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Marine resource scoping report "Ecosystem Approach for Sustainable Management of Marine Resources"

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1. Background

The ocean plays a pivotal role in the global biogeochemical cycles of carbon, nitrogen, phosphorus and a variety of other biologically active elements and chemical compounds, and provides natural resources that are vital to economies and human well-being (Noone et al, 2013). Estuaries and coastal zones are focal areas for land and sea interactions, where a variety of physical, chemical, biological and geological processes, combine, resulting in a complex array of habitats, many of which are sensitive and vulnerable to human activities. Estuaries and coastal seas have also been focal points of human settlement and marine resource use throughout history. Centers of population together with industrial and economic activity are concentrated near to estuaries and coastal zones, where approximately 60 % of the population and about two thirds of the medium to large size cities are concentrated. Rapid urbanization and industrialization along the coast, together with fossil-fuel combustion, agriculture, mining, waste generation as well as climate change, have a growing influence on marine biogeochemistry, both regionally in coastal ecosystems and globally in the open ocean (Fig. 1). Ocean acidification, coral reef degradation, coastal hypoxic, coastal eutrophication, sea level rise, salt marsh loss, increasing heavy metals and emerging pollutants due to coastal exploitation, have become major coastal and marine environmental challenges.

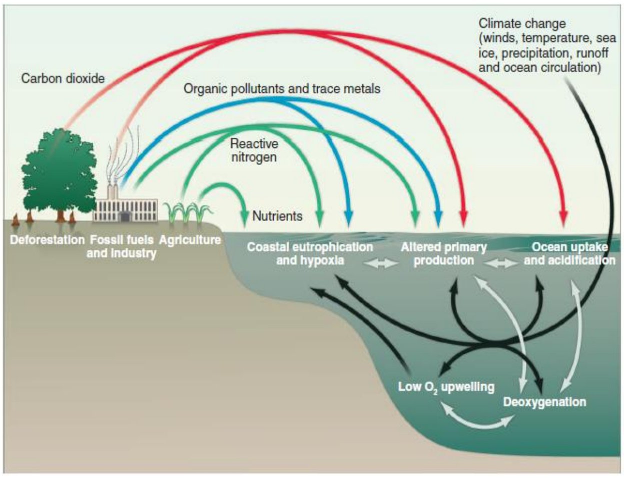

Fig. 1. Schematic of human impacts on ocean biogeochemistry either directly via fluxes of material into the ocean (colored arrows) or indirectly via climate change and altered ocean circulation (black arrows). The gray arrows denote the interconnections among ocean biogeochemical dynamics.

From a global perspective the open ocean (of which 64% is beyond national jurisdiction) is the largest source of oxygen, the greatest heat sink (keeping land temperatures relatively stable despite increasing greenhouse gas levels), the greatest store of CO_2 (now changing the fundamental chemistry of ocean water), and it continues to be globally significant in absorbing CO_2. There are major current concerns over ocean acidification, ocean deoxygenation, shifting currents and productivity patterns due to ocean warming, temperature and salinity shifts, carbon cycles in the ocean and marine plastic debris.

As atmospheric CO_2 increases, so does the amount of CO_2 dissolved in the shallow ocean, which in turn causes ocean pH to decline—a process known as ocean acidification (Munday et al., 2010). From preindustrial levels, contemporary surface ocean pH has dropped on average by about 0.1 pH units, and additional declines of 0.2 and 0.3 pH units will occur over the 21st century unless human CO_2 emissions are curtailed substantially (Doney, 2010). Ocean acidification will likely reduce shell and skeleton growth by many marine calcifying species including corals and mollusks, and also may reduce the tolerance of some species to thermal stress (Doney, 2010). Acidification–warming interactions can cause bleaching and productivity loss in coral reefs (Anthony et al., 2008).

Among all marine habitats, shallow coastal areas, including coral reef ecosystems, support the highest concentration of marine biodiversity. Yet, corals are declining around the world at an alarming rate, mainly as a result of more frequent, larger, and longer lasting bleaching events observed in recent decades (Polidoro et al., 2013). The world's coral reefs are deteriorating - nearly half may have disappeared in the past 30 to 50 years (Hoegh-Guldberg, 2006). Coral bleaching is a response to stress, which can be caused by a number of local or regional anthropogenic disturbances, including climate change, sedimentation, pollution, destructive fishing techniques, and overexploitation of fish and other reef inhabitants that maintain optimal reef conditions and control macroalgal growth (Pandolfi et al., 2011; Anthony et al., 2008). Scientific studies have indicated that human-caused eutrophication i.e., nutrient over-enrichment, is the main driver behind the expansion, intensity and duration of coastal hypoxic conditions (Rabalais et al., 2010). Until recently, hypoxic areas were found mainly on coasts and in estuaries of developed countries but the largest future increases in the number of hypoxic systems are expected in southern and Eastern Asia (Seitzinger et al., 2002). Evidence is growing that open ocean oxygen concentrations are also declining. Based on the analysis of all available data from the global oceans, Gilbert et al. (2010) determined that for the last three decades, oxygen concentrations have been declining faster within 30 Km of the coast between and 0 to 300m water depth than in the open ocean.

Low subsurface O_2, termed hypoxia, occurs naturally in open-ocean and coastal environments from a combination of weak ventilation and/or strong organic matter degradation. Coastal hypoxia is caused by eutrophication - that is, the overloading of waters with nutrients, especially nitrogen, phosphorous and organic matter. The effects of added nutrients on oxygen levels are exacerbated by local water body conditions, particularly strong stratification that prevents mixing and oxygenation of water body layers. Coastal areas, particularly in newly industrializing countries, are suffering from accelerating nutrient pollution from multiple sources, including agriculture and livestock production, sewage and industrial waste, and complex temperature and water exchange impacts from climate change. Worldwide there are now more than 500 coastal hypoxic systems covering an area > 245,000 km^2 (Doney, 2010; STAP, 2011). The number of coastal sites where hypoxia has been reported has increased with an exponential growth rate of 5.54% year-1 over time (Vaquer-Sunyer et al., 2008). Hypoxia directly impacts marine ecosystem function and services through changes in food web structure and biodiversity. The recent expansion of hypoxia in coastal ecosystems has been primarily attributed to global warming and enhanced nutrient input from land and atmosphere (Carstensen et al., 2014). Population growth and further coastal urbanization will exacerbate coastal hypoxia without careful land and ocean management (Doney, 2010).

On a global scale, the inputs of land-derived nitrogen and phosphorus into the ocean have trebled between the 1970s and 1990s which has consequences for the biogeochemistry and ecology of coastal seas (Jennerjahn, 2012). Nutrient inputs to the marine environment originate from point sources such as sewage effluents (treated or untreated) and discharges from industrial plants as well as diffuse sources mainly run off or groundwater outflows from agricultural catchments or polluted aquifers. Human inputs of nutrients to coastal waters can lead to the excessive algal productivity, a process known as eutrophication. Excessive nutrient loadings in coastal waters have been related to harmful algal blooms implicated in mass mortalities of living resources, emergence of pathogens (e.g., cholera, vibrios, red tides, and paralytic shellfish toxins), and colonization of non-indigenous species (Sherman, 2013).Eutrophication is associated with the development of hypoxia and the acidification of subsurface waters, it could increase the susceptibility of coastal waters to ocean acidification (Cai et al., 2011). Nutrient loads cause a variety of impacts such as high levels of chlorophyll-a, excessive growth of seaweeds, algal blooms sometimes toxic, reduction in abundance/biodiversity and decreased water transparency; in more advanced stages high bacteria levels, scums, fungi, hypoxia and finally anoxia (Kitsiou, 2011). The formation of dead zones has been exacerbated by increases in primary production and consequent coastal eutrophication fueled by riverine runoff of fertilizers and the burning of fossil fuels (Diaz and Rosenberg, 2008). Dead zones in the coastal oceans have expanded exponentially since the 1960s and have serious consequences for ecosystem functioning. Additionally, increased nutrient loading can also result in a decline in biodiversity, loss of salt marshes, greater susceptibility to disturbances, and the loss of ecosystem services (Carstensen et al., 2011).

Overfishing is increasingly threatening the world's marine ecosystems (Pauly et al. 2002; F. Berkes et al., 2006). Human hunting and fishing in coastal ecosystems has caused declines in key species, triggered trophic cascades, reduced the size of prey and resulted in reduced catches and loss of economic benefits (Sumaila et al., 2012). Although there is a rising demand for aquatic products, global catch appears to have stabilized or even be declining (Watson et al., 2013; Yamane 2015). In order to feed a growing world population, aquaculture production has increased from 650 thousand tonnes in the 1950s to almost 67 million tonnes (FAO, 2014). In the same period, the total marine catch increased from 10 million to about 80 million tonnes. Today, aquaculture provides half of all fish for human consumption, and the sector is expected to grow. Farmed fish production surpassed beef production in 2012. With the development of marine bio-technology, aquaculture continues to expand more rapidly than other sectors producing food of animal origin with an average annual rate of 8.8 percent since 1970. It is important to ask the question; is it likely that aquaculture can continue growing at this rate into the future? Analyzing the growth of salmon aquaculture in the four leading producing countries (Norway, Chile, Scotland and Canada), Liu and Sumaila (2008) came to the conclusion that we may need to temper our optimism for this sector because of the many constraints that fish farming faces (Naylor et al., 2000)

Broadly speaking, fish farms can release nutrients, undigested feed, veterinary drugs and biocides to the environment. They can also create conditions that increase the risk of diseases and parasites. Farmed fish and shellfish can escape to surrounding waters, which may have negative impacts on ecosystems through genetic regression or introduction of invasive species. In some countries certain forms of shrimp farming have destroyed large areas of coastal habitats, such as mangrove forests. Use of fish-based feeds in aquaculture can put additional pressures on poorly managed wild fish stocks and on the marine environment. Other impacts include pollution by chemicals and pharmaceuticals, eutrophication resulting from releases of nutrients in the form of feed and waste, and salinization of arable land and freshwater supplies. In many places there have also been social and community impacts (Naylor et al., 2000).

The development of productive capacity by human society has been linked to the exploitation of natural resources. During past several millennia, continental land masses were the only source of mineral materials. Demand for minerals and derived metals is growing rapidly due to population growth and increasing wealth. Therefore, it is likely that, in the coming decades, there will be a growing drive towards the exploitation of deep-sea mineral resources. Exploitation of oil resources from the sea-bed started in the last quarter of the 20th century and now provides 20% of world oil production (Baturin 2000). Increased competition for metal resources from rapidly expanding economies may cause shortages in the future. Deep-sea mineral deposits will not replace land-based mining, but will offer an additional source of raw materials to meet the increasing demands. The occurrence of deep-sea minerals has been known for more than a century. However, their grade and tonnage distribution throughout the global ocean is poorly known. Studies dedicated to understanding their genesis, distribution, and resource potential began more recently (Hein et al. 2013), and the first industrial scale deep-sea mining activity began a few years ago with the Solwara-I massive sulfide gold-copper-zinc-silver production project (Nautilus Minerals), which is located in the Bismarck Sea, off the coast of Papua New Guinea, progressing rapidly towards the effective launch of an industrial operation.

In addition, global energy demand is expected to double in the next two decades (Chu and Majumdar 2012). Securing the provision of increasingly large amounts of energy at economically affordable prices (on global and regional levels), reducing greenhouse gas emissions e.g. by increased use of renewable energies, is therefore crucial in a world facing both population and economic growth (Suarez-Arriaga et al. 2014). Geothermal reservoirs contain huge amounts of energy, and their energy potentials are much larger than those of onshore resources. However, there are many problems and threats to sustainability of marine environment resulting from the use of marine resources, such as pollution by introduction of dangerous substances from shipping, oil spills, telluric pollution, marine litter, industrial, agricultural or household waste, pollution of the atmosphere and transatmospheric, noise, etc. (Stan 2013).

A particularly concerning, yet avoidable, pollutant in the oceans is marine debris. Plastics bring numerous societal benefits, these include healthcare and educational applications, lightweight components in vehicles and construction (Andrady and Neal, 2009). Global production of plastics has increased considerably from around 5 million tonnes in the 1950s to some 300 million tonnes today. Despite the durability of plastics they are predominantly used for short-lived applications (around 40% of production is used in packaging sector). As a consequence the accumulation of end-of life plastics is becoming a major environmental problem both in regulated waste management facilities and as litter in the environment (Koelmans et al., 2014; Thompson et al., 2009a). Marine litter is a growing environmental problem, it is widely distributed at the sea surface, on the sea bed and on shorelines (Barnes et al., 2009; Galgani et al., 2000; Pham et al., 2014; STAP, 2011). The majority of this litter is plastic (~75%), with other materials such as glass and metal representing only a small proportion of litter in the oceans. In addition, larger items of plastic debris are progressively fragmenting in to smaller pieces known as microplastics and these are now widely distributed at the sea surface in the water column in sediment s and in biota (Browne et al., 2011; Law and Thompson, 2014; Obbard et al., 2014; Woodall et al., 2014). Even if the addition of new items of plastic debris to the environment were to halt tomorrow, quantities of microplastic would continue to increase because of the fragmentation of larger items (Law and Thompson, 2014). Nearly 700 species are known to encounter marine litter, with many reports of physical harm resulting from entanglement in and ingestion of plastic debris (Gall and Thompson, 2015). There is emerging evidence of the potential for physical and toxicological effects from ingestion of microplastics (Rochman et al., 2013; Wright et al., 2013) and that plastic debris has the potential to affect communities of organisms and the ecosystem services they provide (Green et al., 2015). There is recognition that we need to change the way we produce, use and dispose of plastic items (Koelmans et al., 2014; Thompson et al., 2009b). All of the items that become marine litter are produced on land and the solutions to the problem of marine litter lie in ensuring that, at the end of their lifetime, items are properly disposed of on land (Koelmans et al., 2014; STAP, 2011; Thompson et al., 2009b).

In addition, with the rapid industrialization and economic development along the coast, chemical compounds and heavy metals continue to be introduced to estuarine and coastal environment through river and groundwater discharge, oceanic dumping, and emissions into the air (Kaimoussi et al., 2002). This contamination is especially important in sediments which usually act as a sink receiving the chemical compounds and heavy metals through adsorption onto suspended matter and subsequent sedimentation (Fang and Hong, 1999; Zwolsman et al., 1996). Increasing levels of persistent organic pollutants and heavy metals in the ocean raise concerns for the health of marine ecosystems as well as to human health for example as a consequence of bioaccumulation and biomagnification. Industrial pollutants and oil spills can spread into pristine environment through the atmosphere in the vapor phase, aerosols, and soot particles; by ocean currents; and in some cases by migrating animals, to even the most remote marine locations, where they can disrupt the local and regional marine environment (Doney, 2010).

Economic disincentives, fragmentation or lack of government funding and compliance priority, together with corruption all interact to stifle progress in reversing the degradation and depletion of coastal and open oceans. Failures in governance are most often used to explain the continued depletion and degradation of coastal oceans. It is not just that the existing framework is fragmented and complex due to political considerations, but also natural systems are so complex and variable that it makes it difficult to formulate, adopt, and implement appropriate governance systems. Governance is not just government but it also includes institutions and organizations that can possibly help to influence human behavior and direct it in a good manner. These can vary from market mechanisms to government action and work of non-governmental organizations, social institutions, and civil society.

In summary, the marine ecosystem is being altered at greater scale and rate than ever before. Overexploitation, habitat transformation, and pollution have obscured the total magnitude of estuarine degradation and biodiversity loss and have undermined their ecological resilience. Most of these perturbations, tied either directly or indirectly to human fossil fuel combustion, agriculture, and industrial activity, are projected to grow in coming decades, resulting in increasing negative impacts on ocean biota and marine resources. Taking into consideration the above challenges, the UN Sustainable Development Goals (SDGs) have included goal 14 to conserve and sustainably use the oceans, seas and marine resources for sustainable development, including targets for marine pollution from land-based activities, coastal ecosystems management, ocean acidification, conservation of coastal areas, and sustainable management of fisheries, aquaculture and tourism, and there are all together 60 targets across most of the 17 goals that are relevant to the complex issues facing the coastal zone.

2. Justification

2.1 Existing knowledge base

There are a wide range of international and national organizations working in the field of marine resources, marine ecosystem, and marine environmental management: all UN bodies as well as many other IGOs and NGO's have developed programs of activities; new multi-stakeholders discussion fora have been created such as the Global Ocean Commission or the European Marine Board. Within the UN system, more than 13 organizations are related to research and management of marine resources and environment, with UNEP, FAO and UNESCO most noticeable for inter-linkage between science and policy for marine resource and environment.

UNEP Marine and Coastal Ecosystems Branch (MCEB) hosts the Marine Ecosystems Unit (MEU), the Global Program of Action for the Protection of the Marine Environment from Land based Activities (GPA), and the Regional Seas Program (RSP).

- MEU develops tool, guidelines and implementation of demonstration projects on ecosystem-based adaptation, climate change vulnerability assessments and adaptive marine spatial planning.

- GPA is currently the only global intergovernmental mechanism directly addressing the connectivity between terrestrial, freshwater, coastal and marine ecosystems, and its key component is the development and implementation of the National Programs of Action (NPAs) for the Protection of the Marine Environment from Land-based Activities. The GPA program is focusing its efforts on three source categories: marine litter, wastewater and nutrient management.

- RSP covers 18 regions of the world, making it one of the globally most comprehensive initiatives for the protection of marine and coastal environments, aiming to address the accelerating degradation of the world's oceans and coastal areas through the sustainable management and use of the marine and coastal environment, by engaging neighboring countries in comprehensive and specific actions to protect their shared marine environment. The key issues of RSP include coastal management, ecosystems and biodiversity. The Regional Seas programmes function through an Action Plan, underpinned with a strong legal framework in the form of a regional Convention and associated Protocols on specific problems.

- LME Large Marine Ecosystems (LMEs) are regions of ocean space of 200 000 km2 or greater, encompassing coastal areas from river basins and estuaries out seaward to the break or slope of the continental shelf or out to the seaward extent of a well-defined current system along coasts lacking continental shelves. The World's LMEs are defined by ecological criteria including (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically linked populations (Sherman, 1993; Duda and Sherman, 2002). This is a global effort underway by scientists, stakeholders, resource managers, and multi-sectoral ministerial representatives (e.g. fisheries, transportation, mining, energy, tourism, and environment) from 110 economically developing countries to implement ecosystem-based management at the Large Marine Ecosystem scale. The LME approach is based on five modules for measuring changing states in LMEs including (i) productivity, (ii) fish and fisheries, (iii) pollution and ecosystem health, (iv) socioeconomics, and (v) governance. Analyses of time-series measurements from the modular suites of indicators provide the basis for developing and implementing management actions to recover and sustain LME goods and services.

The UNESCO Intergovernmental Oceanographic Commisson (IOC) focuses on the monitoring of ocean responses to climate change and investigating marine ecology and ecosystem health, and supports marine ecosystem-based management and marine information programs for the sustainable use of the ocean. IOC has established a series of global ocean observing systems like global ocean observation system (GOOS), global sea level observation system (GLOSS), ocean biogeographic information system (OBIS), and ocean observation panel for climate (OOPC), and launched programs for ocean science and networks of scientific logistic facilities at global and regional scale. Together with the Man and the Biosphere (MAB) Programme, UNESCO IOC has also endeavored to strengthen ecosystem-based management through Marine Spatial Planning (MSP) to manage both conflicts and compatibilities in the marine resources development (Ehler and Douvere, 2009).

Thirty years after adoption of the UN Convention on the Law of the Sea (UNCLOS), governance for coastal and marine systems remains a fragmented patchwork of conventions, agreements, programs, and voluntary codes of conduct. The patchwork has become even more complex with newer global conventions on Biological Diversity, Persistent Organic Pollutants, Ship Ballast Water, Mercury reduction and the relatively new concept of Large Marine Ecosystems (LMEs). In order to better understand the complexity of oceans governance, it is instructive to start at the global level with the array of international legal agreements and international organizations with programs that can influence management of coastal areas and oceans. UNCLOS sets the framework and a number of global and regional agreements complement it. Complementary global legal frameworks range from the Fish Stocks Agreement, London Dumping Convention, Convention on Biological Diversity (CBD), the Port State Measures Agreement, Ballast Water Convention, and MARPOL for pollution from vessels to regional seas agreements with UNEP and regional fisheries agreements with Regional Fishery Management Organizations (RFMOs) often with FAO assistance. The patchwork of laws and programs provides mostly thematic and sector-specific authority for some actions, however compliance is questionable in some cases and other issues exist such as trafficking of workers on fishing fleets.

Besides the UN system, many research institutions have been working on international, regional or national programs of ocean science, including International Council for the Exploration of the Sea (ICES), Scripps Institution of Oceanography and Woods Hole Oceanographic Institution in the USA, National Oceanography Centre in UK, Helmholtz

Centre for Ocean Research in Germany, Atmosphere and Ocean Research Institute of the University of Tokyo in Japan, and the relevant institutes within the Chinese Academy of Sciences in China. Many national or regional organizations including for example NOAA in the US or the Prince of Wales International Sustainability Unit in UK, have launched excellent initiatives. The EU is implementing the Marine Strategy Framework (MSF) Directive which inter alia requires EU Member states to monitor and report on the state of their waters, and to draw up Programmes of Action for achieving Good Environmental Status as defined under the directive. In implementating the MSF Directive, the European regional sea commissions, like the Baltic Marine Environment Protection Commission (HELCOM), play a pivotal role. Hence there is considerable knowledge about particular aspects of the marine resource and environmental problems and associated actions.

Data on marine resources, though fragmented or piecemeal, are available from other stakeholders such as civil societies or industrial associations, the following are some examples:

Civil Society

- Earthworks http://www.earthworksaction.org/
- Mining Works Canada http://www.miningwatch.ca/
- Mineral Policy Institute http://www.mpi.org.au/
- Oceana http://oceana.org/

Industry led initiatives

- International Council on Mining and Metals http://www.icmm.com/
- World Ocean Council http://www.oceancouncil.org/site/
- Prospectors and Developers Association of Canada http://www.pdac.ca/
- Australian Mines and Metals Association http://www.amma.org.au/

A considerable body of knowledge and expertise on marine resources – including globally significant practical experiences, challenges and lessons learned – remains isolated in specific regional or disciplinary knowledge communities, and a lot of studies are going on, but they are not always well coordinated. Most importantly there is a lack of systems thinking. Global initiatives such as the Global Ocean Commission, the Global Program of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) or the Regional Seas Programs, have highlighted the need to address the connections between terrestrial, freshwater, coastal and marine ecosystems using holistic and integrated approaches. There is a pressing need for authoritative knowledge synthesis work in this area. The impact of equivalent synthesis-oriented initiatives in related fields (e.g. the IPCC, TEEB Studies, and Millennium Ecosystem Assessment) is illustrative of what has not yet been achieved specifically in relation to marine resources. The IRP is well placed to undertake such a work.

2.2 Added value of an IRP study on "Ecosystem Approach for Sustainable Management of Marine Resources"

Knowledge and data gaps

Although many institutions have considered human impacts within marine or coastal ecosystems (habitat destruction, biodiversity loss, overfishing, pollution, impacts of climate change, and ocean acidification), there are very few that consider the dynamic inter-relations beyond these ecosystems. For instance, over 80% of marine pollution comes from land-based activities, including fertilizers, pesticides, sewage, garbage, metals, plastics and oil (Global Ocean Commission). The speed and magnitude of global change (population growth, rapid urbanization, growing resource and energy intensive consumption), the increasing connectedness of the social and natural systems at the planetary level, and the growing complexity of societies and their impacts all demand systems thinking to identify effective responses to the great environmental and social challenges that lie ahead. Trans-disciplinary approaches will be required for such an analysis.

There is a need for in-depth analysis of the impacts of urbanization on coastal ecosystems, and integrating the biogeochemical elements into the sustainable development goals (SDGs) and strategies. Several UN SDGs are relevant to management of N, P and C cycles aiming at sustainable food production, sustainable water security and healthy and productive ecosystems. We need multidisciplinary studies that cover the whole cause and effect chain to investigate how the SDGs could be met simultaneously in urbanizing coastal regions.

When managing marine pollution problems related to the N and P cycles, links with other pollutants that are transported by water or air need more attention. For example, co-management of pollutants can help to avoid trade-offs. For water pollution, it may be worthwhile to not only focus on links between the N and P cycles, but also on toxic chemicals such as POPs, heavy metals, as well as on the solid items of waste that become marine litter. It would be interesting to study not only the loads of these pollutants that are transported by water from land to sea, but also their effects and ways to reduce their fluxes. The interface of land based industrialization and coastal biogeochemical cycling remains an intriguing one that the research community is only beginning to address, but we see it as a vibrant arena for coastal zone research and management, in tandem with the urbanization process that will intensify over the coming decades.

A further challenge is uncertainty about measurement of future values provided by marine ecosystem services. For example, estimation of habitat–fishery linkages has to be conducted for the multiple benefits arising from entire interconnected habitats to accounting for the spatial variability of habitat–fishery linkages due to coastal wetland reduction or marine aquatic pollution. Valuation of eco-markets for marine ecosystem conservation and sustainable development in the coastal zone is also challenging due to the complicated relationship between economic development and coastal human impact, especially in developing countries.

From a policy and governance perspective, there is currently a lack of focused attention on responses that address poor management of marine resources in a systemic/holistic way that takes into account cross-sectoral and multi-level interactions and impacts of land-based activities. In terms of natural capital accounting and other economic instruments, the considerable methodological, technical, and policy progress in recent years is largely confined to terrestrial contexts. For example, there has to date been comparably little research concerning options for implementing the UN System of Environmental–Economic Accounting (SEEA), the World Bank Wealth Accounting of natural resources and 2013 SEEA Experimental Ecosystem Accounting framework in marine and coastal contexts.

Content of proposed study

In 2014, the UNEP International Resource Panel (IRP) hosted a series of expert discussions to explore the potential added-value of an IRP assessment report on the sustainable management of marine resources. At the 15th IRP meeting held in November 2014, the members of the Panel and of its Steering Committee further discussed the potential added value of an IRP assessment. It was concluded that the IRP could contribute to a better understanding on marine resource exploitation and use through a broader systemic perspective focusing on Resource Efficiency (RE), Decoupling, and Life-Cycle Assessment (LCA). With regard to the topics to be addressed by the IRP, insufficient availability of data on deep sea mineral resources was noted, as well as the fact that there are other fora and initiatives already addressing international governance regimes in the high-seas.

It was suggested that the Panel could focus on the drivers and root-causes of impacts of land based and coastal activities on the coastal and marine environment, and point to solutions and pathways bringing together the blue and green economy agendas through a Resource Efficiency (RE) perspective. At the end of the meeting the IRP Steering Committee (SC) approved a new work area on Marine Resources with a potential focus on the inter-linkages between the blue and green economy, particularly looking at the interactions between land and sea-based activities through a resource efficiency lens using a systems approach.

Three scoping workshops have been held with wide participation of international experts and institutions. After examining the selected topics, the experts highlighted the following potential added value which IRP study could generate:

- Identification of opportunities for **resource efficiency** improvement in land based human activities using an **Ecosystems Services Approach**, where ecosystems services are defined as “the benefits people obtain from ecosystems” (Millennium Ecosystem Assessment, 2005).
- Contribution of these resource efficiency improvements to new economic thinking and development pathways for sustainable resource management (e.g. blue and green economy, decoupling, circular economy).

- Application of **life-cycle assessment** and **systems thinking** to (a) understand land and sea dynamics including the social and economic drivers of current unsustainable trends in marine resource management, and (b) identify critical action points and multi-stakeholder responses at early stages of the system (inland) rather than focus on end-of-pipe solutions.
- **Application of economic valuation (considering externalities)** of impacts on marine ecosystem services from land-based activities, including the cost and benefits of alternative pathways.
- **Incorporation of coastal and marine components into the environmental impact** assessment and planning of land-based activities (even those far in land but with evident hydrological or aeolian connections to the ocean), a significant step in acknowledging the spatially interconnected nature of land-based activities and the ocean setting.
- **Identification of a data set for marine resource use and a set of high level indicators** for marine ecosystem and resource efficiency that can be utilized for establishing SDGs that are related to marine resource, environment and green economy.
- **Assessment of the current multi-level international governance regime** of marine resources, and provision of governance suggestions for sustainable management of marine resources, including where appropriate for resources beyond national jurisdiction.

In summary, the added value of the proposed study includes assessing the multi-functionality of the marine environment, and resource efficiency of human uses, and provision of a grand picture on impacts of land based human activities on marine resource from the perspective of ecosystem functioning and services and considering a life cycle perspective. Through the proposed assessment, the IRP has an opportunity to establish itself firmly as the main information provider for marine resource use data and indicators of local, national and regional policy relevance for target setting and implementation of SDGs.

3. Theoretical or methodology framework

As discussed above, marine ecosystems provide a wide spectrum of goods and services that are fundamental for human wellbeing and development. Meanwhile the function and health of marine ecosystems depend very much directly on the way we manage our resources inland. We rely on these ecosystems for storm buffering, fisheries production, clean air, stable climate, rain and fresh water, transport and energy, recreation and livelihoods. Unfortunately, the benefits arising from many services provided by coastal ecosystems are not marketed, particularly for the indirect use values. It is, therefore, necessary to evaluate also the non-monetary value of the ecological services, and their beneficial flows that are threatened by the continuing degradation and loss of these systems globally, while being the focus of many competing human uses and exacerbated by growing urbanization along the coast.

So far, **ecosystem service (ES) assessments** have mostly concerned terrestrial ecosystems and have not been so much developed in the marine field. So there is much room for an IRP study to properly identify and characterize marine ecosystem services and to provide ecosystem service assessment frame-works for designing future marine policies. The assessment and valuation of marine ecosystem services can provide a benchmark for analyzing the interaction and trade-off between environmental conservation and economic development, and promote understanding of the services provided by the marine environment, and determine values for the benefits arising from them, in the context of changing levels of pressure and alternative management scenarios. These possibilities make the approach attractive to stakeholders and decision makers.

Increasing and diverse use of the marine ecosystem is leading to human-induced changes in marine life, habitats and landscapes, making necessary the development of marine policy that considers all members of the user community and addresses current, multiple, interacting drivers, pressures, states, responses and impacts (DPSIR). Therefore, a systems approach is taken incorporating the DPSIR framework (Fig 2) with ecosystem services and resource efficiency.

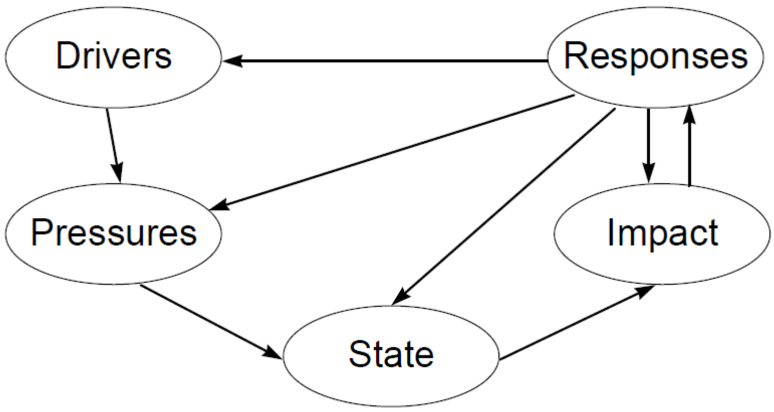

Figure 2. DPSIR framework according to EEA (EEA, 1999).

The DPSIR framework has been widely applied since the 1990s. The latest development is further strengthening and clarification of the socio-economic dimensions especially by emphasizing that consideration of the *Impacts* should focus on the impacts of environmental change on economies and human wellbeing, given that many marine ecosystem processes are affected by multiple stressors and the synergistic effects of human perturbations is a key area. Consequently, the *State* describes the change of the ecosystem due to the *Pressures*, which makes the *State* to cover all environmental changes that were partly included in the Impacts as shown in Table 1.

Table 1. Major components of DPSIR (or DPSWR) framework

Information category	Definition	Comments
Driver	An activity or process intended to enhance human welfare.	• Organizing activities into economic sectors assists in directing attention to the most salient areas of the economy. • Where necessary the category can be split between: -Immediate Drivers: activities proximal to at least one Pressure. -Underlying Driver: population, economic, social and technological factors that influence the level/nature of Immediate Drivers.
Pressure	A means by which at least one Driver causes or contributes to a change in State.	• A pressure is a link between a Driver and a change in environmental State, effectively therefore the agent of change.
State (change)	An attribute or set of attributes of the natural environment that reflect its integrity regarding a specified issue (or change therein).	• The extent to which a system has been subject to disturbance, particularly in terms of ecosystem functionality • Changes in State over time. • Natural variability or other anthropogenic pressures can influence the State change. • Encompasses all ecosystem changes other than those which constitute Pressures
Impact (Welfare)	Impacts on human welfare* A change in human welfare attributable to a change in State**.	• Usually understood as negative impact on human welfare caused by change of State, but the change can be also positive. • Welfare is not only affected by changes in use values; it can be affected by changes in non-use values that people hold.
Response	An initiative intended to reduce at least one negative Impact (State or Welfare change).	• An action that is taken because the effect on Welfare.

* Elliot (2014) uses the term Impact, but in the sense of Cooper (2013)

** Cooper (2013) uses the term Welfare

Marine ecosystem services and resource efficiency can be linked under the DPSIR framework (Fig 3). The key to approaching **resource efficiency** aspects within the DPSIR framework is the dynamic linkages between ***D****rivers* and ***P****ressures*, which includes the concepts of resource decoupling and impact decoupling in the IRP report "Decoupling Natural Resource Use and Environmental Impacts from Economic Growth" (Fischer-Kowalski et al., 2011). **Resources** would be broadly defined, therefore including abiotic or biotic resources, terrestrial or marine resources as well as various **ecosystem services**, focusing on the use of resources that have impacts on the marine ecosystem services. **Resource efficiency** would be defined three-dimensionally as an improvement of productivity while minimizing intensity and maximizing welfare (resource efficiency within resilient boundaries) that helps identifying effective targets for environmental management actions and other policy instruments, in other words, where to target the societal ***R****esponse* to ensure the decoupling effects. This would enable the IRP to propose resource management strategies, for example, how to apply appropriate legal, policy and governance frameworks to mediate or adjust *Drivers, Pressures, States* or *Impacts*, that are economically sound and that secure resilient socio-ecological systems.

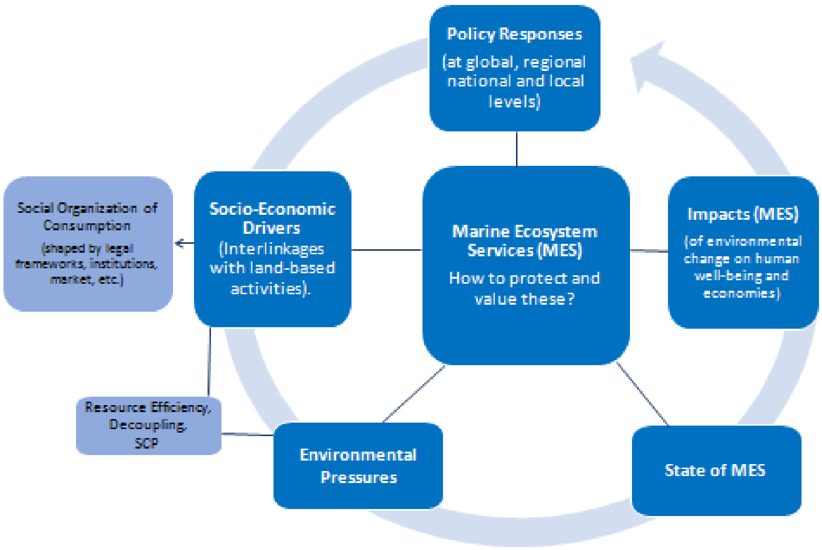

Figure 3 Linking ecosystem services and resource efficiency under DPSIR framework

The delimitation of **boundaries** within the DPSIR analysis will be essential. While the assessment will be global, some principles could be extrapolated and applied at the local level, in particular when looking at responses for efficient coastal zone management. Some experts suggested using services deriving from Large Marine Ecosystems[1] (Sherman, 2014) as a starting point for the DPSIR analysis, looking at impacts from land-based activities up to the Exclusive Economic Zones. Once these services and their state are identified the assessment could zoom into some essential drivers (e.g. aquaculture/mariculture, agriculture, mining, tourism, product design, consumer behavior, trade, natural hazards due to climate change, growing urbanization in coastal zones, etc.) and environmental pressures (marine debris, ocean acidification, coral-reef degradation, invasive species, shoreline alteration, changes in freshwater inflow) and the causal relationship with the identified impacts (e.g., economic: increasing infrastructure investments, land use change, industrial transformation; environmental: carbon emissions, heavy metals, emerging pollutants, and nutrient pollution;

1 Regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundary of continental shelves and the seaward margins of coastal current systems.

social: change in poverty levels in coastal populations, impact on food security and livelihoods).

The DPSIR conceptual framework is comprehensive, providing the scientific foundation and structure to organize and report information across the broad spectrum of needs for regional-scale environmental management, as well as reaching the breadth of audiences with interests in the health of coastal and ocean regions of the world. At the other end of the spectrum, this conceptual framework can help scientists identify uncertainties in those aspects that matter the most to ecosystem health, and then allocate resources towards those studies that will best reduce uncertainties and improve critical understanding of the ecosystem. Moreover, the hierarchical nature of the DPSIR framework provides the structure for most effectively aggregating and combining data to create synthetic indicators, as well as to organize and communicate information most effectively to stakeholders and the public.

An alternative approach would be to use the impacts as a starting point and apply the DPSIR model and ecosystem service assessment methodology to some of these to trace back the drivers and pressures from land-based activities and formulate adequate policy responses (e.g. waste management systems, policy and economic instruments for behavioral change at the production and consumption phase).

4. Framework for the study report

4.1 Objectives

To address the challenges identified, the proposed objectives of this work are:

1. To assess the status of existing knowledge concerning marine resources, especially impacts of land based activities on marine ecosystems, with a focus on coastal urbanization, marine litter, aquaculture/mariculture, nutrient management, heavy metals, and emerging pollutants, based on available academic and policy studies.
2. To assess the current state of methods used in different global and regional studies and datasets, and develop systems thinking with applications of marine ecosystem services and resource efficiency under the DPSIR framework for methodological development.
3. To identify the major drivers, pressures and impacts of marine resource use, the interactions between the social and economic drivers, environmental pressures and impacts on marine ecosystem, and current governance frameworks to mediate or adjust drivers, pressures, or impacts.
4. To identify and develop practical, policy-relevant approaches and techniques for assessing marine resource use and sustainable improvement of marine ecosystems and resource efficiency that can be utilized for implementation, monitoring and

evaluation of SDGs that are related to marine resource, environment and green economy.

5. To identify and characterize key policy gaps concerning marine resource use and marine ecosystem management, opportunities for resource efficiency improvement in land based human activities using an ecosystem services approach, and propose strategic frameworks and policy options for increasing the efficiency of marine resource use at national and regional scales.

4.2 Scope

The scope of this study is an assessment of the current state of knowledge about global marine ecosystem management, marine resource use and productivity, and impacts of land based and coastal activities on marine resource sustainability. The study aims to highlight the importance of incorporating of coastal and marine components into environmental impact assessment and planning of land-based activities. It will acknowledge the spatially interconnected nature of land-based activities and the ocean setting, by expanding knowledge for use by academia, industry and the practitioner community engaged in the marine sustainability policy domain. The study will present systems thinking and a marine ecosystem approach through a comprehensive report, intermediate research papers or datasets, policy suggestions, and various forms of engagement and communication with multiple stakeholders.

4.3 Structure

The assessment study will be delivered in two phases where phase 1 focuses on the current state of knowledge and data availability, while the second phase will have a focus on identifying up-to date knowledge and data into the future and will have a stronger focus on policy development.

The first phase, the assessment study will synthesize the large amount of information that has been generated by the scientific and policy community on marine resources, and produce a report on linkage of land based human activities and marine resource productivity at the global scale.

In the second phase, the working group will develop further the methodology for systems thinking with applications of marine ecosystem services and resource efficiency under the DPSIR framework, compile case studies on country or regional scales for marine ecosystem management, and prepare the final study report with a stronger focus on the policy and capacity needs to improve marine resource efficiency.

4.4 Focus areas

Major land based activities: What are the major land based activities that affect marine ecosystem sustainability? A major challenge is to move away from consideration of aspects of the problem in isolation, such as the accumulation and impacts of marine pollutants from land based activities or from end-of pipe solutions toward a more systemic approach that considers the accumulation of waste, both on land and in the sea, as being part of a broader problem; that stems from linear use of resources, through life in service to the generation of waste. There are specific knowledge gaps for example relating to product design and recycling as well as in identifying approaches to engage the public and key stakeholders. From a policy perspective we need to better understand the linkages between actions on land and inputs to the ocean.

Excess nutrients: Land-based nutrient pollution and the consequent eutrophication in marine environments is a topic that could be investigated further by the Panel. Quantifying the effects of eutrophication on ecosystem services represents a significant challenge, and there is lack of ecological knowledge about the effects of eutrophication on the dynamics of the shelf-sea pump and nutrient transportation. Understanding the complexity of linkages between ecological processes will require new measurements of the social aspects and novel approaches to modelling which incorporate both natural and social sciences. While this issue may be addressed in the wider context of the 'bio-geo-chemical cycle', it does have clear implications for the resource productivity of the oceans.

Marine litter: Marine litter (in particular plastic) has been one of the most high-profile marine issues recently. The Panel could perhaps consider more generally the issue of plastic recovery and recycling, on land, as a driver of marine litter reductions. This is important because the most existing initiatives are focused on evidence of litter occurrence and/or impact in the marine environment rather than being focused on land based solutions i.e. considering activities on land as the ultimate drivers for the accumulation of litter in the marine environment. This could be done in a similar way to the Panel's scrutiny of opportunities and limits of product-centric recycling in increasing metal recovery rates and overall resource efficiency. In addition, the Panel could potentially explore the possibility of contributing to existing efforts for the establishment of a baseline for marine litter, and for defining appropriate indicators for measuring and monitoring progress in reducing marine litter, which could potentially also feed into as well as benefit from the new GESAMP working group on microplastics which will be presented in 2016 at the second session of UNEA.

Aquaculture/mariculture: The United Nations, in particular FAO and UNEP (as well as many other organisations), have done a lot to promote sustainable fisheries, aquaculture and the protection of marine biodiversity. In the context of a report specifically on marine resources, there are areas that could be further developed by the Panel to promote a more integrated and sustainable use of these resources. For example, it would be good to uncover the consequences of global fisheries and aquaculture in relation to local ecosystems and growing demand from a resource efficiency perspective. This could include investigating the links and opportunities in the value chains for fisheries, aquaculture, food, feed, by-catch and waste management with the development of marine biotechnology, as well as undertaking an assessment of how to mitigate pressure on commercial fish stocks.

Heavy metals and emerging pollutants: The impacts of land-based energy production, mining or industrial processing on coastal and marine resources and environment may significantly affect how decision makers define the efficient and relatively sustainable production of metals from primary sources (i.e. mining) as opposed to sourcing from improved recycling processes and life cycle approaches to the production of goods. And for the most part, such cost-benefit analyses of industrial activities have not factored in additional externalities affecting coastal and marine ecosystems. Having the IRP apply green economic thinking to the land-based industry-ocean connection would help facilitate a more activity-based system and spatial thinking approach to decision-making processes that consider new industrial activities relative to potential ways of sourcing metals or emerging pollutants.

The IRP is best placed to serve as a facilitator of the targeted identification, development and sharing of industry and governance best practices. Importantly, the IRP can also help governments in setting frameworks that incentivize socially inclusive and equitable production of low-environmental impact production systems with a broader green economy approach.

5. Policy relevant questions

The IRP study report will provide the current state of scientific knowledge with regard to a set of important questions for marine ecosystem management and resource efficiency improvement that need to be addressed to inform policy making and practice. Key questions include those set out below. This list of questions will be progressively refined and consolidated, taking into account the overall study objectives listed in 4.1. above:

In general:

- Why are marine resources important in the wider context of sustainable resource management, decoupling and environmental impacts?
- What are the potentials and limits of resource efficient policies and governance strategies in promoting the sustainable use of global marine resources?
- What are the governance arrangements and forms of collaboration between key actors and organisations to improve global capacity to address the critical human pressures in an integrated manner?
- How to provide the best scientific background for decision-makers to assess trade-offs and synergies between economic benefits from land based activities and environmental impacts on marine ecosystem, to find the most cost-efficient measures to ensure sustainable use of the resources?

- What are the key aspects of regime shifts that are of critical importance to ecosystem based management (EBM)? How can regime shifts be better incorporated into EBM using the concept of integrated ecosystem assessment (IEA)?
- How to translate ecosystem-based policy and management concepts into practical applications within the context of the blue-green economy?
- How will the integrated and transdisciplinary approach be relevant to meeting the needs of governments in responding to the complex policy issues of the SDGs in the coastal zone in a locally-appropriate way?

Sector specific:

- What are the policy options for a resource efficient aquaculture (common standards) taking into account the whole lifecycle of aquaculture production and products?
- What are the economic, social and health trade-offs to consider?
- Are aquaculture and/or mariculture a sustainable alternative to consumption of captured fish?

- How to ensure food security and at the same time improve efficient use of fertilizers whilst reduce the nutrient emissions into the seas?
- How do fertilizer and commodity prices impact efficient nutrient management?
- How to change perception of contaminants and waste so that they are considered as a potential resource (e.g. from wastewater to re-used water, or from waste management to resource management)?
- What is the economic cost of remedial strategies for nutrient pollution? Who will pay for this cost?
- What are the points of intervention throughout the N and P cycle to improve efficiency rates (best practices)
- What policy incentives can be created to achieve compliance of best practices and encourage investment towards nutrient efficiency improvement?

- What are the drivers of marine debris on land? Can improved resource efficiency in these activities simultaneously help to reduce waste in managed facilities and as litter?
- Are bio-plastics a sustainable alternative to the production of plastics from fossil carbon? What are their impacts (if any) on the reduction of waste and litter?
- What are the recycling rates for end-of-life plastics and how can these be increased?
- How to obtain the benefits of plastic items while decreasing waste and marine debris?
- How can product and packaging design be optimized to maximise the potential for recycling?
- What is the potential role of biodegradable plastics in reducing marine litter

- What are the health implications and associated economic costs of pollution by heavy metals and emerging pollutants? What are the social and economic benefits of a reduction of this pollution?
- What is the economic cost of remedial strategies to health and environmental impacts from heavy-metals and emerging pollutants?
- What is the impacts of heavy-metals and emerging pollutants on food security?

- How can competing uses of the sea floor be managed in such a way that healthy and productive ecosystems remain?

These policy relevant questions have been intensively and extensively discussed by the participants of three scoping workshops organized by IRP Secretariat together with EU and other UN organizations. The extent to which these questions can be addressed will depend on the currently available best science, integrating both natural and social sciences. In doing so, the IRP study will be an important reference point for accessing the state-of-art knowledge base on those issues.

6. Timeline and deliverables

A useful approach might be to deliver one large report with a cross-cutting systems perspective, accompanied by interim peer-reviewed publications focusing on discrete subcomponents of the large report (e.g. urbanization, nutrients, fisheries, plastics, heavy metals and emerging pollutants, etc.). A key feature of each of the subcomponent publications would be a common / mutually integrated methodological framework.

6.1 Work plan and timelines

	Tasks
May 2015	Preparation of scoping study
May 2015	Presentation of scoping report at the Hanoi IRP and Decision by the steering group
May - June 2015	Preparation of study proposal
June-August 2015	Preparation of study plan, report outline and storylines
August 2015 – April 2016	Preparation of first draft of assessment report
April-May 2016	1st meeting of the working group to review progress Presentation of study progress report at IRP meeting
Oct 2016	Presentation of first draft study report at IRP meeting 2nd meeting of the working group, meeting

	with other relevant working groups to work on synergies
Oct 2016 – March 2017	Preparation of final draft for peer-review
April 2017	Decision to initiate peer-review by the IRP at IRP meeting 3rd meeting of the working group to review the documents
May 2017 – August 2017	Peer-review process
August-Sept 2017	Prepare final draft based on peer-review feedback
Oct-Nov. 2017	Launch of the report at the IRP meeting with regional co-launches

6.2 Format of the final product

The working group will produce a comprehensive report of about 150 pages, an executive summary that can be used as a standalone product of about 20 pages, and some papers published in international peer-reviewed journals.

- Comprehensive report on global marine ecosystem and resource productivity tailored to a policy and practitioners audience in the context of SDGs for sustainable marine resource use
- Summary for decision makers on land based activities, marine ecosystem management, and resource efficiency targeting the global or national policy community and industry leaders
- Peer-reviewed papers on marine ecosystem management, life cycle assessment of marine resource use, DPSIR applications in linking drivers, pressures and impacts of marine resources targeting scholars in the frontiers of science.
- A set of information graphs for communication with target audience and for social outreach activities.

7. Target audience

The IRP assessment report on Ecosystem Approach for Sustainable Management of Marine Resources and intermediate publications are intended to be widely used by the global policy, academic and industrial community relevant to marine and coastal issues.

The relevant UN and other international organizations have been invited to co-sponsor the scoping workshops, and their representatives have shown great interest in the forthcoming IRP assessment report on Ecosystem Approach for Sustainable Management of Marine Resources, for it will provide a systemic vision on management of marine resources with coherent interface between science and policy.

The report will be particularly valuable to help island countries or those countries with long coastlines and marine jurisdictions to establish targets for strengthening the management of marine resources, or to help the regions, like the EU, to take concerted actions towards sustainable management of regional marine resources. Institutional setting and policy suggestions for ecosystem based management of marine resource will also be helpful for national or regional governance.

Since the focus of the IRP assessment report is on impacts of land based activities on marine ecosystems, it will also be of interest to multinational companies which are mobilizing resources for land based activities. It is anticipated that executives of the multinational companies will use this report as an important guideline for setting up business plans, implementing environmental management systems, and improving resource efficiency.

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