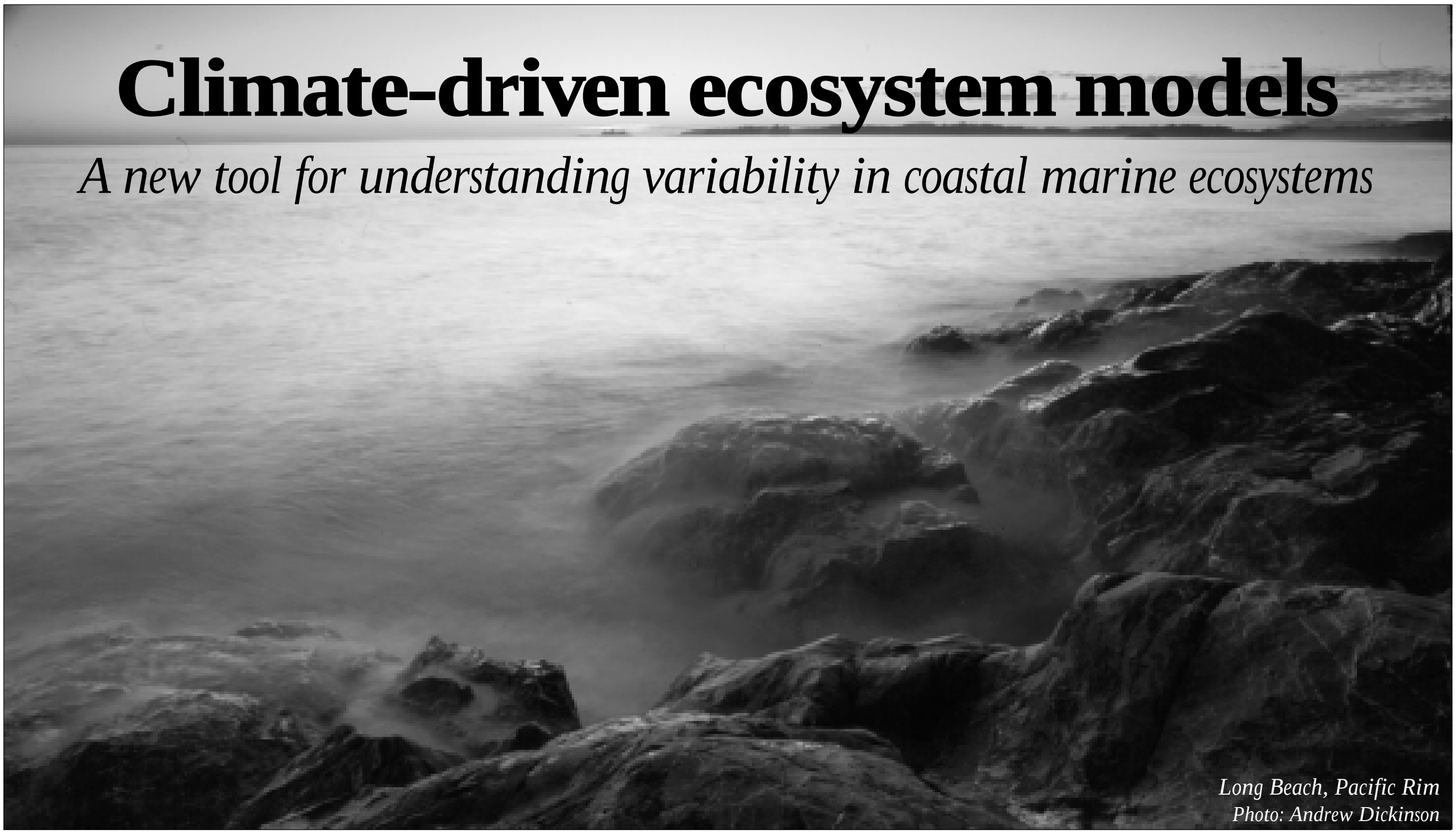
Research Links

A Forum for Natural, Cultural and Social Studies

Climate-driven ecosystem models

A new tool for understanding variability in coastal marine ecosystems



Long Beach, Pacific Rim
Photo: Andrew Dickinson

Clifford L.K. Robinson

The seemingly featureless surface of the ocean belies the incredibly complex interplay among hundreds of species beneath its surface. These mysterious ecosystems are extremely dynamic over space and time. Parks Canada requires tools that integrate what is known of key ecological and environmental processes to understand and manage human impacts on ecosystem structure and function. The development and application of Climate-Driven ECosystem (CDEC) models is one new approach that will assist in the integrated management of sustainable multispecies resource use and conservation in National Marine Conservation Areas (NMCA; see side bar, page 6).

In understanding ecological interactions in the coastal sea we should recognize that the physical oceanic environment (ocean climate) is the overriding process that most commonly affects nearshore ecosystem structure and function. Key components of ocean climate include water temperature, coastal upwelling of nutrients, and surface-mixing winds. The ocean climate off the British Columbia coast is influenced by atmospheric-oceanic processes operating at local (<10 km), regional (100s of km), and basin-wide (1000s of km) spatial scales, and at seasonal, interannual-decadal (e.g., El Nino events) and 20-30 year regime time scales (Robinson, *In press*).

The 70-year record of sea surface temperatures (SST) measured off coastal BC, for example, shows high interannual variability and a recent 23-year trend of warmer-than-average temperatures (Figure 1). Beginning in 1977 there was a marked shift to warmer oceanic conditions that has only recently (1999 and 2000) returned to the long-term cooler oceanic conditions. Although water temperatures in the 1980s and 1990s were at most only 1-2° C above the long-term average, Ware and MacFarlane (1995) estimated that with every 1° C increase in water temperature in summer, there was on average, a 40% increase in the Pacific hake (*Merluccius productus*) population off the west coast of Vancouver Island. This increase in hake biomass is significant because hake are the major fish predators of Pacific herring (*Clupea harengus pallasi*) and the euphausiids (zooplankton). Herring and euphausiids are keystone prey for many species of fish, seabirds and baleen whales.

Climate-driven ecosystem models can assist managers in understanding natural ecosystem variability and in assessing the consequences of activities such as pollution, fishing and logging on coastal marine ecosystem structure and function. CDEC models require information about key species life history components (e.g., growth

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Research Links

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FEATURE ARTICLES

DEPARTMENTS

FRANCOPHONES

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UPCOMING DEADLINES

SUM/AUT 2001 — March 30, 2001
WINTER 2001 — July 27, 2001

EDITORIAL

Parks Canada's responsibility for managing national parks and national historic sites is evolving to include marine environments in coastal national park reserves and proposed marine conservation areas. We have much to learn about our marine ecosystems, but new tools and ongoing research are leading to more effective policies, planning and decision making.

Ecosystem based approaches are relatively new to coastal environments and in many instances baseline research (such as species identification, distribution analysis and habitat mapping) has not been done. Collaborative approaches with the provincial government, other federal departments (DFO; DOE; DND); universities; museums and First Nations are proving vital to achieving results and success. The development of new tools will be critical to provide managers with cost-effective ways of inventorying and monitoring coastal areas.

This issue of *Research Links* features several articles that describe strategies for obtaining and analyzing coastal/marine data. Cliff Robinson applies climate driven ecosystem models to illustrate the complexity and variability of marine ecosystems. Long-term understanding of these processes will be vital to working towards ecosystem based approaches for coastal national park and marine conservation area management. Norm Sloan and Patrick Barter describe how the Marine Species Biodiversity Program for Gwaii Haanas provides a definitive framework which will identify the plant, invertebrate, bird and fish species found in the Gwaii Haanas area. The database is the starting point for understanding marine ecosystems that can lead to descriptions of ecosystem form and function.

New information is arising from a variety of sources. Paleoecological research in coastal BC's national park reserves is providing scientists and managers with the long term evolutionary picture of what is happening with plant and animal communities. Marlow Pellatt's article interprets the results of pollen analyses and indicate how understanding changes in ancient plant community structure respond can help us predict future climate change. In preparing for the marine conservation area feasibility study, Tom Tomascik and Cliff Robinson analyzed SCUBA log data to extract information on species abundance and distribution in the Strait of Georgia. They concluded that historical dive log entries can provide managers with useful ecological data that may be used to assess the status of a species or to apply harvesting restrictions.

Research in marine environments also has to look at the impacts of users. In his article on marine wildlife viewing, Peter Clarkson discusses efforts to monitor ecotourism and the effectiveness of voluntary guidelines. More complete assessments of the impact of ecotourism on marine wildlife populations are longer-term objectives.

The journey to understand our marine environment has just begun. Sylvia Earle, former chief scientist of NOAA (National Oceanic and Atmospheric Administration) and now National Geographic explorer, noted recently that our marine environment is still 75% unexplored. Parks Canada is making changes in how we manage our cultural and natural landscapes. Are we challenged to make a difference in our coastal and marine environments as well?

Brian MacDonald
Manager, Ecosystem Services-Coastal, Parks Canada Western Canada Service Centre, Vancouver, BC

RESEARCH HIGHLIGHT

Osprey Research in the Rocky Mountains

Mark Wayland

Without question, many species of North American birds have benefited from strict North American regulations, first implemented in the 1970s, banning or severely curtailing the use of persistent organochlorine pollutants such as DDT. The osprey, a fish-eating, raptorial bird, is one such species. In eastern North America, osprey populations were decimated by organochlorines during the 1960s. Now that North American organochlorine levels have subsided considerably, ospreys are making a strong comeback. However, recent news suggests that the picture may not be as rosy as it seems. Analysis of dated glacial cores indicates that organochlorine pollution is increasing in high elevation areas in the Rocky Mountain Parks, in some cases, resulting in pollution levels in fish that exceed guideline levels for protecting fish-eating wildlife. Apparently, these pollutants originate in other countries where regulations are not as strict. The atmospheric pollutants are carried by prevailing winds to colder climates where they condense out and are trapped in snow until snowmelt releases them into the surrounding ecosystem. Just a few years ago, osprey eggs from a couple of locations in south-central British Columbia had levels of DDE, a metabolite of the notorious pesticide, DDT, that approached those known to impair reproduction.

Why is this happening? Unfortunately no-one knows for sure. It could be that these migratory birds are picking up pollutants on their wintering grounds in Mexico and South America and storing them in fat tissue, only to deposit them in eggs after returning to North American breeding areas. Increasing levels of pollution in cold, high elevation areas of western North America may also be adding to the problem.

In 1999, Environment Canada, with the co-operation of Parks Canada and Alberta Fish and Wildlife, started to examine whether osprey in the Rocky Mountains are at risk from exposure to these pollutants. Contract biologists, Mike Miller and Jonathan Keating, with the help of climbers, Paul Vidalin and Peter Amman obtained single eggs from nine nests located in or near Alberta's mountain national parks. Preliminary results were encouraging – contaminant levels in these eggs were well below concentrations that cause reproductive failure. Similarly, concentrations of contaminants in blood samples collected from nestlings later in the summer were very low.

During the summer of 2000, biologists and climbers sampled four more nests, one each at Peter Lougheed Provincial Park, Mount Robson Provincial Park, Bow Lake in Banff and Pyramid Lake in Jasper. Because osprey eat fish exclusively, biologists also collected fish from all the lakes and rivers that were sampled in 1999. The osprey samples and fish will be analyzed in the coming months. This data will allow biologists to examine relationships between contaminant levels in osprey and their diet. Once these relationships are worked out, it may be possible to predict contaminant levels in osprey from what is found in the fish.

The results of this study, together with a simultaneous companion study in British Columbia, will help biologists assess whether pollutants are hazardous to osprey in western Canada's mountainous areas.

Mark Wayland is a wildlife biologist with Environment Canada in Saskatoon. He studies the levels and effects of pollutants in wildlife throughout the prairie provinces and Northwest Territories.

Photo: Heather Dempsey

Osprey chick

CORRECTION

Due to an oversight, the authors of "Have We Crossed the Threshold?" Site Development and Cumulative Impacts on National Historic Sites," (*Research Links 8[2])* failed to reference the case study discussed in the article. The study that formed the basis of the article is cited below:

Downie, P. and P. Priess. 1998. Cumulative impact on Cultural Resources at St. Andrew's National Historic Site, Manuscript on file at the Western Canada Service Centre, Parks Canada Western Canada, Winnipeg, MB.

The authors apologize for their oversight.

- David Hems and Paul Downie

UPDATE...

Parks Canada Agency has released the 1999 report on the state of protected areas:

Parks Canada Agency. 2000. State of Protected Heritage Areas 1999 Report. 75 pp.
ISBN: 0-662-29503-X
Cat: R61-15/1999E

Available on the Parks Canada main website:

http://parkscanada.pch.gc.ca/library/SOP/main_e.htm

Mass Movements and Mortality of Tiger Salamanders

on the Trans-Canada Highway in Southwestern AB

Anthony Clevenger, Mike McIvor, Diane McIvor, Bryan Chruszcz and Kari Gunson

The tiger salamander (*Ambystoma tigrinum*) is the most widely distributed amphibian in North America. Populations are found in the province of Alberta south of Edmonton, and from the eastern slope foothills to the Saskatchewan border (Russell and Bauer 1993). The species breeds in almost every month of the year, depending on subspecies, latitude and elevation (Petranka 1998), but mating in the northern latitudes generally occurs after early spring migration to breeding sites. Rarely seen in the open except during breeding season, tiger salamanders are primarily nocturnal and active from early spring to early autumn in Alberta.

Movement patterns of ambystomatid salamanders are particularly unclear since most their life cycle is spent in subterranean burrows and they congregate only briefly at aquatic breeding sites (Duellman and Trueb 1986). Seasonal patterns of migration from terrestrial environments to breeding areas are well documented (Semlitsch 1985), yet movements after the breeding season are poorly understood (Hairston 1987; Whiteman et al. 1994). Here we report on the mid-season movements and mortality of tiger salamanders in a major transportation corridor on the periphery of Banff National Park, Alberta. This work was part of a larger study quantifying road-related mortality of small- and medium-sized vertebrates.

METHODS

The study area was within the Montane ecoregion of the Bow River Valley, the terrain is relatively flat, with little topographic relief. A small pond and a lake (Chilver Lake) are located on the south side of the Trans-Canada highway, while another lake (Middle Lake) is on the north side of the highway (Figure 1). The distance between Chilver Lake and Middle Lake is approximately 1.7 km. Tiger salamanders have been observed recently in all three water bodies (A. Clevenger, wildlife researcher, personal observation*; but see* Salt 1979).

Between the months of April and November in 1997, 1998, and 1999, we systematically surveyed roads by vehicle in Banff National Park and Kananaskis Country, collecting data on road mortality of small- and medium-sized vertebrates. One of two routes surveyed the Trans-Canada highway from the Banff townsite to the junction of Highway 40. Surveys were alternated each day, commenced <1 hr after sunrise, and were conducted by two observers, one driving 10 km/hr below the posted speed limit, while the other searched for road-killed salamanders and other vertebrates. We observed road-killed tiger salamanders on the Trans-Canada highway west of the town of Seebe (51º04'N, 115º04'W; Figure 1) during July 1998, August 1999, and September 1999. All road kills were recorded within a 1.05 km stretch of highway consisting of 4 lanes of traffic and an open grass-covered median (total width 43 m).

We identified the high-kill concentrations on the eastbound and westbound lanes to assess whether road-killed salamanders were traveling in a specific direction. We described the spatial distribution of the salamander road-kills using spatial statistics software (Levine 1999). A cluster analysis was performed to determine where the majority of kills occurred in the eastbound and westbound lanes. We used sample sizes of 92 (eastbound) and 19 (westbound) road-kills to produce 2 clusters. We ran a line between the mean centers of the clusters to approximate the direction the salamanders traveled as they moved across the highway.

RESULTS AND DISCUSSION

We found and collected one road-killed tiger salamander in the westbound lane (north side) of the Trans-Canada highway west of the town of Seebe on July 28, 1998. The following year a minimum of 183 road-killed tiger salamanders were counted at the same location as the year before on 8 days between 11 August and 11 September 1999. The total number of salamanders killed on the roadway this year was obviously much higher. While counting and removing the road-killed specimens from the pavement, we observed additional tiger salamanders approaching the road and unsuccessfully attempting to cross it. All live salamanders were observed moving across the highway in a northerly direction. Further, the road-killed salamanders appeared to be traveling in the same direction prior to being hit by vehicles. High traffic volumes on this section of the Trans-Canada highway during summer (mean daily traffic volume = 21,450 vehicles/day) made it difficult for the slow-moving salamanders to survive the highway traverse.

Late-season tiger salamander movements were random across a Michigan highway; however, there were no nearby ponds or lakes in the area (Duellman 1954). The movements we observed across the TCH were predominantly northbound and in the direction of Middle Lake. We base this conclusion on our observations of tiger salamander movement and the high number of road-killed salamanders on the south side (83%, n=111) of the highway as opposed to the north side.

Tiger salamander kills were distributed on both sides of the highway, although most kills were concentrated in a 300 m section (Figure 1). Movement was concentrated in one area and primarily in one direction suggesting that seasonal migrations, breeding or otherwise, were occurring. Previous studies reported consistently that breeding and non-breeding season movements of tiger salamanders are triggered by environmental factors, precipitation

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The Marine Species Biodiversity Program for Gwaii Haanas

Norm A. Sloan and Pat M. Bartier

In preparation for Gwaii Haanas acquiring a marine area, a marine inventory program is underway for this poorly known region (Sloan and Bartier *submitted*). The "Living Marine Legacy" series will be a multi-volume set issued by Parks Canada bringing together all the historical, georeferenced baseline marine species biodiversity data on Haida Gwaii (Queen Charlotte Islands). Individual volumes on plants (Sloan and Bartier 2000 – Volume I), invertebrates (II), birds (III) and fishes (IV) are underway and volumes on mammals, plankton and oceanography are planned. In the preparation for each volume, we maximize the application of our geographic information system (GIS) in a spatio-temporal database of the historical records. Other information types for the volumes include a complete bibliography, regional natural science history, local First Nations (Haida) knowledge, marine resource extraction data and any special management issues such as species at risk. All databases will eventually be accessible on the internet.

In keeping with Parks Canada policy (Parks Canda 1994), coverage is regional (Haida Gwaii, not just Gwaii Haanas). We maximize the amount of information assembled despite differing reliability of sources. Strictly speaking, the species diversity of Haida Gwaii is confined to species for which vouchered specimens are catalogued in museums or herbaria. Our approach includes *all* published and unpublished "grey" literature. Species records based on specimens in institutional collections are separately flagged in the database.

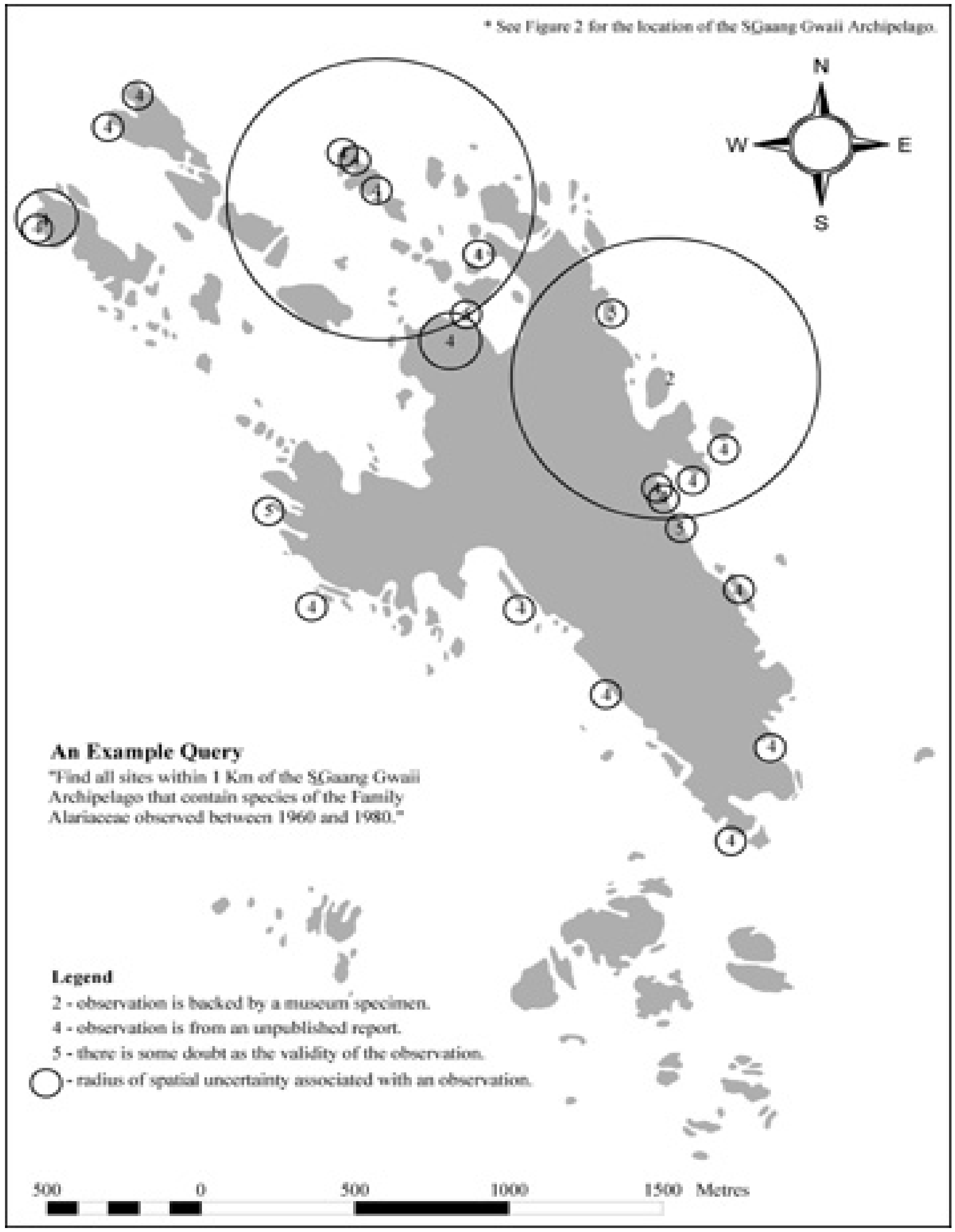

Figure 1. Example of a database query on a brown seaweed Family Alariaceae from SGaang Gwaii (Anthony Island) archipelago.

The database is a starting point for our understanding of components of regional ecosystems. Such inventories address management objectives by:

- advising on the status (including gaps) of knowledge on species biodiversity;
- establishing reliable, accessible baselines for all to build upon; and
- enabling North Pacific regional biodiversity comparisons by scientists.

Species lists are interesting to specialists, but an inventory's appeal is broadened by discussing management applications of such information according to Parks Canada's mandate and making recommendations. The broad coverage in each volume provides "one-stop shopping" for a mixed audience of agency, industry, NGO, lay public and First Nations. Further, the electronic database is structured to enable enquiry by individuals with differing interests. Eventual zonation will be the product of complex negotiations for which a common science baseline will aid discussions. For example, ensuring that certain species coexist with commercial marine harvest within Gwaii Haanas will be a pivotal long-term management issue.

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Background on

National Marine Conservation Areas (NMCA)

In 1986, Parks Canada adopted a policy to protect and conserve national marine areas of Canadian significance. These areas represent the country's three ocean environments and the Great Lakes. The policy also encourages public understanding, appreciation and enjoyment of marine heritage. The resulting National Marine Conservation Areas (NMCA) Program identified 29 marine regions, including 5 on Canada's Pacific coast. Parks Canada intends to establish an NMCA within each region according to the NMCA system plan – Sea to Sea to Sea (Mondor and Mercier 1995). The proposed NMCA adjacent to Gwaii Haanas National Park Reserve (GHNPR), British Columbia, covers 2 marine natural regions.

An important difference between Parks Canada's NMCA policy and terrestrial park policy is that NMCAs will be *managed and used in a sustainable manner* that meets the needs of present and future generations without compromising the structure and function of the ecosystems. This means that renewable resource extraction activities such as fishing will be allowed in NMCAs. Ecologists at the Western Canada Service Centre in Vancouver are trying to understand natural variability of nearshore pelagic and benthic ecosystems, and to separate the effects of human activities in the oceans (e.g., fishing), and on land (e.g., logging) from this background variability. This distinction is important so Parks Canada can uphold our mission to ensure the ecological sustainability or viability of coastal marine ecosystems is not compromised by human activities.

Climate-driven ecosystem models

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rates), and some general ideas about how they respond to ocean climate. Life history observations of species, and their feeding interactions, are mathematically incorporated into a computer simulation model and linked to observed ocean climate time series. A CDEC model can estimate weekly, seasonal and annual changes in biomass, production, growth, and mortality of key higher trophic levels. Once the model output is in agreement with present-day observations, the model can be run backwards in time to see how outputs vary with known changes in oceanic factors such as El Nino events (See diamonds in Figure 1). State-of-the-art ecosystem modelling cannot yet forecast precisely how the internal structure and productivity of a marine ecosystem will change in response to some major shift in ocean climate, the demise of a key species, or the successful introduction of an exotic species. However, as more empirical ecological knowledge is gained and incorporated into technologically more advanced CDEC models it is anticipated that the predictive power of this approach will increase dramatically.

Ecologists at the Western Canada Service Centre and Fisheries and Oceans Canada have developed an operational CDEC model for pelagic marine ecosystems adjacent to Pacific Rim National Park Reserve, and are working on a conceptual CDEC model for marine ecosystems within the proposed Gwaii Haanas National Park Reserve NMCA. Robinson and Ware (1999) discuss in detail the development and output from a CDEC model that has been used to explore linkages between ocean climate variability and zooplankton-pelagic fish production near PRNPR. The species interactions and major oceanic processes included in the CDEC model are shown in Figure 2. The model estimates the daily values of phytoplankton, copepod, and euphausiid biomass and production as they would change with weekly changes in water temperature, solar radiation, and upwelling conditions, and by seasonal changes in fish biomass. Recent comparisons of simulation results with empirical data indicate the model can account for relative interannual changes in copepod biomass, euphausiid biomass and production, the consumption

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Figure 1 (above). The sea surface temperature (SST) anomaly as calculated from measurement taken at Amphitrite lighthouse near Pacific Rim National Park Reserve (PRNPR) off the west coast of Vancouver Island over the past 70 years. The anomaly is calculated by subtracting the 70-year average June-September SST from the SST calculated for a given year, and dividing by the 70-year standard deviation. Positive anomalies indicate higher than average water temperatures, while negative anomalies indicate lower than average. The diamonds indicate years of strong El Nino (surface warming) events in the NE Pacific ocean (see http://www.ogp.noaa.gov/enso/ for more information on El Nino events).

Climate-driven ecosystem models

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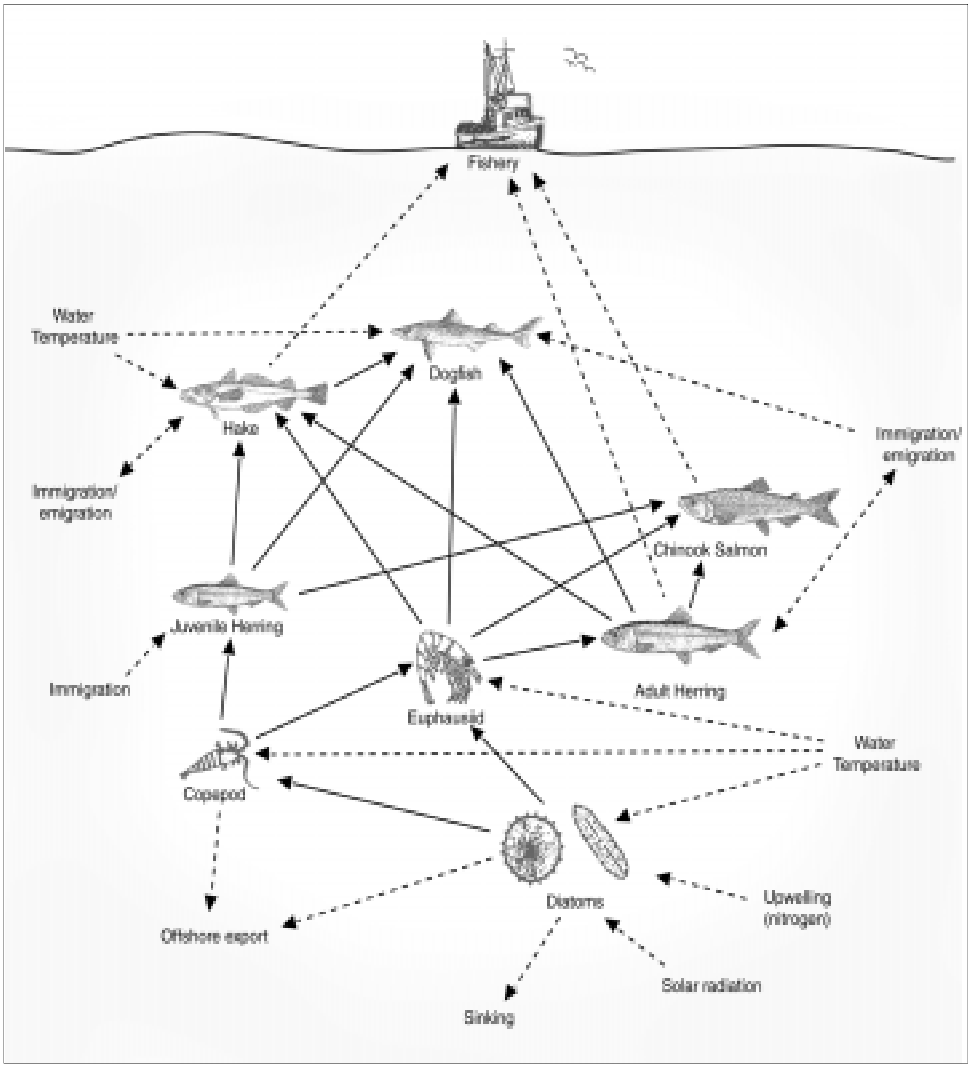

Figure 2.

Conceptual overview of a climate driven ecosystem model for pelagic marine ecosystems adjacent to Pacific Rim National Park Reserve. Solid lines indicate feeding interactions among key trophic groups, while dashed lines indicate non-feeding interactions such as the influence of water temperature on migrations.

of herring by Pacific hake, and the growth condition factor of Pacific hake. A measure of overall model performance suggests the CDEC model performs equally well in periods of strong versus weak upwelling (Robinson and Ware 1999).

How can CDEC model output be used by Park managers? Model output can be used to monitor the response of the ecosystem to natural variability in ocean climate. This allows researchers to understand how ecosystem structure and function could have responded to climatic change alone in comparison to changes imparted by human activities. A good example of model output describes temporal changes in the euphausiids. Euphausiids are typically the most important prey for most species of fish (Robinson 2000), seabirds, and some whales such as humpbacks found off the west coast of Vancouver Island. Empirical evidence suggests large aggregations of euphausiids occur because of upwelling currents, and the euphausiids in turn, attract large aggregations of predators. The Pacific Rim CDEC model generated an annual index of euphausiid biomass and production as determined by interactions between ocean climate processes and predator-prey interactions (Figure 3). Simulated euphausiid biomass was corroborated against field data collected in Barkley Sound by Ron Tanasichuk (Fisheries and Oceans Canada, Nanaimo, BC), and we found a statistically significant relationship between observed and simulated euphausiid biomass for August of each year from 1991 to 1997 ($r = 0.87$; $p < 0.01$). When the model is run backward in time it gives park managers a sense of how variable the production of a keystone prey species has been over 30 years, and indicates anomalous production in any given year. Note the extremely low production of euphausiids in 1997 associated with the strongest El Nino event ever recorded. The simulated low production of euphausiids in 1997 is consistent with observations of low survival and growth of euphausiids dependent species such as herring, juvenile coho salmon and auklets. Gaming with the CDEC model demonstrates how various human activities such as fishing impact

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Mass Movements and Mortality of Tiger Salamanders

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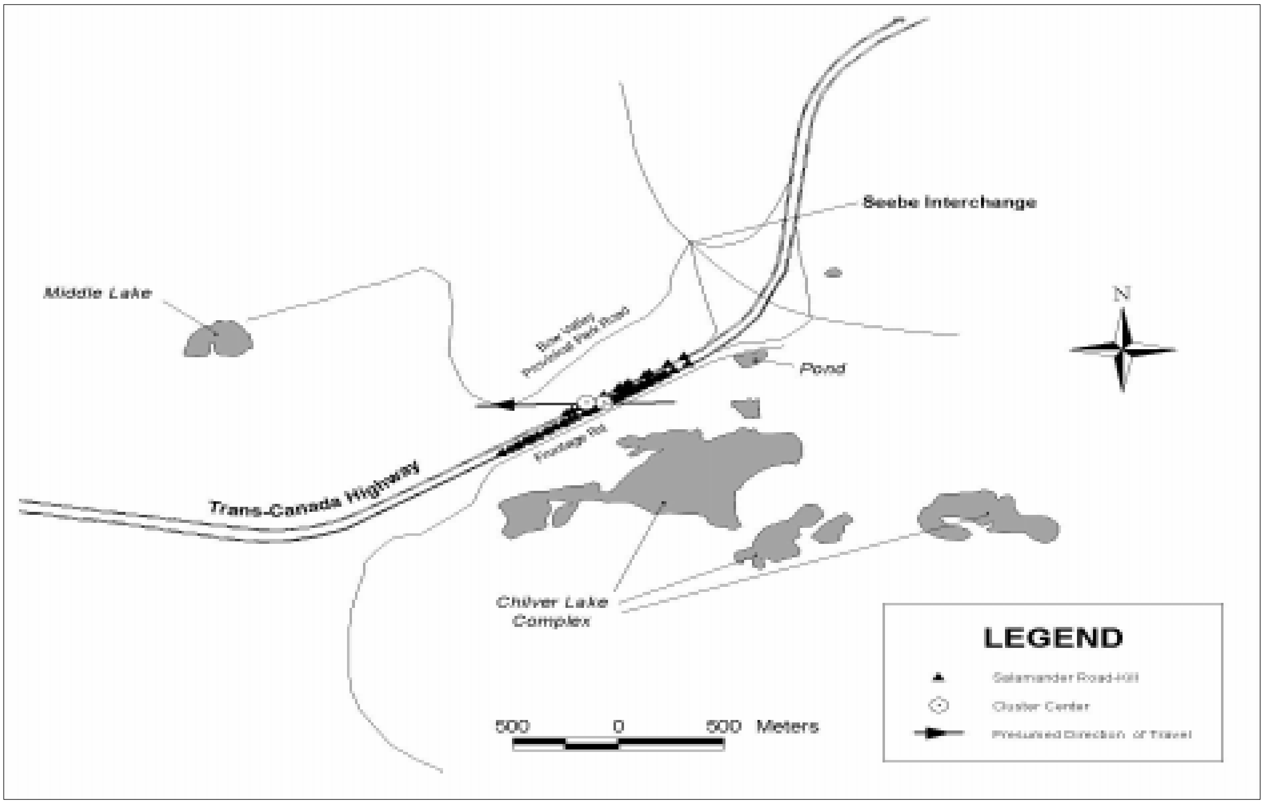

Figure 1. Location of tiger salamander road-kills along the Trans Canada highway, Kananaskis Country, AB.

and temperature particularly (Petranka 1998; Whiteman et al. 1995; Duellman and Trueb 1986; Semlitsch 1983). Pre-breeding movements would normally take place several months earlier and would have been detected during previous road surveys. Mid-season movement between ponds could explain the phenomenon, although it is unclear what triggered the salamanders' move during one year and not others.

The centers of road-kill clusters for east and westbound lanes were offset, indicating that salamanders were apparently crossing the highway at an oblique angle and not straight across. In Figure 1, the arrow implying the general direction of travel shows that movement was in the direction of Middle Lake, but not directly aligned. It was noteworthy that the greatest concentration of salamander movements across the Trans-Canada highway occurred at the highest point in the road and where the highway passed closest to Chilver Lake.

WEATHER

Although there is universal agreement that particular meteorological conditions elicit migratory behavior in tiger salamanders, few studies have noted the specific ambient measures much less test their relationships with movements (Semlitsch 1983; Duellman 1954). In our study area, during the first and most important pulse in salamander movement across the Trans-Canada highway, 17 mm of precipitation fell in less than 24 hours and temperatures ranged from 6.5°C to 17.0°C (University of Calgary Field Station, Kananaskis Country, Alberta).

In 1999 we found tiger salamander movement to be related to heavy rainfall events and warm weather; however, the previous year there were favorable meteorological conditions for salamander movements but we did not detect any migration across the highway. Some questions remain unanswered and will require additional information during subsequent movement events in this area to better understand the phenomenon we observed.

It is not clear whether the mid-season movements we observed were pre-breeding or post-breeding. In relatively northern latitudes breeding occurs from late February through April (Petranka 1998). However, at high elevation ponds in Colorado and Utah, breeding may be as late as July or August (Whiteman et al. 1994; Wissinger and Whiteman 1992; Worthylake and Hovingh 1989). Our study area is near the northern limit of the species' range. If annual movement patterns depend on a particular regime of precipitation and temperature, favorable conditions providing opportunities for migrations in the study area in any given year or between years may be variable and few. If the movements were post-breeding, the reason for the sudden eruption in movements away from Chilver Lake is unclear. They may have been moving to hibernation quarters (Hassinger *et al.* 1970; Fowler 1935) or moving between lakes as a result of density-dependent dispersal. There is some evidence to suggest that amphibian populations range widely for resources, and large scale dispersal events can occur when populations

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Mass Movements and Mortality of Tiger Salamanders

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reach a density threshold (Langton 1989)

There is no historical information on tiger salamander movements in this part of the species' range, nor do we know how frequently movement events of this type have occurred in the past, if at all. In order to assess the potential impacts of the Trans-Canada highway on the persistence of tiger salamander populations in this area, the regional conservation value of the existing ponds and lakes must be determined. Information on the tiger salamander distribution and degree of habitat connectivity in the area will help us understand tiger salamander metapopulation structure and human impacts. At a local level, new data will help us determine the significance of Chilver and Middle Lakes for salamander persistence.

Amphibian populations are naturally variable over time and this can obscure effects of human impacts. Long term studies are needed to differentiate natural variation from changes caused by humans. We recommend that monitoring continue in the Trans-Canada study area, and over a larger area, to better define the species' distribution, confirm breeding site locations, and investigate relationships between bio-physical variables that might elicit salamander movements that potentially conflict with transportation corridors.

Proactive measures could be taken immediately to reduce road mortality of tiger salamanders in the study area by getting animals safely under the highway and still allow natural movements. A 0.75 cm diameter metal culvert is favorably located under the highway less than 50 m from the road-kill cluster centers, and in its present state, with temporary drift fencing, could be adapted seasonally for salamander passage. Tiger salamanders are not philopatric to natal ponds and quickly colonize newly constructed ponds (Petranka 1998). Therefore measures to reduce mortality by creating new habitat on the Chilver Lake side of the highway to discourage cross-highway migrations also could prove effective at reducing salamander mortality.

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Marine Species Biodiversity Program

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Gwaii Haanas' species inventory databases are adapted, in part, from the model developed by the Association for Systematic Collections for managing specimen collections at museums and herbaria (CNC, 1997). Instead of managing specimen collections, however, Gwaii Haanas' databases are designed for managing observations where an observation can represent a museum specimen or a sighting in an unpublished report. The databases incorporate the following design features:

- taxonomic hierarchy – observations can exist at any taxonomic level or be grouped according to phylogenetic relationships;
- location- each observation has spatial coordinates permitting analyses and integration with other data geographically;
- observation dates – these dates permit temporal queries and time-series analyses;
- references – a source citation (ideally bibliographic) exists for each observation; and
- indicators - characteristics such as estimated spatial accuracy and observation quality, are provided for every observation.

Figure 1 illustrates a spatio-temporal query incorporating these features. The reliability of the species identification is indicated and the spatial uncertainty by circle size. Uncertainty is estimated qualitatively on the basis of original site descriptions (often narrative) and original scale of collection (e.g., a 1 mm mark on a 1:50,000 scale map indicates ± 50 m on the ground).

Our database design supports basic activities such as inventory of species and perhaps of assemblages/communities. The database design could perhaps be extended to support more advanced and complex approaches such as examining biodiversity in terms of composition, structure and function (Noss, 1990) or in terms of taxonomy, genetics and ecology (Angermeier and Schlosser, 1995). At this early stage of development, our database scheme supports the composition and taxonomy components of these approaches. With more sophisticated development, the database could perhaps be extended to support ecosystem structure and function such as defining trophic relationships between species or groups of species.

As a working example of database application, plant species diversity can provide improved insight into intertidal shore exposure status. Sloan and Bartier (2000) illustrate rocky intertidal sites around SGaang Gwaii (Anthony Island), at which the dominant conspicuous plant species were recorded and their presence correlated with the site's wave exposure classification acquired from shore orientation, prevailing wind direction and shore morphology analyses by Harper *et al*. (1994). Sloan and Bartier's more detailed conspicuous species data revealed variation within Harper's wave exposure classification at specific sites. A refinement of plant species presence/absence data improved shore exposure assignments (Sloan and Bartier *submitted*).

CONCLUSIONS

Our inventories cover the region's species diversity, respect Aboriginal knowledge, facilitate sophisticated time/space enquiry and discuss relevant technical conservation issues. Further, they support the critical public consultation process by helping level the science information "playing field". The inventories are step 1 in a long-term process in the execution of Parks Canada's mandate to understand marine ecosystem structure and function while permitting multiple sustainable uses. As Ray (1996) commented, "*A profound problem for conservation is that there is very little information about the relationship between species diversity and ecological function*." That is, we will need to evolve from the present exploratory/descriptive phase (the *WHAT*) to a future process/explanatory phase (the *HOW*).

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Fish Assemblages of the Southern Gulf Islands, BC

An analysis of recreational SCUBA dive log data

Tomas Tomascik and Clifford L.K. Robinson

The planning, establishment and management of National Marine Conservation Areas (NMCAs) will require a wide variety of data and information on the diversity of species, communities and ecosystems. Two major issues limit the effectiveness of collecting biodiversity data in coastal marine regions. First, marine ecosystems are highly dynamic in space and time, and thus they require methods that can rapidly and accurately assess biodiversity. Second, field sampling of marine biodiversity is extremely expensive and thus will require methods that can be used consistently and frequently at relatively low cost and with minimal to no impacts on the ecosystems.

One method of assessing marine biodiversity that meets the above criteria is using the observations of recreational SCUBA divers. Standard protocols for conducting volunteer dive surveys have been developed in 1993 by REEF (Reef Environmental Education Foundation) with support from The Nature Conservancy (Pattengill-Semmens and Semmens 1999). The Roving Diver Technique used by REEF employs volunteer divers and/or snorkelers that freely swim through a dive site and record every observed fish species (Schmitt and Sullivan 1996). Participants are encouraged to look under ledges and up in the water column. REEF surveys have already been conducted effectively in Florida, Caribbean, Bahamas, California, Oregon, Washington and British Columbia. The technique has also been very successful in a number of marine protected area studies (Pattengill-Semmens *in press*; Pattengill-Semmens and Semmens 1998). The REEF data are currently being used to evaluate the effects of Marine Protected Areas (i.e., no-take zones) in the Florida Keys National Marine Sanctuary. Researchers used the data to generate species distribution lists that helped them identify temporal shifts in species distribution and GAP analysis for Marine Protected Area siting (Pattengill-Semmens and Semmens 1999). In general, underwater visual census methods are non-destructive means of rapidly studying the structure of shallow-water marine fish communities.

The main objective of this study was to assess whether visual fish surveys conducted by recreational SCUBA divers, trained in fish species identification, can provide Parks Canada with meaningful biodiversity information. We addressed 3 main questions: Can recreational SCUBA diver log data be used to obtain historical information on marine fish biodiversity within NMCAs? Can recreational SCUBA divers be used to define the faunistic features of local fish communities? Are fish assemblages identified from SCUBA surveys correlated with measures of habitat diversity such as water column stratification and maximum tidal current flow?

STUDY AREA & METHODS

The southern Gulf Islands, located in the southern Strait of Georgia, are the focus of a Parks Canada NMCA feasibility study (see side bar). The islands are within the Vancouver Island rain shadow, and consequently the local climate is significantly drier and milder when compared to the mainland. There is relatively little freshwater input from the islands into the marine system. The geology of the southern Gulf Islands is generally dominated by sedimentary rocks belonging to the Nanaimo Group, which formed during the Cretaceous about 140 million years ago (Mya). The current physiographic setting of the southern Gulf Islands can be traced back 55 Mya to the compression of the Kula Plate against the North American Plate (Cannings and Cannings 1999). The islands were originally part of Vancouver Island, but became detached during the past million years by the action of advancing and retreating glaciers, that shaped the islands over four glacial periods (Thomson 1981). The complex physiography has a pronounced effect on oceanographic processes and thus

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NATIONAL MARINE CONSERVATION AREA

Feasibility Study

The establishment of Marine Protected Areas (MPAs) has received considerable scientific, media and public scrutiny within the past decade (Agardy 1997). In Canada, three federal agencies, Environment Canada, Fisheries and Oceans Canada and Parks Canada, are actively involved in the management, conservation and protection of marine biodiversity. Each department has a distinct but complementary role in protecting Canada's offshore and coastal ecosystems. Under the *Oceans Act*, the Minister of Fisheries and Oceans has the lead role in co-ordinating the development of a network of marine protected areas. In 1995, Canada and British Columbia signed the Pacific Marine Heritage Legacy agreement, which envisions the establishment of a system of marine and coastal protected areas along the Pacific Coast. The process to establish a system of marine protected areas along the West Coast is outlined by a draft MPA Strategy for the Pacific Coast of Canada, which was collaboratively developed by six federal and provincial agencies (Canada and British Columbia 1998). In 1998, Canada and British Columbia jointly announced the commencement of a National Marine Conservation Area (NMCA) feasibility study in the southern Gulf Islands, southern Strait of Georgia. NMCAs are part of a family of protected areas administered by Parks Canada to protect and commemorate the country's natural and cultural heritage. The objective of the NMCA Program is to protect and conserve for all times marine areas that are representative of the country's 29 natural regions in its three oceans and the Great Lakes, and to encourage public understanding, appreciation, and enjoyment of this marine heritage so as to leave it unimpaired for future generations (Parks Canada 1995). NMCAs strive to balance ecosystem protection, conservation and sustainable use of renewable natural resources and are accessible to all Canadians for recreation, tourism and learning.

Fish Assemblages of the Southern Gulf Islands

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significant influence on marine biodiversity of the region.

The present study is based on historical dive log data from the southern Gulf Islands, obtained by Parks Canada in 1999 from Andy Lamb, Donna Gibbs and Charlie Gibbs who are associated with Pacific Marine Life Surveys Inc. (PMLSI 1999). Andy Lamb, with 1,880 dives on his record, is the author of "*Coastal Fishes of the Pacific Northwest*" (Lamb and Edgell 1986), a seminal marine fish identification book for BC waters. Andy Lamb is also involved in marine educational programs with Vancouver Aquarium Marine Science Centre. Donna and Charlie Gibbs have 1,300 dives between them and are involved in marine educational programs in BC. Donna Gibbs is also associated with educational programs at Vancouver Aquarium Marine Science Centre. The 408 dive log entries obtained from PMLSI span 32 years (1967-1999) and were grouped into 18 dive areas based on their proximity to one another, habitat descriptions obtained from the dive logs, and discussions with PMLSI members. The dive sites included in this study represent a wide variety of habitats (e.g., muddy slopes, seagrass beds, rocky reefs, kelp bed, etc.) ranging from sheltered to exposed sites, and from bays to straits. The survey technique used in the present study is similar to the Roving Diver Technique.

The PMLSI dive survey technique differed from the Roving Diver Technique discussed above in that the observations made during a dive were recorded after the dive in a debriefing session. After each dive, observed species were enumerated according to the relative abundance of observed individuals. Seven abundance classes were used consistently throughout the log entries: 0 - none; 1 - few; 2 - some; 3 - many; 4 - very many; 5 - abundant; and 6 - very abundant. The scores for each species per location were pooled, multiplied by 100 and divided by 6, thus giving a relative abundance figure between 0 and 100.

To assess whether we can expect increased species richness as more in-depth studies are conducted in the area in the future, we constructed a species-dive curve, which is similar in concept to a classical species-area curve. We found a positive relationship (asymptotic curve) between species richness and the number of dives conducted at each of the 18 dive areas. The curve starts to level off at around 30 dives, suggesting that additional dives would reveal few additional species. However, since there were fewer than 30 dives in the majority of dive areas, we expect more species will be recorded as the number of dive surveys in those areas approaches 30.

Species diversity of each of the 18 dive areas was assessed by species richness (i.e., number of species in the community) and by the Simpson's Index (1-D) (Krebs 1999). Species evenness was measured by the Smith and Wilson's index of evenness. (Krebs 1999). Relative abundance data from the 18 dive areas were analysed by the Kulczynski dissimilarity measure (SYSTAT 1996). To assess faunistic similarities among the 18 dive areas in the study, and to search for spatial patterns, cluster analysis was performed on the Kulczynski's dissimilarity matrix using Ward's minimum distance method (SYSTAT 1996).

Habitat diversity was computed for each of the 18 dive areas by counting the different habitat types for each dive site. For the purpose of this study, habitat is defined as a dwelling place (i.e. place that provides whatever a species needs to survive) and includes such features as caves, vertical walls, seagrass beds, rocky outcrops, etc. Mike Foreman (Institute of Ocean Sciences, Sidney, BC) provided information on tidal currents and water column stratification. Maximum tidal current velocities were assigned to each dive area based on a finite-element numerical model and observations for the period January 1-31. Water column stratification at each dive area was characterised by the stratification parameter, $\log (M) = H/[rC_D <U^3>]$, based on vertical averaging tidal currents obtained from a finite-element model mentioned above.

We performed simple linear regressions to determine whether there were relationships among the faunistic features of fish

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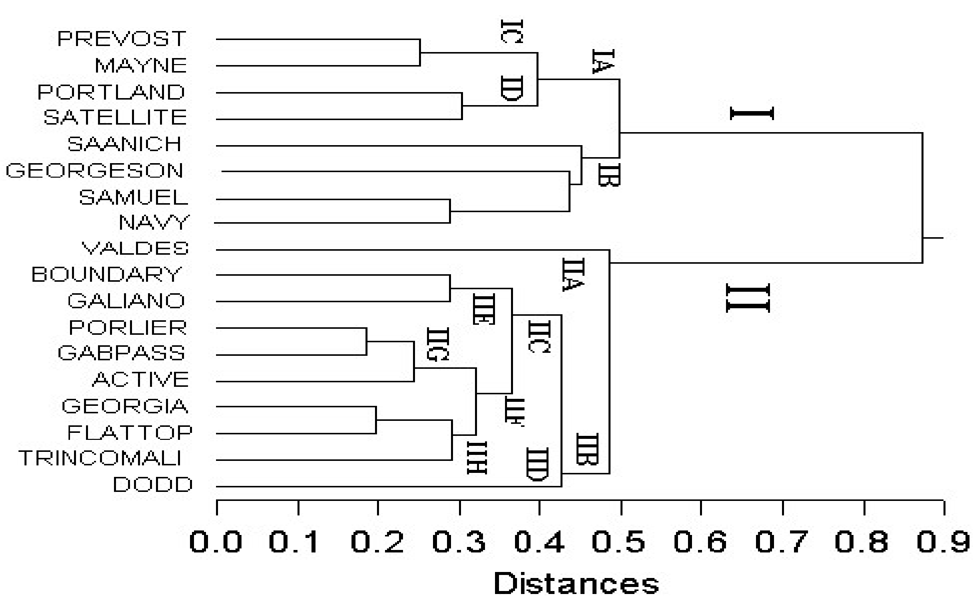

Figure 1.

Cluster diagram showing the relationship among 18 dive areas in the southern Gulf Islands within the PMHL feasibility study zone. Areas were clustered by Ward's minimum distance method based on Kulczynski's dissimilarity index calculated from species-specific relative abundance.

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communities and the environmental conditions in the study area. All statistical analyses were performed using SYSTAT 8.0.

RESULTS AND DISCUSSION

Divers recorded 68 marine fish species (Class Osteichthyes) belonging to 56 genera and 22 families. The two families with the highest number of species were sculpins (*Cottidae*, with 17 species, representing 25% of species richness) and rockfish (*Scorpaenidae*, with 8 species). Only 8 species (11.8%) were common to all dive areas. The most common species observed overall were the copper rockfish (*Sebastes caurinus*), quillback rockfish (*Sebastes maliger*), blackeye goby (*Coryphopterus nicholsi*), longfin sculpin (*Jordania zonope*), scalyhead sculpin (*Artedius harringtoni*), kelp greenling (*Haxagrammos decagrammus*), kingcod (*Ophiodon elongatus*) and striped seaperch (*Embiotoca lateralis*). All of these species were recorded in each of the 18 dive areas at least once during the survey period.

Species diversity of the fish community as measured by the Simpson's Index of diversity (1-D) varied from 0.920 to 0.966, indicating relatively high species diversity at all 18 dive areas. Lowest diversity was recorded in Dodd Narrows; an area characterised by strong tidal currents. The Simpson's index is considered a robust estimate of community diversity (Krebs 1999). In contrast, species evenness, or equitability (measured by the Smith & Wilson's Index of Evenness), varied from 0.34 to 0.96. The lowest evenness measures were recorded in fish communities found in the narrows, while the highest evenness was scored for fish communities in the calm Saanich Inlet. This relationship seems to reflect greater water column stability of Saanich Inlet compared to generally turbulent areas such as Active Pass.

Cluster analysis of the relative abundance data (using Ward minimum distances and Kulczynski's dissimilarities) clearly separated the 18 dive areas into two distinct groups, I & II (Figure 1). Table 1 compares the rank order of the 20 most common fish species in both groups and indicates faunistic difference between the 2 main clusters. The results of the cluster analysis reveal 2 trends. Group I reflects an east-west trend, while group II reflects a north-south trend. Additional research will be needed to determine the ecological significance of these trends. Within group I only Saanich Inlet seems to be an anomaly, since it clusters with group IB, which is a grouping of dive areas characterised by higher water column mixing and higher current velocities compared to Saanich Inlet. Within group II, dive areas representing the 3 major passes (i.e., Gabriola, Porlier and Active) show high degree of faunistic similarity. The results of the cluster analysis also reveal a non-random pattern of fish assemblages and suggest that the spatial distribution of fish communities may be a function of habitat complexity and oceanographic conditions. These ideas were further explored by the use of linear regression analysis. Species diversity (Simpson's 1-D) was negatively correlated with the maximum tidal currents (Figure 2) and positively correlated with water column stratification (Figure 3). These results indicate that fish diversity increases with lower tidal velocity and greater degree of stratification. Furthermore, species diversity is also strongly related to habitat diversity ($r^2 = 0.67$; $P < 0.0001$). These results support the spatial patterns identified through cluster analysis and indicate that structural features of fish communities within the Gulf Islands are directly related to oceanographic characteristics and habitat diversity of the area.

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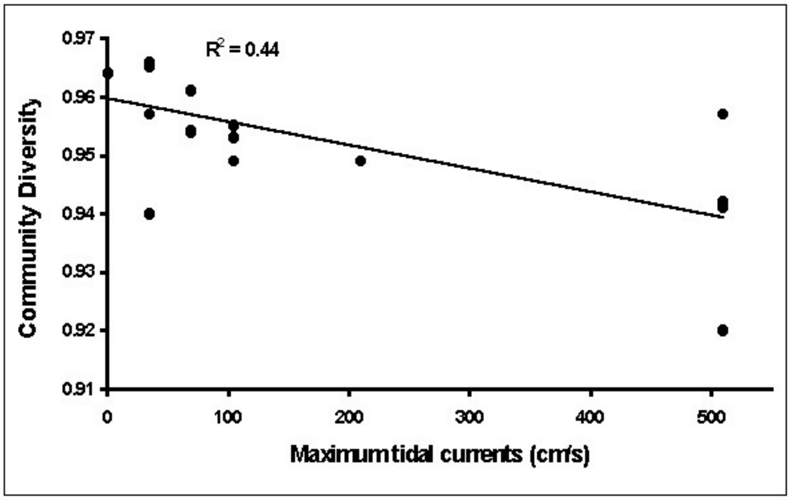


Figure 2. Linear regression showing significant (P<0.003) inverse relationship between community diversity [measured by Simpson's Index (1-D)] and maximum tidal currents (cm/s) in the southern Gulf Islands.

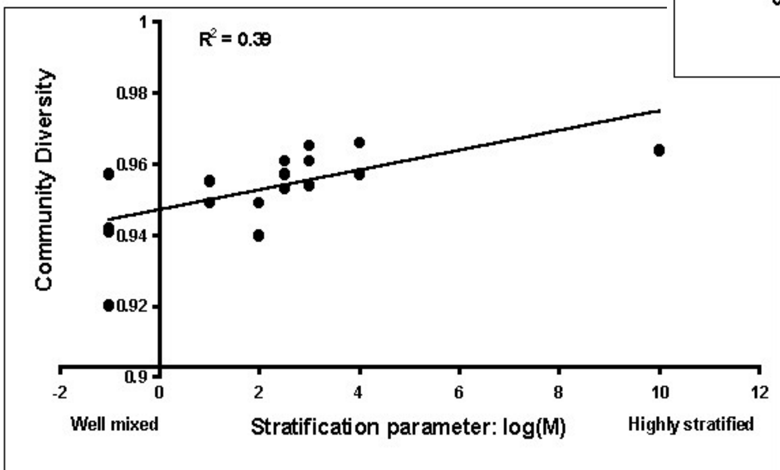


Figure 3. Linear regression showing significant (P<0.006) positive relationship between community diversity [measured by Simpson's Index (1-D)] and water column stratification [measured by the stratification parameter log(M)].

Snapshots of the Past

Paleoecological Research in Coastal British Columbia's National Park Reserves

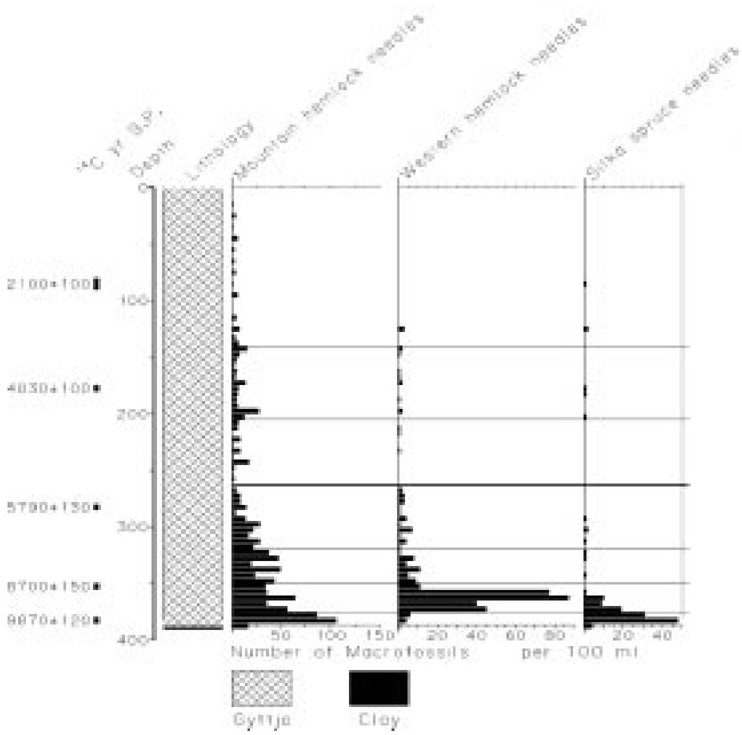
Marlow Pellatt

This article highlights completed and ongoing paleoecological research projects in Gwaii Haanas National Park Reserve (Haida Gwaii and Anthony Island) and southern Vancouver Island (near the proposed Gulf Island National Park Reserve - see map on insert). The studies illustrate how paleoecological information about plant community dynamics can provide scientists and managers with more accurate pictures of long-term ecosystem processes and help them understand the current state of ecological integrity in national parks and protected areas.

The main tools for these investigations are pollen and plant microfossil analyses of radiocarbon dated sediments from lakes, ponds, peat and a fjord. Using information from these sources, Pellatt and Mathewes (1997) researched changes in tree line position and subalpine/alpine vegetation in response to climate change on Haida Gwaii and the Pacific Northwest. Changes in low elevation forest structure on Anthony Island are presently under investigation to identify climate and possible anthropogenic disturbances (Hebda et al., in prep; Pellatt and Macmillan, 2000). A recently-completed high-resolution study examines the roles of climate and potential human land use near Saanich Inlet (Pellatt et al., in press).

PALEOECOLOGY AND PREDICTING CHANGE

Paleoecology is the study of individuals, populations, and communities of plants and animals that lived in the past (years to eons) and their interactions and responses to changing environments (Delcourt and Delcourt, 1991). The Quaternary period (last 2.0 million years) provides a useful ecological record of change in the relatively recent past. It also provides us the opportunity to test ecological hypotheses regarding long-term processes for which no experimental results or records are available (in part, because of our relatively short human life span and limited historical records). Assuming that the physical processes that drove biotic change in the past are the same processes driving change today, scientists can obtain absolute measures of the magnitude and rate of ecological change through time - even predicting the composition of future ecosystems.



GWAII HANAAS

Haida Gwaii

Recent and ongoing research on Haida Gwaii is shedding light on questions relating to climate change, tree line shifts, sea level changes, and the peopling of the Americas. Of particular interest is change in ecosystem structure relative to climate change.

Over the last 10,000 years many changes have occurred to the forest ecosystems of Haida Gwaii. High-elevation tree line, the upper limit of tree growth in mountainous areas, is an ecotone defined largely by temperature, precipitation and snowpack characteristics. Because trees at the subalpine/alpine transition exist at their ecological limits, tree line is an excellent ecotone to study climate change and its effects on ecosystems. Research in the subalpine/alpine transition in Haida Gwaii revealed large-scale change in ecosystem structure during the Holocene (last 10,000 radiocarbon years (^{14}C yr BP) (Pellatt & Mathewes, 1997: Figure 1). In the early Holocene (9600 to 6600 ^{14}C yr BP), the climate was warmer and drier than at present. Based on pollen and plant macrofossil analyses, western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*), which are typically low-elevation tree species, once grew at the present-day treeline. Modern subalpine/alpine ecosystems were established on Haida Gwaii after 3400 ^{14}C yr BP. Quantitative estimates based on statistical analyses (Clague et al., 1992; Pellatt et al., 2000) indicate that early Holocene temperatures were 0.65 to 4°C warmer than present. These data suggest that with a 2° C increase in temperature (the difference suggested by global climate change models), much of the alpine ecosystem on Gwaii Haanas NPR will start to disappear over the next 50 to 100 years.

Anthony Island

Current paleoecological research on Anthony Island in Gwaii Haanas NPR documents 12,000 years of vegeetation and climate history at a low elevation study site (Figure 2) (Pellatt and MacMillan, 2000; Hebda *et al.*, in prep). Fossil pollen data from Anthony Island was incorporated into a multivariate statistical model for coastal BC to quantify changes in pollen assemblages relative to present day vegetation zones. This

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Figure 1. Plant macrofossil diagram for Louise Pond showing radiocarbon ages on the right (pollen from other species was identified and analysed but results are not included in this figure)

-continued from page 13 -

model was developed using modern pollen assemblages from lake surface sediments collected throughout coastal British Columbia. The model uses detrended correspondence analysis (DCA) to relate modern plant communities to modern pollen assemblages to infer past vegetation structure (Pellatt *et al.*, 1997).

Pollen analysis and ordination (DCA) reveal extensive change in plant communities on Anthony Island since deglaciation. Figures 3 and 4 show that early Haida occupancy may have impacted the vegetation of the island significantly between 450 and 1100 ^{14}C yr BP, creating a landscape that is non-analogous to that before (~ 11,000 to 1500 ^{14}C yr BP) and after (present to 450 ^{14}C yr BP). There are 3 particularly strong trends: conditions were warmer than present between ~10,000 and 6500 ^{14}C yr BP; a cool moist "Younger Dryas" like event appears to have occurred at ~ 10,900 ^{14}C yr BP; and a cold continental climate can be inferred around 12,000 ^{14}C yr BP. Based on the results from the DCA ordination, vegetation changes at ~ 770 BP and 12,130 ^{14}C yr BP were quite dramatic and created plant assemblages very different from those currently on Haida Gwaii. High-resolution paleoecological models are being developed for Gwaii Haanas NPR to create a clearer picture of these dramatic climate and vegetation changes.

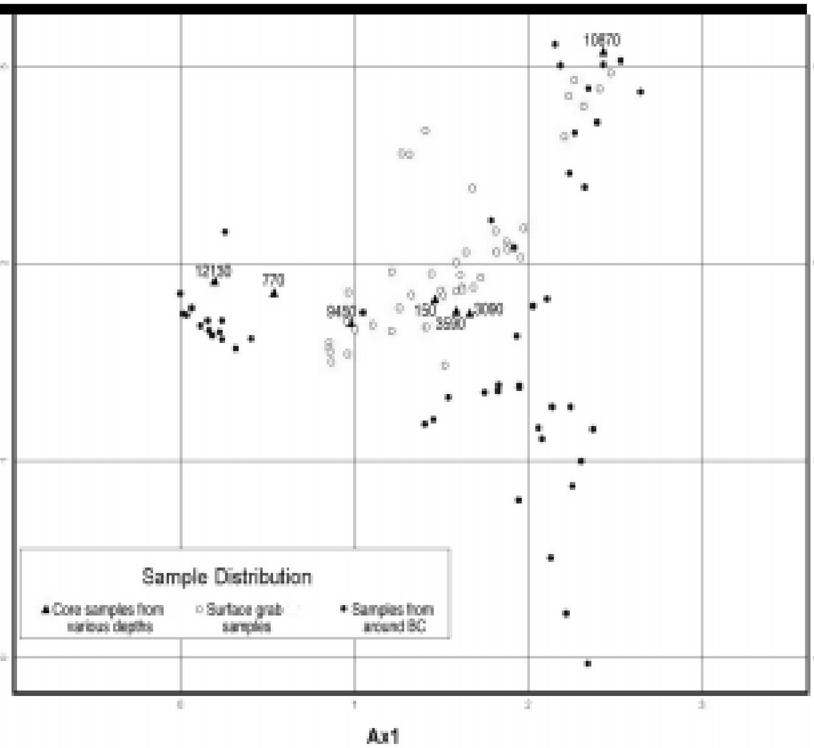

Figure 3. Detrended correspondence analysis (DCA) of modern pollen samples from coastal British Columbia. Pollen samples at selected depths from the SgAn'gwa-i Crevasse sediments were passively included in the data analysis.

Southern Vancouver Island and the Southern Gulf Islands

Paleoecological research on the postglacial history of Garry oak (*Quercus garryana*) will help Parks Canada address questions regarding ecological integrity, fire management, and ecosystem-based management for the proposed NPR in the southern Strait of Georgia. Garry oak is a distinctive component of the southern Vancouver Island and adjacent Gulf Island landscape and represents one of Canada's most endangered ecosystems.

High-resolution pollen analysis of sediment from Saanich Inlet indicates that vegetation and climate change may have occurred rapidly at various points during the Holocene (Figure 4). Vegetation changes from 8700 to 8300 calibrated calendar years before present (BP), and at 5600 BP suggest that plant communities responded "quickly" to changing climate. Decreases in grass (*Poaceae*) and bracken (*Pteridium)* and the increase in oak (*Quercus*) in the early Holocene (8700 - 8300 BP) took place within 400 years, with a dramatic decline in grass and bracken occurring within 50 years. A marked increase in cedar type (Cupressaceae) pollen occurred within a 100-year interval at approximately 5600 BP. These results illustrate how rapidly climate change can impact vegetation structure, which is especially important when considering the impact that future climate change will have on the landscape.

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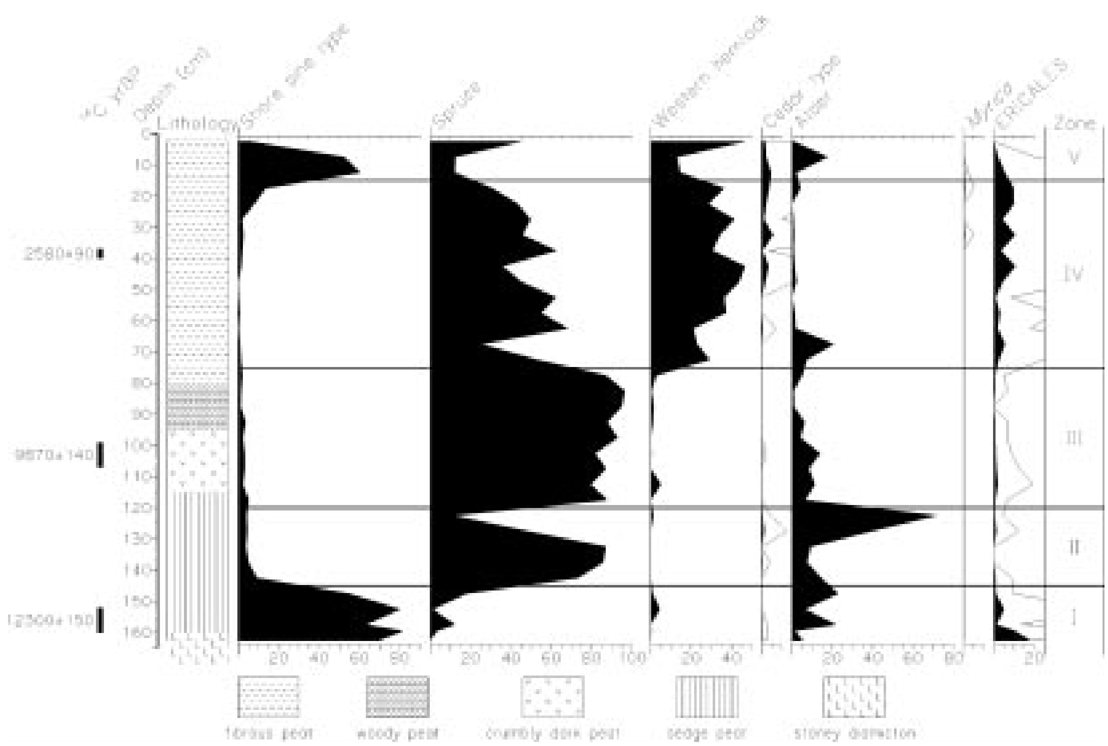

Figure 2.

Pollen percentage diagram of SgAn'gwa-i Crevasse showing radiocarbon ages to the right.

Snapshots of the Past

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Oak pollen occurs in the early Holocene, but does not become a dominant component of the landscape until 7500 BP. After a decrease in oak pollen between 6800 and 3800, pollen accumulation rates (PARs) for oak and grasses increase slightly around 3800 BP (Figure 4). This neoglacial increase corresponds with increased PARs for shade-tolerant conifers such as cedar type (Cupressaceae), western hemlock, spruce (*Picea*), Douglas-fir (*Pseudotsuga*) and fir (*Abies*) (Figure 4). Regional climate was becoming wetter, so this late rise in oak pollen suggests that local influences (i.e., edaphic and/or anthropogenic factors) maintained oak meadow environments near Saanich Inlet. Upon European contact, it was observed that oak savannas in Oregon and southern Vancouver Island were maintained through the use of fire by First Nations people (Boyd 1986). It is reasonable to hypothesize that humans have used fire to maintain savannas throughout the last 3800 years. In fact modern fire suppression techniques have promoted the conversion of open oak savannas and grasslands to woodlands and forests allowing conifers such as Douglas-fir to take over the landscape (Tveten and Fonda, 1999).

The impact that First Nation people had on ecosystem structure brings forth an interesting question regarding protected area management: are we basing management decisions on objective measures of ecological integrity? In many cases, interpretations of ecological integrity are based on value judgements; on the ecosystem structure of a protected area when it was first established; on historic or prehistoric First Nation land use patterns, culturally significant land use patterns; pre or post European contact; or pre-industrial environments. Other extremely important issues regarding ecological integrity of protected areas are disturbance regimes, at risk and exotic species, and global warming.

Many protected areas no longer sustain natural disturbance cycles such as fire, and they may contain many at-risk and "exotic" species. Global warming will certainly result in ecosystem change in coming years, as for example, alpine ecosystems and their dependent species may be greatly reduced. Further changes may take place through rearrangement and/or the migration of ecosystems and their component communities and species. If ecosystem fragmentation prevents connectivity and natural migration corridors, future ecosystems will be dramatically different from what we know today. To understand what we might do in our perpetual quest to establish and maintain ecological integrity in our national parks we must understand ecosystems at scales that are relevant to ecosystems. Paleoecological research will no doubt be important in our understanding of these complex processes.

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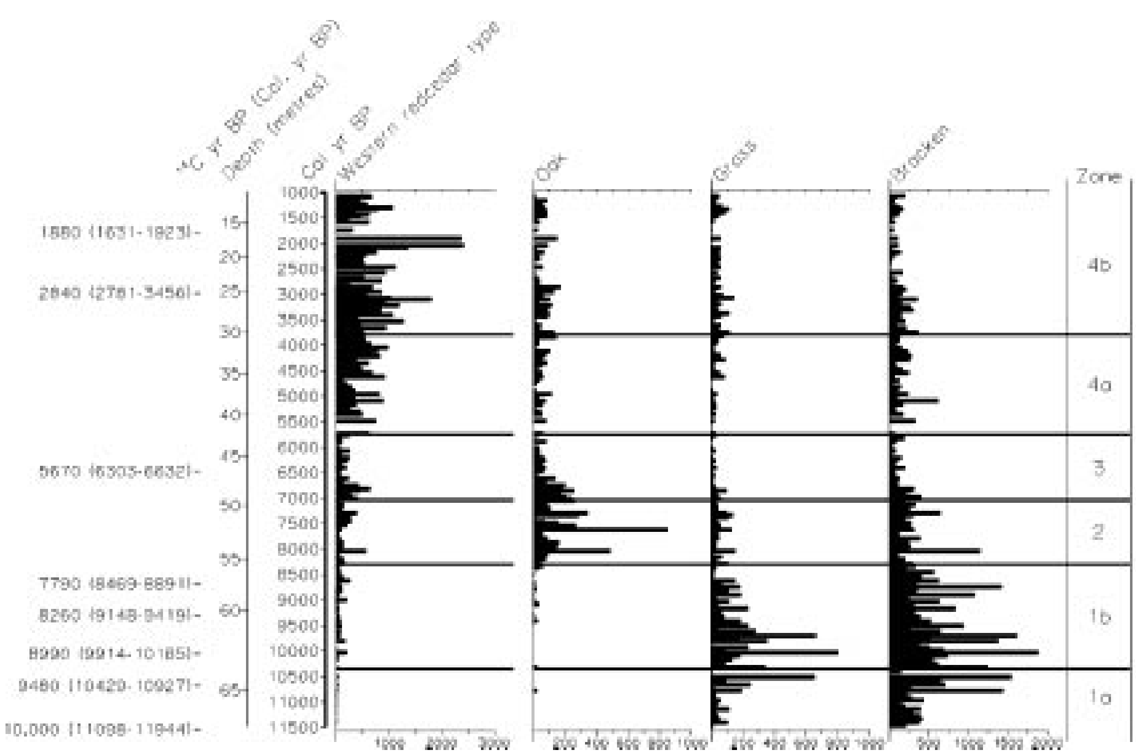

Figure 4.

Pollen Accumulation Rate Diagram for Saanich Inlet showing radiocarbon ages to the right.

Snapshots of the Past

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Climate-driven ecosystem models

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Figure 3.

The annual euphausiid production index generated by a climate driven ecosystem model (see Figure 2) for the southwestern coast of Vancouver Island.

food-web feeding dynamics and how impacts cascade to other euphausiid dependent predators.

In sum, coastal marine ecosystems are extremely dynamic over space and time. If Parks Canada is to understand how human activity impacts ecosystem structure and function then managers will require tools that integrate our best knowledge and understanding of key ecological and environmental processes. The development and application of CDEC models is one new approach that will enhance our understanding and assist in the integrated management of sustainable multispecies resource use and conservation in National Marine Conservation Areas.

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LIGHTNING, LIGHTNING FIRES & FIRE FREQUENCY

IN THE CENTRAL ROCKIES

Kiyoko Miyanishi, Edward A. Johnson, Sheri L. Gutsell, Matthew B. Dickinson and Richard D. Revel

Heathcott (*Research Links* 7[3]) concluded that, because of the low ignition efficiency of lightning strikes on the east slopes of the Rockies, the historically higher fire frequency must be largely attributable to human-caused fires, including cultural burning by indigenous people. Furthermore, he attributed the 20th century reduction in fire frequency to cessation of cultural burning as well as fire suppression. In this paper, we explain why the low correlation between lightning strikes and lightning-caused fires does not preclude lightning as a major cause of the area burned. We also cite fire history studies that point to climate and land use change as the major factors in historical changes in fire frequency.

It has been recognized for some time that the main and front ranges of the Rockies have a lower lightning strike density than areas east of the mountains in the foothills and Alberta plain. This is a result of the flow of air up and over the mountains creating a lee wave east of the Rockies (Chung *et al.* 1976). Higher lightning strike densities are associated with rising parts of the wave (Figure 1), producing a peak of very high strike density (>400 strikes/100 km^2) approximately 100 km east of the mountains and a second peak of somewhat lower density approximately 200 km east of the mountains (Nash and Johnson 1996).

However, lightning-caused fires are not usually any more frequent in areas with very high lightning strike density. In fact, using the lightning locator systems, we can see that the probability of lightning ignitions per lightning strike is very small (Latham and Williams 2000). The complex relationship between lightning strike density and lightning fire occurrence is due largely to differences in fuel moisture conditions resulting from two types of storms that produce lightning: frontal and convective storms. Frontal storms result in wet fuels and do not generally cause many fires. Conversely, convective storms produce very localized precipitation, normally for short periods, and are often associated with high pressure systems that result in clear skies and intense surface heating. These conditions produce dry fuels and consequently most lightning fires are associated with convective storms rather than frontal storms (Nash and Johnson 1996).

High pressure systems are characterized by above normal temperatures and below normal precipitation in spring and summer (Knox and Lawford 1990). These conditions can result in extensive fuel drying. The probability of lightning fire occurrence (number of fires per number of lightning strikes) is near zero until the fuel moisture content is less than 14% of dry weight, after which the probability of fire increases rapidly (Figure 2) (Flannigan and Wotton 1991, Nash and Johnson 1996). Persistent high pressure systems are thus associated with high intensity fires that burn very large areas (Flannigan and Wotton 1991, Johnson and Wowchuk 1993). These blocking highs are tied to the Pacific North America (PNA) pattern or the Hudson Bay High and are associated with drought (Knox and Lawford 1990).

In lieu of a complete causal connection between climate and fire frequency, we have fire frequency data for the last several hundred years, obtained from fire history studies of the boreal, near boreal and subalpine forests (e.g., Yarie 1981, Masters 1990, Bergeron 1991, Johnson and Larsen 1991, Larsen 1997, Weir *et al.* 2000). These studies have shown that the age distribution of the landscape (and hence the fire frequency) is primarily determined by a few large fires (i.e. 1000-10,000 ha) and not by the numerous small fires that in total account for an insignificant proportion of the area burned (Strauss et al. 1989, Johnson et al. 1998). Large fires occur mostly during periods of persistent high pressure systems (Johnson and Wowchuk 1993) and are typically crown fires which kill virtually all of the canopy trees (Johnson 1992). Despite differences in geographic locations, amounts of fire suppression activity, and use by indigenous people, these fire history studies show a remarkable coincidence of changes in fire frequency. The similarities point to climate as a major determining factor.

Fire frequency studies of the central Rockies (Johnson *et al.* 1990, Masters 1990, Johnson and Larsen 1991) have produced results consistent with the boreal forest, showing a more or less synchronous decrease in fire frequency in the mid-1700s. Dendroclimatological studies in the Canadian Rockies (Parker and Henoch 1971) suggest that the period approx. 1500-1700 was warmer and drier, particularly during the spring and summer. A second decrease in fire frequency at the end of the 1800s appears to have occurred more or less synchronously across the boreal forest (Yarie 1981, Bergeron 1991, Bergeron and Archambault 1993, Weir *et al.* 2000). A third decrease in fire frequency has been recorded in the mid 1900s. Unfortunately, while reasonable fire frequency estimates (with narrow 95% confidence limits) can

- *continued on page 19* -

Figure 1. The density of lightning strikes in Alberta and Saskatchewan from May through August of 1988, 1989, 1992 and 1993. Note the increased lightning in the two areas of lee-wave cyclogenesis at approximately 100 and 200 km from the mountains (From Nash and Johnson 1996).

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be calculated for previous epochs (Reed *et al.* 1998), it isn't possible to get reasonable estimates for the current epoch since such estimates have extremely large confidence intervals (e.g., Weir *et al.* 2000).

Although the 20th century decrease in fire frequency has often been attributed to fire suppression, this decrease has been reported even in areas with essentially no fire suppression activity (e.g. Johnson 1979, Yarie 1981, Suffling *et al*. 1982). The most convincing evidence for human effects on fire frequency has come from areas of the boreal forest adjacent to settlement (e.g., Prince Albert National Park) where fire frequency increased during the period of settlement (due to escaped forest clearance fires) and then subsequently decreased once agricultural clearance and settlement had fragmented the forest (Weir and Johnson 1998, Weir *et al.* 2000).

Finally, did fires set by indigenous peoples impact the fire frequency in the central Rockies? Probably not. Human-caused fires must have burned extremely large areas on the order of 1000-10,000 ha (Johnson *et al.* 1990) to have a significant impact on the fire frequency for a region. Studies of burning by native peoples (Lewis 1977) have shown that it was done for specific purposes in localized areas to produce specific effects (e.g., greening pastures to attract large game, managing swamp vegetation). Burning was usually conducted at times when fires could be easily managed (i.e. moderate fuel moisture conditions), and the burned area returned to natural processes once the native peoples moved on. Unfortunately, trying to reconstruct prehistoric cultural practices such as burning by indigenous people has proved extremely difficult due to a lack of objective evidence (Forman and Russell 1983).

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Figure 2. The probability of fire, defined as the number of fires divided by the number of strikes at specific Fine Fuel Moisture Codes. Error bars represent standard error. Open circles designate probabilities based on fewer than 100 strikes. (From Nash and Johnson 1996).

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Fish Assemblages of the Southern Gulf Islands

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The results of this preliminary analysis of historical dive log entries suggest that surveys by recreational SCUBA divers trained in fish species identification may provide NMCA managers with useful ecological data that can be used in addressing management issues. Large volunteer SCUBA diver surveys (e.g., REEF) have already proved to be a valuable resource to Marine Protected Area managers in other countries (see Pattengill-Semmens and Semmens 1998). The Gulf Islands study demonstrates that volunteer divers can produce a relatively complete taxonomic list of an area, an important first step towards effective planning and management. Survey data collected by divers trained in species identification allows a compilation of large quantities of information on the presence/absence and relative abundance of species from a large geographic area, which can be used to determine the geographic distribution of species. This type of information is crucial not only for site characterisation, but also for spatial analysis of species distributions that can be used to assess similarities in species composition among different geographical areas. Furthermore, information on species distribution coupled with abundance estimates can be used to assess rarity. With complete taxonomic lists we can go beyond simple similarity analysis and begin to investigate trophic patterns and fish-habitat interactions. Recently, REEF survey data have been used in siting algorithms for marine reserves (Schmitt *et al*., accepted) and in applying harvesting restriction (Pattengill-Semmens 1999).

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Table 1. Comparison of rank order of the 20 most common fish species in the PMHL study area. Species names in **bold** *are species absent from the other group.*

Group I	*Group II*	*Rank*
Sebastes caurinus	Sebastes caurinus	1
Jordania zonope	Hexagrammos decagrammus	2
Coryphopterus nicholsi	Jordanis zonope	3
Hexagammos decagrammus	Coryphopterus nicholsi	4
Embiotica lateralis	Sebastes maliger	5
Sebastes maliger	Ophiodon elongatus	6
Ophiodon elongatus	Embiotica lateralis	7
Artedius harringtoni	Artedius harringtoni	8
Sebastes emphaeus	Oxylebius pictus	9
Aulorhynchus flavidus	Sebastes emphaeus	10
Cymatogaster aggregata	**Sebastes migrocinctus**	11
Oxylebius pictus	Rhacohilus vacca	12
Rhamphocottus richardsoni	Cymatogaster aggregata	13
Chirolophis nugator	Brachyistius frenatus	14
Citharichthys stigmaeus	**Scorpaenichthys marmoratus**	15
Rhacochilus vacca	Chirolophis nugator	16
Pholis clemensi	**Hemilepidotus hemilepidotus**	17
Brachyistius frenatus	**Clupea pallasi**	18
Hexagrammos stelleri	Rhamphocottus richardsoni	19
Asemichthys taylori	**Enophrys bison**	20

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POD

Marine Wildlife Viewing —

Pete Clarkson

Wildlife viewing is one of the fastest growing activities for visitors to Pacific Rim National Park (PRNP). Historically, whales were the prized viewing target, however visitors are now actively seeking out other marine mammals, shorebirds, sea birds such as tufted puffins (*Fratercula cirrhata*), and black bears *(Ursus americanus)*. In response, an increasing number of businesses are offering marine wildlife watching excursions in and around the park. Tourism trends indicate that we can expect continued expansion of the wildlife viewing industry, particularly in some of the more remote, but wildlife-rich areas in the park such as the West Coast Trail.

Mounting evidence from a variety of sources suggests that uncontrolled wildlife viewing can have a negative impact on wildlife and the visitor experience. Yet, there are few regulations in place to mitigate these impacts because the wildlife viewing industry depends upon a voluntary code of conduct to guide their behaviour. Serious questions remain as to the effectiveness of these guidelines. Often the guidelines are not science-based, and research conducted in the park and elsewhere shows that public and industry compliance is lacking (Hansen 2000).

WILDLIFE IMPACTS

There is a growing body of literature which illustrates the potential impacts of ecotourism on marine wildlife. When boats are present, killer whales (*Orcinus orca*) swim faster and spend less time resting at the surface (Kruse 1998). In Newfoundland, tour boats caused humpback whales (*Megaptera novaeangeliae*) to spend less time in feeding areas (Lien *et al*. 1992). Pinnipeds, harlequin ducks (*Histrionicus histrionicus*), cormorants (*Phalacrocorax sp.*) and black oystercatchers *(Haematopus bachmani)* are being displaced from preferred habitat by sea kayakers (Clarkson 1998, Hazlitt 1999, B. Campbell, pers com). Often the species most sensitive to disturbance are the rarest and, consequently, most highly prized for viewing. As well, many of the most popular viewing sites include seabird colonies that, because they are home to a large number and variety of species, may magnify the area's sensitivity to disturbance (Lien *et al* 1992).

More insidious, but less obvious, are the cumulative effects that these and other activities are having on wildlife and their habitats. Resource extraction, urban encroachment, and environmental degradation are directly and indirectly affecting wildlife, placing many species under stress. Concurrently, the expanding ecotourism industry has the potential to further stress these animals, particularly if they seek them out during sensitive periods of their life cycles (eg. nesting, raising young, foraging). National parks are not alone with these concerns; a recent Fisheries and Oceans Canada (FOC) document notes that: "More frequently, the public is lodging complaints about the operation of boats around wildlife. The number of boats, their behaviour and the increasing frequency of encounters, may contribute to a number of scenarios such as disruption of feeding and social behaviour and, in the long term, complete deviations in habitat use and movement patterns." (Lochbaum and Malcolm 1999)

VISITOR EXPERIENCE

While it is recognized that wildlife viewing is an appropriate and important part of the national park visitor experience, it remains a difficult to define and illusive "product." A wildlife viewing experience is comprised of many factors, of which actually seeing the animal is only one part. The animal's reaction, the number and type of other visitors, and the physical setting, all contribute toward the overall experience. As more people seek out these animals, issues of crowding, inappropriate visitor behaviour, and wildlife habituation can seriously affect both the wildlife and the visitor experience. Although many operators realize the value of a conservative approach, some seem to make extraordinary effort to get right on top of the animals. Known within the industry as "Boy Howdies", these operators are forcing more cautious operators to out-compete each other to provide the "best" view. Too often, best means closest — an attitude perpetuated in popular media and adventure travel advertising. Often this behaviour is pursued with the belief that it provides the visitor with a better experience, which, in turn, will result in a bigger tip for the operator.

Yet, recent media attention and the increasing number of complaints suggest that this aggressive viewing behaviour actually detracts from the overall visitor experience. Not only can it detract from the experience of other visitors (particularly if the animal is chased away), but many also find it offensive if they feel the animals are being surrounded or crowded. In response, a number of operators have developed interpretive programs which focus more on learning about the species than on simply viewing them up close. In some parks, managers have responded by establishing interpretive standards, providing operators with training and information, and more clearly defining the desirable visitor experience. However, there is little research to guide park managers and many staff are uneasy using their personal values to define visitor experience. It seems safe to say that the national park experience, whether provided by the park or by independent operators, should broaden people's horizons by connecting them with nature and illustrating their dependence on healthy ecosystems. In this context, wildlife viewing plays an important role as it provides an opportunity for people to experience wildlife – an obvious and stimulating connection to the natural world.

THE LAW

There are few legal or administrative frameworks for managing the commercial wildlife viewing industry and even fewer tools to guide the recreational boating public. Both the National Parks Act (NPA) and Marine Mammal Regulations under the Fisheries Act stipulate that disturbing marine mammals is prohibited. However, most enforcement staff agree that ambiguous wording makes the regulations impractical to enforce. What is disturbance and how do you prove it? With limited guidance, the industry operates in most areas under a self-directed code of conduct. The industry's intentions may be good, but the effectiveness of voluntary guidelines is questionable. Many scientists and enforcement staff believe the current situation does not foster prudent or proper management of wildlife viewing activities. For example, in the Robson Bight area, an Ecological Reserve specifically established to provide sanctuary for killer whales, there are

–Too much of a good thing?

frequent violations of the voluntary guidelines (Lochbaum and Malcolm 1999). Despite regular intervention from fisheries officers and by provincial wardens, there have been no successful convictions. This problem is mirrored across the country, where, to the best of my knowledge, there has never been a conviction using the disturbance regulations under either act.

National parks have similar problems with regulation enforcement. In 1999 at Pacific Rim, whale watching operators within Grice Bay, a Zone 1 Environmentally Sensitive Area, were monitored for compliance of their own viewing guidelines. Daily infractions were observed involving most companies (Hansen 2000). Interestingly, none of the operators dispute the data, and when confronted, admit that, for a variety of reasons, they just "lost control" (B. Hansen, pers com). Pacific Rim's staff lack the ability to enforce the NPA (the park is not gazetted), and they have had to coax and bluff operators into compliance. This may be a plausible strategy when everyone is in agreement, but it is ineffective when dealing with recurrent problem operators and litigious big business.

IN SEARCH OF SOLUTIONS

To address whale watching concerns at Saguenay-St. Lawrence Marine Park, staff embarked on a multifaceted action plan that includes a detailed regulation package to clarify many of the grey areas and spells out exactly what is meant by "disturbance." Along similar lines, FOC recently responded to public concerns by drafting national Marine Mammal Viewing Regulations. Still under review, these regulations set a national standard for commercial licensing, approach distances, and appropriate viewing behaviour around marine mammals. Not surprisingly, many operators and tourism officials are upset with the proposed legislation, balking at universal standards that can't possibly accommodate the various responses of individual animals, different species, and unique circumstances. Nor will these regulations address the potential impacts on other species (i.e. bears and seabirds) or the overall visitor experience.

In PRNP, the issues associated with wildlife viewing are part of a much larger wildlife management challenge. Cumulative impacts in and around the park are placing increased stress on wildlife. Many of these conflicts are avoidable, and can be attributed to a lack of awareness of wildlife and human behaviour, impacts from other activities, and wildlife habitat needs. To address these issues we've developed a human/wildlife management program called "Living with Wildlife." Living with Wildlife is a community-based program that encourages members of the community to participate in wildlife protection. We do this by hosting meetings and encouraging dialogue on wildlife behaviour and their habitat requirements, and by having community members get involved in local wildlife monitoring programs. These discussions also help us to identify knowledge gaps and shared values, which, in turn, can be used to prioritize research needs. We believe that it is also an effective method of ensuring consistent messages are delivered and reinforced throughout the community.

Recently, we organized a 2-day workshop to review the marine wildlife viewing guidelines, and to examine the potential impacts of ecotourism on PRNP's ecological integrity. The workshop was jointly sponsored by FOC, BC Parks and Parks Canada, and brought together key members of the wildlife viewing community. Our objective was to improve industry compliance and to develop more site- and species-specific guidelines. Although most agreed on the need for better compliance and more specific guidelines, the workshop resulted in few immediate changes. The local ecotourism industry appears slow to embrace the precautionary principle, maintaining that the burden of proof is still primarily the park's responsibility. In light of that, it appears we will need more information on visitor impacts, levels of use, and visitor experience, motivation and satisfaction before the status quo will change voluntarily.

In many ways, the issue of wildlife viewing boils down to a "tragedy of the commons." Since no one has ownership of the resource, short-term profit taking is often at the expense of longer-term conservation objectives. Voluntary guidelines offer little incentive for compliance and, to the contrary, may even reward non-compliant operators with greater profits. As such, the wildlife viewing industry appears to be engaged in an uncontrollable spiral driven by the least compliant operator. The closer one gets, the closer all have to be. For this reason, I believe that we need to develop enforceable site and species-specific viewing regulations. As with any successful initiative, the critical first step is to develop a mutual relationship between the various interested parties, where values can be openly shared. The wildlife viewing workshop helped open the lines of communication, however it is obvious we have a lot of work ahead before wildlife viewing in PRNP is both sustainable and enlightening.

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MEETINGS OF INTEREST

March 1-4, 2001

The Canadian Biodiversity Network Conference. Canada's Natural Capital: Investing in Biodiversity for the Information Age. The Westin Hotel, Ottawa, ON. This conference will address issues related to creating a base of knowledge pertaining to Canada's biological resources. The conference will consist of plenary sessions and workshops on biodiversity science and networking as they relate to: wildlife and habitat conservation, sustainable resource management, biological marketing opportunities, biodiversity education, biosystematics and bioinformatics. The aim of the conference is to develop a strategic plan outlining the steps needed to invest in an deliver Canada's biodiversity science and networking capacity - to create the political will, partnerships and investment to make the network happen. Contact Pierre Lamoreaux, Conference Manager, The Canadian Biodiversity Network Conference, National Research Council Canada, Ottawa, ON, K1A 0R6. Tel: (603) 993-9431; fax: (613) 993-7250; e-mail: biodiversity@nrc.ca; www.nrc.ca/conserv/biodiversity

March 5-7, 2001

Natural Disturbance and Forest Management: What's Happening and Where it's Going. Edmonton, AB. So-sponsored by the Foothills Model Forest and the Sustainable Forest Mangement Network. The use of natural pattens as guides for forest management is becoming widespread in western Canada as one facet of ecoystem management. However, levels of knowledge, interpretations and degrees of committment vary geographically, and across public and private sectors. This syposium will showcase a variety of research and development work and provide a forum for ideas and examples of integration. The objective of the workshop is to learn, talk and move toward a common understanding. Contact: Lisa Risvold: Lisa.Risvold@gov.ab.ca

April 24-26, 2001

International Conference on Restoring Nutrients to Salmonid Ecosystems. Eugene, Oregon. Hosted by the Oregon Chapter of the American Fisheries Society and sponsored by other regional AFS chapters and agencies. The purpose of the conference is to capture and showcase the latest information on one of the most pressing issues affecting the recovery of Pacific salmon and their ecosystems. A plenary session will include presentations from key researchers throughout the North Pacific ecoregion. Contributed papers and posters describe case histories, hypotheses and research related to the North Pacific Rim. Registration forms will be available in October 2000. For information contact Richard Grost: Tel: (541) 496-4580; e-mail: rgrost@compuserve.com

July 30-August 1, 2001

Managing River Flows for Biodiversity: A Conference on Science, Policy, and Conservation Action. Colorado State University, Fort Collins, Colorado. The goals of this conference are to provide attendees with a better understanding of the nature of the conflict between meeting ecosystem needs and human demands for water; explain the state of ecological science concerning the flows required to protect biodiversity; and discuss case studies that address inherent conflicts and potential solutions as a means of engaging in intersdisciplinary dialogue. To register or for more information contact: Office of Conference Services, Colorado State University, Fort Collins, CO 80523-8037; www.freshwaters.org/conference/conf.html

Research Links **is available in PDF format on the Parks Canada main website:**

http://parkscanada.pch.gc.ca

under Library in the Download Documents section.