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The Three Amigos - A Shoreline Biota Monitoring Program for Prince William Sound

prepared for: Oil Spill Recovery Institute
Cordova, Alaska

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[1] The reference to *Three Amigos* is to three dominant taxa – *barnacles*, *mussels* and *rockweed*, which typically dominate the upper intertidal zone of hard substrates in Prince William Sound. As indicated in the 20-year times series of Mearn's Rock (Mearns 2011), these species are commonly associated but can undergo large scale-year-to-year changes in abundance. (Photo by Mary Morris)

Summary
This proposal outlines an approach to establish an intertidal biotic monitoring program within the Gulf of Alaska. As a pilot, the program would support broader scale ecological studies by providing detail on seasonal and inter-annual changes to intertidal biota within Prince William Sound. We propose to develop a draft protocol (our interpretation of a the *white paper* component of the RFP) that is based on a tiered imagery collection program with a few time-lapse camera locations (providing daily data), a dozen or so quarterly photo-registered (e.g., Mearns Rock type photos) and a few dozen annual photo-registered locations. The tiered reference locations would be focused on a single habitat type (e.g., protected, rock cliffs or benches) that can be tied directly to the spatial mapping of ShoreZone. The intention of the tiered station network is to capture temporal changes at the frequently monitored sites and to capture the spatial extent of change within the Sound at a more widely distributed network of monitoring sites. A daily time series of imagery at a few sites is likely to provide direct observations of the agents of change such as hard-freezes, ice-scraping events, severe heat events or biological invasions.

Imagery data collected in PWS will be validated by cross-comparison with annual on-the-ground surveys of an intertidal site in Kachemak Bay, Alaska that has been regularly censused since 1999 (Klinger and Fukuyama, submitted). Establishing a site at which daily, quarterly, and annual images are collected *in combination with* annual quadrat sampling will assist in interpretation of the imagery data and improve the power of the analysis.

An image-based monitoring program will allow citizen scientists and community scientists to interact with research scientists throughout the program. Image acquisition can be performed by citizen scientists and by community-based scientists. Image categorization can be performed by community-based scientists using the *three-amigo* protocol. A quarterly program review will be conducted by research scientists to ensure data management and interpretation meet anticipated standards.

The ultimate goals of such a program are: (1) to publish results in a refereed journal to ensure they are to a rigorous scientific standard and can be used as high-quality baseline data; (2) disseminate the protocols for implementation across a broader geographic area; and (3) invest community scientists in performance of long-term monitoring of their local sites.

The proposed principal investigators for this project are Dr. John Harper and Dr. Terrie Klinger. Dr. Harper is a marine geologist (Coastal & Ocean Resources) who has been a principal of the Alaska ShoreZone program and who spent considerable time monitoring beach recovery from the *Exxon Valdez* oil spill. Dr. Terrie Klinger is a marine ecologist at the University of Washington. She has participated in ecological studies of shorelines impacted by the *Exxon Valdez* oil spill and has maintained a 12-year time series of quadrat-based monitoring of intertidal organisms in Kachemak Bay.

Introduction and Statement of the Problem

Background

One of the challenges facing scientists following the *Exxon Valdez* oil spill has been determining when recovery of shoreline habitats is complete (e.g., see Shigenaka et al 1997). Evidence from 12 years of post-disturbance sampling in Kasitsna Bay, AK suggests that intertidal communities naturally change over time, as evidenced by deviation from the long-term mean (Figure 1). Consequently, a return to "pre-disturbance" or "baseline" condition is unlikely (Klinger 2006; Klinger and Fukuyama 2008). However, recovery in these systems sometimes can be determined from convergence between disturbed and undisturbed communities. In addition, stochastic events can influence recovery.

There have been a wide range of monitoring programs initiated but few have been successful at detecting change because high degrees of spatial and temporal variability typically reduce statistical power. Many approaches have involved volunteers but have proven unsustainable because of the complexity of training (.e.g., Shorekeepers; Jamieson et al 1999; People for Puget Sound) and maintaining a systematic monitoring (e.g., coordination funding).

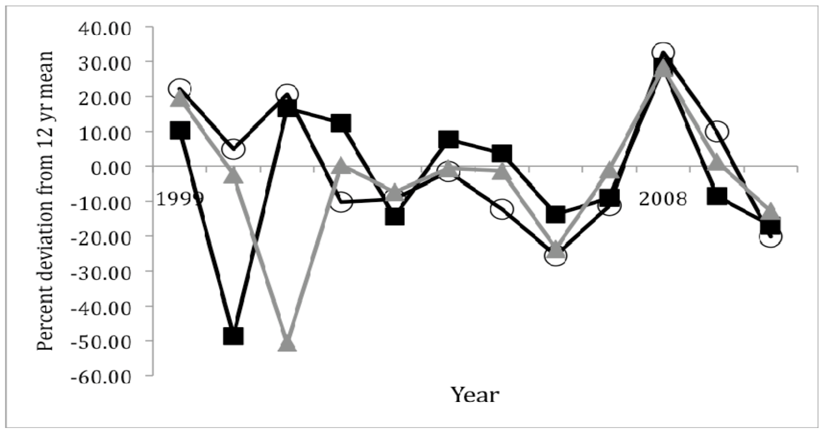

Figure 1. Average annual percent deviation of *Fucus* cover from 12-year mean. Open circles: control; filled squares: experimental disturbance applied in 1999; filled triangles: experimental disturbance applied in 2000 (Klinger and Fukuyama, unpublished data).

Statement of the Problem

Long term monitoring studies are extremely useful, especially in the identification temporal variability of intertidal biota distributions. If they are of sufficient temporal resolution (hours or days) they may be directly linked to agents of change such as severe freezes, severe storms or over-exposure to sunlight. The challenge of this project is to develop a simple monitoring program that can provide meaningful scientific results at modest cost. This issue is identified as one of the key research priorities of the 2011-2015 Oil Spill Recovery Institute Research Plan (OSRI 2011, p. 9).

Project Objective

The primary goal of this project is to develop a workable monitoring program for documenting environmental change within the intertidal zone. In particular, this project would develop a protocol (our term for *white paper*) that provides a tiered approach to measuring temporal and spatial change in upper intertidal biota in a single eco-subregion of Prince William Sound.

Approach

We establish three criteria of the development of a protocol. *First*, the protocol must address the wide variations in environments within a place like Prince William Sound. Without explicit consideration of the wide-range of spatial variation in substrates, exposure, oceanography and freshwater runoff, a monitoring program will likely fail. *Secondly*, coastal communities have a significant interest in the health of the environment in which they live; a protocol that can involve community members will contribute to the communities. *Thirdly*, the protocol will be implemented on a modest budget.

<u>Development of a Draft Monitoring Protocol</u>

The first task in the project will be to develop a draft monitoring protocol. In order to meet our initial criteria (i.e., workable in a spatially complex environment, involvement with coastal communities, a modest implementation budget), we have some very specific views on the major elements of a protocol.

An Imagery Based Monitoring Program

Longitudinal photographic sampling at Mearns Rock (Fig. 1) has shown the value of an image-based monitoring program. The protocol that we envisage would also be image-based, albeit with a much larger number of sites and a hierarchy of collection frequencies. An image-based data collection system is particularly amenable to citizen scientists. Work by Foster *et al* (1990) and Dethier *et al* (1993) have shown that observational data can compare quite favorably to quadrat, point-count data. In the case of this proposed monitoring program, the use of image-based and point-count monitoring will permit a larger number of sites to be inventoried and a permanent record of the observation is automatically created.

We anticipate that photo-registered sites similar to Mearns Rock (Fig. 2 & 3) can used to provide permanent monitoring sites. Photos could be collected by citizen scientists using standard digital, weather-proof cameras.

A photo archival procedure will be developed that ensures that each photo is tagged in a database, archived and duplicated. It is anticipated that a PWSSC technical staff member (community scientist) could coordinate the photo collection and subsequent archiving.

An imagery classification system would be included in the protocol, and it is anticipated that community scientists could conduct the classification. This would provide digital classification on the occurrence of the *three amigos* - barnacles, mussels and rockweed - within each photo. Data from the classification would be suitable for trend analysis.

The community-scientist classification data would be reviewed quarterly as part of the quarterly reporting process.

Figure 2. 2007 photo of Mearns Rock in Snug Harbor, Knight Island. (from Mearns 2011)

Figure 3. 2009 photo of Mearns Rock in Snug Harbor, Knight Island (from Mearns 2011)

A Tiered Approach to Sampling

We recognize that there are tradeoffs between number of sample stations and frequency of sampling. Indeed, many sampling programs document change in intertidal biota but often the cause or agent of change is elusive because it occurred within the gaps between sampling. As such, we anticipate that a tiered approach would be most effective in detecting change.

An example of a tiered approach is summarized in Table 1. We have had considerable experience with time lapse cameras over the past two years and have found them to be extremely reliable and suitable for challenging environments (in our case, the arctic). Alternatively, a suitable location for a web-cam (usually requires power) could be an alternative to a time lapse system.

Table 1 Example of Tiered Sampling Approach

Tier	No. of Sites	Number of Images	Procedure
Daily	2-3	8,760	time lapse camera (hourly)
Quarterly	24	96	local survey, citizen scientists collecting registered photos
Annual	48	48	local to subregional survey, citizen scientists collecting registered photos
Total:	**75**	**8,904**	

While the classification of 8,760 images may appear daunting, generally there is very little change occurring on a day-to-day basis so the classification is rapid. But the high sampling rate does offer the potential *see* the effects of catastrophic change over a short duration (e.g., removal of vegetation due to a single storm event).

Site Selection

A critical part of any monitoring program is to be applicable over a larger geographic area than just the sample sites. This is referred to as "scaling up", where monitoring at a limited number of sites can be extrapolated over a wide area with confidence. Schoch and Dethier (1996) and Dethier and Schoch (2005) have implemented such a program in Puget Sound and have shown that careful selection of sites is required to meet this objective. In particular, they note that careful attention to selection of sites with very similar geomorphic and hydrological properties will significantly reduce spatial variability in observed biota.

Given that we have made the *a priori* assumption the preferred monitoring organisms are sessile species (barnacles, mussels and rockweed), preferred monitoring sites would be stable, hard substrate. An additional site-selection criteria might be to avoid local freshwater sources so some minimum distance from streams would be considered (see also Table 2). Schoch and Dethier (1996) noted that exposure differences will alter communities, so consideration of exposure at different sites is important. Extreme sun exposure can cause mortality and shoreline aspect is an important screening criteria. Other factors include the relative elevation in the intertidal zone, slope of substrate and ecological context with nearby communities.

The PWS ShoreZone project provides an excellent, *on-the-shelf* screening tool for site selection. Not only are a large number of variables mapped (see Figures 4 to 7), there is high resolution, low-tide videography of the entire intertidal zone and over 28,000 high-resolution, georeferenced digital photos on the entire Sound (Figure 8).

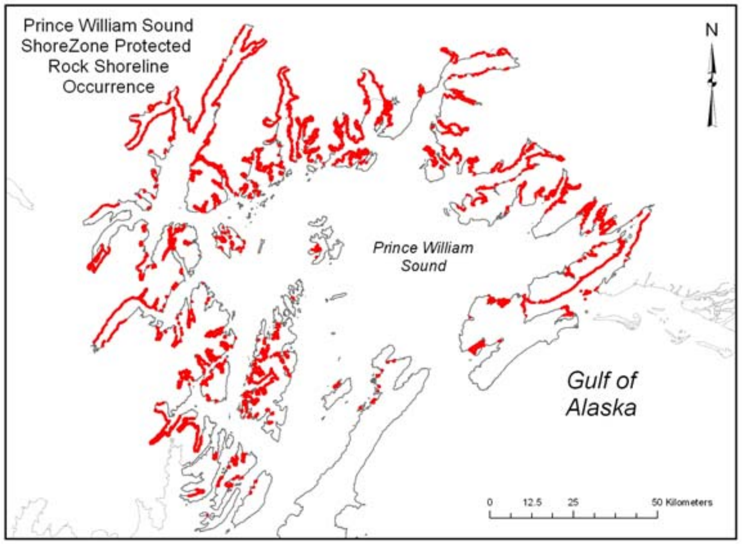

Figure 4. Protected rock shorelines in PWS.

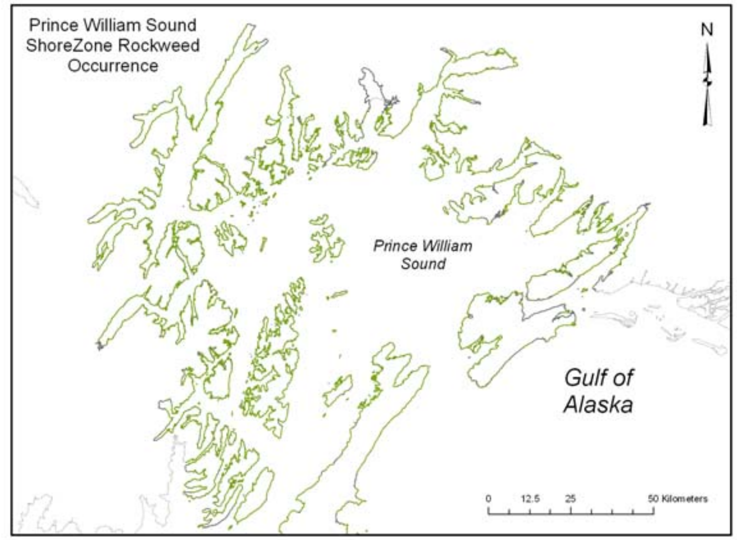

Figure 5 Rockweed distribution in PWS (2007).

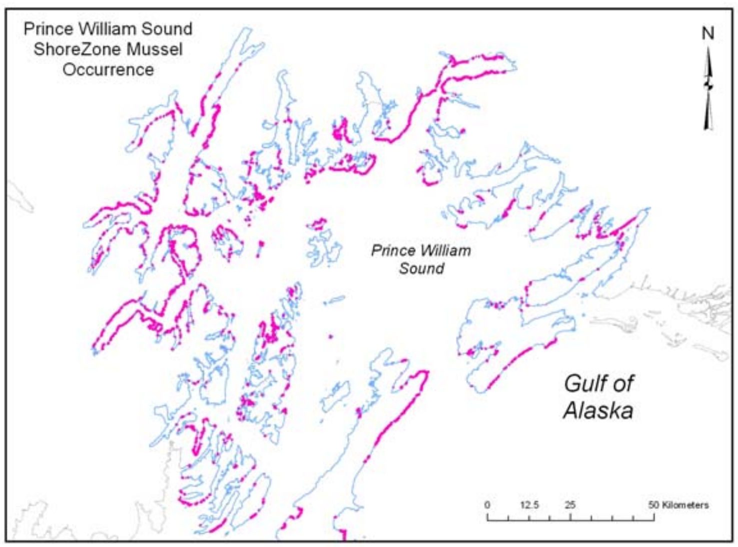

Figure 6. Mussel occurrence in PWS (2007).

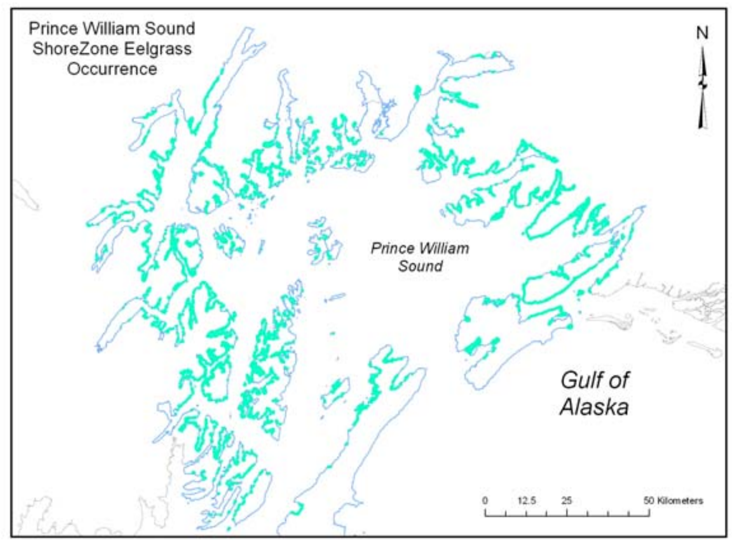

Figure 7. Eelgrass occurrence in PWS (2007).

Figure 8. High resolution oblique photo of a shoreline near Cordova, Alaska showing a rock cliff in the upper intertidal zone and a sand flat in the lower intertidal zone. A dark green rockweed band is clearly visible on the cliff. These high resolution photos and video imagery are excellent screening tools for site selection and there over 28,000 in PWS.

Using these general guidelines, we propose to develop a formalized proposal for monitoring within a single eco-subregion within PWS. We anticipate that the approach would be highly amendable to application in other regions. To this end, we propose that a component of the study be focused on the shoreline of Kasitsna Bay, Alaska where Klinger has a 12 year quadrat-based survey program; it is anticipated that personnel from the Kasitsna Bay or Kachemak Bay NERR could collect registered photos of these sites, which will allow comparison to the long-term quadrat data.

Webinar Presentation of Draft Model

Once a draft protocol is developed, we propose to invite an online review of the protocol. The review would include: distribution of the draft protocol one week in advance of the scheduled webinar, a ½ hr presentation of the main features of the proposed protocol and an hour discussion among on-line participants. It is assumed that the PWSSC and OSRI would be full participants in the webinar and would assist with participant identification.

We considered an external review process by two qualified reviewers and included this as an option as there are additional costs involved.

Suggestions received during the webinar will be recorded and a formal summary prepared and distributed.

Protocol Revision, Preliminary Site Selection

We are confident that the major structure and organization of the protocol will require only minor changes. The protocol will be revised in discussion with OSRI. Should revisions be minor, we anticipate that preliminary screening of sites can be accomplished using ShoreZone mapping data and ShoreZone imagery.

Site selection will be rated on the suitability criteria listed in Table 2. We anticipate concentrating sites within one eco-subregion of PWS for this pilot to minimize logistics; depending on the initial success of the program and on available funding, additional sites could be added for other ecoregions.

Table 2 Potential Sampling Site Screening Criteria

Attribute	Description
substrate	stable substrate is required for epibenthos; a combination of ShoreZone mapping (shore types, habitat types, across-shore morphology) and videography and photography will be used to select sites with similar morphology.
slope	is important because it affects draining efficiency and drying potential
exposure	ShoreZone provides six classes of exposure based on observed assemblages of intertidal biota. These categories can be cross-checked with fetch measurements.
elevation	sites should be at a similar elevation so that submergence-emergence intervals are identical.
biota	regional biota has been mapped within ShoreZone (including the *three amigos;* Fig. 4-7); occurrence at specific location can be checked by reviewing photos.
aspect	shoreline aspect can be estimate from map data (e.g., south-facing shores can be severely stress by extended sunshine).
proximity to freshwater	video imagery and watershed data can be reviewed to estimate potential freshwater influence
access	easy access by boat is important and if possible, land access would also be desirable as winter quarterly observations will have to be made during darkness (no daylight low tides in the winter).
camera servicing	2-3 of the sites may include installation of time lapse camera. It is important that servicing be easy and that the camera is set up in a location where it will not be used for target practice.
grouping	where possible, grouping of sites will allow the most efficient sampling (i.e., minimize transit times during sampling).

Anticipated Outcome

It is extremely important that the principal investigators take ownership of the results from this project and publish the results in a referred journal to establish the scientific credibility of the technique. We are confident that this relatively simple protocol can significantly involve citizen scientists, community scientists and senior researchers in credible scientific monitoring.

Project Team (*the two amigos*)

Dr. Terrie Klinger is Associate Professor of Marine and Environmental Affairs at the University of Washington. She maintains a multi-year time series of intertidal data in Kasitsna Bay, Alaska and sampled shorelines throughout the Gulf of Alaska following the *Exxon Valdez* oil spill. An element of her research at UW concerns community-based approaches to ecosystem management.

Dr. John Harper has directed the ShoreZone mapping program in Alaska since 1991, including participation in PWS surveys in 2004, 2006 and 2007 and is a co-author of the final report (see Lindeberg *et al* 2009). Dr. Harper has 30 years of experience with the ShoreZone dataset which presently includes more that 3 million on-line, downloadable images. Dr. Harper also participated in the *Exxon Valdez* oil spill monitoring program between 1989 and 2002; in the winter of 1989/1990, Dr. Harper coordinated Exxon's monthly shoreline monitoring program. He maintains a long-standing interest in nearshore ecology, including mapping and monitoring studies. He is co-author of a recent publication of change detection in nearshore subtidal habitats (see Nelson et al 2011).

Deliverables

Four deliverables are anticipated:

1. Draft Protocol
2. Workshop Summary

2a. External Review of the Draft Protocol (optional)

3. Revised Protocol, suitable for implementation
4. Preliminary Listing of Recommended monitoring Sites (time permitting)

Schedule

1.	late March	Project Start Date
2.	1 May	Draft Protocol
3.	late May	Webinar
4.	early June	Protocol Finalization, Preliminary Site Identification
5.	late June	contract completion

Costs
Estimated costs are summarized in Table 3.

Table 3 Cost Estimates by Task

Task	Description	JRH	TNK	Tech	Labor
		Effort (days)			
1	Draft Protocol Development	5	5	5	11,250
2	Webinar Workshop	3	2	2	5,450
3a	Revisions	3	3	3	6,750
3b	Preliminary Site Selection	2	2	3	5,000
	Totals:	**13**	**12**	**13**	**28,450**
	Optional Extenral Review (honorarium)				750

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APPENDIX A

Resumes

COASTAL AND OCEAN RESOURCES INC.

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JOHN R. HARPER
P. Geo.

SPECIALTIES:

- **coastal and nearshore habitats**
- **coastal and nearshore processes**
- **multidisciplinary marine studies**
- **oil spill research and planning**

EDUCATION:

B.Sc.	Geology (cum laude), University of Massachusetts (1973); L.R. Wilson Award for Excellence in Geology
M.Sc.	Marine Science, Louisiana State University (1976)
Ph.D.	Marine Science, Louisiana State University (1978)

WORK EXPERIENCE:

1987-present	**Principal**, Coastal and Ocean Resources (previously Harper Environmental Services), British Columbia and Nova Scotia
1989-present	**Adjunct Professor**, Centre of Earth and Ocean Resources, University of Victoria, Victoria, British Columbia
1987-1989	**Marine Geologist/Coastal Coordinator**, Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC), Suva, Fiji
1986-1987	**Manager**, Maritime Region, Dobrocky Seatech Ltd., Halifax, Nova Scotia
1985-1986	**Manager**, West Coast Region, Dobrocky Seatech Ltd., Sidney, BC
1983-1985	**Manager**, Geosciences and Hydrographic Services, Dobrocky Seatech Ltd.
1980-1983	**Senior Project Scientist**, Woodward-Clyde Consultants, Victoria, British Columbia and San Francisco, California
1978-1980	**Post-Doctoral Fellow**, Geological Survey of Canada, Pacific Geoscience Centre., Sidney, British Columbia
1973-1978	**Research Assistant**, Coastal Studies Institute, Louisiana State University, Baton Rouge, Louisiana

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GEOGRAPHIC EXPERIENCE:

East, west and arctic coasts of Canada; east, west and arctic coasts of the United States;Antigua; Brazil; Costa Rica; Fiji; Kenya; Kiribati; Papua New Guinea; Tonga; Western Samoa

Over the past 25 years, Dr. Harper has personally managed over 400 separate projects related to coastal and marine resources including the following disciplines:

Coastal & Nearshore Habitat Mapping - Dr. Harper has been extensively involved with coastal habitat mapping in Alaska, British Columbia and Washington. This includes the development and application of the ShoreZone Mapping system to over 100,000 km of shoreline. This system presently includes a unique web-based imagery display system and variable scale data display using ArcIMS technology (see ShoreZone.org). Dr. Harper is also the developer of the Seabed Imaging and Mapping System (SIMS) that utilizes towed-video imagery as a basis for high resolution mapping of the seabed. SIMS has been used on over 100 projects, ranging from conservation planning (e.g., Race Rocks Marine Protected Area) to ocean dumping (Hudson Bay) to seabed impacts assessment of a coral reef system (Antigua). When combined with seabed side-scan sonar, the SIMS provides a comprehensive (100% of the seabed covered by side-scan), high resolution (SIMS) inventory and monitoring system. A recently published arcticle has shown that repetitive SIMS surveys can be sued for change detection monitoring.

Over the past three years Dr. Harper has been developing a nearshore habitat model that is used to predict nearshore habitats for use in marine spatial planning. The model uses elements of ShoreZone as well as tidal model data and nearshore substrate data to predict nearshore habitat.

Marine Parks - numerous marine park studies including field studies of coastal landforms to delineation of new marine park sites in the Canadian arctic. In 1983, Dr. Harper conducted a strategic planning study for Parks Canada to delineate the marine regions of Canada; major segments of this study, including the delineated regions, have recently been incorporated into Parks Canada policy. Two field seasons of field work have been conducted within Pacific Rim National Park and two field seasons of biophysical research have been conducted in Gwaii Haanas on Haida Gwaii (Queen Charlotte Islands); the Gwaii Haanas work provided the modern framework for the ShoreZone projects in BC, Washington and Alaska.

Oil Spill Research, Planning and Response - oil spill research studies since 1980, including several years of field studies associated with the Baffin Island Oil Spill experiment, sensitivity evaluations for the coasts of northern California, British Columbia, Kodiak Island, the Chukchi and Beaufort Sea coasts of Alaska, the Beaufort Sea coast of Canada, Labrador and Newfoundland. Other research areas have included the long-term fate of oil on shorelines, decision-making for shoreline cleanup operations and long-term monitoring programs. In 1984, he designed and implemented a physical monitoring program of the *MV Puerto Rican* oil spill off San Francisco. In 1991, Coastal and Ocean Resources Inc. compiled the first Directory of Canadian Marine Oilspill Specialists. In 1992, he directed an Oil Spill Sensitivity Mapping Workshop in Costa Rica for ARPEL.

Dr. Harper has been extensively involved in the *Exxon Valdez* oil spill cleanup operation in Prince William Sound (1989-2002) with participation in quality assurance for preparation of oiling maps, coordination of the Prince William Sound Fate and Persistence Studies, and bioremediation monitoring surveys.

Relevant References

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Biographical Sketch

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Professional Preparation
University of California, Berkeley, A.B. Biology, 1979
University of British Columbia, M.Sc. Botany, 1984
Scripps Institution of Oceanography, UC San Diego, Ph.D. Oceanography, 1989
University of California, Riverside, Postdoctoral Researcher, 1989-2001

Appointments
Associate Professor of Marine Affairs, University of Washington, 2007-
Assistant Professor of Marine Affairs, University of Washington, 2001-2007
Adjunct Associate Professor, School of Aquatic and Fisheries Sciences, University of Washington, 2005-
Research Associate and Visiting Instructor, Friday Harbor Laboratories, Univ of Washington, 1992-2000
Visiting Scholar, Washington Cooperative Fish and Wildlife Research Unit, School of Fisheries, University of Washington, 1996-1999

10 Publications:
Hofmann G, Barry J, Edmunds PJ, Gates R, Hutchins DA, Klinger T, Sewell MA. 2010. Impacts of Ocean Acidification on Polar, Temperate and Tropical Calcifying Organisms. Annu. Rev. Ecol. Evol. Syst. 2010. 41:127–47.
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Hoffman JR, Hansen LJ, Klinger T 2003 Interactions between ultraviolet radiation and temperature limit inferences from single-factor experiments. *J Phycol* 39: 268-272

Recent Awards

2010 UW Outstanding Public Service Award
2009 Coastal America Spirit Award
2008 Naturalist of the Year Award, Western Society of Naturalists
2007 Distinguished Graduate Teaching Award, College of Ocean and Fisheries Sciences
2007 National Marine Sanctuaries Volunteer of the Year Award

Synergistic Activities

Director, Center for Ecology of the Changing Ocean, Friday Harbor Laboratories
Chair, Conservation and Policy Committee, Phycological Society of America
Convener, *Human Impacts on Algal Systems*, Phycological Society of America Annual Meeting, 2011
Convener, FHL Research Symposium *Ocean Acidification: Planning for Research and Monitoring In the Northeastern Pacific*, 2008
Chair, Olympic Coast National Marine Sanctuary Advisory Council, 2003-present
Governor's Appointee, Northwest Straits Commission, 2008-present
Science Advisory Panel, COMPASS, 2008-present

Recent Collaborators

Barry JP; Britton-Simmons K; Carney L; Carrington E; Dale V; Edmunds P; Engie K; Essington T; Evans K; Ewing KI; Fluharty D; Gates R; Greene HG; Grunbaum D; Hofmann G; Hutchins DA; Knowlton N; Leschine TM; Murray J; Newton J; O'Donnell M; Padilla D; Sebens K; Sewell MA; Ruckelshaus M; Simenstad C; Waaland J

Advisors

PK Dayton, Scripps Institution of Oceanography (Ph.D); RE DeWreede, University of British Columbia (M.Sc); NC Ellstrand, University of California, Riverside (Post-doctoral)

Advisees

Current graduate students:
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Former graduate students:
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