California Stream Bioassessment Procedure in fall 1995 and spring 1996 and 1997 from the mainstem Russian River and 21 of its tributary streams. The RRIBI was developed to assess the biotic health of Russian River watershed streams, prioritize water quality problems for more stringent assessments, form a basis to obtain future funding to restore and improve habitat in any given stream and evaluate the effectiveness of stream restoration projects. Taxa Richness, EPT Taxa, EPT Index, Shannon Diversity, Tolerance Value and Percent Dominant Taxa were chosen as the most appropriate biological metrics for producing the RRIBI. Since there was no substantial pattern in the magnitude or direction of any of the metric values from fall 1995 to spring 1996 and spring 1997 and among the first to third order Russian River tributary streams, all the sample data were compiled to produce a scoring criteria. Two scoring criteria were presented for use in developing the RRIBI; one based on EPA methodology and one based on visual examination of the distribution of the metric values. The Visual Distribution Score was recommended as the more appropriate scoring criteria since its range of metric values were wider and the metric values necessary to receive an excellent rating more conservative. A conservative approach was recommended because the streams used in developing the scoring criteria were moderately impaired and did not represent pristine reference conditions. Additional data is being collected each year in the Russian River drainage so refinement of the metrics and scoring criteria may occur.

Benthic Invertebrate Assemblages and their Associations with Environmental Variables in the Sacramento and San Joaquin River Drainages, California

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We collected data at 53 sites to evaluate associations between invertebrate assemblages and environmental variables in the San Joaquin and Sacramento river drainages as part of the National Water Quality Assessment Program. Samples were collected from 1993 to 1995 in the San Joaquin River drainage and in 1996 and 1997 in the Sacramento River drainage. Invertebrates were collected from riffles or from large woody debris (snags) when riffles were absent. Snag habitats were sampled within a much narrower range of elevation (4 to 37 meters) than riffle habitats (27 to1,426 meters). Analyses of the invertebrate samples were based on the family level of taxonomic organization. The total number of taxa varied from 4 (snag habitat in an agricultural drain) to 31 (riffle habitat in a foothill stream). Canonical correspondence analysis of the combined data set (snag and riffle habitats) indicated that patterns in assemblage structure were highly correlated with a gradient in physical and chemical conditions associated with elevation. Analysis of the riffle samples gave similar results. Analysis of the snag samples showed that, although elevation remained a significant variable, the mean dominant substrate size, gradient, specific conductance, and percentage of the basin in agricultural and combined agricultural and urban land uses were more important factors in explaining assemblage structure. Invertebrate assemblages on snags may useful in bioassessments of environmental conditions in valley floor habitats. In the Sierra Nevada and its foothills, the strong influence of elevation made it difficult to attribute differences in invertebrate assemblage structure among sites to specific environmental conditions.

Keywords: benthic invertebrates, Sacramento River, San Joaquin River, National Water Quality Assessment Program, canonical correspondence analysis

Multivariate Analysis of Periphyton Assemblages to Identify Environmental Stressors in Colorado Rocky Mountain Stream Ecosystems

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Using redundancy (RDA) and canonical correlation analysis (CCA), we assessed relationships between chemical and physical characteristics and periphyton at 105 stream sites sampled by REMAP in the mineral belt of the southern Rockies ecoregion in Colorado. We contrasted results obtained with community structure measured by species abundance, genera abundance and community metrics, identifying taxa or metrics diagnostic of stressors in these streams. For species abundance (CCA), 4 axes were significant and accounted for 32% of the species-environment relation. The first axis was correlated with presence of mixed canopy and mid-layer vegetation, % fast water habitat, % coarse substrate, and nonagricultural disturbance and inversely correlated with dissolved organic carbon, embeddedness, width x depth, and % pool habitat. The second axis was correlated with TOC, P, embeddedness, alkalinity, suspended solids (TSS), and agricultural disturbance and inversely correlated with % coarse substrates, and presence of herbaceous groundcover. For genera abundance (CCA), the axes were not significant. For metrics (RDA), 3 axes were significant and accounted for 95% of the metric-environment relation. The first axis was correlated with P, embeddedness, TOC, and dissolved As and inversely correlated with presence of mixed canopy or mid-layer, % canopy density, % coarse substrate, and % fast water habitat. The second axis was correlated with DOC, % pool habitat, and alkalinity and inversely correlated with dissolved Cd, Cu, and Zn; sediment Cu and Zn; TSS; and % fast water habitat. Species abundance is sensitive to the subtle physical effects of mining or agriculture, but this sensitivity is lost with genera abundance. The metrics are more sensitive to chemical effects.

Keywords: periphyton, streams, Colorado Rockies, chemical variables, physical habitat variables, taxa abundance, metrics, redundancy analysis, canonical correlation analysis

Relationships of Habitat-Specific Algal Assemblages to Land Use and Water Quality in Streams of the Willamette Basin, Oregon

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Benthic algal assemblages, water chemistry, and habitat were characterized at 25 stream sites in the Willamette Basin, Oregon, during low flow in 1994 as part of the U. S. Geological Survey's National Water-Quality Assessment (NAWQA) Program. Forty-eight algal samples yielded 374 taxa -- mostly diatoms, blue-green algae, and green algae. Algal assemblages from depositional habitats along stream margins were strongly dominated by diatoms (76% mean relative abundance), whereas erosional habitats (rock or wood substrates) were dominated by blue-green algae (68% mean relative abundance). Species diversity was 60% greater in depositional samples than in erosional samples, averaging 60 and 40 taxa, respectively.

Canonical correspondence analysis (CCA) of diatom relative abundance from depositional samples identified four environmental variables (maximum specific conductance, percent canopy open, pH, and drainage area) that were significant in describing patterns of algal taxa among sites. Based on CCA, four groups of sites were identified: streams in forested basins that supported oligotrophic algal taxa, such as Diatoms mesodon; small streams in agricultural and urban basins that contained a variety of eutrophic and nitrogen-heterotrophic algal taxa; larger rivers draining areas of mixed land use that supported planktonic, eutrophic, and nitrogen-heterotrophic algal taxa; and streams with severely degraded or absent riparian vegetation (> 75% canopy open) that were dominated by other planktonic, eutrophic, and nitrogen-heterotrophic algal taxa. Patterns in water chemistry were consistent with the algal autecological interpretations and clearly demonstrate relationships between land use and water quality.

Keywords: water quality, land use, benthic algae, habitat, diatoms, CCA, NAWQA, Willamette Basin

Annual Progress Report on Ecological Indicator Assessment STAR Grants Review Meeting

Multiscale Assessment of the Population State of *Thalassia testudinum* (Turtle Grass): A New Approach to Ecosystem Assessment

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Because seagrasses are extremely sensitive to changes in water quality, they are ideal sentinel species for biological monitoring of estuarine and nearshore ecosystem health. In this project, we are evaluating: 1) demographic, morphological, physiological, and chemical characteristics of the seagrass *Thalassia testudinum* as integrative indicators of chronic stress and 2) multiple spatial scales for assessing the impact of natural and human stressors on seagrass communities. In the first two years of a three year project, we have sampled nine sites from the Chandeleur Islands to the Florida Keys using a hierarchical sampling design based on tesselated hexagons. At each site, we sampled 30 stations at each of three (small-100 m^2, medium-10,000 m^2, and large-1,000,000 m^2) scales. Many parameters, such as leaf nitrogen, leaf phosphorus, and rhizome carbohydrate exhibit significant variations among sites. However, in our routine sampling, variability of most parameters within spatial scales equals or exceeds variation among scales. More than 80% of Thalassia shoots sampled in Tampa Bay were infected by *Labyrinthula* sp., suggesting that highly-stressed seagrass might be susceptible to slime mold infection. Multi-year sampling is demonstrating the importance of episodic events on seagrass community structure: Hurricane Georges and the 1998 El Niño have had marked effects on some sites, and the impacts of these phenomena appear to vary among scales. Differences among sites will be related to variation in the extent and intensity of natural and anthropogenic stressors.

Keywords: seagrass, *Thalassia testudinum*, estuaries, Gulf of Mexico, stable isotopes, ecological stoichiometry, disease

Health Indicators for Salt Marsh Estuaries of the South Atlantic Bight

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This project examines development and testing of simple, inexpensive, and rapid methods for assaying and monitoring the general health of salt marsh ecosystems in the southeastern United States. It is designed to examine a suite of salt marsh indigenous organisms to: (1) evaluate methods that determine critical rates within the macrophyte community, focusing on sublethal impacts; (2) determine the efficacy of using reproductive potential of three species of estuarine crustaceans as a measure of sublethal stress; and (3) evaluate a battery of physiological bioassays using sort-lived marine microorganisms as indicators of salt marsh ecosystem condition.

During the first two years of the project, studies have been conducted at the LCP Superfund site in Brunswick, GA (contaminated with Hg and PCB residues); Terry Creek in Brunswick, GA (contaminated with toxaphene); and twelve sites in Charleston Harbor. Findings to date include: (1) little measurable impact was found on *Spartina alterniflora* physiology, bacterial activity, or fungal biomass as a result of Hg and PCB residue contamination in sediments of the LCP site. Adult size, egg size and reproductive output increased at the LCP site relative to control sites. Laboratory studies show reduced physiological activity of bacteria to Hg and Cu, which is mitigated by natural organic matter and increased salinity. (2) sediment cores were taken at the Terry Creek site along with *Spartina alterniflora* biomass samples and gas exchange measurements of these plants. Several spatial trends were observed and await the results of sedimentary toxaphene analyses for further interpretation. (3) twelve sites have been established in the Charleston Harbor area and sampled for the standard array of biological and physico-chemical parameters taken at the LCP and Terry Creek sites. In addition, two crustacean reproductive potential study sites have been established and sampling begun. Preliminary analyses and trend results will be discussed.

Keywords: ecotoxicology, trace metals, anthropogenic pollution, humic substances, salt marsh estuaries, *Spartina alterniflora*, gas exchange, fungal biomass, crustacean reproductive capacity

Modeling and Multiobjective Risk Decision Tools for Assessment and Management of the Lake Erie Ecosystem

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Integrated ecological assessment and decision making is a challenge for Great Lakes environmental and resource management agencies. Traditionally, water quality, habitat, and fishery management have been the responsibility of separate agencies with sometimes conflicting mandates. However, decisions affecting one aspect of the ecosystem have important implications for other parts. For instance, there is concern that the invasion of zebra mussels together with progress in controlling nutrients (phosphorus) under the Great Lakes Water Quality Agreement may be overconstraining the productivity of Lake Erie's recreational and commercial fisheries. As another example, alterations of offshore community structure as a result of, e.g., fishery management measures have significant implications for contaminant body burdens of fish.

Assessment of these issues requires, among other things, convenient modeling tools for exploring the implications of management and disturbances for ecosystem health and the valued services it provides. The Lake Erie Ecological Model has been enhanced, and results from studies of the following two issues will be summarized: the desirability of multispecies fishery quota management compared to single species management, and their interactions with ecosystem (productivity) constraints; and the relative roles of zebra mussels, decreasing phosphorus loadings, and predator-prey interactions in the recent declines in valued fisheries (yellow perch and walleye).

Integrated management requires not only better tools for assessment of the impacts of management and disturbances, but also explicit and systematic application of value judgments by management and stakeholders. This is because ecosystem health is a multidimensional concept, and tradeoffs among those dimensions and between ecosystem health and socioeconomic concerns are often large and important. Methodologies for considering and valuing tradeoffs, including multicriteria decision making methods and risk analysis, have been applied to phosphorus management as a demonstration of the potential value of these approaches. Lake Erie managers and stakeholders from the US and Canada will be applying selected methods this spring to evaluate alternative visions for Lake Erie's future, and results of that exercise will be presented.

Keywords: integrated assessment, Lake Erie, ecosystem modeling, multicriteria decision analysis, risk analysis

Trophic Transfer of Atmospheric and Sedimentary Contaminants into the Great Lakes Fisheries: Controls on Ecosystem-Scale Response Times

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Top predator fish in the Great Lakes remain contaminated with PCBs and the organochlorine insecticide toxaphene more than a decade after production and use of these chemicals were banned in the region. Clearly regulatory actions do not yield immediate results in these large aquatic ecosystems. This study address the question 'why did the Great Lakes fisheries respond so slowly to the sharp reduction in PCB and toxaphene inputs?'. Our strategy is to conduct intensive field studies in Grand Traverse Bay, Lake Michigan at three temporal scales: daily 'snapshots' of contaminant levels and distributions within the water column and biota, seasonal variations as determined by series of research cruises and continuously deployed sequencing sediment traps, and long-term trends as determined by radiodated sediment cores. While the study continues though the 1999 ice-free season, our findings to date include: (1) concentrations of PCBs on suspended particles vary seasonally, in apparent response to the seasonal primary productivity cycle; (2) particle transport, and therefore PCB movement, is dominated by episodic events in this fjord-like embayment, with a few incredibly large sediment transport events contributing to the majority of the particle settling flux during the season; (3) PCB concentrations in forage fish change seasonally in response to changes in the composition and contaminant levels in their diets; and (4) high resolution sediment core records demonstrate that PCBs continue to decline in the Great Lakes ecosystem, in contrast to earlier reports of stabilized PCB levels in equilibrium with internal recycling and atmospheric loadings.

Keywords: Great Lakes, PCBs, toxaphene, response times, geochronology, contaminated sediments

Assessment and Analysis of Ecosystem Stressors Across Scales Using Remotely Sensed Imagery: Reducing Uncertainty in Managing the Colorado Plateau Ecosystem

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Examining potential characteristic scales at which environmental stressors and their effects may be manifested on ecosystem landscapes using remotely sensed imagery has been performed via the application of scale analysis methodologies across a range of spatial resolutions to a set of mosaicked images of the Colorado Plateau ecoregion. The mosaics were generated for time periods in the 70s, 80s and 90s; as well as for difference images to assess change between time periods. Substantial time and processing went into creation of radiometrically-corrected mosaics. Base data was North American Landscape Characterization (NALC) Landsat MSS data. Some problems with mis-registration of data sets, improperly labeled data and digital data line drop were encountered.

A spatial resampling algorithm was developed for re-scaling data pixels from 60 meter original pixel resolution to resolutions of 120, 240, 480, and 1920 meters. The algorithm is a simulates of coarser resolution data using a dampened sine-wave function. Problems processing the algorithm were encountered due to large file sizes overwhelming the temporary space on the system; ultimately a 2 gigabyte drive was devoted as temporary space.

Results are presented for the ecoregion mosaic analyses using fractal, variogram, multi-scale variance and local variance analyses. Scale analysis techniques were performed on subsets representing more homogeneous land types. The mosaics encompass a vast spatial extent, and data analysis of image subsets across resolution is deemed to be of possible greater use to ecosystem managers. Results are presented and interpreted for potential in use of characterizing landscape patterns and process across scales.

Development of Environmental Assessment, Mitigation and Restoration Techniques for Coral Reefs

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The goal of this project is to develop methods for coral reef assessment that identify stress at sublethal levels and to provide data to guide mitigation and restoration activities. During the past year, gametes were collected from 11 species of corals, and used in fertilization, cultivation and recruitment experiments. Settlement preferences of larvae were determined for two additional coral species: *Acropora wardi* and *Leptoria phrygia*, with planulae of the former induced by the crustose coralline alga (CCA) *Hydrolithon reinboldi*, and the latter by both CCA and biotic films. Bioassays were performed using larval metamorphic induction to test the effects of the organophosphate pesticide chlorpyrifos and the polycyclic aromatic hydrocarbon (PAH) fluoranthene. Chlorpyrifos was found to inhibit settlement and metamorphosis (recruitment) of *Goniastrea retiformis* larvae at levels as low as 5 ppb when the preferred substrata were exposed as well as when larvae were exposed and subsequently offered unexposed substrata. Fluoranthene was found to affect recruitment of *Acropora wardii* larvae at levels of 50 ppb. Planula recruitment bioassays were more sensitive than standard toxicity assays performed on either adult corals or their larvae. Techniques for the cultivation of corals were simplified to the point where planula larvae and cultivated corals can be produced in large numbers and on a routine basis with limited resources. Our studies suggest that while reefs may be reseeded, or corals transplanted, coral reefs cannot be effectively restored to their original state and hence, prevention and protection of existing reef resources must be chosen over mitigation.

Keywords: coral reefs, larvae, recruitment, restoration, PAH, organophosphate, ecological indicators

Modeling Spatial and Temporal Dynamics of Montane Meadows and Biodiversity in the Greater Yellowstone Ecosystem

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Montane meadow communities can function as early indicators of change because they are highly sensitive to variations in precipitation and temperature. However, before an accurate estimation of directional change rates may be made with confidence, the seasonal and interannual rates of change inherent to the system must be quantified. Spectrally-based, spatially-explicit models are being developed for six meadow types using a GIS to stratify the study area by topography and geology. The objectives of this research are to: 1) quantify the spatial and temporal variability in montane meadow communities, 2) develop models for predicting plant and animal species diversity patterns in montane meadows, and 3) test the models for predicting plant and animal species diversity patterns in montane meadows. We have sampled birds, butterflies, and plants for two years in the northern (Gallatin) and southern (Teton) regions of the Greater Yellowstone ecosystem. The plant community showed a range of 1to 65% similarity within meadow types between regions, averaging very close to 30% across all meadow types. The bird community showed a 47 to 59% similarity between regions. Bird species composition in the hydric meadow type was the most similar and thus most accurately predicted between regions. The butterfly community showed 60 to 65% similarity in species composition between the two sampling regions and highest predictability (up to 94%) in the hydric and xeric meadows. Our results also indicate that meadow patch size may play a significant role in predictability of species composition. Teton meadows, which are much larger, showed more highly predictable species assemblages.

Keywords: remote sensing, biodiversity, multitemporal, Yellowstone National Park, Grand Teton National Park

Monitoring Landscape Scale Patterns of Land Cover Change and Hydroperiod in South Florida Ecosystems

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This project focused on developing and applying advanced approaches to using satellite remote sensing data to monitor changes to land cover and land cover conditions in the wetland ecosystems found in southwest Florida. The specific remote sensing techniques being developed were using: (1) time-series Landsat imagery collected between 1972 and 1995 to monitor changes in land cover, and (2) using time series (monthly to bi-weekly) radar imagery collected by the ERS SAR to monitor changes in surface water inundation. In this paper, we will present examples data products produced from both of these efforts, as well as demonstration of their applications. The application for the Landsat data set is focused on producing maps of habitat change for the Florida panther, an endangered species found in this area. This information is combined with surface flooding maps produced by the radar imagery to monitor changes in panther habitat on a seasonal basis. The habitat maps produced in this product are compared to radio-collar-telemetry data collected by the Florida Department of Fish and Game in order to determine how well these products can be used to predict longer-term patterns of panther movement. In addition, the water inundation maps produced by the radar imagery are being compared to outputs from surface flow models for this region. In particular, this information is being used by the National Park Service to determine how the presence of the Taimiami Trail (U.S. 41) is affecting surface water flow in this region.

Use of Multi-Scale Biophysical Models for Ecological Assessment: Applications in the Southeastern United States

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The effects of environmental variability on such ecological properties as species diversity are relatively well-known. However, the effects of biological activity on spatiotemporal variation in environmental properties and ecosystem processes are less well understood. Understanding patterns of spatiotemporal variation in environmental properties and process rates is essential for evaluating the condition of ecosystems, and for distinguishing anthropogenic effects from natural variation. The theory of limiting resources provides a conceptual framework for predicting how patterns of spatiotemporal variation change in response to both environmental conditions and biotic processes. A new model of ecological dynamics based on variance amplification provides insights into both the biological processes that influence spatiotemporal variation in environmental resources and other properties, as well as the effects of spatiotemporal variation in environmental conditions on biological processes themselves. Examples illustrating the regulation and consequences of variance amplification will be drawn from both arid shrubland and grassland ecosystems.

Multi-Scaled Assessment Methods: Prototype Development within the Interior Columbia Basin

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We report on second year results using data compiled for terrestrial and aquatic ecosystems over the 58 million ha interior Columbia River basin assessment area. We tested the power of an existing hierarchical ecological land classification (HELC) and two de novo HELCs to predict vegetation patterns and disturbances at three spatial scales. Results indicate that the three HELCs exhibit strong relationships that vary with spatial scale and pattern of interest. We also tested the use of coarse resolution land cover data to discriminate ecoregions and landscape-scale features important in ecological assessments at two spatial scales and two classification levels. Results suggest that coarse resolution data should be examined for patterns of inconsistent characterization within ecoregions with contrasting landscape textures and configurations, and that biases in such data should be fully understood before being used. We investigated the effects of spatial scale, geographic location, and level of biological organization on the characterization of vegetation patterns. The relative importance of geographic, disturbance, regional, local and spatial variables differed among spatial scales, geographic locations within a spatial scale, and levels of biological organization. We used a knowledge-based system (KBS) implemented in a GIS application framework to delineate and define the suitability of terrestrial land polygons for inclusion in a representative regional conservation network. The KBS makes use of fuzzy logic networks to assign suitability ratings that define the conservation suitability of land polygons based on our understanding of how ecological patterns and processes are interrelated.

Keywords: ecological assessment, representativeness assessment, hierarchical ecological land classification, knowledge-based system

Poster Session

The EMAP Web Site

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The Environmental Monitoring and Assessment Program (EMAP) web site (http://www.epa.gov/emap) is the primary means of dissemination of EMAP information to all user groups. Four principal sections of the web site divide the information into descriptive, technical and scientific information from and about EMAP. Under Components and Contacts, the EMAP Working Groups and Regional EMAP (R-EMAP) Programs are described and contact personnel listed, respectively. Links to the Mid-Atlantic Integrated Assessment (MAIA) and Western Pilot web sites are located here. Data set descriptions (Directory), scientific data and Catalog (metadata) files for EMAP, R-EMAP and related programs are available in standard formats under the Data link. The Data Directory is a searchable Oracle database that tracks these data sets and contains sufficient information for a user to locate data sets of interest. Most of the data sets listed in the Directory are in the possession of EMAP and are accessible on the EMAP WWW site. Associated with each ASCII data set is a metadata file which provides the user with information about methods, assumptions and data quality. Under Documents, standard Laboratory and Field Methods Manuals are provided to view and download, as are Statistical Summaries based on the data collected. In addition, a bibliography of EMAP documents can be searched.

Development of the Information Management Component of the Region 8 State of the Environment Program

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The vision of the Region 8 State of the Environment Program is to report and manage regional scale information on the current status, condition, and trends of the Region 8 environment. The Program intends to be a comprehensive statement about the regional environment, produced by a multi-agency effort. The Program's reporting approach is to formulate and answer questions about environmental issues and values, identified as being important to the public, natural resource and environmental managers, and other decision makers. The products will consist of electronic and hard copy reports and a regional database. The reports include annually updated regional assessments, characterizations, and environmental indicators. Reporting is done through a web-based reporting and information system and a hard copy executive summary.

The scope of the Program's vision presents a challenge for the development and implementation of an information management and dissemination system. GIS, relational data base management system (RDBMS), and web technologies will provide the necessary integration and reporting tools. Given the range of customers with varying information needs, the system must be responsive to demands for several levels of information. The Program's information system has an RDBMS-based, open data access, information management capability and a web-based reporting system. The web-based reporting design provides for summary level text and graphics that are hypertext linked to more detailed information. The information management system will utilize open data access standards and logically link data from different sites, providing access for the analysis and reporting functions.

Keywords: state of the environment, environmental assessment, information management, GIS, WWW, open data access, environmental indicators

Region 8 Landscape Indicator Development in the EMAP Western Pilot

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The landscape component of the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program is conducting a Western Pilot Study to evaluate landscape-level ecological indicators for application to western ecosystems. In the initial study phase, Region 8 has selected three areas in the multi-regional effort to perform indicator quantification and validation based on perceived ecological vulnerability and the existence of a gradient of anthropogenic disturbance. The three initial landscape development areas are the mineralized portion of the Southern Rockies Ecoregion in Colorado, the Lower Yellowstone River Basin in Montana and the Northeastern section of the Colorado Plateau in Utah/Colorado. Biophysical data were collected and indicators selected, developed, and generated for each area. The core group of indicators being investigated include; proportions of land cover adjacent to streams (U-index); erodible soils on steep slopes under cultivation; natural land cover diversity (N-index); index of point sources; population density and change; road density; distance of roads to streams; and proximity of surface mines to streams. A method is presented to correlate landscape-level indicators with existing water quality data.

Keywords: landscape indicators, regional ecological assessment, landscape ecology, EMAP, GIS

Bioassessment of Wadeable Streams in U.S. EPA, Region 8, Using the EMAP Chemistry Indicator, Benthic Macroinvertebrate Indicator, Water Column Toxicity Tests and Sediment Toxicity Tests

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Almost 95% of the mineralized portion of the Rocky Mountains are contained in the Southern Rockies Ecoregion. For the past century, extensive mining of metals has occurred in this area. Runoff and drainage from both active and inactive mining sites have contaminated waters and sediments. The U.S. EPA conducted a probability survey as part of its Environmental Monitoring and Assessment Program (EMAP), Regional Environmental Monitoring and Assessment Program (R-EMAP) in the Colorado portion of the Southern Rockies in 1994 and 1995. The survey targeted second-fourth order wadeable streams as represented on USGS 1:100,000 scale maps. Using data from this study, the potential impact of mining on stream condition was assessed using three approaches. The first approach used water chemistry data collected from the survey to classify streams based on Acid Neutralizing Capacity (ANC), sulfate, chloride, and metal concentrations. In the second assessment approach, water column samples and sediment samples were collected at the same sites as the chemistry samples. *Ceriodaphnia dubia* and *Pimephales promelas* 48-hour tests were conducted on the water column samples and the 7-day survival and growth tests using *Hyalella azteca* were conducted on the sediment samples. The third approach used stream macroinvertebrate assemblages collected at the sample sites to quantify the EMAP multimetric, Stream Benthos Integrity Index (SBII) method. High sulfate and metal concentrations in these sites served as an excellent indicator of mine drainage impacts in the watershed.

The results indicated that almost all of the sites with impacted benthos and water column toxicity occurred in sites classified as mine drainage impacted by water chemistry. The stream chemistry data estimated that 28% of the stream miles in the target population were impacted by mine drainage. The toxicity data estimated that 9% of the stream miles in the target population had stream water toxic to aquatic organisms. The SBII scores indicated that 8% of the stream miles in the target population had impaired benthic invertebrate biotic integrity.

Keywords: bioassessment, wadeable streams, mine waste, benthic invertebrates, aquatic toxicity testing

A Knowledge Based Approach to the Assessment of Watershed Condition

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The Ecosystem Management Decision Support (EMDS) system is an application framework for knowledge based decision support of ecological assessments. EMDS integrates geographic information system and knowledge base system technologies to provide an analytical tool for environmental assessment and monitoring. The basic objective of EMDS is to improve the quality and completeness of environmental assessments and the efficiency with which they are performed. The USDA-FS and the U.S. EPA have cooperatively developed an EMDS knowledge base for watershed condition assessment. Specifically, this knowledge base evaluates watershed processes, patterns, general effects of human activity and fisheries habitat suitability. Such assessments are based on spatially explicit input data concerning current conditions and reference conditions which are subsequently interpreted by user defined "fuzzy" membership functions. In this paper we describe basic components of our watershed condition assessment knowledge base and illustrate its application on the Flathead National Forest of northwestern Montana.

Keywords: ecosystem health, watershed condition, knowledge base

Automated Techniques for Delineating and Characterizing Valley-Bottom Settings in the Rocky Mountains

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In mountainous landscapes, resources, such as water, riparian vegetation and associated animal species, tend to be concentrated in or near valley bottoms—and so do humans. For this reason, accurate delineation and characterization of valley-bottom settings is important for many types of ecological assessments. We sought to develop automated GIS techniques, in raster format, for first delineating and then characterizing these settings across entire river basins using 100,000 scale hydrography (USGS Digital Line Graphs) and 7.5 minute Digital Elevation Models. Our characterization goals were modest: to derive measurements of slope and width for each linear segment of the valley bottom. Delineation occurred in two steps for each basin. First, we used standard GIS functions to define a watershed; we then restricted its geographic extent to approximate the valley-bottoms by setting a user-defined, elevation limit (e.g., 15 meters) above each hydrography cell. For characterization, slope was first calculated for each cell. Despite considerable efforts, we were unable to develop acceptable raster techniques for measuring zone width because errors in the primary data, coupled with inconsistencies in some ARC/INFO (GRID) functions, produced unreliable results. Alternatively, we devised a vector-based solution using the coordinate geometry (COGO) module in ARC/INFO. This poster describes the model for mapping valley-bottom settings and illustrates its application for selected watersheds in the Columbia River Basin.

ECADS - A Multi-Resource Database and Analytical System for Ecosystem Classification and Mapping

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ECADS is an acronym for the "Ecosystem Characterization and Description System" which includes a series of PC-based relational databases and analytical software for multi-scale ecological assessments. Specifically, the system contains databases for multi-intensity sampling methods of various ecosystem components (e.g., vegetation, soil, streams, wildlife, and topography) at the site or plot scale. Ecosystem analysis programs are also included which access such data and produce standard reports, statistical summaries, and resource value interpretations for plots or plot groupings (i.e., classifications). Output from such programs may be used to describe different types of classification (e.g., existing vegetation, potential vegetation, soil, and stream types) in various classification databases. These databases are linked to a series of polygon or map unit databases which are used to describe digitized map themes in environmental assessment efforts. The hierarchical design of this system accommodates rapid updating of map theme attributes based on site-scale inventory data. In this presentation we provide an example of ECADS application in watershed condition assessment. The study area for this example includes a boreal forest setting of the Flathead National Forest in northwestern Montana. Components of ECADS are described and linkages between ECADS and the watershed condition knowledge-based module of EMDS (see Reynolds this session) are reviewed.

Keywords: databases, analytical systems, ecological classification

GIS Modeling of Human Use of Public Lands in the Western United States

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Large areas in western North America are publically owned and managed by government agencies for a variety of uses. As the human population continues to grow, both locally and globally, competing interests will place mounting pressures on how resources from these lands should be managed and used by people. This poster illustrates a GIS protocol for modeling the intensity of local human use of public lands. We focus on a 2.2 million hectare area surrounding the Lolo National Forest in western Montana. Data inputs include human population count (from the 1990 census), density of roads and trails, and the predicted distributions of both terrestrial and aquatic vertebrates. From a dasymetric map of human population density, developed at the block level, we estimate the number of people living in each 30 m^2 grid cell in the area. Using moving-window routines, we count both the number of people living and the linear density of roads within a 1 kilometer distance around each cell. The resulting values are grouped into density classes and then added together to show where people are most likely to use National Forest lands. Finally, by intersecting this human use layer with predicted distributions of both terrestrial and aquatic vertebrates, we identify National Forest lands where humans might be adversely affecting wildlife. This protocol could assist land managers and planners with future decisions in any area where suitable input data are available.

River Reach File 3 (RF3) as an EMAP Sample Frame

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Central Valley, California, R-EMAP project assessed the effects of highly modified agriculturally dominated landuse on the aquatic resources of the lower portion of the Central Valley watersheds. The focus of this paper is to assess the utility of River Reach File version 3 (RF3) 1:100,000 scale Digital Line graph (DLG) as a sampling frame. The study area is approximately 30,000 mi2 and comprises the Sacramento Valley and San Joaquin Valley watersheds to the 1000 ft. elevation. Sampling sites were selected using a tessellation stratified design to represent the two main populations of interest, natural streams and constructed conveyances. Sites were selected to represent 13,226 miles of streams and sloughs, and 14,648 miles of conveyances. To achieve an approximately equal sample size across stream orders and basins, the sample design was weighted by Strahler order categories to ensure sampling occurred in the higher order streams. Based on office and field reconnaissance, the study provided information on the quality of RF3 as a sampling frame. Site selection using RF3 had an error rate of 19%. There was a 22% error rate when selecting sites for constructed conveyances, and approximately 16% error rate for natural streams. The reconnaissance information indicated that presence or absence of irrigation ditches and return drains are dependent on changing agricultural uses. Some of the error in the RF3 for natural streams and constructed conveyances can be attributed to rapid urban expansion, especially in the San Joaquin basin.

Keywords: River Reach File version 3, RF3, stratified design, Strahler order, error

Bioassessment of Water Quality in the Humboldt River Drainage, Nevada

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The Humboldt River drainage covers an area of approximately 17,000 square miles in the Great Basin. There is considerable variation in environmental conditions within and between lotic systems. The study area is sparsely populated, there are increasing human-induced threats to water quality including mining, cattle grazing, irrigated agriculture, and urbanization. This R-EMAP project seeks to assess the drainage-wide quality of water in perennial and intermittent streams over a two year period using a combination of periphyton, macroinvertebrates, physical habitat measurements, water and sediment chemistry, and sediment metabolism. For this study 120 random locations were generated using a probability-based design. Of the sites selected, 85 sites were either dry or inaccessible and 35 of the sites were sampleable. Metals concentrations in sediments within the Humboldt River watershed exceeded Lowest Effects Level (LEL) criteria for copper (54%), manganese (51%), nickel (37%), arsenic (31%), cadmium (14%), selenium (11%), chromium (11%), mercury (9%), lead (3%), and zinc (3%). The Severe Effects Level (SEL) was exceeded for manganese in (6%) of the samples. Aquatic life criteria for metals in water were exceeded for lead (3%) and iron (3%). The streams of the Humboldt River watershed are predominantly (83-100%) limited for nitrogen. Macroinvertebrates were collected by Surber samplers, or by kick nets in deeper water. Samples were taken from 9 points within riffle environments at each site. Analysis of macroinvertebrates is still in progress. The data will be used to establish reference conditions that can be utilized in analysis of specific threats to water quality.

Keywords: Humboldt River, Nevada, lowest effects level, severe effects level, metals concentration, water quality, nitrogen limited

Status, Trends and Variability of Microbial Indicators in Oregon Streams

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The need for new methods and procedures to measure the ecological condition of the nation's aquatic resources is based in part on the public's sense that the chemical, physical and biological integrity of the environment are goals worthy of restoration and maintenance. To achieve these expectations requires approaches that are complex, with particular attention paid to how monitoring sites are chosen, developing and understanding what indicators measure, and recognizing that all of our measurements are subject to variability. One hundred and forty-six streams selected through a probability design and representing 60,041 stream kilometers were sampled throughout the state of Oregon as part of the 1997 EMAP stream survey. This approach enabled us to estimate the proportion of stream length that may exceed a particular level of bacterial abundance. Bacterial levels also differed significantly between ecoregions($p<0.01$, Heterotrophic Plate Count (HPC), Total Coliforms (TC), Fecal Coliforms (FC), and *E. coli*). Numbers of bacteria from resampled streams were not excessive, but generally higher on the second visit than the first. Differences for HPC and TC counts were found to be significant ($p<0.01$), while FC and *E. coli* counts were not ($p= 0.09$, for FC, $p<0.57$ for E. coli).

Keywords: water quality assessment, statistical sampling design, bacterial indicators

Chemistry, Toxicity and Benthic Community Conditions of Sediments from Selected Southern California Bays and Estuaries

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A cooperative research project to assess sediment quality was conducted jointly by the SWRCB's Bay Protection and Toxic Cleanup Program, NOAA's Status and Trends Program, and EPA's Environmental Monitoring and Assessment Program. Using a weight-of-evidence approach based on the Sediment Quality Triad, measures of chemical contamination, toxicity, and benthic community structure were completed at 43 stations to determine relative degradation in selected Southern California bays, estuaries and lagoons. Chemical contamination was considered to be moderate relative to other more highly industrialized areas; 52% of the randomly sampled study area was contaminated relative to PEL sediment quality guideline values (MacDonald, 1996). Approximately 58% of the randomly sampled study area was toxic to amphipods (*Rhepoxynius abronius*); 90% of the study area was toxic to sea urchin development (*Strongylocentrotus purpuratus*). Survival of amphipods and development of sea urchin embryos was negatively associated with a number of contaminants including metals, PCBs, DDT, and, in some cases sediment grain size. There was a strong negative correlation between sea urchin embryo development and interstitial water un-ionized ammonia concentrations. The Reporter Gene System (RGS) P450 biomarker assay demonstrated a strong relationship between sediment PAHs and subcellular response. Benthic community structure was assessed using a Relative Benthic Index, calculated based on measures of the total number of fauna, number of crustacean species, and numbers of positive and negative indicator species; 37% of the randomly sampled study area had degraded benthic community structure. Stations recommended for further investigation were prioritized to help direct future work.

Keywords: sediment quality triad, EMAP, California estuaries

Sediment Quality Assessment in the San Francisco Bay and Delta: Screening for Hot Spots, Investigating Sources and Causes of Toxicity

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Sediment quality was assessed throughout San Francisco Bay and Delta as part of the State Water Resources Control Board - Bay Protection and Toxic Cleanup Program. Assessment was conducted in a phased approach. Reference sites within the Bay were identified and evaluated, and reference site data were used to establish toxicity thresholds for comparison with test site results. In the next phase, 127 sites were screened using laboratory toxicity tests, in which amphipods and sea urchin embryos were exposed to field-collected sediment samples. Sites producing toxic samples were revisited for additional toxicity testing, chemical analysis, and evaluation of infaunal benthic communities. A number of sites were identified as candidate toxic hot spots, and may be subject to further investigation and management. Preliminary investigations of sources and causes of observed toxicity were undertaken at a few of these sites. Samples were collected along site gradients at increasing distances from possible sources of contamination, and Toxicity Identification Evaluations (TIEs) were conducted with sediment porewater. The results of these studies showed increasing adverse biological effects associated with increasing sediment concentrations of numerous covarying chemicals, including pesticides, metals, PCBs, PAHs, hydrogen sulfide and ammonia. TIE results implicated trace metals as probable causes of toxicity at two sites, one in the South Bay and one in Suisun Bay. These studies are described in two reports: Sediment Quality and Biological Effects in San Francisco Bay, and Evaluation and Use of Sediment Reference Sites and Toxicity Tests in San Francisco Bay. Both are available from the State Water Resources Control Board, Sacramento, CA 95812-0100.

Keywords: sediment quality assessment, toxic hot spots, gradient studies, TIE, reference sites

The Biochemistry of Assessing Heavy Metals In Populations Of Coastal Marine Mammals

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The difficulty of working with marine mammals in the wild has limited the ability of determining the biochemistry of metals in these species. Consequently, most studies have determined metals in tissues from stranded specimens which do not provide critical information on whether the observed metal levels were detrimental to normal biochemistry.

We have obtained blood samples from several hundred wild marine mammals along the coastline of Alaska and determined circulating levels of zinc, copper, metallothionein (MT) and nitric oxide (NO). In addition, we are conducting studies on harbor seals and Steller sea lions at the Alaska SeaLife Center in Seward, AK. These studies are the first to determine circulating metal levels in the blood of marine mammals and to examine biochemical reactions through the formation of MT and NO.

Up to 25% of seals and sea lions exhibit elevated metal levels with increased levels of MT and NO. These results indicate a biochemical response by inducing MT to chelate the metals from circulation. The increased NO levels indicate that the metals have altered the anti-oxidant balance in these animals. We also found that a "zinc event" occurred in Southeast Alaska in the early 1990s such that elevated levels of Zn and MT appeared in Steller sea lions.

Marine mammals are utilized for subsistence hunting in Alaska and the chemistry of metal loads in these species becomes critical for human consumption. In addition, certain populations of these mammals are declining rapidly with no clear cause and the possibility of metal contamination must be considered.

Keywords: Marine mammals, heavy metals, blood, zinc, copper, metallothionein, nitric oxide

U.S. Geological Survey, Biomonitoring of Environmental Status and Trends (BEST) Program: Contaminants and Related Effects in Fish from the Mississippi, Columbia and Rio Grande Basins

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We collected fish (mostly common carp, Cyprinus carpio, and black basses, Microperus spp.) from 46 Mississippi River basin sites (1995); 16 Columbia River basin sites (1997); 10 Rio Grande basin sites (1997); and from a West Virginia reference site (1996). Individual fish (about 40 per station) were analyzed for reproductive biomarkers (vitellogenin and sex steroid hormones), histopathological alterations, macrophage aggregates, EROD activity, lysozyme activity, and general health indicators (organosomatic and ponderal indices, and grossly visible lesions). Fish samples composited by species and sex were analyzed for organochlorine and elemental contaminants and for dioxin-like activity with the H4IIE bioassay. In the lower Mississippi River and lower Rio Grande basins, DDT (mostly as p,p'-DDE) residues in fish remained sufficiently high to represent a hazard to sensitive species of fish-eating birds. Toxaphene residues were also evident. The combined results of organochlorine chemical, H4IIE bioassay, and biomarker analyses indicated the presence of a dioxin-like contaminant in the lower Mississippi valley. Cyclodiene pesticides (dieldrin, endrin, and chlordane) were present in agricultural areas and at Memphis, TN, where there is a point-source. Selenium concentrations were sufficiently high to constitute a hazard to piscivorous fishes and wildlife in the upper Arkansas River, where levels have been increasing for approximately 10 years, and in parts of the Rio Grande basin. Mercury concentrations were higher in predators than in bottom fishes, and relatively high concentrations occurred in the Rio Grande basin. Biomarker results suggest that fish from some sites are exposed to endocrine-modulating substances.

Keywords: organochlorine chemicals, metals, metalloids, biomarkers, NAWQA, NASQAN-II

Assessing Relations Among Fish Community Structure and Environmental Factors At Large Geographic Scales

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Physical, chemical, and biological data were collected from 20 major hydrologic basins nationwide as part of the U.S. Geological Survey's National Water Quality Assessment (NAWQA) Program to determine if certain environmental factors are associated with degraded fish communities nationwide. A total of 226 stream sites were sampled during low-flow conditions from 1993 to 1995 and used to compare water quality across the nation. Water quality conditions at each site were assessed using metric-based indices of fish community structure, habitat, and nutrient concentrations. Streamflow characteristics were calculated for each site and included measures of flow variability and predictability, thresholds and patterns of extreme flow events, and frequency and duration of extremes. Watersheds upstream of each site were characterized based on a number of factors including land use/land cover, soils, and topography. Across all study units nationwide, an index of degraded fish community structure was significantly correlated with channel modification and nutrient input. Cluster analysis revealed that degraded fish communities were associated with agricultural, range, and urban land uses, poorly and artificially drained soils, and variation in streamflow characteristics. Results suggest that across large geographic scales, degraded fish community structure appears to be related to habitat alteration and nutrient concentrations resulting largely from land-use changes. However, soil permeability and variation in extreme flow events are also important factors.

Keywords: watershed assessment, water quality, fish community structure, hydrology

Synoptic Assessment of Wetland Species Extinction Risk: A Decision Tool for Protection of Wetland Species Biodiversity

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We present a synoptic model of avoided risk of wetland species extirpation per unit effort of wetland habitat protection within 225 sub-basins in EPA Region 7. Our model is intended to assist environmental managers and conservationists constrained by limited resources by providing a method for distinguishing wetland habitat potentially critical in supporting wetland species biodiversity. Our final endpoint is the total risk of extinction for wetland species in a sub-basin j, given a change in habitat protection within j (e.g., a Section 404 permit denial). We construct a conceptual model of the generalized ecological and multi-scale habitat factors that influence each species distribution and extinction risk. However, because these factors are not measurable at the regional scale, we use judgement indicators drawn from readily available Regional scale data to estimate each term in the conceptual model. Our conceptual model and a set of rules derived from measurement theory guide the combination of judgment indicators via a series of simple cost-benefit equations. Our final prioritization consists of the relative scores in each of the sub-basins in the Region. Interpretation of the distribution of ranks across the Region allows managers to cast their local decisions in the context of effects at the Regional scale. Our results place sub-basins along a continuum of avoided extinction risk per unit of protection effort, given the spatial congruence of landscape condition and anthropogenic factors affecting the viability of the suite of endemic species within each sub-basin. Our results should be useful in prioritizing regional protection efforts.

Keywords: ecological indicators, endemism, extinction risk, geographic prioritization, protection, wetland

Imaging Spectroscopy for Determining Rangeland Stressors to Western Watersheds

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The Environmental Protection Agency is developing rangeland ecological indicators in eleven western states using advanced remote sensing systems. Fine spectral resolution (hyperspectral) sensors, or imaging spectrometers, can detect the subtle spectral features that makes vegetation and soil discrimination possible. This study will use hyperspectral remote sensing data, such as NASA's Airborne Visible-InfraRed Imaging Spectrometer (AVIRIS), a system capable of 5 to 20 meter spatial resolution. Airborne and satellite remote sensing will provide vegetation mapping at the species level, soil types and characteristics, and landscape information such as erosional features. Vegetation community structure, spatial distribution, and health can then be determined and combined with climatic data to classify rangeland condition and identify disturbed regions. Accurate determination of rangeland vegetation and soils is required to establish reliable landscape indicators. An important relationship is the vegetative composition for the extremes of rangeland condition to the function and water quality of the surrounding watershed. Soil attributes such as organic matter content, salinity, moisture, mineralogy, and physical condition influence and are influenced by vegetation cover. The water quality of the watershed is directly impacted by these rangeland variables. Imaging spectroscopy allows for landscape scale assessment and monitoring of stressors to water resources in the west.

Potential research with the Bureau of Land Management (BLM) and U.S. Geological Survey will correlate remote sensing data with ground measurements. The long-term goal of this work is to develop a methodology using current technologies for use with the forthcoming hyperspectral satellites due in the next 2 to 3 years.

Keywords: imaging spectroscopy, remote sensing, rangeland, landscape indicators, watershed condition.

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Emerging and Contemporary Technologies in Remote Sensing for Ecosystem Assessment and Change Detection on Military Reservations

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The Land Condition and Trend Assessment (LCTA) Program is a field-based protocol developed by the Department of Defense (DoD) to characterize and quantify the carrying capacity of DoD land resources to support military training and testing. However, LCTA is limited in both its ability to capture landscape heterogeneity and in the high economic costs associated with conducting field surveys on landscapes of large spatial extent. Our research aims to develop remote sensing-based monitoring and assessment protocols which are complementary to LCTA. Our objectives are: to stratify the landscapes of individual military ranges using contemporary (27 years of wet and dry season Landsat satellite imagery) and emerging (airborne CAMIS, HYDICE, and IFSAR) remote sensing technologies; identify fundamental vegetation and soil attributes of military ranges as they relate to plant succession; establish ecological resilience in relation to disturbance (historical DoD activities) through retrospective studies of remotely sensed indicators of vegetation cover, landscape composition and pattern, and soil erosion; identify the spatial, spectral and temporal attributes of remote sensing systems necessary to identify and distinguish ecotones along environmental and disturbance gradients, and lastly, develop methods for scaling indices between coarse and fine resolution imagery. The ecological risk assessment framework was used to identify measurement indicators. The behavior near or at critical thresholds of these indicators provides an estimate of landscape sustainability. Our study sites are: the Army National Guard Camp Williams, Utah (Great Basin Cold Desert), US Army Ft. Bliss, Texas (Chihuahuan Desert), and 29 Palms Marine Base, California (Mojave Desert).

Keywords: LCTA, DoD land resources, ecotones, remote sensing-based measurement indicators, retrospective ecological risk assessment, land degradation

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Introduction to the Landscape Analysis Tools ArcView Extension

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Geographic Information Systems (GIS) have become a powerful tool in the field of landscape ecology. A common application of GIS is the generation of landscape indicators, which are quantitative measurements of the status or potential health of an area (e.g. ecological region, watershed or county). The generation of these indicators can be a complex, lengthy undertaking, requiring substantial GIS expertise. The Landscape Ecology Branch in cooperation with U.S. EPA Region 4 and TVA are developing a user friendly interface to facilitate this process. The Landscape Analysis Tools Extension is an easy to use ArcView extension that calculates many commonly used landscape indicators. By providing an intuitive interface, the extension provides the ability to generate landscape indicators to a wide range of users, regardless of their GIS knowledge level.

Four groups of indicators are included in the extension: landscape characteristics, human stresses, physical characteristics, and riparian characteristics. Each group has a dialog to accept user input on which indicators to calculate and what input data to use. Once indicator values have been created, the extension has three types of output display available. The first displays areas ranked by individual indicator values, the second ranks areas by an index made up of two or more indicators, and the third displays a bar chart of selected areas and indicators.

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Using Soil Characteristics from STATSGO to Extrapolate Water Quality Parameters from EMAP-SW

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The Environmental Monitoring and Assessment Program - Surface Waters (EMAP-SW) was developed by the United States Environmental Protection Agency to monitor and assess the conditions of the waters of the streams and lakes in the United States. Only a small number of lakes and stream segments can be field sampled and models are needed to extrapolate the sampled information to all surface water resources. The study region consisted of 13 Northeastern and Mid-Atlantic states and water quality parameters (WQP) were sampled in 721 randomly selected sites whose watersheds represented 7.1% of the area of the region. Soil characteristics (SC) from the State Soil Geographic Data Base (STATSGO) were aggregated from layers to a pedon and from pedons to a map unit and grouped into five general texture classes. Linear regression models related SCs from 400 watershed soil map units to the observed WQPs. Next, WQPS were extrapolated to all 882 map units based on the mean SCs of groups of map units having similar whole soil particle size within a texture class. The extrapolated WQPs produced relative standard errors that were, low for pH (0.8%); intermediate for dissolved organic matter (11.0%), total nitrogen (11.9%), total phosphorus (12.1%), turbidity (12.6%), silicate (13.6%), and acid neutralizing capacity (17.6%); and high for nitrate (28.5%), and sulfate (33.3%), and very high for chloride (54.8%). All errors were within the ranges of variabilities of the observed WQPs. These results demonstrate that observed WQPs can be predicted based on relationships with SCs in a region and models can be used to assess water quality conditions in EMAP-SW.

Keywords: water quality parameters, soil characteristics, environmental assessment

The Diamond Method for Partitioning the Surface of an Octahedron or Icosahedron for Use in Global Grids

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In recent years a number of methods have been developed for subdividing the surface of the earth to meet the needs of applications in dynamic modeling, survey sampling, and information storage and display. One set of methods uses the surfaces of Platonic solids, or regular polyhedra, as approximations to the surface of the earth. The diamond method is similar to recursive subdivisions of the triangular faces of either the octahedron or icosahedron. This method views the surface as either four (octahedron) or ten (icosahedron) tessellated diamonds, where each diamond is composed of two adjacent triangular faces of the figure. This method allows for a recursive partition on each diamond, creating nested sub-diamonds, that is immediately implementable as a quadtree, including the provision for a Peano or Morton type coding system for addressing the hierarchical pattern of diamonds and their neighborhoods, and for linearizing storage. Furthermore, the diamond method, in a four-fold hierarchy, provides direct access through the addressing system to the four-fold hierarchy of hexagons developed on the figure. The diamond method provides a nested hierarchy of grid cells for applications that require nesting and it has bilateral symmetry for those that require this property. Finally, the diamond method also can be cross-referenced with the hierarchical triangle partitions used in other methods.

Keywords: global grids, sampling networks

Comparison of ANOVA and Kriging in Detecting Ant Responses to Environmental Stressors

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In arid ecosystems, ants effect ecosystem functions such as water infiltration, soil nutrient distribution and composition of the soil seed bank. Ants have also been used as indicators of ecosystems health. In a study, we hypothesized that some ant species would respond to changes in vegetation characteristics by relocating their colonies, or by modifying their foraging behavior. We examined responses of ant species to environmental stressors (shrub removal and short-term intense seasonal grazing by domestic livestock) over four years period by comparing results from Analysis of Variance and kriging. The study site was located on the Jornada Experimental Range, Las Cruces, NM. Eighteen 0.5 hectare plots were arranged in two rows of nine plots that were blocked along the long axis. Ants were sampled by pitfall traps arranged in 7 x 7 trap arrays with 9.14 meter spacing between traps on each of the 0.5 hectare plots. ANOVA results indicated that abundance of ants was significantly different among years as a result of large differences in rainfall and temperature. Three species, *Conomyrma spp*., *Pogonomyrmex spp*. and *Forelius spp*. did not respond significantly to shrub removal, but they responded significantly to grazing x shrub removal interactions. The habitat structure changes resulting from shrub removal were hypothesized to have a larger effect on the structure and activity of the ant community than grazing by cattle.

Kriging maps demonstrated that spatial analysis can be used to detect changes on behavior of species that respond to environmental stressors. These patterns can be used in developing indicators of exposure to environmental stress.

Keywords: ants, ANOVA, kriging, indicators, grazing, environmental stressors

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Mass Selective Analysis of Natural and Pharmaceutically Derived Estrogens in Surface Waters Receiving Sewage Effluent

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The potential exists for pharmaceutically derived synthetic estrogens, used in oral contraceptives and hormone replacement prescriptions to be present in domestic sewage effluent. The fate and attenuation of these compounds, when discharged to surface waters, is not well characterized and their influence on aquatic biota as environmental estrogens is debated. Analysis of synthetic estrogens in surface water extracts is complicated by their exceedingly low concentrations in waters downstream from discharges. An estrogen-specific, mass selective analytical method is presented for quantitation of estrogens in surface waters at concentrations < 10 ng/L. This method provides a tool by which the fate and attenuation of estrogens from anthropogenic sources may be studied and possible exposure of aquatic biota estimated. It may also be useful for confirmational analysis of estrogens detected by larger scale monitoring for environmental endocrine disruptors.

Keywords: environmental estrogen, pharmaceuticals, sewage effluent, mass selective analysis

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