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PROCEEDINGS OF THE DFO/PSAT SPONSORED MARINE RIPARIAN EXPERTS WORKSHOP, TSAWWASSEN, BC, FEBRUARY 17-18, 2004

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Abstract

Lemieux, J.P., Brennan, J.S., Farrell, M., Levings, C.D., and Myers, D. (Editors). 2004. Proceedings of the DFO/PSAT sponsored Marine Riparian Experts Workshop, Tsawwassen, BC, February 17-18, 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2680: ix + 84 p.

Through cooperation between Washington State's Puget Sound Action Team (PSAT), and Fisheries and Oceans Canada (DFO), a workshop was convened in February 2004 to address the state of scientific knowledge for managing the riparian areas of marine shorelines. By assembling a group of expert practitioners, the workshop was intended to define current knowledge and management approaches, and solicit interim management advice for these areas pending future study. Presenters summarized current knowledge about ecological attributes and processes of marine riparian (MR) areas, as well as current management guidelines for assessing development proposals relevant to the MR in Washington State, British Columbia, and Alaska. Breakout groups allowed participants to review and supplement this information, and to recommend several actions to manage and increase knowledge of marine shorelines in these jurisdictions. A biophysical classification system for marine shorelines was identified as an important priority for development; other priorities included a marine version of standardized curves produced by the Forest Ecosystem Management Assessment Team (FEMAT) in 1993 for freshwater riparian areas. These curves represent ecological attributes as a function of landward distance from shore and serve as guidelines for offsetting disturbance and development from shorelines. Additional priorities included improved outreach tools, and the peer-reviewed publication of marine riparian research and management perspectives.

Resume´

Lemieux, J.P., Brennan, J.S., Farrell, M., Levings, C.D., and Myers, D. (Editors). 2004. Proceedings of the DFO/PSAT sponsored Marine Riparian Experts Workshop, Tsawwassen, BC, February 17-18, 2004. Can. Manuscr. Rep. Fish. Aquat. Sci. 2680: ix + 84 p.

Fruit d'une collaboration entre la Puget Sound Action Team et Pêches et Océans Canada, un atelier a été organisé en février 2004 pour discuterde l'état actuel des connaissances scientifiques concernant la gestion des zones ripariennes le long des côtes maritimes. Mettant en presence plusieurs experts, l'atelier a permis de décrire l'état actuel des connaissances et les approches de gestion présentement en vigueur tout en sollicitant des conseils pour la gestion temporaire de ces zones en attendant que des études supplémentaires soient effectuées. Les divers orateurs ont résumé les connaissances actuelles concernant les attributes et les processus écologiques caractéristiques des secteurs ripariens maritimes ainsi que les directives de gestion actuelles pour l'évaluation des projets de développement susceptibles de toucher de tels secteurs dans l'État de Washington, en Colombie-Britannique et en Alaska. Les groupes de discussion mis sur pied ont permis aux participants d'examiner et de compléter les informations présentées et de recommander une série d'actions visant à mieux connaître et à mieux gérer les zones ripariennes

maritimes dans ces régions. Les participants ont convenu que la mise en place d'un système de classification biophysique des systèmes ripariens et le développement d'une version maritime des courbes normalisées produites par la Forest Ecosystem Management Assessment Team (FEMAT) en 1993 pour les secteurs ripariens dulcicoles étaient des priorités importantes. Ces courbes montrent comment varient une série de variables écologiques en fonction de la distance à la rive et servent de guides pour compenser l'effet des perturbations et des développements qui surviennent à terre. L'amélioration des outils de sensibilisation et la publication de documents de synthèse revus et approuvés par la communauté scientifique constituent également des priorités.

Preface

These proceedings were composed from abstracts and extended abstracts received from authors prior to the workshop, and were augmented by additional information conveyed in presentations and in breakout sessions following presentations. Notes were taken during question and answer sessions and highlights of the discussion were captured in a synoptic form by the senior editor (JPL). Summaries were additionally reviewed by all members of the Steering Committee. All summaries were circulated to original presenters, who were given opportunity to review content relevant to their talks, and suggest changes to improve the accuracy of the proceedings. Information contained in the 'Discussion' and 'Editors' Summary' sections is therefore the best interpretation by the editors, who take responsibility for any statements made therein.

Executive Summary

On February 17-18, 2004 a workshop was held in Tsawwassen, British Columbia (BC), Canada, with the intent of reviewing and advancing research and management in 'marine riparian' areas of the northwest coast of North America (Pacific Northwest). The meeting was sponsored by Fisheries and Oceans Canada (DFO) and the Puget Sound Action Team (PSAT), Washington Sate (WA). The workshop had two primary goals: to assemble a body of experts to speak on various biological or physical processes known to occur in the marine riparian (MR), and to stimulate discussion about best available science for its management. There was an effort to establish not only what knowledge and approaches currently exist for management, but also to define which issues were primarily outstanding, as well as approaches for their investigation. Participants also addressed research approaches, potential collaborators, and funding resources.

The MR was recognized as a dynamic ecotone extending both landward and seaward from the high water level of marine shorelines; the exact extent of that area was subject to substantial discussion. There was some recognition that upland areas are inextricably linked to the MR, but also that the relative importance of distance from shore would vary by each of the main ecological functions attributed to marine riparian areas. Functions were held to be emerging features for which management goals could be set, and were generally identified to be the following: water quality, and pollution abatement, organism habitat, terrain formation and stabilization, aesthetic values, and regulation of elemental and energy flux.

Relating to these functions were an array of management priorities that varied by degree of urbanization in the referenced area. In the highly developed regions of Puget Sound, WA and the Strait of Georgia, BC, city planning guidelines and legislation toward regulating land management practices on private property were of foremost concern. Shoreline armouring and modification as well as upland vegetation removal were the most cited issues in urban areas for which more information was needed. In more remote areas management concerns were being driven by development effects on wilderness values, and terrestrial wildlife needs. Habitat for fish species was recognized as an attribute of concern common to almost all agencies, in both urban and remote areas. Literature referring specifically to the MR was recognized to be deficient, though many participants felt that extrapolating from an abundant freshwater riparian literature should provide management guidelines in lieu of better information. It was suggested that reference in such cases be directed toward lakes and large rivers where possible, as they might more closely reflect the qualities inherent in most non-estuarine marine situations.

Setback distances for development and maintenance of vegetation in the MR were inherent tools already being used by most management agencies; better scientific information to support setback recommendations for each of the marine riparian functions was a common request from workshop participants. The development of nomographs was identified as a management priority (nomographs in this case are the simultaneous plotting of % effectiveness for multiple ecological attributes as a function of distance from shoreline). Some importance was also placed on developing science-based guidelines for buffer lengths in addition to widths in order to promote their effectiveness. The most desired management tool was identified as a shoreline

mapping system that would include both biological and physical attributes, providing the basis for management prescriptions. The ideal system was also thought to include information at a variety of scales so that it could be used for local as well as regional planning. A variety of outreach strategies was identified to facilitate public education and engagement in MR management. It was suggested that public involvement might improve research funding via increasing pressure toward legislators and senior public servants at various levels of government.

Various funding possibilities were discussed, but the overriding theme was to focus on those that could promote 'cross-border' cooperation between agencies in Canada and the United States. This was seen not only to be a desirable feature from an ecological standpoint, but also favourably viewed by many funding agencies. Interagency collaboration was also identified as a mechanism to safeguard against institutional funding cuts.

Acknowledgements

The workshop was the product of hard work and innovative thinking from all of the participants. Funding and support were provided by the Puget Sound Action Team, Office of the Governor, Washington State, and by the Habitat and Enhancement Branch of Fisheries and Oceans Canada. Special thanks are due to Dr. Steve MacDonald (DFO Science Branch) for moderating sessions on both days, and to Beth Piercey (DFO Science Branch) for assisting with registration. Print copies of the document were produced courtesy of Bev Agar, DFO Science Branch, Pacific Biological Station. The Steering Committee conceived, organized and implemented the entire workshop.

Members of the Steering Committee

The workshop was conceived and scoped by: Jim Brennan (King County Dept. Natural Resources, WA), Melody Farrell (Fisheries and Oceans Canada Habitat and Enhancement Branch, Vancouver Headquarters), Colin Levings (Fisheries and Oceans Canada, Habitat Science, West Vancouver Laboratory), and Doug Myers (Puget Sound Action Team, Office of the Governor, WA). Jeff Lemieux acted ex officio on the committee to organize and implement the workshop, and to produce the proceedings.

Introduction

The genesis of this workshop was the demonstrated need of Fisheries and Oceans Canada Habitat Enhancement Staff to have a sound volume of scientific investigation as the foundation for management actions when considering marine shorelines. Habitat managers at Fisheries and Oceans Canada have long recognized both terrestrial and aquatic components of marine shorelines to be important components of fish habitat; through the Pacific Science and Advisory Review Committee (PSARC), formal advice was requested regarding scientifically defensible information to guide governance of shoreline development proposals. The primary concern in this regard has been the protection of fish habitat. Levings and Jamieson (2001) provided the advisory report in this case, wherein they acknowledged a paucity of scientific information on marine riparian functions and setback distances required for protection. Among several of their recommendations was the creation of an expert workshop to compile current information on the best available science for marine riparian (MR) issues. Because Washington State is currently updating a number of coastal land use programs the Puget Sound Action Team (PSAT) has participated with Department of Fisheries and Oceans (DFO) in the Puget Sound /Georgia Basin Task Force, wherein workshop discussion began. DFO Habitat Enforcement Branch (M. Farrell) initiated workshop creation by inviting J. Brennan, C. Levings and D. Myers to form a steering committee.

The workshop was designed to gain consensus regarding the state of knowledge for the management of marine riparian areas, and to identify and prioritize research questions and approaches. On February 17-18, 2004 the workshop was held in Tsawwassen, BC, Canada, convening many of the scientists and managers who are conducting research or managing MR areas in the Pacific Northwest. Workshop participants were invited to attend from four different sectors: research institutions, consulting firms, non-governmental organizations, and resource management agencies. All invitees were identified as expert professionals working with MR themes, who would be capable of contributing to workshop objectives and applying or disseminating workshop information.

The workshop was designed to accomplish three explicit, overarching goals:

1. Summarize best available science on marine riparian ecosystem functions and values
2. Recommend approaches for further research of inherent ecological functions in the MR
3. Provide expert opinion and preliminary recommendations for provisional setback standards or other management strategies to protect MR habitat

The methods used to reach these goals were the following:

1. Presentation of information on the various functions of the MR
2. The review, summary, and discussion of the rationale for current marine riparian management approaches and setback standards in Washington, BC, and Alaska
3. The definition of data deficiencies in the MR, with the production of a list of research questions and opportunities for collaborative research
4. The discussion of 'expert' recommendations or provisional advice for managing the MR, based on 'best available science'

First day presentations were ordered to present information leading from general to specific topics, and were divided into four main sessions:

1. Introductory talks to establish concepts, functions, and definitions of the marine riparian zone
2. Exploratory talks on specific functions and data deficiencies in the MR
3. The effect of scale
4. Rationale for current management guidelines in the three participating jurisdictions (Washington State, British Columbia, and Alaska)

The second day was structured to allow participants to form three smaller breakout groups wherein they discussed a series of questions focusing on two primary issues:

1. The examination of current management approaches for the MR, and the sum knowledge of best available science/experience to justify the approaches (morning session)
2. Definition of data gaps for understanding and managing the MR, including exploration of relevant funding and collaboration opportunity to address deficiencies (afternoon session)

Following each session, all participants (Appendix II) gathered in a plenary session to review the findings of each group, ask questions, and provide comments. The senior editor (JPL) summarized each plenary session and the discussion following each presentation. These documents were sent to breakout session rapporteurs for review and comment. Final drafts of the summaries and discussion were then reviewed by the junior authors of the proceedings. This proceedings therefore summarizes the presentation and dialogue that occurred during the workshop, including the most common and most important themes. Recommendations are given that identify activities likely to provide the most useful information for developing scientifically informed management decisions for marine riparian areas.

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Overview of Research and Thoughts on the Marine Riparian as Fish Habitat in British Columbia

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A. WHAT IS THE MARINE RIPARIAN ANYWAY AND WHY ARE WE INTERESTED IN IT?

Scientific data on the ecotone between the land and the sea, the marine riparian zone, are scarce in the northeast Pacific, and fish habitat managers are dealing with uncertainty when assessing these areas in relation to forestry, urban development, and other industrial activities. This ecotone was called the supralittoral fringe in the classical intertidal ecology studies conducted near Nanaimo, British Columbia (BC) by Stephenson (1949) and this term is well established in the ecological literature. However because the vegetated area immediately above the high tide line is commonly called "marine riparian" by habitat managers, we will use the latter term for the purposes of this paper, and restrict our considerations of the marine riparian zone to areas seaward of the brackish water habitats in estuaries. In British Columbia, marine riparian habitat is found in coastal areas where the annual average salinity is > 25 ‰, which likely accounts for the majority of the 27000 km of coastline in BC.

As pointed out by Richardson et al. (1997), transitional habitats between the sea and land are often ignored because of the different backgrounds of marine and terrestrial biologists; however transitional habitats such as the marine riparian are important for species and ecological processes that span the boundary. A number of different criteria have been used to define the marine riparian zone. Identification of the marine riparian zone by hydrologic and botanical criteria that are used in freshwater habitats is difficult because of certain fundamental differences, especially salinity, and between oceanographic and limnological processes.

The presence of an adjacent body of water that is subject to tidal action is the most important criteria to identify the marine riparian. For a given elevation above chart datum (O.D.), the average frequency of immersion can be estimated for a particular site on a beach using the standard tidal prediction equations that the Canadian Hydrographic Service (CHS) uses. The equations are internationally accepted and based on astronomical events, namely distance of the earth to the sun and moon. For example, at the elevation of the marine riparian at Tsawwassen (3.8 to 4.0 m O.D.), tidal computations predicted about 10-20 % of the high tides in 1995 reached or exceeded these elevations (Levings and Jamieson, 2001).

According to the definitions used by CHS hydrographers, the marine riparian is at the land-water interface at the higher high water large tide (HHWLT), the average of all the higher high waters from 19 years of predictions. Therefore, the shoreline on CHS charts is shown as HHWLT but in practice, it is usually best determined in the field from the vegetation and driftwood. In most B.C. ports, the range of the predicted annual tide is ~ 10 cm. However, the influence of storms (periods shorter than a year) or El Niño (return period longer than a year) are not included. Storms can raise measured sea levels by 30 to 50 cm above predictions for a day or so. Two El Niño events in the past 20 years (1982/83, and 1997/98) have raised the sea level 30 cm above prediction for the entire winter (pers. comm. Bill Crawford, CHS, December 1999).

Marine riparian vegetation includes numerous species of grasses, sedges, shrubs, herbs, and trees found at or near HHWLT. Since many plants along the shoreline (except for halophytes) are limited by the presence of salt water, their seaward growth into the middle intertidal zone is restricted. For coastal trees such as cedar (*Thuja plicata*) or hemlock (*Tsuga heterophylla*) found well above HHWLT wetting of the soil by salt water may be deleterious to the plant but the presence of the vegetation may still be important for stability of the upper beach habitat. These species extend into the backshore zone, here operationally defined as part of the marine riparian. On sandy beaches, dune grass (*Elymus mollis*) and shore pine (*Pinus contorta*) are known as species which stabilize shifting sand. In areas where surf and wave action is a major force, the landward limit of salt spray has been proposed as an indicator of the landward extent of marine processes (Howes and Harper, 1984). On the open coast of California, Barbour (1978) found that the salt spray reached at least 80 m inland from mean tide.

B. POSSIBLE ECOLOGICAL FUNCTIONS OF THE MARINE RIPARIAN FOR FISH ECOLOGY AND SOME UNKNOWNS

Provision of shallow water living space

Several species of salmon fry are adapted to use very shallow water, often only a few cm deep, at high tide, on beaches immediately seaward of marine riparian vegetation. This is likely an adaptation to avoid deep water predators. What is the role of the vegetation in maintaining the natural beach slope, which tends to maximize the area of shallow water?

Food web
Figure 1 shows a highly simplified and schematic food web diagram, suggesting that a variety of arthropods, primarily insects and crustaceans, may link the marine riparian via detrital flow to aquatic organisms including migratory fish. This diagram is based purely on literature data from a variety of sources and most linkages need to be quantified by detailed investigations. The linkage between arthropods and vegetation was recently shown by Romanuk and Levings (2003).

Spawning function
Surf smelt (*Hypomesus pretiousus*) (see Lee and Levings, submitted) and sand lance (*Ammodytes hexapterus*) (see MSRM, 2003) are two species which spawn and incubate their eggs in substrate on high elevation areas of beaches. Herring (*Clupea harengus pallasi*) and numerous non-commercial species such as cottids tend to spawn lower in the intertidal. Marine riparian vegetation might have a direct or indirect influence on incubation success for these species but studies on these topics are scarce in BC.

Sediment stability and water quality function
Sloughing and mass wasting of fine sediment and suspended solids onto beaches and fish habitat may be accelerated on shores where vegetation has been removed. High sediment loads and excess turbidity can affect fish habitat productivity at all elevations of the beach and the material can also be transported alongshore by currents.

Salt soil or spray function
Some vascular plants that characterize the marine riparian are halophytes that are adapted to salt provided in the soil or via airborne particles (Barbour, 1978). Salt marshes are known fish habitats (e.g. Macdonald 1984) but the importance of halophytic shrubs in the context of fish habitat is not known.

C. FACTORING THE MARINE RIPARIAN INTO COASTAL PLANNING

Perhaps because of perceived analogies with "true" riparian ecosystems in freshwater, habitat managers have focused on a need for linear buffers or leave strips or reserves as management guidelines for the marine riparian. Given the assumption that the marine riparian zone is important for species and ecological processes, variation in geomorphology will likely require a system that takes different shoreline types into account. An alternate methodology would be to develop management plans for specific water bodies using ecosystem based management (EBM), as has been done for nine estuaries in B.C. (Williams and Langer, 2002). There is scope for integrating marine riparian guidelines with "bay-wide management plans" but the process of developing guidelines and schemes should be done in a landscape and EBM context. Given the ecological gradient from estuarine to coastal conditions, it would be logical to link the plans in an integrated scheme.

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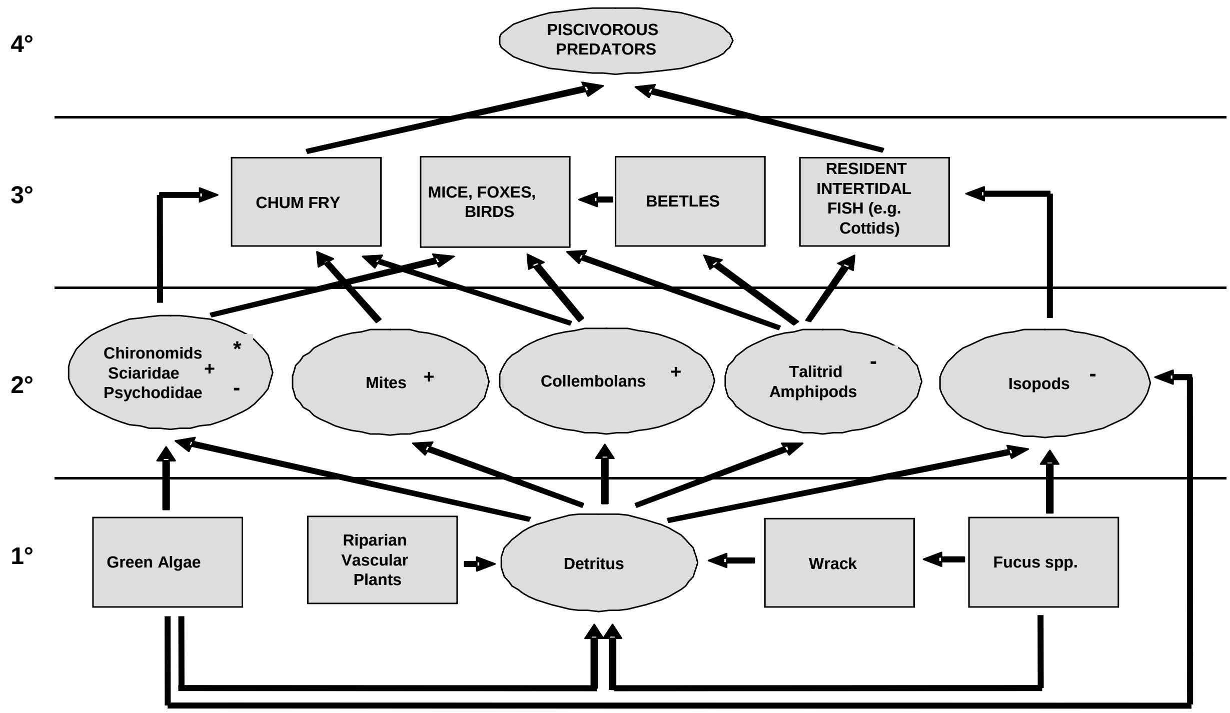

Figure 1. Simplified and schematic food for fish aspects of the marine riparian. Secondary consumers based five most abundant taxa in pit trap data from Romanuk and Levings (2003) (Howe Sound) and Lemieux et al. (2004, unpublished, Alberni Inlet). * indicates strong evidence of food web preference; + indicates some evidence of food web preference; - no data available on food web preference in the northeast Pacific.

Riparian Functions and the Development of Management Actions in Marine Nearshore Ecosystems

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As scientists and resource managers move away from smaller scale investigations and management strategies (e.g., single species or discrete habitats) toward ecosystem management, the recognition and an improved understanding of linkages between systems is needed. Understanding temporal and spatial scales, within which ecosystem processes, structure, and functions operate, is critical in determining the appropriate scale(s) for analysis and implementation of management actions. Although the level of attention toward marine nearshore ecosystems has increased in recent years, the focus has been on the aquatic environment and the riparian areas adjacent to marine waters have only recently been identified as an integral part of nearshore ecosystems. The transitional areas between aquatic and terrestrial environments, commonly called "ecotones", are important ecologically due to their unique structure and functions in support of plants, fish, and wildlife (among other ecosystem services) in both environments. Marine riparian areas are distinct ecosystems, which influence the health and integrity of nearshore marine systems and are also influenced by their proximity to marine waters. In other words, there are mutual influences, such as the exchange of nutrients, energy, temperature, and moisture that contribute to how each of these systems operates independently and collectively. However, the processes, structure, and functions of marine riparian areas are poorly understood because they are not well studied. Information on the social and ecological importance of freshwater riparian systems is abundant and clear, while studies of marine riparian systems are sparse and scattered throughout the literature. Many coastal areas have already experienced significant modification, degradation, and fragmentation of riparian areas as a result of human population growth and demands for access, commercial, residential, and infrastructure development. Human population growth in coastal areas has increased exponentially in recent decades and is expected to continue on this track in coming decades (Good et al 1997; Culliton 1998). This will undoubtedly have an effect on coastal resources and require coastal resource managers to develop an improved understanding of these systems and new approaches for management.

The development of management actions is commonly based on our knowledge of ecosystem functions and benefits. Therefore the development of successful management approaches and management actions for maintaining or enhancing ecosystems requires a scientific foundation. In an attempt to advance our understanding of marine riparian systems and contribute to the development of management recommendations, I provide a brief review of riparian functions and benefits, suggest management approaches that could be used, and offer a short list of management actions. Based upon my review of the scientific and resource management literature, these recommendations are likely to be effective for maintaining or restoring marine riparian functions and nearshore ecosystem integrity.

MARINE RIPARIAN FUNCTIONS – A REVIEW

Freshwater riparian areas have been studied intensely in recent years because of their critical functional relationships with stream and wetland ecosystems. While they are generally understood to be the upland/terrestrial component of the interface (that part of the continuum) between terrestrial and aquatic ecosystems, many authors use a definition of riparian that lacks any reference to tidal waters. This seems to be more of a reflection of the study area, or experience of the investigator, rather than a definition of ecological characteristics. However, the National Research Council (NRC) made a point of including marine-estuarine shorelines in their definition of riparian areas (NRC 2002). They defined riparian areas as follows:

> Riparian areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes, and estuarine-marine shorelines (NRC 2002).

While marine riparian systems have not been subject to the same level of investigation as freshwater systems, and subsequently receive much lower levels of attention and protection, increasing evidence suggests that riparian systems serve similar functions regardless of the salinity of the water bodies they border. Desbonnet et al (1994) conclude that the functional mechanisms that apply to inland riparian areas should be similarly applied to coastal areas. They point out that marine and freshwater riparian zones serve almost identical purposes. A review by Brennan and Culverwell (unpublished, in review) resulted in similar findings. Using the most commonly described functions of freshwater riparian systems as a template for comparison, marine riparian systems appear to provide similar functions in addition to other functions unique to marine nearshore ecosystems. These functions include: Water quality/pollution abatement; Soil stability and Sediment control; Wildlife habitat; Microclimates; Shade; Nutrient inputs; Fish prey production; and, Habitat structure (e.g., large wood). In addition to these ecosystem services, there are a number of social values supported by marine riparian areas, including cultural, human health and safety, and aesthetics benefits.

Water Quality

The degradation of urban waterways is directly linked to urbanization and has been exacerbated by the lack of adequate storage, treatment, and filtration mechanisms for runoff. The major pollutants found in runoff from urban areas include sediment, nutrients, oxygen-demanding substances (i.e., organic compounds), road salts, heavy metals, petroleum hydrocarbons, pathogenic bacteria, and viruses (U.S. EPA 1993). Many contaminants bind to sediments, which, when suspended, constitute the largest mass of pollutant loadings to receiving waters from urban areas (U.S. EPA 1993). Typically, clearing and grading is followed by the installation of impervious surfaces such as roads, buildings, sidewalks, and parking lots. Water collected in stormwater systems, sewage, and from industrial sources may or may not be treated and contains varying levels of silt, waste, and chemical constituents that could otherwise be absorbed, or removed by allowing for infiltration, detention, and absorption by soils and vegetation.

The use of riparian areas for pollution abatement is well documented (e.g.; Phillips 1989; Groffman et al. 1990; Desbonnet et al. 1994; Lorance et al. 1997a, b; Knutson and Naef 1997; Rein 1999; Wenger 1999). In addition, vegetated buffers are known to be both efficient and cost effective for reducing pollutants from upland sources. In an analysis of multiple soil types found in several states along the Atlantic coast, Phillips (1989) found that a 91 m (300 foot) vegetated buffer area would provide sufficient filtration for nonpoint pollution concerns around estuaries. Clark et al. (1980) recommended 80 foot minimum buffers for slopes of 20% with slight erosion, and 150 foot minimum buffers for 30% slopes with severe erosion for controlling agricultural runoff. Lee and Olsen (1985) found that the majority of nitrogen loading in estuarine lagoons (70-90%) and resultant algal blooms and eutrophication resulted from upland residential development and application of herbicides and pesticides. In addition, a number of studies provide evidence that link declines in seagrasses (i.e., *Zostera* spp.) and changes in species composition to degraded water quality associated with shoreline development (see Short and Burdick 1996; Pennings et al 2002). In order to resolve these problems, recommendations included maintaining and replacing septic systems, reducing further development, and a requirement for natural vegetation buffers. However, the determination of appropriate buffer widths to provide pollution abatement functions will require some basic knowledge of multiple environmental conditions, including soils, vegetation, hydrology and other factors.

Soil Stability

Vegetation affects both the surficial and mass stability of slopes in significant and important ways, ranging from mechanical reinforcement and restraint by the roots and stems to modification of slope hydrology as a result of soil moisture extraction via evapotranspiration (Gray and Sotir 1996). Vegetation, once established, provides a self-perpetuating and increasingly effective permanent erosion control (Kittredge 1948; Menashe 1993). Soils, slope height and angle, drainage, and other factors are also very important in determining susceptibility to erosion. However, for all shorelines, and particularly those in areas with steep and eroding bluffs, native vegetation is usually the best tool for keeping the bluff intact and for minimizing erosion (Broadhurst 1998). The loss or removal of slope vegetation can result in increased rates of erosion and higher frequencies of slope failure. This cause-and-effect relationship can be demonstrated convincingly as a result of many field and laboratory studies reported in the technical literature (Gray and Sotir 1996). Disturbing the face or toe of a bluff or bank can cause destabilization, slides, and cave-ins (Clark et al. 1980). Surface vegetation removal and excavation both increase the chance of slumping, which results in imperilled structures, lost land, a disruption to the ecological edge-zone, and increased sedimentation to the aquatic environment (Clark et al. 1980).

Sediment Control

The control of sediments entering waterways is one of the most commonly identified functions of riparian areas in both freshwater and coastal riparian studies. Most discussions of sediment control are addressed in the functional mechanisms of pollution abatement and soil stability provided by riparian buffers. Since most pollutants associated with stormwater are adsorbed to sediments (Karr and Schlosser 1978), trapping sediments also removes a certain percentage of the pollutant load carried in surface runoff (Desbonnet et al. 1995). Pollutants that adsorb to sediments, and therefore can be effectively treated by riparian vegetation, include most forms of nitrogen and phosphorus, hydrocarbons, PCBs, most metals, and pesticides (Karr and Schlosser 1977, 1978; Lake and Morrison 1977; Lee et al. 1989; Zirschky et al. 1989; Desbonnet et al. 1995). In addition to the various pollutants associated with sediments, fine sediments can have a dramatic effect on aquatic organisms. Siltation can clog the breathing apparatus (i.e. gills) of fishes and invertebrates, inhibit proper respiratory function in eggs and larvae (suffocation), alter substrates, and can result in burial of benthic organisms. Siltation and erosion controls have long been recognized as best management practices for development projects regardless of their proximity to a water body. The most common recommendations made for silt and erosion control in the technical literature are to minimize vegetation removal in the area being cleared, maintain vegetated buffers, detain runoff on site, and provide water quality treatment.

Wildlife Habitat

Healthy (i.e., intact and functional) riparian systems along marine shorelines support abundant and diverse assemblages of wildlife. For example, in our review of the 335 wildlife species known to inhabit all of King County, Washington (King County 1987; Kate Stenberg, personal communication), we identified 263 wildlife species (9 amphibians; 5 reptiles; 192 birds; 57 mammals) known, or expected to have an association with riparian habitat on marine shorelines in Puget Sound. This represents 78.5 percent of all (335) wildlife species found in King County. Many wildlife species are dependent upon riparian areas for their entire life cycle, with requirements for feeding, breeding, refuge, cover, movement, migration, and climate that are intricately interwoven into the ecological balance of riparian structure, functions, and processes. Other wildlife may only depend on riparian areas during a specific life stage, for limited periods during seasonal migrations, or simply as a migration corridor. However, regardless of the timing, the availability and condition of riparian habitat can be a determining factor in their survival. Wildlife habitat requirements in riparian systems are complex and have received a significant amount of review and analysis. For example, Knutson and Naef (1997), Desbonnet et al. (1994), and Wenger (1999) have performed extensive literature reviews to determine buffer widths required to maintain riparian functions for wildlife. For Washington State, Knutson and Naef (1997) determined that the average width reported to retain the riparian function for wildlife habitat was 287 feet (88 meters). In their review of the literature on wildlife habitat protection, Desbonnet et al. (1994) show recommendations of 60-100 meters for general wildlife habitat, 92 meters for the protection of significant wildlife habitat, and 600 meters for the protection of critical species. Unfortunately, there has been little discussion of, and even less effort to preserve marine riparian areas for wildlife species in Puget Sound, or elsewhere. This has resulted in a dramatic loss and fragmentation of riparian habitat and associated wildlife.

Microclimate

Riparian plant and animal communities are greatly influenced by marine waters, especially those communities immediately adjacent to marine waters, by temperature and moisture regulation, tidal inundation, wind exposure, and salt spray. Marine littoral communities are, in turn, influenced by riparian condition. The interaction of these two systems creates an ecotone, a unique transition zone from a marine system to an upland ecosystem that supports a diverse assemblage of plants and wildlife.

The greatest influence of marine waters on riparian communities is temperature, keeping lowland areas cooler in the summer and warmer in the winter. Temperature and moisture are also regulated by the amount of vegetative cover on the land. Together, these factors contribute to microclimates upon which fish and wildlife depend, especially climate-sensitive species such as amphibians. Even the quality of the soil (biological, chemical, and physical properties) is influenced by climate, thereby influencing conditions for both plants and animals.

Shade

For freshwater systems, shade plays an important role for regulating water temperature, which can influence the survival of aquatic organisms (Bescheta et al. 1987). Unlike the influence on small streams and rivers, a shaded fringe along coastal or estuarine waters is not likely to have much influence on marine water temperatures. However, solar radiation (which leads to increased temperatures and desiccation) has long been recognized as one of the classic limiting factors for upper intertidal organisms and plays an important role in determining distribution, abundance, and species composition (Calvin and Ricketts 1968; Connell 1972; and others). Foster et al. (1986), in their literature review of causes of spatial and temporal patterns in intertidal communities found that the most commonly reported factor responsible for setting the upper limits of intertidal animals is desiccation. Although the influence and importance of shade derived from shoreline vegetation in the Puget Sound nearshore ecosystem is not well understood, it is recognized as a limiting factor to be considered and has prompted investigations to determine direct linkages between riparian vegetation and marine organisms. One such link is the relationship between shade and surf smelt, a common nearshore forage fish found throughout the Puget Sound basin (see Penttila 2001).

Nutrient Inputs

One of the characteristics that make estuaries so productive is that they act as sinks for nutrients derived from upland and marine sources. Estuarine ecosystems have a functional dependency on capturing and processing organic matter to support detritus-based food webs. Furthermore, this function is dependent upon the right kinds and appropriate levels of organic nutrient input. The primary source of nutrients in the system is derived from primary producers (i.e., aquatic and terrestrial vegetation, phytoplankton). Alterations of intertidal and subtidal areas by dredging, filling, diking, overwater structures, and shoreline armoring have had a dramatic impact on the sources of marine wetland and other aquatic vegetation (i.e., eelgrass, algae). Likewise, upland development has greatly reduced the amount of vegetation and nutrients available to the marine system. In their assessment of shoreline armoring effects on selected biological resources in Puget Sound, Shreffler et al. (1994) noted that increased beach erosion caused by shoreline armoring can convert the beach from a system that shows net accumulation of organic matter to one that shows net loss of organic matter on an annual or seasonal basis. Organic matter is essentially stripped from the beach, or no longer accumulates as a result of the increased energy, lowering of the beach profile and loss of intertidal area due to the placement of armoring. Their assessment also illustrates that armoring results in a direct loss of riparian vegetation, alterations of sediment input, deposition and retention, nutrient flux, species assemblage shifts and ultimately, negative effects on aquatic organisms such as forage fishes, salmonids, clams, crabs, and other invertebrates. The loss of organic matter, shifts in species assemblages, and reductions in benefits of shoreline vegetation as a result of shoreline armoring have been identified in numerous studies and reports (see Sobocinski 2003; Broadhurst 1998; MacDonald et al. 1994; and Kozloff 1974; for summaries and references). Yet, little attention, and fewer studies have attempted to quantify the cumulative impacts of such losses.

Fish Prey Production

Although a number of studies have identified functional linkages between riparian areas and marine aquatic systems, a limited number of studies have established direct linkages between specific prey resources derived from riparian vegetation and marine fishes. A number of studies have identified the diversity, abundance, and distribution of insects in marine environments (Cheng 1976), some occurring hundreds of kilometers offshore (Harrell and Holzapfel 1966) and serving as prey to some of the most unlikely teleost predators (e.g., midwater fishes, such as myctophids [lanternfishes]) (Craddock 1969). Of the dietary studies of marine fishes that were reviewed for this report, it appears that salmonids may benefit most from riparian vegetation. The direct input of insect prey from riparian vegetation for salmonids in freshwater systems has been well documented. However, the importance of insect fallout from riparian vegetation in juvenile salmon (and juvenile and adult cutthroat trout) diets in the marine environment is just being realized and may play an important role in early marine survival.

The success of salmon feeding in shallow estuarine and marine areas may have an important influence on the early marine growth and survival of the fish utilizing these areas for rearing (Pearce et al., 1982). Successful feeding and growth depends upon the availability of preferred prey in the right space and time. In the nearshore environment, dietary studies of juvenile salmonids have been sporadic, but have shown interspecific differences in prey selectivity, and intraspecific differences in space and time. However, for those species of salmonids (i.e., cutthroat trout, chinook and chum salmon) known to be most dependent upon shallow nearshore waters, insects derived from the terrestrial environment appear to play an important role in the diets of these species (Brennan and Higgins unpublished data, in review).

Several studies have shown that chum salmon prey on terrestrially derived insects in northwest estuaries. Simenstad (1998) found that summer chum collected in Hood Canal preyed upon insects. In the central Puget Sound Basin, Cordell et al. (1998, 1999a,b) found that insects were a dominant prey item in chum stomachs and consisted of chironomid fly larvae, pupae/emergent adults, dipteran flies, and spiders. The predominance of insects, especially chironomids, found in these studies is similar to results of chum salmon diets from other estuarine sites (Congleton 1979; Northcote et al. 1979; Shreffler et al. 1992; Cordell et al. 1997; Fresh et al. 1979).

Juvenile chinook salmon have also been shown to prey upon insects in the Puget Sound nearshore and other estuaries in Washington State. Insects were identified as a significant dietary component of juvenile chinook collected off of Bainbridge and Anderson Islands by Fresh et al. (1981). Miller and Simenstad (1997) found that insects (chironomids and aphids) were the most important prey items for juvenile chinook at created and natural channels in the Chehalis River estuary. Studies by Cordell et al. (1997, 1998, 1999a,b) have shown similar results in juvenile chinook salmon diet studies, but have also shown prey species variability between years and seasons studied in the Duwamish and Snohomish River estuaries. The importance of insects in juvenile chinook diets is also supported by studies in the Fraser River estuary (Levings et al. 1991, Levings et al. 1995), the Nisqually estuary (Pearce et al. 1982), the Puyallup River estuary (Shreffler et al. 1992), the Nanaimo estuary (Healey 1980), and the Nusqually Reach area of Puget Sound (Fresh et al. 1979). More recently, juvenile chinook salmon stomach contents analyzed from beach seine samples collected throughout King County shorelines in Central Puget Sound indicate a predominance of terrestrial insects in their diet (King County, DNRP, unpublished data).

Habitat Structure/LWD

Riparian vegetation and large woody debris (LWD) provide a multitude of functions in both aquatic ecosystems and riparian forests. One of the primary roles of vegetation and LWD is habitat structure. The role and importance of LWD in freshwater lotic systems has been well documented and has led to increasing efforts to utilize LWD for bank stabilization and habitat restoration (e.g., WDFW 1998; Johnson and Stypula 1993). Coarse woody debris is also an important part of estuarine and oceanic habitats, from upper tidewater of coastal rivers to the open ocean surface and the deep sea floor (Gonor et al. 1988). The ecological functions of riparian vegetation and wood in the estuarine environment are much the same as those in freshwater systems, but many of the wildlife species, and most of the fish species that have direct and indirect dependency upon riparian functions are different. Structurally, LWD provides potential roosting, nesting, refuge, and foraging opportunities for wildlife; foraging, refuge, and spawning substrate for fishes; and, foraging, refuge, spawning, and attachment substrate for aquatic invertebrates and algae in the marine/estuarine environment. As the source of this material has diminished, the many functions provided to fish and wildlife have likely diminished as well. The importance of LWD to aquatic organisms is variable and highly dependent upon its location. Logs high in the intertidal may become imbedded and alter deposition patterns of organic litter, or beach wrack (vegetation derived from both aquatic and upland sources), and sediments that support diverse assemblages of terrestrial and aquatic invertebrates. Logs may also become waterlogged and provide substrate in intertidal zones. Vegetation and woody debris also provide refugia for fishes. In addition, LWD that is dropped onto beaches from adjacent riparian areas, or is deposited during high tides, has an influence on sediment transport and deposition. Some logs are transient, while others may become imbedded and serve as effective traps for sand and gravel. As sediments accumulate, back beaches, berms and spits may be created, which are typically colonized by dune grass, beach rocket, and other plants tolerant of the conditions found in this zone (i.e., halophytes). The logs retain moisture that becomes available to dune plants and plays an important role in their establishment and survival.

MANAGEMENT APPROACHES

Lands next to the water are fundamental to the livelihood of many species of plants and animals, including humans (NRC 2002). Despite recent advancements in science and the development of new assessment, restoration, educational, and other management tools, coastal areas lack adequate protection standards and continue to be degraded. Human population growth and poorly designed or unregulated development practices have taken a serious toll on marine nearshore resources. While much work has been done to advance our knowledge of the functions and benefits of riparian areas for streams and wetlands, resource managers have neglected the ecological importance of marine riparian areas. For example, although Washington State has recognized the ecological importance and social values of shoreline areas (i.e., Shoreline Management Act), marine riparian vegetation and associated functions are not specifically recognized, or protected. Much work needs to be done to advance our knowledge and improve management of marine riparian areas as part of coastal management strategies. Numerous approaches have been developed for resource management, and while the following list is not comprehensive, it identifies some of the important approaches that will be needed for improved management of marine riparian areas.

1) First, resource managers must recognize that riparian systems are an integral part of marine nearshore ecosystems. The varied functions and benefits must be identified and evaluated at the appropriate temporal and spatial scales. In addition, managers must recognize problems associated with the modification, degradation, and fragmentation of marine riparian areas. This involves an understanding of the implications and consequences of management actions or inaction.
2) Inventory and assessment is essential to understanding the extent and composition of marine riparian areas. Many of the tools used to map and evaluate riparian areas could be transferred from studies of freshwater riparian systems.
3) Best available science should be used to guide development of management actions and policies.
4) A multidisciplinary approach should be used in any management strategy. Due to the complex nature of marine riparian systems, no single discipline would be qualified to provide a complete understanding of functions and benefits.
5) Managers should use long-term/large-scale perspectives to address the scale and complexity of marine riparian systems.
6) Public education and outreach should be incorporated into the management strategy to achieve public recognition and support for management actions.
7) Develop a “toolbox” of approaches to increase knowledge and develop effective management actions. It is unlikely that any single tool will result in successful management of natural resources. In addition to approaches listed above, the use of models, research, and emerging technologies should be considered for advancing our knowledge and improving management actions and outcomes.

MANAGEMENT ACTIONS

Management actions involve the application, or implementation of the various strategies developed for managing coastal ecosystems and resources. The goals and objectives of management actions should seek to protect and restore riparian areas to maintain and improve ecological functions for improving sustainability and productivity for the benefit of current and future generations. There are many alternatives to protection and restoration, including active creation, reclamation, rehabilitation, mitigation, replacement, enhancement, and naturalization (NRC 2002). Passive approaches are also effective and include removal of human disturbances and curtailing land use activities that prevent recovery. In general, however, multiple actions taken in concert are most likely to result in successful outcomes. In addition, a precautionary, more conservative approach should be taken when faced with uncertainty. The most commonly used management actions are listed below.

1) Fill the "toolbox" and use multiple tools for evaluating, regulating, and restoring riparian areas. Data gathering to fill gaps in knowledge and inform other actions is an important first step for determining appropriate, defensible actions.
2) Use regulations to limit, or prevent degradation and loss of riparian functions and benefits.
3) Enforce regulations. Regulations are useless unless management agencies have and are willing to use the authority to protect riparian areas.
4) Use buffers. Buffers are an efficient and cost-effective tool for protecting upland/riparian and aquatic ecosystems. A buffer is defined as a horizontal distance separating a coastal feature or resource from human activities and within which activities are typically regulated or controlled (i.e., limited) in order to protect the resource or minimize the risk of creating a coastal hazard. Buffers widths are typically based upon the desire to maintain a healthy "separation zone" and are determined by their functions and benefits.
5) Use setbacks. While not as effective as buffers, setbacks do provide some measure of protection. A setback is defined as a distance landward of some coastal feature (e.g., OHWM) within which certain types of structures or activities are prohibited (NOAA 1998).
6) Identify and protect undisturbed marine riparian areas. Depending upon their condition, these areas may serve as a reference for developing an improved understanding of marine riparian functions and, if intact, provide for functions lost in disturbed areas.
7) Restore marine riparian areas whenever and wherever possible. Considering that there are many restoration options, as stated above, a long-term and large-scale approach should be used to achieve restoration goals.
8) Develop and implement public education and outreach programs that recognize and restore marine riparian areas. Education, outreach and public involvement is critical to the acceptance, participation, and compliance with other management actions.

In consideration of past practices and the impending threat to coastal ecosystems from human population growth in coastal areas, immediate actions are needed. Marine riparian areas need to be accounted for in resource management planning from the local to national scale. This will require large-scale collaborative efforts and the dedication of resources by management agencies. In addition, protection and restoration actions will need to occur at all temporal and spatial scales (i.e., from local to regional-scale projects over extended periods of time. Further neglect can only result in additional degradation and loss of marine riparian and nearshore marine ecosystems.

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DISCUSSION (SESSION 1; LEVINGS AND BRENNAN COMBINED)

Questions were taken after both presentations were given in the first session. Discussion regarding the nature of food webs in the supralittoral zone included questions about the nature of detritus, as well as an interest in any documentation regarding microorganism activity in the seaward substrate. There was also interest in the relative role of insects in beach detritus. Detritus was identified as potentially any decaying material, but that constituting typical 'wrack' was thought to be the most common. There was indication that some literature regarding microorganism distribution in beach soils does exist. A question was asked about invasive species in the marine supralittoral zone, and the presence of introduced plant species was indicated in both Howe Sound and in Barkley Sound, BC. The nature of the former was regarded to be of a planted nature, and included English ivy and holly, whereas the latter were identified as escaped species, established around the Sound, and likely further. Purple loosestrife and *Spartina* spp. were identified as taxa that are invasive and established in the MR of the west coast of North America.

It was noted that it is important to be able to distinguish the relative role of upland areas in estuarine from non-estuarine areas in contributing terrestrial arthropod subsidies to marine food webs. Further discussion suggested that known life histories of fish species could be used to work this out, and that another approach would be to induce a disturbance in one or other of the systems, coupled with diet observations to examine any possible change.

A question was raised about the effects of vegetation buffer strips on ground water flow in the MR, and it was said that to examine this issue a study is currently being conducted in the Hood Canal by the United States Geological Survey.

It was noted that the dissection of the MR into several different zones is a useful exercise but that the MR also needs to be considered in a holistic sense in order to account for multiple processes occurring across different sub-zones. Lastly, there was an enquiry regarding the known intrusion of seawater into upland soil structures to which no one could provide any known reference.

Physical Processes Affecting the Marine Riparian Zone and Associated Classification Rationale

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The "marine riparian zone" is taken as that area from approximately the elevation of mean high water level to the limit of fully-developed terrestrial vegetation (after Levings and Jamieson 2001). A variety of atmospheric, terrestrial and marine processes affect (a) the extent of this zone and (b) the associated assemblages of vegetation. Near the coast, terrestrial vegetation communities are modified by marine processes, creating a unique coastal vegetation fringe or transition zone. Unmodified terrestrial assemblages are represented as part of biogeoclimatic regions in British Columbia, but the coastal fringe of the marine riparian is poorly characterized. Substrate is considered one of the primary factors in determining marine riparian vegetation *where rocky shorelines* are stable but typically have poorly developed soil; *sediment shorelines* may have better developed soil horizons but can be unstable, depending on wave exposure and other coastal processes. Wave exposure levels at the shore are very important in determining the marine riparian height and width where *high exposure* shores typically have high and wide marine riparian zones and *low exposure* shores typically have very narrow zones. Wave exposure is seen as the key factor affecting terrestrial vegetation overhang of the intertidal zone. Coastal stability is also an important factor influencing marine riparian. *Rapidly eroding, sediment shores* are dominated by mass-wasting processes (slides, slumps, surface wash) and the marine riparian is typically bare. Sediment shores eroding at less than 30cm/yr may develop partial to complete vegetation cover in the marine riparian; erosion may often be episodic, however, with resulting temporal and spatial variation in the marine riparian vegetation. *Stable*, soft sediment shorelines often have the most stable vegetation community. *Accretional shores* typically have unique colonizing assemblages that may be modified by episodic changes in sediment supply and accretion rates.

A physical classification framework is developed *as a focus for discussion* (see below). Important factors included in this trial classification are: biogeoclimatic region, substrate type, coastal relief, wave exposure and shoreline stability. The classification defines physical units to which vegetation assemblages or profiles (based on observations) would be assigned. Such biophysical units can be mapped and might be useful as a resource management or public awareness tool.

Biophysical Classification of Marine Riparian *for Discussion Purposes*

Substrate	Relief	Exposure	Stability	Riparian Type	Veg. Cover	Veg. Overhang	Mass-Wasting
Bedrock	High	High	Stable	1	Bare	no	none
		Med	Stable	2	Partial	some	none
		Low	Stable	3	Heavy	yes	none
	Low	High	Stable	4	Bare	no	none
		Med	Stable	5	Partial	no	none
		Low	Stable	6	Heavy	yes	none
Sediment	High	High	Erosional	7	Bare	no	slides
			Stable	8	Partial	no	slides/surface wash
		Med	Erosional	9	Bare	no	slides
			Stable	10	Partial	some	slides/surface wash
		Low	Erosional	11	Partial	some	slides
			Stable	12	Heavy	yes	surface wash
	Low	High	Stable	13	Partial	no	none
			Accretional	14	Heavy	no	none
		Med	Stable	15	Partial	no	none
			Accretional	16	Heavy	no	none
		Low	Stable	17	Heavy	yes	none
			Accretional	18	Partial	no	none

Modifiers: aspect, fluvial input

De la Beche Type Locality

Cliff rock: occurs on vertical cliffs in wetter part of Gwaii Haanas. Trees occur as scattered, stunted individuals of western red cedar, yellow cedar and Sitka spruce. Characteristic shrubs are salmon berry, salal and black twinberry. False-lily-of-the-valley is the common species in a diverse herb layer.[1]

[1] Harper, J.R., Austin, W.T., Morris, M.C., Reimer P.D., and Reitmeier, R. 1994. A biophysical inventory of the coastal resources in Gwaii Haanas. Contract Report by Coastal & Ocean Resources Inc. of Sidney, BC for Parks Canada, Calgary, Alberta.

EDITORS' SUMMARY

The classification regime given at the end of the author's abstract is a typical example of the approach advocated in his presentation. The extent to which the existing Biogeoclimatic Ecosystem Classification (BEC) can be used as a template for shoreline classifications is unknown, though the BEC approach was clearly identified as an important framework for consideration. The author reported that the west coast of North America has a variety of shoreline substrates, due principally to the tectonic and glacially induced geologic diversity found in the western Cordilleras. Since substrate is one of the primary factors determining 'types' in the BEC classification system, the geological history of the west coast was implicated as the genesis of shoreline biophysical diversity. The author reported that extensive shoreline mapping has been performed in BC, Washington State, and in Alaska, though because of the lack of a good analogue for BEC in the US, that particular classification approach has not been used there. Intertidal 'biobands' were indicated to be useful classification features consisting of the lichen and associated colonizing flora resident on rocky shores between the terrestrial vegetation fringe and the so-called 'storm high water line'. These can be videotaped during flight and later inventoried. The classification system likely has a diverse array of applications but includes the additional feature of being able to indicate shoreline erosion and accretion potential, facilitating safety and hazard assessment during shoreline development.

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DISCUSSION

There was discussion about an existing classification scheme for biophysical classification further inland and whether it could be applied to the coastline (e.g., the BC Biogeoclimatic Ecosystem Classification system; see Meidinger and Pojar 1991). The indicated system was thought not to have considered the special conditions at the shoreline, and to be therefore largely inapplicable. Terrestrial vegetation mapping systems are appropriate models for a biophysical MR classification system, but would have to be modified to address the specialized vegetation and process combinations of marine riparian areas. Examples include extensive dune systems or very wide spits.

There was some discussion regarding rules to prohibit building in the MR, especially when high rates of erosion are present. The question referred specifically to the author's documentation of a situation in Cook Inlet, Alaska, where warehouses and residential buildings were sited dangerously close to an obviously erosion-prone bank. The response indicated that Mother Nature appropriately took care of such cases. It was then said that local landowners were well aware of the problems and that many buildings had been periodically moved away from the cliff face.

Fish Habitat Values and Functions of the Marine Riparian Zone

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A major premise that some species and life history types of juvenile salmon require specific estuarine nursery habitats is poorly substantiated by evidence that these habitats contribute disproportionately to individuals that survive to recruit to adult populations. While the broader contributions of estuaries to the production of certain species and life history types of Pacific salmon is *somewhat* established, the relevance of discrete estuarine habitats is unresolved. A critical issue is whether "habitat dependence" can be interpreted from either juvenile salmon abundance or their diet composition when found associated with particular estuarine habitats.

The estuaries and nearshore marine shorelines of Puget Sound are the rearing grounds for several species of Pacific salmon, including several stocks of endangered Chinook salmon. Present understanding of juvenile Puget Sound Chinook salmon feeding ecology indicates that they forage on estuarine invertebrates initially, becoming piscivorous as they reach larger size. Relatively little is known about feeding of juvenile coho salmon and cutthroat trout in their early marine residence in Puget Sound. Most regional juvenile salmon diet data is biased in that it was collected within estuaries, near river mouths and along shorelines relatively early during outmigration.

Results from diet analysis of Chinook, coho, and cutthroat collected along Puget Sound marine beaches suggest important food web linkages between the smallest juvenile Chinook salmon and nearshore benthic/epibenthic habitats, characterized by their feeding early in the year on herbivorous polychaete worms and other eelgrass associated invertebrates (Figure 1). Terrestrial/riparian insects were prominent in Chinook of larger size classes later in the year, and fish dominated the prey of the largest Chinook salmon. Numerically, insect prey were dominant, though by weight, marine benthic and planktonic prey were of more importance (Figure 2). Planktonic taxa such as hyperiid amphipods and decapod larvae were also common Chinook prey. We note that the ecology of planktivorous salmon in Puget Sound is poorly known, and that plankton biology, predator-prey interactions, oceanography, and other environmental conditions need to be better studied and integrated in order to understand fluctuations in these fish.

Alteration of much of the Puget Sound shoreline by human activity and development has probably affected production of terrestrial/riparian and shallow water benthic/epibenthic prey for juvenile Chinook salmon, and future habitat restoration efforts should take this into account. A study comparing biota at paired beaches (with and without shoreline modifications) showed benthic invertebrates, such as talitrid amphipods, insects, and collembolans to be significantly more abundant at natural beach stretches. The insect assemblage in nearshore vegetation, measured with fallout traps, is highly diverse, including over 100 taxa. This study showed taxa richness to be higher at natural beach sites than at the paired sites with shoreline armoring. Dominant taxa included: chironomids, other dipterans, talitrids, homopterans, coleopterans, and collembolans, all important juvenile salmonid prey.

The relative proportion of salmonid prey originating in marine shoreline vegetation and the supratidal zone is unknown. However, shoreline armoring interrupts biotic processes and decreases abundance and taxa richness in both benthic infaunal invertebrate and insect assemblages in the supratidal zone. The impacts to fish of shoreline modifications are most profound when they are installed below MHHW (likely reduced foraging opportunity) and where backshore vegetation has been removed (reduced input of insect prey). The large scale cumulative impacts of shoreline modifications and the associated removal of shoreline vegetation are also unknown, but could adversely affect salmonid rearing in nearshore marine habitats.

In determining the importance of the marine riparian zone to foraging salmonids, several data gaps exist:

- Habitat occupation versus dependence
- Point of origin of terrestrial insects
- Bioenergetics of common salmonid prey items
- Interactions between species
- Cumulative impacts of large-scale habitat loss

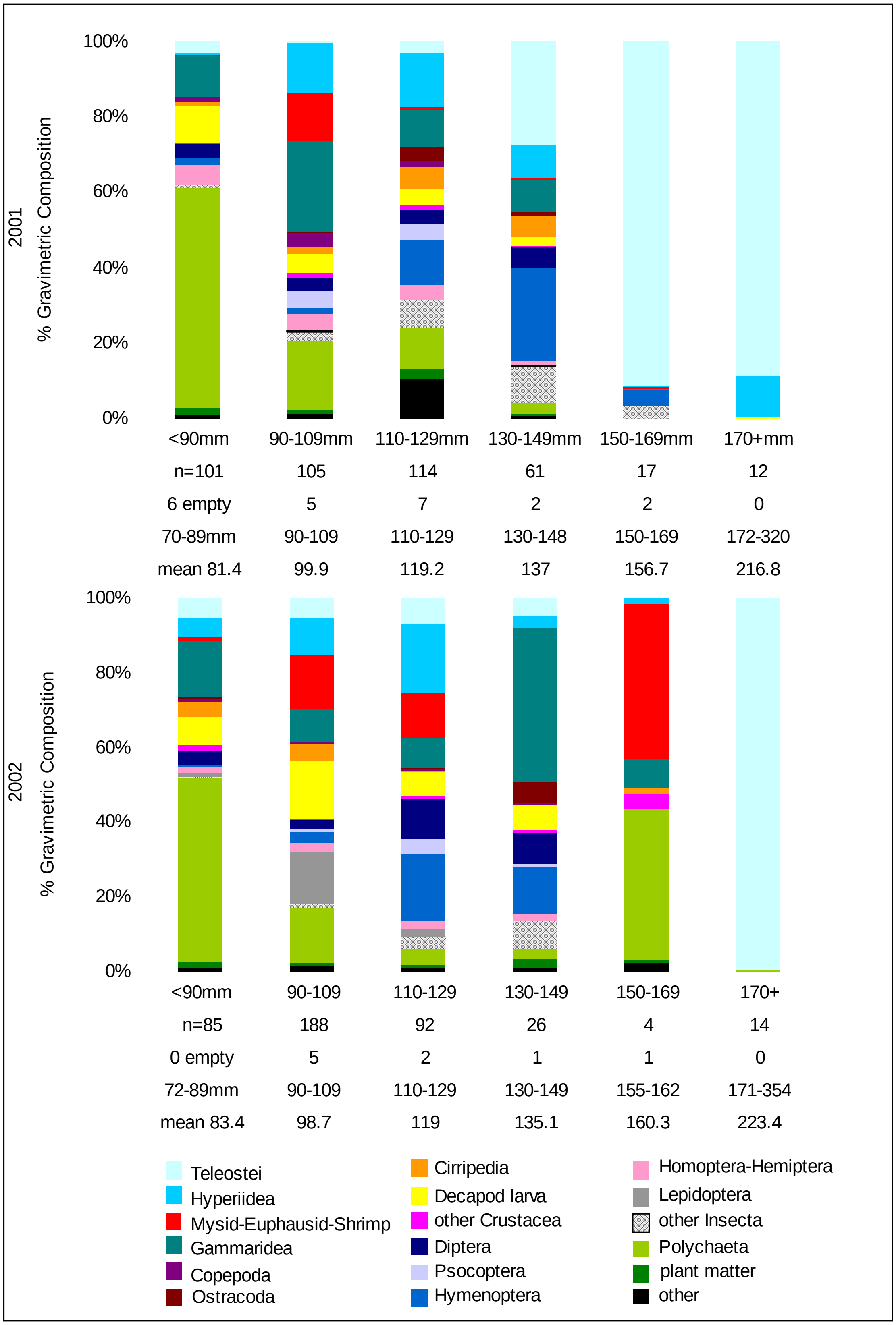

Figure 1. Diet composition (gravimetric) of Chinook salmon collected along Puget Sound marine beaches for 2001 and 2002, from a study in King County, Washington.

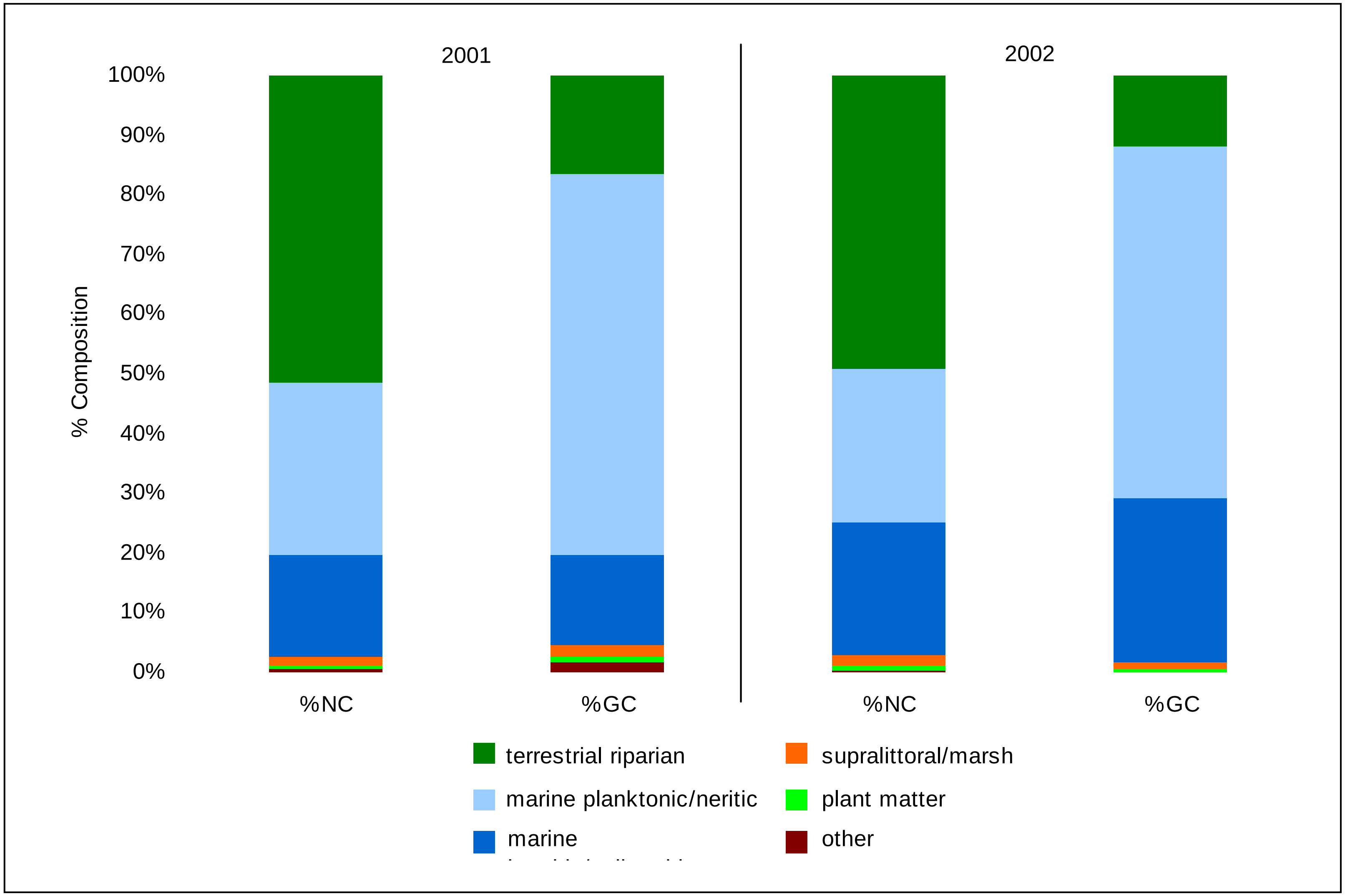

Figure 2. Diet of juvenile Chinook salmon analyzed by ecology of prey items, 2001 (n=410) and 2002 (n=409). Categories are based upon the organism's primary habitat, though organisms were likely consumed in the water column. From a study in King County, Washington.

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DISCUSSION

There was interest in possible ecological advantages of adding rip-rap in front of armoured bulkheads to mitigate the loss of shallow water. It was said that in some places primary productivity might be elevated because of rip-rap placement (though estuarine sand flats have been shown to be more productive than macroalgae growing on rip rap (Pomeroy and Levings, 1980)); it was said that rip-rap might also provide good habitat for perch and cottid species under these conditions, though generally speaking the majority of authors doing research in this field have indicated that the placement of rip-rap has an overall negative impact on nearshore marine habitat.

There was some doubt expressed about the strength of inference that can be made from fish catches at any given site, given the mobility of most species; specifically, whether catches imply species-habitat dependence. Discussion indicated that pink and chum salmon fry are confined to the nearshore marine habitat upon leaving freshwater environments, but that prey availability is not necessarily the factor responsible for this. However, it was noted that available data indicates terrestrial arthropods are important components of fry diet, and that terrestrial prey items are associated with nearshore areas, where they are deposited. There was indication that the present study sampled at several tidal heights to encompass tidal latitude, and that there have been no observed differences in catch per unit effort among different species of salmonid fry in this respect. It was also said that Chinook salmon are especially opportunistic, with data suggesting that Chinook diet reflects natural abundances of prey species and Chinook life history stages.

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Forage Fish Spawning Habitats

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The occurrence of a "marine riparian" forest corridor along the backshore zone of a marine beach may be a significant positive habitat-quality element for summer-spawning populations of the surf smelt (*Hypomesus)*, an ecologically-important "forage fish" in the Puget Sound basin. Surf smelt deposit their demersal-adhesive eggs on the surfaces of sand-gravel beaches, generally within the uppermost one-third of the intertidal zone. Eggs deposited during the summer months are vulnerable to mass mortality from desiccation and thermal stress during their two-week incubation period. The occurrence of shade on the uppermost beach from overhanging trees appears to increase the survival of surf smelt spawn incubating in the beach substrate beneath them, compared with spawn deposits in adjacent sun-exposed locations. While documented surf smelt spawning sites are protected by regulation from the effects of shoreline development, the preservation and/or re-establishment of shading marine riparian forest corridors, very vulnerable to shoreline development activities, are only just now being explored as concepts of rational shoreline management and mitigation. It should be made clear that overhanging vegetation-induced shade appears not to be a factor in the survival rates of surf smelt eggs, or the eggs of the Pacific sand lance (*Ammodytes*), that happen to be deposited on upper intertidal beaches in the fall-winter months, when the threat of excessive thermal stress is low.

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Penttila, D.E. 2002. Effects of shading upland vegetation on egg survival for summer-spawning surf smelt on upper intertidal beach in Puget Sound. *In* Proceedings of the Puget Sound Research-2001 Conference, February 12-14, 2001, Bellevue, WA. Edited by the Puget Sound Water Quality Action Team, Olympia, WA.

EDITORS' SUMMARY

The author's presentation indicated the distribution of surf smelt to be widespread, to Alaska, but that spawning locations are very poorly documented in BC. The particular substrate in which surf smelt spawn was said to be only 5,000 years old, inferred from the developmental age of sand types after accretion events on the North American west coast. It is thought therefore that the shoreline dependence of this species has evolved very recently, but that the adaptive significance of the development of this life-history strategy is not well understood. There was emphasis on the importance of shade being restricted to summer versus winter spawning populations, but that even in summer non-shaded beaches are sometimes populated with viable eggs. For example, beaches with constant wave action were said to facilitate the burying of surf smelt eggs several cm below the beach surface, were shade, moisture and temperature regimes assumedly facilitate egg survival. Excessive organic detritus on beaches was said to be a known deterrent to egg survival, perhaps via inducing asphyxiation by reducing gas exchange across egg surfaces.

DISCUSSION

The role of detritus on beaches and its incorporation into beach soils was queried. The author stated that detritus does integrate with beach soils but that it might not play important roles where surf smelt are spawning. The majority of litter input was said to come in the fall and seems absent during either the winter or summer spawning periods, suggesting that it is an unimportant factor. It was also reiterated that vegetation might not be important to beach sites that harboured winter spawning adults, due to their apparent independence from shaded habitat. The incubation period for surf smelt eggs was identified to be 4-8 weeks.

There was some interest in the knowledge of population ecology of surf smelt; whether specific spawning stocks had been identified in British Columbia, and what their spatial distribution might be. The author replied that there was insufficient documentation to comment on this topic.

There was further discussion about surf smelt conservation and the importance of a biophysical mapping regime proposed by John Harper, given that substrates are important factors. The author noted that evaluation of surf smelt habitat should take into account the fact that even on beaches with vegetation, viable eggs are often detected in non-shaded locations. Discussion then referred to existing evidence about the effects of ultraviolet radiation on egg viability, which was said to be unstudied. However, the author noted that repeated observations of viable eggs have been made several cm below beach surfaces, indicating that radiation might not be the most important factor.

Discussion ensued about Puget Sound and shoreline habitat loss, where it was stated that 65% of the shoreline in the central Puget Sound area has already been armoured. A final question was asked about seasonal variation of surf smelt fecundity, which was said to be unstudied. However the author noted that observations indicate summer spawning populations deposit higher numbers of eggs, but also experience much higher mortality [it was unclear from comments which life history stage mortality was being referred to].

Other (non-fisheries) Ecological Functions and Values of the Marine Riparian Zone

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Direct and indirect ecological functions of marine riparian shorelines should not be constrained by a limited focus on just support of important fisheries resources, such as juvenile salmon. Natural marine riparian shorelines not only provide unique habitat for non-fisheries associated species and other ecosystem functions, such as provision and decomposition of organic matter sources antecedent to nearshore detritus-based food webs, but also constitute fundamental ecotone elements of land-margin landscapes. As land-water ecotones, they are the site of transitional, steep-gradients in the flux of material, energy and organisms between the upland and nearshore landscape elements. Thus, some of the functions of the adjoining landscape elements are equally contingent on the integrity of this ecotone. However logical and intuitive these functions may be, and how much value we may allude to them, we lack scientific evidence that documents the strength of interacting processes within and across this ecotone. While the null hypothesis—*H_0: there is no significant difference in fundamental ecosystem processes in the absence of a marine riparian ecosystem*—can probably be rejected with little uncertainty, we lack the knowledge necessary to establish which and how much anthropogenic change in marine riparian attributes constitutes a significant deterioration in function. Evidence in support of management criteria and tools requires explicit experiments and monitoring, the opportunity for which could be effectively implemented through many of the nearshore restoration initiatives now emerging in the Pacific Northwest region.

EDITORS' SUMMARY

The author identified the MR to be among the stronger examples of ecotones, by exhibiting sharp changes in species composition and physical attributes over short distances. The MR was said to contain dynamic and diverse features maintained by constant disturbances, including rapid recruitment and morality of species and populations, and associated shifts in conditions. Because of its exceptionally sharp gradients in both abiotic and biotic variables, the MR was indicated to be composed of several interacting elements that lend themselves to identification at different scales, including elemental cycles that are both internal and external in nature. Primary production was identified as an important internal feature, supported by evidence of the origins of organic carbon, indicating autochthonous rather than allochthonous cycling. Habitat for all estuarine species, including those of a non-commercial interest, was said to be influenced by detrital pools created during primary production. The entrainment of organic matter by nearshore transport cells was suggested as one important feature influencing the spatial distribution of biological activity in the aquatic component of the MR. Processes external to the aquatic environment were indicated to be primarily those induced on the aquatic by the terrestrial component, including sediment, water, nutrient, temperature, moisture modulation, and organic matter input in the form of litterfall and arthropods. Sediment movements from upland sources toward the waterline were said to exist across a natural range of scale from chronic, high frequency and low intensity to episodic, low frequency, and high intensity events. Water flux to the shoreline was suggested to be responsible for non-estuarine delta features, meso-scale low salinity plumes, the export of some types of organic materials, and various forms of nutrient mediation. Structural alternation of the shoreline was indicated to produces the following effects: Loss of littoral sediment, wave reflection and scouring, hydrological impacts, loss of riparian vegetation, passive erosion, and various forms of cumulative impact resulting from combinations of these factors. Beach lowering and the alteration of rates of organic matter input and processing were implicated as two important consequences of these impacts. Additionally, modification of terrestrial components can produce known barriers to organism dispersal both along and away from the MR.

Cultural use of the shoreline was said to be prevalent among aboriginal peoples, including its use for transportation, habitation, foraging and materials gathering. Modern day analogues for many of these values exists, and the use of buffer zones help to lend at least the impression of integrity to an area that embodies an array of important values for most humans.

DISCUSSION

In contrast to terrestrial ecosystems subsidizing marine systems, the extent to which marine environments can subsidize terrestrial systems was asked about. It was indicated that there were papers showing that in riverine environments marine-derived nutrients originating in salmon tissues had been shown to influence forest growth, but that isotope evidence for this dynamic in strictly marine environments was missing. Studies by G. Polis and others (e.g. see Polis and Hurd 1996) were referred to, which apparently have shown the influence of marine productivity on tropical oceanic island communities was significant. This was thought to be a special case because it involved the activity of terrestrial biota foraging in the nearshore environment and did not indicate any marine-borne mechanism that could promote terrestrial productivity independent of activity from the terrestrial system.

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Potential for Terrestrial Vegetation to Influence Nutrient Subsidy to Non-estuarine Marine Environments in Temperate Ecosystems: Summary Background for Thinking about Management and Research Approaches

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After temperature and moisture, nutrient availability tends to be the most important factor regulating the development of terrestrial ecosystems. Plants play important roles in regulating the flow of elements in ecosystems, and can serve as both inhibitors and promoters of nutrient subsidy between adjacent systems. In the context of aquatic-terrestrial interfaces, where mass and water flow tends to be from upland sources toward water, vegetation communities have the potential to intercept and modify compounds moving on and through the soil surface, but also to contribute nutrients in the form of allochthonous input (litterfall and consumers, mostly in the form of terrestrial arthropods). The former case is most relevant under circumstances of anthropogenic influence when upland vegetation has been cleared and large amounts of foreign waste, fertilizer, and other products are being shed. Vegetation communities have the ability to mitigate the movement of such materials by directly absorbing compounds into plants through growth (uptake), by influencing soil structure such that it better binds certain compounds to soil particles (sorption), and by promoting the development of decomposer communities that can absorb and modify soil compounds (several biochemical processes, including denitrification). By prohibiting nutrient transfer to aquatic systems under these circumstances plants prevent excess nutrient loads, which can be overtly toxic to some organisms, and can allow others to undergo competitive release and dominate a biological community. Typical examples of this are found in aquatic systems that have become eutrophied and have consequently experienced a significant reduction in species richness (Pennings et al. 2002; D'Avanzo et al. 1996). Desbonnet et al. (1995, 1994) and Wenger (1999) provide a good review of the literature documenting the use of vegetation to mitigate such effects.

Typically, phosphorous and nitrogen are the primary nutrient elements of concern in upland runoff, because of their prevalence in fertilizers, sewage and to a lesser extent in detergents (Desbonnet et al. 1994). These two elements are also the two most commonly cited nutrient limitations to production in ecological systems (Schlesinger 1997). Phosphorus is a key element because of its role in the energy transfer system of almost all living organisms, and its role in other ubiquitous structures like cell membranes. Nitrogen is a critical component of most protein synthesis. Both phosphorous and nitrogen exist in several common chemical forms with different solubility, binding and uptake properties. These different forms should therefore differ in their response to the influence of soil and vegetation variables. Despite these differences, most vegetation buffers have been shown to be effective at reducing levels of total phosphorous in soils (see Wenger 1999). The primary known mechanism for phosphorus removal from water sources is via binding and restriction to soil particles. However, unless phosphorous is taken up into plants and exported offsite by litter fall, or by anthropogenic harvest, soils should eventually become saturated by excessive phosphorous inputs, and begin to leak their contents at higher rates. For this reason, vegetation communities should not be relied on as the sole tool for managing phosphorous runoff into aquatic systems (Wenger 1999). Nitrogen is a slightly different case in that there exists a prevalent biochemical pathway in soil ecosystems which converts nutritive nitrogen forms to an inert, gaseous form: denitrification can result in net export of nitrogen to the surrounding atmosphere (Schlesinger 1997). However, it should also be possible to saturate these kinds of mechanisms. There is some indirect evidence that this occurs under extreme conditions, such as experimental application of sewage doses to the forest floor (Jordan et al. 1997).

Soil variables known to affect uptake rates in plants and soil mitigation processes like sorption and denitrification include soil moisture, soil age, temperature, parent material, pH, and available carbon content. These factors are likely influenced by a variety of environmental factors including the particular species in a plant assemblage as well as their age structures and surrounding topography. Other important nutrients that have received lesser study in this regard include potassium, sulphur, labile carbohydrates, and the so-called ‘micronutrients’ such as calcium, and several other kinds of metals (Schlesinger 1997).

NUTRIENT SUBSIDY POTENTIAL OF TERRESTRIAL TO MARINE SYSTEMS ON THE NORTHWEST COAST OF NORTH AMERICA

In conditions under which anthropogenic nutrient input is negligible, terrestrial vegetation has the potentially opposite role in influencing aquatic systems: that of a subsidy donor rather than inhibitor. Terrestrial plants on average shed over 50% of their annual carbon accumulation (Barbour and Billings 2000) and thus are capable of influencing aquatic systems when bordered by them. Temperate, fresh-water lotic systems are well-known examples of this; because they are bordered by relatively productive forests that continually recharge running waters with fresh litter input (e.g. Vannote et al. 1980; Naiman and Sibert 1979). Because of this estuaries are quite rich in organic content, receiving large amounts of upstream runoff that has undergone a significant amount of biological processing. A study of the Nanaimo River estuary on southern Vancouver Island, for example, estimated the annual carbon input from upstream forests to be roughly four times the total annual productivity for the entire estuary (Naiman and Sibert 1979).

The case for non-estuarine marine shores is less clear. In temperate coastal ecosystems, forests definitely possess the capacity to enrich aquatic systems, if carbon fixation rates can be used as a good measure. Some estimates of conifer forest ANPP (aboveground net primary productivity) on the temperate west coast of North America range around 1800 g $C/m^2/yr$ (Franklin and Dyrness 1973). By comparison tropical wet broad-leaf forests have been reported to average around 800 g $C/m^2/yr$, while estimates for wetlands, boreal forests, and cultivated farmland values are 1300, 430, and 760 g $C/m^2/yr$, respectively (reported in Schlesinger 1997). Some partial-system marine estuary estimates from the west coast of North America range from 237-688 g $C/m^2/yr$, with variation due largely to vegetation type and location in the estuary (Nishimura et al. 1996). One reported open ocean NPP estimate is 130 g $C/m^2/yr$, while coastal zones are estimated by the same author to be nearly double that at 250 g $C/m^2/yr$ (in Schlesinger 1997). Whether the shoreline increase is the effect of estuary contribution alone or is influenced by non-riverine terrestrial subsidy is unclear. Increased pelagic activity at shorelines is also likely to affect this figure. Marine productivity enhancement due to the influence of terrestrially borne nutrient loading is potentially significant, but its estimation will require the determination of some difficult information. This includes the decay rate and fate of plant and arthropod material under a variety of shoreline and backshore conditions. It also includes the determination of nutrient limitation in the marine nearshore system, as well as the nutrient use efficiency of prevalent primary producers.

δC^{13} stable isotope evidence from Washington State indicated that autochthonous cycling is relatively more important to marine carbon fixation than allochthonous input, including cases in both estuarine and non-estuarine marine conditions (Simenstad et al. 1985). Still, there is an unspecified role for terrestrial input to non-estuarine coastal marine conditions that should be further quantified to understand its specific role in littoral and supralittoral environments. The influence of terrestrial subsidy on marine processes should be greatest in areas of highly reticulated coastline where ratios of shoreline length to water body area are high, where water depths and volumes are reduced, and where tidal evacuation of nutrient inputs is incomplete. These conditions are typical of many areas from the southern coast of British Columbia through to the Gulf of Alaska.

EFFECTS OF DISTURBANCE

Nearly the entire area of Vancouver Island has been anthropogenically aforested in the last century by industrial logging; a trend that is increasingly prevalent with decreasing latitude (National Geographic Society 2003). Thus, any realistic consideration of terrestrial subsidies in southern Canada and the lower 48 United States needs to consider the effects of forest disturbance. In this region, depending on the particular site, late-seral 'marine-riparian' forests are dominated by various mixtures of Douglas-fir, western red cedar, western hemlock, and Sitka spruce (Pojar and Mackinnon 1994). Because of the dynamic and exposed nature of many shores, vegetation is often additionally composed by species that are either disturbance specialists or indicators of exceptionally poor growing conditions (Pojar and Mackinnon 1994). These often include various deciduous species such as red alder, big-leaf maple, willows and various concurrent shrub and herb species such as salal. Influence of disturbance-oriented species is often heightened after industrial clearcutting, especially when no action has been taken to promote immediate post-harvest conifer regeneration. As a common example, red alder stands typically give way to conifer regeneration somewhere around 40 years post-harvest in coastal areas of western North America (e.g. see Balian 2001). During this period such regenerating forests have the ability to contribute relatively high nitrogen loads through litterfall due to relatively high foliar nitrogen content when compared with conifers (e.g. see Richardson et al. 2004). This is true too because young trees typically allocate a disproportionate fraction of NPP to the photosynthetic apparatus, and because typically stand-level NPP is slightly higher in younger, rather than older forests (Acker et al. 2000; Harcombe et al. 1990). However, any model of litter input from terrestrial vegetation must also consider tree height and the conditions in the backshore that facilitate wind-driven transport to the water.

The initial replacement of evergreen conifer trees by broadleaf deciduous also means that annual timing of litterfall input changes from a relatively ubiquitous supply to seasonal pulses, and that woody residues have a much shorter residence time on the forest floor and on beaches. Lower C:N ratios in deciduous boles as well as lower lignin content mean that terrestrial decay rates are much higher for most deciduous species when compared against evergreen conifers (e.g. see Edmonds et al. 1986). Some authors have implied that large, persistent woody structures on coastal beaches were once much more prevalent than they are now, and that their roles in retaining wrack detritus and providing shade for detritivore communities must now be significantly altered (Maser and Sedell 1994; Stembridge 1979); others go on to claim that tree boles play important roles in deep-sea foodwebs (Turner 1977; Jones et al. 1976; Kodata, 1958). Too, it has been suggested that larger and older forest structures bordering beaches should have important consequences to shoreline physiographical development, including dune formation, and that certain plant species might be particularly dependent on unique moisture conditions at beach-forest edges (Maser and Sedell 1994; Stembridge 1979). All of these factors in some fashion can be implicated as nutrient changing events brought on by changes in forest structure following disturbance. Of course there are many site-dependent permutations of alternate vegetation development following disturbances, but many of the dynamics listed above are factors that should be taken into consideration when thinking about consequences to nutrient supply in and from the marine-riparian zone.

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DISCUSSION

There was discussion regarding soil type diversity on the west coast, which was identified as a possible factor in regulating terrestrial input to marine systems. No specific indication of the range of diversity could be given, other than it probably being considerable due to the range of parent materials available for soil formation in the western Cordilleras. Other discussion focused on the author's statements about the possible role of large wood on beaches in creating so-called habitat islands. The current versus past source for woody debris on marine shores was discussed in light of observation that current pieces most often have chainsaw marks and are likely of smaller diameter now. The role of root wads was indicated as another possible feature that has been lost in modern-day woody debris input, which would have served to anchor pieces more firmly to one single spot. Habitat islands were identified as moisture, shade, and possibly nutrient enclaves for organisms living in the probably harsh conditions of the marine intertidal and supralittoral zones. A question was raised about the efficacy of a reported 15m setback requirement for septic fields to control nutrient input to the MR. No definite answer was available from the speaker or from the audience.

The role of Oceanographic Processes in the Marine Riparian Zone (a coastal engineer's perspective)

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A primary consideration in the establishment of productive supralittoral marine riparian habitat is the frequency, duration and intensity of its inundation by the sea. It is the coastal engineer's role to quantify physical processes within the coastal zone to provide a sound footing for the design of engineering works and for making good environmental planning decisions. Since the author has no professional expertise in ecology, the present paper deals with those aspects of the riparian zone that are quantifiable using standard coastal engineering techniques. Quantifying those physical parameters that can be computed with relative confidence will lead to an improved definition of the minimum riparian buffer width required for productive habitat purposes. The inland extent of sea effects can be estimated by computing the various water level components shown in Fig. 1.

The riparian zone falls between the offshore, which is generally of interest to the mariner, and the uplands which are of interest to everyone else. Since nautical charts are the most extensive source of offshore bathymetric data, it is important to understand how the vertical datum of these charts (Chart Datum, CD) relates to vertical datum of the upland topographic maps (Canadian Geodetic Vertical Datum, CGVD). Chart Datum on Canadian charts is a tidal datum set to Lower Low Water Large Tides (LLWLT) which is the average of the lowest low waters, one from each of 19 years of prediction. Chart Datum on US charts (and US portions of Canadian charts) is a tidal datum that is vertically higher corresponding to the average of all lower low waters. Canadian Geodetic Vertical Datum corresponds roughly to Mean Water Level (MWL). Chart datum slopes between charts and experience has shown it to be a major source of error in coastal work.

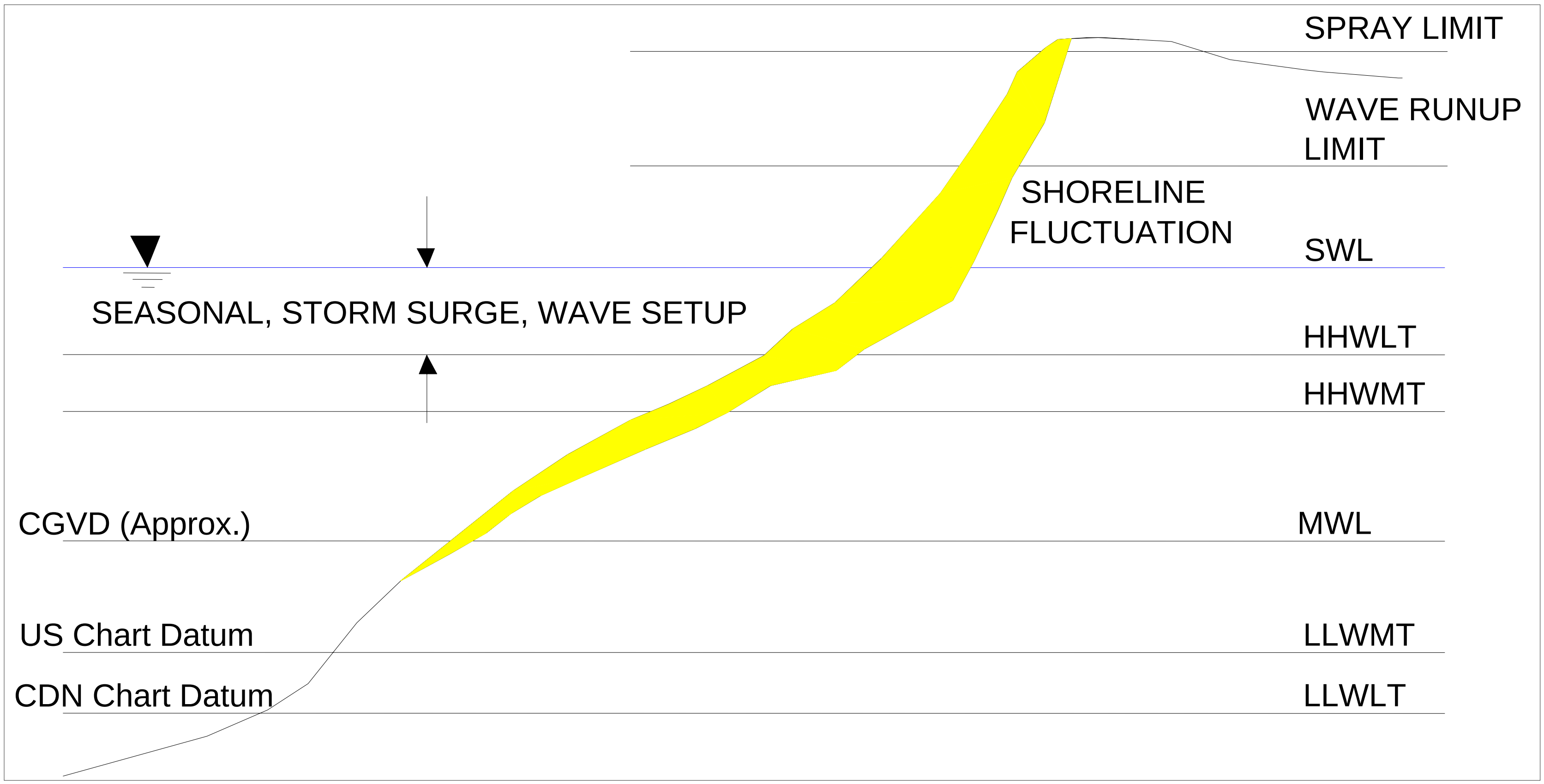

Figure 1. Water level components defining landward limit of water action.

Tidal elevations such as higher high water mean tide (HHWMT) and higher high water large tide (HHWLT) are referenced to chart datum and are computed by applying their definitions to predicted tides using Canadian Hydrographic Service (CHS) measured tidal constituents or constituents inferred over much wider areas using numerical tidal models such as that shown in Fig. 2.

The frequency that predicted water levels are at or near HHWLT is quite low. Fig. 3 shows frequency curves for four locations in BC. The curves are normalized with respect to CHS published values of HHWLT. For all four locations, tidal water levels are higher than 90% of HHWLT less than one week per year. Note that the generation of similar curves based on different seasons, years, daylight/dark hours, etc. is a straightforward exercise using specialized coastal engineering tools.

Other components affecting water level include wind-induced storm surge, barometric surge, ENSO, wave setup, global climate change and geophysical processes such as isostatic rebound. To provide some indication of the magnitude of these effects, water level measurements from Point Atkinson (1963 to 2001) were obtained and assessed in a similar manner to that done for tidal predictions (Fig. 4). It is clear that actual water levels are higher than predicted tides, but that water levels are still higher than HHWLT (in this case 5.1 m CD) less than 10 hours per year.

The difference between predicted and measured water levels at Point Atkinson were computed and analyzed statistically to provide an indicator of the frequency and magnitude of these effects (Fig. 5). This rather preliminary analysis indicates that a 1 m surge in the Strait of Georgia might be expected once every 10 or 20 years (and not necessarily at high tide).

With the exception of the west coast of Vancouver Island, wave conditions are relatively mild in most BC waters. Figure 6 shows the distribution of measured significant wave height and peak period at Halibut Bank (in the centre of the Strait of Georgia). Note that significant wave heights were measured higher than 2.0 m for only 67 hours (less than 0.1 percent of the time).

The way that such offshore waves are modified as they approach the riparian zone can be simulated using standard wave transformation numerical models such as that shown in Fig. 6. The marked way that wave heights and directions are modified, particularly in the vicinity of obstructions, is critical in determining the wave energy incident to the shoreline. Wave models such as this can be used in conjunction with water level (and current) models such as that shown in Fig. 7 to map the limit of inundation.

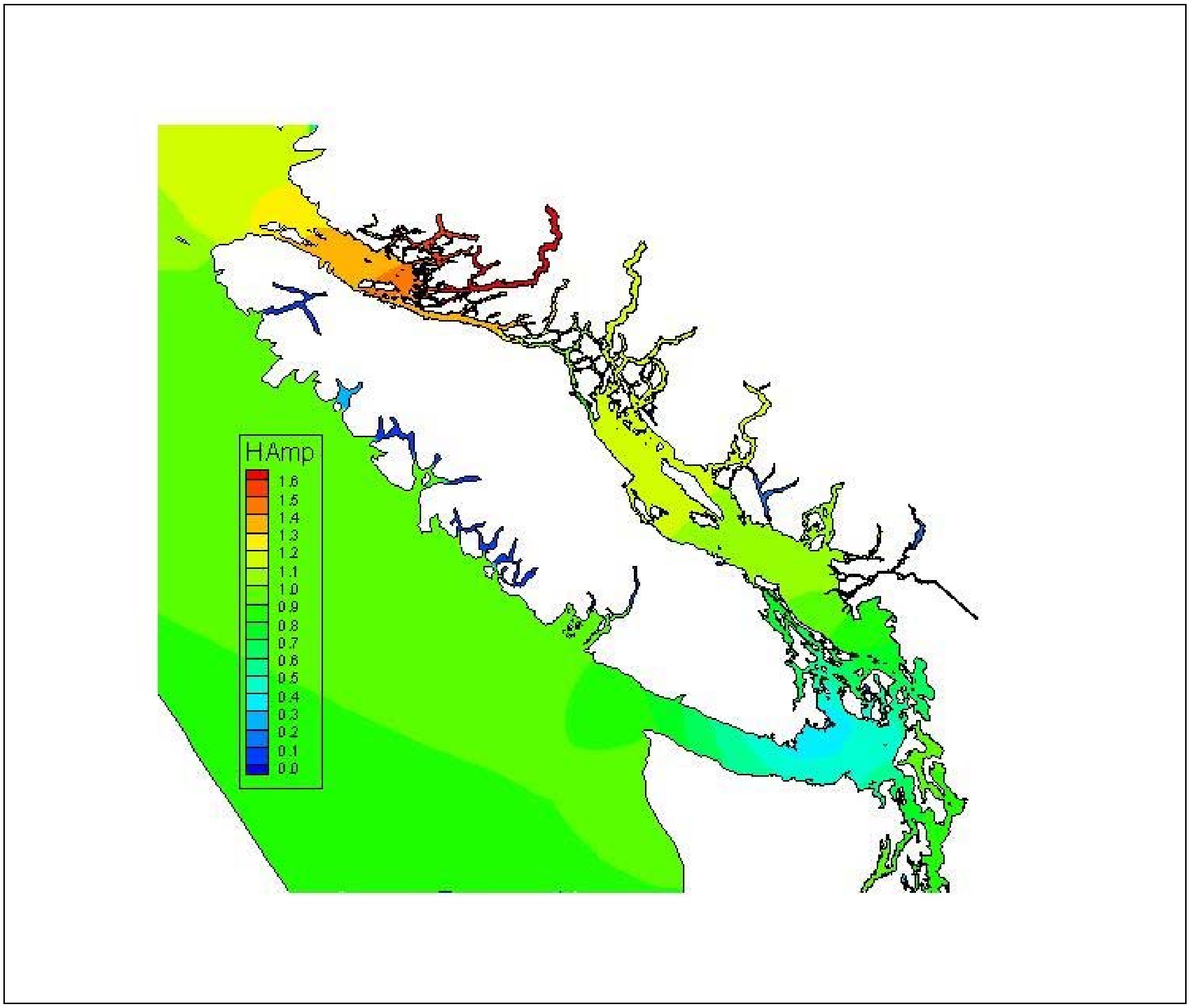

Figure 2. Vancouver Island, British Columbia, showing spatial variation of M2 tidal height amplitude.

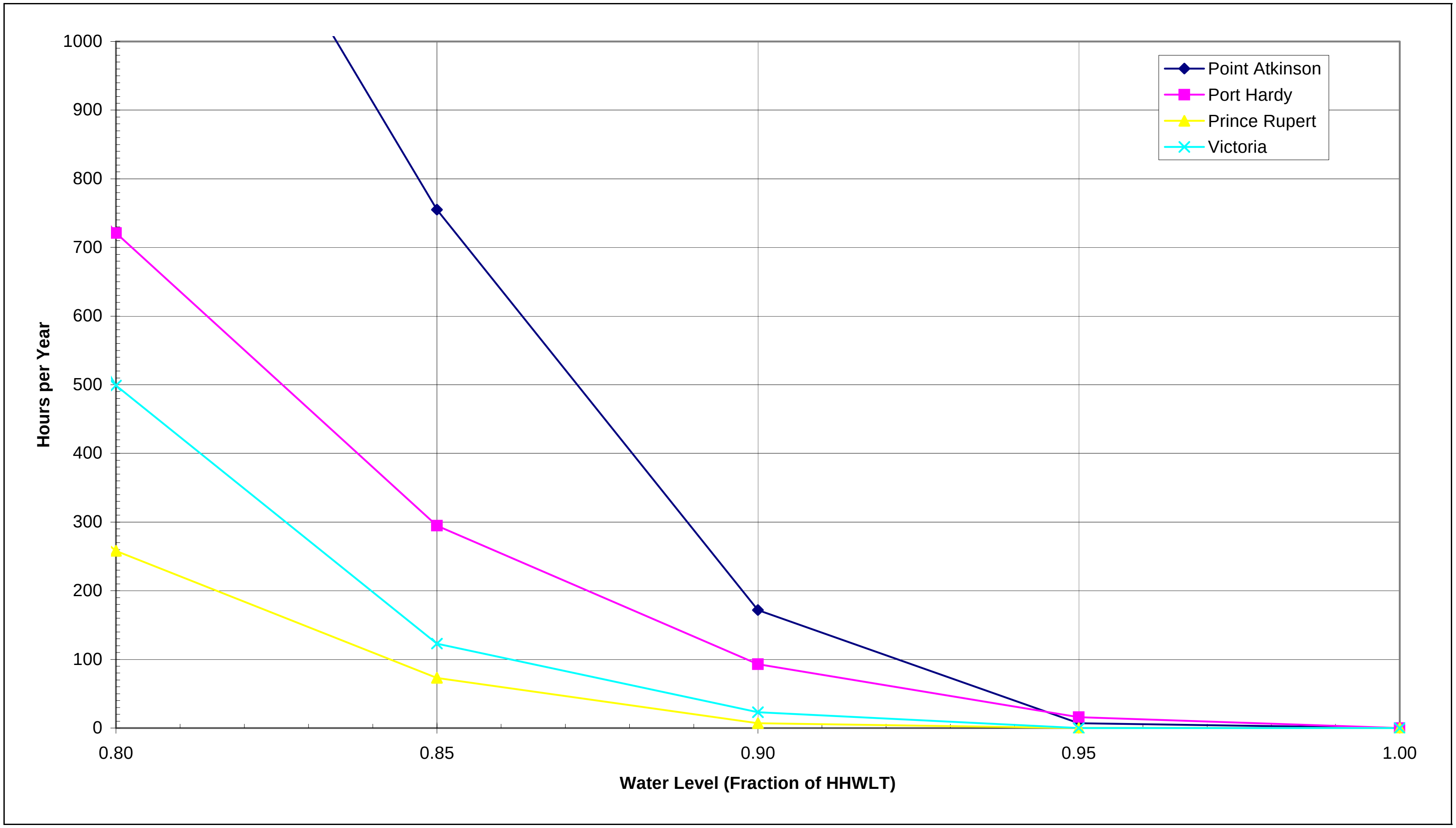

Figure 3. Typical BC tidal height frequency of exceedance curves.

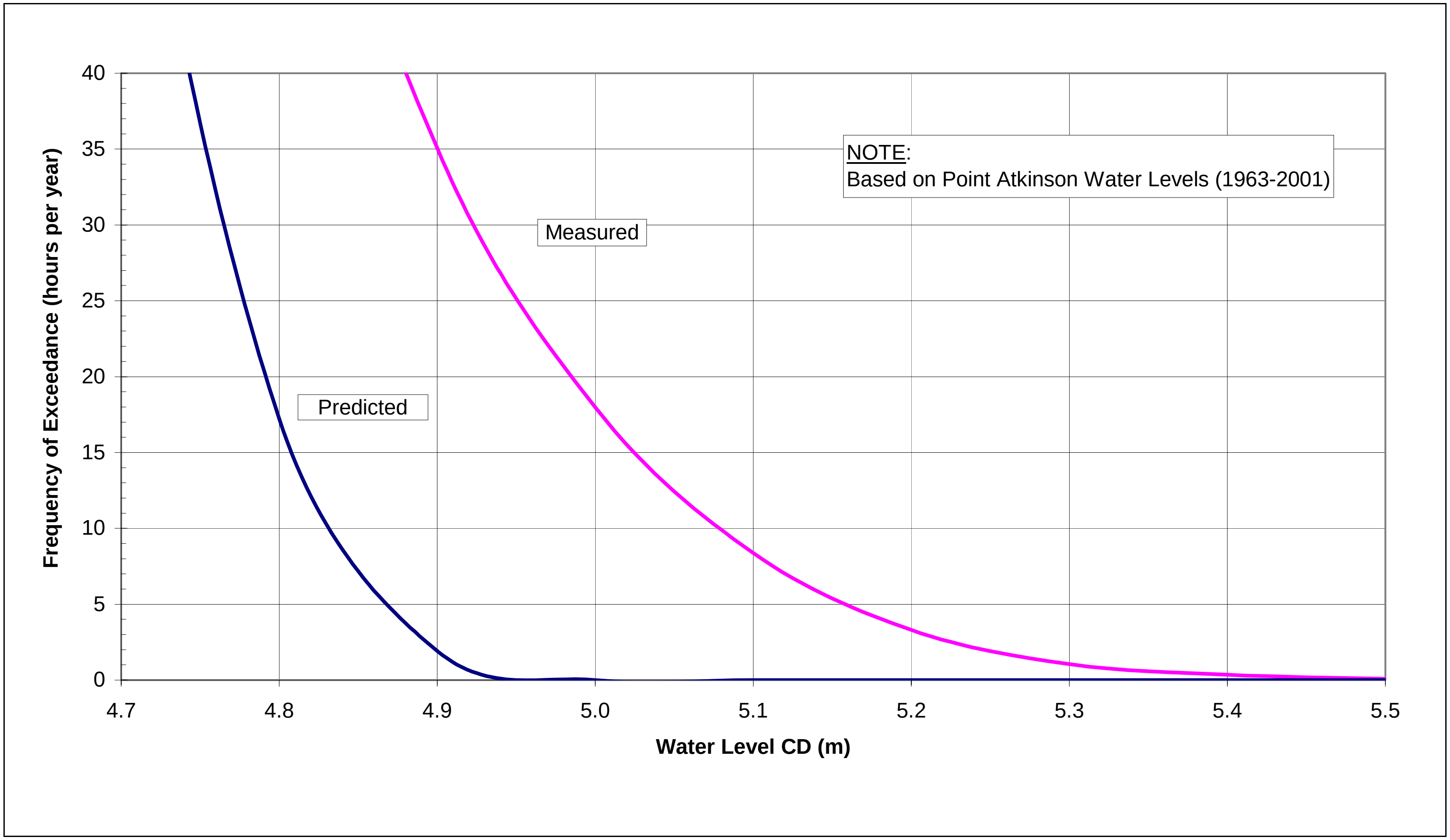

Figure 4. Measured versus predicted tidal height frequency of exceedance curves – Point Atkinson.

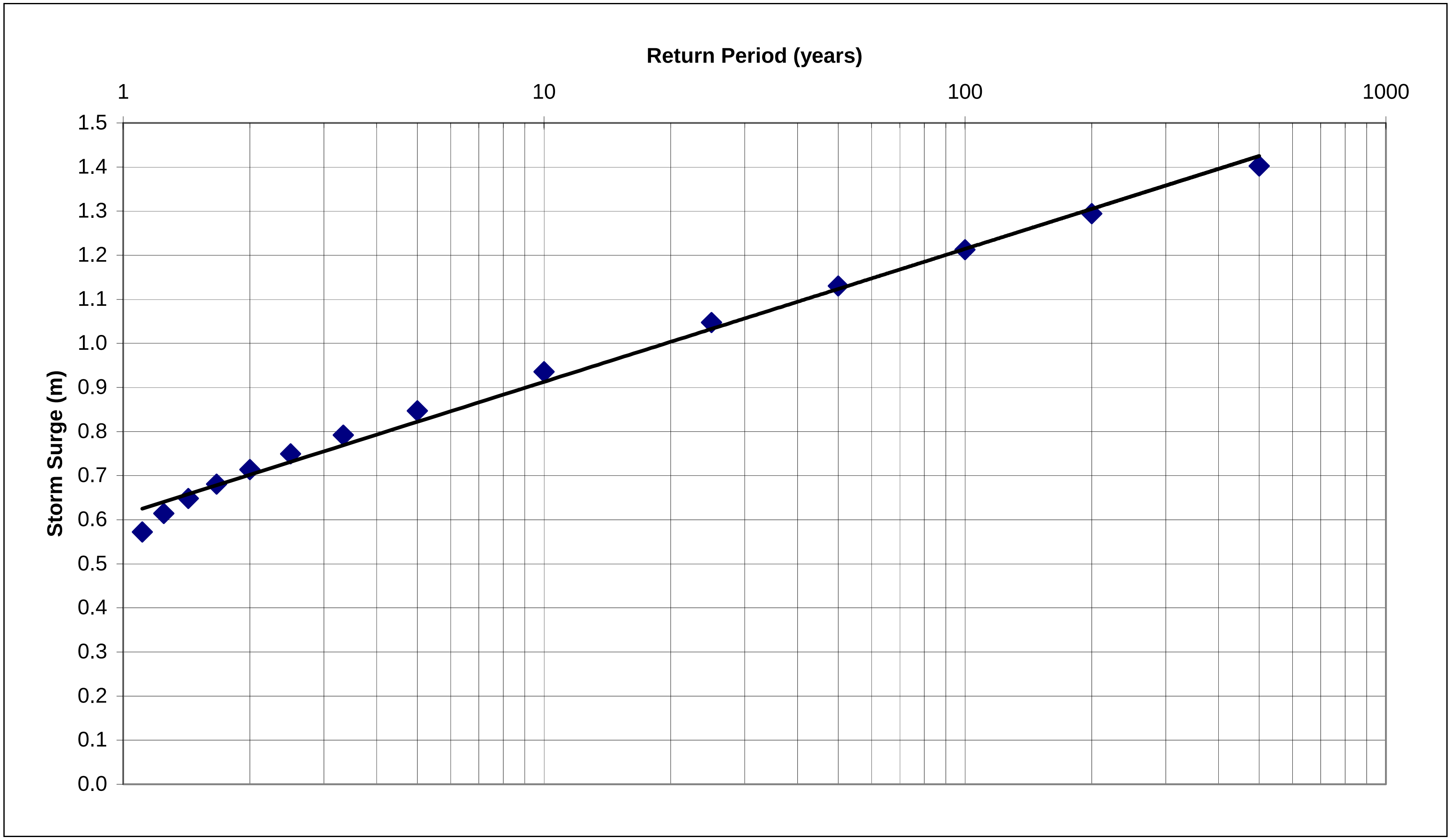

Figure 5. Indicative storm surge return periods in the Strait of Georgia.

Potential Number of Observations in Specified Time Interval (-): 78912
Actual Number of Valid Observations in Specified Time Interval (-): 61408
Number of Calm Observations in Specified Time Interval (-): 39735
Number of Valid Observations Meeting All Search Criteria (-): 61408

Significant Height (m)	Total	Peak Spectral Period (s) 2.0	3.0	4.0	5.0	6.0 (observations)	7.0	8.0	9.0	10.0
0.0										
	39735									
0.10										
	14330	3134	3721	1193	2500	3405	159	113	105	
0.50										
	5647	110	4008	1439	79	6	4	1	0	
1.00										
	1369	1	92	1122	148	5	1	0	0	
1.50										
	260	0	0	99	128	32	1	0	0	
2.00										
	54	0	0	0	39	15	0	0	0	
2.50										
	13	0	0	0	3	10	0	0	0	
3.00										
Total	61408	3245	7821	3853	2897	3473	165	114	105	

Figure 6. Bivariate histogram of measured significant wave height versus peak period in the Strait of Georgia.

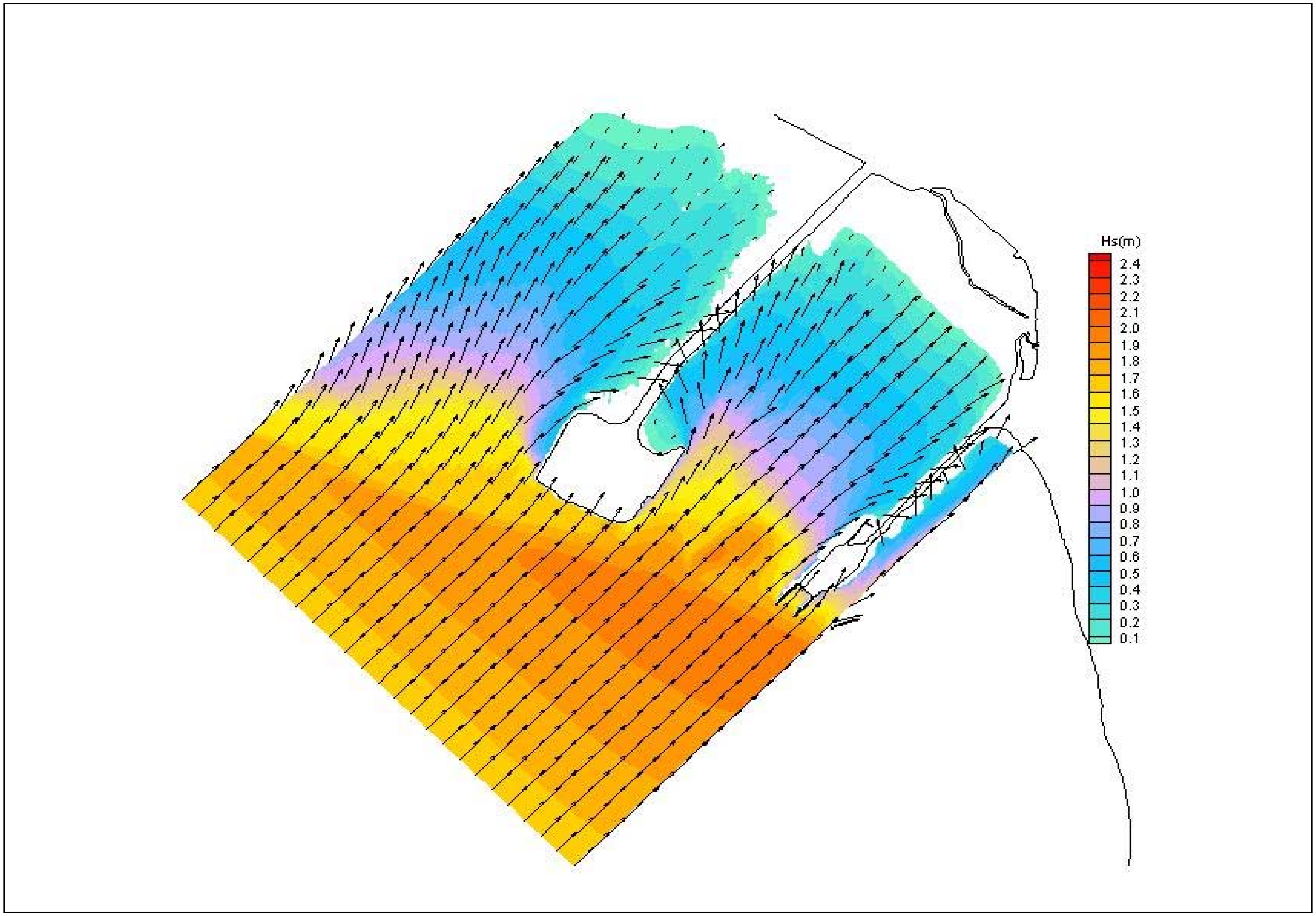

Figure 7. Spatial variation of wave conditions near Roberts Bank, British Columbia (2.0 m, 6 second wave from the SW).

The runup of a 2.0 m high wave on various types of shoreline can be computed for various foreshore slopes as indicated in Fig. 8. The differences in runup between the various shoreline types are primarily attributable to the dissipation of wave energy into the seabed as the wave rushes up the foreshore. The effect of vegetation is typically accounted for through the inclusion of an additional roughness factor.

The final oceanographic component of Fig. 9 is the effect of shoreline evolution. Background for this consideration is well described in the Coastal Shore Stewardship document available from **www.stewardshipcentre.bc.ca**. This document describes the various shoreline types that are typical of the BC coast such as sandy, rocky shores, bluff, vegetated and anthropogenically-modified shores. The predominant erosion and deposition mechanisms at work on these shorelines are described qualitatively. Coastal geomorphology studies, in conjunction with numerical cross-shore and plan-form shoreline evolution (e.g. Fig. 1), can be used to define quantitatively the expected shoreline position at some time in the foreseeable future.
In conclusion, standard coastal engineering techniques can be used to define the frequency, duration, intensity and extent of shoreline inundation. These parameters are complex and highly site specific, but are calculable and can be used as the defendable basis on which to superimpose the additional buffer width required to support sustainable riparian habitat.

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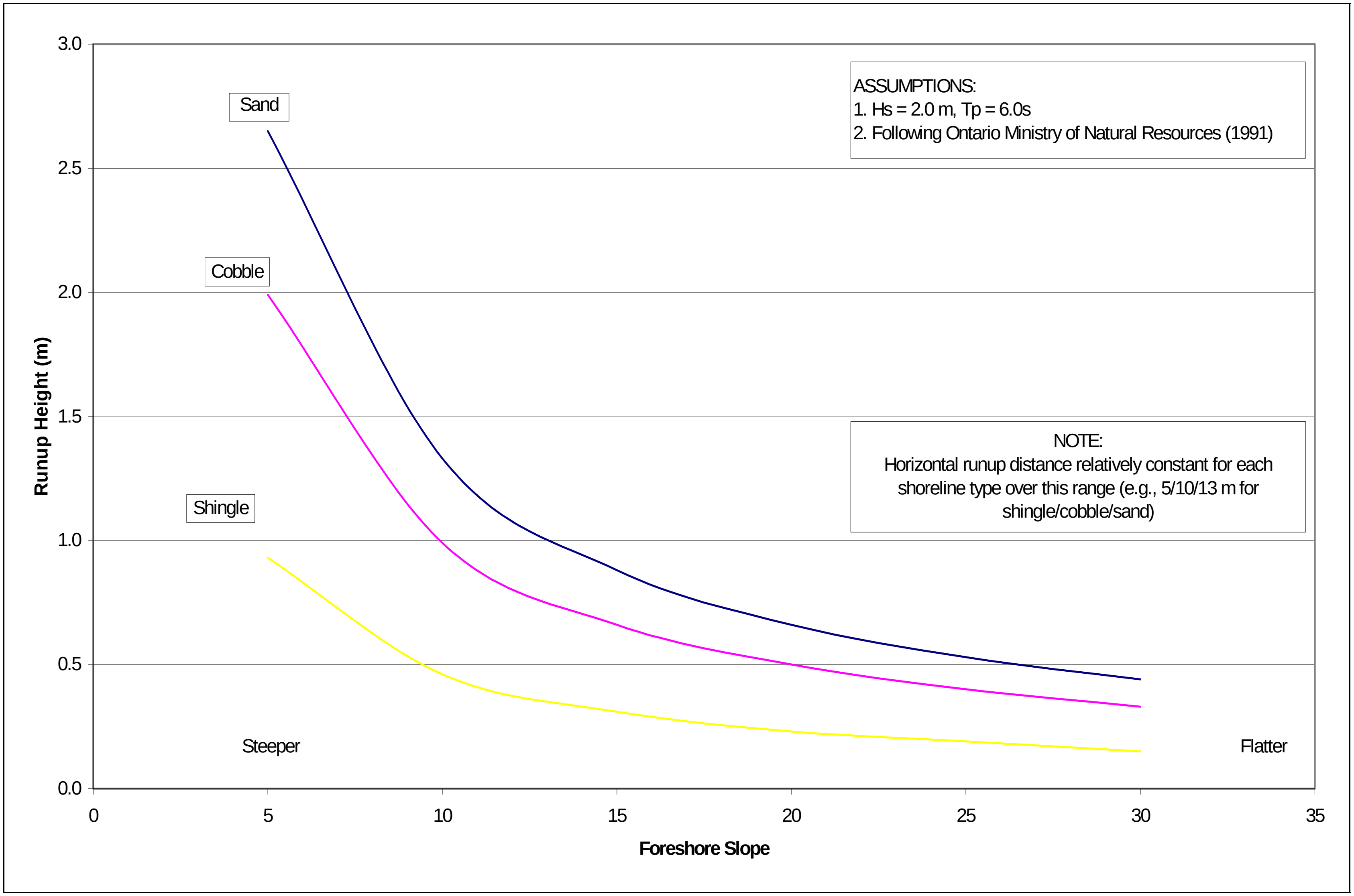

Figure 8. Indicative wave runup on various shoreline types.

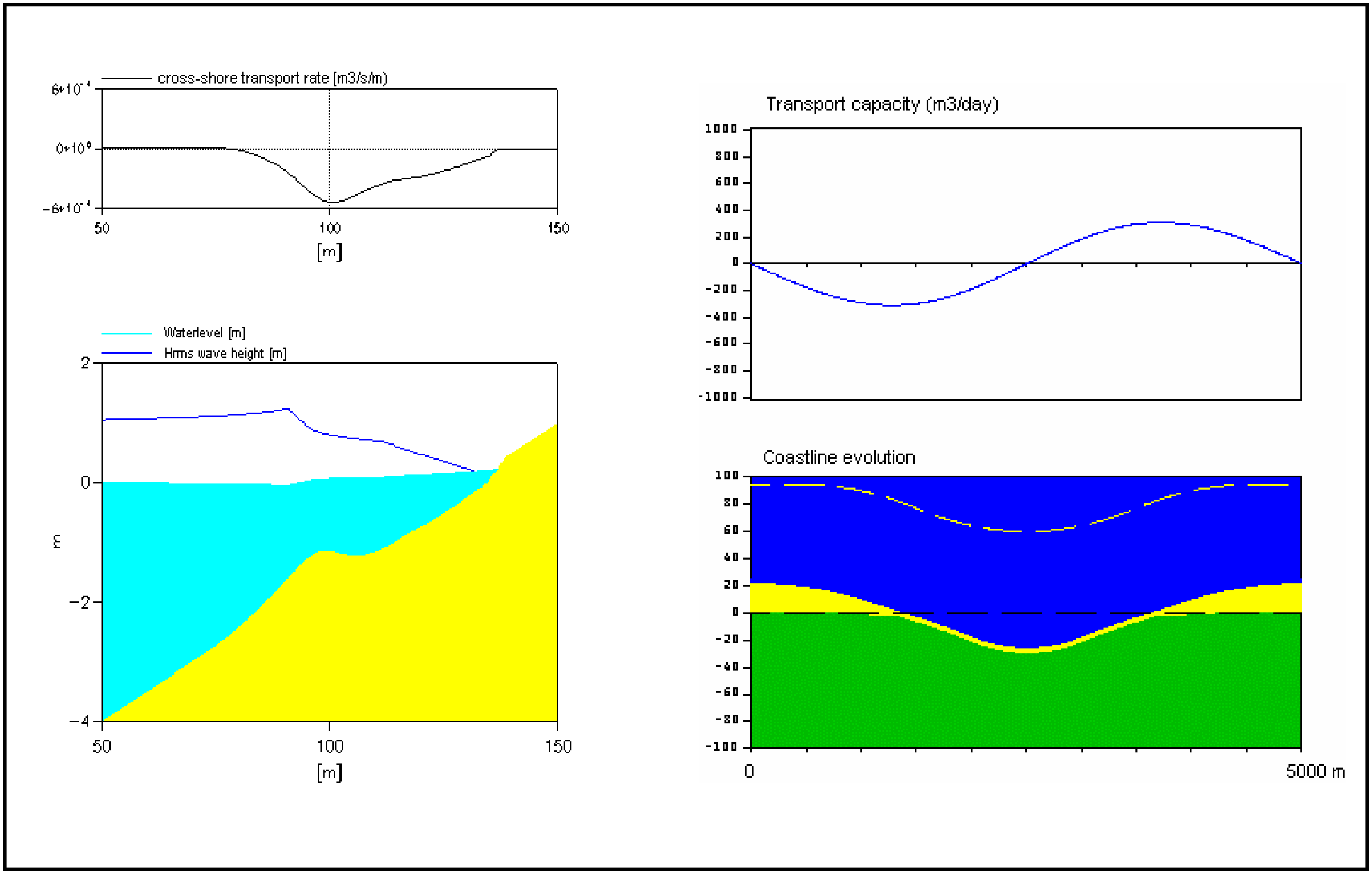

Figure 9. Example output from cross shore and alongshore shoreline morphology models.

DISCUSSION

Discussion focused on the ability of coastal engineers to predict the effects of structure removal at the shoreline. This was identified as an important topic because opposition to removing structures from shorelines is often made with the argument that they act as stabilizing features. It was felt that this can be done, but not to the resolution of effects across distances of a one-foot length, which is typically requested by homeowners.

The ability of engineers to test their models was also raised, and it was indicated that only in very limited circumstances has this been formally possible; i.e. the majority of quality assurance comes from an adaptive management style, where feedback from operational procedures is used to improve modeling procedures. One known formal study was established in the Caribbean region to test the accuracy of model predictions. Further questions were directed toward current technology in using wood and soft armouring in place of concrete and other ‘harder’ materials to build shoreline structures. There apparently have been no published studies of the success of these materials or any explicit modeling of changes that would be expected by their use as substitutes.

Likely Scaling of Basin Area with some Marine Riparian Zone Functions

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The marine riparian zone (MRZ) provides a variety of ecological functions (Levings and Jamieson 2001). Many of them involve movement of material from the terrestrial system to the marine system, and much of this movement is mediated through the flow of either surface water or groundwater. Consequently, consideration of drainage basin area is essential to understanding the amount and spatial pattern of material flows through the MRZ.

To explore spatial variation in basin area for drainages terminating in the coastline, I used a routine GIS watershed delineation program to analyze 10-m USGS DEMs (U.S. Geological Survey digital elevation models) of Whidbey and Camano Islands. I also examined current USGS topographic maps and historical USGS T-sheets to delineate coastal wetlands (including stream delta marshes and lagoons). Regression analysis was used to examine relationships between marsh area and basin area. Additionally, basin areas were calculated for various coastline forms, i.e., cove, point, or straight coastline, and analysis of variance (ANOVA) was used to determine whether basin area standardized by coastline length varied with coastline form.

The results indicated that basin area was a strong predictor of stream delta marsh area ($r^2 = 0.70$, $p < 0.05$) and of lagoon area ($r^2 = 0.71$, $p < 0.05$) when power functions were fitted to the data ($y = 0.015x^{1.18}$ for delta marshes, $y = 0.056x^{1.41}$ for lagoons, where x = basin area and y = coastal wetland area). The results were not surprising for delta marshes, because similar scaling of marsh area with basin area can be shown for much larger scaled landscapes (Simenstad et al. 1982, Walker 1998). However, the relationship between basin area and lagoon area was surprising because lagoons are coastal wetlands partially or completely enclosed by sandy spits, and spit formation is thought to result from patterns in coastal erosion and sediment transport by tidal currents and waves. However, the results indicate that terrestrial drainages influence lagoon size. This could be due to basin influences on nearshore topography and bathymetry, or to inputs of basin sediments and water whose influence on lagoon morphology has not been previously recognized.

The results also illustrate the degree to which coastal spits facilitate the formation of coastal marshes. The smallest basin that was associated with a delta marsh was 53 ha, while the smallest basin associated with a lagoon was 2 ha. For a given area of costal wetland, basins were about seven times smaller for lagoons than for delta marshes.

Comparison of basin area, standardized for coastline length, between coves, points, and staight coastlines showed that standardized basin areas varied significantly between categories ($F_{2,22}$ = 11.13, $p < 0.0005$) and post hoc comparisons indicated significant pair-wise differences between coves versus points ($p < 0.01$) and straight coastlines versus points ($p < 0.02$) with a suggestive difference ($p < 0.09$) between coves and straight coastlines. Standardized basin areas averaged approximately 790 m^2 per meter of coastline for coves, 480 m^2 for straight coastlines, and 140 m^2 for points. These results suggest that inputs of freshwater and suspended and dissolved materials to the MR and nearshore will vary substantially with coastline form. In addition to influencing terrestrial inputs to the MR, coastline form likely influences the ability of marine currents, wind, and tide to disperse or concentrate these terrestrial inputs, with coves being sheltered, depostional environments and points being exposed, erosive environments.

Spatially variable input of freshwater, sediments, nutrients, pollutants and other similar materials to the MR has clear expression in the development of coastal lagoons and delta marshes of various sizes, and their associated geomorphology and biology. Similar ecological consequences of variation in basin size between coves, points, and straight shorelines could likewise be elucidated for these areas.

From a management perspective, the results indicate that the MR is not independent of terrestrial basins. Human activities in areas distant from the MR may have significant impacts (e.g., changes in freshwater inputs, nutrient inputs, sediment inputs, or pollution) on ecological processes and structures in the MR. Additionally, sensitivity to basin disturbance likely varies with coastline form. From the perspective of basin size, coves could be considered the most sensitive coastline form and points the least sensitive. However, there may be other considerations, not addressed in this exploratory analysis, which may vary with coastline form or basin size, e.g., basin slope and geology, which also may affect sensitivity to human disturbance.

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EDITORS' SUMMARY

The author introduced the talk by approaching a number of ecologically important functions attributable to the MR, which were noted to have been well covered in previous talks. The bulk of the presentation focused on some preliminary analyses examining landscape features, relevant to the MR. The author established that associations should exist between physiographic features and biological features at the shoreline and gave evidence from arctic and temperate areas showing that upland, large-scale features, like watershed size, are strongly linked to shoreline features. The mechanism promoted to explain this was the interaction of oceanic erosion against different kinds of landscape features prevalent on the coast. Data were presented from other authors showing positive relationships between watershed area and delta size, freshwater discharge, suspended sediment load, estuary area, and wetland area. Those relationships were echoed with original data from Washington State showing a positive relationship between watershed area and tidal wetland area.

The author concluded that the nature of ecological interactions between aquatic and terrestrial components of the MR is possibly a function of upland features, and that upland protection might be more important than previously thought. The comparison was made between spits and coves (lagoons), where coves tended to be associated with watersheds of larger area, leading to speculation that upland drainage patterns were significantly modifying coastal features. The author concluded that both upland and seaward processes interact to form important MR features and gave the concluding example of spits adjacent to coves at the terminus of relatively small watersheds. In this particular case it was argued that spits act as sediment traps, promoting the formation of salt marshes. The caveat was given that no consideration of longshore transport had been formally made in the given analyses.

DISCUSSION

Dialogue began with questions about the origin of small spits in the marine environment, and whether these represented marine convergence zones. No conclusion was reached regarding the interaction of offshore effects with any possible upland processes to result in the shaping of shoreline features. A second comment referred to the role of groundwater input to the nearshore from areas that had no visible channelization; a typical example was given as a small island which was thought to be a watershed, despite defying the formal definition of such. It was indicated that this should somehow be considered in an analysis between upland features and shorelines. A reference was given to a modeling regime that indicated 14% of water in Puget Sound originated from non-point sources, i.e., groundwater input. The importance of distinguishing between tidal and wave effects on shoreline formation was discussed. Further discussion referred to the tools currently available for watershed mapping where Terrestrial Resource Inventory Management data (TRIM) and other digital elevation model sources were indicated as newer tools that would enhance prediction and relationship modeling of the kind outlined in the talk.

Current Marine Riparian Setback Standards Used by DFO in BC

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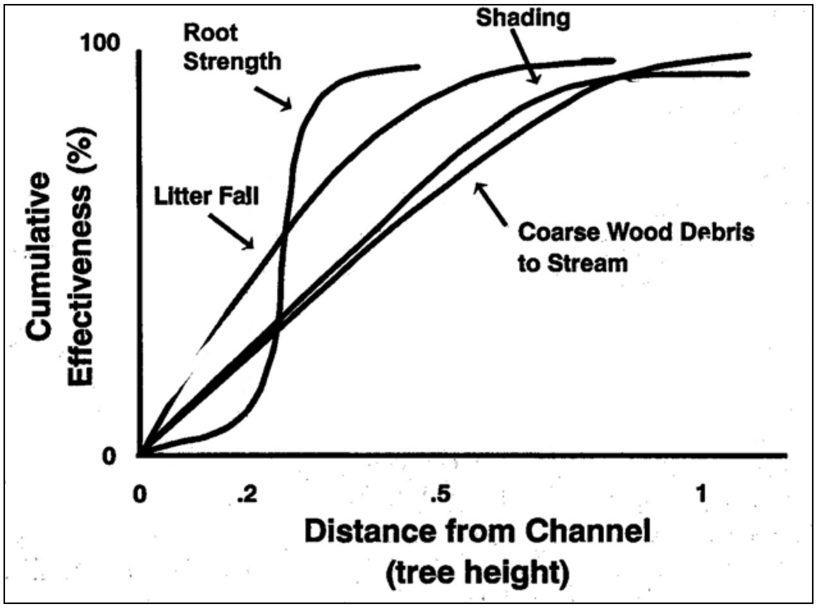
The science of marine riparian zone function and width for effective conservation of fish habitat features and functions is very poorly developed compared to freshwater lentic and lotic systems.

There is however a pressing need from habitat management staff for direction and guidance on reserve widths required to protect fish habitat on marine foreshores as a result of the ever increasing number of applications for developments and works in and about the intertidal and marine riparian zone of BC. Many of the proposed activities affect both the backshore and the riparian area directly (e.g., involve clearcutting or selective removal of vegetation) or will affect the riparian area indirectly via changes in local surface and subsurface freshwater flows, intertidal gradient and wave run-up behaviour, or sediment recruitment to the riparian zone and beach as a result of backshore development activities.

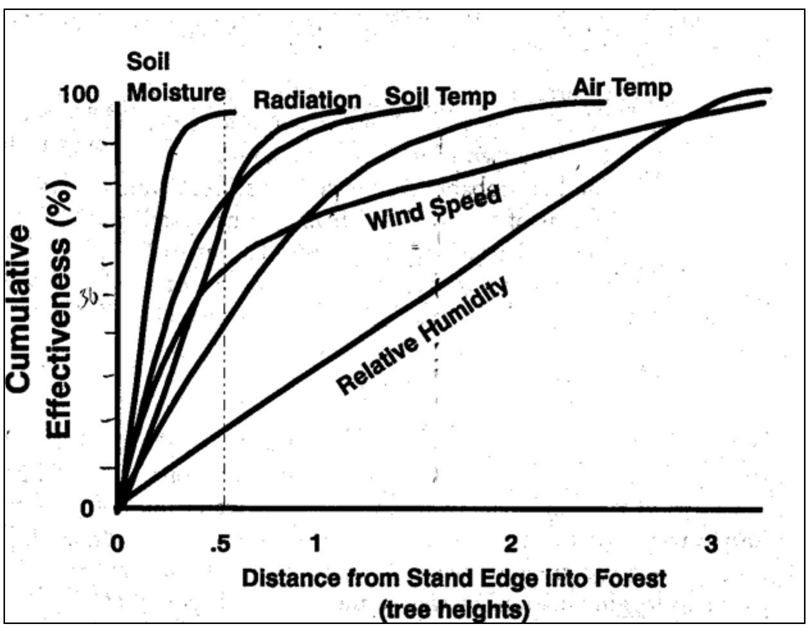
In the absence of scientific advice specific to marine riparian areas the Department of Fisheries and Oceans (DFO) habitat management has borrowed standards from freshwater environments and has modified these based on several biological and socio-economic criteria.

There are several main sources of guidance for marine riparian setbacks that are currently used in BC by DFO. One of these is the 1993 Land Development Guidelines (Chilbeck et al. 1993), which were specifically intended for use adjacent to small streams and rivers in settlement areas. The other is the Clayoquot Sound Scientific Panel report (CSSP, 1995).

Much of the source information for the recommended setback widths reflected in both the Land Development Guidelines and the CSSP report were derived from the FEMAT (Forest Ecosystem Management Assessment Team) report of 1993. This report, authored by a number of U.S. land management agencies, provided some excellent guidance in Section V- Aquatic Ecosystem Assessment, on the rationale for buffer widths and presented generalized curves of % cumulative effectiveness for particular riparian effects and functions as a function of buffer width. This information, summarized in Fig. 1A, became the basis for the buffer or reserve widths adopted in the Land Development Guidelines while Figure 1B provided part of the basis for the CSSP report recommendations.



A



B

Figure 1. Curves demonstrating percent effectiveness as a function of distance from shore (A), and from forest stand edges (B). Reproduced from Figures V-12 and V-13, FEMAT (1993), respectively.

The context for application of these standards also differs considerably. As stated earlier, the Land Development Guidelines were intended to provide guidance to developers and planners on minimum riparian leave area or setback widths required in association with urban development. The Clayoquot Sound Science Panel's goals, on the other hand, as stated by former BC Premier Mike Harcourt were "to make forest practices in Clayoquot Sound not only the best in the province, but in the world". The Panel took this as a mandate to develop a sustainable forest ecosystem management approach, which would include a radically different way of looking at riparian/ aquatic relationships in the forestry harvesting sector.

Because of this broad mandate, both the nature and variety of reserves recommended by the Science Panel went well beyond those that would have been proposed by a single agency with a single or limited mandate such as fish. They were also not constrained by feasibility of application in an urban context.

The CSSP also proposed a marine shore classification system to which different riparian standards would apply (Fig. 2). Buffer or reserve width recommendations ranged from 150 m for low shores adjacent to open oceans where vulnerability to wind effects was considered significant, to 100 m on open water rocky bluffs and protected lagoon, saltmarsh, dune, and estuarine features which are considered more structurally complex, protected and less vulnerable to fetch and wind effects. In the case of estuaries a smooth transition zone from the marine riparian to the streamside riparian management zone was also recommended.

The various buffer widths used in BC and the basis for each are given in Table 1**.** The criteria for establishing different marine setbacks included adjacent land use, adjacency to sensitive habitats and feasibility of application.

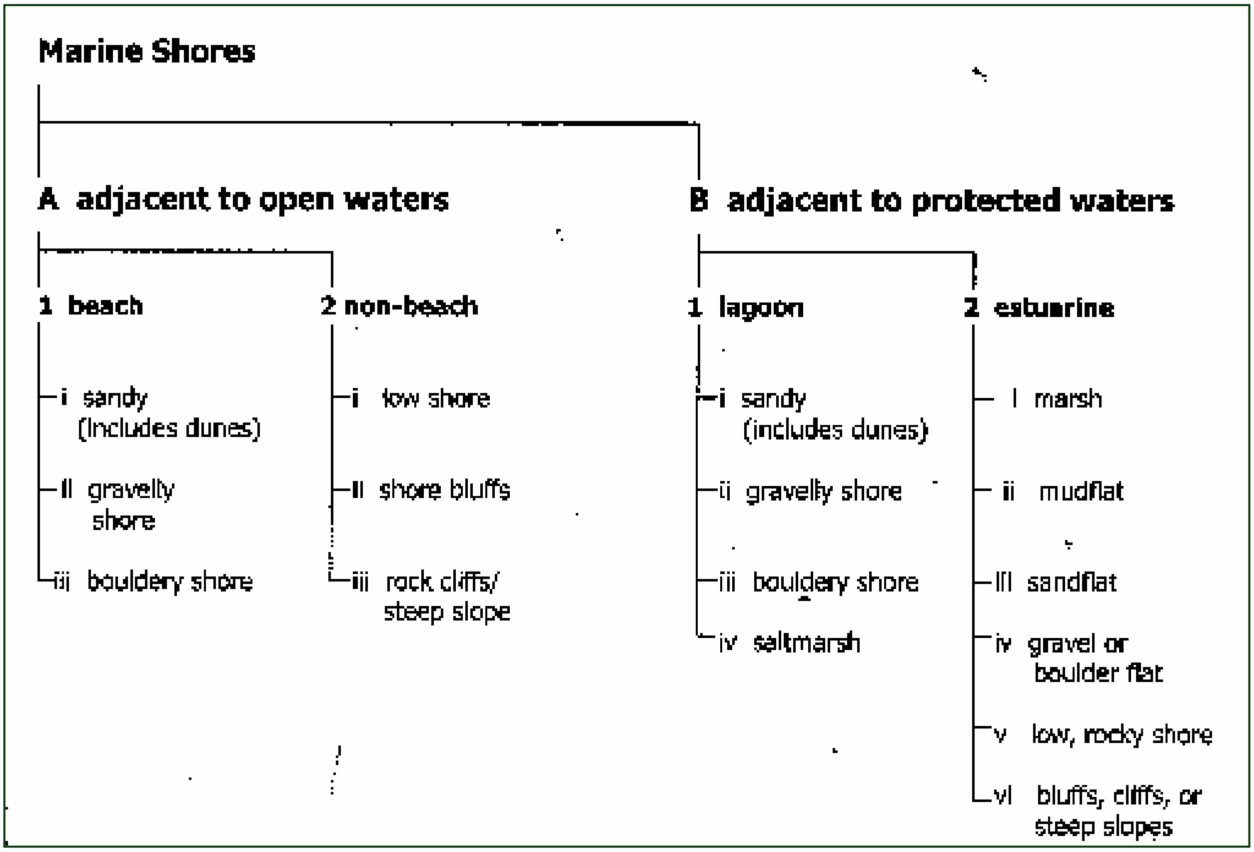


Figure 2. Marine shoreline classification system. Taken from CSSP (1995). Sustainable ecosystem management in Clayquot Sound: planning and practice. Prepared by the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound.

Table 1. Land use classification scheme and associated setback distances currently used by Fisheries and Oceans Canada. Source acronyms are the same as those in the text. HHW=High high water line, and refers to the maximum annual tidal height.

Adjacent land use	Current setback Standard	Source
Urban commercial /industrial/high density residential	30m from HHW	Chilbeck et al. (1993)
Urban low density residential	15m from HHW	Chilbeck et al. (1993)
Undisturbed crown foreshore adjacent to "sensitive habitats"*	100m +windfirm buffer	CSSP (1995)
Other undisturbed crown foreshore	50m +windfirm buffer	CSSP (1995)

* Sensitive marine fish habitats used for the purpose of applying a 100 m marine riparian setback standard on crown forest foreshores include the following: estuaries, eelgrass meadows, kelp beds, herring and forage fish spawn areas, salt marshes, mudflats, rocky reefs providing rockfish spawning or rearing habitat, salmon spawning areas, and nursery/rearing and adult holding areas

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Current Standards for Marine Riparian Setbacks and Buffers in Washington State

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Washington manages development on marine shorelines through a combination of local and state permits and land use authorizations. With recent listing of some species of anadromous salmonids, additional consultation with federal agencies is often required as well. There is no uniform code of regulations to protect marine riparian area functions and the ordinances are quite variable by jurisdiction, and shoreline reach. Rationale for selected standards enforced by local agencies, recommended or required by state or federal agencies as part of permit consultation will be discussed.

Editors' Summary: Current Standards by Jurisdiction

The principle tool for managing the MR is currently the use of 'setback' distances from the shoreline, which typically form the basis for either the retention or the restoration of a vegetation buffer zone between upland activity and the marine shoreline. The history and rationale for the development of setback standards in the Pacific Northwest were presented by Steve Fadden (Alaska), Melody Farrell (British Columbia), and Doug Myers (Washington State).

Much of the shoreline in southeast Alaska currently exists within the Tongass National Forest (TNF), administered in part by the US Forest Service. Because of the low population density and significant wilderness values in that region, the principal management concerns were said to be habitat for terrestrial wildlife species, and visual aesthetics. Industrial logging was indicated to be the primary activity of concern regarding these values. Although the TNF represents the northern terminus of temperate coniferous forest in the Pacific Northwest, its high latitude means that forested land is restricted to areas within five miles of the coastline, and to an elevation limit ranging from 1,500-2,000 feet. Forest dwelling species were therefore said to have limited habitat area, especially those known to depend heavily on MR forests and other features. The author listed several species known to use MR features, for which the US Forest Service has partial management responsibility, including: bears, wolves, marten, mink, river otter, moose, Sitka black-tail deer, seals, walrus, numerous raptors, king salmon (Chinook), silver salmon (coho), pink salmon (humpback), red salmon (sockeye), dog salmon (chum), dolly varden, steelhead, cutt-throat trout, and halibut. Primary habitat related features for which guidelines are designed focus on: the need for shoreline forest connectivity by marten, mink and otter, the MR as a feature for bald eagle and goshawk nesting habitat, and winter foraging habitat for deer. The most compelling reason for extensive setback distances has been telemetry data indicating the preferential use of the MR for foraging habitat by the northern goshawk (data provided by Alaska Dept. Fish and Game). The current standard for setback distance was indicated to be 1000 feet from shoreline.

Washington State was indicated to manage development on marine shorelines through a combination of local and state permits and land use authorizations. This included five sources as current guidelines for shoreline development: The Shoreline Management Act, the Growth Management Act, the Uniform Building Code, the Clean Water Act, and local building codes. Primary features of interest that are guided by those sources were as follows: landslide hazard, steep slope hazard, fish and wildlife habitat areas, kelp and eelgrass beds, commercial and recreational shellfish interests, wetland habitat, and herring, sand lance and smelt spawning areas. Setback distances from marine shorelines were said to be 25-200 feet (~7-60 meters) for residential development. When structures are to be built on bluffs, setback distances were said to be equal to 1/3 bluff height, where bluff height is not to exceed 100 ft. For water-dependent commercial structures, it was indicated that no setback distances were required. For shorelines of 'statewide significance', 200-foot buffers were indicated for timber harvesting. Additionally, building setbacks are commonly set to be 8-50 feet from any vegetation buffer. The author raised some concern about the definition and concept of vegetation buffers in Washington State as many activities are permitted within the buffers, including: cutting of no more than 30%

merchantable timber over ten years, water conveyances, trails and access stairs or ramps, utility corridors, view trimming and pruning, mining and quarrying, shoreline stabilization, and the replacement of existing, dilapidated structures built preceding current restrictions. However, under certain conditions, restrictions can be enforced to limit such activity. These can include no touch zones, limits to impervious surfaces, limits to vegetation clearing, the requirement for consultation regarding geological features and drainage features, and in some cases restoration requirements can be imposed as a condition for a proposed development. Requirements were said to be evaluated on a case-by-case basis, given the rules inherent in guiding documents.

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Requirement for Use of Best Available Science

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Washington's Growth Management Act requires that updates of critical areas ordinances be based on Best Available Science (BAS). While there is a statutory definition of BAS for the purpose of the Act, many other management programs have begun to adopt this philosophy. This places a burden on regulators to stay current with scientific findings that affect the resource but has the effect of keeping the regulation "alive" in the face of changing knowledge. It also urges more frequent contact between resource managers and the scientific community.

EDITORS' SUMMARY

Doug Myers gave brief comments about the use of best available science as required by the State's Growth Management Act. He referred specifically to a document known as the 'Critical Areas Assistance Handbook'. The document is used as a guidance manual for updating critical areas ordinances required under the Act. The criteria for use of such science are: 1. The science in question must have been contained in a manuscript that has undergone peer review, 2. it must be logically cohesive, 3. it must contain quantitative measures of some kind, and 4. its conclusions must be set in a proper context.

Within the handbook is a model ordinance. The ordinance was indicated to be useful because despite its limitations, it can be applied to a large area of marine shorelines in Puget Sound, and contains strict guidelines for the provision of riparian vegetation buffers and/or setbacks; 150-250 foot distances are common. Clarification was requested as to whether the County recognized open space as a planning priority. It was indicated that the County currently does recognize and implement open space as a priority during development planning.

Discussion that followed the presentation focused largely on the guidelines within urbanized areas. The issue of lengthwise connectivity among segments was brought up, which in turn raised issues about the scale at which management decisions are being made. The conclusion was reached that neither managers nor scientists should act to reinforce the management measures in current legislation because they are somewhat arbitrary. They should instead advocate adjustments justified by best available science.

BREAKOUT SESSION 1

Group 1
Caveats about choosing management approaches were stated and included the need for a clear statement of goals, and a good understanding of ecosystem principles. Impediments to forming good approaches were identified as: differing terminology among agencies, differing management units, including the basis for their delineation, data gaps, under-representation of some stakeholders during planning processes, and the lack of communication between managers, policy makers and the scientific community. Currently available management approaches were identified as: general stewardship and advice provision from the variety of appropriate agencies; the use of planning at variety of scales; conservation efforts; regulatory efforts; public education efforts; formal research, inventory and assessment. Adaptive management was seen as an important form of data reconnaissance. "Green engineering', which includes attempts to create ecologically non-intrusive structures, was also seen as a valuable approach that should be pursued as there was a perceived demand for such structures; it was felt that any inherent merit should be applicable to the MR.

The group agreed that there was little scientific study to support any of these initiatives for the MR. Given the current state of knowledge for the MR, management recommendations were thought to be best proposed in the general sense, and included approaches such as: using a variety of temporal and spatial scales to evaluate problems; the pursuit of cumulative impacts assessment; and methods to address ecological problems by ecological rather than jurisdictional boundaries. The application of such approaches was felt to be complicit with the goals of a regionally wide management plan in that most tools could address large as well as small scale issues. It was felt that a regionally wide management plan would help to communicate regional objectives to actions taken at a local scale. Some concern was expressed that the large-scale planning process currently underway known as the 'Georgia Basin Action Plan', was not taking the MR into account as an explicit management unit. Specific actions to approach the various issues listed above were suggested as:

- working towards more definitive models that include factors like substrate, slope and estuary proximity
- Establish better communication between scientific community and local governments
- Further inventory, assessment and mapping; including cumulative impacts
- Public education and stewardship promotion

Group 2
Current management approaches were identified by the group to consist of: currently existing inventory maps for MR features, historic inventory for restoration purposes, the identification of sensitive management areas and management risks, vegetation buffers, and setback distances from the MR. However, much of the group effort focused on particular methods for future management approaches, including the identification of sensitive areas at larger scales than

currently performed, and better investigation of vegetation buffer lengths and widths needed to protect identified functions of the MR. A vegetation buffer width of 30 m was suggested as a starting point in the absence of marine-specific data, as there appeared to be some justification for this, at least from freshwater FEMAT documentation. The group also discussed broader, 'ecosystem based' approaches such as larger-scale inventory, mapping, and coastal zone planning. There was some expression of the need to improve reporting of research to the public, and to decision makers, and to improve public education as a management approach. There was also recognition of a virtual lack of economic approaches for the study of the MR, including current and future dollar values, the use of land covenants, and full cost accounting of ecosystem services to humans. It was suggested that a good link between education and the outright purchase of land as a management tool would be to develop demonstration areas in the MR, using property acquired by a variety of sectors; the sectors were identified to be private businesses, governments, NGOs, and private foundations. Demonstrable items were to include conservation principles, restoration and enhancement efforts, and non-standard erosion protection measures.

Group 3

Identified current management practices were: the principle of working to 'conserve rather than restore' habitat and systems, specific recommendations about the construction of shoreline armouring, the use of vegetation buffers at shorelines, and the use of biophysical mapping. The community working with MR issues should anticipate legislation attempts to mimic approaches developed from terrestrial wetlands management where development is allowed in lieu of offsite restoration and recreation efforts. It was felt that there was no good evidence to suggest that this can be accomplished for more than a few of the many values inherent in such systems.

Alternatively, shoreline armouring data were cited indicating that siting structures above the higher high water large tide (HHWLT) would prevent harmful effects to the littoral zone, and would also promote the deposition of large wood from the ocean to shorelines. Scientifically defensible recommendations for vegetation buffers were felt to be limited to the recommendation of vegetation presence over absence when a choice is implicated. There was suggestion that pursuing the presence of vegetation might be more important than the pursuit of armouring restrictions, given the identified strong role of vegetation in generating terrestrial input in marine fish diets. It was felt that no good science currently exists to recommend vegetation buffer widths in the MR at this time. In terms of addressing regionally wide plans, it was felt that a biophysical mapping regime would be the first and most important development priority. It was felt that such a tool should consider living and physical elements, and that much of the information existed already as fragmented sources in a variety of formats, and in the custody of several organizations.

DISCUSSION, PLENARY SESSION 1

There was objection to the recommendation regarding position of armouring structures above the HHWLT to the effect that such blanket prescriptions would have deleterious effects on shoreline processes. The recommendation was refuted by several members of the audience who identified adverse impacts associated with shoreline armouring, regardless of location.

It was then suggested that it is better to avoid bulkheads altogether rather than try to make recommendations for preferred positioning. There was also some discomfort expressed toward the blanket recommendation of any fixed width for a buffer, especially small (30 m); such values can become quickly entrenched and difficult to adjust if future data warrants. It was suggested that life history requirements of individual species should be used to address appropriate vegetation buffer widths. There was some concern that buffers were not being applied to the marine side of shorelines. Since both marine and terrestrial regions are thought to influence one another in a reciprocal fashion, it was felt that perhaps a buffer width extending seaward should be considered. One approach to width determination in this case was given as the distance for which the euphotic zone and the ocean floor were inclusive of one another. Support for demonstration projects was expressed, referring to the earlier idea of coupling public education and awareness effort with the establishment of MR protection areas.

The concept of producing 'nomographs' for the MR was put forth, possibly useful in visualizing concurrent changes of multiple functions across distance in the MR. A typical example was given in Melody Farrell's talk (day 1).

BREAKOUT SESSION 2

Group 1

The following data areas were identified as data deficient: a mapping tool for inventory and analysis. Species inventory, quantification of natural systems and identification of threshold points for critical losses of function services; long term limits of water actions on beaches, and a general need to think in longer terms; soil types and processes in the MR; a need for natural reference sites was identified to establish goals for management and restoration; much more information on water quality in the MR; data at the basin or large watershed scale.

The methods to approach data reconnaissance for the above were as follows: the use of a multidisciplinary approach, especially where collaboration is implicated. This not only helps to identify dependence between different measured variables, but also to avoid discontinuity in research effort. It was felt that at least in some circumstances the co-involvement of multiple agencies maintains funding stability via interagency commitments. It was felt that tools to assess natural and acceptable ranges of disturbance should be developed and used to define and illustrate those types of disturbance falling outside of the indicated range. The use of 'citizen science' (involving laypersons in data reconnaissance) was advocated as a method to increase public ownership over knowledge as well as support for formal research. A need for better data management was identified through 'quality assurance/control' methods. Digital elevation models were discussed as valuable tools for which more data need to be gathered. Other discussion focused on the need for data regarding effects of a rising sea level, and the comparative role of terrestrial versus marine insect species contributions to fish diets. Further, the topic of vegetation buffer widths was identified to be data deficient as well as the investigation of 'no touch zones' within buffers. Ground water flux and sea water intrusion landward were also areas for which there was little known information. Further stimulation for research could be accomplished by the development of a focused MR conference or a symposium at a larger ecological meeting.

Funding agencies were identified to include: United Nations, state governments in the United States, United States Geological Survey, Geological Survey of Canada, National Science Foundation (US), NSERC (Canada), Parks Canada via its mandate with marine protected areas, and the real estate board of BC. The concept of a MR website was given as a way to promote the MR as an ecological reference term.

Collaborations were suggested between some groups which had not been considered in the workshop. For example, public health and safety groups should be interested in managing the MR for non-ecological values, but such activity could have positive ecological consequence. The institutions responsible for the development of seaward oil and gas exploration were identified as a funding source that had been overlooked, as this industry could adversely affect MR areas.

Group 2
Biophysical mapping of the coast was recognized as the natural starting point for describing the distributions of structural features. It was felt that spatial analyses of multiple data sets would allow the establishment of hypotheses regarding the interaction and covariance of multiple functions in the MR. A list of functions was identified to include: wildlife habitat, water filtration, foodweb support, habitat complexity (woody debris was given as an example), microclimate control including temperature, moisture and ultraviolet radiation moderation, regulation of water flow, slope stability, sediment supply, and various measures inherent in the biodiversity concept. Methods for filling data gaps were identified as the following: Classification of ecological units, the comparison of modified to more pristine areas (the use of a formal measure called the 'coefficient of condition' was suggested), experimental approaches, and landscape level analyses. Social functions of the MR were also identified as non-quantified values; including public appreciation and support of areas that habitat managers would consider to be 'natural', and performing a full range of desirable ecological functions.

Research priorities were identified in descending order as: 1. Biophysical mapping. 2. The comprehension of ecological functions (in this case it was felt that freshwater literature could be referred to as a starting point). 3. The establishment of experimental programmes. 4. The exploration of socioeconomic dynamics responsible for typical patterns of coastal development, and strategies to change patterns to better fit conservation goals.

Research programmes were identified to be most desirable in a cross-border context, with cooperation from Canadian and US organizations. Canadian funding organizations were identified as: National Sciences and Engineering Council, Forest Renewal BC (now referred to as the Forest Investment Initiative), regional districts, Parks Canada, The Nature Conservancy, Ecotrust, and the World Wildlife Fund. US agencies were identified as: US Forest Service, county governments, the forest, cruise-ship, and ecotourism industries, US Army Corps of Engineers, Puget Sound Action Team, Sea Grant, Environmental Protection Agency, and the National Science Foundation. It was felt that First Nations should also be approached for their interest in research and management of the MR.

Group 3
Five different data areas were identified as data deficient: Data for the establishment of vegetation buffer widths in the MR, data relating to aesthetic functions in the MR, data comparing 'soft versus hard' engineering approaches in the MR, data for the effect of disturbing groundwater flow, and specifications for different plant species for their functions as restoration tools (in general but also applicable to the MR). In the case of buffer widths, the concept of variable widths by function was expressed in the 'on-the-ground' management context: For making decisions regarding setback distances, it was felt that having a flexible approach at the time of decision would be helpful, where the particular case could be accommodated by identifying the most relevant issues and making decisions based on them. In this regard, some sort of prioritization scheme was identified also as a useful tool, to help choose among multiple objectives in a given management scenario.

The lack of data regarding aesthetic value, and function in the marine riparian was thought to be in contradiction to the obvious appeal the MR has for humans. It was expressed that some data relating property values to ‘greenspace’ should motivate local governments to protect ecological features at the shoreline, given the ramifications to taxation revenue. It was felt that other interested parties in this case would be chambers of commerce and relevant NGOs. The approach to gaining comparative data for hard versus soft engineering features was explored in terms of retrospective and more formal prospective studies. The role of freshwater seeps in the intertidal area was thought to be unstudied and it was identified that legislation governing the modification of groundwater pattern in BC is sparse or non-existent. It was suggested that no legislation could be motivated without proper study. Casual observation by some group members indicated that nearshore development often affects groundwater, and increases channelization. The issue of technical data for individual species as restoration tools in the MR was explored, indicating that no central source existed. A database of technical attributes like growth rates and rooting depths was thought to be desirable, as was information regarding how to manage plant succession during restoration.

The single most important issue in promoting long-term funding availability was identified as public education. It was felt that awareness of ecological issues resulted in pressure toward legislators to allocate funds toward research. Collaboration between NGOs, graduate research programmes, and private foundations was thought to be less than fully developed. First Nations participation by coastal groups was identified as a natural step.

DISCUSSION, PLENARY SESSION 2

Due to time restrictions, participants decided to forego explicit plenary discussion and move on to reviewing the ‘next steps’ considerations emerging from the sum discussion of both workshop days.

Next Steps

Doug Myers and Melody Farrell

Four different undertakings were recognized as good 'next steps' to promote awareness and funding for MR issues. These included the development of nomographs for the different MR-associated functions, the development of a biophysical classification and mapping regime for the coastline of northwest North America, the development of stewardship and outreach products to public venues and to non government organizations, and the development of a peer-reviewed prospectus/position paper on the MR.

In the case of nomographs some doubt was expressed toward the availability of good information to generate them currently, indicating that primary research would need to be the foundation for these in most cases. In cases were they are generated from existing literature, they will need to be tested with in-situ measures. There was reasonable agreement that starting the process by extrapolating from freshwater literature would be a good initial step, with the caveat that data taken from large rivers and lakes would be more appropriate than those from small rivers and streams. It was noted that the latter case represents the bulk of freshwater riparian literature. Some work by the Forest Ecosystem Management and Assessment Team has been done for freshwater riparian systems, but would need to be verified for marine conditions. The list of functions would likely need to be pared down to a more fundamental list with the caveat that in a multidisciplinary environment such attempts should proceed with caution for risk of deterring participation by some disciplines.

Biophysical mapping was discussed as an expansion of the 'ShoreZone' mapping system. Supplemental data sources were indicated to be Terrestrial Resource Inventory and Mapping data (TRIM; physical/topographical data), and perhaps the adaptation of already existing Biogeoclimatic Ecosystem Classification (BEC) data in BC. There was some concern expressed that this would be a time-consuming process given the effort taken to create the BEC. Long term monitoring sites of forest lands in the United States were suggested as data sources for MR forest cover information.

Outreach tools were thought to be best approached with planning scales larger than the property lot-by lot approach.

Lastly, it was felt that a prospectus article would be easy to accomplish, adaptable from the workshop proceedings. It was indicated that a peer-reviewed scientific article would be an important tool to generate research interest, and to establish 'Marine Riparian' as a common reference term.

Appendix I. Biographical Sketches of Workshop Speakers

Jim Brennan

Jim Brennan is the Senior Marine Ecologist for the King County Department of Natural Resources and Parks. Responsibilities include: Marine inventory, assessment, and integration with watershed and salmon recovery planning efforts; consultation on roads, wastewater, environmental review and permitting, and the development of marine resource management actions, including restoration, regulatory, and public education projects/programs. Jim has 22 years of experience working in both the private and public sectors, has conducted marine fisheries research in Antarctica, California, Oregon, Washington, and Alaska, and has taught fish biology/ecology classes in California, Mexico and Jamaica. Current interests are in marine nearshore ecosystems of the Puget Sound/Georgia Basin. Jim holds a M.S. in Marine Sciences from Moss Landing Marine Laboratories.

Melody Farrell

Melody Farrell is an Oceans planner with the Habitat and Enhancement Branch of Fisheries and Oceans Canada. She has worked for the Canadian federal government for 21 years and holds a bachelor's degree (honours) in marine biology, and has completed course work towards a Master of Resource Management degree. She is currently the chair of the DFO Marine and Estuarine Habitat Working Group and represents Fisheries and Oceans Canada on the Georgia Basin Action Plan Joint Management Committee. She is also a member of the Habitat and Species Planning and Implementation Team and the Pacific North Coast Integrated Management Planning Team, and is involved in a variety of marine and nearshore habitat programs and projects.

John Harper

Dr. John Harper is a marine geologist, a co-owner of Coastal & Ocean Resources Inc. and adjunct professor in the School of Earth and Ocean Sciences of University of Victoria. His research specialty is in coastal and nearshore ecosystems, particularly mapping and classification. Dr. Harper is a co-developer of the ShoreZone Mapping system, which has been widely applied in Washington, British Columbia and Alaska. He is also a co-developer of the Seabed Imaging and Mapping System (SIMS), which is a nearshore seabed mapping and monitoring system based on biophysical classification of towed video imagery. Dr. Harper has conducted research in the Pacific Northwest since 1978.

Greg Hood

Greg Hood is senior restoration ecologist for the Skagit River System Cooperative, a tribal environmental research and management organization. He received his Ph.D. from the University of Washington, School of Fisheries in 2000 (Si Simenstad and R. C. Wissmar major professors), and has fourteen years of experience in estuarine habitat restoration in the Pacific Northwest. Greg is lead or sole author for journal articles published in *Restoration Ecology, Estuaries, Canadian Journal of Fisheries and Aquatic Science, Plant Ecology,* and *Physiological Entomology.* His areas of research interest include interactions between landscape form and ecology, scale, estuarine ecology and geomorphology, applied ecology of habitat restoration.

Max Larson

Mr. Larson has twenty years of experience as a consultant in the fields of coastal, ocean and hydraulic engineering, and holds a graduate degree in Coastal Engineering from Queen's University at Kingston (1987). He is presently a principal of Triton Consultants offering a wide range of coastal engineering expertise in the development of metocean design criteria, the design and construction of coastal structures, dynamic mooring analyses, and the physical and numerical simulation of coastal processes. Mr. Larson's experience was gained both within a large multi-disciplined port engineering design group and within various small specialized coastal engineering consultancies across Canada; this experience resulted in the construction of operational marine facilities in Canada, South America, Indonesia, Australia and the Caribbean. Prior to 1991, Mr. Larson worked as a coastal engineer in Atlantic Canada, a Shoreline Management Engineer on the Great Lakes, a Stability Engineer on a Beaufort Sea offshore oil platform, and in various capacities for a heavy-construction contractor in Eastern Canada.

Jeff Lemieux

Jeff Lemieux currently resides in the Fraser Valley region of British Columbia, having recently completed a Ph.D. programme at Oregon State University. His work has focused on the distribution and roles of arthropod communities in forest ecosystems but has recently had a terrestrial-marine systems component under the direction of Dr. Colin Levings, Fisheries and Oceans Canada. Current research interests include the roles of organisms in promoting ecosystem processes, especially the movement of rate-limiting elements. Current research includes the use of stable isotope techniques to examine effects of forest harvesting on littoral and supralittoral marine foodwebs and ecotones. One special aspect of this work is the investigation of the life histories of intertidal Chironomidae and their role in the diet of chum salmon on the west coast of Vancouver Island.

Colin Levings

Based at the West Vancouver Laboratory, Dr. Colin Levings is head of the Coastal and Marine Habitat Science Section within the Marine Environment and Habitat Science Division, Science Branch, Pacific Region, Department of Fisheries and Oceans (DFO), Canada. Dr. Levings has degrees in Fisheries and Zoology from UBC and in Biological Oceanography from Dalhousie University. He has been working on applied fish habitat research in coastal British Columbia since 1972, in support of habitat managers. He also worked on this topic in Nova Scotia, Norway, Korea, and Japan. He is the author or co-author of over 200 papers and reports on fish habitat topics. Dr. Levings is frequently called upon for advice by DFO habitat and ocean managers on a wide variety of coastal ecology topics ranging from log storage impacts on the north coast to sediment impacts in southern estuaries. In support of needs for information on the role of the marine riparian zone (MR) in coastal British Columbia as fish habitat, in 2001 he began researching the potential food web links between vegetation, arthropods and fish. He is also involved in other projects relating to marine conservation and habitat management including environmental aspects of aquaculture, ballast water as a vector for non-indigenous species, and effects of fishing gear on benthic habitats. The studies have been conducted in the Strait of Georgia, the Broughton Archipelago on the Central Coast of BC, and Barkley Sound-Alberni Inlet on the West Coast of Vancouver Island. Dr. Levings is an Adjunct Professor at the Institute for Resources and Environmental Sustainability at UBC and has supervised graduate students working on applied ecological research.

Doug Myers

Doug Myers supervises two priority projects at the Puget Sound Action Team: Restoration of Marine and Freshwater Habitats and Recovery of Salmon in the Nearshore. He is state co-lead for the Estuary Restoration Project portion of the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP). Doug holds a B.S. in Marine Biology, an M.S. in environmental science and has over 17 years of experience in coastal resource management issues.

Dan Penttila

Dan Penttila was born and raised in the Pacific Northwest. He received a B.S. in Zoology from the University of Washington in 1970, and an M.S. in Biology from the University of Oregon in 1971. He has been involved in marine forage fish matters in western Washington State for the Washington Department of Fisheries/Fish and Wildlife since 1972. Professional activities in this region have included herring/surf smelt/sand lance spawning habitat surveys (including development of new survey methods and exploratory surveys in previously unsampled regions) and herring hydro-acoustic/trawl surveys, herring larval/juvenile surveys, eelgrass shading studies, contributions to forage fish habitat protection policies and regulations, testimony as an expert witness on forage fish habitat matters, and numerous public presentations, workshops and training sessions pertaining to forage fish spawning ecology. Mr. Penttila is deeply committed to the preservation of critical marine habitats for the benefit of the citizens of Washington State. He currently resides in Anacortes, WA, and enjoys fishing, boating, SCUBA diving, paleontology, astronomy, and natural-history travel.

Kathryn Sobocinski

Kathryn Sobocinski is currently a research scientist with the University of Washington, School of Aquatic and Fishery Sciences working on projects related to salmonid ecology in nearshore and marsh environments in the Pacific Northwest and San Francisco Bay. Other previous endeavours include: Graduate Student, University of Washington, School of Aquatic and Fishery Sciences, Wetland Ecosystem Team, (Thesis title: *The impact of shoreline armoring on upper beach fauna in central Puget Sound*)*;* scientist for NOAA/NMFS Alaska Fisheries Science Center, Gulf of Alaska Groundfish Survey, working on variety of projects relating to salmonid use of nearshore and estuarine habitats; teaching assistant at University of Washington Friday Harbor Laboratories; and water quality technician, Snohomish County, Surface Water Management.

Si Simenstad

Charles A. ("Si") Simenstad, Research Associate Professor at the University of Washington's School of Aquatic and Fishery Sciences (SAFS), is an estuarine and coastal marine ecologist and Coordinator of the *Wetland Ecosystem Team* (WET). Si has conducted research on estuarine and coastal marine ecosystems throughout Puget Sound, the Washington coast, and Alaska for over thirty years. Much of this research has focused on the functional role of estuarine and coastal habitats to support juvenile Pacific salmon and other fish and wildlife, and the associated ecological interactions that are responsible for enhancing their production and life history diversity. His research concerns primarily natural (e.g., basic) ecosystem-, community- and habitat-level interactions, with emphasis on predator-prey relationships, the sources, organization and flow of organic matter through food webs, and landscape-scale interaction between estuarine physicochemical and ecological processes. Recent research has integrated ecosystem dynamics with applied issues such as restoration and rehabilitation of estuarine and coastal wetland ecosystems, and ecological approaches to evaluating the success of coastal wetland restoration at ecosystem and landscape scales. He holds a B.S. (1969) and M.S. (1971) from the School of Fisheries at the University of Washington.

Appendix II. List of Workshop Participants

Name	Institution	Electronic mailing address
Jim Brennan	King County, Department of Natural Resources and Parks	Jim.Brennan@METROKC.GOV
Clive Callaway	Living by Water Program	clivec@jetstream.net
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Dan Pentilla	Washington State Dept. Fish and Wildlife	PENTTDEP@dfw.wa.gov
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Si Simenstad	University of Washington School of Aquatic and Fishery Sciences	simenstd@u.washington.edu
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Gregory D. Williams	Battelle Marine Sciences Laboratory	gregory.williams@pnl.gov
Gary Williams	G.L. Williams and Associates	glwill@telus.net

*Attended first day only and did not participate in breakout sessions

Appendix III. Breakout Session Questions Posed to Workshop Participants

<u>Breakout Session 1</u>

1. What management approaches exist to maintain and restore or enhance the various functions of marine riparian zone and are they supported by scientific investigation?

2. Based on best available science (refer to talks on day 1 plus expertise and experience within the breakout session group) what management recommendation that can be put forward from the group?

3. How could a regionally wide approach (coastal management plan) facilitate accomplishing multiple goals in items 1-2?

<u>Breakout Session 2</u>

1. What are the outstanding management priorities from breakout session 1 for which you have insufficient data?
2. What kinds of data are needed to fill the gap? (scale, observational/ monitoring, experimental)
3. What funding sources are currently potentials to address this issue?
4. Are there any suggested collaborations between groups that would increase likelihood of successful study?

Appendix IV. Breakout Session Group Members

<u>Group 1:</u>
Moderator: Colin Levings
Rapporteur: Brian Emmett (morning)/Jim Brennan (afternoon)
Clive Callaway
Doug Cannings
Brian Emmett
Joy Hillier
Greg Hood
Andrea McLennan
Karen Myers
Dan Pentilla
Max Larson

<u>Group 2:</u>
Moderator: Melody Farrell
Rapporteur: Steve MacDonald (morning) / Steve Fadden (afternoon)
Fred Goetz
John Harper
Shelley Jepps
Brad Koroluk
Elliot Menashe
Brian Naito
Anne Nelson
Si Simenstad

<u>Group 3:</u>
Moderator: Doug Myers (morning)/Jeff Lemieux (afternoon)
Rapporteur: Jeff Lemieux / Suzie Lavallee
Robert Donnelly
Suzie Lavallee
Don Norman
Scott Northrup
Rob Russell
Jennifer Simpson
Kathryn Sobocinski
Tina Whitman
Gregory Williams
Gary Williams

Appendix V. Workshop Agenda

Tuesday, February 17, 2004

8:00-9:00 Continental breakfast served buffet style in meeting salon

9:00-9:15 *Welcome and introduction to the workshop* (Melody Farrell)

Session 1: Setting the stage

9:15-10:15
Overview of research and thoughts on the marine riparian as fish habitat in British Columbia
Colin Levings/Tamara Romanuk

An Overview of riparian functions and management issues in marine nearshore ecosystems
Jim Brennan

10:15-10:30 Questions and answers

10:30-10:45 HEALTH BREAK

Session II: Functions, values, and data gaps

10:45 -11:15
Physical processes affecting the marine riparian zone and associated classification rationale
John Harper

11:15-12:15
Fish habitat values and functions of the marine riparian zone
Kathryn Sobocinski/ Jeff Cordell/ Si Simenstad

Forage fish spawning habitats
Dan Pentilla

12:15-1:15 LUNCH

1:15-1:45
Other (non fisheries) ecological functions and values of the marine riparian zone
Si Simenstad

1:45-2:15
Potential for terrestrial vegetation to influence nutrient subsidy to non-estuarine marine environments in temperate ecosystems: summary background for thinking about management and research approaches
Jeff Lemieux

2:15- 2:30 HEALTH BREAK

2:30-3:00
Effect of oceanographic processes on supralittoral marine riparian habitat (from a coastal engineer's perspective)
Max Larson

Session III: The effect of scale

3:00 -3:30
Scaling marine riparian zone form and function
Greg Hood

Session IV: Current standards by jurisdiction

3:30-4:15
Rationale for current marine riparian setback standards and buffer widths in the Pacific Northwest
Alaska- Steve Fadden
BC –Melody Farrell
Washington State- Doug Myers

4:15 -4:30 Questions and answers

4:30 Adjourn

Wednesday, February 18, 2004

8:00-9:00 Continental Breakfast served buffet style in meeting salon

9:00-9:15
Summary of day 1 and introduction to day 2 (Melody Farrell)

9:15-9:30
Requirements for use of "best available science" by managers (Doug Myers)

BREAKOUT SESSIONS

Session 1
9:30-11:00 Develop and prioritize recommendations for management actions for protection/conservation

11:00 – 11:45 Report back to plenary and discussion

11:45-- 1:00 LUNCH

Session 2
1:00 - 2:30 Identify data gaps and develop and prioritize a list of research questions.

2:30- 3:15 Report back to plenary and discussion

3:15-3:45 Workshop outputs and next steps

3:45 Adjourn