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Marine Ecosystems: State, pressures, economic values and policy instruments to foster sustainable use

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Marine Ecosystems:
State, pressures, economic values and policy instruments*

1. Marine ecosystems and the international policy context

Marine ecosystems are immensely varied both in type and geographical extent. They encompass oceans, salt marshes and intertidal zones, estuaries and lagoons, mangroves and coral reefs, the deep sea and the sea floor (Kaiser and Roumasset, 2002). Covering about 70% of the earth's surface, these ecosystems play a crucial role in human welfare, providing social, economic and environmental benefits to the earth's growing population. It is estimated, for example, that 3.1 billion people rely on oceans for almost 20% their animal protein intake (through seafood) (FAO, 2016), and that more than 500 million people are engaged in ocean-related livelihoods (UNDP, 2012). Marine ecosystems also provide a variety of other services that are critical for human well-being, such as coastal protection, marine biodiversity and carbon sequestration. Oceans, for example, contain nearly 300 000 identified species (though actual numbers may lie in the millions) and have absorbed one-third of the carbon dioxide resulting from human activities (Bijma et al., 2013), while mangroves and coral reefs provide valuable protection against extreme weather events such as storms and floods.

These ecosystems are under increasing pressure due to human activity. Today, 60% of the world's major marine ecosystems have been degraded or are being used unsustainably (UNEP, 2011). Many fisheries are over-exploited, with some stocks on the verge of collapse, and coral reefs are bleaching due to exposure to high temperatures and other pressures. Concurrently, pollution from land-based sources including marine litter is threatening species and marine habitats and climate change compounds these effects, altering both the thermal and chemical characteristics of the ocean as well as its dynamics and nutrient availability (Bijma et al., 2013). Since the 1980s, for example, an estimated 20% of global mangroves have been lost and 19% of coral reefs have disappeared (UNDP, 2012). The welfare costs that this imposes on society are high – estimates suggest that the cumulative economic impact of poor ocean management practices is in the order of USD 200 billion per year (UNDP, 2012).

Growing awareness of the significance of the challenge as well as the need for more co-ordinated action to counteract these trends has put the conservation and sustainable use of the marine environment firmly on the international agenda. Marine biodiversity features among the Aichi Targets under the Convention on Biological Diversity (CBD), including Target 11 on the conservation of marine areas: "By 2020, at least … 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures …" (CBD, 2010). Marine ecosystems also feature as one of the UN Sustainable Development Goals (SDGs), i.e. to "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" (UN, 2015). Specifically, Target 14.5 states: "By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information". Moreover, Target 14.2 is to sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, and Target 14.4 is on effectively regulating, harvesting and ending overfishing.

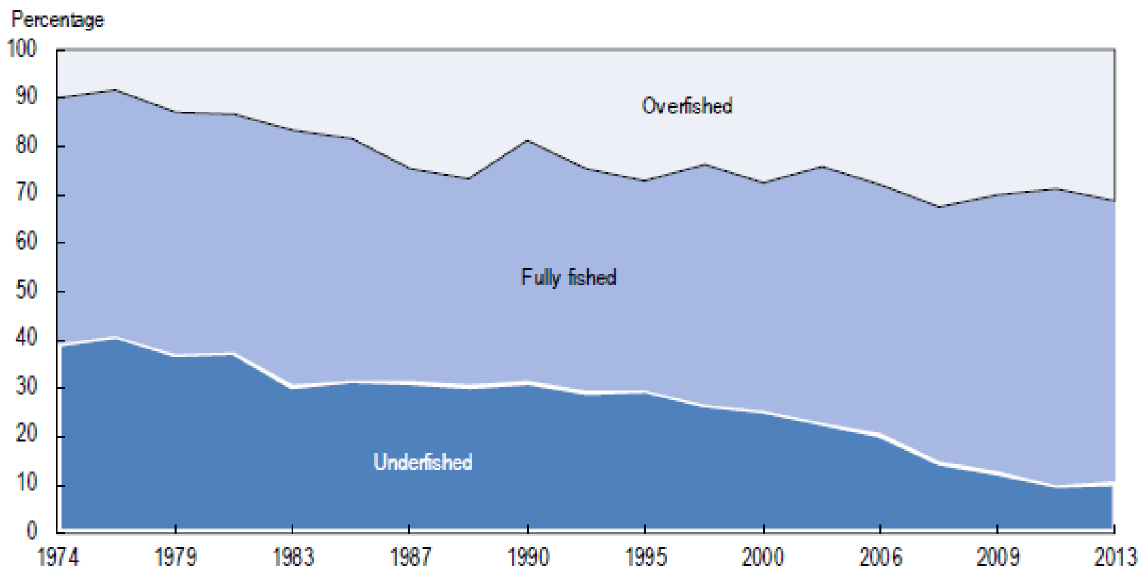
* This document is an excerpt from Chapter 1 of OECD (2017), *Marine Protected Areas: Economics, Management and Effective Policy Mixes*, OECD Publishing, Paris. All references are provided therein.

2. State of and pressures on marine biodiversity

The state of and pressures on marine biodiversity are alarming and available state indicators point overwhelmingly to declining trends. According to the Living Planet Index, marine species declined by 39% between 1970 and 2010 (Loh et al., 2010) and currently over 550 species of fish and invertebrates are listed as threatened (critically endangered, endangered and vulnerable) on the IUCN Red List (Pitcher and Cheung, 2013). According to the same list, coral species are moving towards increased extinction risk most rapidly and coral reefs have been singled out as an ecosystem that is probably under more immediate threat from human impacts than any other (Rogers and Laffoley, 2013). Up to 19% of coral reefs have been effectively destroyed and 24% are under threat due to human pressures such as unsustainable tourism, coastal development and overfishing (Wilkinson, 2008; 2004). Some hotspots are particularly fragile, such as within the Great Barrier Reef where hard coral cover has declined from 28% to 14% since 1986 and the rate of decline has increased substantially in recent years (De'ath et al., 2012).

Turning to the state of world fish stocks, the Food and Agriculture Organization (FAO) (2016) finds that in 2013, 31.4% of fish stocks were estimated as fished at a biologically unsustainable level (and therefore overfished), compared to 10% in 1974 (Figure 1.1). Of the total number of stocks assessed in 2013, fully fished stocks accounted for 58.1% and under-fished stocks 10.5% (separated by the white line in Figure 1.1). Branch et al. (2011) find that at present 28-33% of all stocks are overexploited and 7-13% of all stocks are collapsed. Excessive depletion poses risks to the viability of stocks and can threaten biodiversity, and from an economic perspective represents foregone yields. Moreover, the Intergovernmental Panel on Climate Change (IPCC) (2014) finds that ocean acidification has increased by around 26% since pre-industrial times[8] and notes that, based on historical evidence, recovery from such changes in ocean pH can take many thousands of years. It is projected that continued anthropogenic carbon dioxide emissions will further increase ocean acidity to levels that will have widespread impacts, mostly deleterious, on marine organisms and ecosystems. Ocean acidification is particularly a threat to coral reefs and calcifying animals such as shellfish and plankton.

Figure 1.1. **Global trends in the state of world marine fish stocks, 1974-2013**



Notes: Dark shading: within biologically sustainable levels; light shading: at biologically unsustainable levels. The light line divides the stocks within biologically sustainable levels into two subcategories: fully fished (above the line) and underfished (below the line).

Source: Food and Agriculture Organization (2016), *The State of the World Fisheries and Aquaculture*. Reproduced with permission.

The main pressures driving marine biodiversity and ecosystems loss and decline include over-exploitation of fish and other resources, pollution, habitat destruction, climate change and invasive alien species. Each of these is summarised below. It is important to note, however, that these pressures can also re-enforce each other, exerting cumulative impacts on marine biodiversity.

Over-exploitation of fish and other resources

With rising incomes, growing population and evolving diets, demand for fish has been steadily increasing. Global fish production is increasing at an average annual rate of 3.2%, outpacing world population growth at 1.6% (FAO, 2014). In 2014, total global fish capture production was 93.4 million tonnes with the share of fish production used for direct human consumption increasing from 70% in the 1980s to more than 85% in 2012 (FAO, 2016; 2014). Fish continues to be one of the most traded food commodities in the world, with annual exports rising to USD 148 billion in 2014 (FAO, 2016).

Aquaculture is one of the fastest growing food-producing sectors and provides half of all fish for human consumption. Its production expanded at an average annual rate of 6.2% in the period between 2000 and 2012 (FAO, 2014). The total number of fishing vessels in the world was estimated to be about 4.72 million in 2012, with efforts to reduce overcapacity in fishing fleets not resulting in effective outcomes across the board (FAO, 2014). In addition, world fishery production is expected to be 17% higher by 2023 (OECD-FAO, 2014), mainly due to projected increases in aquaculture. Illegal, unreported and unregulated (IUU) fishing also continues to present challenges. About 11-26 million tonnes of fish is lost to IUU annually, i.e. a mean loss of 18% across all fisheries (Agnew et al., 2009). Distinct from this is the issue of wastage, where 8%, or 7.2 million tonnes, of the global fisheries catch consists of non-target species, which are subsequently discarded (FAO, 2004), and thus has impacts on species and ecosystems.

Pollution

Marine pollution occurs when harmful, or potentially harmful, effects result from the entry into the ocean of chemicals; particles; industrial, agricultural and residential waste; noise; or the spread of invasive organisms.[10] Most sources of marine pollution are land based (80%; GOC, 2014), often from non-point sources such as agricultural runoff. The pathways of marine pollution include direct discharge, land run-off, ship pollution (e.g. ballast water and hot water discharge), atmospheric pollution and deep-sea mining (e.g. for oil and gas), with the resulting types of pollution consisting of acidification, eutrophication, marine litter, toxins and underwater noise. Carbon dioxide emissions are the main driver of ocean acidification, whereas excess nutrients lead to eutrophication. For example, 85% of the sewage discharged in the Mediterranean Sea is untreated, leading to eutrophication. Left unchecked, eutrophication can lead to the creation of dead zones, which is occurring in different parts of the world including the Gulf of Mexico, the Black Sea and the Baltic Sea.

Habitat destruction

Habitat destruction along the coast and in the ocean results from harmful fishing practices such as trawling or dynamite fishing; poor land-use practices in agriculture, coastal development and forestry sectors; and other human activities such as mining,[12] dredging and anchoring, as well as tourism and coastal encroachment. For example, logging and vegetation removal can introduce sediments from soil erosion, and harbour development and other land-based activities (such as shrimp aquaculture) can lead to the destruction of mangroves, which serve as nurseries for species of fish and shellfish, and provide flood protection. Poor shipping practices and coastal tourist activities such as snorkelling, boating and scuba diving come in direct contact with fragile wetlands and coral reefs, consequently damaging marine habitats and degrading the ecosystem services they provide.

Climate change

Climate change is rapidly impacting species and ecosystems that are already under stress from overfishing and habitat loss. Rising sea surface temperatures and sea levels due to thermal expansion of water and melting of the continental glaciers is altering the behaviour and demographic traits of marine species. Tropical storms and heavy rainfall have physically damaged coral reefs, marine ecosystems and coastal regions. According to Doney et al. (2011), climate change impacts on marine biodiversity have already resulted in either a loss or degradation of 50% of salt marshes, 35% of mangroves, 30% of coral reefs and 20% of seagrasses worldwide. Coral reefs are one of the most vulnerable ecosystems to climate change impacts. Episodes of coral bleaching due to ocean acidification and anomalously high sea water temperatures have become more frequent in recent times, leading to coral mortality and declining coral cover, showing no immediate prospects of recovery. Cheung et al. (2009) (cited in the IPCC 5th Assessment Report) have projected climate change impacts to marine biodiversity to 2050 and predict numerous local extinctions, species invasion and turnover of over 60% of present biodiversity with implications for ecological disturbances that potentially disrupt ecosystem services.

Invasive alien species

The introduction of non-native marine species to marine ecosystems to which they do not belong constitutes another serious threat to the marine environment. Most of these alien species are rapidly introduced to a different habitat through ballast water from commercial shipping operations across the oceans. An estimated 7 000 marine species are carried around the world in ballast water every day (WWF, 2009). Coastal tourism, boat hulls, eutrophication and marine pollution also move marine species far from their natural ranges. These foreign organisms are responsible for severe environmental impacts, such as altering native ecosystem by disrupting native habitats, extinction of some marine flora and fauna, decreased water quality, increasing competition and predation among species, and spread of disease. Across the oceans, fish, crabs, clams, mussels and corals that were unintentionally introduced have also resulted in adverse economic impacts, such as collapse of fish stock, damage to coastal areas (smothering of beaches; decreased recreational opportunities) and cost for control. For example, the comb jelly in the Black Sea (and most recently invaded Baltic Sea) is held responsible for the collapse of fisheries worth several million dollars annually (Science Daily, 2008). Invasive alien species affect marine industries (including fishing and tourism) as well as human health (via the introduction of fatal pathogens such as cholera bacteria) (see Bax et al., 2003).

3. The economic value of marine ecosystems

Marine ecosystems degradation is arguably pushing beyond ecologically and economically sustainable thresholds. One of the underlying reasons for this is that many of the services provided by marine and coastal ecosystems[13] – such as coastal protection, fish nursery, water purification, marine biodiversity and carbon sequestration (see Table 1.1) – are not reflected in the prices of traditional goods and services on the market (and hence referred to as non-market values). While there is often a lack of scientific information to clearly understand the complex links between these marine ecosystem services and their economic value, this undervaluation of marine ecosystem services results in under-investment in their conservation and sustainable use, and lost opportunities for economic growth and poverty reduction. Estimating and accounting for the economic values associated with some bundles of these ecosystem services is important to help improve decision- and policy-making processes, including management decisions and priority setting (i.e. to more efficiently allocate resources between competing uses) (Naber, Lange and Hatziolos, 2008), as well as the design of policy instruments for marine conservation and sustainable use. The Marine Ecosystem Services Partnership (MESP) provides information on more than 1 000 valuation-oriented studies worldwide, by ecosystem type. In Sri Lanka, for example, greater conservation efforts of its salt water marsh, a natural buffer against flooding, were prompted when its ability to protect cities was valued at USD 5 million annually (Global Partnership for Oceans, n.d.).

A number of studies have estimated the economic value of marine ecosystems, examples of which are highlighted below. While these vary in terms of scope (e.g. different ecosystems, varying geographical scales), they serve to illustrate that the benefits are considerable. Taking into account the number of people engaged in coastal livelihood activities, marine and coastal resources directly provide at least USD 3 trillion worth of economic goods and services annually (UNDP, 2012). The marine environment supports approximately 61% of world's total gross national product (GNP) by directly and indirectly providing fundamental goods and ecosystem services (including coastal tourism, recreation and employment) upon which human well-being depends (UNESCO, 2012). Global aquaculture production (including food fish and aquatic algae) contributes about USD 162.2 billion towards the global economy (FAO, 2016); the shipping industry contributes to 90% of the global trade; the tourism industry, of which marine and coastal tourism is a major part, represents 5% of global GDP (UNDP, 2012).

Table 1.1. **Examples of marine and coastal ecosystem services and their scale**

Category (examples)	Geographic scale
Food (e.g. fisheries and aquaculture)	Local/regional/global
Fuel (e.g. mangrove wood)	Local/regional/global
Water	Local/regional
Natural products (e.g. sand, pearls, diatomaceous earth)	Local/regional/global
Genetic and pharmaceutical products	Local/regional/global
Lifecycle maintenance, habitat and gene pool protection	Global
Atmospheric composition, carbon sequestration and climate regulation	Local/regional/global
Shoreline stabilization/erosion control	Local
Natural hazard protection (e.g. from storms, hurricanes and floods)	Local/regional
Pollution buffering and water quality	Local/regional
Soil, sediment, and sand formation and composition	Local/regional
Tourism	Local/regional/global
Recreation	Local/regional/global
Spiritual values	Local/regional/global
Education and research	Local/regional/global
Aesthetics	Local

Source: OECD (2017), *Marine Protected Areas: Economics, Management and Effective Policy Mixes*

Coral ecosystems are estimated to provide an average value of approximately USD 172 billion a year to the world economy (Veron et al., 2009). The value is based on ecosystem services including food and raw materials, moderation of extreme ocean events, water purification, recreation, tourism, and maintenance of biodiversity. Moreover, about 500 million people directly or indirectly depend on coral reefs as their source of livelihood (Wilkinson, 2004). The Global Ocean Commission estimates that the global economic value of carbon sequestration associated with seas and oceans ranges between USD 74 billion and USD 222 billion per year (GOC, 2014).

In a more comprehensive study, de Groot et al. (2012) provide global estimates of a number of ecosystems and services, including for open oceans, coral reefs, coastal systems, and coastal and inland wetlands. They find the total value of ecosystem services ranges between 490 int$/year for the total bundle of ecosystem services that can potentially be provided by an "average" hectare of open oceans to almost 350 000 int$/year for the potential services of an "average" hectare of coral reefs.

There are numerous other valuation studies which have been undertaken at national or local scale and/or cover fewer ecosystem components. For example, a national level study for the United Kingdom provides "best estimates" of the monetary value of 8 of the 13 goods and services of marine biodiversity (Beaumont et al., 2008). These include food provision (GBP 513 million), raw materials (GBP 81.5 million), gas and climate regulation (GBP 0.4-8.4 billion), disturbance prevention and alleviation (GBP 0.5-1.1 billion), and leisure and recreation (GBP 11.77 billion). Similarly, Lange (2009) estimates the value of marine ecosystem services in Zanzibar and finds it accounts for 30% of GDP. As the marine environment continues to be threatened, if corrective measures are not taken soon, the costs of inaction are anticipated to continue to increase (Box 1.1).

Box 1.1. **Examples of costs of inaction (global)**

- The cumulative economic impact of poor ocean management practices is about USD 200 billion per year (UNDP, 2012). For example, invasive marine species, especially those carried in ship ballast water and on ship hulls, cause an estimated USD 100 billion each year in economic damage to infrastructure, ecosystems and livelihoods (based on estimates in the UNDP-GEF GloBallast programme, as cited in UNDP [2012]). The World Bank and Food and Agriculture Organization estimated the economic losses due to overfishing at USD 50 billion annually (World Bank-FAO,2008, cited in UNDP [2012]).

- The Intergovernmental Panel on Climate Change (IPCC) (2014) model projections suggest a potential loss of up to 13% to annual total fishery value in the United States, and globally over USD 100 billion annually, by 2100 (Cooley and Doney, 2009; Narita, Rehdanz and Tol, 2012).

- Brander et al. (2012) estimate that the loss of tropical reef cover due to ocean acidification will cause damages of between USD 528 billion and USD 870 billion (year 2000 value) by 2100.

- The total estimated costs of coastal protection, relocation of people and loss of land to sea-level rise ranges from about USD 200 billion for an increase of sea level of 0.5 metres to five times that – USD 1 trillion – for a 1-metre rise, to about USD 2 trillion for an increase of 2 metres (Nicholls and Cazenave, 2010).

- In the absence of proactive mitigation measures, climate change will increase the cost of damage to the ocean by an additional USD 322 billion per year by 2050 (Noone, Sumaila and Diaz, 2012).

4. Policy instruments for the conservation and sustainable use of marine biodiversity

A number of policy instruments are available to promote the conservation and sustainable use of marine biodiversity. Table 1.2 categorises these in terms of regulatory, economic, and information and voluntary instruments. Each of these is discussed in turn.

Regulatory (command-and-control) approaches

Marine protected areas are gaining increasing attention as a policy instrument for marine biodiversity conservation, and currently cover about 4.1% of the total marine environment. The number of MPAs is increasing at approximately 5% annually (Wood et al., 2008)[19]. This has been due, at least in part, to the calls at international level to scale up the conservation of marine areas (such as under the CBD) as well as other directives and regulations such as the 1992 European Directive on the conservation of natural habitats and of wild flora and fauna, and the more recent Marine Strategy Framework Directive. Studies have shown that MPAs can increase the density, diversity and size of species (Halpern, 2003; Gaines et al., 2010), protect habitats, and provide other economic benefits such as for tourism and recreation.

The Convention on International Trade in Endangered Species (CITES) is also important for marine species, as many species that are traded internationally are highly migratory. CITES provides a legal framework to regulate the international trade of species and includes restrictions on commercial trade when species are threatened with extinction. As of October 2013, there were 16 fish species listed under Appendix I (trade is permitted only under exceptional circumstances) and 87 species in Appendix II (trade is allowed but must be controlled).

Table 1.2. **Policy instruments for marine biodiversity conservation and sustainable use**

Regulatory instruments (i.e. command-and-control)	Economic instruments	Information and voluntary approaches
Marine protected areas	Taxes, charges, user fees (e.g. entrance fees to marine parks)	Certification, eco-labelling (e.g. Marine Stewardship Council)
Marine spatial planning	Individually transferable quotas	Voluntary agreements, including public-private partnerships (which can include, for example, voluntary biodiversity offset schemes)
Spatial and temporal fishing closures; bans and standards on fishing gear; limits on number and size of vessels (input controls); other restrictions or prohibitions on use (e.g. CITES)	Subsidies to promote biodiversity – and the reform of environmentally harmful subsidies	
Catch limits or quotas (output controls)	Payments for ecosystem services (PES)[1]	
Standards (e.g. MARPOL for ships); bans on dynamite fishing	Biodiversity offsets	
Licenses (e.g. aquaculture and offshore windfarms)	Non-compliance penalties	
Planning requirements (e.g. environmental impact assessments and strategic environmental assessments)	Fines on damages	

Notes: CITES: Convention on International Trade in Endangered Species; MARPOL: International Convention for the Prevention of Pollution from Ships ("marine pollution"). 1. France uses the term payments for environmental services to emphasise that payments should only be made for services rendered that are additional to what the natural ecosystem would provide (i.e. in the absence of changes in management practices). This should, in fact, be a requirement for all PES programmes; see OECD (2010) for further discussion.

Source: OECD (2017), *Marine Protected Areas: Economics, Management and Effective Policy Mixes*.

Another instrument that has been increasingly used over the past decade is marine spatial planning (MSP). MSP refers to a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives. MPAs can (and should) form an integral part of an MSP (see also Chapter 5 for further discussion). The main elements of an MSP include an interlinked system of plans, policies and regulations, which are generally accompanied by the use of maps.[21] MSPs are currently being used in about 50 countries worldwide including Canada, the People's Republic of China, Germany, New Zealand, the Netherlands, Norway and the United States. Collie et al. (2013) examine 16 MSPs around the world to compare practical experience with formulaic guidance on MSPs.

As the development of MSPs is still fairly recent, further progress is needed in areas such as identifying data needs as well as clear criteria or frameworks for developing planning options (see, for example, Jay [2015]). Other regulatory instruments include the more traditional standards on fishing gear, quotas on fish catch, commercial fishing permits, emission standards for waterway engines, fuel sulphur limits for vessels, among many others. Habitat conservation bycatch limits (or individual habitat quotas) also exist though these are not yet common (for an application in British Colombia, Canada, see Wallace et al. [2015]). Planning tools such as environmental impact assessments (EIAs) and strategic environmental assessments (SEAs) are also used. EIAs can be required to assess the impacts of projects such as offshore windfarms, harbour expansion and dredging, marine aquaculture, and oil platforms and rigs. SEAs tend to be undertaken for larger activities, such as to inform a country's strategy for the development of marine energy (e.g. Scotland).

Economic instruments

Probably the most commonly applied economic instrument to address marine conservation and sustainable use is individually transferable quota (ITQ) systems for fisheries or other variants to ITQs. As of 2008, 148 major fisheries around the world had adopted some variant of this approach (Costello, Gaines and Lynham, 2008), along with approximately 100 smaller fisheries in individual countries. Approximately 10% of the marine harvest was managed by ITQs as of 2008. ITQs for habitat also exist, though very few have been implemented in practice (see Innes [2015] for a discussion). Other examples of economic instruments include the US 10% federal excise tax on sales of sport fishing equipment and motorboat fuel, which is used to finance the US Aquatic Resources Trust Fund. In Israel, a marine environmental protection fee is levied on ships calling at Israeli ports and oil unloading platforms. This fee varies according to the size of the ship and the amount of oil, with the revenues going to the Marine Pollution Prevention Fund (OECD, 2011a).

Entrance fees to marine national parks are being used in a number of countries, including Belize, Mexico, Thailand and the Galapagos Islands in Ecuador. Payments for ecosystem services (PES) in the marine context have also been introduced. For example, local hotels and tourism operators can pay for reef conservation due to the benefits associated with decreased beach erosion and species conservation (e.g. for scuba divers) (see Chapter 4 for a further discussion). The Great Barrier Reef Marine Park Authority requires the payment of bonds to manage certain approved activities within the park (e.g. marina development, dredge disposal, tourism and aquaculture facilities) (Lal and Brown, 1996). Revenue from fines imposed on damages caused can also be used for MPAs. In Canada, for example, an environmental protection fund was created for the Gilbert Bay MPA through proceeds of fines imposed on business following an oil spill. Another concept that is being explored is marine biodiversity offsets, for industries such as petroleum exploration, renewable energy and seabed mining. Scoping work for such instruments has been undertaken for Belize and the United Kingdom.

Information and voluntary instruments

Information instruments aim to address informational asymmetries that often exist between business, government and society. Eco-labels and certification are instruments that have been fairly widely adopted in the case of fisheries. Two hundred and twenty-four fisheries have been independently certified as meeting the Marine Stewardship Council (MSC) standard for sustainable fishing with another 94 currently undergoing assessment (MSC, 2014). Friend of the Sea is another important certification scheme in terms of volume, though several others also exist (OECD, 2011b). Other voluntary instruments that have been used include negotiated agreements between government and fishers to establish voluntary marine conservation areas.

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