Wave Energy Ecological Effects Workshop
Ecological Assessment Briefing Paper

Hatfield Marine Science Center
Oregon State University
October 11-12, 2007

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1.0. Introduction

1.1. Goals and Objectives of Workshop and Expected Results

The *Wave Energy Ecological Effects Workshop* will consist of a one and a half-day meeting with goals of: 1) developing an initial assessment of the potential impacting agents and ecological effects of wave energy development in Oregon's coastal ocean; and 2) developing a general conceptual framework of physical and biological relationships that can be applied to assess both specific wave energy projects and cumulative effects of multiple projects. The workshop will share present understanding and initiate a broad discussion of the potential ecological effects of developing this form of ocean energy. The resulting publication will address, from the view of the participants: what we know; what we don't know, including key information gaps; level of uncertainty, level of agreement; a sense of priority of environmental issues; an assessment of the utility of the conceptual approach; and any recommended studies and monitoring parameters.

This workshop will not directly address socioeconomic effects or user conflicts; rather, it will focus on building capacity to more adequately address the potential ecosystem effects of wave energy development along the Oregon coast. The workshop will also not attempt to discuss and vet policy issues pertaining to wave energy parks, except as they affect development decisions that have ecological consequences. After the workshop results have been collated, there will be a separate half-day session in which the workshop session chairs or rapporteurs will report out to a body of policy makers and natural resource managers. It is intended that this function will be performed at the first meeting of the Oregon Ocean Policy Advisory Council following the workshop (now scheduled for December 14, 2007). This session will allow for an exchange of information among the scientists and policy and management practitioners that is not well-accommodated by the written publication. In addition, a series of public forums will be conducted to share workshop findings, and the proceedings from the workshop will be published and made available to the public on the internet.

1.2. How This Workshop Fits Into the Larger Policy Context

There are a myriad of federal and state laws and regulations that must be addressed in order for wave energy development to take place on Oregon's continental shelf. The agencies responsible for implementing these requirements are under an increasing number of mandates to manage for communities instead of species, and wide geographic areas and multiple habitats instead of narrow areas. These mandates are essentially a charge to manage on the basis of large ecosystems (so-called ecosystem-based management) and in a manner that will provide sustainable ocean resources for future generations (sustainability).

The precautionary approach has also become an important part of the policy context. In practical terms, it focuses the burden of proof of acceptable environmental effects onto the proponents of proposals for ocean activities, and the agencies permitting them. The precautionary approach is also important as agencies attempt to manage resources in an ocean that may be changing in fundamental and unpredictable ways. Hence, the mandates in the policy context are driving the management community towards more rigorous and complete consideration of environmental issues.

The intent of this workshop is to focus on the purely scientific aspects of wave energy ecological effects, but in a manner that will best inform those ensuing policy discussions. Those discussions, in turn, require a complete consideration of all of the possible effects of the intended actions, both positive and negative. However, it is clear that we cannot investigate every possible ecological effect. Thus, it is also the intent of the workshop to “scope” the environmental issues, in the sense of the National Environmental Policy Act (NEPA). We will ask members of the scientific community to provide guidance based on their best professional judgment and best available science on which effects are reasonably foreseeable or likely, and which, although they may have serious consequences, are extremely unlikely. Likewise, we hope to establish priority in terms of ecologically significant effects. If the workshop output does include ancillary information germane to issues like user conflicts or adaptive management, that information will be gleaned and reported as well.

1.3. Content of This Briefing Paper

The approach for this briefing paper was to get the technology, ecological setting and effects issues documented, with needed substantive information available in the public sector provided as attachments on a CD. The paper is organized in a format parallel to a NEPA Environmental Assessment or Environmental Impact Statement. Section 2 addresses the Proposed Action (i.e., the technology, since this is a programmatic approach); Section 3, the Affected Environment; and Section 4, the approach to considering the Environmental Consequences. Alternative development proposals, except for the differing technologies, are not discussed in this paper, but it is hoped that the workshop participants will consider possible development alternatives where they may have differing environmental effects. As stated above, Section 3 is presented at the programmatic level, but concludes with a specific description of at least one proposed project.

Section 5 lays out the structure and process for the workshop itself. The key to this section is the use of the impact matrix, which forms a deconstructed conceptual approach to the ecological risk analysis (e.g., USEPA 1998), and allows explicit treatment of stressors and receptors at any level of specificity, as well as uncertainty and mitigation potential. The Bibliography and References Cited (Section 6) is also a key to a relatively voluminous set of attachments that consists of a CD containing key papers cited in the briefing paper or the bibliography and available in the public sector.

1.4. Acknowledgments

This workshop was organized by a Steering Committee with the following members: George Boehlert, Director, Hatfield Marine Science Center, Oregon State University; Robin Hartmann, Ocean Program Director, Oregon Shores Coastal Coalition; Maurice Hill, OCS Alternative Energy Coordinator, Minerals Management Service; Justin Klure, Interim Director, Oregon Wave Energy Trust; Greg McMurray, Marine Affairs Coordinator, Oregon Department of Land Conservation and Development (DLCD); John Meyer, Policy Coordinator, Communication Partnership for Science and the Sea (COMPASS); and Cathy Tortorici, Chief, Oregon Coast/Lower Columbia River Branch, NOAA-National Marine Fisheries Service. Amy

Windrope, then-Policy Coordinator for the Partnership for Interdisciplinary Studies of Coastal Oceans, first conceived of this workshop during early 2006.

The workshop and breakout process has drawn heavily on an earlier workshop conducted by Oregon State University's Institute for Natural Resources during spring of 2005 to address dredging issues at the mouth of the Columbia River. That workshop was designed by Renee Davis-Borne, Gail Achterman and Susan Brody. Discussion among members of this Steering Committee and numerous other individuals has also added greatly to the planning for this workshop.

Sponsorship for this workshop has been graciously provided by: the Oregon Wave Energy Trust; the Minerals Management Service, US Department of the Interior; PacifiCorp; Portland General Electric; Northwest Fisheries Science Center, NOAA Fisheries; National Renewable Energy Laboratory, Department of Energy; Communications Partnership for Science in the Sea (COMPASS); Lincoln County, Oregon; Oregon Department of Land Conservation and Development; Oregon Department of State Lands; Oregon Department of Energy; Oregon Parks and Recreation Department; the Central Lincoln Public Utilities District; the Yaquina Bay Economic Foundation; and the Oregon State University Institute for Natural Resources.

The views, premises, hypotheses, and any conclusions expressed in this briefing paper are solely those of the compiling author, and do not represent the views of any of the participating or sponsoring individuals, agencies, or entities.

2.0 The Technology

The review of existing technology in Section 2.1 is followed by a more detailed description of the intended Reedsport Wave Energy Park as a case in point in Section 2.2. This information is intended to introduce some consideration of the types of stressors that will be expressed through wave energy development.

2.1. Existing Techology

The following section has been extracted from the Minerals Management Service's *Technology White Paper on Wave Energy Potential on the U.S. Outer Continental Shelf* (2006). At the time of writing, Finavera (AquaBuoy® – point absorber), Energetech (terminator – oscillating water column) , Ocean Power Delivery (attenuator), and Ocean Power Technology (PowerBuoy® – point absorber) have all expressed interest in, or applied for FERC Preliminary Permits, on the Oregon coast.

RESOURCE UTILIZATION TECHNOLOGIES

A variety of technologies have been proposed to capture the energy from waves; however, each is in too early a stage of development to predict which technology or mix of technologies would be most prevalent in future commercialization. Some of the technologies that have been the target of recent developmental efforts and are appropriate for the offshore applications being considered in this assessment are terminators, attenuators, point absorbers, and overtopping devices.

Terminators

Terminator devices extend perpendicular to the direction of wave travel and capture or reflect the power of the wave. These devices are typically installed onshore or nearshore; however, floating versions have been designed for offshore applications. The oscillating water column (OWC) is a form of terminator in which water enters through a subsurface opening into a chamber with air trapped above it. The wave action causes the captured water column to move up and down like a piston to force the air though an opening connected to a turbine. A full-scale, 500-kW, prototype OWC designed and built by Energetech (2006) (Figure 1) is undergoing testing offshore at Port Kembla in Australia, and a further project is under development for Rhode Island.

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2 This estimate was made at a specified water depth of 60 m (irrespective of the distance from the shore at which that depth occurs) in order to allow comparisons of wave energies between coastal areas and to eliminate the possible, but unpredictable loss of energy of the wave through its interactions with the sea bottom (scouring) at shallower depths. Typical wave energy in U.S. offshore regions ranges from 2 to 6 kW/m in the mid-Atlantic, 12 to 22 kW/m in regions such as Hawaii with trade winds, and 36 to 72 kW/m in northwestern U.S. coastal areas near Washington and Oregon.

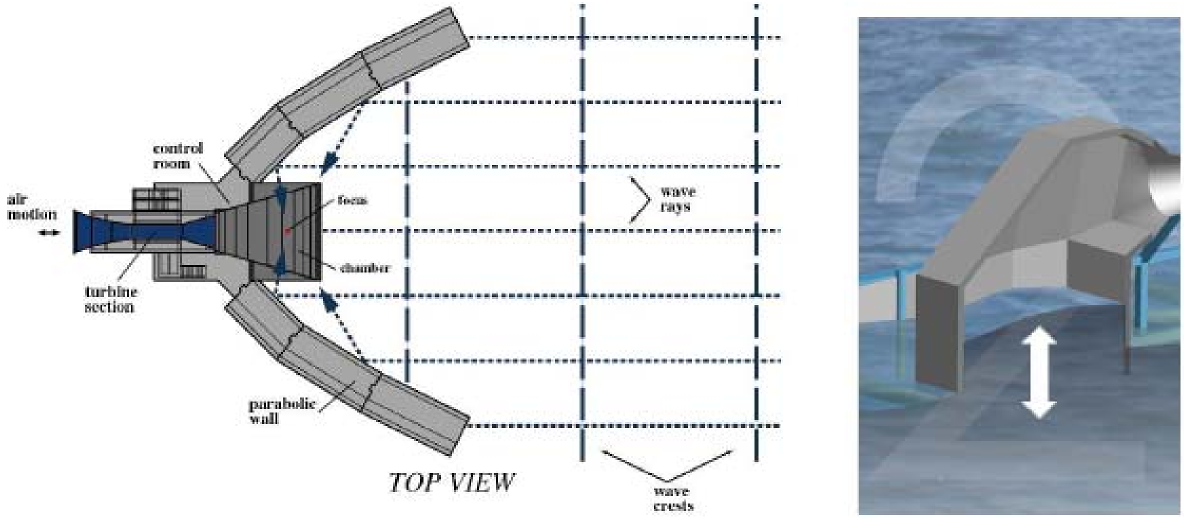


FIGURE 1 Oscillating Water Column (Source: Energetech 2006)

In an Electric Power Research Institute (EPRI)-cosponsored study (Bedard et al. 2005), a design, performance, and cost assessment was conducted for an Energetech commercial-scale OWC with a 1,000-kW rated capacity, sited 22 km from the California shore. With the wave conditions at this site (20 kW/m average annual), the estimated annual energy produced was 1,973 MWh/yr. For a scaled-up commercial system with multiple units producing 300,000 MWh/yr, the estimated cost of electricity would be on the order of $0.10/kWh.

Another floating OWC is the "Mighty Whale" offshore floating prototype, which has been under development at the Japan Marine Science and Technology Center since 1987 (JAMSTC 2006)

Attenuators

Attenuators are long multisegment floating structures oriented parallel to the direction of the wave travel. The differing heights of waves along the length of the device causes flexing where the segments connect, and this flexing is connected to hydraulic pumps or other converters. The attenuators with the most advanced development are the McCabe wave pump and the Pelamis by Ocean Power Delivery, Ltd. (2006).

The McCabe wave pump (Figure 2) has three pontoons linearly hinged together and pointed parallel to the wave direction. The center pontoon is attached to a submerged damper plate, which causes it to remain still relative to fore and aft pontoons. Hydraulic pumps attached between the center and end pontoons are activated as the waves force the end pontoons up and down. The pressurized hydraulic fluid can be used to drive a motor generator or to pressurize water for desalinization. A full-size 40-m prototype was tested off the coast of Ireland in 1996, and commercial devices are being offered by the manufacturer.

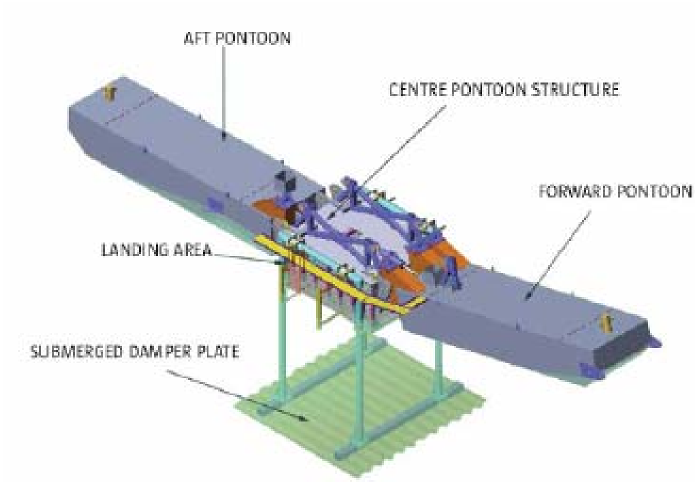


FIGURE 2 McCabe Wave Pump (Source: Polaski 2003)

A similar concept is used by the Pelamis (designed by Ocean Power Delivery Ltd. [2006]), which has four 30-m long by 3.5-m diameter floating cylindrical pontoons connected by three hinged joints (Figure 3). Flexing at the hinged joints due to wave action drives hydraulic pumps built into the joints. A full-scale, four-segment production prototype rated at 750 kW was sea tested for 1,000 hours in 2004. This successful demonstration was followed by the first order in 2005 of a commercial WEC system from a consortium led by the Portuguese power company Enersis SA. The first stage, scheduled to be completed in 2006, consists of three Pelamis machines with a combined rating of 2.25 MW to be sited about 5 km off the coast of northern Portugal. An expansion to more than 20-MW capacity is being considered. A Pelamis-powered 22.5-W wave energy facility is also planned for Scotland, with the first phase targeted for 2006.

The EPRI wave energy feasibility demonstration project has selected the Pelamis as one of the technologies for design, performance, cost, and economic assessment (Bedard et al. 2005). Sites for evaluation were selected off the coasts of Hawaii (15.2 kW/m average annual wave energy), Oregon (21.2 kW/m), California (11.2 kW/m), Massachusetts (13.8 kW/m), and Maine (4.9 kW/m). For systems at these sites scaled to a commercial level generating 300,000 MWh/yr, the cost of electricity ranged from about $0.10/kWh for the areas with high wave energy, to about $0.40/kWh for Maine, which has relatively lower levels of wave energy.

Point Absorbers

Point absorbers have a small horizontal dimension compared with the vertical dimension and utilize the rise and fall of the wave height at a single point for WEC.

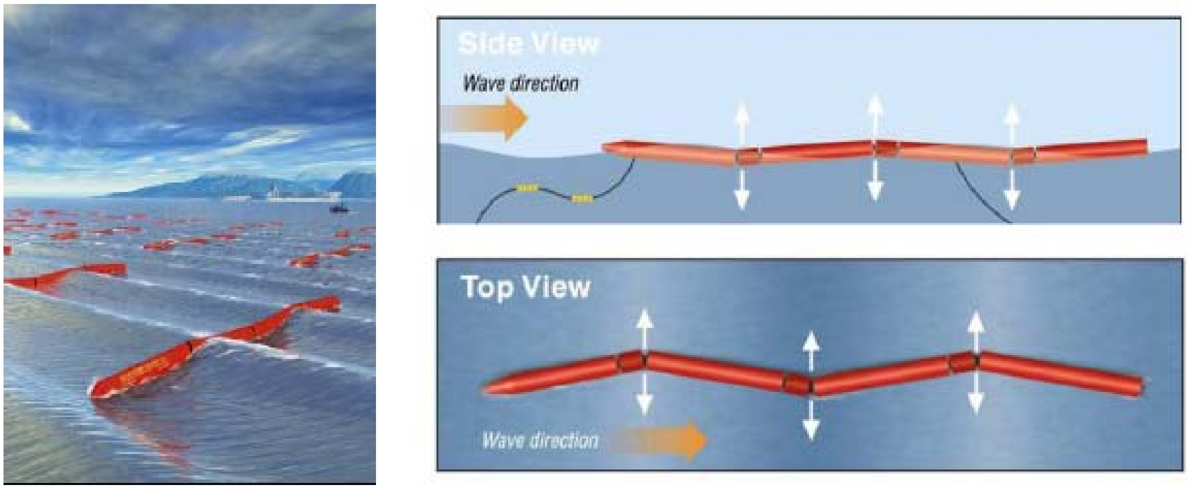


FIGURE 3 Pelamis Wave Energy Converter (Source: Ocean Power Delivery Ltd. 2006)

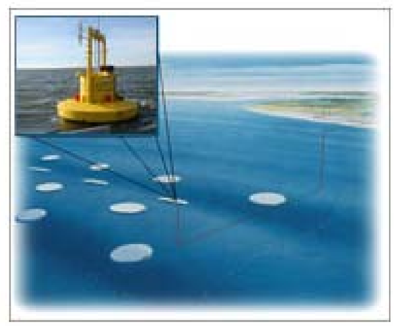


FIGURE 4 PowerBuoy Point Absorber Wave Energy Converter (Source: Ocean Power Technologies 2006)

One such device is the PowerBuoy™ developed by Ocean Power Technologies (2006) (Figure 4). The construction involves a floating structure with one component relatively immobile, and a second component with movement driven by wave motion (a floating buoy inside a fixed cylinder). The relative motion is used to drive electromechanical or hydraulic energy converters. A PowerBuoy demonstration unit rated at 40 kW was installed in 2005 for testing offshore from Atlantic City, New Jersey. Testing in the Pacific Ocean is also being conducted, with a unit installed in 2004 and 2005 off the coast of the Marine Corps Base in Oahu, Hawaii. A commercial-scale PowerBuoy system is planned for the northern coast of Spain, with an initial wave park (multiple units) at a 1.25-MW rating. Initial operation is expected in 2007.

The AquaBuOY™ WEC (Figure 5) being developed by the AquaEnergy Group, Ltd. (2005) is a point absorber that is the third generation of two Swedish designs that utilize the wave energy to pressurize a fluid that is then used to drive a turbine generator. The vertical movement of the buoy drives a broad, neutrally buoyant disk acting as a water piston contained in a long tube beneath the buoy. The water piston motion in turn elongates and relaxes a hose containing seawater, and the change in hose volume acts as a pump to pressurize the seawater. The AquaBuOY design has been tested using a full-scale prototype, and a 1-MW pilot offshore demonstration power plant is being developed offshore at Makah Bay, Washington. The Makah Bay demonstration will include four units rated at 250 kW placed 5.9 km (3.2 nautical miles) offshore in water approximately 46 m deep.

FIGURE 5 AquaBuOY Point Absorber Wave Energy Converter (Source: AquaEnergy Group, Ltd. 2005)

Other point absorbers that have been tested at prototype scale include the Archimedes Wave Swing (2006), which consists of an air-filled cylinder that moves up and down as waves pass over. This motion relative to a second cylinder fixed to the ocean floor is used to drive a linear electrical generator. A 2-MW capacity device has been tested offshore of Portugal.

FIGURE 6 Wave Dragon Overtopping Device (Source: Wave Dragon 2005)

Overtopping Devices

Overtopping devices have reservoirs that are filled by impinging waves to levels above the average surrounding ocean. The released reservoir water is used to drive hydro turbines or other conversion devices. Overtopping devices have been designed and tested for both onshore and floating offshore applications. The offshore devices include the Wave Dragon™ (Wave Dragon 2005), whose design includes wave reflectors that concentrate the waves toward it and thus raises the effective wave height. Wave Dragon development includes a 7-MW demonstration project off the coast of Wales and a precommercial prototype project performing long-term and real sea tests on hydraulic behavior, turbine strategy, and power production to the grid in Denmark. The Wave Dragon design has been scaled to 11 MW (Christensen 2006), but larger systems are feasible since the overtopping devices do not need to be in resonance with the waves as is the case for point absorbing devices.

The WavePlane™ (WavePlane Production 2006) overtopping device has a smaller reservoir. The waves are fed directly into a chamber that funnels the water to a turbine or other conversion device.

2.2. Case Study: The Reedsport Wave Energy Park

Ocean Power Technology (OPT) is working towards applying for a FERC operating license for 14 buoys (a 2.1 MW facility) during late fall 2007, with intended deployment during spring 2009. The 14 buoy project would encompass approximately ½ square mile in area. OPT proposes that the 14 buoys would be built out to approximately 200 units, for a 50 MW facility in the ensuing years. OPT manufactures the PowerBuoy®, which at the intended scale (150 kW), is 41 m high, 12 m at the widest point (the surge plate) and 11 m at the floating collar, and has 8 m above the surface and 34 m below the surface. The wave park would be centered over the 50 m isobath, about 2 ½ miles offshore of Reedsport, Oregon. The 14 buoys would be arranged in a grid as shown in Figure 2.2, below. The full build-out of 200 buoys (four rows of 50, parallel to shore) would have a footprint of about ½ mile by 3 miles, plus any required standoff zone.

Figure 2.1. PowerBuoy® layout and dimensions. (FERC 2007).

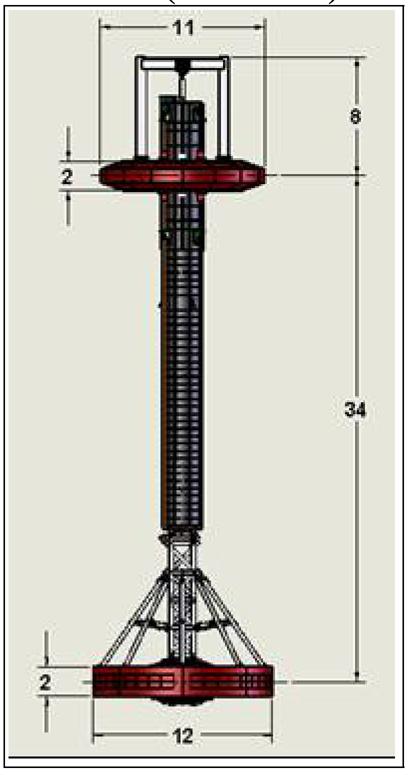
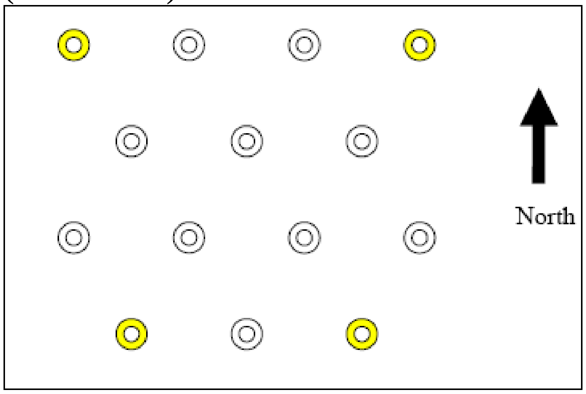


Figure 2.2 Proposed PowerBuoy® Array (FERC 2007).



The spacings between the buoys are intended to be about 100m. The anchoring system for a single buoy is shown in Figure 2.3. The subsurface buoys between the tendon and catenary lines are intended to have significant positive buoyancy in order to limit the buoys to a small area. Anchors are now intended to be precast concrete blocks measuring 6 x 6 x 3 m.

The power will be generated as asynchronous alternating current (1/8 to 1/12 Hertz AC) , but will be converted to 60 cycle, three-phase AC at the subsea pod. The buoys' electrical cables will be joined at the subsea pod that houses a transformer and switchgear and steps up the voltage. That unit is now designed to be 6 ft in diameter and 15 ft long, and is held down with concrete ballast blocks. A sketch is shown in Figure 2.4.

Figure 2.3. Reedsport Wave Energy Park anchoring schematic (FERC 2007); anchor spacing at about 100 meters.

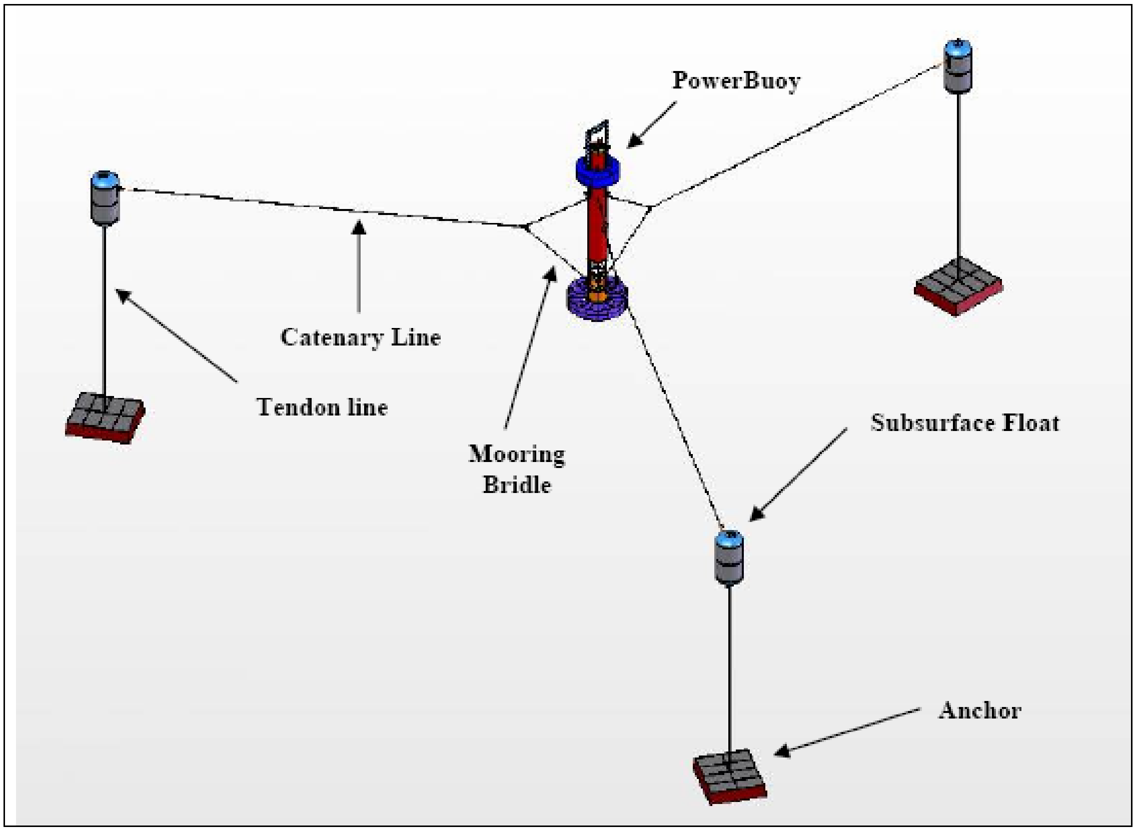
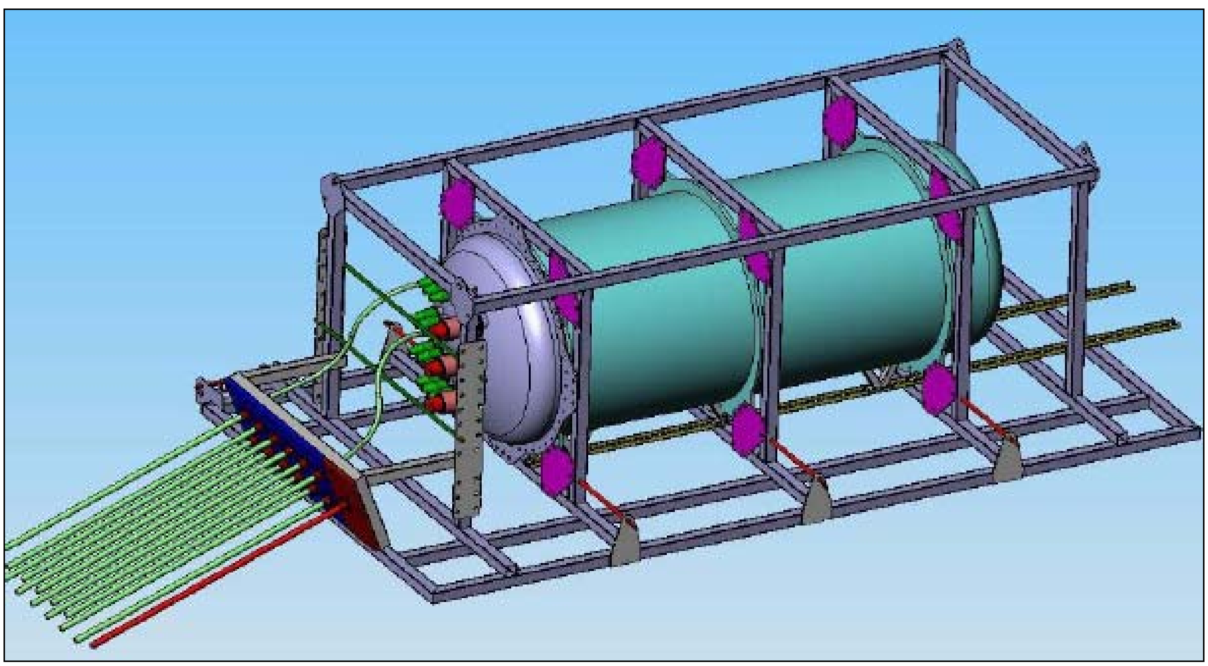


Figure 2.4. Reedsport Wave Energy Park subsea pod schematic (FERC 2007).



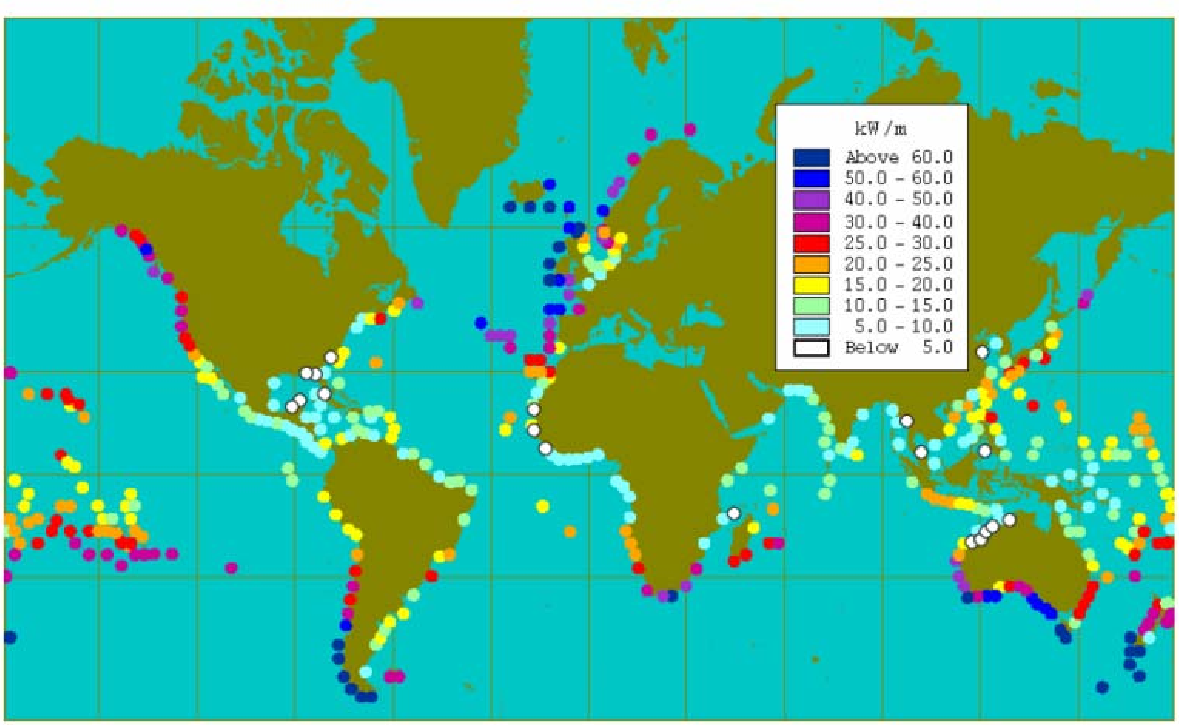
3.0. The Affected Environment: Oregon's Continental Shelf

The area of interest to this workshop is the nearshore zone along the Oregon's coast, from near the 50-meter depth contour to the shoreline. The "sweet spot" for wave energy development along Oregon's coast, at least for most of the technologies yet proposed at this time, is about 50m depth, or just inside 30 fathoms. This depth is roughly the closest distance from shore that long period, large wave forms have yet to begin to react to shoaling. This area is also the focus of the Oregon Department of Fish & Wildlife's recently published Nearshore Strategy (ODFW Nearshore Team 2006), and this section of the briefing paper relies heavily on the content of that report. Figure 3.1 (see page 14) is taken from the Nearshore Strategy and shows the area of interest, depth, and rocky versus sandy shoreline types (ODFW Nearshore Team 2006).

3.1. Wave Climate and Currents

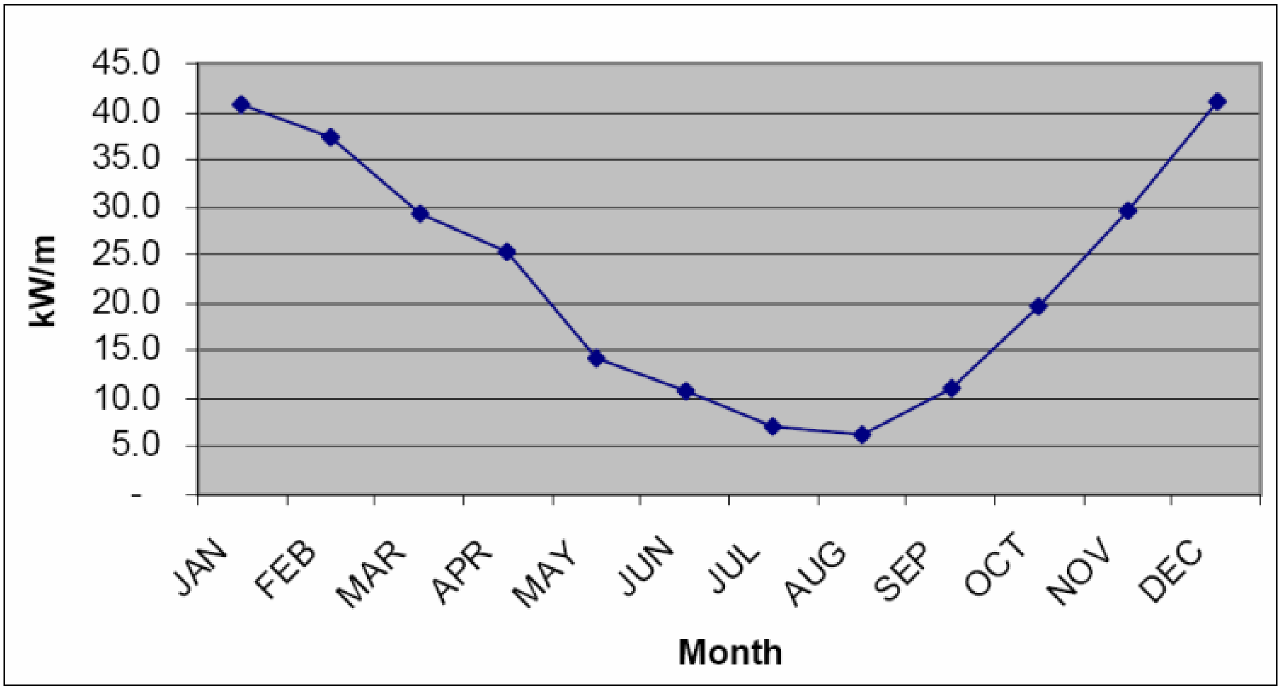
Oregon's wave climate is the major reason for the high level of industry interest, along with easy access to transmission infrastructure. The relative amount of annual wave energy world wide is shown in Figure 3.2 (Bedard 2005), and shows that the best US resource is the West Coast, resulting from the prevailing Westerlies and the large fetch of the open Pacific. Significant wave heights (the average height, trough to crest, of the one-third highest waves valid for the time

Figure 3.2. Annual wave energy averages worldwide in kW/m wave front (Bedard 2005).



period) at Coquille from 1984 to 1996 reached 7.8 m, with a maximum wave height on the order of 15 m (Bedard 2005). The monthly average wave energy flux, shown in Figure 3.3, illustrates that the seasonal energy during winter and summer differs by a factor of about eight. Whereas other markets are characterized by higher demands in summer for air conditioning, the Oregon coast market corresponds roughly to the resource.

Figure 3.3. Monthly average wave energy flux in KW/m (Bedard 2005).



Currents on the Oregon shelf are strongly seasonal. Winter is characterized by low pressure systems that drive episodic, strong southwesterly winds, and result in the northerly flowing Davidson Current and downwelling conditions. Summer is characterized by episodes of high pressure offshore and strong northerly or northwesterly winds that drive the California Current and upwelling conditions. The spring transition takes place in March-April and fall transition in late September-October; both are characterized by very calm local weather and seas. The seasonal prevailing winds and resulting sea surface temperatures are illustrated in Figure 3.4, from the Reedsport Wave Energy Preliminary Application Document (FERC 2007).

3.2. Littoral Transport System

There exist eighteen identified littoral circulation cells on the Oregon Coast, as shown in a map developed by the Oregon Department of Geology and Mineral Industries (Figure 3.5). Reedsport, location of the intended first wave energy park in Oregon, is in the middle of the Coos cell. Sub-cell information is not available at the time of writing.

Figure 3.1 Oregon's nearshore ocean showing the 30-fathom depth contour and the 3-nautical mile demarcation of the Territorial Sea (ODFW Nearshore Team 2006). Read areas are rocky shore habitats; areas not blocked in red are sedimented shorelines.

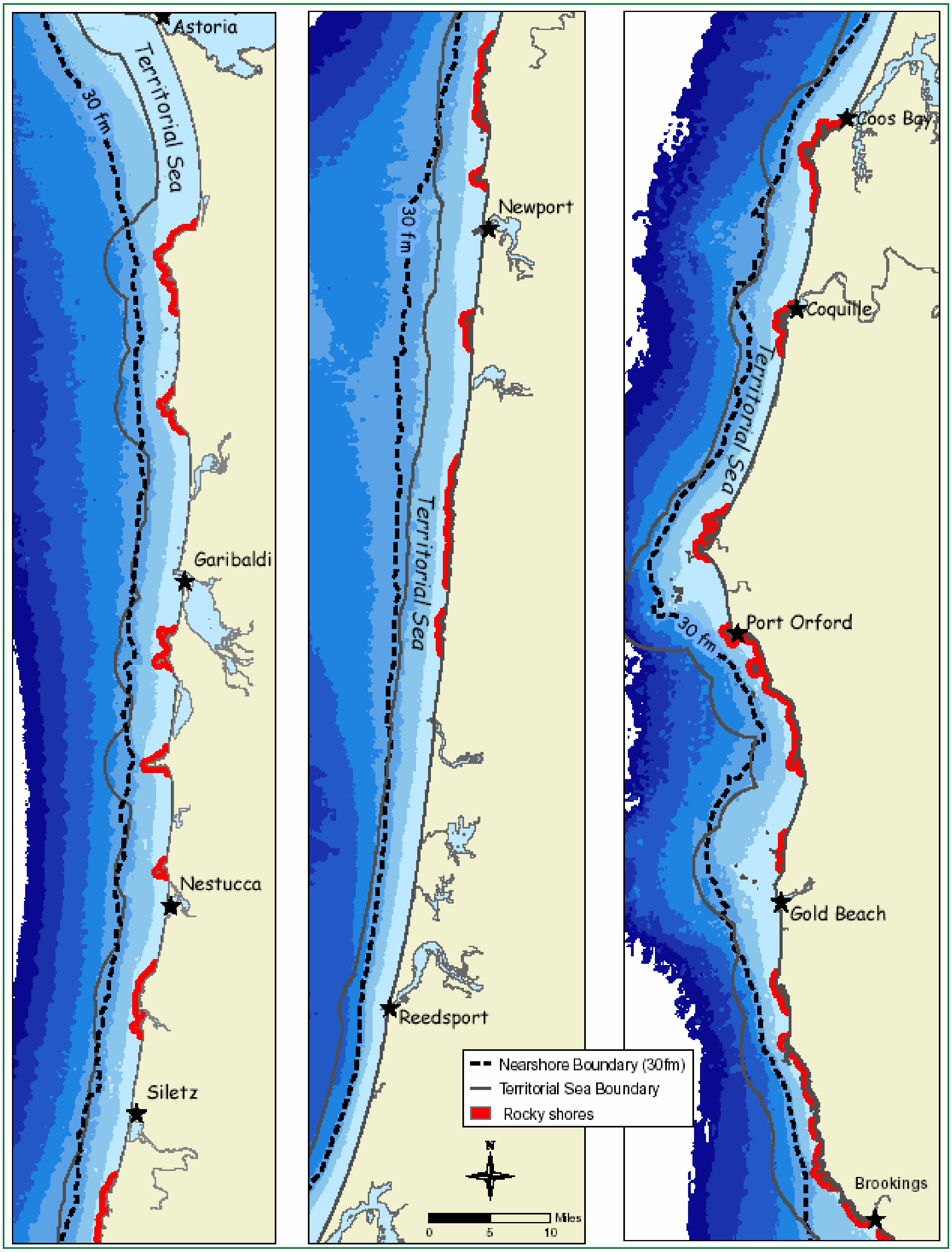
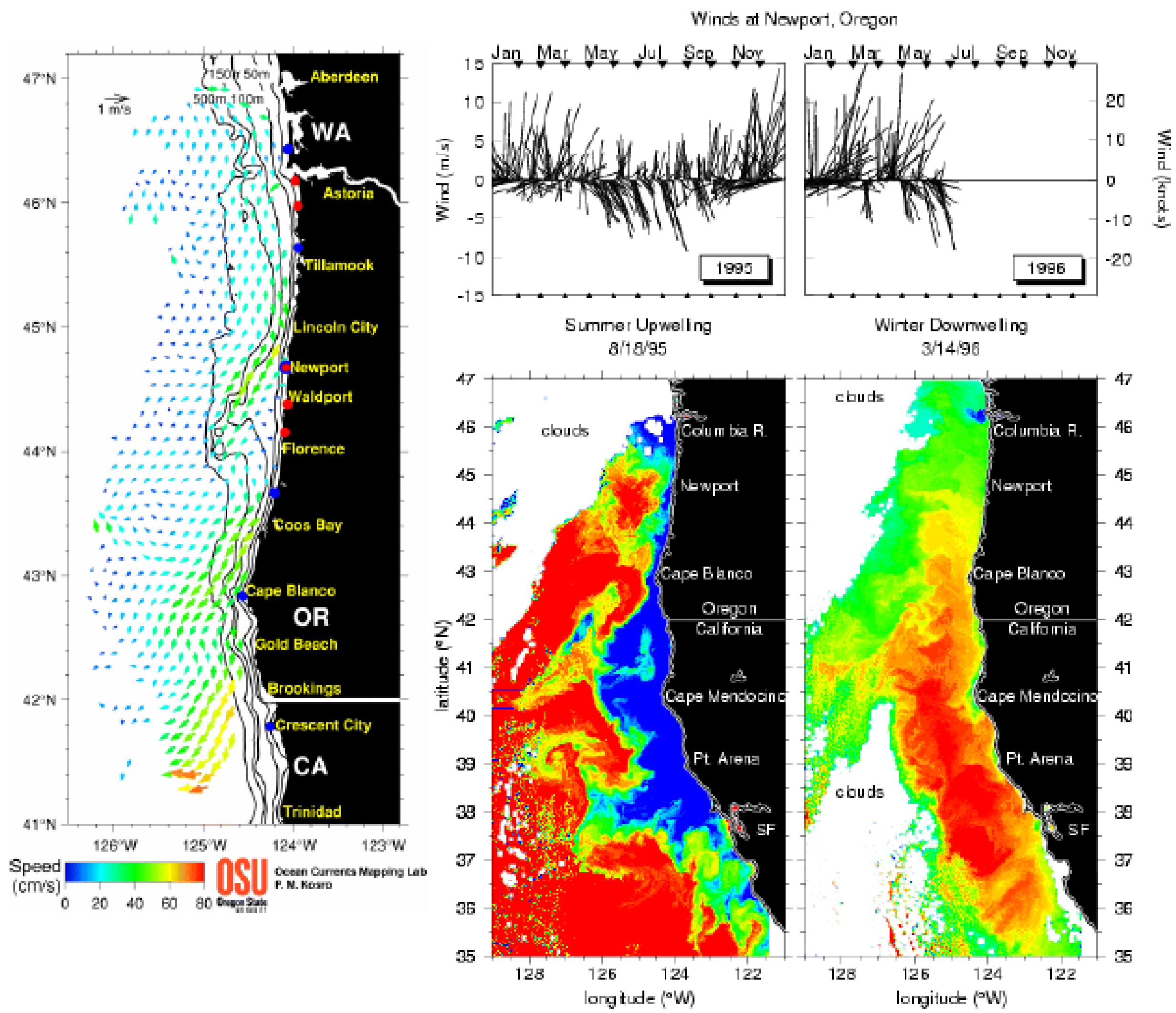
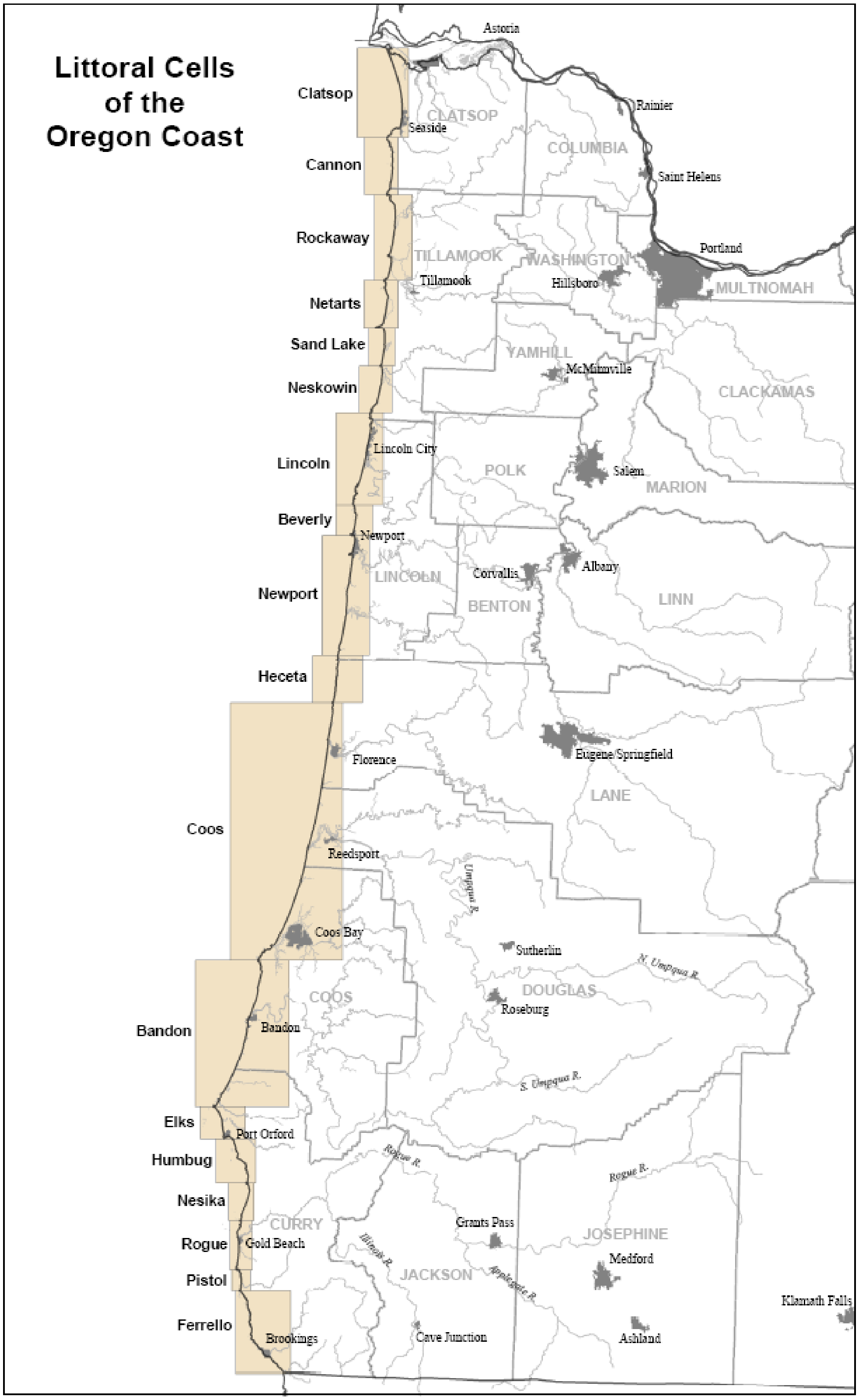


Figure 3.4. Visual display of current patterns along the Oregon coast (left), winds and correlating water temperatures along the southern Oregon coast (right)(FERC 2007).



Note: Daily sticks point toward the direction the wind is blowing and their length indicates the strength of the wind. Figures adapted from Kosro (2007) and GLOBEC (2001).

Figure 3.5 Map of the littoral cells of the Oregon coast (DOGAMI).



3.3. Pelagic Habitat Physical Characterization

The pelagic habitat on Oregon's nearshore continental shelf is generally reflective of either winter or summer conditions. During winter, very nearshore surface temperatures are on the order of 9-10°C and salinities on the order of 30-32 NSU (Landry, et al. 1989). Winter currents nearshore are generally northwards with the Davidson current, and large waves come from the southwest and west, corresponding to episodic major winter storms (see Fig. 3.4). During summer upwelling, surface temperatures are on the order of 12-14°C and salinities on the order of 30-32 NTU with colder, more saline water on the inner shelf (see Fig. 3.4; Landry, et al. 1989). During upwelling relaxation events, warmer surface water moves towards shore. In winter, the Columbia River plume swings north very close to shore, and during summer, swings south and offshore covering a very large area (Landry, et al. 1989). Light transmission is generally higher in winter (away from river mouths) and lower after the spring transition, when phytoplankton begin to bloom. Ocean "fronts" (regions of high rates of change in temperature and salinity) on the edges of upwelling surface structure are well known as biological hotspots and may be bathymetrically controlled (and geographically recurrent) in some locations (see for example GLOBEC 1996). Regime transitions during spring (March- April) and fall (September-October) exhibit generally calm conditions of wind and waves.

3.4. Benthic Habitat Physical Characterization

The wave energy industry has thus far shown a strong preference for locating in sedimented areas with no known rocky outcrops, so that concrete block can be used as anchors. The high energy coastline yields a gradient in sediment size from sand on the beaches to mud in deep water. The sediment at 50-100 m varies from fine sand at 50 m to sandy silt towards 100 m depth, as shown by Table 3-1 from the Reedsport preliminary application (FERC 2007). Samples from the EPA's Environmental Assessment and Mapping Program (EMAP) sampling of depths from 20 to 120 m during 2003 yielded similar sediment size results (from 50.1 to 99.1% sand), and organics percentages from 0.30 to 1.4 (LASAR 2007).

Table 3-1. Grain size distributions from seabed surface sediment samples collected in the vicinity of the Reedsport Wave Energy Project (FERC 2007).

Site Name	Latitude	Longitude	Water Depth (m)	Sampler	% Sand	% Silt	% Clay	Shepard Code
OSU6901-1	43.815	-124.260	89	Box Core	64	22	14	SILTY SAND
OSU6901-2	43.817	-124.233	70	Box Core	90	6	4	SAND
OSU6901-3	43.817	-124.215	50	Box Core	85	2	13	SAND
OSU6901-4	43.817	-124.197	30	Box Core	88	12	0	SAND
OSU6403-265	43.783	-124.272	88	Dietz-LaFond	42	44	14	SANDY SILT
OSU6403-266	43.733	-124.270	95	Dietz-LaFond	31	51	18	SANDY SILT

Source: USGS 2007*a*.

3.5. The Biota

For purposes of this briefing paper, the biota will be addressed as assemblages in the habitat, including the assemblages in the water column (pelagic), those at the bottom of the water column (demersal/epibenthic) and those within the sediment (benthic infauna). Seabirds and marine mammals are treated in their own sections. This section leans heavily on the ODFW Nearshore Strategy (ODFW Nearshore Team 2006), as that work is the most recent and complete synthesis of nearshore biology, especially as it relates to Oregon's fish resources.

3.5.1. Epipelagic/Pelagic Species Assemblage

Phytoplankton. Phytoplankton are the base of the food web, and thrive in Oregon's nutrient-rich upwelling conditions. Spring transition (March – April) generally leads to an annual diatom bloom which is an important component of the food base for copepods, euphausiids, mysids and other grazers in the plankton community. Many other groups of phytoplankton are found in the community, including toxic diatoms (*Pesudonitzschia* sp.) that can cause amnesiac shellfish poisoning (ASP) and certain species of dinoflagellates that can cause paralytic shellfish poisoning (PSP). The phytoplankton species respond to major ocean changes as do the zooplankton (below).

Zooplankton. The zooplankton include holozooplankton (animals found in the water column throughout their life history) and meroplankton (animals found in the water column during part of their life history). The Reedsport Wave Energy project briefly reviewed the holozooplankton as inserted below (FERC 2007).

> Plankton is found throughout the Oregon Coast, but concentrated populations generally occur near the continental shelf. Lamb and Peterson (2005) found the highest concentration of zooplankton inshore of the 300-foot isobath. Within that isobath, species are separated by preferences in water temperature and salinity (Sutor et al. 2005). Actual offshore location and density of plankton is directly affected by seasonal variations in wind and current (Keister and Peterson 2003). Generally, upwelling events occur in late summer. Uncommon El Niño years tend to upset the usual pattern of upwelling events and can alter timing and occurrence of plankton abundance, species composition, and blooms (Keister and Peterson 2003).

Fouling Community. The fouling community consists of meroplanktonic invertebrates whose larvae have evolved to settle on hard substrates, and thus will settle on man-made surfaces as well. Many of these meroplanktonic organisms are found in the neuston, plants and animals that are attracted to and often found in the upper 10 cm of the water column, at least during calm weather and seas. There are also some invasive species in this community that may make opportunistic use of new hard structures, like wave energy devices, to extend their range.

Krill. Krill is a term applied to numerous species of euphausiids, vertically migrating, shrimp-like crustaceans; they are a very important source of forage for many small fish and invertebrates, as well as some baleen whales. Key species on the Oregon shelf are *Euphausia pacifica* and *Thysanoessa spinifera* (Peterson, personal communication). The Pacific Fishery Management Council (PMFC) recently took action to preclude any krill fisheries on the West Coast of the United States (PFMC 2006).

Market Squid. The market squid (*Loligo opalescens*) is a key, schooling invertebrate species that provides important forage for Oregon's fish communities and is included in ODFW's list of watch species (see below and Table 3.3).

Fish. The Pacific Fisheries Management Council (PMFC) is given authority over West Coast fisheries under the Magnusen-Stevens Fishery Conservation Act (MSA). It its latest iteration, the MSA requires the regional councils to identify Essential Fish Habitat (EFH): "those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity." All aquatic habitat that was historically accessible to groundfish species, coastal pelagic species, coho salmon, Chinook salmon, and pink salmon is designated as EFH. NOAA Fisheries has listed the species (both pelagic and demersal) with essential fish habitat in the nearshore area (Table 3-2).

ODFW's Nearshore Strategy (ODFW Nearshore Team 2006) listed the key pelagic species with respect to nearshore fisheries planning. Their table is show in its entirety as Table 3-3. Strategy species are defined as important nearshore species in need of greatest management attention, and watch list species are defined as those that do not require immediate management attention, but may in the future. Note that some invertebrate species are included in the ODFW tables, and that there is some crossover between the pelagic and epibenthic/demersal table species.

Table 3-2. Species with designated Essential Fish Habitat (EFH) in the nearshore area.

Groundfish Species				
SpeciesCommon	*Species Scientific Name*	Lifestage	Activity	Prey
Arrowtooth flounder	*Atheresthes stomias*	Adults		Clupeids, gadids, krill, shrimp, Theragra chalcogramma
	Atheresthes stomias	Larvae		Copepod eggs, copepod nauplii, copepods
Bank rockfish	*Sebastes rufus*	Adults		gelatinous plankton, krill, small fishes, tunicates
	Sebastes rufus	Juveniles		gelatinous plankton, krill, small fishes, tunicates
Big skate	*Raja binoculata*	Adults		Crustaceans, fish
Black rockfish	*Sebastes melanops*	Adults		Amphipods, cephalopods, clupeids, euphausiids, mysids, polychaetes, salps
Blue rockfish	*Sebastes mystinus*	Adults	Feeding	algae, crab, juvenile fish, fish larvae, hydroids, jellyfish, krill, salps, tunicates

Groundfish Species				
SpeciesCommon	*Species Scientific Name*	Lifestage	Activity	Prey
	Sebastes mystinus	Juveniles	Feeding	algae, copepods, crab, euphausiids, juvenile fish, hydroids, krill, salps, tunicates
	Sebastes mystinus	Juveniles	All	algae, copepods, crab, euphausiids, juvenile fish, hydroids, krill, salps, tunicates
Bocaccio	*Sebastes paucispinis*	Adults	Feeding	Juvenile rockfish, molluscs, small fishes
	Sebastes paucispinis	Juveniles	Feeding	Copepods, euphausiids
Butter sole	*Isopsetta isolepis*	Adults		Amphipods, decapod crustaceans, molluscs, polychaetes, sea stars, shrimp
Cabezon	*Scorpaenichthys marmoratus*	Adults		Crabs, fish eggs, lobsters, molluscs, small fishes
Canary rockfish	*Sebastes pinniger*	Adults		Euphausiids, fish, krill
Chilipepper	*Sebastes goodei*	Adults		Clupeids, euphausiids, krill, Merluccius productus,squids
	Sebastes goodei	Juveniles		Copepods, euphausiids
Copper rockfish	*Sebastes caurinus*	Adults		Crustaceans, fish, molluscs, shrimp
Cowcod	*Sebastes levis*	Adults		Fish, octopi, squids
Curlfin sole	*Pleuronichthys decurrens*	Adults	All	Crustacean eggs, echiurid proboscises, nudibranchs, polychaetes
Darkblotched rockfish	*Sebastes crameri*	Adults		Amphipods, euphausiids, octopi, salps, small fishes
English sole	*Parophrys vetulus*	Adults		Amphipods, crustaceans, cumaceans, molluscs, ophiuroids, polychaetes
	Parophrys vetulus	Juveniles		Amphipods, copepods, cumaceans, molluscs, mysids, polychaetes
Flag rockfish	*Sebastes rubrivinctus*	Adults		Crabs, fish, octopi, shrimp
Flathead sole	*Hippoglossoides elassodon*	Adults		Clupeids, fish, molluscs, mysids, polychaetes, shrimp
Grass rockfish	*Sebastes rastrelliger*	Adults		Cephalopods, crabs, crustaceans, fish, gastropod, shrimp
Greenstriped rockfish	*Sebastes elongatus*	Adults		Copepods, euphausiids, shrimp, small fishes, squids, tunicates
Kelp greenling	*Hexagrammos decagrammus*	Adults		Brittle Stars, crabs, octopi, shrimp, small fishes, snails, worms
	Hexagrammos decagrammus	Larvae		Amphipods, brachyuran, copepod nauplii, copepods, euphausiids, fish larvae
Lingcod	*Ophiodon elongatus*	Adults	Unknown	Demersal fish, juvenile crab, octopi, squid,
	Ophiodon elongatus	Larvae	Unknown	amphipods, copepod eggs, copepod nauplii, copepods, decapod larvae, euphausiids

Groundfish Species				
SpeciesCommon	*Species Scientific Name*	Lifestage	Activity	Prey
Pacific cod	*Gadus macrocephalus*	Adults		Amphipods, crabs, mysids, sandlance, shrimp, Theragra chalcogramma
	Gadus macrocephalus	Juveniles		Amphipods, copepods, crabs, shrimp
	Gadus macrocephalus	Larvae		Copepods
	Gadus macrocephalus	Larvae		Copepods
Pacific hake	*Merluccius productus*	Juveniles		Euphausiids
	Merluccius productus	Adults	All	Amphipods, clupeids, crabs, Merluccius productus, rockfish, squids
Pacific ocean perch	*Sebastes alutus*	Adults		Copepods, euphausiids, mysids, shrimp, small fishes, squids
	Sebastes alutus	Juveniles		Copepods, euphausiids,
Pacific sanddab	*Citharichthys sordidus*	Adults		Clupeids, crab larvae, octopi, squids
Petrale sole	*Eopsetta jordani*	Adults		Eopsetta jordani, euphausiids, ophiuroids, pelagic fishes, shrimp
Quillback rockfish	*Sebastes maliger*	Adults		Amphipods, clupeids, crabs, euphausiids, juvenile fish, molluscs, polychaetes, shrimp
Redstripe rockfish	*Sebastes proriger*	Adults		Clupeids, juvenile fish, squid
Rex sole	*Glyptocephalus zachirus*	Adults		Cumaceans, euphausidds, larvacea, polychaetes
Rock sole	*Lepidopsetta bilineata*	Adults		echinoderms, echiurans, fish, molluscs, polychaetes, tunicates
Rosethorn rockfish	*Sebastes helvomaculatus*	Adults		Amphipods, copepods, euphausiids
Rosy rockfish	*Sebastes rosaceus*	Adults		Crabs, shrimp
Sablefish	*Anoplopoma fimbria*	Juveniles	Growth to Maturity	Amphipods, cephalopods, copepods, demersal fish, euphausiids, krill, small fishes, squids, tunicates
	Anoplopoma fimbria	Larvae	Feeding	Copepod eggs, copepod nauplii, copepods
Sand sole	*Psettichthys melanostictus*	Adults		Clupeids, crabs, fish, molluscs,mysids, polychaetes, shrimp
Sand sole	*Psettichthys melanostictus*	Juveniles		Euphausiids, molluscs, mysids, polychaetes, shrimp
Sharpchin rockfish	*Sebastes zacentrus*	Adults		Amphipods, copepods, euphausiids, shrimp, small fishes
	Sebastes zacentrus	Juveniles		Amphipods, copepods, euphausiids, shrimp, small fishes
Shortbelly rockfish	*Sebastes jordani*	Adults		Copepods, euphausiids

Groundfish Species				
SpeciesCommon	*Species Scientific Name*	Lifestage	Activity	Prey
Shortraker rockfish	*Sebastes borealis*	Adults		bathylagids, cephalopods, decapod crustaceans, fish, molluscs, myctophids, mysids, shrimp
Shortspine thornyhead	*Sebastolobus alascanus*	Adults		Amphipods, copepods, crabs, fish, polychaetes, Sebastolobus alascanus, Sebastolobus altivelis, shrimp
Soupfin shark	*Galeorhinus galeus*	Juveniles	Growth to Maturity	Fish, invertebrates
	Galeorhinus galeus	Adults		Fish, invertebrates
Spiny dogfish	*Squalus acanthias*	Adults	All	Invertebrates, pelagic fishes
	Squalus acanthias	Adults	Feeding	Invertebrates, pelagic fishes
Splitnose rockfish	*Sebastes diploproa*	Juveniles		Amphipods, cladocerans, copepods
Spotted ratfish	*Hydrolagus colliei*	Adults		algae, amphipods, annelids, brittle stars, fish, hydrolagus collei, molluscs, nudibranchs, opisthobranchs, ostracods, small crustacea, squid
	Hydrolagus colliei	Juveniles		algae, amphipods, annelids, brittle stars, fish, hydrolagus collei, molluscs, nudibranchs, opisthobranchs, ostracods, small crustacea, squid
Starry flounder	*Platichthys stellatus*	Adults		Crabs, fish juveniles, molluscs, polychaetes
	Platichthys stellatus	Juveniles		Amphipods, copepods, polychaetes
Stripetail rockfish	*Sebastes saxicola*	Adults		Copepods, euphausiids
	Sebastes saxicola	Juveniles		Copepods
Tiger rockfish	*Sebastes nigrocinctus*	Adults		Amphipods, clupeids, crabs, juvenile fish, juvenile rockfish, shrimp
Vermilion rockfish	*Sebastes miniatus*	Adults		Clupeids, juvenile rockfish, krill, octopi, squid
Widow rockfish	*Sebastes entomelas*	Adults		Amphipods, copepods, euphausiids, Merluccius productus, salps, shrimp, squids
	Sebastes entomelas	Juveniles		Copepod eggs, copepods, euphausiid eggs
Yelloweye rockfish	*Sebastes ruberrimus*	Adults		Clupeids, cottids, crabs, gadids, juvenile rockfish, sea urchin, shrimp, snails
Yellowtail rockfish	*Sebastes flavidus*	Adults		Clupeids, euphausiids, krill, Merluccius productus, mysids, salps, squids, tunicates
Pacific Salmon				

Groundfish Species				
SpeciesCommon	*Species Scientific Name*	Lifestage	Activity	Prey
Coho Salmon	*Oncorhynchus kisutch*			
Chinook Salmon	*Oncorhynchus tshawytscha*			
Coastal Pelagic Species				
Pacific Sardine	*Sardinops sagax*			
Pacific (Chub) Mackerel	*Scomber japonicus*			
Northern Anchovy	*Engraulis mordax*			
Jack Mackerel	*Trachurus symmetricus*			
California Market Squid	*Loligo opalescens*			

3.5.2. Epibenthic/Demersal Organsims

ODFW's Nearshore Strategy (ODFW Nearshore Team 2006) also listed the strategy and watch list soft-bottom demersal/epibenthic species with respect to nearshore fisheries planning. Their table is show in its entirety as Table 3-3.

Epibenthic Macroinvertebrates.
Decapod crustaceans in this group are commercially important and include the Pacific pink shrimp (*Pandalus jordani*) and Dungeness crab (*Cancer magister*). Other important groups include both cephalopod and bivalve mollusks, and echinoderms, represented by seastars and sea urchins.

Forage Fishes. In addition to the forage fishes that are treated above, the Pacific sandlance (*Ammodytes hexapterus*) are also an important in the region, but are characteristically undersampled or not sampled, because they can burrow into the sediment to avoid trawl capture (Emmett, personal communication).

Demersal Fishes. Groundfish in the managed community are numerous, including the principally *Sebastes* complex, which includes the many rockfish species and the kelp greenling and ling cod (see Table 3-3). There are also a number of flatfish species, such as sanddabs, in the assemblage.

Elasmobranchs. Common soft-rayed fishes (elasmobranches) on the Oregon shelf include the dogfish shark (*Squalus acanthias*), bat ray (*Myliobatis californica*), and the big skate (*Raja binoculata*). White sharks (*Carcharadon carcharias*) inhabit the Oregon coast year round, and are of great concern to the surfing community. Elasmobranchs are of interest here because of their ability to perceive electromagnetic fields.

Table 3-3. Pelagic species assemblages (ODFW Nearshore Team 2006).

STRATEGY SPECIES		
Bony Fishes		
Black rockfish *Sebastes melanops*	Black-and-yellow rockfish *Sebastes chrysomelas*	Blue rockfish *Sebastes mystinus*
Bocaccio *Sebastes paucispinis*	Canary rockfish *Sebastes pinniger*	Copper rockfish *Sebastes caurinus*
Gopher rockfish *Sebastes carnatus*	Grass rockfish *Sebastes rastrelliger*	Green sturgeon *Acipenser medirostris*
Lingcod *Ophiodon elongates*	Pile perch *Rhacochilus vacca*	Quillback rockfish *Sebastes maliger*
Redtail surfperch *Amphistichus rhodoterus*	Shiner perch *Cymatogaster aggregate*	Starry flounder *Platichthys stellatus*
Surf smelt *Hypomesus pretiosus*	Topsmelt *Atherinops affinis*	Vermilion rockfish *Sebastes miniatus*
White sturgeon *Acipenser transmontanus*	Yellowtail rockfish *Sebastes flavidus*	
Cartilaginous Fishes		
Big skate *Raja binoculata*	Spiny dogfish *Squalus acanthias*	
Marine Mammals		
Gray whale *Eschrichtius robustus*	Harbor porpoise *Phocoena phocoena*	
Invertebrates		
Dungeness crab Cancer magister	Giant octopus Octopus dofleini	Razor clam Siliqua patula

WATCH LIST SPECIES		
Bony Fishes		
Buffalo sculpin *Enophrys bison*	Butter sole *Pleuronectes isolepis*	California halibut *Paralichthys californicus*
Curlfin turbot *Pleuronichthys decurrens*	English sole *Pleuronectes vetulus*	Flathead sole *Hippoglossoides elassodon*
Giant wrymouth *Delolepis gigantean*	Pacific sand lance *Ammodytes hexapterus*	Pacific sanddab *Citharichthys sordidus*
Pacific sandfish *Trichodon trichodon*	Pacific staghorn sculpin *Leptocottus armatus*	Rock sole *Pleuronectes bilineatus*
Sand sole *Psettichthys melanostictus*		
Cartilaginous Fishes		
Brown smoothhound *Mustelus henlei*	California skate *Raja inornata*	Leopard shark *Triakis semifasciata*
Pacific angel shark *Squatina californica*	Soupfin shark *Galeorhinus galeus*	Spotted ratfish *Hydrolagus colliei*
Invertebrates		
California sea cucumber *Parastichopus californicus*	Coonstripe shrimp *Pandalus danae*	Market squid *Loligo opalescens*
Oregon triton *Fusitriton oregonensis*	Red rock crab *Cancer productus*	

COMMONLY ASSOCIATED SPECIES		
Bony Fishes		
Calico surfperch *Amphistichus koelzi*	**Grunt sculpin** *Rhamphocottus richardsonii*	**Lumptail searobin** *Prionotus stephanophrys*
Pacific hooker sculpin *Artediellus pacificus*	**Pricklebreast poacher** *Stellerina xyosterna*	**Pygmy poacher** *Odontopyxis trispinosa*
Roughback sculpin *Chitonotus pugetensis*	**Saddleback gunnel** *Pholis ornate*	**Sailfin sculpin** *Nautichthys oculofasciatus*
Sharpnose sculpin *Clinocottus acuticeps*	**Silver surfperch** *Hyperprosopon ellipticum*	**Speckled sanddab** *Citharichthys stigmaeus*
Spotfin surfperch *Hyperprosopon anale*	**Sturgeon poacher** *Agonus acipenserinus*	**Tubesnout** *Aulorhynchus flavidus*
Walleye surfperch *Hyperprosopon argenteum*	**White surfperch** *Phanerodon furcatus*	
Cartilaginous Fishes		
Bat ray *Myliobatis californica*	**Pacific electric ray** *Torpedo californica*	
Invertebrates		
Brown rock crab *Cancer antennarius*	**Cockle clam** *Clinocardium nuttallii*	**Hermit crabs** *Pagurus spp.*
Sabellid worm *Myxicola infundibulum*	**Sand dollar** *Dendraster excentricus*	

3.5.3. Benthic Infauna

EPA's Environmental Assessment and Monitoring Program conducted a random stratified sampling program on the Oregon shelf in 2003 that included benthic infauna analysis. Fifty stations between 20 and 120m water depth were sampled, and the benthic infauna identified to species or the most specific taxonomic group feasible. The results are still provisional, but a 79m sample was taken very near the intended Reedsport wave park. The infauna was numerically and taxonomically dominated by polychaete worms, and also included gastropods, amphipods, brittle stars, bivalves, ribbon worms, shrimp, scaphopods, cumaceans, oligochaete worms, and anemones in the 76 taxa identified (Edmond, personal communication). The most numerous species were *Magelona longicornis, Galathowena oculata* and *Scoletoma luti* – all polychetes.

Braun (2005) recently reviewed the existing literature for the area near the mouth of the Columbia River with a focus on depths under 30m, and offered some insight into the life histories of the dominant species found in sand to mud substrates in high energy environments, as shown below:

> *Spiophanes bombyx*, a small, slender bristleworm (5 to 6 cm long by 0.15 cm wide), is found in clean sand from the low water mark to about 60 meters. *Spiophanes bombyx* is regarded as a typical 'r'-selected species with a short life span, high dispersal potential, and a high reproductive rate (Kröncke 1980; Niermann et al. 1990). It is often found at the early successional stages of variable, unstable habitats that it is quick to colonize following perturbation (Pearson & Rosenberg 1978). Its larval dispersal phase may allow

Table 3-4. Soft-bottom epibenthic/demersal species assemblages (ODFW Nearshore Team 2006).

STRATEGY SPECIES		
* Strategy Species that have any part of their life history, including larval and juvenile stages, commonly occur in neritic habitats are included in the table		
Bony Fishes		
Black rockfish *Sebastes melanops*	Black-and-yellow rockfish *Sebastes chrysomelas*	Blue rockfish *Sebastes mystinus*
Bocaccio *Sebastes paucispinis*	Cabezon *Scorpaenichthys marmoratus*	Canary rockfish *Sebastes pinniger*
China rockfish *Sebastes nebulosus*	Copper rockfish *Sebastes caurinus*	Eulachon *Thaleichthys pacificus*
Gopher rockfish *Sebastes carnatus*	Grass rockfish *Sebastes rastrelliger*	Kelp greenling *Hexagrammos decagrammus*
Lingcod *Ophiodon elongates*	Northern anchovy *Engraulis mordax*	Pacific herring *Clupea pallasii*
Quillback rockfish *Sebastes maliger*	Rock greenling *Hexagrammos lagocephalus*	Starry flounder *Platichthys stellatus*
Striped perch *Embiota lateralis*	Surf smelt *Hypomesus pretiosus*	Topsmelt *Atherinops affinis*
Vermilion rockfish *Sebastes miniatus*	Wolf-eel *Anarrhichthys ocellatus*	Yellowtail rockfish *Sebastes flavidus*
Cartilaginous Fishes		
Spiny dogfish *Squalus acanthias*		
Marine Mammals		
California sea lion *Zalophus califonianus*	Gray whale *Eschrichtius robustus*	Harbor porpoise *Phocoena phocoena*
Northern elephant seal *Mirounga angustirostris*	Pacific harbor seal *Phoca vitulina*	Steller sea lion *Eumetopias jubatus*
Invertebrates		
California mussel *Mytilus californianus*	Dungeness crab *Cancer magister*	Flat abalone *Haliotis walallensis*
Giant octopus *Octopus dofleini*	Ochre sea star *Pisaster ochraceus*	Purple sea urchin *Strongylocentrotus purpuratus*
Razor clam *Siliqua patula*	Red abalone *Haliotis rufescens*	Red sea urchin *Strongylocentrotus franciscanus*
Rock scallop *Hinnites giganteus*		

WATCH LIST SPECIES		
Bony Fishes		
Pacific sand lance *Ammodytes hexapterus*	Pacific sardine *Sardinops sagax*	
Cartilaginous Fishes		
Blue shark *Prionace glauca*	Common thresher *Alopias vulpinus*	Salmon shark *Lamna ditropis*
Shortfin mako shark *Isurus oxyrinchus*	White shark *Carcharodon carcharias*	
Invertebrates		
Market squid *Loligo opalescens*		

COMMONLY ASSOCIATED SPECIES		
Bony Fishes		
Jacksmelt *Atherinopsis californiensis*	**Longfin smelt** *Spirinchus thaleichthys*	**Night smelt** *Spirinchus starksi*
Snake prickleback *Lumpenus sagitta*	**Walleye surfperch** *Hyperprosopon argenteum*	**White surfperch** *Phanerodon furcatus*
Whitebait smelt *Allosmerus elongates*		
Cartilaginous Fishes		
Bat ray *Myliobatis californica*		

the species to colonize remote habitats. Tube building worms, including *Spiophanes bombyx*, modify the sediment making it suitable for later colonization and succession (Gallagher *et al*., 1983).

Magelona spp. typically burrows in fine sand at low water and in the shallow sublittoral. It does not produce a tube. *Magelona spp.* is adapted for life in highly unstable sediments, characterized by surf, strong currents, and sediment mobility.

Owenia fusiformis is a thin, cylindrical, segmented worm, up to 10 cm long, that lives in a tough, flexible tube buried in the sand with its anterior end just protruding from the surface. It is found buried in sand or muddy sand, at or below low water, on fairly sheltered beaches.

Spio filicornis is found in clean sand, from the low water mark into the shallow sublittoral. It inhabits a tube made of sediment grains and detritus stuck together with mucus. Tube-building worms, including *Spio filicornis*, modify the sediment, making it suitable for later colonization and succession (Gallagher et al. 1983).

Hippomedon denticulatus is a lysianassid amphipod. They are scavengers on muddy and sandy sediments in bays, the continental shelf, and the deep sea where they clean up the carcasses of dead fishes and invertebrates. This species of lysianassid amphipod is large (14 mm), shiny, and white, with a pair of fat antennae attached to the front of the head and a small hook on the last side-plate of the abdomen.

This is useful context when considering the response of the benthic infaunal community to physical disturbances.

3.5.4. Turtles

Turtles that can be found on the Oregon nearshore shelf, and could thus be affected by wave energy development, include the leatherback turtle (*Dermochelys coriacea*) and loggerhead turtle (*Caretta caretta*).

3.5.5. Seabirds

The Reedsport Wave Energy Project has recently reviewed seabird observations from the central Oregon coast. Dominant species in 1989 surveys are shown in Table 3-5 (FERC 2007); and timing of occurrence for common species offshore Douglas County is shown in Table 3-6.

3.5.6. Marine Mammals

The Reedsport Wave Energy Project provided a good summary table of marine mammals possibly found in the Reedsport vicinity (FERC 2007). This is presented as Table 3-7, and includes information on prior sightings, distribution and preferred habitat, and population status. Whale species found on the Oregon continental shelf include the gray whale (*Eschrichtius robustus*), humpback whale (*Megaptera novaeangliae*), blue whale (*Balaenoptera musculus*), fin whale (*B. physalis*), sei whale (*B. borealis*) and sperm whale (*Physeter macrocephalus*).

Gray Whales. Gray whales are of particular concern because the entire population of 18-20,000 animals in the eastern North Pacific transits the length of the Oregon coast twice a year (Herzing and Mate 1984). Mate and Harvey used VHF radio tags to track north-bound migrating whales during 1979 and 1980 from Mexico to Alaska (Mate and Harvey 1984). More recently, gray whales have been tagged in Mexico to estimate use of reproductive habitats (Mate et al. 2003) and tracked northward with satellite-monitored radio tags (Mate and Urban 2003; Mate et al., in prep.). These studies provide more locations and precision about distances from shore, water depths and speeds than previous research. Some gray whale mothers with calves were tracked up to 77^{o} N and 320 days. The tracks have established the first good estimates of home ranges for the entire summer feeding season as well as individual estimates characterizing the south-bound migration.

Sea Otters. Sea otters (*Enhydra lutris*) were extirpated in Oregon's nearshore waters by the end of the 19th Century (Lance et al. 2004). They are thought to be a keystone species in the California Current's kelp forest environments, mediating kelp grazing by controlling sea urchin populations (Lance et al. 2004). Although sea otter issues are not a focal point of this workshop, any predictions of wave energy development effects on the success of local individuals or possible future reintroductions would be of value to natural resource managers.

Table 3-5. Seabirds identified during the 1989 Oregon and Washington marine mammal and seabird survey (FERC 2007).

Common Name	Scientific Name	August 7, 1989	August 9, 1989	August 10, 1989	August 11, 1989	Bird Count
Albatros	*Phoebastria Spp.*		1	1		2
Brandt's Cormorant	*Phalacrocoraxs penicillatus*		1			1
California Gull	*Larus californicus*	12	29	39	3	83
Cassin's Auklet	*Ptychoramphus aleuticus*		12	12		24
Common Murre	*Uria aalge*	6	35	19		60
Common Tern	*Sterna hirundo*		1			1
Fork-tailed Storm-Petrel	*Oceanodroma furcata*	24	3	2		29
Glaucous-winged Gull	*Larus glaucescens*			1		1
Northern Fulmar	*Fulmarus glacialis*	1	45	8		54
Pomarine Jaeger	*Stercorarius pomarinus*		3	4		7
Red Phalarope	*Phalaropus fulicaria*	1	3	8		12
Red-necked Phalarope	*Phalaropus lobatus*		4	34		38
Ring-billed Gull	*Larus delawarensis*			1		1
Sooty Shearwater	*Puffinus griseus*	16	377	45	19	457
Tufted Puffin	*Fratercula cirrhata*		1			1
Western Gull	*Larus occidentalis*	6	21	30	6	63
	Daily Survey Count	**66**	**536**	**204**	**28**	**834**

Table 3-6. Expected abundance and timing of select seabird species found along the Oregon coast of Douglas County (FERC 2007).

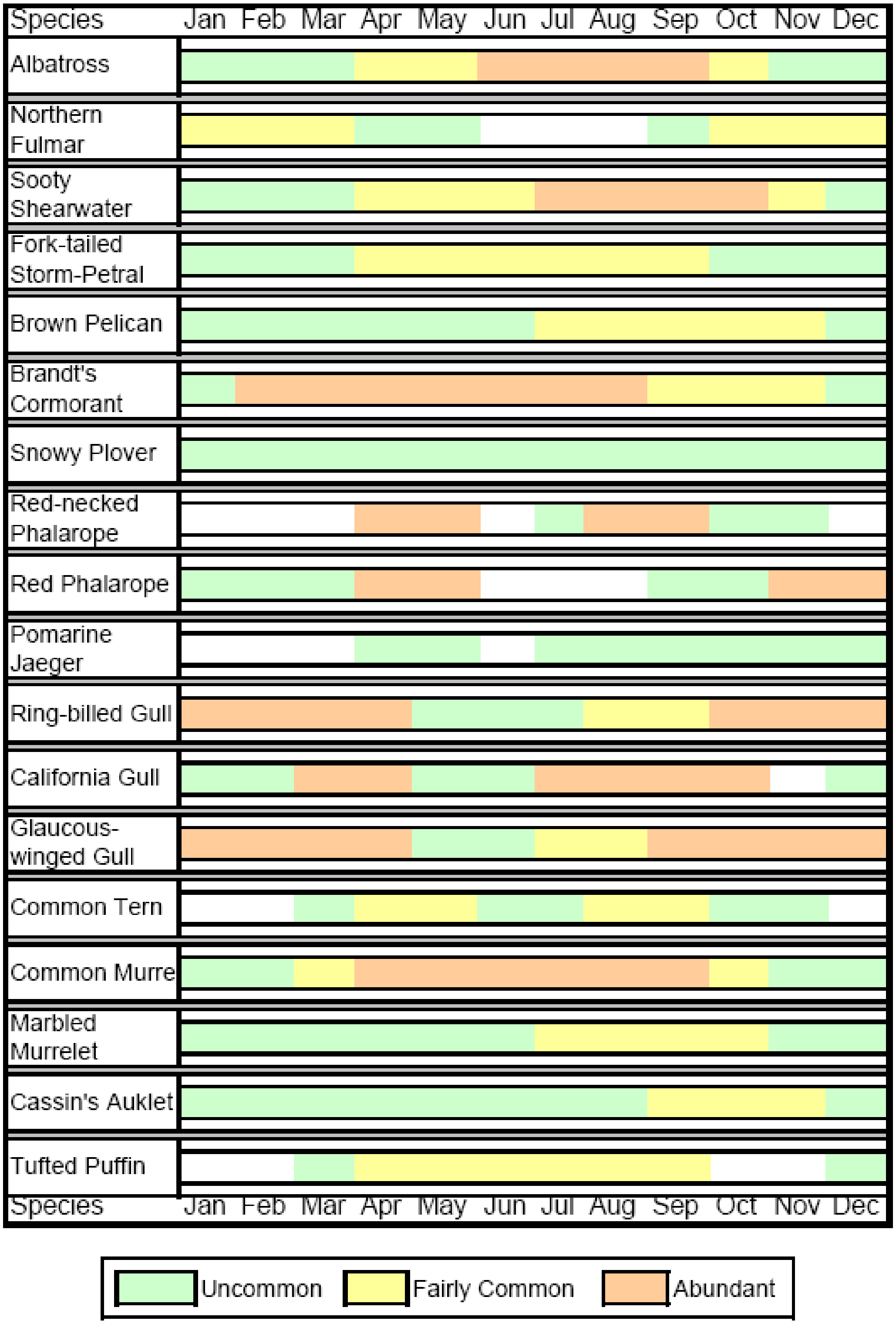


Table adapted from Contreras 1998.

Table 3-7 Summary of potential marine mammals in the Reedsport project area from NOAA stock assessment reports (FERC 2007).

Common Name	Scientific Name	Sightings Proximal to Project Area	Distribution and Habitat	Population Status
Minke Whale	*Balaenoptera acutorostrata*	Few sightings located over continental shelf.	Migratory movement along Oregon's continental shelf.	No direct population estimates are available. Population not considered threatened and is not a strategic stock.
Gray Whale	*Eschrichtius robustus*	Predictable seasonal migration occurs along the West Coast in relatively nearshore habitat	Eastern population migrates seasonally along the West Coast. Northbound migration generally in nearshore habitat, while southern migration further offshore.	Species was delisted in 1994 and is making a marked recovery. Population is currently over 20,000 individuals and showing positive growth.
Bottlenose dolphin	*Tursiops truncatus*	Prefer warm water and distant offshore locations.	Located primarily in warm waters of southern California. Rarely venture into Oregon and found in distant offshore areas.	No direct population estimates are available, but population considered in good health.
Common dolphin (short beaked)	*Delphinus delphis*	Few sightings in southern Oregon.	Primarily found in California coast. Few sightings in southern Oregon. Can be found from nearshore up to 300 nm (nautical miles) offshore.	The common dolphin represents the most abundant cetacean off of California and its population status is in excellent condition.
Striped dolphin	*Stenella coeruleoalba*	No sightings in Oregon.	Located within 100-300 nm from coastline in California. Prefer warm water and distant offshore locations.	Potential increase in population. Population not considered threatened and is not a strategic stock.
Northern right whale dolphin	*Lissodelphis borealis*	Seasonally migrate through Oregon in late spring and summer.	Found in shelf and slope waters in California Oregon and Washington. Undergoes seasonal migrations along the coastline.	While moderate risk of unnatural mortality exists, insufficient data is available to indicate low abundance or negative population trends.
Pacific white sided dolphin	*Lagenorhynchus obliquidens*	Seasonally migrate through Oregon in late spring and summer.	Found in shelf and slope waters in California Oregon and Washington. Concentrated in California. Undergoes seasonal migrations along the coastline.	Population trend appears stable and unchanged. Population not considered threatened and is not a strategic stock.
Risso dolphin	*Grampus griseus*	Seasonally migrate through Oregon in late spring and summer.	Found in shelf and slope waters in California Oregon and Washington. Undergoes seasonal migrations along the coastline.	Population trend appears stable and unchanged. Population not considered threatened and is not a strategic stock.

Table 3–7(continued). Summary of potential marine mammals in the Reedsport project area from NOAA stock assessment reports (FERC 2007).

Common Name	Scientific Name	Sightings Proximal to Project Area	Distribution and Habitat	Population Status
Dall's porpoise	*Phocoenoides dalli*	Commonly seen and make interannual north and south movements.	Located in near and offshore waters within shelf and slope habitat. Movement along coastline determined by seasonality and interannual time scales.	Assessment of population trends are not available, but no direct threat to the population was identified and is considered a non-critical stock.
Harbor or common porpoise	*Phocoena phocoena*	Sighted year-around in nearshore transboundary waters. Frequent use of project vicinity was not identified	Located in nearshore habitat during most of year, but can shift to deeper offshore waters during winter months. Population concentrations driven by primarily by prey availability.	Population is not considered "strategic" due to low annual unnatural mortality. Numbers are not listed as depleted. Overall population trends are not known.
Baird's beaked whale	*Berardius bairdii*	Few sightings in deep waters along continental slope.	Found primarily near Japan with only a few offshore deepwater sightings occurring in Oregon. Most sightings occur from late spring and early fall. Offshore movements occur from November to late April.	Due to rarity, population trend assessment is not available. Population not considered threatened and is not a strategic stock.
Mesoplodont beaked whale	*Mesoplodon spp.*	Only five sightings along entire U.S. west coast.	Found in deepwater habitats near the continental shelf.	Due to rarity, population trend assessment is not available. Population not considered threatened and is not a strategic stock.
Curviers beaked whale	*Ziphius cavirostris*	Few sightings in deep waters along continental slope.	Found in deepwater habitats near the continental shelf.	Due to rarity, population trend assessment is not available. Population not considered threatened and is not a strategic stock.
Pygmy sperm whale	*Kogia braviceps*	Few sightings in distant offshore pelagic waters.	Species remains submerged in distant offshore pelagic waters for long periods of time. Small size make species cryptic and poorly understood.	Due to rarity, population trend assessment is not available. Population not considered threatened and is not a strategic stock.
Harbor seal	*Phoca vitulina richarii*	Common residents in nearshore waters year-around.	Individuals are local non-migratory residents that occupy rocks, reefs, and beaches. Local movements are driven by season, pupping and prey location.	Large population numbers appear to have exceeded equilibrium and may now be balancing.
Pilot whale (short finned)	*Globicephala macrorhynchus*	Few sightings in offshore waters	Primarily found in southern California coast. Possible migrants sighted in Oregon were in offshore waters.	Population appears healthy, although no trend analyses are available.

Source: NOAA 2007e.

4.0. Environmental Effects

4.1. Conceptual Approach

A generic framework for ecological risk assessment was developed by the US Environmental Protection Agency during the early 1990s (USEPA 1998). This approach provides a simple conceptual model of ecological risk that is valuable in the context of developing a systematic view of possible ecological effects. For purposes of this workshop, a “conceptual model” is defined as an ecosystems-based diagram that illustrates integrated physical and biological relationships for understanding the potential ecological effects on the ecosystem off the Oregon coast. The conceptual model also helps to clarify risks and uncertainties, guide the analysis of effects, and could provide a framework for an adaptive management program.

The needed terminology for this model requires defining stressors and receptors: *stressors* are agents of change in the environment; and *receptors* are characteristics of the environment (generally ecological entities) in which change from stressors can result and, hopefully, be measured. The terms stressor and agent are synonymous in the parlance of ecological risk assessment.

The assessment of ecological risk additionally requires the characterization of two complementary components of the risk in the model. First, e*xposure* is defined as “the contact or co-occurrence of a stressor with a receptor” (USEPA 1998). Hence, a very important part of ecological risk assessment is the analysis that leads to estimates of exposure for key species or assemblages or habitats. Second, the “characterization of *ecological effects* describes the ability of a stressor(s) to cause adverse effects under a particular set of circumstances” (USEPA 1998). An ecological effect may be as simple as a basic toxicological dose-response curve, or as complicated as the modification of a complex behavioral repertoire. An estimate of ecological risk accordingly requires estimates of the magnitudes of both the exposure and the effects. The focus of this briefing paper, and the related workshop exercise, is principally to assess the magnitude of the exposure of the receptors to the stressors. In some cases it may be appropriate to begin to assess the magnitude of the effects.

In order to be comprehensive, many environmental analyses utilize one or a set of impact matrices. Such a matrix is employed by the European Marine Energy Centre (EMEC 2005), the European Union’s research and development center for alternative energy development, to summarize the possible effects of wave energy devices deployed at the center. Table 4-1 is a wave energy development summary impact matrix modified from the EMEC model. The columns correspond to groups of receptors, whereas the rows correspond to groups of stressors. It may be helpful to differentiate between the exposure and effects factors for each box in the matrix, however specific. Table 4-2 shows a hypothetical summary matrix for the operations stressors that could be used to communicate information about level of concern, possible mitigation effectiveness, and level of confidence.

The summary matrix lumps stressors and receptors, but in practice, it may be expanded to the level specific to the risk analysis. For example, the mooring lines, not the anchors or subsurface floats, may be the Mooring System stressor of concern for whale entanglement. However,

Table 4-1. Summary impact matrix for wave energy development on the Oregon continental shelf.

Activity (agent or stressor)	Receptors												
	Ocean Waves	Ocean Currents	Sediments	Plankton	Fouling Community	Migratory Fish	Forage Fish and Invertebrates	Demersal Fish	Epibenthic Macroinvertebrates	Benthic Infauna	Seabirds	Pinnipeds	Cetaceans
Emplacement													
Mooring System													
Electrical Transmission Infrastructure													
Operation													
Mooring System													
Buoy or Other Generation Device													
Electrical Transmission Infrastructure													
Chemical Coatings													
Decommissioning													
Buoy or Device Removal													
Transmission Infrastructure Removal													
Anchor Removal or Decommissioning													

Table 4-2. Portion of hypothetical summary impact matrix for project operations with annotations for level of concern (**colors:** green – of minor concern; yellow – of moderate concern; orange – of major concern), level of confidence (**?**), and possible mitigation effectiveness (**m**). Indications in the boxes are only for presentation purposes.

Activity (stressor)	Receptor												
	A. Ocean Waves	B. Ocean Currents	C. Sediments and Benthic Habitats	D. Plankton	E. Fouling Community	F. Pelagic Fish and Invertebrates	G. Forage Fish and Invertebrates	H. Demersal Fish	I. Epibenthic Macroinvertebrates	J. Benthic Infauna	K. Seabirds	L. Pinnipeds	M. Cetaceans
4. Mooring System	(green)	(green)	(yellow)	(green)	(yellow)	? (green)	? (green)	? (yellow)	? (green)	? (green)	m (yellow)	m (yellow)	?m (orange)
5. Buoy or Other Generation Device	? (yellow)	? (yellow)	(yellow)	? (green)	? (yellow)	m (orange)	m (yellow)	(yellow)	(green)	(green)	m (yellow)	m (orange)	?m (orange)
6. Electrical Transmission Infrastructure	(green)	(green)	(yellow)	? (green)	(yellow)	m (green)	m (green)	m (orange)	(green)	(green)	(green)	(green)	(green)
7. Chemical Coatings	(green)	(green)	(green)	? (yellow)	? (yellow)	(green)	(green)	(green)	(green)	(green)	(yellow)	(green)	(green)
8. Acoustic Guidance System	(green)	(green)	(green)	(green)	(green)	(green)	(green)	(green)	(green)	(green)	? (green)	? (orange)	? (orange)

Table 4-3. Hypothetical summary impact matrix for a specific set of stressors, in this case, acoustics.

Activity (agent or stressor)	Receptors												
	Ocean Waves	Ocean Currents	Benthic Habitats	Plankton	Fouling Community	Pelagic Fish	Forage Fish and Invertebrates	Demersal Fish	Epibenthic Macroinvertebrates	Benthic Infauna	Seabirds	Pinnipeds	Cetaceans
Acoustic Frequency Signatures													
Point Absorber													
Attenuator													
Oscillating Water Column													
Overtopping													
Mild Weather Acoustics (Quiet Days)[1]													
Heavy Weather Acoustics (Loud Days)[1]													
Important Frequencies for Key Biota													
Acoustic Guidance Systems													
Echo Effects?													
Amplitude Effects (Overpressure)													
Service Boats and Equipment													

different species of whales (e.g., baleen whales or toothed whales) may have different levels of exposure or different responses to the stressor, whereas the summary matrix includes only a column for cetaceans. The matrix may be expanded to the level necessary at the appropriate level of the assessment (the present level is regional). Table 4-3 shows a matrix that addresses the acoustics stressor at a more specific level that may be useful in considering specific stressors or receptors.

Finally, it may be helpful to use a small, submatrix to structure the discussion. Table 4-4 shows a sub-matrix that includes estimates of exposure and response to a given stressor, potential effectiveness of mitigation, residual effect – that is, effect after any mitigation. Levels of confidence may be estimated as low, medium or high for each row; this would ultimately affect the prioritization of effects and a gap analysis. Stochastic components might take part in predictions of both exposure (e.g., proportion of a whale population actually encountering a stressor wave energy buoy) and response (e.g., proportion of a population seriously injured by a collision). Level of confidence is meant to include level of uncertainty (measured or not) and level of scientific agreement. Ideally, such a submatrix might underpin each call made in an overall effects matrix.

Table 4-4. Submatrix for discussion and evaluation of specific matrix intersection points.

Category/Rank	Low	Medium	High	Level of confidence
Potential for Exposure to Stressor				
Potential for Response to Stressor				
Potential Effectiveness of Mitigation				
Residual Environmental Effect				

4.2. Reasonably Likely and Foreseeable Effects

Reasonably likely and foreseeable effects may be considered as a product of exposure and response in a four-way contingency table. Where both exposure and response are minor or of low likelihood, the issue may well be scoped out of the analysis. Where either the level of exposure or the response is of great cause for concern, the issue will not likely be scoped out of the analysis. Ultimately, the intent is to give a sense of priority for the meaningful allocation of limited resources to the right issues.

4.3. Emplacement/Deployment Effects

Deployment of wave energy devices will include service boat and barge use, and their attendant risks, and considerable bottom disturbance during deployment of bottom structures, including the anchoring systems or mooring and the transmission systems. This bottom disturbance will impact the infauna and the epifauna that are not motile enough to leave the area.

4.4. Operational Stressor Signals

The operational stressors are considered in turn below, and high points of the findings of the significant reviews or syntheses are very briefly reported. The key references for this section are Scottish Executive's Strategic Environmental Assessment (Faber Maunsell and METOC PLC 2007), with two supporting documents on vertebrate collisions (Wilson, et al. 2007) and acoustics (Richards, et al. 2007); the Environmental Assessment for the Makah Bay (WA) project (FERC 2006); the preliminary application for the Reedsport (OR) project (FERC 2007; the Minerals Management Service's (MMS) worldwide assessment (Michel et al. 2007); MMS' programmatic draft EIS for alternative energy (MMS 2007); a technical review in support of the Kaneohe Bay (HI) project (Sound Sea Technology 2002); and a memorandum on electromagnetic field in support of the Cape Wind (MA) wind energy project (Valberg 2005). All of the above references are included on the enclosed CD.

In applying the evolving literature on alternative energy effects in coastal seas, particularly the work coming from Europe (e.g., Faber-Maunsell and METOC PLC 2007), a focal consideration is the effect of the array. Buoy or device effects may be considered individually, but the effect of a full commercial array, up to three miles long and comprised of hundreds of buoys or other devices, may create more than an additive risk for a given stressor. Long, linear arrays may, in fact, act as barriers to certain groups of biota, depending on the signature of concern, for example, sound. The distance of the devices from one another (e.g., 100 m at Reedsport) will also be a major factor in array effects. Moreover, the effects of the array need to be considered in the context and scale of the ecosystem component, whether it is the littoral cell, or sub-cell, in the physical process, or the life history context of migratory species such as whales, seabirds or anadromous fish. Mitigation is intended in the following section to mean minimization or avoidance of effects, not to mean ecological or monetary compensation. Mitigation may be very effective in some cases, especially through siting decisions that take into account the physical or ecological process context.

4.4.1. Physical Signatures on Wave Energy, Currents and Sediment Transport

Issue. Wave energy devices will necessarily remove some energy from the wave train, and thus, the littoral system. Resultant effects may include alterations in currents and sediment transport.

Findings. *Makah Bay*: The environmental assessment for Makah Bay concluded that there would be a negligible effect on littoral transport from a single buoy and that the deployment depth (150 ft) was well below the so-called wave *closure depth* of about 56 ft (2.28 times the maximum 12 hour wave height) such that changes in bathymetry would not be expected (FERC 2006). *Programmatic Draft EIS*: MMS' PDEIS for alternative energy estimated that a wave energy facility could reduce wave height by 10 to15% with maximum effect within 2 km inshore, and could result in an interruption of littoral drift depending on placement in the littoral cell. Structural drag on currents is not expected to be a significant component (MMS 2007). *Worldwide Assessment*: This assessment found that wave energy reduction has been estimated at between 3 and 13% at the shoreline and recognized that the effect on waves, currents and sediment transport will be technology- and location-specific, hence, underscoring the importance of appropriate siting (Michel et al. 2007). *Reedsport Project*: The Preliminary Application Document (PAD) cites cumulative wave strength attenuation of up to 12 to 15% for an array of 14 buoys. Modeling predicted a maximum instantaneous attenuation of wave amplitude of 2.1%, and OPT concludes that the project will have an immeasurable effect on erosion/accretion at the shoreline (FERC 2007). *Scottish Executive*: The Strategic Environmental Analysis found that, with realistic calculations, a maximum of 10% of the energy and 5% of the wave height arriving at the shoreline might be absorbed by a wave energy array 3 km long. The report concluded there would be only minor effects, but with low confidence, and recommended appropriate analysis and siting within local littoral cells (Faber Maunsell and METOC PLC 2007).

Mitigation. Some mitigation of the physical effects of energy absorption may be achieved by appropriate siting and choice of appropriate technologies.

4.4.2. Hard Surfaces: Buoys and Anchoring Systems – Collision, Entanglement and/or Entrapment

Issue: The deployment of structures in a previously clear area brings the risk of collision and/or entanglement of animals; primarily the larger fish, the seabirds and the marine mammals.

Findings. *Kaneohe Bay*: The risk of cetacean entanglement was considered minimal for this project because the four buoys were attached to the seafloor instead of being anchored by buoys with lines, and the cable was intended to run along the seafloor. Entrapment risk was minimized by buoy design, and collision risk was not assessed (Sea Sound Technology 2002). *Makah Bay*: The Environmental Assessment concluded that risk of cetacean entanglement was minimal because the exposure of a single buoy was low, and the anchor lines would have sufficient tension to avoid the entanglement characteristically seen with smaller and lighter tensions (FERC 2006). *Programmatic Draft EIS*: The MMS PDEIS for alternative energy (MMS 2007) states that wave energy facilities may have as many as 2,500 mooring lines securing the wave energy devices to the ocean floor. Thus, marine mammals swimming through a wave energy facility may strike and become entangled in these lines, becoming injured or drowning. Depending on the species affected, entanglement may result in minor to major impacts to marine mammals. *Worldwide Assessment*: This assessment found it likely that migrating gray whales would interact with wave energy devices on the US West Coast and that entanglement in mooring cables could cause an impact. It also found that seabird exposure would likely increase due to attraction to fish responding to the Fish Attraction (or Aggregation) Devices (FAD) (see below) effect (Michel et al. 2007). *Reedsport Project*: This document addresses the possible collision or entanglement of cetaceans by recommending mitigation via acoustic "guidance" devices. Seabirds are not expected to have significant collision risk because all structures will be large enough to be visible. The document also states that design characteristics of the buoys themselves will prevent hauling-out by pinnipeds (FERC 2007). *Scottish Executive*: This report dealt with vertebrate collision risk in some detail, citing many conclusions of a supporting study by the Scottish Association for Marine Science that made clear the complexity of vertebrate behavioral responses (Wilson, et al. 2007). The strategic environmental assessment concluded that risk of collision for marine mammals and seabirds was very uncertain and that the conclusion was made with very low confidence (Faber Maunsell and METOC PLC 2007).

Mitigation. Mitigation for collision and entanglement can include visual cues, such as highly visible paints and acoustic "guidance" to cause animals to perceive the structures or avoid them. Entanglement may also be avoided by using thick, high-tension mooring lines. Entrapment mitigation may be achieved both by visual or acoustic avoidance, but more likely by appropriate device design considerations.

4.4.3. Hard Surfaces: Buoys and Anchoring Systems – Trophic Effects

Issue: Wave energy arrays will provide a matrix of hard structures in areas previously devoid of any hard structure: this will include buoys at the surface and through much of the water column, subsea pods (see fig. 2.4), and anchors on sedimented substrates. This will likely have ecological consequences from the fouling community up through the highest levels of trophic structure.

Findings. *Makah Bay*: The Environmental Assessment concluded that there would be no effect of the four buoys on rockfish, surf smelt or other marine fish. It further concluded that: "Instead, project construction may result in a net gain for fish and other marine life that will benefit from the protection from fishing……and potential development of small artificial reef areas along the transmission cable" (FERC 2006). *Programmatic Draft EIS* (MMS 2007): The MMS PDEIS states that placement of structures, such as pilings on the OCS, would introduce an artificial hard substrate that opportunistic benthic species that prefer such substrate could colonize, and minor changes in species associated with softer sediments could occur due to scouring around the pilings. Fishes, including pelagic species, would likely be attracted to these artificial habitats, and fish population numbers in the immediate vicinity of the platforms are likely to be higher than in surrounding waters away from the structures. The overall change in habitat could result in changes in local community assemblage and diversity. Although the anchors or pilings needed to install an individual wave energy unit would represent only a small amount of artificial habitat that would likely have little effect on overall fish populations, there is a possibility that major projects that cover large areas could result in substantial changes in the abundance and diversity of particular fish species within the area. Effects on diversity and fish abundance would be project-specific since they would be largely dependent on the prevalence of various types of habitats and fish species within surrounding areas. *Worldwide Assessment*: This assessment concludes that wave energy device arrays will function as Fish Attraction (or Aggregation) Devices (FADs), and that the ultimate community of resident fish will change to an assemblage with more place-based affinity (Michel et al. 2007). *Reedsport Project*: This document recognizes the potential for the anchoring system to act as hard substrate for the fouling community, and consequent potential for changes in the other resident biota, especially fish species. The fouling community is also expected to colonize the mooring lines, which will need periodic maintenance for removal (FERC 2007). *Scottish Executive*: The report on collision risks detailed the effect of arrays as FADs, and concluded that this effect might attract birds and marine mammals as well as fish (Wilson, et al. 2007).

Mitigation. The mitigation potential for trophic changes due to hard surfaces and structure is not known at this time.

4.4.4. Chemicals: Coatings, Metals and Organics

Issue: Wave energy devices will create the potential for chemical effects from a variety of sources, including toxins in antifouling paints, metals including lead and zinc, and organics, such as those used for hydraulic fluids.

Findings. *Makah Bay*: The environmental assessment noted that the Aquabuoy® uses seawater as its hydraulic fluid, and the project applicant agreed to “try different brands of antifouling paints to identify those that work best.” (FERC 2006). *Programmatic Draft EIS* (MMS 2007) The PDEIS for alternative energy stated that copper- or tin-containing compounds could be used to control fouling, but that tin would remain effective for longer, but no attempt was made to assess the environmental impact. Hydraulic spills are also a risk (MMS 2007). *Worldwide Assessment*: This assessment recognized the importance of non-impacting antifouling coatings, noting that the US has banned domestic use of tri-butyl tin (TBT) products and is working to have their use banned worldwide (Michel et al. 2007). *Reedsport Project*: This document addresses the issue of hydraulic leaks by stating that no device will contain more than 400 gallons of vegetable-based, biodegradable hydraulic fluid (FERC 2007). Other sources of toxicity are not discussed.

Mitigation. Partial mitigation for hydraulic spills is achieved through the use of vegetable-based, rather than petroleum-based, hydraulic fluids. New, less toxic antifouling chemicals are continuously being tested in an effort to find less toxic and more specifically targeted agents.

4.4.5. Electromagnetic Fields

Issue: Wave energy devices will necessarily generate electrical (E fields) and magnetic (B fields) fields (EMF) as they produce and transmit electrical currents. At issue is the sensitivity of particular groups of the biota, especially the potential responses of elasmobranchs (attraction, repulsion, or other behavioral taxis), and the effectiveness of mitigation, primarily through shielding.

Findings. *Cape Wind*: The Cape wind study concludes that trenching and shielding would effectively prevent any effects to the biota (Valberg 2005), but this report considered only the cabling. *Kaneohe Bay*: This report found that effects of electrical fields could be minimized by shielding, as shown by studies on existing cables (e.g., New Zealand). It also found that elasmobranchs, sea turtles and cetaceans might sense the magnetic field surrounding the cabling from the project, but any effects were uncertain (Sea Sound Technology 2002). This study did not consider the EMF effects of the buoys themselves. *Makah Bay*: The Makah Bay

Environmental Assessment concluded that EMF effects would be "minor and temporary ranging from no impact to avoidance for organisms inhabiting the seafloor near the cable" on the basis of the Kanehoe Bay findings, the amount of power passing through the cable, and the fact that the signal would be DC, thereby creating less of an EMF than AC (FERC 2006). No analysis was made of the EMF signature or effects of the buoy itself. *Programmatic Draft EIS*: The PDEIS for alternative energy found that EMF effects from a submarine power cable would be negligible, but underscored the lack of information on effects (MMS 2007). Again, no analysis was made of the EMF signature or effects of the buoys themselves. *Worldwide Assessment*: This assessment notes that Pacific salmon may be affected by magnetic fields and also that there is substantial uncertainty about the response of marine mammals to EMF (Michel et al. 2007). *Reedsport Project*: The Preliminary Application Document for the Reedsport project includes a good review of the literature also cited here. It states that the electricity generated by the buoys will be at 1/12 to 1/8 Hertz, presumably corresponding to an 8 to 12 second period reciprocation time. (This is well below the 7-8 Hertz lower limit above which sharks and rays apparently cannot perceive AC.) The current will be rectified at the subsea pod to 60 Hertz. The report states categorically that the electrical field around the buoys and the subsea pods will be completely eliminated by the Faraday cage effect of the surrounding steel structures. Any EMF impacts to migrating salmon are expected to be minimal due to this group's brief period of exposure. Magnetic fields around the transmission cables are expected to be minimal (FERC 2007). *Scottish Executive*: The strategic environmental assessment concludes that DC and low frequency AC electrical fields are of concern, mainly for elasmobranches. The report noted that wave energy "devices themselves will also have an electrical signature, however this will be specific to the individual devices" and that this is an unknown at the present time (Faber Maunsell and METOC PLC 2007).

Mitigation. Armoring and trenching are claimed to be effective EMF mitigation for submarine cables. The use of so-called Faraday cages to eliminate EMF fields around wave energy devices or subsea pods has a basis in theory, but has not to date been demonstrated in practice.

4.4.6. Acoustics

Issue: Wave energy devices will have acoustic signatures, from the impingement of waves on above-water structures to generators and switching systems. Fish and seabirds are sensitive to sounds and many marine mammals are dependent on sound for life processes from feeding to mating. Acoustic guidance systems themselves may also have ecological effects other than those intended.

Findings. *Kaneohe Bay*: This report treats acoustics in some detail and provides a good review of the sensitivity of the biota in the area. The report concludes that only humpback whales, two species of dolphins and green sea turtles could be affected, and that there is no evidence that the frequency or amplitude of the sound from the four buoys would cause harm to these species (Sea Sound Technology 2002). *Makah Bay*: The Environmental Assessment claimed that there would be no adverse effect on whales due to the relative strengths of the device versus ambient (ocean) noise and the fact that the devices would be well below 145 dB; this finding was also applicable to fish (FERC 2006). *Programmatic Draft EIS*: (MMS 2007). This review indicates that although underwater noise would be produced by the hydraulic machinery associated with wave energy generation devices, it is currently unclear what the sound levels would be. Noise and vibrations associated with the operation of the generation units would be transmitted into the water column and, depending on the anchoring system used, the sediment. Depending on the intensity, such noises could potentially disturb or displace some marine mammals and fish within surrounding areas or could mask sounds used by these animals for communicating and/or detecting prey. *Worldwide Assessment*: This assessment cited Hagerman and Bedard (2004) in finding that expected wave generation device noises would be "light" as compared to transportation noises (Michel et al. 2007). (The two prior reports considered amplitude but not frequency in their evaluations.) *Reedsport Project*: This document acknowledges the potential use of acoustic guidance devices to mitigate the potential for collision and entanglement of cetaceans; the overall effect of either passive (the buoys' own sounds) or active (use of sound generating devices) sound to cause whales to avoid the buoy array is not yet known (FERC 2007). *Scottish Executive*: The strategic assessment was supported by a detailed study that concluded major overpressures (loudness) leading to temporary or permanent hearing loss were not a major risk during operations, even within square arrays, but rather that arrays could act as physical barriers due to the responses of fields of sound. This report recommended appropriate studies of acoustic signatures of devices and of site-specific ambient sound in a wide array of conditions (Richards et al. 2007).

Mitigation. Known mitigation for operational noises is limited to design factors, and appropriate siting.

4.4.7. Lighting Effects

Issue: The lighting required by the US Coast Guard to address safety considerations may attract biota, especially seabirds, to the generation devices.

Findings: *Reedsport Project*: This document reports that a 14-buoy array will have "at least four to eight lights", and concludes that lighting may lessen the potential for night-time seabird collisions (FERC 2007).

Mitigation: Mitigation may be limited to the minimum use of nighttime lighting to achieve safety goals.

4.4.8. Cumulative Effects

The National Environmental Policy Act (NEPA) defines cumulative impact as: "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

For purposes of this workshop, the consideration of cumulative operational wave energy effects should include the summary effects of all of the stressors and receptors in the system. Cumulative effects also go beyond the effects of a single wave energy array to assess the effects of multiple arrays. Ultimately, three key questions may be appropriate for consideration of cumulative effects in a given oceanographic region like the Pacific Northwest:

1. How large can a single array of devices get before effects begin to accumulate?
2. How many arrays can be deployed in a region before effects begin to accumulate?
3. Over what time-frame is/are the effect(s) going to occur?

One breakout session at the workshop will be tasked with a systems view of cumulative impacts.

4.5. Maintenance Effects

Wave energy devices will require routine maintenance. Low level maintenance will likely involve the use of service boats to perform maintenance activities *in situ*. Higher level maintenance or overhaul will likely require transport of devices by service boat to port where the work will take place. Effects would include those associated with operation of the vessel class of the service boats.

4.6. Accident Effects

System survivability is an issue with this new technology; and the effects analysis should include some consideration of the effects of wave energy devices coming loose from their moorings. Maintenance may also be required in inclement conditions, thereby increasing the probability of accidents. A potential accidental effect is the loss of electrical insulating oil (mineral oil) which is housed with the transformers located in the subsea pods.

4.7. Decommissioning Effects

Decommissioning of wave energy parks will include the use of service boats and/or barges to remove all deployed equipment, devices, anchoring systems and transmission systems from the site. Removal of very large anchors may require jetting and could possibly cause more bottom disturbance than deployment. Balancing of decommissioning cost and benefits will also involve consideration of any artificial reef benefits from structures such as anchors.

4.8. Policy Linkages for Effects Analysis

One area in which natural resource management policy impacts the scientific discussion is the existence lists of Federal and state Threatened and Endangered species under the Endangered Species Act (ESA). A preliminary list of ESA species possibly affected by wave energy development on the Oregon shelf is shown in Table 4-5 below. The workshop participants will be asked to give some sense of priority to these resources, which are already at risk.

Table 4-5. Federal and state listed species found in the Oregon nearshore ocean.

Common Name	Scientific Name	Lister	Status
Fish			
Snake River Chinook Salmon (spring/summer)	*Onchorhynchus tshawaytscha*	F	T
Snake River Chinook Salmon (fall)	*Onchorhynchus tshawaytscha*	F	T
Upper Willamette River Chinook Salmon	*Onchorhynchus tshawaytscha*	F	E
Oregon Coast Coho Salmon	*Onchorhynchus kisutch*	F	T*
Lower Columbia River Coho Salmon	*Onchorhynchus kisutch*	F	E
Columbia River Chum Salmon	*Onchorhynchus keta*	F	T
Upper Willamette River Steelhead	*Onchorhynchus mykiss irideus*	F	T
Lower Columbia River Steelhead	*Onchorhynchus mykiss irideu*	F	T
Upper Columbia River Steelhead	*Onchorhynchus mykiss gairdneri*	F	T
Snake River Steelhead	*Onchorhynchus mykiss gairdneri*	F	T
Snake River Sockeye Salmon	*Onchorhynchus nerka*	F	E
Reptiles			
Green Sea Turtle	*Chelonia mydas*	F	E
Leatherback Turtle	*Dermochelys coriacea*	F	E
Loggerhead Sea Turtle	*Caretta caretta*	F	T
Pacific Ridley Sea Turtle	*Lepidochelys olivacea*	F	T
Birds			
Short-tailed Albatross	*Diomedea albatrus*	F	E
Brown Pelican	*Pelecanus occidentalis*	F	E
Western Snowy Plover	*Charadrius alexandrinus nivosus*	F	T
California Least Tern	*Sterna antillarum browni*	F	E
Marbled Murrelet	*Brachyramphus marmoratus*	F	T
Mammals			
Sei Whale	*Balaenoptera borealis*	F	E
Blue Whale	*Balaenoptera musculus*	F	E
Fin Whale	*Balaenoptera physalus*	F	E
Gray Whale	*Eschrichtius robustus*	S	E
North Pacific Right Whale	*Eubalaena japonica*	F	E

Humpback Whale	*Megaptera novaeangliae*	F	E
Sperm Whale	*Physeter macrocephalus*	F	E
Northern (Steller) Sea Lion	*Eumetopias jubatus*	F	T

Key: **Lister –** S = State; F = Federal. **Status –** T = Threatened; E = Endangered; * = In litigation.

5.0. Workshop Process and Breakouts

5.1. Explanation of Workshop Process

The intent of this workshop is to meet the earlier stated goals by maximizing the time that the workshop participants have to discuss key questions and maximizing the data capture from those discussions. The goals are: 1) develop an initial assessment of the potential impacting agents and ecological effects of wave energy development in Oregon's coastal ocean; and 2) develop a general conceptual framework that can be applied to assess both specific wave energy projects and cumulative effects of multiple projects. Again, the resulting publication will address, from the view of the participants: what we know; what we don't know, including key information gaps; level of uncertainty, level of agreement; a sense of priority of environmental issues; an assessment of the utility of the conceptual approach; recommended mitigation measures; and any recommended studies and monitoring parameters.

The workshop steering committee has designed the workshop in four phases. The first morning will be a plenary session with presentations that provide a common understanding of wave energy technology and ecological issues involved. The afternoon will consist of receptor-structured breakout groups, and the second morning will consist of stressor-structured breakout groups and a summary session. The breakout groups will generate written summaries that will be published in a proceedings volume.

5.2. Breakout Groups and Key Questions

There will be six receptor-based breakouts the first afternoon as follows:

1. Physical Environment (waves, currents, sediment)
2. Pelagic Habitat
3. Benthic Habitat
4. Fish & Fisheries
5. Seabirds
6. Marine Mammals

As a guide for discussion, we provide the following questions for the receptor-based groups:

1. Can exposure factors for the ___ receptor and/or key subgroups or species be estimated or ranked?
2. Can a vulnerability (effects) factor for the ___ receptor be estimated or ranked?
3. What is/are the key stressors of interest for the ___ receptor?
4. What are the key information gaps for exposure and effects for the ___ receptor?
5. What are the appropriate monitoring parameters for the ___ receptor?

There will be six stressor-based breakouts the second morning:

1. Energy Absorbing Structures
2. Chemical Effects (antifouling coatings [e.g., Cu++], hydraulic fluids, other toxic chemicals)

3. New Hard Structures and Lighting
4. Acoustics
5. Electromagnetic Field Effects
6. Systems View/Cumulative Effects

As a guide for discussion, we provide the following questions for the stressor-based groups::

1. What is the status of knowledge of the __ stressor and the implementation of its direct and indirect effects?
2. What are the key information gaps and uncertainties about the __ stressor or its effects?
3. What are the key/vulnerable receptors for the __ stressor?
4. What are the appropriate monitoring parameters and possible management triggers for the ___ stressor?
5. What are the known mitigation strategies for the ___ stressor and their possible effectiveness? What are new mitigation strategies?
6. (For breakout #6, the above questions should be integrated across the stressors stressor processes and receptors; culminating in the specific question: Are there any system vulnerabilities not apparent in the stressor- or receptor-specific analyses?

6.0. Bibliography and References Cited

(The **Bold print** below indicates that the reference is provided on the accompanying CD)

AquaEnergy Group, Ltd. 2006. "AquaBuOY Wave Energy Converter." Available at www.aquaenergygroup.com.

Archimedes Wave Swing. 2006. "Archimedes Wave Swing Website." Available at www.waveswing.com.

Bedard, R. 2005. Oregon Offshore Wave Energy Demonstration Project: Bridging the Gap Between the Completed Phase 1 Project Definition Study and and the Next Phase – Phase 2 Detailed Design and Permitting Electrical Power Research Institute Report E21 EPRI WP-010 OR. Palo Alto, CA.

Bedard, R., et al. 2005. *Final Summary Report, Project Definition Study, Offshore Wave Power Feasibility Demonstration Project*, EPRI Global WP 009 – US Rev 1, Jan. 14, 2005. Electrical Power Research Institute. Palo Alto, CA.

Bottom, D., J.A. Lichatowich and C.A. Frissell. 1998. Variability of Pacific Northwest Marine Ecosystem and Relation to Salmon Production. In: McMurray, G.R. and R.J. Bailey (eds.). Change in Pacific Northwest Coastal Ecosystems. NOAA Coastal Ocean Program Decision Analysis Series No. 11. Silver Spring, MD.

Braun, G.M. 2005. Draft White Paper: Benthic infauna at the mouth of the Columbia River. Institute for Natural Resources, Oregon State University. Corvallis, OR.

Cada, G., J. Ahlgrimm, M. Bahleda, S.D. Stavrakas, D. Hall, R. Moursund and M. Sale. 2007. Potential impacts of hydrokinetic and wave energy conversion technologies on aquatic environments. *Fisheries* (32):174-181.

Christensen, L., 2006, e-mail from Christensen (Wave Dragon ApS, Copenhagen, Denmark) to L. Habegger (Argonne National Laboratory, Argonne, Ill.), June 22.

Cox, D. 2005. Draft White Paper: Sediment transport and nearshore hydrodynamics at the mouth of the Columbia River. Institute for Natural Resources, Oregon State University. Corvallis, OR.

Department of the Navy. 2003. E*vironmental Assessment, Proposed Wave Energy Technology Project, Marine Corps Base Hawaii, Kaneohe Bay, Hawaii*, Jan.

Emmett, R. 2007. Personal communication.

EMEC. 2005. Environmental impact assessment (EIA) guidance for developers at the European Marine Energy Centre. European Marine Energy Centre. Orkney.

Energetech. 2006. "Media Release: Port Kembla Trial Deployment Results," Nov. 2005. Available at www.energetech.com.au.

European Thematic Network on Wave Energy (ETNWE). 2003. *Results from the Work of the European Thematic Network on Wave Energy*, ERK5-CT-1999-2001, 2000–2003. Available at www.wave-energy.net.

Faber Maunsell and METOC PLC. 2007. Scottish Marine Renewables SEA Environmental Report. Scottish Executive, Strategic Environmental Assessment.

FERC. 2006. Preliminary Draft Environmental Assessment: Makah Bay Offshore Wave Energy Pilot Project. FERC Docket No. DI02-3-002. Federal Energy Regulatory Commission. Washington, DC.

FERC. 2007. Pre-Application Document: Reedsport OPT Wave Park. Reedsport Wave Energy Project, LLC, FERC Project No. 12713. Federal Energy Regulatory Commission. Washington, DC.

GLOBEC. 1997. North Pacific Carrying Capacity and Climate Change (CCCC) Science Plan. Report Number 16. U.S. Global Ocean Ecosystem Dynamics (GLOBEC) Program.

GLOBEC. 2001. Ocean surface drafters released off the Oregon Coast, wind driven circulation off Oregon. Global Ocean Ecosystem Dynamics (GLOBEC) Northeast Pacific Program. Available at: http://diana.oce.oregonstate.edu/drift/wind-driven.shtml.

Greenland, D. 1998. Variability and Stability of Climatic/Oceanic Regimes in the Pacific Northwest. In: McMurray, G.R. and R.J.Bailey (eds.). Change in Pacific Northwest Coastal Ecosystems. NOAA Coastal Ocean Program Decision Analysis Series No. 11. Silver Spring, MD.

Hagerman, G, and R. Bedard. 2004. Offshore Wave Power in the US: Environmental Issues. Global Energy Partners, LLC. E21 Global EPRI-007-US.

Hagerman, G., R. Bedard and M. Previsic, 2004. E21 EPRI Survey and Characterization of Potential Offshore Wave Energy Sites in Oregon. Electrical Power Research Institute Report E21 EPRI WP-OR-003. Palo Alto, CA.

Herzing, D. L. and B. R. Mate. 1984. Gray whale migrations along the Oregon coast, 1978-1981. In: *The Gray Whale* (M. L. Jones, S. Swartz and S. Leatherwood, eds.), Academic Press, pp. 289-307.

Hodder, J. 2005. Marine mammal use of the nearshore waters along Clatsop Spit: an assessment of distribution, abundance, and potential effects from dredge spoil deposition adjacent to the south jetty of the Columbia River. Review Draft. Institute for Natural Resources, Oregon State University. Corvallis, OR.

Keister J., and W. Peterson. 2003. Zonal and seasonal variations in zooplankton community structure off the central Oregon coast, 1998-2000. *Progress in Oceanography* (57):341-361.

Kosro, P.M. 2007. Ocean Currents Mapping Lab. Available at: http://bragg.coas.oregonstate.edu/.

Japan Marine Science and Technology Center (JAMSTEC). 2006. "Wave Energy Research and Development at JAMSTEC, Offshore Floating Wave Energy Device, Mighty Whale." Available at www.jamstec.go.jp/jamstec/MTD/Whale/index.html.

Lamb, J., and W. Peterson. 2005. Ecological zonation of zooplankton in the COAST study region off central Oregon in June and August 2001 with consideration of retention mechanisms. *Journal of Geophysical Research* (110).

Lance, Monique M., Scott A. Richardson and Harriet A. Allen. 2004. Sea Otter Recovery Program, Sate of Washington. Washington Department of Fish and Wildlife Wildlife Program. Olympia, WA.

Landry, M.R., J.R. Postel, W.K. Peterson and J. Newman. 1989. Broad-scale patterns in the distribution of hydrographic variables. p. 1-41. In: M.R. Landry and B.M. Hickey. *Coastal Oceanography of Washington and Oregon.* Elsevier Press, Amsterdam.

Lane, N. 2007. Issues Affecting Tidal, Wave, and In-Stream Generation Projects. Congressional Research Service RL33883.

LASAR. 2007. Preliminary laboratory results for EPA-funded Coastal Environmental Mapping and Assessment Program (EMAP). Lab Analytical Storage and Retrieval (LASAR) System, Oregon Department of Environmental Quality, Laboratory Division. Portland.

Mate, B.R. and J. Harvey. 1984. Ocean movements of radio-tagged gray whales. In: *The Gray Whale* (M. L. Jones, S. Swartz and S. Leatherwood, eds.), Academic Press, pp. 577-589.

Mate, B.R., Lagerquist, B.A., and J. Urban-Ramirez. 2003. A note on using satellite telemetry to document the use of San Ignacio Lagoon by gray whales (*Eschrichtius robustus*) during their reproductive season. *J. Cetacean Res. Manage*. 5(2):149-154.

Mate, B. R. and J. Urban-Ramirez. 2003. A note on the route and speed of a gray whale on its northern migration from Mexico to central California, tracked by satellite-monitored radio tag. *J. Cetacean Res. Manage*. 5(2):155-157.

Michel, J., H. Dunagan, C. Boring, E. Healy, W. Evans., J.M. Dean, A. McGillis and J., Hain.. 2007. Worldwide Synthesis and Analysis of Existing Information Regarding

Environmental Effects of Alternative Energy Uses on the Outer Continental Shelf. Minerals Management Service OCS Report MMS-2007-038.

MMS. 2006. Technology White Paper on Wave Energy Potential on the U.S. Outer Continental Shelf. Renewable Energy and Alternate Use Program, Minerals Management Service, Reston, VA.

MMS. 2007. Programmatic Draft Environmental Impact Statement for Alternative Energy Development and Alternate Uses on the OCS. Minerals Management Service, Reston, VA.

NMFS. 2003. Large whale entanglement report 2001 (updated 2003). National Marine Fisheries Service, Protected Resources Division. Glouster, MA.

NMFS. 2005. Pacific Coast Groundfish Fishery Management Plan: Essential Fish Habitat Designation and Minimization of Adverse Impacts. Final Environmental Impact Statement. NOAA National Marine Fisheries Service. Seattle, WA.

Ocean Power Delivery Ltd. 2006. "World's First Wave Farm – Shipping of First Machine to Portugal," Press Release, March 14. Available at www.oceanpd.com.

Ocean Power Technologies 2006. "Making Waves in Power." Available at www.oceanpowertechnologies.com.

ODFW Nearshore Team. 2006. The Oregon Nearshore Strategy. Oregon Department of Fish & Wildlife, Marine Resources Program, Newport, OR.

Pearcy, W.G. 2005. Draft White Paper: Marine Fishes. Institute for Natural Resources, Oregon State University. Corvallis.

Pearson, W.H. 2005. Issues concerning Dungeness crabs and the demonstration project for the Columbia River Nearshore Beneficial Use Project. Review Draft. Institute for Natural Resources, Oregon State University. Corvallis, OR.

Peterson, W.T. 2007. Personal communication.

PMFC. 2006. Measures to prohibit fishing for krill in the Exclusive Economic Zone off the West Coast. Pacific Fishery Management Council. Portland, OR.

Polaski, K. 2003. "Waiting for the Waves," *The IEA Ocean Energy Systems Newsletter*, Issue 2, Sept. Available at http://www.iea-oceans.org/newsletters/news2.pdf.

Rhinefrank, K. 2005. "Wave Energy Research, Development, and Demonstration at Oregon State University," presented at Energy Ocean 2005, April 26–28, Washington, D.C.

Richards, S.D., E.J. Harland and S.A.S. Jones. 2007. Underwater Noise Study Supporting Scottish Executive Strategic Environmental Assessment for Marine Renewables. QinetiQ Ltd. Farnborough, Hampshire.

Sound & Sea Technology Ocean Engineering. 2002. Wave Energy (WET) Environmental Impacts of Selected Components. Report 02-06. Prepared for Belt Collins Hawai i.

Strong, C. 2005. Marine bird use of the nearshore waters along Clatsop Spit: an assessment of composition, abundance, and potential effects from dredge spoil deposition adjacent to the south jetty of the Columbia River. Review Draft. Institute for Natural Resources, Oregon State University. Corvallis, OR.

Sutor, M., T. Cowles, W. Peterson and S. Pierce. 2005. Acoustic observations of finescale zooplankton distributions in the Oregon upwelling region. *Deep-Sea Research II* (52):109-121.

Thorpe, T.W. 1999. *A Brief Review of Wave Energy*, ETSU Report R-122, prepared for the United Kingdom Department of Trade and Industry.

USDOE. 2006. Proceedings of the hydrokinetic and wave energy technologies technical and environmental issues workshop. Prepared by RESOLVE, Inc. for US Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind and Hydropower Technologies Program. Washington, DC.

USEPA. 1998. Guidelines for Ecological Risk Assessment. US Environmental Protection Agency, Risk Assessment Forum. EPA/630/R-95/002F.

Valberg, P.A. 2005. Memorandum addressing electric and magnetic field (EMF) questions. Cape Wind Energy Project, Nantucket Sound.

Wave Dragon. 2005, "Technology." Available at http://www.wavedragon.net. WavePlane Production A/S = WPP A/S, 2006, Home page. Available at www.waveplane.com.

Wilson, B., R.S. Batty, F. Daunt and C. Carter. 2007. Collision Risk Between Marine Renewable Energy Devices and Mammals, Fish and Diving Birds. Report ot the Scottish Executive for Marine Science, Oban, Scotland. PA37 1QA.