Marine Studies Initiative (MSI) Research Working Group Report (final draft)

Executive Summary

Thinking globally, acting locally. It's all about connections – how we connect to people, communities, and place with purpose and impact. The oceans have been referred to as the "lungs of the planet". Whether we derive our livelihood from the ocean, enjoy its bounty, seek solace along its shores, or marvel at the weather we experience, we are all surprisingly and remarkably connected to the world's ocean and marine environment. As much as oceans and the marine environment have shaped human culture, we have also affected them.

The Oregon coast stands out for its mixture of unparalleled access to the beach and ocean and the natural beauty of its coastline. It offers one of the most aesthetic, diverse, and productive marine coastlines in the country. The coastal economy is significantly influenced by what happens in marine waters and the wellbeing of our freshwater systems. Hence, the ocean, and coastal marine environments, as well as all the inland factors that significantly influence them are a matter of economic and cultural importance to all Oregonians.

Ocean and marine environments face unprecedented opportunities and threats. And, they are providing increasingly more complex policy and management problems. Sound decision making within this context requires a coordinated mix of publicly-engaged problem definition, integrating scientific knowledge with social and policy conditions, negotiating around uncertainty, iterative policy development, adaptive planning, and attentive monitoring. Research is key to informing how we confront these opportunities and challenges.

MSI-Research will be a keystone to knowledge discovery, decision-making, strategic planning, education and Oregon's sustainability vision by focusing on data and prediction across three thematic areas enveloped by a mountain to sea perspective:

- *Integrated Marine Systems Science*
- *Reliance on the Sea*
- *Global Change and Coastal Community Resilience*

Achieving MSI's mission across its research themes requires an integrated spectrum of expertise. As such, MSI-Research will, among many objectives:

- emphasize disciplinary convergence to spur innovations from basic scientific discovery to its practical applications;
- explore the intersection of natural and human systems in our changing planet, and how we may adapt and continue to prosper while sustaining our natural resources;
- encourage leadership on marine issues by providing physical and virtual space as well as facilities and personnel for fruitful collaborations, near and far.

Two key themes of the MSI are Sustainability and Convergence, the first is a core principle for OSU and Oregonians, the second an approach to emergent research themes and challenges to promote a sustainable future for all Oregonians. Convergence integrates knowledge, tools, and ways of thinking from a broad range of disciplines to form a comprehensive synthetic framework for tackling scientific and societal challenges that exist at the interfaces of multiple fields. Building on the international leadership of OSU on marine issues and merging these diverse areas of expertise under the MSI within a

network of partnerships, convergence will stimulate innovation from basic science discovery to translational application. OSU is also committed to sustainability and has been recognized as national leader in sustainability practices. But our concept of sustainability continues to evolve as we explore ways to achieve sustainable socio-ecological systems; importantly this includes us and our utilization and stewardship of our natural resources. A convergent research approach in the MSI will allow us to understand how to maintain resilient natural systems as well as create and support adaptive, resilient human systems. We are dedicated to advancing the science of earth ecosystems, improving human health and wellness, promoting innovation and economic prosperity, which are all integral aspects of a sustainable future and will require a convergent approach in light of the challenges facing our future generations.

From Mountain Tops to the Deep Ocean, Oregon provides an unparalleled natural and socio-economic laboratory and its residents possess a deep sense of stewardship and connection to the land and sea. Water connects these seemingly disparate habitats, through rain and snow, through the rivers, to the estuaries, and ultimately to the ocean, where the cycle begins again. Successful future approaches to ensure a sustainable future will cross social, economic and ecological boundaries from watersheds to the sea and will encompass local, regional, and global concerns. This sense of place and connectedness sets the stage for integrating and expanding research efforts under the MSI. The MSI will remain flexible and responsive to developing research areas and the needs of the stakeholders through a Think Tank approach to facilitating new research collaborations, providing incubators of knowledge to action. Three organizing and integrating research themes the OSU-MSI will be poised to support initially are Integrated Marine Systems Science, Reliance on the Sea, and Global Change and Resilient Coastal Communities.

OSU is currently well poised to develop an Integrated Marine Systems Science foundation to advance research on climate change impacts on marine ecosystems, coastal ecology, paleo-oceanography, and ocean observing. From time-scales of minutes to millennia, the MSI will provide opportunities to expand and integrate these current research strengths.

Reliance on the Sea by Oregon's communities and economies warrants greater efforts to understand the feedbacks between humans and resources through the food we take from the ocean, development of marine renewable energy, recreation and tourism opportunities, and the cultural heritage of recent Oregonians and the First Nations.

The thin ribbon of land between Oregon's coast range and the Pacific Ocean supports vibrant communities of people that will face increasing global change challenges. The Global Change and Resilient Coastal Communities theme will address the threats from geologic, climate, and biophysical change and how coastal communities may adapt and mitigate these challenges.

Across the major research themes, Data Science and Process Outcome and Evaluation will provide two cross cutting themes. With increasing opportunities in big data, the MSI will provide opportunities to answer pressing questions and digest large data sets from ocean observing systems through dedicated efforts in computational science. Finally for the MSI to adapt to an ever changing socio-political landscape, expertise in outcome and evaluation will provide informed, scientifically based opportunities to adjust the course and approach of MSI, ensuring the best possible outcomes and adaptive capacity for ongoing and future research.

I. Overview and Motivation for MSI Research

Thinking globally, acting locally. It's all about connections – how we connect to people, communities, and place with purpose and impact. Whether we live on the Oregon coast, Central Oregon, or Portland; or whether we live in the Great Plains or Zanzibar, we are all surprisingly and remarkably connected to the world's ocean and marine environment. For centuries oceans have provided jobs, goods, and services; inspired myths and legends; and captivated our sense of wonder through mystery and discovery. As much as oceans and the marine environment have shaped human culture, we have also affected them.

The Oregon coast stands out for its mixture of unparalleled access to the beach and ocean and the natural beauty of its coastline. It offers one of the most aesthetic, diverse, and productive marine coastlines in the country (1). The coastal economy is significantly influenced by what happens in marine waters and the well being of our freshwater systems. Hence, the ocean, and coastal marine environments, as well as all the inland factors that significantly influence them are a matter of economic and cultural importance to all Oregonians.

Imagine a world without the provisions, inspirations, and captivations oceans have invoked. What is, or could be, the problem? What does the science tell us? What are our options? Do the options change how we understand and experience the ocean and marine environments? Do the options diminish or enhance environmental, social, and economic outcomes – not only today but for future generations? When tackled superficially, these seemingly simple questions deliver deceptively simplistic answers.

Ocean and marine environments face unprecedented opportunities and threats. And, they are providing increasingly more complex policy and management problems. Sound decision making within this context requires a coordinated mix of publicly-engaged problem definition, integrating scientific knowledge with social and policy conditions, negotiating around uncertainty, iterative policy development, adaptive planning, and attentive monitoring. It is never a straightforward process, but one that taps into the knowledge base of all relevant stakeholders and uses all the knowledge we have, for all fields and disciplines that contribute.

The research arm of the Marine Studies Initiative (MSI-Research) is primed to rigorously tackle questions and challenges that exist in the intersections of sea, land, air, people, and culture. Because of the MSI's position within Oregon's public universities and its proposed headquarters on the Oregon coast, MSI-Research has great opportunities to bring together transdisciplinary research teams, stakeholders, and students to explore and convey complex ocean and marine issues in depth, with local and global impact.

1.http://www.eartheconomics.org/FileLibrary/file/Reports/Understanding_Oregons_Coastal_Economy_and_Environment.pdf

The mission of MSI-Research is to create a *physical, philosophical* and *conceptual* infrastructure to foster scientific, political and socio-cultural research networks that advance our collective ability to accurately predict the outcomes of current human actions and model the future trajectory of our complex ecosystems. MSI-Research will be a keystone to knowledge discovery, decision-making, strategic planning, education and Oregon's sustainability vision by focusing on data and prediction across three thematic areas enveloped by a mountain to sea perspective:

- ***Integrated Marine Systems Science*** – advancing the understanding and documentation of the status and trends of marine systems, and predicting how they will respond to rapidly occurring change
- ***Reliance on the Sea*** – ensuring sustainability of marine resources through study of safe seafood production, marine renewable energy, and the cultural resources and ecosystem services we derive from the sea.
- ***Global Change and Coastal Community Resilience*** – applying integrated approaches to understanding and facilitating the ability of coupled natural-human systems to foresee, respond, and adapt to future change

Achieving MSI's mission across its research themes requires an integrated spectrum of expertise. As such, MSI-Research will:

- go beyond the typical idea of interdisciplinarity to emphasize convergence – the merging of diverse disciplines to spur innovations from basic scientific discovery to its practical applications;
- explore the intersection of natural and human systems in the unparalleled *natural and socio-economic laboratory* of Oregon's coastal watershed, estuaries, and ocean systems;
- enhance and expand OSU's success with initiatives that cultivate strong connections between computational/quantitative resources, engineering, technology, and earth and biological sciences.

II. Sustainability, The Future We Want: A Core Principle of OSU and the MSI

Sustainability is the continued productivity of Earth's natural and human systems. Sustainability is a goal that promotes well being worldwide and a goal adopted by individuals, organizations, communities, and nations around the globe (2). We rely on Earth's systems for all aspects of our livelihood and the creation and maintenance of a sustainable future requires us to live within the capacity of our planet while striving for innovation and greater efficiency in all that we do. Sustainability will require innovative, functional integration of our natural and human systems. Sustainable systems rely on a comprehensive understanding of Earth's systems, smart technology, and social and economic equity; they will require deep integration across diverse disciplines including the biological, ecological, physical, and social sciences with economics, mathematics, statistics, and engineering. OSU is committed to sustainability and has been

2. Prototype Global Sustainable Development Report. 2014.
https://sustainabledevelopment.un.org/content/documents/975GSDR%20Executive%20Summary.pdf

recognized as national leader in sustainability practices by the Sierra Club, the U.S. Green Building council, The Princeton Review, the Kaplan College Guide, and the U.S. Environmental Protection Agency. But our concept of sustainability continues to evolve as we explore ways to achieve sustainable socio-ecological systems. Sustainable systems are resilient and have the ability able to adapt as conditions change. Although we have made great progress, there is still much to do. The establishment of the MSI and the development of a convergent research approach to address current and future challenges across Earth's systems will enhance our abilities and advance our efforts to understand and promote sustainable systems. Moving forward we must understand how to maintain resilient natural systems as well as create and support adaptive, resilient human systems. In many respects, this will require a transformation of our human systems, our organizational structures, our research approaches. OSU is well poised to meet this challenge. We are dedicated to advancing the science of earth ecosystems, improving human health and wellness, promoting innovation and economic prosperity, which are all integral aspects of a sustainable future.

III. Convergence: An Approach to Emergent Research Themes for the OSU MSI

Convergence is an approach to problem solving that cuts across disciplinary boundaries, and a current focus of the National Academies of Science as a mechanism for tackling the most ambitious and pressing research issues (3). Convergence integrates knowledge, tools, and ways of thinking from life and health sciences, physical, mathematical, and computational sciences, engineering disciplines, and beyond to form a comprehensive synthetic framework for tackling scientific and societal challenges that exist at the interfaces of multiple fields. By merging these diverse areas of expertise under the MSI within a network of partnerships, convergence stimulates innovation from basic science discovery to translational application. It provides fertile ground for new collaborations that engage stakeholders and partners not only from academia, but also from national laboratories, industry, clinical settings, and funding bodies. The organizing principle of convergence as represented here is meant to capture two closely related but distinct research roles of the MSI: the convergence of expertise necessary to address a set of emerging marine research problems, and the formation of the web of partnerships involved in supporting such scientific investigations and enabling the resulting advances to be translated into new forms of innovation and new products. There are three emergent research themes the MSI will be well suited to address, which are pressing societal challenges: 1. Integrated Marine Systems Science; 2. Reliance on the Sea; and 3. Global Change and Resiliency. The MSI will provide the infrastructure and network supporting convergence and expansion of OSU strengths to address these local and global challenges that range from the mountain tops to the deep oceans.

3. National Academy of Sciences. Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond. 2014. Available at http://www.nap.edu/catalog.php?record_id=18722

IV. From The Mountain Tops to the Ocean: A Stewardship of Place in Oregon

Vision

Watershed Science: Across OSU, researchers collaborate to address interdisciplinary and transdisciplinary water research issues including the impacts of climate change on snow, glaciers, ice sheets, and society, mountain watershed hydrology, and projects aimed to help policy makers and water managers seek solutions to complex water issues.

Water connects the land to ocean from the fresh rain and snow in the mountains carrying materials downstream, through the flowing creeks and rivers, to the oscillating estuaries and eventually to the salty coastal ocean, water completes this cycle frequently along the Oregon coast. Successful future approaches to ensure a sustainable future will cross social, economic and ecological boundaries from watersheds to the sea and will encompass local, regional, and global concerns. At the northern border of Oregon, one of the largest rivers in the United States, the Columbia drains the snow-charged Cascade Mountains and flows into the Pacific Ocean. The Columbia and the other coastal rivers move approximately 91 trillion gallons of water to the ocean each year. These water ways fuel our region and are home to six species of Pacific salmon; they provide navigable waterways, clean power and a multitude of mariculture and harvest opportunities while nourishing the coastal ocean. The sustainability of these rivers and the adjoining coastal ocean are challenged by climate change, human population growth, and increasing demand for resources. Protection of the ecosystem services provided by the integrated mountain to sea landscape globally will require transdisciplinary research and convergence with enhanced communication within and across disciplines. OSU can lead this mission. OSU is home to a diverse and dedicated group of oceanographers, ecologists, geoscientists, engineers, mathematicians, economists, social scientists, writers, and artists who all believe in the future of our oceans, and work tirelessly to generate solutions and build capacity for the future via novel, convergent research spanning our mountain tops to our seas.

Areas of Distinction: The OSU mission for a healthy planet, healthy people and healthy economies

Oregon is home to a rich and bountiful agriculture; creative and innovative solutions to water management and water policy have originated here; some of the most sustainable fisheries in the world are managed in Oregon; and groundbreaking ocean exploration occurs here. In this productive natural setting, we are poised to create integrated solutions to sustain the diverse ecosystems, communities and economies at the confluence of the continent and the sea. But it's not just the work we do; it's how we do it. OSU is home to leading researchers in interdisciplinary studies across coastal ecosystems and fosters exemplary research partnerships address topics crossing relevant physical, biological, chemical, social, and economic aspects of issues of societal importance, including climate change, natural hazards, and resource exploration and utilization. Across this land and seascape we strive to not only collaborate with

other university researchers, we work with state and federal agencies, non-profits, and other stakeholders. Researchers at OSU have been recognized for their efforts to work with industry partners in forestry, fisheries, aquaculture, and a variety of other fields that benefit from healthy, sustainably managed resources. Collaboration is at the heart of this institution's mission *but a structural and intellectual convergence* will be needed to meet the needs of the future generations.

Continuing forward

In a changing climate, OSU aims to address broad issues of sustainability across social, economic and ecological boundaries from watersheds to the sea. Key challenges that will need to be met in order to enable the most effective research include

- Improved access to the sea, including ships and boats, autonomous vehicles, dive support, and enhancements to seawater system, and
- Physical space and funding for cross-disciplinary research to enable the path forward as we seek to addresses these new challenges

As these infrastructure needs are addressed, the MSI will be uniquely prepared to answer a number of the most significant global concerns facing coastal ecosystems. These issues include but are not limited to

- Defining the socioeconomic requirements for to facilitate coastal sustainability and resilience
- Development of accurate multi-trophic models of the impact of global change on coastal systems, e.g. predicting impacts of ocean acidification from microbes to animals
- Reduce risk of natural hazards and increase preparedness
- Derivation of new sources of renewable energy from the land and sea
- Assembly of the intellectual and technological requirements to build 'think tanks' that will focus on multivariate problems such as population connectivity of keystone marine species or preservation of watershed resources
- Incorporate native knowledge into existing models of ecosystem management and systems ecology
- Develop strategies to protect clean water for recreation and human consumption
- Harness the emergent power of big data in transdisciplinary research spanning genes to ecosystems

Molecules to Megafauna:

At OSU, we work from the microscope to the macroscope across watersheds to the sea. From understanding water chemistry and physical processes to learning how the planet's largest creatures ply those waters, we work throughout the Pacific Northwest and around the globe to meet the University's mission of Healthy People, Healthy Planet, and Healthy Economy

The inherent intellectual and scientific curiosity driving the above research foci will allow the MSI to predict and respond to the socioeconomic and ecological hazards that may face future generations.

IVa. Integrated Marine Systems Science

Vision

The oceans, covering about 70% of the Earth's surface, represented an almost alien environment for the bulk of humanity, yet over half of the human population lives in coastal areas, and a similar number rely on ocean-derived resources. These resources comprise many important ecosystem services that include provisioning, regulating, and cultural services supporting the most intimate of ocean users such native cultures or commercial fishermen, to the climate regulating services that impact people across the globe. Integral to the stability of these services is the interplay among the physical, chemical, biological, and sociological components of the ocean, and the responses to natural and anthropogenic forcing. Hence the anthropogenic pressures imposed on marine systems are intense and growing, as the human population expands. Arguably, climate change and particularly its impacts on global ecosystems is the most daunting challenge ever faced by humankind. This challenge has led to a convergence in interests in the natural and social sciences, with a universal focus on achieving a state of sustainability between humans and their life support system on Earth. Nationally and internationally, recognition of the need for achieving balance between the ocean's ability to provide resources and humanity's need for these resources has grown dramatically. Yet considerable challenges still exist in understanding the how marine ecosystems, including the humans that depend on them, work.

Sea Stars, Disease, Climate Change:

Researchers at OSU have extensively studied the habitats in which sea stars reside and how they shape their communities through species interactions. Recently a mysterious disease has caused extensive die-offs of these important organisms, and OSU researchers are leading the way in understanding the dynamics among marine organisms, disease, and climate change.

The Oregon coast has and continues to be a highly productive environment supporting bountiful, sustainably managed fisheries associated with the California Current Large Marine Ecosystem. This upwelling-dominated system and the tightly coupled near-shore coastal ecosystems are highly sensitive to global and local change. A convergent approach to understanding the basic dynamics of our oceans is needed to understand how the ecosystem services upon which we depend may change. Under the MSI, OSU will further secure its place as a world's leader in marine systems science.

Areas of Distinction

Climate change impacts on marine systems. Few institutions house the extensive expertise in marine systems across the fields of physics, chemistry, geology, biology, ecology, resource management, public policy, and sociology found at OSU, where we also house unique observational and measurement capacities. OSU continues to be a world leader on

understanding how marine systems work, from the iconic rocky-intertidal shores, to the deep blue tuna rich waters off-shore. Continued alterations of our global climate will continue to result in changes in local weather and oceanographic conditions, potentially altering the structure and function of marine ecosystems. The cascading effects of these global changes and local consequences on our marine resources are poorly understood and require significant coordination and collaboration to better anticipate future conditions. The breadth of approaches at OSU to understanding marine systems is staggering as well, from traditional observationalists, to experimentalists, and modelers, across all time and space scales, OSU scientists tackle some of the most pressing and immediate questions about our marine systems.

Ocean Acidification and Oysters:

The acidification of the world's oceans through carbon emissions threaten many marine organisms. OSU scientists in close collaboration with the Pacific Northwest Shellfish industry identified excess carbon as the primary cause of significant economic losses in the region's hatcheries. Continuing work has instrumented shellfish hatcheries along the entire US west coast, and providing adaptation tools to allow the industry to succeed.

Coastal Ecology. OSU scientists work on the tiniest organisms that make up the base of the food chain all the way up to the largest marine mammals on the planet, and they all interact in Oregon's coastal waters. Understanding the basic population and community ecology of the habitats encompassing the off-shore tuna schools all the way to estuaries, sea grasses, and salt marshes, right into the spawning grounds of the various salmon species is covered by marine scientists at OSU. The continuing effects of a changing environment on these species and the habitats in which they reside provide considerable opportunities for understanding primary questions about the structure and function of these ecosystems. Whether it is hypoxia impacts on Dungeness crabs or salmon utilization of estuarine habitats, OSU scientists will continue to uncover the complexity of marine ecosystems to better understand coastal ecosystems.

Paleo-Oceanography. Understanding the past oceans is a key component in predicting future global conditions. OSU researchers study the composition of tiny organisms preserved in marine sediments to understand how the oceans worked locally and around the globe. Housing the Marine Geology Repository, OSU, catalogs and preserves nearly 10,000 samples of sediment cores, rocks, and plankton tows from around the globe. OSU researchers use these samples and ice cores to reconstruct climate records, past ocean circulation patterns, and inform models of global systems and climate.

Ocean Observing. OSU is home to one of the key nodes of the US Ocean Observing Initiative (OOI), and operates a dizzying array of buoys, drifters, glides, and cabled sea floor arrays to help fill in the tremendous gaps in knowledge and data about the spatial and temporal changes in ocean physics, chemistry, and biology. In addition, OSU is globally recognized for its work on using satellite imagery for understanding coastal ocean dynamics. Implementing these observing assets in coastal waters and providing data through web-portals allows scientists,

policy makers, resource managers, and the public a distinctly unique view and understanding of the ocean. The forecasting of our weather depends on the extensive data collection of conditions across the globe, and the OOI is poised to begin providing the data that will one day be able to inform the same kinds of forecasting models for ocean users.

Continuing Forward

Oregon State University's new MSI represents a novel opportunity to meet the most basic and fundamental challenge of understanding how marine systems work. Under the MSI model, researchers, scientists and students working on the many challenges regarding marine systems science can collaborate closely, while better integrating the social science aspects of human integration with the marine environment. Sustainable coastal communities will ultimately depend on the research about how our oceans work, and the potential contribution to affecting change on global levels to ensure that sustainability is a critical contribution of the MSI research endeavor.

Ocean Observing at OSU:

OSU is one of the leading institutions on the Ocean Observatories Initiative and is responsible for a suite of buoys, gliders, and cabled arrays on the seafloor. This cabled observing system feeds real-time data from the deep ocean floor to land through high speed fiber-optic cables.

IVB. Reliance on the Sea

Vision

Human societies increasingly rely on the sea for renewable food and energy, recreation and a wide range of ecosystem services. In addition, Native Americans and other coastal communities have strong cultural and historic connections with the sea. MSI can play a key role in enhancing our understanding and develop new approaches that support long-term sustainable use of a wide range of marine resources while maintaining the beauty and wildness of the coast.

Food from the Sea A major challenge is to develop approaches that enable fishermen and farmers to meet increasing demands for healthy seafood while protecting wild fisheries, human communities and consumers, as well as the environment upon which all these depend.

Renewable Energy The Oregon coast is an energy-rich environment that has the potential to supply renewable wind and wave energy. While developers are engineering devices for harvesting these renewable resources, much is not well understood regarding environmental effects, effects on communities, and technical advances that will reduce the cost of energy of these promising new energy sources

Recreation and Tourism Recreation and tourism play a vital role in coastal communities, contributing more than $350 million to local economies. How can development associated with increased recreation and tourism be managed so that Oregon's coastal natural beauty and wild habitats are preserved?

Sustainable Fisheries:

Oregon's diverse marine resources support commercial fisheries valued at more than $500 million in annual income. Dungeness crab, Salmon, Pacific shrimp, albacore and halibut are all certified through the Marine Stewardship Council for sustainability. These fisheries have long been an integral part of the fabric of many coastal communities. Farther afield, OSU researchers seek to enhance fisheries sustainability across the country and around the world.

Cultural heritage Coastal communities and Native American tribes, including the Confederated Tribes of Coos, Grand Ronde, Lower Umpqua and Siuslaw Indians, and the Siletz and Coquille Indian Confederated Tribes, inherit a rich marine history and share strong cultural ties with the ocean. Traditional ecological knowledge, native foods, natural resource management and stewardship, and place-based senses of cultural identity are areas that continue to link the interests and concerns of Native tribes to the Oregon coast.

Areas of Distinction

Food from the Sea OSU has a long history in working with fishermen, farmers, seafood processors and coastal communities and is well positioned, through the USDA-AID funded AquaFish program, to contribute to the alleviation of hunger in developing countries by a combination of seafood research, outreach and education.

OSU is also one of the few universities in the U.S. that continues to place considerable capital and human investment in postharvest seafood research. Faculty across campus provides the seafood industry with new technologies, strategies and information on enhancing seafood quality and safety as well as improved production, product development and marketing. OSU researchers also share expertise on the effects of harmful algal blooms, human pathogens and pollution on seafood production and safety.

Renewable Energy The US Department of Energy established the Northwest Marine Renewable Energy Center (NNMREC) in 2008, which began as a collaboration between OSU and the University of Washington to support marine energy research, development, and testing in the U.S. The collective NNMREC activities facilitate commercialization of wave and tidal energy devices, inform regulatory and policy decisions, and close key gaps in marine renewable energy understanding with an emphasis on student learning. In 2014, the University of Alaska Fairbanks joined NNMREC and brought their expertise in in-river hydro testing to the renewable energy portfolio.

NNMREC's research and development activities range from optimizing energy extracted from marine energy converter arrays, to forecasting extreme wave events and increasing reliability of converters, to understanding environmental effects of converters and engineering new monitoring devices that are more efficient and less expensive than the technologies currently available.

Conservation of Marine Resources: OSU researchers work closely with local, state, and federal agencies, as well as local constituents, on Marine Reserves and Protected Areas to sustain the ecological integrity of the resource while incorporating local socio-economic concerns.

Recreation and Tourism The Tourism and Outdoor Leadership program located at OSU-Cascades in Bend, Oregon provides tourism, outdoor leadership, business, communication and other skills necessary for success in the tourism and outdoor leadership sectors. Faculty are involved in research that examines the benefits gained from participating in tourism and outdoor leadership related activities on inland and coastal waterways in the state and abroad. Expertize in the socioeconomics of coastal communities can be found across several OSU academic units, including the School of Business, Department of Applied Economics.

Cultural heritage OSU faculty generate knowledge about the first peoples of western North America by discovering, recovering, and studying key archaeological and geo-archaeological information. For example, The Pacific Slope Archaeological Laboratory, housed in the School of Language, Culture, and Society, work collaboratively on research projects with state, federal and private partners. Other faculty members have collaborated with tribes on the Oregon Coast on research and community projects. The Eena Haws Native American Longhouse has been instrumental in connecting OSU researchers with Native students as well as Native tribes in Oregon and beyond.

Renewable Energy: The Northwest National Marine Renewable Energy Center and OSU researchers work towards the goal of accelerating responsible development of renewable energy, investigating technical, environmental, and social dimensions of ocean energy technologies, performing research that fills knowledge gaps. Through this research, students are becoming industry pioneers, educating themselves in these promising new fields.

Continuing forward

Examples of key challenges that OSU is well poised to address include:

Food from the Sea

Fisheries and farming

- Understanding of ecosystems that sustain seafood production
- Changing ocean chemistry (acidification, nitrification) and temperatures
- Loss of biodiversity
- Fishing and aquaculture technologies
- Sustainable and incentive-based management strategies
- Health and safety of fishermen and farmers

Seafood processing and food safety

- Efficient and safe processing practices and technologies
- High quality, nutritional seafood that is free of pathogens, toxins and pollutants
- Increased byproduct utilization

Consumers and public health

- Optimizing human nutrition while minimizing risk from contaminants
- Effective marketing, consumer research and education
- Sound economic models and policies
- Effective laws and regulations for seafood production and consumption

Local, regional, and global hunger

- Food security, within Oregon and globally
- Nutrition and dietetics
- Transfer of appropriate technologies, management approaches and knowledge
- Reduction of postharvest fishery waste

Renewable Energy

Technological Development:

- Research and development to increase the efficiency and reduce the impact of marine energy technology

Environmental Effects

- Understanding interactions between marine energy converters and ocean ecosystems

Socio-Economic Impacts

- Understanding economic effects and trade-offs to communities of marine energy installations
- Developing best practices for engaging communities in marine energy project siting
- Informing policy development for marine energy development

Recreation and tourism

- Develop strategies to balance growth of tourism and recreation with the preservation of Oregon's coastal beauty and wild habitats.
- Develop economic models to describe interactions between the numerous and diverse activities related to recreation and tourism in order to optimize synergies

Cultural heritage

- Increase collaboration with Native American coastal communities
- Understand how humans can adapt to environmental change along coastal margins
- Facilitate human response to natural disasters such as tsunamis, mega-storms, floods, landslides, fire, etc.
- Evolution of sustainable extractive technologies suited for coastal environments.
- Understand coastal / interior trade networks: commodity exchange / value systems
- Impact of varied regional coastal environmental zones on social systems, political organization, religious organization, and economic systems.
- Changes in coastal resource exploitation after European/ Euro-American occupation: fishing, logging, mining, settlements, roads, shipping, tourism, from an archaeological perspective.

IVc. Global Change and Resilient Coastal Communities

Vision

Coastal communities must increase their adaptive capacity to acute and chronic change and ensure resilience of the natural and built environment crucial to their sustainability. These coupled natural-human systems need to adapt and transform in light of multiple agents of change. For example, **geological change** includes extreme M9 Cascadia Subduction Zone earthquakes, co-seismic subsidence, tsunami, and the associated cascading natural and technological hazards. **Climate change** includes chronic impacts from storms and sea level rise such as coastal erosion and flooding. **Biophysical change** includes ocean acidification, hypoxia and dead zones, species migration, invasive and endangered species. Finally, *social change* includes the evolving social responses in anticipation of economic, technological, demographic, cultural, and policy changes.

Resilience to Coastal Hazards: OSU researchers, students, and outreach specialists are co-developing, with deep coastal community engagement, the information and tools necessary to assess impacts and associated evolving community and ecosystem vulnerability, and initiate adaptation strategies over the next several decades in the context of sea level rise, changing storminess, and the possibility of an extreme Cascadia Subduction Zone earthquake and tsunami.

Areas of Distinction

OSU researchers are leaders in identifying hazards associated with **geological change,** developing socio-economic and public policy approaches to resilient communities, and understanding the impacts of the hazards on the built environment. OSU faculty and Sea Grant specialists in sociology, engineering, community engagement, and informal science education are evaluating new evacuation plans and technology, particularly with regard to socially vulnerable populations.

Changing Coastal Economies:
People rely on marine and coastal resources for their economic livelihoods, identity, spirituality, and recreation. OSU researchers work to understand shifting local and global economic systems while integrating the myriad social, cultural and political impacts.

OSU has pioneering scholars investigating global-scale processes in marine systems and their links to **climate change** and variability. Researchers are applying integrated approaches to understanding coupled natural-human systems that facilitate the ability to foresee, respond, and adapt to future change. Coastal and nearshore oceanography researchers at OSU are leaders in developing and using novel observational, analytical, and modeling tools to study fundamental physical, chemical, and biological processes, spanning the coastal zone and beaches, estuaries, nearshore ocean, and continental shelf, and connecting the ocean to the interior.

Researchers at Oregon State University are developing an understanding of **biophysical change** associated with the dynamics of ocean acidification and hypoxia in nearshore marine and estuarine environments. They study interactions between native and non-native species in marine and estuarine environments. By virtue of location, history and expertise, OSU is a leader in the transdisciplinary study of upwelling zones and the economic and social components of human settlement in this margin.

OSU faculty bring together empirical knowledge, cultural, moral and spiritual understanding to respond creatively, justly and sustainably to *social change*. Researchers are integrating economics and sociology (human dimensions) into assessments and decision-making.

Continuing Forward

In light of the aforementioned agents of **geological, climate, biophysical, and social change**, OSU aims to address broad issues of coastal community resilience. Key challenges that will need to be met include:

- Adjusting to changing coastal economies, from resource extraction to tourism and retirement communities. Coastal Oregon has witnessed an economic shift from resource extraction and natural resources-based manufacturing to service sector related

economies, followed closely by incomes related to investment and transfer payments. An accompanied demographic shift in retirement-age populations and increase in tourism sectors has important implications for community resilience.

- Maintaining an aging civil infrastructure.
- Adapting to change in the face of significant uncertainties. For example: What are the rates, mechanisms, impacts, and geographic variability of sea level change? How will changes in global hydrologic cycles, sea level, and human uses of land and sea impact coastal and estuarine oceans? How can we better characterize and improve the ability to forecast geohazards (and their impacts) like mega-earthquakes, tsunamis, extreme coastal storms, undersea landslides, and volcanic eruptions? How do feedbacks between physical, biological, and socioeconomic processes determine the temporal dynamics and spatial structure of coastal and marine ecosystems? How will climate-induced changes in coastal and marine ecosystems affect the delivery of ecosystem services provided by those ecosystems. What are the important tradeoffs between ecosystem services and policy decisions such as coastal development, green versus gray infrastructure, recreation, and restoration?

Sustainable Coastal Communities: Transdisciplinary groups of OSU researchers and outreach specialists are working with coastal communities to develop the adaptive capacity necessary to ensure sustainability in light of geological, climate, biophysical and social change.

- Learning how to deliver the practical benefits of MSI-research directly to the public that supports it. To be impactful and develop useable science for decision-making researchers might engage with 'knowledge to action networks' in coastal communities to characterize existing networks and develop a shared conceptual framework for identifying key change processes, drivers, and policy constraints affecting coastal vulnerability. Our vision is that the work will contribute to enhancing the sustainability of coupled human-natural systems worldwide.

IVd. Cross-cutting role of Data Science in MSI: Finding Solutions

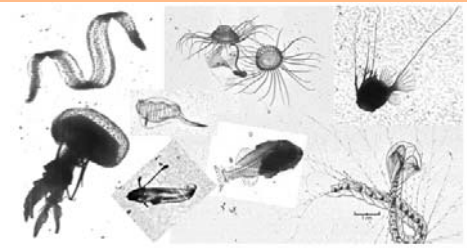
Solutions to many of the most complex problems relevant to sustainable marine systems -- such as ecosystem response to change, health of marine life, coastal community economies and cultures, resilient coastal structures, and energy generation -- increasingly require the integration and interpretation of massive and diverse data sets (big data) and the linked development of computational models encompassing multiple levels of scale. Massive biological, chemical, physical, geographical, demographic, and economic data sets are being generated by increasingly powerful technologies. Computational models have the ability to explain the principles underlying patterns observed in big data sets, and big data sets provide the resources for testing and improving models.

The ability to build accurate predictive models of marine processes that can inform the building of sustainable relationships with our marine environments is a cross-cutting requirement of all three research themes of the MSI. The skills and expertise of computer scientists, mathematicians, statisticians and engineers will be integrated with the efforts of marine, life, and social scientists and engineers to address the complex problems being tackled by the MSI. New data analytical tools will be developed along with new hardware and software capabilities to analyze these large and complex data sets. In many cases, these data analytical capabilities, including data mining, statistical analysis, and multi-scale modeling, will be applicable to diverse problems, resulting in great synergy among MSI working groups.

Mathematical, statistical and computational methods are already being applied at OSU to discover, analyze, simulate and predict the structures and processes of marine systems. For example, tsunami modeling research is developing numerical models for faster and more reliable forecasts of tsunamis advancing through the ocean and striking coastal communities. The forecasting system, in part, involves matching data collected in real time from deep-ocean buoys to a database of pre-computed computer-intensive mathematical models, each associated with a geographical location. Statistical procedures are used to select these mathematical models to improve the timing and accuracy of these warnings.

Similarly, mathematical, statistical and computational methods play a vital role in determining the optimal placement of Marine Reserves and Marine Protected Areas and in studying the subsequent impact of ecological structures. Mathematical, statistical and computational analyses are also used to enhance long-term biological productivity and achieve more effective measures for habitat protection.

Identifying and Counting Critters in the Sea: OSU marine ecologists and mathematicians collaborate to develop automated assessment techniques of images collected to identify and count plankton including their spatial distribution in the oceans. Development of these methods will allow greater understanding of the base of marine food webs, and can ultimately pair with ocean observing systems to better understand ocean ecosystems.



A further example that is just launching is to employ new mathematical, statistical and computational algorithms for advanced automated image classification of marine plankton. In 18 days the Hatfield Marine Science Center can collect nearly 50 million plankton images (80 terabytes of data), but for a person to identify the plankton species in each of these images one-by-one would take 18 years.

These examples highlight the creative approaches at the interface of disciplinary sciences, statistics, mathematics, informatics, and computational science that will be employed by MSI for improving our understanding of complex marine systems.

Data intensive projects greatly benefit from close involvement of quantitative scientists at all levels of the research endeavor, including the project planning, and experimental design stages *prior* to data generation, through to the interpretation of study results into policy making. The transdisciplinary approach that MSI will adopt will actively facilitate this close involvement.

OSU already has great strength in computer science (especially data mining and visualization), applied mathematics, statistics, biological and ecological informatics, and materials and structural engineering. OSU also has powerful data centers in the College of Earth, Ocean and Atmospheric Science, the College of Engineering, and the Center for Genome Research and Biocomputing, united via a new high speed (40-100 Gb) data network ("a Science DMV"). This strength will form a critical foundation for transdisciplinary problem-solving by the MSI.

A Think Tank Problem, Salmon Restoration: Salmon recovery has been a significant challenge for decades as it as the nexus of several processes in both natural and human systems. Moreover, it has linkages between regional and global-scale processes and spans annual to decadal time scales. Climate change (both directional and variability) will continue to have significant impacts on these processes, and it may change the fundamental nature of these interactions and our policy responses. Developing scenarios in the context of substantial uncertainty could be a valuable approach to inform decision-making.

V. The MSI Think Tank: Incubators of Knowledge to Action

To facilitate convergence of transdisciplinary research, education, and outreach and engagement across the MSI, there must be opportunities for faculty members to step away from their regular duties for some period of time to devote their attention to these efforts. This focus on innovative, transdisciplinary Marine Studies can be accomplished by establishing an MSI "think tank." The think tank will bring together researchers, educators, outreach and engagement specialists, and even students, focused on a common goal for a limited, preset period of time. The ideal amount of time may differ between projects, but could be as short as a quarter or as long as a few years. **Think tank topics will align with MSI goals and be motivated by finding solutions to challenges facing society related to sustaining healthy marine and coastal environments and communities.** A few examples are given below. As with other national and international think tanks, funding for these efforts could be acquired from private individuals, foundations and industry, in addition to state and federal funding. What is needed from the universities is 1) recognition that this is a valuable and important faculty activity; 2) mechanisms for allowing the temporary assignment of a faculty member to the think tank, including, for example, dealing with position descriptions, the tenure clock, and promotion and tenure considerations; 3) leadership to

coordinate think tank topics and activities, evaluate faculty applications for participation, and for pursuing external funding; and 4) resources to buy out faculty time so that they may participate in the think tank.

An MSI think tank will conduct fundamental transdisciplinary research on marine and coastal systems, synthesize existing research, and, perhaps most importantly, project complex consequences of political policies and human activities. In order to achieve these goals, it is necessary to develop models and scenarios that combine biophysical and human processes through complex and nonlinear feedback links. While easy to write, this is an exceptionally difficult challenge. The think tank would be tasked with generating new knowledge about the underlying processes as well as promote integration of knowledge to develop, test and explore these models and scenarios.

The think tank will provide a venue for bringing global experts in a particular field together for short-time duration workshops or for a longer research stay to work collaboratively on a yearly focus topic. This type of model exists in various capacities, for example, at University of Minnesota's Institute for Mathematics and its Applications, at the University of California at Berkeley's Marine Sciences Research Institute, at the National Center for Ecological Analysis and Synthesis at the University of California at Santa Barbara, at the University of Maryland The National Socio-Environmental Synthesis Center, and in the North Carolina Research Triangle Park at the Statistical and Applied Mathematical Sciences Institute. These facilities hold workshops, host postdoctoral researchers, and host visitors for year-long focus studies on topics of particular interest. Through such interactions, these facilities have brought international visibility to their institutions, and have advanced understanding of complex problems, and have developed new methods and approaches.

An MSI think tank will:

- Be a world class center for integration of knowledge from multiple disciplines
- Attract "virtual" participation beyond OSU and Oregon, including collaborations across national and international institutions
- Utilize and synthesize information from massive data bases including environmental observatories (Long Term Ecological Research, National Ecological Observing Network, Ocean Observatories Initiative, etc.) and data on human decision-making, demographics and politics.
- Develop and test sophisticated coupled models and scenarios, both empirical and process-based, of complex environmental, economic, and social systems
- Forecast complex social and environmental consequences of political and economic policies

Examples of topics/projects that an MSI think tank might tackle include:

- Forecasting climate change impacts on coastal and marine ecosystems and communities, including downscaling climate change scenarios to the local level
- Characterizing interactions between climate change impacts, policy incentives, and adaptation opportunities within marine and coastal systems

- Analyzing the complex interactions of new technologies (e.g., ocean energy extraction devices) on the coastal ecosystems, that is, socio-economic, physical environment, and ecological systems
- Improving community resilience to and recovery from natural disasters, including the effects of a subduction zone mega earthquake and the ensuing ground shaking across western Oregon and the inundation of coastal communities by the resulting tsunami

VI. Examples of OSU's Current Marine Expertise

Fisheries and farming

OSU's Department of Fisheries and Wildlife (FW), the Coastal Oregon Marine Experiment Station (COMES) and the College of Earth, Oceans and Atmospheric Sciences (CEOAS) have numerous faculty who focus on fisheries and interactions with their associated ecosystems. These faculty work closely with fisheries management entities such as NOAA's Northwest and Alaska Fisheries Science Centers, Oregon Department of Fisheries and Wildlife, Oregon Sea Grant, the Pacific Fishery Management Council, various fisheries commissions as well as private foundations and the fishing industry. Many of the fisheries management, research and regulatory agencies are located at HMSC.

In addition, OSU Extension, the Marine Resource Management (MRM) program of CEOAS, Oregon Sea Grant and other entities, such as the HMSC Visitor Center, help explain and resolve fishery issues that are often complex and contentious, as well as facilitate transfer of research findings to stakeholder groups. In support of this important work, a new combined COMES and Applied Economics faculty position has been established as part of the MSI, to support development and understanding of economic-based public policies, regulations and management of marine resources, including fisheries.

FW and COMES faculty work on a range of aquaculture species and technologies, including salmon and shellfish genetics, nutrition and polyculture. In addition, CEOAS faculty has developed seawater-monitoring systems and strategies to help oyster hatcheries and farmers deal with adverse effects of ocean acidification. USDA-ARS has established a shellfish aquaculture program at HMSC that currently focuses on interactions between shellfish aquaculture and estuarine ecosystems. HMSC has excellent facilities for aquaculture research but these are mainly located in NOAA-owned and operated buildings.

Several faculty in the College of Veterinary Medicine (CVM), Department of Microbiology and the Salmon Disease Laboratory focus on diseases of salmon and other aquatic species. In addition, the Oregon Central Coast Community College (OCCC), located close to HMSC, has built a recirculating aquaculture facility to support an NSF-funded aquarium science program. The program provides courses and training for students planning a career in the multi-billion dollar US aquarium industry.

Faculty in the College of Public Health and Human Sciences have partnered with Oregon Sea Grant to conduct community-based research to prevent injuries in the West Coast Dungeness crab fleet. These faculties also are completing an injury epidemiological study examining data on fishery worker injury in Alaska, Washington and Oregon in collaboration with the US Coast Guard and the National Institutes for Occupational, Safety and Health.

Consumers, public health, and toxicology

Faculty in the Departments of Food Science and Technology, the Astoria-COMES laboratory, the Food Innovation Center in Portland work closely with the seafood industry to develop new seafood products desired by consumers. They also educate consumers about the health benefits and risks of eating seafood. The College of Public Health and Human Sciences has programs in nutrition and dietetics that improve our understanding of the benefits of fish consumption and micronutrients found in fish. Additionally, the Environmental & Occupational Health program examines different risk assessment models that balance the health benefits of seafood consumption with the risks posed by contaminants in seafood to craft public health advisories regarding fish consumption.

The Nutrition program in the College of Public Health and Human Sciences and Linus Pauling Institute are also poised to play a significant role in determining the nutritional value and health benefits of consuming seafood and disseminating information to the public. In particular the Family and Community Health (FCH), 4H and other Extension outreach programs could facilitate dissemination and education. Other faculty in FW, the Marine Resource Management Program of COEAS and Oregon Sea Grant facilitate integration of OSU seafood research with the interests of a wide range of stakeholder groups.

The Toxicology Program (Department of Environmental and Molecular Toxicology - EMT) at Oregon State University has a long history of research and education in the general field of environmental toxicology and is internationally recognized for its excellence in aquatic toxicology research, testing and education. Faculty research programs in the department span the entire spectrum of environmental toxicology, studying the fate, distribution, metabolism and mechanisms of toxic action of anthropogenic chemicals present in the environment (air, water, soil, food, consumer products, industrial and agricultural processes, etc.), essentially all of which eventually translocate as inputs to marine ecosystems to some extent, and subsequently exert biological effects on marine organisms and ecosystems. Thus the EMT department studies how human activities impact the health and productivity of the marine ecosystem and subsequent impacts on human and environmental health, as well as the productivity and safety of marine food webs important for human consumption, marine ecosystem health or both.

OSU is also one of the few universities in the U.S. that continues to place considerable capital and human investment in postharvest seafood research. Faculty in the Departments of Food Science and Technology, the Astoria-COMES laboratory, the Food Innovation Center in Portland and the School of Business provide the seafood industry with new technologies, strategies and

information on enhancing seafood quality and safety as well as improved production, product development and marketing. Faculty in the Departments of Microbiology, Environmental and Molecular Toxicology, CVM, COMES and CEOAS also share expertise on the effects of harmful algal blooms, human pathogens and pollution on seafood production and safety. Faculty in the College of Public Health and OSU Extension has a long history of tackling food security issues, especially in family and youth.

Watershed studies

Examples of integrative research efforts at OSU include **Watershed Extension,** a multidisciplinary team of OSU professionals that address all aspects of watershed health and management, from restoration and gardening to fish biology and ecology.

- Sea Grant's **Master Watershed Stewardship** program, this team has trained hundreds of Oregonians in watershed processes, salmonid ecology, stream and riparian assessment and restoration, water quality monitoring and related topics.
- The **Ocean Observing Initiative** is another example of OSU leadership and excellence; this program is breaking new ground in observational oceanography and making remarkable new advances in ocean technology.
- The **Hatfield Marine Science Center** provides unparalleled access to the coastal and marine environment, research facilities, and state and federal partners that facilitate and enhance exceptional research opportunities.
- Work from the Watershed to the Sea also takes place at OSU through the marine mammal institute, the Oregon Climate Change Research Institute, the Northwest Climate Science Center, OH Hinsdale Wave Research Laboratory, Cooperative Institute for Marine Resources Studies, Coastal Oregon Marine Experiment Station, OSU Extension Service, 4-H Youth Development Programs (and many other youth outreach programs), OSU Sea Grant, the Institute for Water and Watersheds, Ties to the Land (Family Land Ownership and Conservation), the Integrated Plant Protection Center, Oregon Hatchery Research Center, the Pacific Northwest Ecosystem Research Consortium, Oregon Cooperative Fish and Wildlife Research Unit, Oregon Small Farms program, Master Watershed Stewardship Program, Northwest National Marine Renewable Energy Center, Pacific Marine Energy Center, HJ Andrews Experimental Forest, Portland-Vancouver Urban Long-Term Research Area, The Watershed Research Cooperative, and the Spring Creek Project to name a few.

Ocean and Coastal Engineering

- Modeling the ocean environment, fluid structure interactions, experimental work around wave characterization, soils and anchors
- Engineering faculty who have an interest in work in the marine environment: materials behavior; design and control of marine energy devices; underwater robotics

- Northwest National Marine Renewable Energy Center (NNMREC)—the national leader in marine renewable energy research, development and testing (and recognized as a global leader)
- The proposed Pacific Marine Energy Center-South Energy Test Site which will serve as the only grid connected wave energy device testing facility in the continental US—and a unique facility for a variety of research in the engineering and environmental areas
- Marine Biologists and Public Policy faculty engaged with marine energy

Oceanography, Ecology and Biogeochemistry

- We are among the best in the world in marine ecology, with expertise spread across multiple departments and colleges. These include groups of faculty in Integrative Biology and Microbiology (COS), Fisheries and Wildlife (COA), and Oceanography, most on the main campus but with several at HMSC part or full-time. Teaching in this area occurs on both campuses as well, but is limited to a small number of low-enrollment courses at HMSC.
- We have a small group of outstanding faculty in marine organismal biology, mostly in Integrative Biology, Microbiology and Fisheries and Wildlife.
- OSU's College of Earth, Ocean, and Atmospheric Sciences (CEOAS) also ranks nationally and internationally at the top and has outstanding expertise across most if not all oceanographic and geoscience subdisciplines.
- OSU and CEOAS in particular is a world-renowned leader in interdisciplinary marine studies, including basic research on physical, chemical and biological processes in the solid Earth, ocean, and atmosphere, and on fundamentals of relevant social science, as well as applications of the science to issues of societal importance, including climate change, natural hazards, resource exploration/exploitation, and the human dimensions of these issues. OSU is also at the forefront of observational oceanography via OOI and ocean technology.

PISCO: Partnership for Interdisciplinary Studies of Coastal Oceans.

- PISCO is a marine consortium of four universities along the US west coast, including OSU as the lead, and UC Santa Cruz, UC Santa Barbara, and Hopkins Marine Station (Stanford). Now in its 16th year of existence the focus was on understanding of coastal ecosystems along the California Current Large Marine Ecosystem (CCLME), and likely responses to climate change. PISCO is unique in coupling oceanographic and ecological research at multiple sites along the CCLME within the "inner shelf" by integrating mooring-based oceanographic platforms with cruises that is coupled genetic and physiological research aimed at understanding the mechanisms underlying organismal responses to environmental variability.

Marine Mammal Institute

- A multi-disciplinary facility incorporating the work of academics from engineering, genetics, agriculture, aquatics, ecology, veterinary medicine, biology, and

communications. As the only institute of its kind, the Marine Mammal Institute combines the efforts of top researchers from around the world to continue the legacy of discovery and preservation of critical habitats of target species and to understand how those species interact with their environment and human activities. Programs include the Whale Telemetry Group, Cetacean Conservation and Genomics Laboratory (CCGL), Pinniped Ecology Applied Research Laboratory (PEARL), and the Oregon Marine Mammal Stranding Network (OMMSN).

College of Public Health and Human Services

- Researchers in the College of Public Health and Human Sciences and the OSU Superfund Research Program's Community Engagement Core are building scientific capacity in Tribal communities and cultural capacity within the research community to evaluate chemical exposures that are a concern for Pacific Northwest Tribes. They engage in community-based participatory research with tribal members from the Confederated Tribes of the Umatilla Indian Reservation. A recent study measured polycyclic aromatic hydrocarbon (PAH) exposures in volunteers who smoke salmon using traditional methods. The data collected in this study showed the air in the smoking structures contained PAHs and that the volunteers absorbed PAHs into their bodies after smoking one batch of salmon. This study also showed that PAHs were present in the smoked salmon. Another study measured how PAHS that are found in traditionally smoked salmon are processed by the body. Mathematical models will be created using this information to evaluate the potential for human health risks from these PAHs.

- Researchers from OSU's Superfund Research Program have also collaborated with two northwestern Tribes, the Swinomish and the Samish, to analyze environmental samples for contaminants. The team worked with tribal representatives to identify Tribal concerns regarding pollution of butter clams (*Saxidomus gigantean*). In addition to identifying what contaminants may be present in the butter clams, the research team also aims to identify a new testing method to reduce the amount of resident shellfish that are collected when environmental sampling is needed. The goal is to predict clam contamination using passive pore-water samplers. If successful, this would enable researchers to determine shellfish contamination by putting out passive samplers instead of collecting clams. Using passive samplers is cheaper, faster, and less harmful to the local ecosystem than collecting resident organisms. This work will hopefully provide important information regarding risk from consumption of butter clams, new methods for monitoring baselines trends of contaminants, and may inform novel sampling methods useful to Tribes and Superfund researchers around the country.

- The goal with all of these Tribal studies is to address Tribal concerns regarding their environmental exposures, build Tribal capacity to measure environmental pollutants, and develop risk reduction strategies that will improve health without adversely affecting cultural practices.

V. Future Growth & Development

The Research Working Group considered the additional expertise that would be needed at OSU to ensure the success and enhance the impact of MSI-Research. Working group members solicited input from their colleges, departments, and colleagues and recommendations were made for the expertise needed within the proposed thematic research areas: 1) Integrated Marine Systems Science; 2) Reliance on the Sea; and 3) Global Change and Resiliency as well as "Cross-cutting" expertise that would enhance research across thematic areas. Examples of the needed expertise and potential clusters of related expertise are presented in Appendix A. The working group also recommended that establishment of certain technical positions, such as support services for ship operations and field activities, will be integral to the success of MSI-Research.

VI. Measuring Excellence in the Marine Studies Initiative

The development of a successful transdiscilpinary, convergent approach to marine studies will require novel thinking, unique approaches, and new metrics. To effectively develop meaningful metrics of excellence, the MSI will need faculty dedicated to study of transdisciplinary learning within higher education, faculty who study how students and the broader communities around Oregon and the world come to understand the complex processes that link the health of the land and sea via coastal waters. The MSI is an ambition vision and over the course of its growth and maturation, we must provide evidence that the MSI is providing value and is doing so effectively and efficiently. Measuring the impact of the MSI in this context is challenging and requires a scholarly approach. Therefore, the development of valuable metrics that assess the excellence and efficacy of the MSI will require an early investment in people with the appropriate training in the theory and practice of evaluation in research, policy, and education.

VII. Contacts

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Jessica Miller, College of Agricultural Sciences, Hatfield Marine Science Center (co-chair)
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Brett Tyler, Center for Genome Research and Biocomputing
Angel White, College of Earth, Ocean, and Atmospheric Sciences

Appendix A: General expertise for MSI Research	
Hired in 2015	
Geospatial intelligence, Climate Change Adaptation, and Coastal Processes (CEOAS)	
Marine and Coastal Economics and Ecosystems Services (CAS)	
Marine Evolutionary Systems Biologist (COS)	
Marine Policy (CLA)	
Marine Geodetic and Geodynamic Engineering (COE)	
Geospatial Intelligence and Planning for Marine Systems (CEOAS)	
Civil Engineer - Hinsdale Laboratory Director (wave tanks)	
EXAMPLE CLUSTER: RELIANCE ON THE SEA	
Tourism management/development	Some combination of skills in the following areas. Familiarity with the tourism sector, ideally in Oregon specifically. Understanding and experience with economic impact analysis. Understanding and experience within social impacts in the tourism context. Recreation ecology. Skills in sustainability and interdisciplinarity (convergence) given the interaction between this sector, natural environments, local economies, and local communities. Or skills in entrepreneurship, operations, finance, marketing, and so on -- ideally in tourism specifically. This may be well suited to an extension role.
Aquaculture	Seawater systems engineering, quantitative genetics, conservation, food production
Finfish aquaculture	Varied, but needs to address both the technical side of vertebrate aquaculture and should also be engaged in the ecological/economic/environmental aspects as well. A holistic approach to aquaculture.
Stock assessment	Research on data poor fisheries as well as on "non-conforming" fisheries (aggregations, hermaphroditism, skip spawning, and other complex life history strategies)

EXAMPLE CLUSTER: RELIANCE ON THE SEA: Healthy Coastal Communities	
Environmental and Occupational Health	Environmental sciences/ toxicology/ the science of climate change
Community Development	OSU Extension/ Social work/ Business
Social scientist - fisheries	Community-based research on various aspects of West Coast fishing communities, including ecology, energy, labor, food, markets, development, policies, institutions, and cultures. Qualitative and quantitative approaches. Ability to interface with government agencies, Outreach and Engagement (Extension), and Oregon SeaGrant.
Marine anthropologist - cultural heritage management	Community-based research on human dimensions of West Coast region. Focus may include: tourism, recreation, cultural heritage, conservation, coastal hazards, marine energy development, etc. Qualitative and quantitative approaches. Ability to interface with government agencies, Outreach and Engagement (Extension), and Oregon SeaGrant.
Food Security and Ecology	Nutrition/ Epidemiology/ Biostatistics
EXAMPLE CLUSTER: GLOBAL CHANGE AND COASTAL RESILIENCY: Coastal Community Resiliency	
Spatial Planner	This position would focus on elements of community and land use planning, especially as it relates to resource management.
Coastal Governance	Primarily responsible for developing approaches to understand complex decision making processes related to coastal and marine politics.
Coastal Hazards Education	This position, while similar to the environmental education position above, would focus specifically on coastal hazards (broadly defined).
Maritime Studies/Literature	This position would focus on elements of marine history, literature, and possibly archaeology. Or position could focus on international history/policies, such as international maritime trade and policies (including regional emphases), maritime security, maritime environmental issues, maritime law and organizations, and/or related fields.

EXAMPLE CLUSTER: GLOBAL CHANGE AND RESILIENCY	
Marine climate and climate change (metocean dynamics)	Study of metocean dynamics at different spatial and temporal scales, the analysis of the climatic variability of these dynamics, the development of mathematical methodologies and statistics to analyse extremes, climatic variability and the uncertainty risk of marine infrastructure; statistical approaches to GCM downscaling, weather typing, non-stationary extreme value theory, tailor made climate indices.
Long-term large-scale morphodynamic modeling	Coastal evolution modeling at scales of decades to centuries, coupling all components of the coastal tract - from the shelf, coastal zone, backshore, to bays and inlets; Influence of sea level rise on coastal/inlet morphodynamics
Remote Sensing	Researcher using state-of-the-art laboratory and/or field techniques to advance understanding on physical-biological interactions in marine plankton ecosystems, particularly in the context of how these interactions provide insight into potential consequences of global ocean warming. Systems of interest include but are not limited to the estuarine and continental shelf regions, intertidal systems, and the global pelagic zone. Topics of study include but are not limited to physical-biological interactions governing phytoplankton annual cycles in species composition and biomass, particularly regarding the intimate balance between phytoplankton growth and losses to zooplankton grazers and/or viruses.
Eco-informatics	correlations of diverse large data sets to infer causal relationships
Ecosystem ecology-biogeochemistry	field, lab and modeling research to document and model changes in and linkages among coastal ecosystems in response to climate change
Mathematical modeling of climate change	Using mathematical models to understand how climate change affects marine systems. Approach via model analysis, computation and simulation.
EXAMPLE EXPERTISE NEEDED FOR INTEGRATED MARINE SYSTEMS SCIENCE	
Mathematical modeling of marine systems	Using mathematical models to understand how marine systems behave. Approach via model analysis,computation and simulation
Statistics: big data in marine science	Big data applications in marine science plays an important role in the studies of marine ecology and marine environment, in geospatial intelligence, in meteorology, oceanography and satellite remote-sensing and in meta analysis.
Nearshore coastal processes -physical-biological interactions	Potentially, but not limited to larval dispersal modeling, population dynamics, ROMS and other regional oceanographic models, others

Bioacoustics	active and passive bioacoustics to study marine ecosystems; use of bioacoustics instruments from variety of platforms
Marine Algal Biologist and/or Systematist	Researcher involved in vigorous and innovative research on macro-algal and/or phytoplankton biology and interested in teaching courses in these areas. Or researcher involved in vigorous and innovative studies on macro-algal and/or phytoplankton biodiversity and interested in teaching courses in these areas.
Marine Optics/optical imaging	Researcher using marine optical measurements and data analysis to address contemporary issues in marine ecology and carbon cycling, including but not limited to those occurring at the land-ocean interface, the water column-sediment interface, and the pelagic open ocean Expertise in areas of theoretical optical modeling, field optical measurements, and/or in situ to satellite remote sensing are desirable. Advanced bio-optical imaging of marine organisms from cells to plankton to small fish; from variety of platforms
Plankton Physical-Biological Interactions	Researcher using state-of-the-art remote sensing approaches to advance understanding of ocean ecosystem composition and change, with areas of focus ranging in spatial scale from coastal/estuary systems to the global ocean and in temporal scale from sub-seasonal to decadal periods. Expertise includes but is not limited to bacterial, phytoplankton, and/or zooplankton communities, particularly involving interdisciplinary collaborations with field ecologists/physiologist and/or ecosystem modelers.
Ocean health	Assessment of diseases in upper trophic levels, including mammals
Toxicology across all trophic levels	Examining trends of natural and man-made compounds
Environmental Chemistry	Environmental chemistry of ocean/atmosphere interactions
Physcial scientist, focus on climate change and sea level rise	interactions between ice sheets, climate, oceans, and sea level
Paleoenvironmental reconstruction	geochemistry, paleobotany, Quaternary geology, ethnobotany, zooarchaeology
Archaeology	Excavation, materials analysis, artifact analysis. Expertise in GIS, remote sensing, and/or digital applications in archaeology
Geoarchaeology	Stratigraphic and geomorphic analysis and interpretation
	Additional Cross-Cutting Expertise
Transdisciplinary learning processes	Studies how learning and teaching processes within the MSI initative develop and provides input into curricular approaches and MSI evaluation.
Environmental education research	Study how undergraduate students, but also broader communities around Oregon come to understand (and act upon this understanding) the complex processes that link land with the health of the sea via coastal waters.

Citizen Science scholarship	Investigates the nature and outcomes of citizen science projects. Makes relevant scholarship available to MSI and OSU. Works with OSU researchers to support citizens science approaches to research, community development and learning through research, evaluation and consulting
Process and outcome evaluation for complex projects and initiatives	Primary responsibility for developing holistic approaches (and potentially push the limits on them) for the overall evaluation of the MSI initiative. Provides broader scholarship for assessing the value added and benefit/cost of major research and education investments to all stakeholders.
Statistics: uncertainty quantification	Mathematical models and their numerical outputs play a central role in climate studies (including how climate change affects marine systems), ocean circulations, tsunami predictions, geo-hazards mapping and in analyzing, simulating and predicting various other structures and processes of marine systems. Uncertainty quantification of these mathematical models is a key step that allows us to achieve bias correction, parameter calibration, efficient computer implementation and improved model predictions.
Mechanical engineering	Design and construction of 'devices' used for sampling the oceans directly or on animals
Electrical engineering	Energy-efficient sensors and sampling strategies for devices