OCEANS
THE NEW FRONTIER
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Agence Française de Développement (AFD) is a public development finance institution that has worked to fight poverty and support economic growth efficiently in developing countries and the French Overseas Communities for almost 70 years. AFD executes the French government’s development aid policies. Through offices in more than fifty countries and nine French Overseas Communities, AFD provides financing and support for projects that improve people’s living conditions, promote economic growth and protect the planet: schooling, maternal healthcare, help for farmers and small business, water supply, preservation of tropical forests, and fighting climate change, among other concerns. In 2009, AFD committed more than €6.2 billion to financing aid activities in developing and emerging countries and the French Overseas Communities. The funds will help vaccinate 1.8 million children, improve drinking water access for 7.3 million people and support 900,000 private sector jobs, while energy efficiency projects save nearly 5 million tons of carbon dioxide emissions per year. More information and publications available at www.afd.fr

The Institute for Sustainable Development and International Relations (IDDRI) is a think tank based in Paris (France) and Brussels (Belgium). Its mission is to bridge the gap between research and decision-making and investigate international policy issues on sustainable development and global governance. IDDRI focuses its activities on four major topics: climate change, biodiversity, global governance and urban fabric. It also seeks to facilitate discussions between the various stakeholders involved in global issues related to sustainable development. Through its partnership with Sciences Po in Paris, France, IDDRI is also involved in teaching and participates in the development of research programmes with support from the Sustainable Development Centre at Sciences Po. More information and publications available at www.iddri.org

The Energy and Resources Institute (TERI) was set up in 1974 to deal inter alia with issues relating to sustainable development, the environment, energy efficiency and the sustainable use of natural resources. Its goal is to develop innovative solutions for achieving sustainable development. Its activities range from the formulation of local and national strategies, to proposals for global solutions, to energy and environment-related issues. TERI is based in New Delhi, and also present in many other regions of India. It has 700 employees and is headed by Rajendra K. Pachauri who is also the Chairman of the Intergovernmental Panel on Climate Change (IPCC), which was awarded the 2007 Nobel Prize. More information and publications available at www.teriin.org

Oceans: The New Frontier
Pierre Jacquet, Rajendra K. Pachauri and Laurence Tubiana (Editors)
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This is the 2011 edition of an annual publication on sustainable development, A Planet for Life, first published in 2007. In this introduction, we assess the past year’s events from a global perspective, starting with the aftermath of the worldwide financial and economic crises and continuing through the Cancun Climate Change Summit. These events provide context for this volume’s central focus: the challenges the international community faces in protecting ocean ecosystems and promoting sustainable development.

It seems fitting that 2010, the Year of Biodiversity, should close with a volume dedicated to oceans – vast reservoirs of biodiversity, and central to the world’s primary challenges. Oceans play a major role in climate regulation, food production, industry, transportation, leisure, species conservation and technological innovation. Many social, economic, environmental, cultural and political aspects of contemporary life intersect with oceans, making them a “new frontier” for human endeavour; meanwhile, illegal activities and ocean-centred conflicts raise global governance concerns. The sea serves as a vast testing ground for collective
action at several levels, and for interactions between human societies and natural resources – topics central to this edition and presented more fully in the associate editors’ introduction.

The present overview of sustainable development issues will focus on the current economic and governance context. The fallout of the current recession naturally diverted attention from two of sustainable development’s three pillars: environmental and social issues were overshadowed by economic ones. These latter concerns focused on three subjects: changes in global growth projections, inequalities within and between countries, and governmental ability to find capital for green and cohesive growth. Fortunately, 2010 ended with encouraging results from the Nagoya Biodiversity Summit (18-22 October 2010), and the Cancun Climate Summit (29 November -10 December 2010) where multilateral negotiations, stalled since the 2009 Climate Summit in Copenhagen, once again picked up momentum.

WHAT WORLD ECONOMY WILL EMERGE FROM THE CRISIS?
Can we say the financial and subsequent economic crisis has truly ended? The brutal shock of the bursting financial bubble has passed, but its repercussions reverberate in the world economy: they will affect growth, international relations and global governance for years to come. Stimulus programmes proved helpful in developing and developed countries, allowing some countries to limit damage and accelerating recovery in emerging economies. However, such efforts did not fix global macroeconomic imbalances, e.g. excess liquidity in some Asian countries and uncoordinated financial and monetary governance at the global level. Stimulus measures in large industrialized countries have left public finances less than viable.

DECOUPLING AND REFOCUSING The economic crisis has affected many developing countries less severely than industrialized ones. The latter suffer from structurally higher unemployment; at best, they will probably see sluggish economic growth for 2011 and the next few years. However, large emerging economies and many developing ones have recovered more energetically; the often-painful economic adjustments of previous decades have proven beneficial, providing countries with room to manoeuvre at a macroeconomic level. The crisis certainly slowed economic growth everywhere; the financial shock wave upset the real economy by sinking world trade volumes. But as Kemal Dervis has observed, this cyclical convergence hides a structural divergence, evident in projected 2010-2015 GDP growth rates: 2.3% for advanced countries versus 6.3% for emerging and developing ones (Dervis 2010; IMF 2010a).

The much higher growth trends in emerging countries, notably in Asia, have accelerated the world economy’s shift toward Asian and developing nations. This will give the emerging powers a larger influence, as their positions on international issues and their economic policy choices come to the negotiating table. This is already evident in meetings of finance ministers, central bank governors, and heads of state.
at the Group of Twenty (G-20), and in other international negotiations. Rebalancing external deficits and current account surpluses, and reforming the international monetary system, will require emerging economies with large surpluses – especially China – to shift from their export-driven growth model toward one structured by internal demand. This adjustment has gradually begun. The crisis has also taught emerging countries that they require prudent and autonomous financial market reforms, and should increase control over how they participate in international financial integration (see e.g. Bellocq and Zlotowski 2011). The emerging powers are actively engaging in international negotiations and showing great initiative in many domains, from monetary and financial issues to environmental ones.

NEW AFRICAN FRONTIERS African economies also proved resilient during the financial crisis (IMF 2010b), in part because their lesser integration in world capital flows gave some protection from the financial turmoil. In 2010, rising agricultural and mineral commodity prices bolstered recovery. Since the beginning of this century, sub-Saharan African countries have witnessed encouraging growth rates. A report presented at the September 2010 United Nations’ Millennium Development Goals Summit in New York noted delays in meeting goals; nonetheless, many African countries’ Human Development Indicators show significant improvement, (UNDP 2010). Economic analyses increasingly focus on the continent’s potential, drawing resurgent private investor interest and investments (see e.g. Severino and Ray 2010).

Obviously, important challenges endure. Democratic transition remains an important stake in many countries. It has indeed received a promising boost with the January, 2011 Tunisian revolution that led to the departure of former President Ben Ali. But the presidential elections in Côte d’Ivoire at the end of 2010, and preceding elections in Guinea, Burundi and Rwanda, show that conflicts afflict many African regions, and democracy may emerge slowly, painfully and contentiously. Terrorist groups linked to Al Qaeda stalk North and East Africa. The continent also remains vulnerable to natural catastrophes; the ravages of droughts and floods extract high economic and human costs every year. A near-doubling of Africa’s population by 2050 looms in the background, invoking two major challenges – youth employment and urbanization – as well as broader questions about Africa’s growth model and its integration in the world economy. In addition to confronting the intrinsic difficulties of natural resource management – rent-seeking behaviour, the absence of any incentive to diversify, the “Dutch Disease,”1 – African countries must prioritize three crucial concerns if they are to escape poverty: agricultural development, industrial modernization, social policies and inclusive growth. International aid policies and many countries have neglected the development of food staples and agricultural export products for a long time. The aftermath of the 2008 surge in food prices reaffirmed

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1. The notion of “Dutch Disease” refers to a real exchange rate overvaluation (resulting in a loss in export price competitiveness) in a country following a national resource discovery or an increase in commodity prices. A similar impact may occur through a surge in foreign capital inflows may have a similar impact.
agriculture’s primacy, leading to the present need for action to meet local nutritional and export requirements. The 2011 G-20, under the French presidency, has declared vulnerabilities to food shocks and price volatility a priority, while expanding local and export-oriented food industries gains renewed attention. “Land-grabbing” looms as another concern; foreign investment in African lands could prove beneficial if it increases agricultural productivity, social development and environmental protections. However, a risk lies in its potential for simply transferring resources and rents to foreigners. Beyond agriculture, many African countries’ level of industrialization lags that of other countries, calling for a review of public policies and greater efforts to modernize, diversify, and integrate with international markets (see e.g. Afrique Contemporaine 2010). High energy costs and poor infrastructure hinder industrial development, as does the fragmented nature of African markets. Policies promoting employment and welfare for the poor must also be developed to help people escape so-called poverty traps and benefit from economic growth.

ADVANCED ECONOMIES STRUGGLE In some industrialized countries, the Great Recession left high debt levels in its wake, a problem that must be addressed. The excessive private-sector debt that came to light during the crisis has given way to public-sector debt for economic support, jeopardizing the viability of public finances. Decisions on needed adjustments will fundamentally challenge economic policy in the coming years; the Euro-zone’s debt problems have drawn the most attention and prompted nervous reactions in financial markets, although other advanced economies – the United States, United Kingdom and Japan – have similar problems.

The European debt crisis – like the global current accounts imbalance – reveals an intrinsic problem in managing international economic interdependence. Surplus economies tend to ignore their contribution to the situation, and seek out excessive-deficit economies to bear the burden of adjustment. For example, excess savings from Japan in the 1980s, and more recently from emerging powers, found good investment opportunities in the United States, where domestic, state and federal savings have crumbled since the 1980s. This worsened America’s large current-account deficit, but provided needed funding, showing the bias in any argument blaming emerging economies for excess savings. At the European level, meanwhile, Germany has called for a reining-in of “irresponsible” public spending in many other Euro-zone countries.

At least two weaknesses undermine such arguments. First, they underestimate the extent of economic interdependence: wherever responsibility may lie, the problem affects all countries and calls for cooperative response to preserve each state’s interests. Second, the arguments ignore the ineluctable symmetry of the problem: excessive debts imply excessive lending on the part of creditors. Over-indebted countries must reduce their debt, whether it arises from public or private sector overspending, and surplus countries must support growth. International and European debates about China and Germany – both accused of pursuing mercantilist policies, even as they condemn America’s “easy money” policy or peripheral Europe’s overspending
– reveal the conflicts that impede a rebalancing of the world economy. However, debt excesses also imply excess lending by creditors. John Maynard Keynes evoked the problem of adjustment asymmetry as “compulsory for the debtor and voluntary for the creditor” in his Clearing Union Plan of 1942 (Keynes 1942). His analyses of monetary systems seem especially relevant today, as the G-20, under the French presidency, searches for effective ways to respond to the international crisis through monetary system reform.

The industrialized countries’ difficulties pose an extra challenge for interdependence and suitable global governance. Advanced economies may be tempted to withdraw, tending to national interests instead. Legitimate worries about regulating international trade and capital flows may mutate into politically and economically damaging protectionism. In this context, multilateralism urgently needs consolidation, and states must respect collectively established rules of engagement. The World Trade Organization’s long-stalled Doha global trade negotiations provide a warning, since participants apparently see no need to reach agreement. Beyond trade matters, we see further danger in generally devoting too little political energy to strengthen the multilateral system and to be misled by the false promises of narrowly defined national interests.

**THE EUROPEAN DEBT CRISIS – LIKE THE GLOBAL CURRENT ACCOUNTS IMBALANCE – REVEALS AN INTRINSIC PROBLEM IN MANAGING INTERNATIONAL ECONOMIC INTERDEPENDENCE**

**PROGRESS ON THE “GREEN GROWTH” AGENDA**

**A BIODIVERSITY AGREEMENT** The first positive step towards global environmental governance came – somewhat unexpectedly after previous disappointments – at the Biodiversity Summit in Nagoya, Japan, in October 2010. The summit produced a landmark agreement to protect the world’s ecosystems, genetic resources, and species diversity. The Conference of the Parties on Biodiversity Conservation reformulated its core aims in a more realistic way: rather than drawing up meaningless global goals, countries must define sectoral objectives for activities with known impacts on biodiversity, e.g. agriculture, fishing, manufacturing. The creation of a body, the International Panel on Biodiversity and Ecosystems (IPBES) (similar to the Intergovernmental Panel on Climate change) was unanimously approved in Nagoya – and later on adopted by the United Nations General Assembly in December 2010, without the reservations expressed previously by developing countries.

Among Nagoya’s many decisions, a new protocol resolved a long-standing deadlock on access to and benefit-sharing of genetic resources. It also bolsters the 1992 Convention on Biological Diversity. Concluding negotiations that started in 2002, the Nagoya Protocol sends a strong signal in favour of a multilateral system. It touches on intellectual property rights – a particularly contentious area in most international negotiations – and changes the balance of power between developed and developing countries to favour the latter, many of which are great repositories of biodiversity. The agreement also demonstrates that despite its critics, the United Nations
process can be effective and create consensus; 193 countries signed on: the United States, which is not a party to the Convention on Biodiversity, did not. The strong participation and proactive stance of developing countries sends another important signal: since 2002, they have made large contributions – alongside European countries – to the results achieved in Nagoya, showing that they are not free-riders or passive “norm-takers” in the international system, but rather “norm-makers” contributing to it. These positive signals resurfaced at the Conference of the Parties of the United Nations Framework Convention on Climate Change in Cancun, Mexico in early December.

**PROGRESS ON CLIMATE CHANGE** One goal of the Copenhagen Climate Change Summit in December 2009 – binding agreements to curb greenhouse gas emissions – had been deferred, if not abandoned, in the wake of the Summit’s inconclusive talks. Although the Conference of the Parties in Cancun in December 2010 did not succeed in making commitments binding either, it made progress on several fronts. First, the parties included policy elements in their global decision that had not found formal acceptance in Copenhagen. They also launched the so-called “REDD” mechanisms, for Reducing Emissions from Deforestation and Forest Degradation – defining the general means of monitoring and reviewing them, and advancing the financial architecture required to fund them.

Like the Nagoya agreement, the Cancun decisions renewed confidence in the multilateral process. The agreement establishes new means of measuring and verifying each country’s actions and commitments. This mechanism does not guarantee that all countries will honour their commitments, but monitoring mechanisms do create a basis for comparisons – notably by introducing an international review of each country's data and results – that will affect the reputation of individual countries. This mutual monitoring is critical, since it can allay two types of uncertainty that hamper action: concerns about the risk of unilateral action and doubts about feasibility. Governments and economic actors remain loath to act if they believe they are taking risks that their competitors have avoided. Governments also tend to minimize their stated commitments out of fear of being unable to fulfil them. Some doubt the feasibility of climate policies and wonder if the long-term aim of a carbon-free economy is realistic. The information gained from monitoring can promote compliance among governments and businesses – behaviours key to international coordination.

Another positive outcome appears in the new “Green Fund.” Announced in Copenhagen, it supports mitigation and adaptation efforts in vulnerable countries, as they combat the effects of global warming and move toward low-carbon economies. The Copenhagen Green Climate Fund will be administered by a council composed of developed and developing countries; it will extend the “Fast Start” Climate Fund’s
pledge of $30 billion by 2012 (also decided in Copenhagen) by contributing $100 billion annually as of 2020. The Green Fund awaits initial financing pledges, along with an outline for its activities; it should not be designed as a new international institution, added to existing ones. Rather, the much needed additional resources it will gather should be used to effectively mobilize all concerned parties and all available public and private financing, by providing monies that will catalyze further action and contributions.

By overcoming many of the Copenhagen Climate Summit’s weaknesses, the Cancun Summit proved politically and symbolically significant, confirming the legitimacy of the UN process: all countries except one (Bolivia) voiced approval of the agreement on the last night of the summit. Building on the trend observed in Nagoya, Cancun also signalled the key contribution of emerging countries: India played a principal role – along with Mexico – in achieving agreement, particularly by conducting bilateral discussions with China.

THE LIMITS OF COLLECTIVE CLIMATE ACTION Despite substantial progress, the Cancun Climate Agreement also showed some of the limits of collective action. It does not provide a clear outlook for the soon-to-expire Kyoto Protocol, nor for its possible replacement with another agreement of the same scope. More worrisome still, formal emissions-reduction commitments, determined in 2010 after the Copenhagen summit, will not – even in the best-case scenario – meet the goal of limiting average global temperature rise by 2 degrees Celsius. Cancun’s constraints do not allow for more than the unilateral adoption of non-binding commitments. Unfortunately, the sum total of such commitments proves insufficient, even including potential outcomes of local and national policies: they will not prevent the highest risk scenario of a 3 to 5-degrees-Celsius rise in global temperatures. Nonetheless, the parties took an important step forward in Cancun by providing for a 2013 review: this will examine collective aggregated efforts in light of new scientific evaluations, gather notes on progress, and accelerate the movement toward combating climate change.

A further problem arose, however, in financing climate-related actions. The UN Secretary-General’s advisory group on this issue (created in Copenhagen, with Ethiopian Prime Minister Meles Zenawi and Norway’s Jens Stoltenberg as co-presidents) was charged with identifying new sources of funding – which they did – and proposing a preferred one – which they did not. The appropriate forum for such decisions remains unclear; the Conference of the Parties to the UN Climate Change Convention – headed by environment rather than finance ministers – cannot legitimately claim competence for funding matters. Few countries would accept the G-20 assuming a direct role in climate-change financing, at least not in the near term. Moreover, there is simply no political consensus to support taxing financial transactions or international transport, two forms of fundraising proposed by the advisory group. The Green Fund’s sources of financing remain undefined, along with the larger investments required for the transition to low-carbon economies. These
decision-making and funding difficulties encapsulate the issues surrounding “green growth” or a “green economy.” They also raise the crucial question: will countries commit to changing their development trajectory?

**A GLASS HALF-EMPTY OR HALF-FULL?** Environmental performance measurements gain increasing traction among governments and the public, although many operational details remain unresolved. More than a year after the Stiglitz-Sen-Fitoussi Commission on the Measurement of Economic Performance and Social Progress submitted its 2009 report (Stiglitz et al. 2009), additional reports gained attention. For example, the United Nations Development Programme chose the twentieth anniversary of the Human Development Index (HDI) to publish its 2010 Human Development Report, after significantly modernizing the HDI and introducing pertinent new key indicators (UNDP 2010). Inspired by the Stern Review on the economics of climate change (Stern 2006), Pavan Sukhdev and his colleagues assessed the economics of ecosystems and biodiversity (TEEB 2010) to increase awareness about biodiversity loss.

Countries have been slow to accept and adopt instruments to measure “green growth” and other relevant tools, such as ecosystem evaluations; yet we should emphasize the progress made in international, national and local discussions. International pressures – scientific warnings, public opinion, changing consumer preferences – have combined favourably with the will to preserve national sovereignty; as a result, virtually every country has implemented significant environmental policies. For instance, in the last decade, environmental concerns have increasingly informed China’s political agenda. In 2008, the Chinese government passed the Circular Economy Law – the world’s first – to raise resource utilization rates, reduce energy and waste, and protect and improve the environment. China’s 11th Five-Year Plan (2006-2010) included environmental targets, notably a 10% reduction in SO₂ and COD (chemical oxygen demand) emissions and a 20% decrease in energy intensity. In recent years, the government has amended anti-pollution laws to emphasize the “polluter pays” principle that requires that the costs of pollution be borne by those who cause it, as affirmed in the 1992 Rio Declaration (UNEP 1972). China’s 12th Five-Year Plan (2011-2015), outlined in October 2010 for adoption in March 2011, would give environmental and social welfare concerns the same priority as economic growth – a genuine turning point in national policy. By 2020, the Plan seeks a 40% to 45% reduction in carbon intensity from 2005 levels, and targets a primary energy demand that includes 15% renewables, compared to 9% in 2009. China has not acted alone in taking strong measures: India, Mexico, South Korea, Indonesia, Vietnam, Mauritius and many other countries have proven equally committed to ambitious environmental performance.

However, the recession has delayed if not compromised some plans for curbing emissions. In Europe, the economic crisis, combined with disappointment over the Copenhagen Climate Summit, led some governments and industrial groups to challenge greenhouse gas emissions targets (the proposed 20% reduction by 2020); they have deferred reforms that nonetheless remain necessary for the long term.
Calls for a “pause” in environmental efforts, pending economic recovery, reflect the continuing conflict between these priorities. In Asia, China’s €400 billion economic stimulus plan favours projects that consume a great deal of energy – buildings and infrastructure made of steel, concrete, metal, etc. In the United States, the federal government struggles to define a clear emissions policy despite President Obama’s oft-repeated intentions to do so. The Obama Administration appears stymied by a recently-installed Republican majority in the U.S. Congress.

Innovation-driven growth as a basis for sustainable development: this goal has yet to take firm root in governments and the private sector. Rendering that aim concrete and credible remains our most important intellectual and practical challenge, in 2011 and beyond.
During the twentieth century, the oceans’ frontier receded as humans pushed deeper and further into vast marine territories. Since coastal dwellers first attempted to tame a naturally hostile environment, one development has irrevocably changed the human/marine divide: today, humanity has access to the entire ocean. Distance from the coast and depth of the sea floor no longer pose insurmountable obstacles. The human community insistently pushes the oceans’ limits, seeking to exploit all of their varied resources – fisheries, fuels, minerals and genetic material. Ocean frontiers are constantly redefined by new technologies, scientific discoveries, industrial requirements, national strategies, and most recently, by ecological imperatives; no sea escapes these demands.

Energy demands show, paradigmatically, how this frontier has retreated across the globe. Once conceived as an inaccessible and relatively unexplored world of ice, the Arctic now serves as a milepost in the race for new energy supplies. This race, started in the twentieth century, has gradually gained momentum (Chapter 13). Prior to World War II, oceans provided little oil; today they supply 30% of the world’s fossil fuel needs. The sea thus satisfies the energy demands of an ever-increasing
population through oil extracted from ultra-deep waters and wind turbines multi-
plying along coastlines (Chapter 3; Radar 13.1).

With new discoveries occurring daily, the frontiers of human knowledge about oceans have expanded, even as the physical ones recede in front of societies' pursuit of new resources and processes. The Census of Marine Life estimates that 6,000 new species have been found in the last decade. New navigation and fishing technologies allow further exploitation of some marine ecosystems, such as seamounts in the distant high seas. First discovered in the 1930s, seamounts remained mostly unknown until recent years, even though they have been intensively fished since the 1950s (Radar 2.1). Meanwhile, fish and shellfish farms have developed along coastlines, using feed and techniques previously reserved for land-based animals. These aquaculture installations have steadily grown larger, providing a large part of the world's protein production: in 2008, they accounted for 37% of global fish products.

Oceans also provide key links in the logistics and value chains of a rapidly globalizing world, as demonstrated by the impressive rise of seaborne cargo transport in all sectors (Chapter 8). “Ocean highways” now carry 80% to 90% of the world’s freight volumes, serving as the backbone of a globalized twenty-first century world. All of these developments draw the ocean closer to the heart of contempo-
rary human society.

This apparent “domestication” of the ocean accompanies a radical evolution in maritime economies, one similar to the modernization that drives mainland indus-
tries. The frail skiffs of earlier times, sailing near the coastline and dragging their small nets, have given way to massive trawlers – veritable ocean-going bulldozers. Fully equipped with sophisticated technology and capable of scouring the ocean floor 2,000 metres (6600 feet) below the high-
seas surface in any weather, these “fish-killing machines” boast powerful engines that can haul in driftnets and extract loads of fish (Chapters 5, 9, 10; Radars 9.1, 9.2). These research-driven changes in the fishing industry follow dynamic models of fish stocks, built from massive empirical databases and the advanced technology used to assess fisheries.

As maritime economies have mutated they have also transformed the frontier between the mainland and ocean. The standardized 20- or 40-foot long box known as a container – a major technological innovation, bearing the colours of large international shipping lines – brought an age of ultra-large container ships that can carry 100,000 tonnes of an infinite variety of cargoes from Singapore to Rotterdam in twenty days (Chapter 8). But it has done much more than this to change the relation of land and sea. The container set standards for ports and inland freight conveyances, allowing intermodal transport chains to connect the world. This “containerization” has accelerated international trade by making logistics chains
more efficient. A symbol of the globalized economy as much as of maritime transport, ocean freight containers reach the world’s most isolated places, thousands of kilometres distant from any seaport. They structure mainland economies so powerfully that new economic centres form along shipping routes – themselves formed by market forces –, and landlocked countries fall behind, their economic growth lagging behind coastal nations by 1.5% on average.

In fact, the frontier between land and sea has blurred and will go on doing so. These chapters show that maritime economies were long confined to certain coastal points, organized around communities. That has changed in countries as economically diverse as Norway (Chapter 5), Senegal (Radar 9.1), Mauritania (Radar 9.2) and Namibia (Chapter 9). In each, the fishing industry has increased in complexity, organized around multiple professional networks that extend far inland. The oceans’ natural resources – once the purview of small coastal communities – now serve as “national” resources, public property often exploited by large, international companies. “National policies” spill over the coastline to include ocean resources, much as they do for energy resources. For instance, Namibia’s stability since independence in 1990 depends on national fishing revenues (Chapter 9). Quayside negotiations in small fishing ports no longer set wholesale prices for fish; the cost also depends on subsidies granted by governments in capitals far from the coast, e.g. Brussels (Radar 9.2). Furthermore, international financial centres increasingly control fishermen’s access to credit and their business activities (Chapter 5).

The various chapters in this volume bear witness to these increasingly intense, diverse and complicated evolutions – in relationships between societies and the sea, and between the states that comprise the international community, during the twentieth century and in the first decade of the twenty-first. They show how thoroughly technological innovations and economic, political and industrial factors renew the oceans’ challenges. Still full of secrets, the seas remain relatively little known or explored (Chapter 2). Their riches, revealed with each new discovery, heighten entrepreneurial interest and offer much new product potential, particularly for pharmaceuticals (Chapter 11), water desalination, and wave or tidal energy production. However, populations and economies increasingly concentrate along coasts worldwide, exposed to natural risks, e.g. tsunamis, and to climate change impacts, such as sea level rise (Chapter 14). Even as scientific discovery and economic opportunities draw humanity closer to oceans, these same spaces defy the potential their resources seem to offer.

A THREATENED SHARED ENVIRONMENT
Although long considered infinite spaces, where resources could be taken freely and without restraint, the oceans’ resources are not inexhaustible. Rather, the ocean is fragile and its equilibrium precarious, its resources increasingly threatened. Shipping’s exponential growth in recent decades multiplies risks to ecosystems and species. Massive oil spills justifiably anger and alarm coastal residents; yet hydrocarbon pollution (from illegal emptying of fuel tanks) and non-native
species incursions (from de-ballasting operations) cause more damage to biodiversity on a daily basis. The “silent world” magisterially shown by Commander Jacques Cousteau is only a distant memory; ships cause intense acoustic pollution, affecting fish, marine mammals and invertebrates.

At the same time, scarce fisheries resources raise growing concerns. According to the United Nations Food and Agriculture Organization, 75% of marine species are fully exploited or over-exploited. Massively-deployed industrial fishing techniques – sometimes subsidized to ensure the industry’s profitability – threaten the survival of some species, destroy deepwater habitats, and cast a shadow over the future of millions who depend on fishing for a living (Chapter 9; Radars 9.2, 5.1). Furthermore, the exponential growth in traditional pursuits poses an even greater threat when joined by new industries – many just as risky for marine ecosystems. Increased knowledge about the mechanisms that govern deepwater habitats has opened opportunities, for pharmaceuticals in particular, but it is vital that the industry find bioprospecting methods that preserve ecosystems (Chapter 11).

Humanity’s footprint extends over spaces previously preserved from contact – the Arctic providing an emblematic example (Chapter 13) – and ocean exploitation risks are often extreme or unreasonable (Radar 13.1). We can trawl the ocean floor at 1,500 metres (5,000 feet), drill for oil more than 2,000 metres (6,500 feet) deep, and extract DNA from species living in the ocean’s depths. But, astonishingly, we remain incapable of stopping a pipeline from spewing oil, as seen in the 2010 Deepwater Horizon catastrophe in the Gulf of Mexico (Radar 13.1). We flail, impotent, when fighting oil slicks, and remain completely at a loss when faced with the Pacific Trash Vortex (Radar 13.2). And in this inventory of threats to the ocean, we must not forget one often-ignored factor: more than 80% of ocean pollutants come from land-based activity. Industry, agriculture, tourism, urbanization – this silent pollution has many sources and even more enduring and harmful effects. For instance, in the Mediterranean basin, more than half of urban wastewater enters the sea without any treatment. It is the earth, above all, that makes the oceans unwell (Radars 7.3, 13.2): the seas serve as trash bins for urban garbage, waste from defective sanitation systems, and agricultural pollutants running off into rivers and oceans (Radar 7.3).

Different parties, motivated by diverse interests and values, strive to share the oceans; inevitably, this leads to conflict. Seaports in particular illustrate the conflicts inherent in sharing this environment: they are synonymous with pollution and danger because of their concentrated petroleum and petrochemical installations. Seaports face increasing environmental pressure in North America, Europe and even Busan, China (Chapter 8). Vitally strategic at the national level, at the local level seaports prove controversial, not simply for environmental issues, but because of their contribution (or, increasingly, lack of it) to local economies. Many ports risk becoming autonomous territories, no longer ensuring local economic growth. More closely connected to other seaports and major cities in the hinterland than to their immediate contexts, ports impose many negatives – noise, pollution, heavy traffic, etc. – on their nearby host cities. The dominant “landlord” port model, where a
private operator runs a publicly-owned concession, may mean that the port favours its operator’s demands even when they conflict with local interests. The most extreme case arises when a port situated in a coastal community serves only as a transhipment hub, disconnected from the local economy, contributing nothing positive.

As some find more – and more intensive – uses for the oceans, they raise barriers to others’ use; formerly open to all, the oceans grow increasingly divided, compartmentalized and closed-off. Fisheries access provides a striking example: whether along the West African coast or in Norway’s territorial waters, industrial fishing rests on very limited rights to quotas defined by fisheries management plans. Control of these rights by a small “club” of users who combine industrial and political interests causes major conflicts with local, artisanal fishermen who are often forgotten in national fisheries policies, particularly in developing countries. This has often led to serious conflicts between traditional fisherman and modern fishing companies, creating political unrest in turn. Consequently, the most desirable fish stocks go to export markets while local economies must settle for lesser fish, as occurs in Senegal (Radar 9.1).

Scientific knowledge has greatly contributed to enclosing and delimiting resources, via the fish stocks analyses or oil reserve estimates used in management plans. However, the history of ocean exploration (Chapter 2) has also produced new types of research and knowledge; with ecosystem preservation as a founding principle, new studies have addressed the social consequences of maritime industries. This type of research has highlighted previously invisible phenomena, such as acoustic pollution from ships, land-based pollution impacts on the marine environment, and shipbreaking’s effects on workers’ health in Asian yards (Radar 4.1).

**THE OCEANS’ GOVERNANCE CHALLENGE**

The international community is fully aware of such issues, and has deliberated them for many decades; international environmental law has, in fact, largely grown up around marine issues. Still, some environmentally progressive actions have emerged, reshaping Grotius’ seventeenth-century notion of high-seas freedom (*Mare Liberum*). A “Constitution for the Oceans” was created in 1982 – the United Nations Convention on the Law of the Sea (UNCLOS). The result of long negotiations after World War II, UNCLOS drew up rules aimed at sustainable and peaceful use of the oceans and their resources by putting a large part of both under national jurisdiction.

However, everything moves quickly in the maritime world, and UNCLOS has not kept pace on several fronts. First, it provides only fragmented regulation, leaving nearly 70% of the ocean subject to the relative and largely archaic principle of high seas freedom (Chapter 11; Radar 11.1). Second, the physical and biological dynamics operating – often trans-border in nature – overflow its very framework.
Land-based pollution provides an illustration: it transgresses the frontier between land and sea before currents carry it away to the larger ecosystem; it then decomposes into micro-particles and is ingested by fish and other animals or aggregated into a vast plastic debris soup mid-ocean (Radar 13.2). Schools of fish also illustrate how biology “overlaps” or “crosses borders,” outside UNCLOS’ framework: fish have no need of a visa to swim from one territorial water to another, or to run in the high seas where *Mare Liberum* remains the rule (Chapter 8).

The strategies of maritime stakeholders also circumvent UNCLOS’ constraints; designed in line with an evolving institutional framework, they seek to exploit its gaps. The maritime shipping industry owes its formidable economic efficiency to the unregulated system in which it developed (Chapter 8). Commercial competition has given birth to unregulated and suspect flags of convenience sailing beyond the reach of nations (Chapter 4). Tactics to evade fishing rules spring from colossal financial interests, difficult to counter. In the end, public authorities delegate marine resource management and regulation to private organizations – calling UNCLOS’ founding principles into question, since it was intended to empower the oceans’ management by nation-states rather than private parties. The oil industry pushes this trend to its extreme limit: the industry’s financial interests overwhelm public means, while public officials lack the technical expertise needed to monitor sophisticated drilling operations (Radar 13.1). Not to be outdone, states, too, seek to overrun UNCLOS’ constraints: they constantly promote their national interests (Chapter 1) and attempt to extend their territorial frontiers, as demonstrated by the race for the Arctic’s energy reserves (Chapter 13). The fisheries agreements concluded between the European Union (EU) and some West African coastal nations shows the EU’s fishing footprint far exceeds its territorial waters. Analysis of the agreements shows that they contribute to fisheries degradation and represent disguised subsidies to European fishing fleets (Radar 9.2). A great geopolitical game plays out around the oceans; nations have an interest in outstripping UNCLOS’ framework, not to mention that some major countries – such as the United States – have never even ratified it.

The new relationship between oceans and societies brings together such a diversity of stakeholders and actors that cooperation – so critical for sustainable development – becomes a complex challenge. Divergent interests abound: nations attached to the historical concept of high seas freedom; governments aiming for an equitable share of ocean resources; shipowners seeking more rapid navigation; fishermen compensating for scarcities with heavier, deeper and more distant fishing; scientists dreaming of exploring new territories; industrialists hungry for new discoveries; non-governmental organizations demanding larger marine preserves. These competing interests clash in the negotiations fora, immensely complicating the decision-making process (Chapters 1, 6; Radar 11.1).
Without doubt, sectoral conventions (Chapter 6) and regional arrangements (Chapter 7; Radars 7.1, 7.2) have attempted to complete UNCLOS’ global framework and refine tools for assessing (Radar 2.2), protecting (Radar 7.2), controlling and monitoring (Chapter 9) maritime industries and ecosystems. However, legal and institutional frameworks progress more slowly than human appropriation of the sea; they struggle to anticipate new practices and risks such as climate change impacts (Chapters 11, 12, 13, 14). Additionally, the sheer scale of ocean monitoring required limits efforts to manage resources sustainably (Chapter 9). These factors combine with others to undermine the effectiveness of international law – shared responsibility for environmental protection across several international bodies; the difficulty of integrating scientific recommendations in decision-making processes; the weak articulation between regional fishing and biodiversity conservation agreements.

**CONCLUSION**

The outlook is neither unduly pessimistic nor optimistic. It reflects the maritime world itself, torn between development aims and preservation needs – both mirroring, in turn, the many conflicting interests of the global community. This collection aims to enrich and nourish debate about changes that cause upheaval in maritime activities (Chapters 1 to 5), about the complexities involved in achieving sustainable resource use (Chapters 6 to 10), and about making tomorrow’s economies compatible with ecosystem preservation (Chapters 11 to 14). Both global and cross-disciplinary in its approach, this volume treats the ocean’s challenges scientifically, situating them in current political processes. It carefully explores diverse subjects, from marine ecosystems and sustainable fisheries management to genetic resources exploitation and the fight against ocean pollution, expanding knowledge about this new frontier.
The oceans are the rule; the land, the exception. If the Earth were precisely spherical, the oceans would cover the entire globe to a depth of 2646 metres (8682 feet). Humanity’s relationship to the oceans is foundational to all life on Earth, to the way we live and the environment that sustains us. With political authority on Earth divided among states, each more or less sovereign, the oceans have become the subject of intense international negotiation over the centuries. This chapter addresses where those negotiations have taken us and where they still need to go.

Historically, the oceans have been both an arena for the extension of conflict on land and a source of competition for the resources they contain. Comprising approximately 70 percent of the surface of the planet, the oceans play an enormous role in the affairs of nations. Over the past several centuries, there have been several attempts to devise a legal framework that can provide stable expectations in this valuable area, thereby avoiding conflict and promoting cooperation. This framework has been achieved, but it faces significant challenges.

CHAPTER 1

NEGOTIATING OUR FUTURE WITH THE OCEANS

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THE FOUNDATIONAL CHOICE: FREEDOM OF THE HIGH SEAS
The modern law of the sea is rooted in the expansion of European maritime state powers some 400 years ago. This growth of maritime powers gave rise to debate and conflict between the states that sought exclusive control over large expanses of the oceans and those that wanted such areas to remain relatively ungoverned and open to all. Two publications illustrate the opposing viewpoints. The Dutch scholar Hugo Grotius wrote Mare Liberum in 1604, advocating for freedom of the high seas.
and arguing that the vastness of oceans precluded the exercise of dominion, except for a state’s narrow band of exclusive waters (the “territorial sea”) (Grotius 1604 [2000]). In contrast, the British scholar John Selden wrote Mare Clausum in 1617 in which he defended an expansive view of territorial sovereignty over the seas and their resources (Selden 1617 [2004]). This debate was resolved in favor of Grotius’s “freedom” position, although it should be noted that the precise content of that freedom remained unclear and would be elaborated upon by international custom in succeeding centuries. This foundational choice in favor of freedom of the high seas meant a limited notion of shared governance: it existed only in the sense that the seas were agreed to be open to all, and that use of the seas must be pursued with respect for the freedom of others to do the same.

The core principle that no state may subject the oceans to its exclusive use, thereby denying all other states access, also avoided open conflict between states. But the resulting decentralization (if not outright lack) of authority left the oceans open to misuse and over-exploitation. If freedom of the high seas may be said to represent a foundational choice in maritime law, two developments over the past century have eroded the core of that choice. The modern period of the law of the sea is marked by the international community slowly moving from a basically unsupervised freedom of the high seas to (1) greater and greater allocation of ocean spaces and their resources to adjacent coastal states (thereby “enclosing” the high seas) and (2) the negotiation and widespread acceptance of treaties and institutions to govern activities on the oceans. The movement both toward larger coastal state exclusive-use zones and toward more detailed high-seas governance regimes primarily arose as technological developments rendered both living and nonliving resources more accessible and more subject to overexploitation. Many treaties address ocean uses, but the center of the present legal framework is the 1982 Law of the Sea Convention (UNCLOS) that provides the basic framework defining the rights and duties of states.

TECHNOLOGY: THE NEGOTIATION TRIGGER

The general acceptance of the underlying principle of freedom of the seas, expanded upon by custom, led to a relatively stable legal regime by the early 1800s. This is not to say that the oceans were free of violence and conflicts: this period and the century that followed witnessed piracy and horrific warfare at sea (naval battles, blockades, submarine warfare and attacks on civilian and neutral shipping). But this violence and conflict were not so much about the oceans themselves as they were extensions of conflicts on land into the oceanic arena. Nonetheless, with some exceptions, the law of the sea was basically agreed upon in broad terms, and one might have thought further elaboration by custom would address the remaining disagreements and uncertainties.

However, technological advances – arising slowly through the nineteenth century and then accelerating dramatically throughout the twentieth – altered this picture.
Indeed, such advances in technology (and the demand to utilize them) have repeatedly destabilized the existing law of the sea, and there is little reason to think that this pattern will not continue.

In particular, and very significantly, in the early 1900s the fishing industry rapidly increased its capacity to harvest living ocean resources through the advent of steam engines and refrigeration. These changes resulted in large-scale fishing fleets, often operating at substantial distances from their homeports. This development not only changed the scale of fishing, but also complicated negotiations concerning fisheries. Up to that point, nations were primarily concerned with protecting the local fisheries sought after by their nationals. One objective of negotiations was therefore to extend exclusive control of coastal states to cover adjacent fisheries. But as some states also developed long-distance fishery fleets, their negotiations aimed instead to preserve access to fisheries abroad. These changes also placed demonstrable stresses on the living resources of the oceans that had once been thought essentially inexhaustible.

Just as importantly, the period between the two world wars witnessed a growing interest in offshore oil exploration, an interest that exploded after World War II. The first wells were immediately adjacent to shore in shallow water. But the rapidly emerging knowledge of continental shelf structure and the shift in energy generation from coal to oil – especially in the wake of World War II’s demands – dramatically increased coastal states’ demands for exclusive control of the oil adjacent to their coasts.

These two parallel developments in fish and oil lent urgency to international negotiations, not only to codify the existing law of the sea but also to progressively develop it. In both cases, the fundamental question was how far out to sea the exclusive control of the adjacent state extended. This was an acute question, because extending exclusive control meant that states would widen their territorial sea; and extending the territorial sea would enclose (make smaller) the high seas and their freedoms, including the right to freely navigate.

At the end of World War II, then, the outstanding question was the maximum width of a nation’s territorial sea, a width that grew more significant as the interest of states in both fisheries and oil increased; this became the central issue of negotiation and, apparently, one almost impossible to resolve. Moreover, as these negotiations dragged on through the twentieth century, it became manifest that the oceans and their living resources were physically finite. Thus, concerns grew not only over who would get to exploit them, but also how to conserve them.

THE 20TH CENTURY AND THE NEGOTIATION OF A GLOBAL FRAMEWORK

In 1930, the League of Nations convened the first international forum to codify the customary law of the sea. The conference made some advances in ascertaining customary law at that time, but it critically failed to produce a consensus as to the appropriate breadth of the territorial sea. Shortly thereafter, the question of ocean law and governance was put aside by the exigencies of World War II – a war that, in
hindsight, now seems to have provided a much-needed respite for fish and whale stocks already evidencing depletion.

At the conclusion of the Second World War, two proclamations triggered a cascade of events that challenged the precarious balance in the law of the sea. President Harry S. Truman issued both in 1945; they reflected the increasing value of ocean resources to the adjacent coastal state. One proclamation asserted the right to jurisdiction over the continental shelf and its resources. Importantly, this assertion claimed only the seabed, not the water column above (Truman 1945a). In this way, the proclamation did not reduce the size of the high seas or the ability to navigate freely on or below the surface. The nations of the world quickly moved to adopt such assertions of sovereign rights. Definitions of the outer edge of the continental shelf varied, and the legal limit therefore was not entirely clear, but the basic concept moved into practice. The other proclamation proved more problematic. It asserted the United States’ right to establish fishery conservation zones in the waters above (Truman 1945b). The United States did not claim such a fishery zone, but soon thereafter a number of Latin American countries (most notably Chile, Peru and Ecuador) began asserting 200-mile fisheries jurisdictions, if not 200-mile territorial seas. Thus the portion of the high seas under at least partial exclusive control of a state expanded significantly. The United States attempted to reverse direction on the fishery proclamation, but it was too late. The precarious customary balance between a narrow territorial sea and the broad high seas had been broken. By triggering other unilateral actions, the proclamations increased the perceived need to develop an internationally coordinated approach to national claims of authority over the oceans.

THE FIRST AND SECOND UN CONFERENCES ON THE LAW OF THE SEA

In 1950, the International Law Commission undertook a study of the law of the sea; and building on that effort, the first United Nations Conference of the Law of the Sea (UNCLOS I) opened in Geneva in 1958. The results of the conference were splintered into four separate conventions. A state could sign as many or as few of them as it wished, defeating the original intention to create a comprehensive governance scheme. Because the conventions combined customary with new international law, if a state opted not to sign all the conventions, it remained unclear which international norms applied to it. Moreover, hopes for a new consensus from the conference had not taken into account the large number of states decolonizing in the succeeding years, states that had not participated in the negotiations and did not feel compelled to sign or comply. Although one of the four conventions addressed the territorial sea, the conference failed to produce agreement on the critical question of its permissible width.

A second conference in 1960 attempted to address the outstanding questions, but failed to achieve a majority vote on the breadth of territorial seas or on an extended adjacent, yet narrow, fishing zone. For this and other reasons, these two multilateral negotiating conferences, UNCLOS I and II, are seen in hindsight as important
learning experiences but ultimately unsuccessful on the central challenges facing stability in the law of the sea.

**THE THIRD UN CONFERENCE ON THE LAW OF THE SEA**

One of the events credited with instigating the third UN conference was a historic speech that Ambassador Arvid Pardo of Malta made to the UN General Assembly on 1 November 1967 (Pardo 1967). It must be recalled that after World War II, the outer edge of the continental shelf had no precise definition and states’ legal limits in practice often were unclear. That lack of clarity worsened with a reference in the 1958 Convention on the Continental Shelf, which declared that the outer limit of the shelf extended offshore “to a depth of 200 metres or, beyond that limit, to where the depth of the superjacent waters admits of . . . exploitation” (Pardo 1967). This left open the possibility that the coastal states would reach out further and further, claiming “adjacent” seafloor areas until the entire bottom of the oceans was carved up. Arvid Pardo proposed that the deep seafloor, the area beyond what is geologically understood as the continental margin, should not be open to exploration and extraction by individual states, but rather that the seafloor underlying areas beyond national jurisdiction should be considered the “common heritage” of humankind. In his view, the race to be the first to possess ocean floor resources would give way to an international authority to oversee development of this shared resource. The proposal led to the establishment of the Ad Hoc Seabed Committee in 1968. Within two years, the committee had outlined common heritage principles to govern the deep seafloor, and called for a convening of the third conference on the law of the sea.

Before UNCLOS III began in 1973, two unrelated but influential international forums convened. In June 1972, the UN Conference on the Human Environment met in Stockholm and promulgated twenty-six principles regarding international environmental and developmental concerns (UNCHE 1972). The following November, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter was adopted in London, the first effort to control marine pollution by regulating ocean dumping (UNCPMP 1972). The agreements represented proactive efforts to curb the overutilization of the oceans, and it was within this context that the first meeting of UNCLOS III took place.

When the conference began in 1973, it was divided into three negotiating groups. The first focused on the legal regime of the deep seafloor and mining; the second on jurisdictional questions such as the extent of the territorial sea; and the third on issues such as preservation of the marine environment and scientific research. Two widely shared negotiating principles helped ensure the success of UNCLOS III: the convention was based on consensus rather than voting, and any document produced had to be all-inclusive, unlike the fragmented outputs from UNCLOS I. Original estimates foresaw a draft within a few years, but it ultimately took nine.
The final document was signed in Jamaica on 10 December 1982. The requisite sixtieth signature was received in 1993, and after a one-year waiting period the convention entered into force in November 1994. Today, 160 states are party to the 1982 Law of the Sea Convention (the Convention or UNCLOS) making it one of the most widely ratified treaties on any subject. Broadly speaking, it may be said that the Convention accomplishes three things:

- it provides relatively clear jurisdictional allocations and boundaries between states and between states and the international community;
- it provides substantive foundational principles of conduct both in the internationally shared areas and in areas allocated to state control; and
- it provides for a system of mandatory dispute resolution.

**UNCLOS AND THE ALLOCATION OF JURISDICTION**

The Convention (UNCLOS 1982) allocates authority over the oceans through a set of maritime zones summarized visually in Figure 1. UNCLOS provides for (1) a territorial sea up 12 miles in width (Articles 2-3); (2) a contiguous zone that can extend from 12 out to 24 miles from shore (Article 33); (3) an Exclusive Economic Zone (EEZ) that grants sovereign control over both the resources of the water column and the seabed out to 200 miles (Articles 55-59); and (4) a High Seas regime beyond 200 miles (Article 86). In addition, seabed jurisdiction can extend further to the edge of the continental margin or shelf, as determined by a specific methodology and as reviewed by a supervisory committee (Articles 76-77). Beyond fixing areas of national jurisdiction, the Convention also realized Ambassador Pardo’s vision of designating the mineral resources of the deep seabed as the common heritage of humankind (Articles 1(1), and 136-137). The Convention finesse the problem of extending coastal state sovereignty into the High Seas by creating a unique zone, the EEZ. The EEZ is an area of mixed competences: on the one hand, it allocates economic rights to the coastal state, but it otherwise preserves the traditional freedom of the high seas enjoyed in those waters (Articles 56, 58-59).

**UNCLOS AND PRINCIPLES APPLICABLE TO NATIONAL GOVERNANCE**

A critical point: by allocating jurisdiction to coastal states, the Convention relies on individual nations for governance of much of ocean space. But nations have obligations as to how they will govern. At numerous points, the Convention requires that the nation with jurisdiction ensure the environmental integrity of the oceans. Similarly, the Convention requires the coastal state to conserve and optimally utilize the living resources within an EEZ (Articles 61-62).

In a strong endorsement of governance, the state parties are required to submit disagreements to dispute resolution. The forum for resolution is chosen when a state ratifies the convention: the International Tribunal of the Law of the Sea, the International Court of Justice, or an arbitrating tribunal. If the parties do not agree as to the forum, the default is arbitration (Articles 286-288).
Two concerns regarding the Convention were addressed by subsequent implementing agreements. The first was the 1994 Agreement Relating to the Implementation of Part XI of UNCLOS (Part XI Agreement); the second was the December 1995 Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (Fish Stocks Agreement). The two agreements served very different purposes. The Part XI Agreement scaled back the cooperative, resource-sharing components of the deep seabed regime in hopes of attracting signatures from developed states. By addressing the main area of concern to the United States, the Part XI Agreement freed up many other developed states, such as Germany and Japan, to ratify the convention. The Fish Stocks Agreement served to complement and expand the conservation role of the treaty, addressing the question of fish stocks that straddle the EEZ of a coastal state and the high seas open to all.

NESTING TREATIES FOR ACTIVITIES AND REGIONS WITHIN THE FRAMEWORK

The 1982 Law of the Sea Convention provides a framework. It foresees that many particular questions will nest within this framework, either through treaties addressing particular activities on the oceans (for example shipping), or through
treaties more comprehensively addressing a particular ocean region (for example the South Pacific). We now turn to a sampling of these treaties. (See Table 1)

International negotiations tend to focus on particular activities, or even specific issues regarding such activities, to increase the likelihood of diplomatic success. In the 1800s, negotiating conferences were called by a host government; often, they were bilateral and sought to resolve a particular existing dispute. Today, by contrast, such conferences are most often hosted by permanent multilateral organizations with expertise in the field. And the state parties in that context often seek a multilateral arrangement that regulates future actions. In the area of the oceans, a few international organizations dominate: the International Maritime Organization (IMO) in London addresses issues involving ships and offshore oil platforms, including concerns with safety and pollution, as well as the dumping of wastes at sea; the Food & Agriculture Organization (FAO) in Rome has increasingly addressed fisheries conservation; and the United Nations Environmental Programme (UNEP) in Nairobi has a broad mandate to facilitate consideration of oceanic environmental questions.

The law-making processes that structure ocean governance thus take place in various organizations in response to particular activities causing concern. Numerous IMO treaties, for example, have negotiated measures to make ships and shipping safer to those aboard and to the marine environment. In these treaties, the governance of shipping tends to focus on implementation by the flag state of each vessel, that is, the state whose nationality the ship possesses. The ability to reflag ships to states with less rigorous governance (“flags of convenience”) has been a constant point of weakness in this approach. This impetus has led to particular efforts aimed at such flags and to the opening of concurrent jurisdiction over the vessels: jurisdiction according to the state the ship sails past (“coastal state jurisdiction”) and jurisdiction by the state that the ship sails to (“port state jurisdiction”). Fisheries management tends to be negotiated on a regional basis and, even then, fishing stock by fishing stock.

Ocean governance efforts also take place at the regional level. Here, UNEP supplied a foundation by initiating its Regional Seas Programme, aimed at the creation of small regional organizations that would foster a shared sense of ownership in the long-term health of their region. Today, there are fourteen such regional seas programmes involving some 140 states. An example is the Seychelles-based East African Regional Seas Programme, created under the 1985 Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of Eastern Africa. Its members include Comoros, France (Reunion), Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, South Africa, and Tanzania; they are working together, for example, on the protection of reef systems from coral bleaching.

THE CHALLENGES IN NEGOTIATION AND GOVERNANCE AHEAD

Despite the successful growth of the law of the sea, several extremely serious challenges have emerged recently, such as fishery collapse, coastal ‘dead zones’ due to land-based sources of pollution, and the many issues that accompany climate
change, such as ocean acidification. It will be our continuing task to ensure that the hard-won law of the sea will continue to evolve to meet the conflicting and changing demands on the oceans, and thereby provide a stable environment for cooperation. Three particular challenges to negotiating our future with the oceans loom ahead.

The stresses on fishery stocks and the marine environment have grown more apparent, as earlier impacts manifest themselves and as a growing global population and increasingly efficient technology place ever-greater demands on the oceans. It remains to be seen whether UNCLOS and complicated regulatory systems are capable of solving these problems, or whether the central issue is simply inadequate enforcement of present laws. Enforcement resources are already stretched thin, for example, in efforts to identify flags of convenience and to effectively monitor enough of the oceans to deter illegal conduct. Although the lack of enforcement capacity is most evident in the area of fisheries, it presents a challenge to all efforts at ocean governance.

It should not surprise us that problems of ocean health and ocean governance increase nearer to the coastline. This does not imply that nations fail at governance, although that may occur simply because they lack the capacity to govern such large zones. Rather, it reflects the fact that some aspects of ocean governance become more difficult as one approaches populations and more human activity. Such activity on the high seas is, as stated above, difficult to govern. But the amount of activity is limited, particularly in comparison to the range of activities encountered near the coast. More and more of the world’s population resides in the coastal zones of the Earth. And critically, it becomes rapidly apparent that ocean governance is
inseparable from governance of the coastal zone generally. Indeed, the major threat
to the health of coastal ocean areas is “land-based” pollution – meaning, in significant
part, the pollutant run-off from rivers into the ocean, pollutants that can originate
far inland from agriculture, among other activities.

Not that long ago, a negotiation about fisheries was a discussion about the interests of the states involved. More and more, negotiators now find another entity at the table: the environment. The environment is a difficult negotiating party. It not only does not compromise; it does not present its demands until it is too late. Climate change has made this clear. Future negotiations and the resulting governance mechanisms therefore must institutionalize continuous learning processes: scientists can “interrogate” the ocean environment regarding its “position.” The states involved, in turn, are more apt to legitimate the knowledge resulting from such institutionalized learning, and use it effectively to prompt new laws and changes in management priorities.

A strong and widely-accepted framework for ocean governance currently exists, complemented by activity-specific treaties and by regional arrangements. However, the difficulty of enforcement undermines its governance, and the balance of interests implicit in the global framework will be tested as ever-increasing demand and climate change stress ocean resources. The future of ocean governance, like its past, requires leaders with dedication and imagination.

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The ocean remains a little-explored and unknown world. For a long time, fisheries commercialization and energy exploitation drove marine science, but efforts to assess ocean ecosystems started at the end of the twentieth century. Today the challenge lies in using marine science to protect – and not just exploit – oceans.

AN ENVIRONMENT TO DISCOVER: MARINE BIODIVERSITY ASSESSMENTS

Oceans represent over 95% of the biosphere, and host a great share of Earth’s biodiversity. This allows marine ecosystems to generate current and future resources, often called “ecosystem services,” such as food, cancer-curing medicines, and regulation of the Earth’s climate. Some 93% of the Earth’s CO₂ is stored and cycled through the oceans, which also “sequester” approximately 50% of atmospheric carbon. Nevertheless, our current knowledge of marine biodiversity is limited. Despite the scientific research promoted via multinational cooperation over the past 50 years, the ocean remains relatively unexplored. More than 1,500 people have climbed Mount Everest; more than 300 have journeyed into space, and 12 have walked on the moon; but only 5% of the ocean floor has been investigated, and only two divers have descended to and returned from the deepest part of the ocean. This essay will explore current gaps in knowledge and discuss multilateral efforts to resolve them, focusing on one process, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), that recognizes the urgency of action. The scientific study of oceans should be an international priority. No part of the ocean escapes negative effects from human activities – climate change, eutrophication, fishing, habitat destruction, hypoxia, pollution, and species introductions; at the same time, the ocean plays a critical role in regulating the Earth’s climate.

1. Marine and coastal habitats include coral reefs, mangrove forests, sea grass beds, estuaries, hydrothermal vents, seamounts, and soft sediments on the ocean floor deep below the surface.

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time, ecosystem resilience at both local and global scales depends on the health of marine processes and biodiversity.

THE HISTORY OF DISCOVERING AN UNKNOWN WORLD

The history of discoveries in marine biodiversity has been described in detail by Costello et al. (2010). Surveys for marine biodiversity vary in date for different regional seas and countries, but they all fall into one of three periods: the exploratory phase from the mid-1700s until the late-1800s, associated with the major exploration voyages; the local coastal "descriptive" studies around the mid-1900s, during the founding of the major oceanographic institutions and research stations; and large-scale multidisciplinary investigations since the 1990s, related to modern technology development and large-scale multinational research projects. Syntheses of such efforts continue to the present day: the Census of Marine Life, discussed below, is considered the largest effort of this kind in the early twenty-first century (see Table 1).

Before World War II, biological oceanography had two main themes. The first and more important related to fisheries: the availability of exploitable resources, their variability, and their abundance. The second major theme was exploration per se: sightings of exotic and strange animals triggered interest among scientists and the general public. After World War II, biological oceanography changed, focusing on knowledge for the sake of knowledge: with the impact of postwar pollution, knowledge of how marine ecosystems worked became vital to prevent their destruction.

The study of marine biodiversity has followed various methodologies during this history. It began with nomenclatures based on comparative studies of anatomy, morphology, embryology, physiology and behaviour. In the mid-nineteenth century, Ernst Haeckel coined names for the different branches of the evolutionary tree, providing a basis for later taxonomy (the science of classification). As new technologies become available, the pace of biological investigation of the ocean accelerated in the first half of the 20th century. Today, increasing software availability and greater hardware capacity have diversified the analyses that researchers can undertake (Huettmann and Cushman 2009).

A total of 22 million species have been recorded in the Ocean Biogeographic Information System (OBIS), and new methods are expected to discover many more, particularly as research moves offshore: deep-sea biodiversity is considered some of the richest on the planet (Ramirez-Llodra et al. 2010). The largest environment on Earth, the deep sea hosts numerous sub-habitats, unique abiotic and biological characteristics, and supports a particularly high biodiversity.

ACCORDING TO THE CENSUS OF MARINE LIFE, 6000 NEW SPECIES HAVE BEEN RECORDED IN THE LAST TEN YEARS

2. The pyrosequencing approach for microbes in water samples will help identify up to 10,000 holoplankter species in the years to come (O’Dor et al. 2010). With parallel tag sequencing strategy, Sogin et al. (2006) have reported that bacterial communities of deep-water masses contain over a million species.
The assembled knowledge on this vast biodiversity increases daily. However, no one knows precisely how many new marine species are discovered each day; global estimates of marine biodiversity have either not been done or remain unpublished. A simple calculation based on the Census of Marine Life – which reports nearly 6000 potential new species recorded in the last ten years – allows an estimate of close to two new species per day, assuming no time lag between their collection, description and publication. The raw data on the actual finding and description process suggest a
lower average, less than half a species per day. In the decade from 2000–2010 alone, at least 1,200 species new-to-science were discovered; some specimen collections are still being analyzed, and will certainly result in more new species descriptions (Costello et al. 2010). Datasets with global coverage have slowly increased for key concerns: marine species, important habitat/critical areas, and vast ecosystems such as the open ocean, as well as deep seas and marine genetic resources (UNEP and IOC/UNESCO 2009).

In contrast to disciplines such as physical or chemical oceanography, marine biology faces basic challenges in assessing the deep-ocean pelagic ecosystem: less than 0.001 per cent of the deep seafloor has been investigated (Stuart et al. 2008). Several databases are available, but these chiefly document specific groups, such as dominant fishing species and seabirds, marine mammals, and conspicuous coastal macroflora. Additionally, such databases have major gaps in by-catch fisheries data, hindering accurate estimates of many species, such as sea turtles, sharks and small cetaceans. This necessitates further data collection for highly diverse groups such as marine invertebrates, algae and zooplankton. Moreover, the majority of global biodiversity assessments (excluding those for fisheries) concentrate on sensitive habitats in near-shore areas and on endangered and threatened marine species. Assessments often focus on a single issue, e.g. acidification in coral reefs (Turley et al. 2007).

Of course, in some countries collaborations between nongovernmental organizations (NGOs) and intergovernmental organizations (IGOs) have expanded assessment, in order to prioritize sites for protection and conservation. But there is no global synthesis that links small-scale sensitive habitats and/or endangered/threatened species with larger, regional-scale ecosystems. More generally, the field lacks multi-sector impact assessments;3 which, if they exist at all, generally cover only established protected areas.

A REGULAR PROCESS OF REPORTING AND BIODIVERSITY ASSESSMENT

The last decade has seen the launch of major international efforts toward assessing ocean biodiversity; these aim, among other goals, to provide a holistic and shared vision of the state of the marine environment for policy-makers. Some examples will show their contribution to current knowledge of marine biodiversity at different geographic scales.

In Agenda 21, adopted at the UN Conference on Environment and Development in Rio de Janeiro in 1992, participant states pledged to improve understanding of the marine environment, the better to assess present and future conditions (UN 1993). In 1999, at the seventh session of the Commission on Sustainable Development, at the initiative of Iceland, national governments approved the concept of a regular marine environment assessment to provide accurate information to

3. A synthesis of scientific knowledge on global trends in marine biodiversity was published by Sala and Knowlton (2006)
This idea matured into a political decision at the 2002 World Summit on Sustainable Development (WSSD), which established a Regular Process for assessing the state of the marine environment, including its socio-economic aspects, to begin in 2004. The UN General Assembly endorsed this process in 2002, and in 2005 requested that the UN Environment Programme (UNEP) and the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) serve as the lead agencies during a three-year start-up phase. The outcome was the “Assessment of Assessments (AoA),” a scientific evaluation process for the oceans, similar to the Regular Process for climate reporting through the Intergovernmental Panel on Climate Change (IPCC).

The biodiversity AoA summarized priority threats at the regional and the global levels and analyzed the institutional capacity for conducting future assessments. The biodiversity assessment of the AoA identified a number of substantial data-collection and database initiatives conducted at the regional and global scales. Some of these include socio-economic information on human activities that exploit and affect biodiversity within and beyond areas of national jurisdiction, through major activities such as shipping and fishing. Such data collection, however, seldom takes place in order to gauge specific uses and impacts in a given marine resource or ecosystem, and this limits its potential integration in marine assessments. For instance, a 2000 socio-economic manual for coral reef management (Bunce et al. 2000) reflected a need to integrate biophysical and socio-economic aspects in coral reef assessments. The economic valuation of marine and coastal biodiversity is another new field: to date, no global assessments exist, although examples of local valuations for the Caribbean reefs appear in a recent report by the World Resource Institute (Burke et al. 2008).

The marine diversity review of the AoA gave a prominent place to the Census of Marine Life. Launched in 2000 and funded by the Alfred P. Sloan Foundation, the Census recognized implicitly that no country in the world could meet its obligations to catalogue marine species under the Convention on Biological Diversity (CBD) (National Research Council 1995). A growing network of researchers in more than 45 nations has engaged in a ten-year initiative to assess the diversity, distribution and abundance of life in the oceans – past, present, and future (Vanden Berghe et al. 2007).

Under the recommendations of the AoA report, the first cycle (2010-2014) of the proposed Regular Process would include capacity-building, improving knowledge
and common methods of analysis; enhanced networking among those engaged in assessment, international monitoring and research programmes; creating communications tools and strategies for reaching different target audiences; and producing regular updates on marine areas to inform policy development. This last would address agreed cross-cutting issues such as food security, and establish a baseline for future global marine assessments.

**IPBES, A SCIENCE-POLICY PLATFORM FOR BIODIVERSITY.**
Better-informed biodiversity assessments and policy-making call for specific research priorities in the short term. These include data validation, improved biogeographic classifications, and studies of open-ocean and sea-bottom ecosystems and their dynamics. Until now, limited funds and capacity have hindered such efforts. Most scientific research occurs in shallow coastal waters whose biodiversity is more accessible than that of deep-sea environments, where research requires specialized technology – e.g. submersible-equipped vessels, remotely operated underwater vehicles (ROV), moored equipment, or long-term observatories. The few submersible studies to date suggest that some species may concentrate into narrow depth zones (Robison 2004). These major gaps in data and knowledge about the oceans preclude purely taxonomic classification based on biogeographic data.\(^6\)

However, data and knowledge assemblage is not enough. Biodiversity protection calls for a science-policy platform, similar to the IPCC for climate issues. The current science-policy interface comprises multiple national and international mechanisms. This is particularly true in the marine environment, where several UN and non-UN entities provide scientific data on marine biodiversity.\(^7\) The fragmentation of mandates amongst different organizations and, often, the weakness of their scientific processes create obstacles to a holistic vision of biodiversity status at global and regional scales. In other words, the scale of global-view governance does not match the scale of available biodiversity data. A holistic vision must take this discrepancy into account: global-scale initiatives must integrate local and regional “close-up” views to understand large ecological processes and cumulative impacts, and consider the consequences and hurdles this implies for governance. When decision-making moves towards the local levels, knowledge commonly becomes choices and decisions, not through “translation” but through

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6. The current biogeographic theory suffers from limited understanding of open-ocean and deep-sea ecosystems, as well as from a lack of knowledge about the vulnerability, resilience and functioning of marine biodiversity in these areas.

7. E.g. Convention on Biological Diversity (CBD), Food and Agriculture Organization (FAO), Joint group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), International Coral Reef Initiative (ICRI), International Whaling Commission, UN Division of Ocean Affairs and Law of the Sea (UNDOALS), Millennium Ecosystem Assessment (MEA), etc.
its development by relevant stakeholders. Often, this participatory process gives knowledge its real legitimacy and saliency (Cash et al. 2003). A dedicated intergovernmental science-policy platform could strengthen such contributions to policy-making, ensuring the credibility, legitimacy and relevance of emerging scientific findings and recommendations. Over time, assessments have contributed to changing perceptions about issues, thus paving the way for later assessments to wield more influence; this has been demonstrated by the series of Intergovernmental Panel on Climate Change (IPCC) assessments (IPCC 2002). IPBES, also known as the “IPCC for biodiversity,” began in 2008 under the leadership of UNEP. Its goal is to focus on data and information standards and infrastructure for biodiversity science. The information gathered would also strengthen and harmonize the use of predictive models of global change, and identify areas requiring relevant information and scientific effort. The IPBES will link with the Group on Earth Observations Biodiversity Observation Network (GEO BON) — a collaboration of more than 100 governmental and other organizations that already share data and analyses of biodiversity (Larigauderie and Mooney 2010).

Such participatory processes entail high costs, but in the longer run these may be lower than the enormous costs of failure owing to lack of saliency, legitimacy and acceptability (Soberon and Sarukhan 2010). IPBES’ framework would allow consolidation of regional data into a global-scale synthesis and ensure effective communication of lessons learned. The initiative’s success rests on the quality of the scientists involved and the independence of their scientific work, as exemplified by IPCC’s precedent. It is hoped that their international character, consensus approach to scientific knowledge, and transparent peer-review process may make the reports more legitimate and useful to policy-makers at the national level. IPBES’ periodic nature aims — over time — to mobilize public opinion and structure the scientific community around a set of common goals, accelerating progress in both science and relevant policy.

In June 2010, the final preparatory consultation on IPBES held in Busan (South Korea) led to a proposal for the UN General Assembly: IPBES would have the legal status of an independent intergovernmental body, administered by one or more existing UN bodies. Its “constituency” of stakeholders who could make requests would include governments, signatories to the six biodiversity-related multilateral agreements (including the World Heritage Convention), UN bodies, non-governmental organizations, and the private sector.

In December 2010, the UN General Assembly decided that the UN Environment Programme would take steps to create this new international body, and the first meeting would probably occur place in the summer of 2011. With the establishment of the Regular Process and IPBES in 2011, the issue of marine biodiversity will be addressed in both fora. It is therefore critical that IPBES coordinate with, rather than duplicate, existing and future assessments such as the Regular Process. In early 2011, UN member states will have to define the articulation between IPBES and the Regular Process, and consider how to avoid duplication and waste of resources. This
will be an interesting and unprecedented challenge. It would also be a mistake to try to replace or integrate one within the other one. The Regular Process and IPBES respond to different needs and constituencies and will operate in quite different ways, due to their independent goals and origins.

CONCLUSION
Research at unprecedented geographic scales will be required to further our knowledge of biodiversity and ecosystems and to assess the importance of resources the marine environment provides. Whilst scientific knowledge has increased tremendously over the last 50 years, thanks mainly to technological advancements, it remains open to question how effectively governments and international organizations have been able to use it, either for biodiversity conservation or sustainable management. IBPES and the Regular Process offer some hope that one aspect of the puzzle – the match between global scientific challenge and local action – will see future progress.


SEAMOUNTS: OASES FOR BIODIVERSITY

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Offshore up- and down-welling, thermal fronts, eddies and gyres can generate short-lived, rich biodiversity areas; by contrast, static sea-bottom features, such as seamounts, frequently host the more stable processes that enhance ocean productivity. Although a substantial number of studies have been conducted on single seamount locations, their census is far from complete, and more investigation is needed to understand their role as oases of pelagic (offshore open water) biodiversity. Estimates put the number of seamounts spread across the oceans as high as 100,000 (Kitchingman et al. 2007), and this suggests that they are one of the most highly-represented habitats in the offshore environment (Fig. 1). The present paper will outline some of the biodiversity issues that have arisen in recent seamount research.

Seamounts are typically cone-shaped undersea mountains that never emerge above sea level. They are defined as features that rise to at least 1,000 metres above the seafloor, and their peaks are found from tens to hundreds of metres below the surface. Seamounts can be very large in terms of height as well as area. They often occur in chains or clusters that are probably linked to seafloor hotspots and plate movements, and they are frequently associated with past and present volcanic activity (e.g. Emperor Seamount, Central Pacific ocean); isolated seamounts without clear volcanic origins appear less common (e.g. Eratosthenes Seamount, Eastern Mediterranean Sea).

SEAMOUNT OCEANOGRAPHIC AND BIOLOGICAL PROCESSES
Benthic invertebrate populations from geographically separated seamounts (and the continental slope) may reveal varying degrees of genetic isolation. Rates of endemism (habitat-unique species) between 10% and 50% have been reported; however, these numbers will likely change with increased sampling efforts and with an integrated genetic/morphology-based approach to the mechanisms involved in faunal isolation (Stocks and Hart 2007).

Seamount effects extend into the water column: nutrient enrichment and enhanced primary productivity occur over seamounts because of the above-mentioned hydrodynamic processes. However, such enhanced productivity varies over time; its effects may be confined within the seamount area and/or spread...
by ocean currents as far away as 10-40 nautical miles. Studies of pelagic communities above seamounts have revealed both qualitative and quantitative differences from the pelagic fauna and flora found in surrounding waters. Planktonic biomass is often higher over seamounts than in surrounding areas: this probably results from up-welling around the seamount. Many pelagic predators aggregate (especially to forage) as a result of static sea bottom morphological features, such as seamounts. These in turn increase the incidence of high primary production by aggregating herbivorous zooplankton. Irregularities of the sea floor often alter the currents above them, which favors mixing of water mass and the rise of nutrient-rich waters to the surface. This in turn increases primary production of phytoplankton and concentrates the herbivorous zooplankton that feed upon them. Finally, there is evidence that seamounts trap vertically migrating zooplankton, making them more accessible to near-surface and diving predators (Fig. 2).

Small actively-swimming (nektonic) species, usually located in deep waters during the day (500-600m in the case of Myctophids), have been observed moving over seamounts at a depth of 80-150m at night. Myctophids are small mesopelagic fishes that feed on diurnally migrating plankton; they are an important component of the diet of large fish species and dolphins. The closed circulation associated with seamounts is likely to retain the enhanced local energy production – much of it transferred to first levels of the pelagic food web – which in turn supports dense aggregations of highly mobile top predators. Many pelagic vertebrates, including seabirds, swordfish, tunas, sharks, sea turtles, dolphins and whales, forage on mesopelagic and demersal (bottom-dwelling) fishes and squids; they concentrate in these areas to feed on the elevated primary production and high standing stocks of zooplankton and micronekton.

All these factors support the conclusion that, given the specific communities they support, seamounts are distinct habitats and not simply part of their larger biogeographic regions. In addition, seamounts often serve as mating and spawning areas for a wide range of pelagic species.
The predictable mating and foraging aggregations of pelagic species around seamounts make them especially susceptible to destructive pulse fisheries, which frequently also damage slow-growing resident fish and invertebrate communities (Hyrenbach et al. 2000). “Pulse fisheries” occur when a migratory species, such as bluefin tuna, passes through an area only occasionally, attracting heavy fishing pressure while it is present. Overall, fisheries exploitation is a major threat to seamount ecosystems. Serious stock depletion on continental shelves has created new pressure for alternative fishing grounds. Because of technological improvements in navigation and fishing, even seamounts in remote offshore areas have become “newly” exploited ecosystems, intensively fished since the second half of the twentieth century. Because most seamount species are also found on the continental slope, it is quite difficult to allocate and to quantify the catches taken from seamounts around the world. Since global landings of demersal marine fishes have shifted to deeper-water species over the last fifty years, this could be an indirect indication that seamounts have also increased in importance for long-line fishing, bottom-set netting and trawl fishing.

As an example of successive rapid development and decline patterns, the case of the orange roughy (*Hoplostethus atlanticus*) highlights how fisheries based on seamount-only species have collapsed with greater frequency and shown poorer recovery. Most catches of this species have been identified as seamount harvests; with the collapse of earlier fisheries, only the discovery and exploitation of new seamounts has permitted orange roughy fishing to continue (Watson and Morato 2004). Moreover, seamounts have been valuable fishing areas for purse seiners, pelagic long lines, and drift net fishing for tunas, swordfish, billfishes and sharks. Some 150 of the known seamount fish species have been identified as commercially exploited. Most of the species for which data are available have both low or very low productivity and low resilience to exploitation. Only a few seamount fishes appear in the 2009 IUCN Red List: *Sebastes paucispinis*, listed as “critically endangered;” *Sphoeroides pachygaster* and *Hexanchus***
griseus, cited as “vulnerable;” and Squalus acanthias, Dalatias licha and Prionace glauca, classified as “lower risk, near threatened” (IUCN 2009). In 2005, the Census of Marine Life undertook a global study of seamount ecosystems (CenSeam) to determine their role in ocean biodiversity and the effects of human exploitation. Despite this research effort, much remains unknown at the project’s end in 2010, given the large number of seamounts, their widespread distribution, and the wide variability of their habitat types.

SEAMOUNT HABITAT CONSERVATION

The overwhelming evidence of the fragility of seamounts and their associated resources suggests that they require a high level of protection. Seamounts, given their global distribution, exist within and beyond areas under national jurisdiction. Those under national jurisdiction can be protected by use of legal mechanisms, such as protected areas and fisheries restrictions. However, the protection of international waters, including numerous far-flung seamounts, poses broader legal and geopolitical challenges. Because no unified managing authority exists, seamounts in particular are subject to unmanaged exploitation by several countries. One may conclude that not only seamount fisheries but deep-water trawling in general may not prove sustainable in the long term (Alder and Wood 2004). However, according to Watson and Morato (2004) seamount ecosystems could sustain regulated small-scale artisanal fishing fleets. Further research on sustainability levels is unquestionably needed.

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Public and economic policies have long considered nature as *res nullius*, something that has no owner. Ecosystem services valuation aims to assign a monetary value to nature and the goods and services environmental resources provide. It rests on a double weakness in current policy-making, which neither gives such services their full economic weight nor accounts sufficiently for environmental damage caused by human activity. Setting monetary values for ecosystem services and for anthropogenic degradation of the environment helps create market-based mechanisms to pay for such services, or to compensate for such damages. Ecological economists currently believe this approach represents the only way to curb biodiversity loss; it situates biodiversity in economics and public policy for efficient spending decisions.

The first marine and coastal economic valuation took place in 1926, when a specialist in fisheries biology, Percy Viosca, estimated the conservation value of Louisiana’s coastal wetlands. Recently, accidental marine pollution incidents have increased the need for such valuation: following the 1989 Exxon Valdez oil tanker spill in Alaska, the American Supreme Court fined Exxon over $1 billion in its final court judgment in 2008 for ecological losses and compensatory damages. Ecosystem valuations are currently being used to estimate the 2010 Deepwater Horizon oil spill impacts on coastal ecosystems in the Gulf of Mexico.

During the 1990s, such valuations aimed for a larger scale when a team of researchers led by Robert Costanza estimated the economic value the entire world’s ecosystem services. They calculated that marine and coastal ecosystem services

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1. Ecosystem services are defined as those functions of ecosystems that (directly or indirectly) support human welfare. They occur at multiple scales, from climate regulation and carbon sequestration at the global scale, to flood protection, soil formation, and nutrient cycling at the local and regional scales (Gund Institute 2007).

2. The loss estimates were determined through an economic analysis, largely surpassing economic losses directly due to the accident and encompassing non-market losses. The less well-known 1978 Amoco Cadiz case bolstered the need to measure the cost of ecological damage, but demands for indemnities based on economic valuations were abandoned during litigation.
contributed $21 trillion dollars annually to human well-being: most (60%) of these services concentrate along coastlines that make up only 9% of the world’s surface area (Costanza 1999). These coastal and marine areas – including coastal wetlands and mangroves – represent 77% of the world’s total ecosystem services value (Martinez et al. 2007) (See Figure 1).

Internationally, studies of marine and coastal ecosystem services valuation are increasingly numerous: all underscore the importance of marine areas in furnishing goods and services. In the Mediterranean, they are worth nearly €26 billion annually, with cultural and leisure services providing two-thirds of that total (Mangos et al. 2010). In the United Kingdom, provisioning services are worth €713 million, cultural services €15 billion, regulating services between €840 million to €10 billion, while supporting services exceed €1 trillion in value (Beaumont et al. 2008). In these valuations, the estimated worth of “commercial” goods and services proves relatively less than that of cultural, supporting and regulating services.

In France, studies of ecosystem services valuations remain rare, and marine ecosystems valuations studies even more so. An important exception took place in 2008, when the Civil Superior Court in Paris considered the economic value of ecological damage due to the 1999 Erika oil tanker spill in its €370 million judgment against Total. The judgment included not only compensatory damages for lost commercial goods and services, but also the value of intangibles – beauty and inspiration, and more generally, the assurance of healthy ecosystems for future generations. Such valuations will probably become more common in the future. In 2009, a report by France’s Strategic Analysis Council reviewed the concept of biodiversity and ecosystem services valuations, analyzing methodology along with potential applications and limitations (Chevassus-au-Louis et al. 2009). As yet, few French marine ecosystem services valuations are available, excepting one conducted through the French Initiative

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**FIGURE 1. VALUE OF MARINE AND COASTAL ECOSYSTEM SERVICES**

![Graph showing the value of marine and coastal ecosystem services](Source: Costanza (1999))
for Coral Reefs that valued reefs in certain “Overseas French Provinces,” such as Martinique (see Box 1). In addition, the French Administration for Austral and Antarctic Lands launched a study in 2010 to value land and marine biodiversity, within the framework of its Biodiversity Action Plan. Although few studies have targeted its two seacoasts, France is conducting a valuation of some of its Marine Protected Areas in the Mediterranean, and of the Saint Brieuc Bay in the English Channel and Atlantic Ocean.

Assigning value to biodiversity undeniably aids efforts towards marine resources conservation and sustainable exploitation. Ecosystem services valuation provides a powerful integrated, multi-actor management tool that brings together knowledge from different disciplines – ecology, biology, economics and social sciences – and expresses it in a monetary form understood by all. It provides two crucial policy tools: means to represent the costs of marine ecosystems’ degradation and destruction, and to define the “good” environmental status that the European Union’s 2008 Marine Strategy Framework Directive requires by 2020 (EU 2008).

Nevertheless, ecosystem services valuation has its skeptics with regard to both its ability to supply accurate data and the use of such data. On large scales, values are often astronomically high: consequently, they are hard to compare with economic reality or to integrate in a national accounting system. Practitioners debate methodological questions, notably issues surrounding benefit transfer and the aggregation and use of results. Even the core principle of

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3. Sovereign French territory extends beyond mainland France to islands and territories in the Pacific, Atlantic and Indian Oceans, South America and Antarctica. These French “overseas” provinces are composed of different administrative entities: the most important ones for marine biodiversity are located in the Caribbean, Indian Ocean, Southern and Southeastern Pacific.

4. “The benefit transfer method rests on a simple principle: using a valuation conducted on one site, called a ‘study site,’ to deduce the valuation of a second site, the ‘application site’” (Rozan and Stenger 2000).
valuation is questioned, since studies tend to show that the more humans exploit an ecosystem, the more its economic value increases, boosted by direct use values (Failler 2010). Such results run counter to marine biodiversity management policies that tend to limit some ecosystem uses.

Ecosystem services valuation’s next challenge lies in overcoming this services-based approach – so constraining in many ways – and developing an approach based directly on ecosystem functions and their interactions. This calls for an inventory of knowledge from the many disciplines involved in ecosystem valuations, one that establishes connections between fields. Beyond questions of method, however, further work must be done on how to integrate valuations into practical decision-making, making them more relevant and useful for policymakers.

### WORKS CITED


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#### FIGURE 2. TOTAL VALUE OF MARTINIQUE’S MARINE AND COASTAL ECOSYSTEMS

<table>
<thead>
<tr>
<th>Type of Use</th>
<th>Economic Value of Coral Reefs, Seagrass Beds and Mangroves (€ million/year and % of total)</th>
<th>Value (€ million/km²/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coral Reefs</td>
<td>Seagrass Beds</td>
</tr>
<tr>
<td>Direct Use</td>
<td>132 (52%)</td>
<td>1.02</td>
</tr>
<tr>
<td>Indirect Use</td>
<td>107 (42%)</td>
<td>0.08</td>
</tr>
<tr>
<td>Non-use</td>
<td>13 (5%)</td>
<td>0.07</td>
</tr>
<tr>
<td>Total</td>
<td>252 (100%)</td>
<td>1.17</td>
</tr>
</tbody>
</table>

Source: Failler et al. (2010)
The oceans are home to a wealth of resources that society has long depended on to meet many of its critical needs, including food, commerce and transportation. As the world’s energy demands have grown, oceans have emerged as an increasingly viable source of energy. Resource analyses demonstrate the large stores of energy held in various forms in the world's offshore areas. These vast resources have stimulated the development of the offshore energy industry, traditionally geared towards fossil fuel exploitation. However, many unutilized energy resources of the oceans present numerous opportunities to expand the global energy repertoire and to meet growing demands in a sustainable manner.

This chapter provides a historical and prospective analysis of energy exploitation at sea, from the earliest forms of offshore energy to the recent shift towards offshore renewable resources, such as wind, wave and tidal power. It provides an analysis of the respective costs and benefits of offshore energy, with a focus on renewable energy, as well as the political and socioeconomic context in which various resources have developed or may become viable in the future.

**A BRIEF HISTORY OF TRADITIONAL OFFSHORE ENERGY EXPLOITATION**

Whale oil was one of the earliest forms of energy derived from the ocean and was largely employed for use in lamps and as candle wax. In the nineteenth century, demand for whale oil, valued for its use as a lubricant, animal feed and fertilizer,
drove the development of modern whaling techniques. Whale oil exploitation proved quite lucrative until unsustainable levels of whale hunting and the rapid growth of the petroleum industry brought about its decline (Starbuck 1989).

Coal has also been harvested in offshore areas at various points throughout history, although offshore mining has been unable to compete with land-based operations. The ancient Greeks extracted coal reserves from offshore areas (although not for energy), as did the Scottish in the sixteenth century. More recently, coal has been extracted offshore near Europe, Asia and the US (Charlier and Charlier 1992).

Oil and gas have long been exploited from land-based sources, yet offshore exploitation did not become cost-effective until the mid-twentieth century. The first modern offshore drilling platforms were launched in the Gulf of Mexico in the late 1940s. Significant growth of the offshore oil and gas industry, however, did not occur until the 1970s, when the global energy crisis dramatically raised the price of oil, making offshore operations more economically viable. Industrialized nations’ severe energy vulnerabilities and the security issues extending from fossil fuel dependence on OPEC (Organization of Petroleum Exporting Countries) stimulated interest in exploiting domestic petroleum reserves, including those found in offshore areas. Increased investment in offshore drilling technology, partially in response to rising gas prices, allowed the industry to overcome technical constraints associated with greater water depths. Consequently, larger offshore reserves became available, although the recoverability of many offshore reserves still heavily depends on the balance between development costs and oil price (IEA 2008). As the industry has progressed, so have policies and technical standards aimed at refining extraction techniques and facilitating more efficient and environmentally-sound practices. Since its inception, more than 70 nations around the world have been active in the offshore oil industry (Charlier and Charlier 1992).

The growth of the offshore drilling industry has also stimulated interest in the construction of offshore terminals for the storage and delivery of liquefied natural gas (LNG). Increased global attention to offshore LNG storage reflects both an interest in large, unexploited offshore natural gas reserves and concerns with the safety of traditional modes of natural gas transport. The first offshore LNG terminal was constructed off the coast of Italy in 2009, and new terminals are currently being sited in other areas. These projects have, however, come under fire for their potential environmental impacts and their negative implications for coastal aesthetics (Popham 2007).

**THE UNSUSTAINABLE NATURE OF OFFSHORE OIL AND GAS**

While the offshore oil and gas industry continues to grow, it is also becoming increasingly unsustainable. Global fossil fuel reserves are being quickly depleted, and untapped stores are estimated to be relatively minimal. A recent report estimates the global total proven and probable reserves to be between 854 and 1,255 gigabarrels, which would satisfy roughly 30 to 40 years’ demand if economic growth were to stop immediately (EWG 2007; IHS 2006). However, recent projections of the continuing
rise in world energy demand (see Figure 1) indicate that these reserves will likely be depleted more rapidly than previously estimated. Critics also argue that many of these reserves are largely inaccessible due to technical constraints, and that estimates of recoverable petroleum resources are, therefore, inflated.

Mounting evidence indicates that fossil fuel exploration and exploitation carry severe environmental costs, both locally and globally, which contribute to their unsustainability. A recent report from the Intergovernmental Panel on Climate Change states that the onset of climate change is not due to natural causes alone, and that human activities, namely the emission of greenhouse gases (GHGs) through the use of fossil fuels, have likely triggered this phenomenon (IPCC 2007).

Offshore drilling operations can also carry more localized environmental and ecological impacts, which include physical damage to habitats and ecosystems, and sedimentation. Large-scale disasters resulting from blowouts, explosions, spills and leakages can have severe environmental and socioeconomic effects, and remain an ever-present threat (see Box 1). While technological developments and improved standards have somewhat mitigated traditional hazards, enormous risks remain.

**OFFSHORE RENEWABLE ENERGY AS A VIABLE RESOURCE**

With increased recognition of fossil fuels’ lack of sustainability, political attention to renewable energy resources has grown as well. In this respect, the oceans present a notable opportunity to meet growing energy demands in a sustainable and environmentally friendly manner. The world’s ocean areas contain enormous amounts of clean, renewable energy in the form of wind, wave and tidal power (among others) that, until recently, had limited prospects for commercial viability. While renewable energy has been utilized in limited forms throughout history, it was not until the oil crisis of the mid-1970s that political support emerged for research and development in new energy technologies. Wind and solar power technology benefited greatly from this attention; however, offshore renewables (e.g. wave, tidal, thermal, and other ocean-generated energies) were still widely considered uneconomical at the time.
Renewed interest in offshore renewable energy sources has recently surged in light of the unsustainable nature of fossil fuel exploitation arising from adverse environmental and ecological impacts, dwindling global reserves, and rising oil and gas prices. Technological developments have overcome some of the traditional technical constraints associated with these energy sources, as well. Offshore renewables present a number of important benefits over traditional energy sources, and possess significant potential to sustainably meet the growing energy demands of the world’s coastal areas. They are predictable, abundant, environmentally friendly (carrying relatively few localized environmental impacts), and pair well with the high energy demands of coastal populations. They can also increase the energy self-sufficiency of coastal communities. According to one scenario-based model, success in wave and tidal technology, combined with the appropriate regulatory environment, could yield global power generation capacity of up to 200 GW by 2025\(^1\) (Pike Research 2009). According to a recent analysis, up to 2 GW of wave and tidal capacity could be installed by 2020 in the UK alone – enough to power 1.4 million homes (UKDECC 2009).

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1. This does not include offshore wind energy.

**Box 1. Offshore Disasters: The Risk of Offshore Oil and Gas**

Despite improvements in regulations and equipment standards, offshore oil and gas operations remain risky and have led to numerous disasters, often with devastating environmental and socioeconomic impacts. There have been many notable disasters in the history of offshore petroleum exploitation, including the following:

- **Deepwater Horizon.** (20 April 2010) In the Gulf of Mexico, an explosion on the Deepwater Horizon offshore drilling rig killed 11 crewmen and left open a deepwater well that released an estimated 4.9 million barrels of crude oil into the ocean before it was shut more than three months later on 4 August 2010.

- **Argo Merchant.** (15 December 1976) The Argo Merchant ran aground 29 nautical miles southeast of Nantucket Island, Massachusetts in high winds and ten-foot seas. Six days later, the vessel broke apart, spilling its entire cargo of 7.7 million gallons of fuel oil.

- **Amoco Cadiz.** (16 March 1978) The Amoco Cadiz ran aground in inclement weather off the coast of Brittany, releasing its entire cargo of 68.7 million gallons of oil and polluting roughly 200 miles of the French coastline.

- **Ixtoc I.** (3 June 1979) The 2-mile-deep exploratory well blew out in the Bay of Campeche off Ciudad del Carmen, Mexico. By the time the well was brought under control nearly 10 months later, roughly 140 million gallons (approximately 3.3 million barrels) of oil had been spilled.

- **Exxon Valdez.** (24 March 1989) The Exxon Valdez ran aground on Bligh Reef in Prince William Sound, Alaska, while traveling outside the normal shipping lanes to avoid ice. 10.8 million gallons of oil were spilled into the Sound, affecting more than 1,100 miles of Alaskan coastline and severely affecting the region’s fishing industry and wildlife.

- **Barge Bouchard 155.** (10 August 1993) Two barges, the Bouchard 155 and the Ocean 255, and a freighter, the Balsa 37, collided in Tampa Bay, Florida. The Bouchard 155 spilled an estimated 336,000 gallons of No. 6 fuel oil into Tampa Bay.

Sources: NOAA (2010) and Lubchenco et al. (2010)
OFFSHORE WIND ENERGY Offshore wind energy has become an increasingly viable source of renewable energy, attracting global attention due to its inherent advantages over other forms of both non-renewable and renewable sources. comparatively, it is the most developed form of offshore energy production in terms of technology and regulatory frameworks, and presents considerable near- and long-term potential to meet the growing energy demands of coastal areas. The abundance of powerful offshore wind contributes substantially to its viability. A number of academic sources have estimated that the world’s exploitable offshore wind resource could exceed 200,000 TWh/yr (1 terawatt-hour or 1 TWh = 1 billion kilowatt-hours) – twelve times greater than the International Energy Agency’s 2002 estimate of global energy demand. An independent consultancy has estimated Europe’s exploitable offshore wind resource of Europe alone to be 313.6 TWh (DTI 2004). Offshore wind farms operate in different areas around the world (See Figure 2). While the majority of these projects are in Europe, many other countries are assessing resource potentials and examining suitable sites for development.

Research and experience in land-based projects have accelerated offshore wind technology development. Proven technology currently allows the placement of turbines at relatively shallow depths of up to 40 metres; deepwater floating

FIGURE 2. LARGE WIND FARMS IN EUROPE AND CHINA

Source: Data compiled by author in June 2010 based on RenewableUK (2010).
technologies are in the development and demonstration phase (UKDTI 2004). In 2009, StatoilHydro launched the world’s first full-scale floating offshore wind turbine off the coast of Norway. This technology provides access to areas further offshore, where the wind is stronger and more sustained than in areas closer to shore, and where user conflicts and impacts on coastal aesthetics are less of a concern.

**WAVE ENERGY** Wave energy has also emerged as a potentially viable source of renewable energy in areas with a powerful wave resource. Waves can be a destructive force on coastal areas, contributing to erosion and damaging infrastructure. With appropriate technology, however, waves can become a significant energy resource with comparatively few environmental impacts. The global wave power resource is estimated to be around 8,000-80,000 TWh/yr (1-10TW), which is the same order of magnitude as world electrical energy consumption. Temperate zones, where strong storms often occur, have proven to be the ideal areas for harnessing wave energy (RenewableUK 2010).

Wave energy can be harnessed using either floating or fixed installations. The latter uses the oscillating water column generated by the wave to push air through a turbine. Floating devices convert the wave’s energy by coupling the vertical movements of the waves to a hydraulic system. Other technologies, such as overtopping devices and wave surge converters, are also being tested and demonstrated in different areas. There are some examples of successful wave energy projects, although technical constraints have limited large-scale implementation. The Islay Limpet, the world’s first grid-connected land-based wave energy converter, was built in 2000 and has been operating successfully since (UKDTI 2004). The world’s first offshore wave energy farm, the Aguçadoura Wave Farm, was launched off the coast of Portugal in September 2008. This installation, developed by Pelamis Wave Power, employs three 750 kW devices with a total capacity of 2.25 MW (RenewableUK 2010). Some other nations, primarily in Europe, are actively pursuing wave energy by estimating production potentials, examining viable sites, and implementing demonstration projects.

**TIDAL ENERGY** The immense and predictable power of the tides was recognized early by the ancient Greeks, who utilized the tidal energy of the Euripus Straight through mills at Chalcis and Argostoli. Bernard Forest de Bélidor published a treatise on water power in the mid-eighteenth century (Charlier and Charlier 1992). Tidal mills have also been used in the US, the UK and Russia, among other locations. France’s Rance Tidal Power Station, completed in 1966, remains the largest tidal barrage in operation. South Korea plans to construct a barrage more than five times larger than the Rance Station in the Incheon Bay with a capacity of 1.32 GW. The UK’s proposed Severn Barrage project would, however, surpass the South Korean plant, proposing to install up to 10 miles of dams and sluice gates across the Severn Estuary, with a potential capacity ranging from 1.05 to 8.6 GW (Kho 2010).
While tidal power has traditionally been harnessed using barrages, there is expanding interest in installing arrays of underwater turbines to exploit this resource. Tidal energy turbines were initially proposed after the oil crisis of the 1970s, but have only recently become a reality. In 2003, Marine Current Turbines installed the first full-scale prototype turbine in the UK (UKDTI 2004). Other companies in the UK, Ireland, Norway, Australia, and the US have also begun establishing test sites for underwater turbines in various configurations.

Many nations are now actively pursuing this industry. The UK has been especially active, mapping its tidal resource and examining potential sites for tidal energy projects. The World Offshore Renewable Energy Report 2004-2008, estimates that while a staggering 3000 GW of tidal energy may be available, less than 3% is located in areas suitable for power generation (UKDTI 2004). Tidal energy is, therefore, very site-specific and feasible only where strong tidal flows are amplified by factors such as funneling in estuaries.

**OCEAN CURRENT ENERGY** The world’s powerful ocean currents, such as the Gulf Stream off the east coast of the US and the Kuroshio Current off the coast of Japan, represent an enormous and untapped source of potentially exploitable energy. Some efforts are exploring the possibility of harnessing this power through underwater turbines and other types of developing technologies. However, due to high implementation costs and technical constraints, commercial viability is only gradually emerging and no commercial, grid-connected turbines currently operate.

Since ocean currents flow steadily in one direction, there is no flow reversal, creating a substantial baseload (continuous power generation) potential. Ocean current energy installations, therefore, do not have to expend additional technological capacity to accommodate multiple flow vectors, factors that might contribute to equipment sensitivity in the hostile marine environment. Yet a number of technical challenges to viability exist, e.g., constraints associated with large water depths and long submarine cable transmission distances, negative impacts of cavitations (bubble formation), biofouling prevention, corrosion resistance, and reliability.

**OCEAN THERMAL ENERGY CONVERSION (OTEC)** Ocean thermal energy conversion (OTEC) assumes that significant power can be generated by utilizing surface and subsurface ocean water temperature differences. Tropical areas with large thermoclines have proven to be the most fertile regions for OTEC energy production.

While OTEC technologies were tested as early as the 1930s, thus far OTEC has been limited to small-scale pilot projects, and has yet to encourage much investment and commercial development (USDOE 2008). Nevertheless, research initiatives in the US, Japan, and India continue to test OTEC technologies. With technology development and the location of additional sites, OTEC can potentially become a viable, clean and sustainable energy resource in tropical areas that possess relatively few other prospects for local energy production.
ASSOCIATED BENEFITS AND POTENTIAL SYNERGIES In addition to the immediate benefit of clean and sustainable power generation, offshore renewables can contribute to climate change mitigation by satisfying the rising energy demands of coastal areas that would have otherwise been met by fossil fuels, thereby reducing net greenhouse gas emissions. Consequently, a number of climate change strategies have emphasized their importance.

An inherent advantage of offshore renewable energy over many land-based options is its proximity to coastal areas with typically high population densities and, consequently, high energy demands. Offshore energy projects can also result in significant local economic returns, generating jobs for their construction, installation, operation and maintenance, thus helping stimulate local support for project implementation and long-term success.

Offshore renewable energy projects can also provide a number of beneficial by-products and synergies with other activities. Immobile underwater structures, such as the tower portion and jacket structure of an offshore wind turbine, can serve as an artificial habitat for various aquatic species. Many supporters also hold that offshore wind farms can protect marine ecosystems from the impacts of boat traffic, support offshore aquaculture and mariculture projects, and even become tourist attractions.

Some types of wave energy technology may reduce coastal erosion by absorbing powerful hydrokinetic energy that would otherwise impact the coastline. OTEC, in particular, presents a number of potentially beneficial by-products. Used cold seawater from an OTEC plant can chill freshwater in a heat exchanger, or flow directly into a cooling system for use in air-conditioning. The cold, nutrient-rich, seawater brought to the surface by OTEC plants can also support chilled-soil agriculture, allowing temperate plants to be grown in tropical climates, and can support the culturing of cold-water commercial fish species. Another potential yet largely unexplored advantage of OTEC plants is their inherent capability to produce freshwater from seawater. Research has indicated that, theoretically, an OTEC plant that generates 2 MW of net electricity could produce about 4,300 cubic metres of desalinated water each day (USDOE 2008). This has specific implications for low-lying tropical islands who possess viable OTEC sites and whose freshwater reserves may be threatened by sea-level rise.

POTENTIAL COSTS ASSOCIATED WITH OFFSHORE RENEWABLE ENERGY EXPLOITATION While offshore renewable energy presents many tangible benefits and can prove to be an important source of energy generation, such projects also carry environmental and socioeconomic costs that present notable obstacles to their near-term viability. These potential impacts have been shown, in some cases, to generate public opposition to offshore renewable energy projects.

In terms of environmental and ecological effects, installations can cause physical damage to the substrate and associated habitats, and the noise generated from
construction has been shown to result in behavioral modifications in some marine mammals (Tourgaard et al. 2009). Tidal energy barrages can cause changes in water turbidity and nutrient dynamics as well as restricting fish movements, thereby hampering access to spawning grounds and sources of food (Dadswell et al. 1986). Wind and hydrokinetic turbines may lead to wildlife mortality. OTEC projects, by introducing nutrient-rich waters to the surface layers, can potentially lead to algae overgrowth and harmful algal blooms (HAB). The degree of these impacts depends on factors such as the abundance and distribution of habitats and marine species, and the site’s geographical characteristics. The sensitive state of many coastal ecosystems, especially near heavily populated coastal areas, can also exacerbate potential impacts.

Offshore renewable energy projects can also have significant socioeconomic implications for coastal communities. Offshore energy presents an additional human use in frequently crowded ocean areas and must vie for space with other economically important activities, such as shipping, commercial fishing, and recreation. These projects can also negatively affect coastal tourism in a number of ways. Some installations, namely offshore wind farms, alter the coastal viewshed, which underpins tourist appeal (Lilley et al. 2010). Since some coastal areas are popular destinations for bird-watchers, avian impacts from offshore wind turbines may also deter nature enthusiasts. These issues become even more pronounced given many coastal communities’ economic dependence on tourism (see Box 2).

**CRAFTING THE POLICY ENVIRONMENT TO BECOME COMPETITIVE**

The modern energy landscape is highly competitive and has been traditionally dominated by relatively few energy resources. Offshore renewable energy must compete with other forms of renewable energy as well as traditional forms of energy, which are often more politically entrenched, for funding, for space in an increasingly crowded ocean, and for appropriate consideration in regulatory frameworks. While there is widespread recognition for the need to scale back dependence on their traditional spiritual ritual practices and submerged ancestral burying grounds. These objections presented serious obstacles to the project’s development, nearly halting it altogether. Although the majority of the state’s residents support the project, which was approved for construction on 28 April 2010, this case demonstrates how differing values of coastal areas can have a significant impact on the development of offshore renewable energy projects.

**BOX 2. THE COMMUNITY SUPPORT FACTOR: CAPE WIND IN MASSACHUSETTS**

The offshore areas of Massachusetts in the United States have been shown to possess an enormous wind resource. Cape Wind, a US-based windpower company, recognized this potential and in 2001 proposed the installation of a large wind farm on Horsehoe Shoal in Nantucket Sound near Cape Cod. The proposed site was, however, located between three historically popular vacation spots: Nantucket Island, Cape Cod, and Martha’s Vineyard. Since the area depends on coastal tourism and also houses the vacation homes of many high-profile politicians and celebrities, the proposal stimulated much opposition and debate. The Alliance to Protect Nantucket Sound formed to oppose the visual, environmental, economic and other impacts of the project. Two local Native American tribes, the Aquinnah Wampanoag and the Mashpee Wampanoag, also objected, claiming that the proposed wind farm would disturb
fossil fuels and move towards renewable energy, achieving this requires a policy environment that facilitates competition between offshore renewables and traditional and land-based energy.

The use of various types of policy mechanisms, supported by effective long-term carbon regulation, will prove crucial to offshore renewable energy development. Some nations actively employ quota-based mechanisms (i.e. Renewable Portfolio Standards), which require electricity supply companies to produce a specified fraction of their electricity from renewable sources and Power Purchase Agreements (PPA), or contracts between electricity generators and power purchasers to purchase energy from renewable energy providers, thereby creating a market for offshore renewables. Feed-in tariffs, which are becoming increasingly popular in Europe, provide a guaranteed fixed price for renewables and can serve to create a secure investment climate for the offshore industry. These mechanisms are most effective as part of a national renewable energy policy, with targeted budgets for research and development and guaranteed prices. The UK, Ireland, France, Germany, Japan, and New Zealand, among other nations, have developed various types of national renewable energy policies, some of which contain specific provisions for offshore renewable energy.

The availability of stable sources of capital funding poses a central obstacle to this industry. Generally, projects require a large amount of early-stage capital and must compete for funding with other energy resources. The technology is also often costly and unproven, which can hamper investor confidence. Although capital costs have begun to fall, due in part to investments in technological development and the relative price stability of renewable energy compared to oil and gas, capital funding remains a central obstacle. Commercial viability and competitiveness require clear incentives for public and private investment, such as tax credits and incentives to use abandoned shipyards and decommissioned platforms for prototypes and demonstration projects (OREC 2006). Governments can provide funding through grants, loans and loan guarantees, limited partnerships, and royalty trusts. For example, the UK government launched the Wave and Tidal Stream Energy Demonstration Scheme in 2006, providing capital grants and revenue support for pre-commercial demonstration of marine renewable energy projects (Portman 2010). Another potentially useful mechanism is a “partnership flip.” This involves joint ownership of a project by a developer and an institutional investor, who is allocated the majority of the economic returns until the return reaches a certain level, at which point his ownership interest is lowered and the developer has an option to repurchase the investor’s interest. A prepaid service contract, where the buyer makes an advance payment for electricity, can also stimulate capital financing (Martin 2008).

The development of effective and reliable technology also depends on appropriate policies that reduce risk, thereby stimulating investor confidence and increasing capital investment and financing for research and development. This is critical to
support technology development for energy installations and overcoming technical obstacles in offshore renewable energy storage and transmission. Since much of the industry’s technology remains somewhat unproven, policies to support research and development and scaled-down testing are vital to ensuring equipment reliability and durability. The development of technical standards and “roadmaps” that define the long-term strategy of a project and address deployment, technical, and commercial concerns is also crucial to industry growth. The International Electrotechnical Commission (IEC) has recently created a technical committee to address the rising demand for alternative renewable resources by developing international standards for offshore renewable technologies. Such standards will help improve technological development and address some of the associated environmental concerns.

Adequate regulatory frameworks, with equitable leasing and permitting processes, are also essential to industry development. While such frameworks have developed in some areas, considerable regulatory uncertainty remains, often characterized by overlapping and drawn-out permitting and leasing procedures (Leary and Esteban 2009). Regulations that are more streamlined are under development, such as a faster permitting and leasing process for installations in the UK. In Portugal, the delimitation of a Maritime Pilot Zone aims to simplify licensing and permitting through a single managing body; it will also identify and promote offshore corridors and the construction and maintenance of surrounding infrastructure (Portman 2010).

Current efforts towards developing more integrated coastal management frameworks and decision-support tools may also lead to the development and implementation of more robust regulatory frameworks for offshore renewable energy. These include improved monitoring and modeling of the natural environment, legislative atlases outlining jurisdictional aspects of coastal and marine laws, and comprehensive mapping of ocean uses. Coastal and marine spatial planning frameworks, which are currently in use or under development in China, the UK, and the US, among others nations, may mitigate user conflicts over ocean space, address cumulative environmental impacts from multiple activities, and streamline regulatory processes. Improved resource assessments, which include considerations for important practical factors such as exclusion zones for shipping lanes, avian migratory paths, sand borrow areas, and sensitive natural habitats may also enhance the development of regulatory frameworks.

**POTENTIAL OFFSHORE ENERGY RESOURCES OF THE FUTURE** While relatively few offshore energy resources are presently commercially viable, a number of prospective resources may become feasible in the future. Utilization of these resources faces a number of obstacles, including uncertain resource potentials and the general lack of feasible and economical technology.

**METHANE HYDRATES** Scientists, private companies and governments have expressed interest in utilizing the energy of methane hydrates found in oceanic seabed sediments and permafrost. While some initial studies estimated large stores of
methane hydrates, much uncertainty remains regarding the size of this resource: estimates have decreased significantly since its initial discovery. Improved analyses of methane hydrate chemistry and sedimentology have revealed that they only form in a narrow range of depths and typically occur in relatively low concentrations. The potential for the release of large methane reserves, a powerful greenhouse gas, has also raised concern about contribution to climate change. Nonetheless, interest has arisen in exploiting potentially large reserves in areas such as the Gulf of Mexico (Milkov 2004) and the Arctic.

**SALINITY GRADIENT ENERGY/OSMOTIC POWER** Salinity gradients, or pronounced differences in water salinity, also present a potential opportunity for renewable energy generation. Concepts for exploiting this potential resource have been around for more than twenty years. Most of these technologies utilize water movements through a semi-permeable membrane, driven by salinity compensation to generate power. Early technologies relied on expensive membranes and were not considered promising. While membrane technologies have advanced, they remain a central technical barrier and viable development of this resource has yet to occur. Osmotic power also carries environmental concerns, as changes in salinity can adversely affect marine species and ecosystems. In Norway, a company called Statkraft has recently developed the world’s first complete facility for osmotic power generation and seeks to develop a full-scale commercial plant by 2015.

**ENERGY FROM MARINE BIOMASS** Expanding evidence indicates that algae may become a viable source of biodiesel. While the primary opportunities for culturing algae biofuel remain in land-based operations, pilot projects and proposals indicate the potential viability of ocean-based algae farms in the future (Lane 2008). While not yet commercially viable, the technology may become more attractive as it develops, and as nations with favorable growing conditions and plentiful coastal areas pursue clean and sustainable energy sources.

**HYDROGEN FUEL FROM “BLACK SMOKERS”** An additional theoretical but unrealized energy source is hydrogen fuel produced from deep-sea hydrothermal vents, otherwise known as “black smokers.” Although some research supports this possibility, it has yet to be explored and technologies have yet to be developed (Bubis et al. 1993).

**CONCLUSION**
The offshore energy industry possesses enormous implications for the global energy landscape. Large amounts of energy present in ocean areas in various forms present significant opportunities to meet the world’s growing energy demands sustainably, offering potentially beneficial by-products while reducing consumption of unsustainable fossil fuels. However, assessing the viability of offshore renewable energy sources requires careful weighing of their respective costs and benefits. An appropriate policy environment will help to overcome existing obstacles and facilitate
successful competition with traditional and land-based sources. Viable policy mechanisms, innovative financing options, and improved technical standards will prove critical to realizing the potential of offshore renewables. Since policies to encourage their development differ across countries, exchanging experiences and best practices will be vital to the industry’s success. An expanded energy repertoire, with support for the examination of emerging sources of offshore energy, will likely make global energy systems more stable, sustainable, and secure in the long-term.

**FEW OFFSHORE ENERGY RESOURCES ARE PRESENTLY COMMERCIALY VIALBLE**

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**WORKS CITED**


Globalization depends on ocean cargo shipping, one of the world’s most globalized industries. During the twentieth century, the legal relationship between a nation and its ships changed greatly, redefining shipowners’ and operators’ liabilities and responsibilities to fleets, seafarers and the marine environment.

A GLOBALIZED MARITIME ECONOMY: AT WHAT PRICE?

The globalization of world trade – mostly conducted through ocean shipping – rests on improvements in navigation and logistics technologies. International maritime shipping has altered the legal relationship between ships and states, emerging as the most globalized of all economic activities, and completely redefining countries’ responsibilities to their fleets, crewmembers and the ocean. This essay will explore some of the implications, examining the legal apparatus of ship registrations and its effect upon the labour market in particular.

Ocean navigation revolutionized the world: the invention of the compass, the stem-mounted rudder and the caravel – a small two- or three-masted windward-sailing ship – led to great discoveries in the sixteenth century. As seafaring expanded, debates arose about freedom on the high seas and maritime trade, as seen in the argument between Hugo Grotius, author of *Mare Liberum* (free sea) in 1609, and John Selden, who replied in 1635 with *Mare Clausum* (closed sea) (Gaurier 2005). Freedom of navigation and trade – the “Grotian principle” – eventually prevailed.

As free trade widened in the second half of the twentieth century, international seaborne trade also grew considerably: ocean freight volumes increased seven-fold in forty-five years, rising from one to seven billion tonnes (Guillotreau 2008) to account for 90% of worldwide merchandise cargo (Figs. 1 and 2).
THE RELATIONSHIP BETWEEN SHIP AND STATE IN A GLOBALIZED WORLD

Maritime transport originally involved a direct relationship between a nation and its ships, a link made more complex with the globalization of the maritime economy. The 1982 United Nations Convention on the Law of the Sea (UNCLOS) enshrined the principle that ships follow the nationality and laws of the “flag-state” – the country that enrols them, through a national registry, to sail under its “flag” or civil ensign. A vessel may possess only one flag. Any ship using a false flag lacks legal protection; on the high seas, it will be suspected of piracy. Each country defines the administrative, tax and employment conditions required for vessels flying its flag. The freedom of navigation underpinning maritime trade rests on a ship’s connection to a state, the “genuine link” required by UNCLOS (UNCLOS 1982, Articles 91-92). We will see, however, that international maritime law has neither precisely defined nor enforced this “genuine link;” classic laws are ill-adapted for those flag-states that disregard their international obligations (see e.g. UNCLOS Article 94) and increasingly use so-called “flags of convenience”.¹

¹ The term “flag of convenience” describes the practice of permitting registration of ships owned by non-residents; it usually occurs in countries whose tax on the profits of trading ships is low, or whose requirements concerning manning or maintenance are not stringent (ISL 2008: 419).
OPEN REGISTRY’S EFFECTS

“Open registry” allows shipowners to freely choose under which country’s flag their ships will sail, to best exploit tax, labour and other advantages. Such flags of convenience came into use during the final years of the Atlantic slave trade, at the end of the nineteenth century. The modern practice of flagging ships in foreign countries began in the 1920s in the United States, when shipowners frustrated by increased regulations and rising labour costs began to register their ships to Panama. The practice has resurged since 1950, when newly independent countries arrived on the international maritime scene: Cyprus, Malta and Liberia join Panama as the leaders. These countries changed the world’s economic order and accelerated adoption of open registry, greatly affecting ship registrations and the maritime job market (Fig. 3). They also drove adoption of complex legal and financial structures. To understand how this works, one should distinguish between the country that registers a ship and the nationality of the entities that control it. For example, large parts of the Chinese- and American-owned merchant fleets are registered in Panama and sail under its flag, while 46% of all ships registered in Panama belong to Japanese entities. A critical portion of the Greek fleet sails under the flag of Cyprus or Malta, and 25% of Liberia’s registered fleet belongs to Germans (see Figure 3).

Weak ship registration laws give place to *lex loci contractus*, “the law of the place where the contract is agreed,” allowing a shipowner, or a “manning” company that provides marine workers, to chose a flag based on the crew’s country of origin.
A GLOBALIZED MARITIME ECONOMY: AT WHAT PRICE?

(Monzani 2004). This results in a more international maritime job market: open registry allows shipowners and manning companies to hire in countries with low-cost labour – initially, onboard crewmembers (seamen, engineers, oilers) and more recently, merchant marine officers (see Box 1).

DILUTED RESPONSIBILITIES

Not only the labour market but the entire marine transport chain has become globalized. The Erika oil tanker that foundered off the coast of Brittany in 1999, polluting more than 400 kilometres (248 miles) of France’s western coastline, perfectly illustrates the tangle of actors, companies and nationalities involved in ocean shipping. Events unfolded as follows: the French multinational oil company, Total-France, sold a cargo of heavy crude oil to Total-Bermuda, who resold it to an Italian energy company, Enel, for delivery to Livorno, Italy. Total-London chartered the Erika oil tanker through an (unnamed) London company; Tevere Shipping,

2. Under officers’ orders, crewmembers steer the vessel, operate engines, signal to other vessels, perform maintenance and handle lines, and operate towing or dredging gear. Seamen work on deck, engineers operate engines and machinery and oilers work below deck maintaining the engines and machinery.
A Maltese “single company” (e.g. one created to own a single vessel – often with no other assets – to limit commercial and financial risks) owned the twenty-five-year-old Maltese-registered ship. Tevere delegated nautical and technical management of the vessel to Panship, a ship-management company registered in Ravenna, Italy; Panship managed thirty vessels, each owned by a Maltese single company. A Bahamian company had first chartered the Erika, as had various oil companies prior to the Total voyage. Several had found the Erika unsuitable for duty following vetting exercises, but the vessel passed Total’s scrutiny (i.e. Total SA, Total Transport Corp., and Total Gas and Power Services, Ltd). The last repairs made to the ship in Croatia would ultimately be judged insufficient, although an Italian classification company, Registro Italian Navale ed Aeronautica (RINA) had surveyed and passed them prior to the ship setting sail with Total’s oil cargo.

An Indian manning company, Panship Mumbai, provided the onboard crew. The Erika’s Captain Mathur came onboard only fifteen days before the ship sank on 12 December 1999. Such an extremely complex structure is not unusual: it allows for separation of ownership and management, and in principle limits liability to the owner.

ADAPTATIONS TO OPEN REGISTRY: “SECOND REGISTRY” AND “FLAGS OF NECESSITY”

In 1986, faced with the need to remain competitive and reduce ship defections to flags of convenience, European Union (EU) member states began registrations in their overseas territories. Presented as “flags of necessity,” these “second-order” national registries aim to retain merchant marine officer posts and about 25% of

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3. A ship-management company handles the technical and nautical management of a vessel: it takes out insurance, recruits the crew, checks the certification documents, carries out maintenance and inspects the ship’s condition.

4. Vetting refers to a major oil company performing an external examination of an oil tanker, carefully assessing its condition, defects, technical and commercial management, and crew, to identify risks it could pose to the chartering oil company and suitability for duty.

5. A classification company classifies a vessel for the ship owner and certifies the vessel for the flag state. It verifies compliance with safety regulations and standards and delivers a Certificate of Classification regarding the ship’s structural integrity, among other aspects. In the Erika case, RINA performed this task for Panship.

6. RINA was judged criminally liable after the Erika sank.
onboard crew positions for European Common Market citizens, while recruiting foreign nationals through manning companies on international terms to complete crew rosters. With these arrangements, the principle of “equal work, equal pay” vanishes. Some registries are based in overseas territories with autonomous legal systems where national laws and occupational protections do not apply, such as France’s Wallis and Futuna Islands and its Austral and Antarctic territories, the Portuguese island of Madeira, Spain’s Canary Islands, or the United Kingdom’s Isle of Man. The need to adapt to international competition “justifies” differential treatment of a ship’s officers and crew according to their European or foreign origins, for vacation time, salaries and occupational benefits, among other labour costs.

Economically, this policy has succeeded beyond question, allowing European countries to control 42% of the world’s merchant fleet in 2006, up from 38% in 1990. These adaptations also stabilize the number of ships flying European national flags, save European officers’ jobs, and reserve onboard crew positions for “international” seafarers who cost notably less (especially in benefits). Beyond its economic success, this system restricts Common Market-citizen access to seaman, engineer and boiler jobs, shifting them to higher-level maritime job training. This leads to shorter sailing careers, generally followed by jobs on land in the maritime industry. The steps taken by national registries to compete internationally have not reduced the worldwide number of ships flying flags of convenience. Nor have they reduced the size of the “controlled” fleet, i.e. vessels owned by developed countries but registered under other flags. However, this process has stratified occupational rights for seafarers, with foreign nationals receiving only the benefits required by international conventions.

**THE STEPS TAKEN BY NATIONAL REGISTRIES TO COMPETE INTERNATIONALLY HAVE NOT REDUCED THE WORLDWIDE NUMBER OF SHIPS FLYING FLAGS OF CONVENIENCE**

**MARINE WORKERS IN A GLOBALIZED ECONOMY**

The globalization of ocean shipping has caused enormous upheaval in workers’ onboard living conditions. Efficiency and profitability motives constrain seafarers’ time spent in port: fast turnarounds mean they must concentrate exclusively on onboard operations and attend to administrative formalities. Leaving the port zone is out of the question; crewmembers rarely even find two hours to read letters from friends and family in the local Seaman’s Club. At sea, hard work in difficult conditions often shortens their careers. Long shore leaves between work stints and good pay cannot compensate for fatigue accumulated over many voyages. Seamen’s autonomy up and down the ranks has disappeared: onshore services monitor ships constantly. At the same time, liabilities increase: if a ship pollutes a coastline because of its maintenance or lack of it, the captain may need to defend himself from a jail cell, even if he only recently took command of the vessel.

This abandonment of troubled vessels represents the height of deregulation, and crews and officers bear the brunt of it. It has become common for shipowners
– generally hidden behind a single-ship company – to disappear when creditors seize a vessel, when a port authority detains it, or when marine workers strike over non-payment of their wages. The Olga J. cargo ship case sheds light on such practices. Built in 1956, the vessel was purchased by a Greek shipowner after a long career at sea. In 1998, a company based in Belize managed it and a Cypriot shipowner chartered it under a Honduran flag. In February of that year, the ship left Dakar with one Cape Verdean and twelve Ghanaian seafarers and a Greek captain aboard. It sailed toward Greece, then Bulgaria, probably in search of the lowest-cost repair port. On 24 September, the ship entered the port of Burgas in Bulgaria. On 12 October, the port inspectors found the ship unsuitable for duty and ordered it detained quayside. It remained immobilized for a long time; its seafarers stayed onboard for two and a half years, until they were repatriated in April of 2001. One of them, ill with pneumonia, was allowed to leave earlier for health reasons and because he could not afford $100 for medical care; he died on 30 August in Ghana.

While in Burgas, the crew was first confined to the ship, and then allowed access only to the port zone and an Internet café. The International Transport Worker’s Federation7 (ITF) made a repatriation proposal that the crew refused; they hoped to see their salaries paid from proceeds of the ship’s sale at auction. On 17 December 1998, they ceded their receivable salaries to the Bulgarian marine workers union: it pursued legal action on their behalf until August 2000, without success. That same month, the ship received no bids at auction. Finally, humanitarian support and the ITF paid for the sick seafarers’ return to their home countries on 11 April 2001. On February 2002, the CCFD, a Catholic development-aid group from France, sued Bulgaria for violation of trade union and fair trial laws, in the European Court of Human Rights. The court refused a hearing on 22 January 2008 because the suit had not been filed within six months of the seafarers’ repatriation; it also determined that since they had ceded their salary claims to the Bulgarian trade union, it alone could file suit in the absence of other legal remedies or because of unreasonable delay in deciding the claim’s merits. In addition, only the dead sailor’s relatives were permitted to sue for inhumane treatment (Chaumette 2009).

In response to the marine workers’ exclusion from legal redress in the Olga J. case, the International Organization for Migration (IOM) and the International Labour Organization (ILO) designed a mandatory salary and repatriation guarantee for crewmembers: both organizations validated the principle in 2001. When the rule takes effect, the guarantee will be the first amendment to the 2006 ILO Maritime Labour Convention (Chaumette 2007; Chaumette 2008; Fotinopoulos-Basurko (2009). It avoids making good shipowners pay for bad ones, and instead requires guarantees from each operator; this ensures, first of all, that no owner or management

7. The International Transport Workers’ Federation (ITF) is an international trade union federation of transport workers’ unions, established in 1896 with headquarters in London. ITF represents more than 759 unions in 155 countries and 4.6 million workers worldwide. It is one of the ten international trade union federations affiliated with the International Trade Union Confederation.
failure punishes workers, and that no one, even in international operations, can declare bankruptcy voluntarily.

Countries that supply maritime workers to the ocean shipping industry are flagrantly absent from such supervisory efforts, even though the certificates they grant must meet the requirements of the IMO’s Convention on Standards of Training, Certification and Watchkeeping for Seafarers. The labour-supplying countries also issue identification cards, facilitating crew travel before embarkation and after disembarkation. This lack of oversight should not, however, deter labour-supplying countries from strengthening protections for their nationals, rather than prioritizing the cash such workers send home to their families.

THE PORT STATE AS NEW INSPECTOR
The “genuine link” required by UNCLOS vanishes when the flag state shirks its international duties: maritime law loses one of its major pillars, seriously weakening its balance of power. Coastal states’ regulations and decisions on navigation laws cannot compensate for the inertia of many flag states, which hinders improved safety and anti-pollution measures; neither can the emergence of port state control and ship inspection during loading and unloading operations. Such port controls attempt to rebalance the equation in favour of international maritime laws by requiring that vessels obey international regulations, regardless of registration flag (Ozcayir 2004; Christodoulou-Varotsi 2003).

The ILO’s 1976 Convention number 147 concerning Minimum Standards in Merchant Ships requires that ratifying states apply it to all ships registered in their territories (ILO 1976). The Convention also grants port states the right to “take measures [against any non-conforming ship] necessary to rectify any conditions on board which are clearly hazardous to safety or health” (ILO 1976, Article 4); this ensures that ships registered to non-ratifying countries will not be treated more favourably. The 1982 Paris Memorandum of Understanding on Port State Control constitutes an agreement between state authorities to enforce the ILO conventions8 (ParisMOU 1982). While the Paris Memorandum refers to the ILO’s Convention No. 147, the inspections it foresees primarily cover technical issues and few occupational ones; they focus first and foremost on enforcing “safety of life at sea” (SOLAS) conventions, and those aimed at preventing marine pollution, e.g. the MARPOL Convention. However, crewmember qualifications must also pass inspection under the Convention on Standards of Training Certification and Watchkeeping (Boisson 1998).

The European Union adopted this maritime safety process via its Directive 95/21 (19 June 1995, Council on State Port Control). This directive applies the Paris Memorandum and other conventions regionally, setting up common databases and strengthening safety regulations without taking unilateral measures (Ndende and Vende 2000; EC 2009). The European Maritime Safety Agency is responsible

8. The ILO produces international rules, but has no inspectors or enforcement power over states, nor any sanction powers with regard to ship operators.
for coordinating port inspections conducted by member-state authorities, thereby ensuring ship monitoring from port to port.

**A NEW MARITIME CONVENTION**

On 23 February 2006, the UN adopted the New Consolidated Maritime Labour Convention in Geneva, anticipated to take effect in 2011, with at least 30 ratifications representing 33% of the world’s fleet. This Labour Convention will open a new era in the history of maritime labour, formalizing occupational welfare as well as complaint and inspection procedures (Doumbia-Henry 2004; Fotinopoulou-Basurko 2006). The flag state must certify that the ship owner follows the Convention, facilitating state port control. The 2006 Convention constitutes the fourth pillar of international maritime law, alongside SOLAS, MARPOL and Standards of Training, Certification and Watchkeeping for Seafarers.

Occupational issues (salaries and employee welfare) are addressed by international trade unions: since 1948, they have campaigned against flags of convenience and have brought more than half of the world’s fleet under Total Crew Cost (TTC) agreements (i.e. work contracts for seafarers, regulated by the International Transport Workers Federation [ITF]), without waiting for worldwide conventions to take effect. The collective agreement of the International Bargaining Forum affects 700,000 sailors, seamen, engineers, oilers and officers working on more than 3,500 ships; it was negotiated by the ITF, European shipowner members of the International Maritime Employer’s Committee, and Japanese shipowners in 2003. A revised agreement at the end of 2008 doubled salaries in light of war risks, particularly increased pirate activity in the Gulf of Aden off the Somalia coast.

Thus the market and labour relations in the international maritime industry have evolved in recent years, and may lead to new standards. Even though no worldwide collective bargaining agreement exists, a regional framework – especially the European one – could assist transnational negotiations, and ensure free trade unions and collective bargaining. These are fundamental ILO principles, recognized by the European Convention on Human Rights (formerly the Convention for the Protection of Human Rights and Fundamental Freedoms) and protected by law through the European Court of Human Rights.

**CONCLUSION**

Maritime transport emerged from its national frameworks, born at the end of the seventeenth century, to take its place in a globalized market, characterized by open ship registration, in the middle of the twentieth. Traditional legal relationships between ships and maritime workers changed with the growth of services companies for ship management and manning. Since then, ocean shipping has sought a new legal order, involving both coastal states and port states. Private inspections, e.g. those conducted by classification societies or vetting by oil companies, cannot replace state controls; each operator within the industry must assume its responsibilities and liability.
The industry is a kind of laboratory, creating an experimental framework for relationships adapted to a globalized world: it must link international, regional and national rules, state and private inspections, open registration and coastal state or port state intervention. Within this experiment, labour-supplying countries have lagged, failing to ensure even minimum protections for their citizens – who after all go to sea to earn their living, not lose it. Too many seafarers still liken embarkation to prison, recalling the words of oilers below deck as steam engines developed at the turn of the twentieth century:

“Going to sea meant enclosure between plates of black metal, in front of a hearth, facing burning coals, flames furiously whistling against their chests. When they stuck their noses outside, on deck, their watch ended, the free air suffocated them, their eyes blinked in the daylight; they returned to their domain, waiting for the ship to be loaded, able to forget their boiler room for a few hours” (Peisson 1932: 16).


When ships reach the end of their useful economic life, they may be sunk, broken up and recycled, hulked, or converted for other sea-going purposes. Increasingly-strict national and international laws require that potentially dangerous substances – such as asbestos, polychlorinated biphenyls (PCB), polyvinyl-chloride (PVC), chlorofluorocarbons (CFC), ammonia, radioactive materials, heavy metals and polluted water – be removed at the ship owner’s expense prior to refurbishment, recycling or sinking. Instead of internalizing such costs, a ship owner receives money from the salvage industry for the ship’s scrap value: current prices reach nearly US$400 per ton. As the number of old and obsolete ships increases, concerns about sustainable development heighten interest in the conditions – economic, social and environmental – surrounding their disposal.

**ASIAN SHIPBREAKING YARDS: COMPETITIVE ADVANTAGES**

Until the end of the 1950s, ships were mechanically demolished in industrialized countries (United States, Great Britain, Germany and Italy). The first wave of the industry’s delocalization to semi-industrialized countries – Spain, Turkey, Taiwan – began in the 1960s and 1970s. In the 1980s, a second wave brought the industry to Asian shipbreaking yards, most often located directly on beaches rather than in dry docks. Since then, Asia’s market leadership has not wavered: 90% of all ships (Tourret 2008) are dismantled in four countries – India, Bangladesh, China and Pakistan (Fig. 1). These countries’ economic development propels a strong demand for steel and other commodities, creating a global industry that supports more than an estimated one million people (Bailey 2006). The rising average salvage price of US$400 per tonne offered by Asian yards reaches nearly US$700 per tonne for ships containing stainless steel (Robin des Bois 2010). Thus the ships are broken up for recycling where demand for steel is the highest. Furthermore, Asian shipbreaking yards are attractive because they use untrained, cheap labor; an almost complete lack of workplace safety enforcement also keeps labor costs low. An Indian or Bangladeshi worker earns one or two dollars per day, while a European worker receives about US$250 daily. The ship-recycling countries’ much lower occupational health and safety standards give them a competitive advantage over industrialized countries, one they gain at the expense of environmental and labor protection.
OVERLOOKED SOCIAL AND ENVIRONMENTAL COSTS

Even though ships contain many toxic or even radioactive elements, the vast majority are now dismantled in shipbreaking yards that lack infrastructure to protect workers and the environment. In such yards, rates of accident and exposure to very toxic contaminants are high while the level of social protections is abysmal. Available data reveal that one out of six workers laboring in an Alang (India) shipbreaking yard suffers from asbestosis\(^1\) (European Commission 2007). In 2005, the fatal accident rate in Indian yards outpaced that of the mining industry by six to one. The Chittagong shipbreaking yards in Bangladesh are equally deadly: thousands die each year due to workplace conditions (European Commission 2007). Such numbers are impressive but in fact provide incomplete mortality rates, given the lack of death and accident registers and the difficulty of obtaining information from local authorities. Circumstances will certainly deteriorate further in coming months as (often-inexperienced) workers break up increasing numbers of “end-of-life” vessels.

In addition to workplace hazards, serious human rights violations occur regularly, such as preventing free association and collective bargaining, paying wages below legal minimums, demanding work hours in excess of legal maximums, refusing to pay for rest or vacation days, providing unsanitary and unsafe housing, and using child labor. Nearly all workers lack employment contracts; indemnities for illness and accidents are low or nonexistent\(^2\) (EMSA 2008; Greenpeace et al. 2005).

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1. Asbestosis is a serious, chronic respiratory disease caused when inhaled asbestos fibers aggravate lung tissues. There is no known effective treatment for asbestosis, and the disease is usually disabling or fatal.

2. In Bangladesh, a non-governmental organization created in 1985, “Young Power in Social Action” furnishes most of the data for workplace accidents and illnesses declared by shipbreaking workers, in the absence of national census institutions. The International Labour Organization and the European Maritime Safety Agency draw upon this data for their reports (EMSA 2008). In addition, representatives from Greenpeace and the International Federation for Human Rights Leagues (FIDH) have conducted interviews with workers, their families and neighbors about shipbreaking working conditions and their consequences in India: these eyewitness accounts supplement the incomplete data provided by India’s national agency, the Gujarat Maritime Board (Greenpeace et al. 2005).
The problems and dangers of shipbreaking join with weak national environmental standards and unreliable regulatory mechanisms. In this context, refuse and emissions from shipbreaking sites directly enter the surrounding natural environment, causing high pollution levels whose long-term effects are known, but overlooked. Samples taken near sites in India and Bangladesh reveal an alarming level of toxic substances in coastal waters, soils and groundwater (Hossain and Islam 2006). Toxic vapors and asbestos fibers often fill the air (Figs. 2 and 3). Practically no means exist to store or treat dangerous waste: it is disposed of illegally in unauthorized sites near densely-populated areas. Such practices affect the health of neighboring populations, who are themselves highly dependent on the ship recycling and salvage industry, as are many other business sectors (IMO 2001). Consequently, any improvement in the industry’s labor, occupational health or environmental conditions requires an integrated approach and the international community’s support.

LEGAL REGULATION IS URGENT
At a time when human rights protections timidly temper the growth of liberal and neo-liberal economic activity, these accounts of the Asian shipbreaking yards’ exploitative conditions strengthen the urgent need for action: a common legal framework to address “end-of-life” ship disposals is the only way to curb the spread of environmental and human health risks. On 15 May 2009, the Convention for Safe and Environmentally Sound Recycling of Ships was adopted in Hong Kong under the aegis of the International Maritime Organization, a specialized UN agency. The Convention aims to define each party’s responsibilities, clarifying regulations for the market, and giving national authorities the impetus to improve occupational health and safety for workers and to protect the environment. Nevertheless, effective implementation of the Convention may not occur before 2015, due to its challenging requirements (Bourrel 2010). It must be ratified by fifteen states representing forty percent of the world’s commercial shipping fleet, and whose ten-year demolition capacity is three percent of their fleet’s gross tonnage; additionally, the wider ship-disposal industry has few incentives for change.

Only five states have signed the Convention at present: France, Italy, the Netherlands, Turkey and Saint Kitts and Nevis. Between now and 2015, many ships will need to be dismantled, most coming from OECD nations that are, in principle, subject to strict rules regarding hazardous waste and ship disposal. Presently, nearly twenty ships per week are sent abroad for demolition: most are labeled substandard by states unable to recycle them locally (Bourrel 2010; European Commission 2007). While many of the industry’s workplace and anti-pollution conditions have improved recently (notably in India and Bangladesh), the remaining concrete and underestimated risks to humans and the environment make the Hong Kong Convention’s implementation a pressing necessity.

3. Inspections conducted by Indian authorities identified many “wildcat” waste sites (SCMC 2005).
FIGURE 2. SHIPBREAKING’S TOXIC WASTES: CURRENT AND PROJECTED

Source: Data compiled by author based on COWI (2004).

FIGURE 3. DANGERS IDENTIFIED BY EMPLOYEES AT A SHIPBREAKING YARD (CHITTAGONG, BANGLADESH)

Data compiled by author based on EMSA (2008).


The fishing industry’s modernization saw radical changes in capture techniques, and in the fish themselves. Fisheries science created virtual fish-stocks analyses and transformed fish into manageable objects via quotas. Although intended to create sustainable fisheries, the resulting focus on financial concerns actually reduces fisheries’ sustainability.

THE RISE OF THE CYBORG FISH: ON ATTEMPTS TO MAKE FISHERIES MANAGEABLE

Although natural resources have been exploited since humanity’s origins, modern resource management is a recent phenomenon.\(^1\) The huge variety in resource types, adaptations, knowledge systems, institutions, and practices have made it difficult to bring the harvest of common property resources under political and managerial control. In the maritime arena, fish as well as fishermen have historically been “unmanageable” for all practical purposes. Since the late 1960s, when the threat of fisheries over-exploitation became apparent, efforts intensified to transform fish, people and technologies into “manageable” entities, a process that accelerated in the 1980s and 1990s. In this paper, we discuss conditions, processes and instruments through which this transformation or “translation”\(^2\) becomes practically possible. The application of science plays an important role in turning the “wild” object into a “manageable” one. The outcome of this process – for which we use

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1. This is a revised version of an article in *Maritime Studies (MAST)* in 2009 with the title, “The cyborgization of the fisheries. On attempts to make fisheries management possible “ *MAST* 7: 9-34. The article is revised and republished with approval from *MAST*.

2. This argument draws on methodology developed within the sociology of science, in particular ANT (Actor-Network Theory) (Latour 1987, 1990; Callon 1986; Haraway 1997). We retain the core concept of “translation,” the process by which innovators attempt to build and stabilize the relationships among heterogeneous entities in order to form a network that can perform as a coordinated actor. Translation implies that the entities in a network take on identity in much the same way as words become meaningful in language, through their relationships with other words.
the metaphor of the “cyborg fish” – is a complex and heterogeneous network that links nature, society, technology, science, markets and policy in new ways.

MANAGING THE UNMANAGEABLE
While fisheries management is typically seen as regulation imposed from the outside on entities – fishermen, nations, fisheries – that remain essentially unchanged, we will argue here that management fundamentally transforms and reconstitutes the managed objects. Traditionally, marine fisheries have been beyond societal control, an order of things institutionalized in the centuries-long Mare Liberum regime. Today, however, marine fisheries have been recognized as “manageable” – a regime change symbolically and institutionally grounded with the signing of the UN Law of the Sea Convention (UNCLOS) in December 1982. The convention confirmed the coastal states’ the right to establish a 200-nautical-mile-wide economic zone (EEZ), a move that brought more than 95% of fisheries resources under national jurisdiction. Mare Liberum was replaced by a new regime in which management authority was invested in the coastal state.

A swift and dramatic reform has followed. Fish have transformed into measureable and controllable entities, primarily in the form of single-species stocks subject to regular counting and assessment. Fishermen have transformed from commoners and hunters into businessmen and property owners. Fisheries management has developed from bare-bones efforts to control food security and crises into an ambitious framework, orchestrating fisheries into a well-ordered and rational pattern. The “governance” of fisheries depends in no small part on this mapping of representations onto practices, so that it becomes possible to shift between these two realms (Holm 1996; 2001). The effectiveness of this mapping determines not only how closely the symbolic system will correspond to the practical one, but also how readily decisions within the former can translate to the latter. Figure 1 sketches this model of managerial control.

We refer to the processes by which the fish and their human predators transform from unmanageable to manageable objects as cyborgization.

We refer to the processes by which the fish and their human predators transform from unmanageable to manageable objects as cyborgization. This paper will review its consequences, drawing primarily from examples in Norway. As a result of UNCLOS and the introduction of the EEZ, Norway gained control over rich fish and petroleum resources. The revenues from oil and gas extraction contributed to a radical modernisation of Norwegian society as a whole, one that also has relevance for the fisheries sector. Although the Norwegian case finds echoes in Canada and other high-technology western fisheries, “cyborgization” in Norway is probably more extreme than in other countries (Johnsen et al. 2009).

3. Transforming unmanageable objects into manageable ones requires much work and tends to meet resistance.

4. In addition, Norway has established an internationally-accepted fishery zone around the Island of Jan Mayen and a disputed fishery protection zone around Svalbard.
CATCHING FISH – FROM HUMAN RELATIONS TO CYBERNETIC CAPTURE SYSTEMS

Once upon a time, there were fish, vessels, and men, like those we see in Figure 2. Although a few larger steam ships worked in the herring fisheries, small fishermen-owned vessels dominated the Norwegian industry. The fishermen in the photo are representative in this respect. A family partnership owned the vessel; non-partner crew members (like the first author’s grandfather, number three from the left) were neighbours and/or more distant relatives, all living in the same community. Together, they exploited fish as a common property resource.\(^5\) While the social relationships within the commons may have been complex, the relations to the fish were simple and direct. The fishermen, as members of hungry households and cash-strapped communities, pursued fish that could be exchanged for money. The basic relationship between fish and fisherman was mediated by the hook and line. If the hook slipped or the line broke, the fisherman would lose income; his family might starve and the community economy would suffer. Skill with the gear constituted the man as fisherman and breadwinner. The hook and line produced him not only as a catcher of fish, but also as an active subject and a bearer of community values.

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5. Traditionally, all Norwegian citizens had a right to undertake commercial fishing inside, as well as outside, Norwegian waters, and to use all types of fishing gear except trawlers, which were strictly regulated. The only requirement was to register both vessel and personnel, designating each as engaged exclusively in fishing.
However, the 1930s saw a transformation in the relationships between fishermen, fish, coastal communities and the state. Influenced by the hardships of the global depression, the authorities first intervened to protect small-scale coastal fishermen from fierce competition by industrial capitalists and large-scale trawlers. The parliament adopted the first temporary Trawler Act in 1936 to regulate trawling activity in Norwegian waters. Two years later, in 1938, the Raw Fish Act gave small-scale fishermen a legal monopoly in the first-hand fish market, and helped establish sales organizations they could control. Taken together, these two acts strengthened the small-scale fishermen’s position in the Norwegian fisheries sector; institutionally, they increased the complexity of the fish-fisherman relationship. By the end of World War II, however, the government’s priorities shifted, and the small-scale fishermen no longer received the same level of protection. Instead, a modernisation programme for Norwegian fisheries emerged, defining governance, institutional change, and technological development as its three pillars. This programme supported the controlled development of a trawler fleet, along with technological and social development of the coastal fisheries. From a troubled start – the small-scale fishermen intensely loathed the trawlers – the offshore fleet grew into a very powerful creature during the next 60 years.

Nevertheless, within the fisheries commons, the modernisation process neither marginalized nor fundamentally transformed the conventional coastal fleet. While considerably smaller than that of the 1920s, in the 1980s it still had basically the
same geographical distribution, work organization and ownership structure. Even if the vessels had become more technologically sophisticated than their predecessors – with more powerful engines, hydraulic equipment, sonar, radar, autopilots, and so on – there were striking continuities. Most coastal vessels were still made of wood (Fig. 3). They still exploited a common property resource. Most crew members were recruited locally, through family or personal connections. And the crew size on a gill-netter, still a dominant gear type, remained similar to what it had been six decades before (Johnsen 2005).

By 2000, all this had changed. In the new millennium, a typical coastal fishing vessel is between 30 and 50 feet and technologically sophisticated. It is made of fibreglass or steel, and the wheelhouse has been moved to the front. Usually, no more than three people work aboard, aided by hydraulic haulers and mechanical helpers. They navigate using radar, GPS, digital chart machines, and autopilot. The electronic equipment is fully interfaced: a click on the mouse at the wheelhouse computer steers the vessel to its position, pre-selected and saved by the skipper. Given a short introductory course, almost anyone can navigate. And while experience still comes into play in locating fish, new colour sonar equipment makes this part of the process easier. The deck machinery is more specialized than on the early 1980 gill-netters, with different gear and mechanized hauling and clearing (Fig. 4).

Fishing operations have become more or less self-contained, and are now deeply embedded in the service programme and knowledge infrastructure provided by gear
manufacturers, shipyards and other professional networks. Where fishermen, their families or communities formerly saw to rigging, maintenance and storage of gear, to a great extent they now purchase these services from the manufacturers. Thus the focus of the fisherman’s responsibilities has shifted towards those of running a business, controlling finances and investments, and keeping up with fishing legislation.

The fishing enterprise of today is not simply a boat and crew; it comprises many interlinked professional systems that all contribute to the efficiency of the operation. Among other effects, these changes result in a reduced need for manpower onboard. A steering post at starboard reeling, behind the hauling equipment, is a standard feature that allows the skipper to control both the vessel and the hauling from one position (Fig. 4). Mechanisation permits three men to tend the same number of gillnets on a 42-footer as six men could handle in the same period of time on a 64-footer. It is not unusual for two vessels to “buddy up” and operate together to reduce labour costs. As a result, many former fishermen have sold out, found other jobs or retired.

This replacement of people by machines and institutions has transformed the Norwegian fisheries. Fishing is part of a larger national and international harvesting system, based on much the same ideology as the production and manufacture of other industrial products. Thus the designers and the producers of the vessels’ equipment become more prominent in fishing. The vessel is now the node in a technological and symbolic capture system. In former times, one vessel could easily replace or
pull gear for another; today, vessel and gear integrate in a quite different way. The modern fishing vessel, transformed into a highly effective “fish-killing machine,” is part human, part mechanism: one can reasonably describe the assemblage of gear, vessel, the crew and the work processes as a cybernetic system (Johnsen et al. 2009).

THE CYBORGIZATION OF THE FISHERMAN

“The existing Norwegian regulations give the seaman’s doctor the right to evaluate if a sailor with a Body Mass Index (BMI) between 30 and 35 is healthy enough to sail.” Norwegian Minister of Trade and Industry, Ansgar Garbrielsen. (Parliament of Norway 2002)

Humans do not stand outside the machinery as users and masters, but must be seen as an integrated part of it. The quote above shows that the technoscientific network of fishing requires specific physical abilities. The dimensions of the gear, the work speed expected, and the precision required in operations mean that human skills alone cannot produce the desired performance. Machinery comes to replace humans because it can be adapted more readily than human bodies. As a consequence, human fishing performance becomes regulated by the technology of the harvest machinery; where these operations prove easier to learn and perform than traditional practices, the latter vanish, as does the knowledge linked to them. Where one could once speak of human fishermen with individual fishing expertise, knowledge is now increasingly embedded in machinery and organizations (Murray et al. 2005; Johnsen et al. 2009).

Through this process, where humans interact with both technological elements and governance mechanisms, the fisherman – formerly a human at the end of a line, or hauling gill nets by hand – ceases to exist as an independent individual. Instead, the fisherman has been transformed into a cybernetic organization, a cyborg, who at the micro level might be called a robo-fisher (Fig. 5). But the robo-fisher also reflects a similar type of process at a macro level, where fisheries as a whole shift towards a cybernetic organization based on intervention and feedback mechanisms, as depicted in Figure 1 above.

Despite the “wiring in” of greater proportions of fishing “knowledge,” not just anyone can fill the human positions in the cybernetic organization or network. These require specialists to maintain and operate the different bits, bytes, and pieces, as well as the relations between them. Relatively few will qualify as robo-fishers, even if the selection process is less extreme than that for, say, fighter pilots; while the open commons of the past had fewer restrictions, today’s fisheries can and do discriminate on the basis of “disability.”

Even if cyborgization comes with new demands and restrictions, it also opens new opportunities. One outcome is certain: with killing machines and robo-fishers ruling the oceans, the fish itself will also be transformed.
TRANSFORMING FISH: THE TAC MACHINE

Today, fisheries science—a blend of biology, oceanography and computer modelling tools—drives much of the effort toward sustainable fisheries resource management (Government of Norway 2003). The origin of modern fisheries science lies in the industrial revolution (Murray and Hjort 1912). The nineteenth-century widened the scope and scale of marine exploration. Through oceanographic expeditions, trial fishing, and collection of catch information, marine researchers from many countries amassed a tremendous amount of empirical material about the seas and its creatures, material for calculating, measuring and modelling marine life (Murray and Hjort 1912). Almost a century after the first scientific venture into fisheries, a breakthrough came in 1965 with the invention of an effective stock assessment technology, the Virtual Population Analysis (VPA) (Finlayson 1994; Holm 1996; Nielsen 2008; Roepstorff 2000). The VPA made it practicable to assess the strength and development of major fish stocks on the basis of available data, mainly year-class structure and catch rates. While these assessments were rough and often missed by large margins, they legitimised fisheries scientists as independent, objective experts who could advise on optimal use of fish stocks. The VPA assessment was integrated with the Total Allowable Catch (TAC), a practical intervention that allowed regulation of fishing pressure through quotas on specified fish stocks. Together, the VPA and the TAC informed a powerful management instrument, the “TAC machine” (Nielsen and Holm 2007), which assessed fish stocks and set quotas accordingly in a repetitive, annual cycle.
The advent of this TAC machine, along with the new oceans regime negotiated through the 1970s, represent two major preconditions for a new fisheries entity: what we term here the cyborg fish (Holm 2007), a cybernetic organization for defining and measuring fish. This process institutionalized fisheries science with strong ties to political institutions as well as the fishing industry (Holm 1996). Despite its apparent simplicity, the cyborg fish is a complex and heterogeneous object, one that links nature, society, technology, science, markets, and policy (Holm 2007). With the construction of the cyborg fish, the unmanageable fish-in-nature has been domesticated and become manageable. In this process, the fish, as well as the fishermen, have been redefined (Johnsen et al. 2009).

THE FISHERIES LEVIATHAN – THE LINKS BETWEEN POLICY, SCIENCE, TECHNOLOGY, AND ECONOMY
The killing machines, the robo-fisher, the TAC machine and the cyborg fish are all elements in a technoscientific network – combining humans and non-humans into a creature that acts as one. Together, they form a cybernetic organization that allows governance of nature and society. We started our history with the 1920s, describing the close, simple and direct relations between humans and fish that characterized the traditional fisheries. In comparison, the relations between humans and fish in modern fisheries are strikingly more complex, with highly developed scientific, regulatory and governance mechanisms. The creature that in Norway drew its first breath with the introduction of the Trawler Act in 1936 has grown up and come to the surface: its scope, intricacy and all-encompassing character justify the name of “fisheries Leviathan” (see Callon and Latour 1981). This “Leviathan” acts as a strong and powerful cyborg, representing, linking and to some extent programming the actions and space of all the system’s components.

Since the 1960s, fishing technology has become effective enough to threaten natural resources. In tandem with the growth of a stronger “Leviathan” in the fisheries, fish-capture capacity has continued to expand, and with it, the need for more management and governance. Currently, the successful fisheries enterprise comprises not just the owner, the crew, the vessel, the fish and the available quotas; it has also been woven into a network of regulations that define its relations to fish, and extend to negotiations with other states (for example, the Joint Norwegian-Russian Fisheries Commission, which oversees the management of the Northeast arctic cod and other important species). Scientific production, interpretation and application also integrate the fishing enterprise, as with the International Council of the Exploration of the Seas (ICES) and the development of gear and vessel technology. Enterprises must furthermore buy and sell rights and quotas, undertake planning, obtain finance and credit, and evaluate risks. A wide range of cybernetic mechanisms therefore orchestrates fisheries access. This process of cyborgization
is changing the relationship of crews, coastal communities and general public to marine resources.

Paradoxically, in Norway the development of the “fisheries Leviathan” has transferred rights and responsibilities for management from the public to the private sector, despite adhesion to public “ownership” of resources as the main principle of governance (Government of Norway 2007). The ordinary crew (who no longer have any legal claim to fish resources) their families, and their communities now depend on the vessel owners for their access to fisheries and the wealth they generate.

Nature, the fish as a biological creature, is woven into fishing enterprises. Based on vessel length and other criteria, these enterprises receive pre-specified volumes of fish to pursue. Exclusive rights and quotas now provide the basis for the industry’s profitability and sustainability. A fishing vessel is not only a “killing machine,” but also represents an option on a certain quantity of fish. These mechanisms have at least temporarily approached Norway’s long-term political goals for its fisheries: increased stability and profitability (see Government of Norway 2007). As pointed out by Standal and Aarseth (2002), however, they have also favoured technological modernisation and increasing harvest capacity. Changing patterns of investment also reflect this process. From 1995 to 2002, more than 7 billion kroner were invested in the Norwegian fishing fleet. The long-term liabilities of the full-time operating fleet (vessels over 13m /50ft) increased by 168% during the period 1995-2001, many times higher than the rate of inflation; this reflects an increase in technical standards on the vessels (Johnsen 2005). Even with fewer people and boats directly involved in fishing, in 2003 the fishing cyborgs had to achieve a higher catch value than in 1995 in order to pay for the increasing costs.

Many fishing vessels today, even small ones, are organized as corporations rather than partnerships. The ideology, the forms of organization, the institutional framework, the tax rules, and the financing of the fishing fleet therefore resemble the patterns we find in land-based businesses. For example, when rights and quotas become elements in transactions, financing institutions gain more control over fishing activities and become parts of the cybernetic organization. Capital seeks investment opportunities, but given a smaller number of vessels and individuals with access to rights, fisheries investment positions have grown scarce. Fewer fish and fishermen, and more restrictive quotas, can increase the price for entering into relationships. If scarcity increases the price of fish, quota options and the related costs of fishing, and more intensive fishing becomes necessary to meet the increased costs, then the ecological benefits of limiting access to the fisheries may disappear. The fisheries policy and the cybernetic organization of the Leviathan give priority to economic values; along with managing resource access, they tend to impel “cyborg” action in a certain direction. As a result, fishing enterprises appear less as producers of fish, labour and social benefits than as producers of added economic
value. This reduces informal social and economic pay-offs, because the professional-
ized network formalises as many practices and relationships as possible. The cyborgs
in the fisheries must therefore behave as rational actors, with huge consequences
for the fisheries as well as the fisheries Leviathan itself.

THE FUTURE OF THE FISHERIES LEVIATHAN
Despite its success in prioritizing resource management and modernizing fisheries
into a much more profitable, safe and secure business, the fisheries Leviathan is not
– at least not yet – a stable entity. Fisheries management is, if not in crisis, at least
continuously in dispute. One reason is the difficulty of stabilising harvest capacity – a
key goal of management. In fact, it has been claimed that management and govern-
ance instruments contribute to increased efficiency and harvest capacity (Johnsen
2005; Government of Norway 1998; Standal and Aarset 2002). And here we come
to the paradox of fisheries management efforts. While they aim to create sustain-
able fisheries, the resulting system often reduces sustainability. Why does a system
that has succeeded institutionally, transforming fisheries from the ground up, give
so poor a technical performance? We propose here that this has something to do
with how the “unmanageable” objects are translated into manageable ones – such
as the cyborg fish, the killing machines and the robo-fishers, the ontology of the
actors, and development of the fisheries as a cybernetic organization. The cyborgs
are relationships, and linked together, they form cybernetic harvest systems that start
to follow their own logic, and therefore prove difficult to govern. The efficiency, the
power, and the need for fish in these systems are so vast that they require continuous
restructuring of the fish-killing system. A pivotal question is whether the Leviathan
will survive attacks from its own component parts; we may yet see fully privatized
fisheries where a few killing machines, even more “robotized” than today, bring
both the cyborgs and the natural fish under their control.

As conflicts persist in fisheries, efforts to create new relationships and links have
emerged. These include incorporation of local fishermen’ knowledge, more open and
participatory scientific methods, increased user participation in decision-making,
expansion of market- over state-based management, addressing claims for traditional
rights and extending rights to new groups. The results remain uncertain. Profitability,
the precautionary principle, ecosystem approaches, the emergence of industrial
carnivorous aquaculture and many other issues will affect how fisheries resource
management develops in the future. Will commercial fisheries continue to exist as
a politically and morally viable option for humankind? If we want to understand
how fisheries management actually works and what it can accomplish, we need to
start understanding how modern fisheries – these cybernetic creatures – function.
The dynamics of the cyborgization process are hidden in the relations holding this
heterogeneous network together.


Up until the end of the 1980s, capture fisheries provided most of the world’s rising supply of fish and shellfish. Since then, the apex of these fisheries’ production appears to have passed: for the last two decades, declared global catch volumes have topped out at around 90 million tonnes annually. Meanwhile, aquaculture (farming fish, shellfish, etc.) has grown spectacularly, increasing the world’s seafood supply: its share rose from 12% in 1988 to 37% in 2008, or 52 million tonnes. The rise of aquaculture over the last twenty years met a soaring demand for seafood; the world’s population now consumes three kilos (nearly 7 pounds) per person more annually than they did twenty years ago, averaging 17 kilos (37 lbs.) per person (see Fig. 1). However, the growth rate for farmed seafood production has slowed over the last decade: its decline, combined with a ceiling on fish catches and overfishing of many stocks, raises questions about aquaculture’s long-term capacity to satisfy rising demand for seafood (FAO 2008).

AQUACULTURE’S GEOGRAPHIC STRUCTURE AND VOLUMES
Aquaculture’s global rise began with traditionally-farmed freshwater fish (especially carp) and shellfish. New types followed, such as “intensive” fish and shrimp farming, where stocks receive an external food supply; salmon farming is the best-known form in Europe and North America. Worldwide, freshwater fish farming produces 55% of global aquaculture volumes, and farmed bivalve molluscs (oysters, mussels, clams, etc.) produce 25% (not including marine plants). Farmed crustaceans (shrimp, prawn, lobsters, etc.) contribute 10% of volumes, as do farmed saltwater and diadromous fish (FAO 2008) (Fig. 2). Asia concentrates the largest share of the world’s farmed seafood production (89%): China alone produces 62% of worldwide volumes. It leads in all types of aquaculture except for farmed

1. Diadromous fish travel between salt and fresh water.
salmon, where Norway and Chile remain the world’s top producers (Fig. 3).

RESOURCES USED BY THE FISHERIES AND AQUACULTURE SECTOR

Large-scale growth of aquaculture results in an ever-larger ecological footprint, particularly because of increased use of fish oil and meal for feed. Fish feed is produced from “forage” or small pelagic fish, such as Peruvian anchovies, blue whiting, capelin, etc.: their catch levels – around 20 million tonnes annually – have remained stable over the last twenty years. Originally, forage fisheries principally supplied pig and fowl feed; today, the whole aquaculture sector\(^2\) consumes 70% of all fishmeal and 90% of fish oils (a source of omega-3 fatty acids). Aquaculture also draws on “trash fish” that have little or no commercial value. Their catch volume is hard to estimate, but appears to be growing as the aquaculture industry expands in Asia (de Silva 2008). By-products from the fish processing industry provide added feed sources, and agricultural inputs make up an increasing share of the mix as fish farming intensifies. A trend toward incorporating vegetable-derived proteins in carnivorous fish feed (see Fig. 4) will probably grow, as well, to reduce dependence on fishmeal and oils from fully-exploited forage fish.

This review of the resources used by the fisheries and aquaculture sector shows its rising dependence on fish for feed: this may curb the growth of intensive aquaculture. Species desired by consumers and largely destined for export, such as salmon, shrimp and carnivorous marine fish (sea bass, etc.) consume 60% of all fishmeal and 75% of all fish oils used in aquaculture (Tacon and Metian 2008), even though these farmed fish make up only 15% of aquaculture produce worldwide. This use of limited fisheries resources to benefit a small segment of global seafood demand raises questions about food security for those with protein-deficient diets. The system’s overall

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\(^2\) Bivalve molluscs do not require these fish by-products since they consume naturally produced plankton and organic matter.
FIGURE 2. AQUACULTURAL PRODUCTION 1980-2008

Source: Compiled by the authors from the FAO FishStat database.

FIGURE 3. ASIAN AQUACULTURE SHARE OF VOLUMES: CHINA LEADS

Source: Based on Naylor et al. (2000; 2009), FAO (2008; 2009), Tacon and Metian (2009)

FIGURE 4. RESOURCES USED BY THE FISHERIES AND AQUACULTURE SECTOR

Source: Compiled by the authors from the FAO FishStat database.
food-production efficiency is debatable; aquaculture’s resource use competes with direct consumption – forage and trash fish could otherwise (at least in part) feed humans rather than fish. Forage fisheries are controversial from an ecological point of view as well, since they exploit the middle level of the food web, between plankton and predator fish. Despite improvements in fish farm feeding practices (e.g. feed substitutes, breed selection), recent changes in the structure of aquaculture production – as with the intensive farming movement in general – tend to increase pressure on forage fish stocks.

**SUSTAINABLE AQUACULTURE’S CHALLENGES**

In the middle and long-term, aquaculture’s growth will face constraints through heightened competition for scarce resources – fishery and agricultural products, but also water and energy – and from rising conflicts over usage as the world’s population grows. In addition, vulnerability to parasites, lice and pathogens increases as farming intensifies and aquatic ecosystems deteriorate. Aquaculture's environmental impacts vary greatly. Beyond its global impact on forage fisheries and its introduction of non-native species, it sometimes destroys local habitats, e.g. mangroves razed at the start of shrimp farming. It pollutes water with organic, mineral and pharmaceutical waste, and also pollutes native species’ gene pools with farmed species. Concern about these impacts has led the Food and Agriculture Organization of the United Nations (FAO) and the Federation of European Aquaculture Producers (FEAP) to codify “best practices” as a means to reduce negative effects (FAO 1995; FEAP 2000). Beyond such efforts, global governance of fisheries and aquaculture must be strengthened to spread sustainable fisheries practices – preserving habitats, restoring fish stocks, and eradicating illegal, unregulated and unreported (IUU) fishing (see FAO 2001). Such regulation must also encourage fish farms that consume fewer resources, and improve use of fisheries for human consumption.

**WORKS CITED**


The 1982 UN Convention on the Law of the Sea (the Convention, or UNCLOS) has often been proclaimed as the “constitution for the oceans.” However, despite many affirmations that UNCLOS provides the framework for all ocean-related issues, questions persist about the fragmented nature of oceans governance. Some states that are not party to the Convention continue to question the pre-eminence of UNCLOS. The high rate of degradation of the marine environment, both within and beyond areas of national jurisdiction, raises questions about efficacy of the Convention – and indeed international law in general. The myriad instruments regulating oceans and their resources and the many fora within which oceans issues are considered also strain the Convention’s proponents’ claim that it is the supreme and sole “constitution of the oceans.” This chapter considers whether UNCLOS truly encompasses all ocean regulation; it examines both potential gaps within its framework and other, potentially competing or complementary norms in the law of the sea.

INSTITUTIONAL SETTING OF OCEAN GOVERNANCE PRIOR TO THE CONVENTION
The adoption of UNCLOS did not mark the beginning of the law of the sea. Up to the middle of the twentieth century, much of the law of the sea was to be found in customary international law, which, under Hugo Grotius’ influence (Grotius 1604), rested on the freedom of the seas. In 1945, the International Law Commission adopted a set of draft Articles on the Law of the Sea, used by the First and Second

Despite the First Conference's success in adopting four treaties, its effects proved limited when these Conventions failed to garner sufficient support in the form of ratifications by states. Moreover, the Conventions did not resolve a number of important issues, such as the breadth of the territorial sea. Their very partial success appears evident in that barely twenty years later the UN convened the Third Conference on the Law of the Sea, which led to the adoption of UNCLOS.

From a governance perspective, the law of the sea prior to the adoption of UNCLOS was characterized by fragmentation, with multiple actors playing different, potentially conflicting roles. The first among these is the International Maritime Organization (the IMO). The IMO is a Specialized Agency of the United Nations, established by the IMO Convention in 1948. The IMO’s mandate relates to shipping, and it has adopted a vast set of treaties and other supporting measures on a number of issues; these fall into three main categories. The first concerns treaties and measures related to maritime safety, in particular the prevention of accidents. The second category relates to the prevention of marine pollution; the third addresses liability and compensation. Examples of the first category include the 1972 Convention on the International Regulations for Preventing Collisions at Sea, the 1974 International Convention for the Safety of Life at Sea and the 1979 International Convention on Maritime Search and Rescue. Treaties concerned with pollution include the 1973 International Convention for the Prevention of Pollution from Ships (modified by the 1978 Protocol) and the 2001 International Convention on the Control of Harmful Anti-Fouling Systems on Ships. Finally, the liability instruments adopted under the IMO include the 2001 International Convention on Civil Liability for Bunker Oil Pollution Damage and the 1996 International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (all cited in Lowe and Talmon 2009).

While the IMO has a comprehensive set of treaties and regulations, its mandate is limited to maritime safety and pollution; it is not in a position to regulate all aspects of the marine environment. Fisheries regulation, protection of seabed from destructive practices and even the regulation of pollution from land-based sources – the single largest source of marine pollution – remain outside the purview of IMO.

Fisheries come under the mandate of the Food and Agricultural Organization (the FAO), another Specialized Agency of the United Nations, founded in 1945. The FAO’s
stated mission is to achieve food security; core activities under its purview therefore include fisheries and aquaculture. The FAO has helped develop policy instruments on fishing, both binding and non-binding. These include the 1993 FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas and the 1995 FAO Code of Conduct for Responsible Fisheries. To promote implementation of the Code of Conduct, the FAO has also developed Plans of Action on seabirds, sharks, management of fishing capacity, and illegal, unreported and unregulated (IUU) fishing (in Lowe and Talmon 2009).

As with the IMO, the FAO’s mandate is limited. Thus while the FAO has adopted a wide range of fisheries measures, it lacks the competence to provide for marine environment protection in general. In addition to the FAO and IMO, a number of other international organizations and fora play diverse roles in oceans matters – for example, the International Whaling Commission (IWC), established by the 1946 International Convention for the Regulation of Whaling. The Intergovernmental Oceanographic Commission, an arm of the United Nations Educational, Scientific and Cultural Organization (UNESCO), similarly plays an important, albeit non-regulatory role: it provides a platform for coordinated exchange of information between states and encourages marine scientific research. In addition, the United Nations Environment Programme (UNEP) is also involved in law of the sea matters through its Regional Seas Programme.

Beyond these organizations – all of which help generate norms in ocean regulation – several other bodies contribute to oceans affairs. The Global Environment Facility is an innovative institution created by three parallel resolutions of the United Nations Development Programme (UNDP), UNEP and the World Bank; its mandate is to finance the “incremental costs” of global environmental protection in a number of focal areas, one being international waters.\(^1\) To these agencies, one can also add the International Labor Organization, the World Meteorological Organization and the World Health Organization, which all play incidental roles in oceans issues.

The large number of institutions involved in oceans regulation does not, in itself, indicate fragmentation and lack of coordination. Indeed, the variety of fora implies a wealth of sources for developing the law of the sea. However, the myriad institutions described above bear no real relationship to one another, and operate independently without an overarching framework to ensure structure, consistency and coherence. This lack of structural cohesion does little to unify the fragmented regulations described above. While the UN General Assembly, the chief deliberative organ of the United Nations, serves as an overarching forum and does review oceans policies, it defers to other bodies in their specific areas of competence, and this limits its ability to provide regulatory cohesion and integration. (The General Assembly’s particular contribution, past and future, will be described in further detail below.) This lack of cohesion carries two potential risks for oceans governance. First, there is a

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\(^1\) Other focal areas include climate change, biodiversity, land degradation, persistent organic pollutants and ozone protection.
risk of inconsistent regulation and approaches to the management of the oceans. Second, the limited mandate of the responsible organizations may lead to governance, regulatory or implementation gaps. I will next consider whether the adoption and implementation of UNCLOS has resolved these risks, particularly as they affect protection of the marine environment.

THE CONVENTION AND FRAGMENTATION

Certainly, one of UNCLOS’ primary objectives was to create a more integrated, less fragmented system to govern the oceans. To this end, the Convention aims at the creation “of a legal order for the seas and oceans which ... will promote ... the protection and preservation of the marine environment.” (UNCLOS 1982). The Convention is littered with provisions purporting to meet this aim. Article 61(2), for example, provides that the coastal States “shall ensure through proper conservation and management measures that the maintenance of the living resources in the exclusive economic zone is not endangered by overexploitation.” With respect to the high seas, Article 119 of the Convention requires states to establish conservation measures for living resources “which are designed to restore populations of harvested species at levels that can produce the maximum sustainable yield.” Similarly, Article 145 of the Convention gives the International Seabed Authority responsibility for measures protecting the marine environment from harmful activities on the seabed beyond national jurisdiction (the Area).

The provisions highlighted above illustrate the zonal approach adopted by UNCLOS, i.e. that different maritime zones determine rights and obligations. As will be seen below, this zonal approach may contribute to fragmentation of the law of the sea. However, in addition to the provisions applicable to specific maritime zones, Article 192 of the Convention also creates a general obligation for states, irrespective of zone, “to protect and preserve the marine environment.” To this end, Article 194 requires states to take “all measures...that are necessary to prevent, reduce and control pollution of the marine environment” (UNCLOS 1982). Article 240 also creates a further general obligation across zones, to ensure that marine scientific research comply with provisions for “the protection and preservation of the marine environment.” In addition, the Convention obliges states to generally monitor and assess the environmental effects of marine activities under their jurisdiction or control, and to adopt rules to prevent and control pollution – from land-based sources, activities in the seabed, dumping, vessels and the atmosphere (Articles 204 – 212). Even given all these environmental protection provisions, analysts have questioned UNCLOS’ effectiveness and its claim to serve as “the constitution of the oceans.” Redgwell (2006) has suggested that UNCLOS has gaps or lacunae, at least in regulation of dumping activities. Similarly, with respect to the EEZ, Barnes (2006) notes that UNCLOS has failed to spell out a “sufficiently coherent obligation to steward” resources, and that this has led to the collapse of domestic fisheries. Barnes identifies failures stemming, on the one hand, from the too-general character of UNCLOS
obligations, which leave its norms open to interpretation, and on the other hand from the reliance on maximum sustainable yield and the coastal state’s unfettered authority in the EEZ. In the same volume, Gjerde (2006) also identifies a number of UNCLOS deficiencies: she notes declining high seas fish stocks and rising biodiversity concerns, suggesting that these result from UNCLOS’s failure to keep up with current requirements. Her analysis implies that the notion of freedom of the high seas, and in particular the freedom to fish, contribute to the decline in fisheries and the rise in threats to marine biodiversity.

Certainly, UNCLOS’s provisions for marine environmental protection stand in a delicate balance with economic interests. One of the clearest examples is Article 193, which provides states with the “the right to exploit their natural resources pursuant to their environmental policies and in accordance with their duty to protect and preserve the environment” – a provision clearly meant to apply within areas of national jurisdiction (UNCLOS 1982). To be fair, UNCLOS’s formula for this well-known principle is more environmentally friendly than the previous formulation in Principle 2 of the Rio Declaration (Rio Declaration 1992). Nonetheless, the “right to exploit resources” does signify that the Convention’s drafters recognized that the environment was not the sole value in ocean regulation. The “maximum sustainable yield” concept provides another reflection of economic interests in UNCLOS.² In addition to Article 119 referred to above (which applies maximum sustainable yield as the guiding principle for conservation on the high seas), UNCLOS Article 61 also applies this principle to managing marine resource conservation in the EEZ (UNCLOS 1982).

It is equally hard to deny that UNCLOS grants broad authority and rights to coastal states in the exclusive economic zone - a zone that hosts 90 percent of commercially exploited fisheries. Although UNCLOS also imposes duties to manage and conserve the EEZ’s living resources, these obligations have been criticized for being overly general, ambiguous and lacking in specificity (Barnes 2006) — in contrast to the clear rights and jurisdictions outlined in Part V of the Convention. Barnes (2006) points out that the obligations specified are owed to no one in particular. In such conditions, one might ask whether the provisions can sufficiently protect and preserve the marine environment. Similar concerns about too-general language arise with other conservation provisions of the Convention, including the catch-all Article 192.

Without question, the principle of the freedom of the high seas, confirmed and entrenched in UNCLOS, militates against effective protection and preservation of

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². Maximum sustainable yield refers to the largest catch that can be taken from a stock of fish that would allow the stock to continuously regenerate.
the marine environment. The effect of this Grotian principle is effectively to re-enact Hardin’s “tragedy of the commons” in the high seas (Hardin 1968). In essence, it assumes that states (and the vessels under their jurisdiction) are free to do as they please in seas beyond national jurisdiction. It must be said that UNCLOS does provide some constraints on this principle. First, Article 87(1) provides that the freedom of the high seas is to be “exercised under the conditions laid down by this Convention and by other rules of international law;” needless to say, this would include the obligation in Article 192 to protect and preserve the marine environment. Second, Article 87(2) provides that the freedoms are to be exercised “with due regard to the interest of other States in their exercise of the freedom of the high seas” and “for the rights under [the] Convention with respect to activities in the Area” (UNCLOS 1982). Nonetheless, the criticisms raised concerning the generality and vagueness of the constraints still apply.

Given the foregoing, one could argue that UNCLOS’s environmental protections are inadequate and require augmentation. The problem, as discussed in the first section, is that no overarching institution exists with the mandate to further develop these provisions. This may suggest that UNCLOS has done little to address fragmentation concerns in oceans governance; if anything, it may be argued that by creating more institutions, with potentially overlapping areas of competence, the Convention has exacerbated the problem. We refer in particular to the three main institutions UNCLOS created: the Commission on the Limits of the Continental Shelf (the Commission), the International Tribunal for the Law of the Sea (the Tribunal) and the International Seabed Authority (the Authority).

The mandate of the Authority is to control and manage activities in the seabed beyond national jurisdiction (the Area) in accordance with Article 136, which states that the “Area and its resources are the common heritage of mankind” (UNCLOS 1982). There has been debate between developed and developing countries about whether the “common heritage of mankind” applies to the Area in general or only to its mineral resources, an issue considered in more detail elsewhere. Whatever one’s view on the common heritage debate, however, the Authority’s role in biodiversity issues cannot be denied. Leaving aside the debate’s commonly raised arguments, Article 145 expressly provides that the Authority should adopt measures “to ensure effective protection for the marine environment from harmful effects which may arise from [activities]” in the Area (UNCLOS 1982). This has implications for freedom of the seas, because any high-seas activity with impact on the seabed would need to

3. Hardin’s tragedy of the commons postulates that finite resources in “the commons” or areas open to all will eventually be depleted if each actor is free to consume the resources without regulation. In other words, short-term interests will dictate overexploitation even though this is in no one’s long-term interest.

4. See e.g. Tladi (2008), Millicay (2007) and other papers in this volume.
take the Authority’s mandate into account. This latter point does not simply specify the legal regime that applies to the Area; it also suggests a flaw in the logic of the Convention. UNCLOS’s zonal approach does not adequately reflect the fact that what happens in the EEZ affects the high seas, and what happens in the water column (the high seas) affects the seabed below (the Area). This creates institutional difficulties, because the Authority’s mandate in the Area does not extend to the water column above the seabed – a further sign of a lack of integration.

UNCLOS establishes the International Tribunal as a body for the settlement of disputes relating to the law of the sea. However, it also recognizes a number of other mechanisms as competent to settle such disputes – in particular, the International Court of Justice and various arbitrating tribunals. The Convention does not provide a hierarchy among these bodies, and this too raises questions about potential fragmentation: the possibility always exists that the competent tribunals will come up with conflicting interpretations.

Modern international environmental agreements often make provision for a Conference of the Parties, with the mandate to develop the rules of the agreements as the need arises. While UNCLOS also provides for a Meeting of States Parties to the Law of the Sea Convention (SPLOS), views diverge as to whether SPLOS has the competence to consider substantive matters. For this reason, SPLOS has, by and large, been relegated to considering administrative and budgetary issues and has had little impact on the development of the law of the sea. Given the major political divide implicit in these diverging views, the prospects for SPLOS taking on a more substantive role appear dim, to say the least.

The large number of regulating institutions and fora, both within and outside the Convention, is not the only problem confronting UNCLOS’s “constitutional” ambitions. The refusal of some parties to recognize UNCLOS as the main legal framework governing the oceans has also raised obstacles. The tension between the Convention on Biological Diversity (Biodiversity Convention) and UNCLOS plays out in various UN fora: some States that have not ratified UNCLOS (notably Venezuela, Turkey and a few others) refuse to acknowledge it as the framework governing oceans issues, and insist that the Biodiversity Convention be accorded equal status. Other states oppose any language that would place UNCLOS on an equal footing with any other instrument, including the Biodiversity Convention. The standard language that has been used to resolve this disagreement is “international law, as reflected in the Convention.”

The preceding analysis appears to suggest that UNCLOS has not alleviated the fragmentation of oceans governance and has not made sufficient provision for
environmental protection. To sum up, such criticisms focus on UNCLOS’ over-general environmental safeguards and the apparent entrenchment of the freedom of the high seas principle. These substantive weaknesses, it may be argued, are exacerbated by the lack of an integrated institutional framework capable of progressively developing the law of the sea for protection of the marine environment.

**UNCLOS FRAGMENTATION: EVALUATION AND ASSESSMENT**

In evaluating the criticisms leveled at UNCLOS’s normative framework, one should bear in mind what it does and does not claim to do. In its own terms, it aspires to create “a legal order for the seas and oceans” and establish a “constitutional” framework within which all activities in the oceans and seas are to be governed. None of these qualifiers suggests more detailed ambitions. Rather, like constitutions in domestic legal systems, the Convention provides a structural framework and high-level norms, the concrete details of which can be worked out through other law-making avenues.

As a constitution-like instrument, UNCLOS not only embraces such further development of its norms but indeed requires it. And as with any constitution, UNCLOS reserves a place of supremacy for itself, not only among legal norms existing at its adoption but in respect to future ones. Article 311 and Article 237 recognize the validity of norms and agreements developed by relevant institutions and states, either prior to or subsequent to UNCLOS adoption, to the extent that such norms do not conflict with the aims of the Convention (UNCLOS 1982). This recognition of outside norms allows development of the law of the sea, with UNCLOS as framework. The 1995 United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling and Highly Migratory Fish Stocks (Fish Stocks Agreement [FSA]) provides one example (UNFSA 1995): it promotes, in Article 5, precautionary and ecosystem approaches, and the use of best scientific evidence. While the Fish Stocks Agreement retains the maximum sustainable yield concept, its environmentally-friendly provisions strengthen and advance UNCLOS principles.

Both UNCLOS and the Fish Stocks Agreement stress cooperation as critical for meeting their requirements. In this connection, Regional Fisheries Management Organizations and Arrangements (RFMO/As) have emerged as means to develop further rules in fisheries conservation and management. Although analysts have lamented RFMO/As’ lack of progress to date in stemming the tide of unsustainable fishing, they remain potentially useful mechanisms for developing UNCLOS provisions.

Developments in the area of dumping also illustrate expansion of the law of the sea within the UNCLOS framework. The pertinent provisions of Article 210 are instructive in this regard. First, they require states to take action, including the adoption of legislation, to prevent, reduce and control pollution by dumping. Second,
they require that dumping only occur with permission of the relevant authorities. Third, and most important for the purposes of this paper, they require that states establish global and regional rules and standards on dumping through, *inter alia*, competent international organizations (UNCLOS 1982). The 1992 Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR Convention) goes further than UNCLOS in regulating dumping. Article 3 of Annex II, for example, prohibits the dumping of all wastes except those specifically listed in the Article (in Lowe and Talmon 2009). The 1996 Protocol to the 1972 International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters similarly takes a more stringent approach towards dumping at sea (in Lowe and Talmon 2009). While moving beyond the Convention’s normative prescriptions, both instruments are fully consistent with it, and can be seen as further developments of UNCLOS’ legal framework.

Other instruments, whether adopted prior or subsequent to UNCLOS, also evince the normative development of the law of the sea, as underpinned by the Convention. The Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a case in point, particularly in enforcement of some sustainable fisheries norms. CITES contributes to the protection of the marine environment by listing marine species in its Appendices, thereby bringing them under its purview (in Cullet and Gowlland-Gualtieri 2004). The Biodiversity Convention, which covers both terrestrial and marine species, also plays a noteworthy role in normative maritime law: for example, the ninth Conference of the Parties under this Convention agreed to adopt scientific criteria for identifying ecologically and biologically sensitive marine areas (in Cullet and Gowlland-Gualtieri 2004).

Normatively, then, UNCLOS appears to give structure to the variety of rules and provisions adopted by institutions with a role in oceans governance. Nonetheless, international fora continue to make calls for an institutional authority with an overarching mandate over ocean affairs. Such an institution would have responsibility for both the normative development of oceans regulation and the implementation of existing ones. In reality, the prospects for this are remote. However, the General Assembly of the United Nations continues to provide a setting for deliberating issues pertaining to the law of the sea while recognizing the primacy of UNCLOS.

The General Assembly fulfils its function in a number of ways, including its annual resolutions and subsidiary fora. The first of these is the UN Open-Ended Informal Consultative Process on Oceans and the Law of Sea (the ICP), established by the General Assembly in 1999. The ICP provides a forum where diplomats, scientists and other experts can discuss ocean and the law of the sea issues in an informal way. Since its inception, the ICP has considered a number of topics, including fisheries, ecosystem approaches, marine genetic resources and new and sustainable uses of the oceans. The ICP discussions (and any “agreed consensual elements” whenever these
have been adopted) have often contributed significantly to the language adopted in the annual General Assembly resolutions. In 2004, the General Assembly established the Ad Hoc Open-Ended Informal Working Group to study issues relating to the Biological Diversity in Areas Beyond National Jurisdiction (Ad Hoc Working Group). This forum examines, *inter alia*, scientific, technical, legal, economic and environmental issues pertaining to the conservation and sustainable use of biological diversity. The Ad Hoc Working Group has held meetings in 2006, 2008 and 2010, with the question of laws applying to marine genetic resources taking centre stage at all three. The 2010 meeting – which produced recommendations, unlike the first two sessions – also considered potential gaps in regulation and governance related to the law of the sea. In this respect, the vast majority of countries proposed a process to negotiate and ultimately adopt an implementing agreement to the Convention to deal with any governance, regulatory or implementation gaps. However, a few delegations objected to the proposal and it was therefore not included in the recommendations submitted to the General Assembly. Nonetheless, the call for such an implementing agreement suggests some dissatisfaction with current law.

The General Assembly annually adopts two resolutions on the law of the sea: first, the omnibus Resolution on Oceans and the Law of the Sea and second, the sustainable fisheries resolution. Whether by design or not, the resolutions do contribute to the development and evolution of norms in the Convention. General Assembly Resolution 61/105 (8 December 2006) provides an illustration: paragraphs 83 to 86 called upon RFMOs overseeing high seas fisheries and states engaging in high seas fishing to “adopt and implement measures in accordance with the precautionary approach, ecosystem approaches and international law” (UNGA 2006) and to prohibit, with respect to areas with vulnerable marine ecosystems, bottom fishing “unless conservation and management measures have been established to prevent significant diverse impacts.” The number of paragraphs in the omnibus resolution calling for ecosystem approaches beyond the scope of UNCLOS and the Fish Stocks Agreement also attests to the role of the General Assembly resolutions in developing the law of the sea.

**CONCLUSION**

While UNCLOS provides the legal framework for ocean activities and establishes a legal order for the oceans, it does not regulate every aspect of the oceans to the same degree. As with any “constitutional” framework, the Convention does not provide all the details. It thus makes allowances for the development and evolution of the law of the sea through the adoption of other norms in various institutional settings. Implementing agreements, treaties under other organizations and “soft” law instruments (e.g. non-binding documents adopted by states, such as resolutions) all contribute to making the law of the sea, underpinned by UNCLOS, a vibrant and dynamic legal system capable of adopting new norms as the need arises.
That the system is capable of adapting and evolving does not mean that it has done so. The current impasse in the Ad Hoc Working Group on Biodiversity, particularly in relation to the legal regime question and conservation measures in the high seas, underscores the need to develop new norms. The system is capable of incorporating such norms, however, if the states that must agree have the political will to follow through.

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While a global regulatory framework can establish common principles for managing the ocean, only specific local and regional measures can address the varied threats affecting diverse marine areas. Since the 1970s, regional arrangements to protect the ocean environment have arisen precisely to allow such differentiation.

A REGIONAL APPROACH TO MARINE ENVIRONMENTAL PROTECTION: THE “REGIONAL SEAS” EXPERIENCE

At the Second United Nations Conference on the Law of the Sea in 1960, the Brazilian delegate made an observation to the effect that no two seas are identical and consequently, it is not easy – nor has it ever been – to resolve problems using a single universal solution. The question persists today: how can a single international convention or action plan simultaneously combat coral bleaching in the Philippines, regulate offshore drilling in the Arctic, preserve the monk seal in the Mediterranean, and manage the plastic trash vortex near the Hawaiian Islands? Even if a global framework can establish common management principles for seas and oceans, only specific measures can address the varied threats affecting diverse marine areas; regional approaches have arisen precisely to allow such differentiation.

Reflecting the development of the global framework, regional initiatives have taken multiple, fragmented and even overlapping forms. Following World War II, the Food and Agriculture Organization of the United Nations (FAO) pushed for the formation of regional fisheries management organizations (RFMOs), dedicated to managing fish stocks in certain ocean areas. After the mid-1970s, the United Nations Environment Programme (UNEP) moved to protect marine areas through regional governance systems – our focus in this chapter. UNEP's Regional Seas Programmes multiplied in the Mediterranean, Baltic, East Asian and Pacific regions; they created

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a new scale for marine environmental management between the traditional national approach and an emerging global one. We will review the results of some regional-scale programmes, highlighting their benefits and the limits of regional versus other approaches, before discussing their future.

THE EMERGENCE AND DISTRIBUTION OF REGIONAL SEAS PROGRAMMES
The “regionalization” of international environmental law has emerged as one of the most important legal events in recent years. An Action Plan developed at the 1972 United Nations Conference on the Human Environment (Stockholm Conference) first gave impetus to the regional approach to marine protection (UN 1972). It led to UNEP’s Regional Seas Programme in 1974, which addressed both causes and consequences of marine degradation and proposed broad preventive management of marine and coastal regions (UNEP 1982). The 1982 adoption of the UN Convention on the Law of the Sea (UNCLOS), a global framework for managing marine areas and resources, complemented and encouraged UNEP’s initiatives. UNCLOS stipulates that “States shall co-operate on a global basis and, as appropriate, on a regional basis….for the protection and preservation of the marine environment, taking into account characteristic regional features” (UNCLOS 1982, Article 197).

Since their launch in the 1970s, the Regional Seas Programme has proven highly successful, as evidenced by the more than one hundred member states participating in them. UNEP promoted and supported some initiatives, e.g. for the Mediterranean (1975), the Wider Caribbean (1981) and Western Indian Ocean (1985); other regional arrangements developed independently, such as those for the Baltic (1974), North-East Atlantic (1992) and Caspian (2003) regions (Fig 1). Some observers note two different philosophies underpinning the various programmes, depending on whether they take place within or outside the ambit of UNEP: the former often see “regional arrangements as a step towards global ones, as a way to make progress in global cooperation” while the latter may focus solely on more local concerns (Alhérithière 1982). However, whether or not UNEP drives the initiatives, we believe regional conservation programmes follow similar processes, applying and extending global-scale commitments.

UNEP traditionally promotes a framework convention and sectoral protocols – a classic agreement architecture. As a “cornerstone for action” (Dejeant-Pons 1987), the convention usually provides general terms and conditions and an overall direction for countries to follow. However important such principles may be, they remain insufficient, and parties must negotiate specific agreements to implement them in various domains. The Mediterranean, Western Indian Ocean, Wider Caribbean, West and Central African, and South-East Pacific Programmes followed this convention-plus-sectoral-protocols model. Other arrangements, such as the East Asian Programme, follow a different model, one based on action plans and specific activities. Since the 1970s, the topics for regional-scale protocols and actions have developed along
lines paralleling global environmental protections (Bodansky 2010). These have gradually moved from fighting marine pollution by ships or land-based activities to encompass biodiversity conservation, via Marine Protected Areas in particular; more recently and in a still-limited way, they have taken on goals for sustainable development. The first step toward such an approach came with the 2008 adoption of the Mediterranean Protocol on Integrated Coastal Zone Management; it aims to conserve biodiversity while developing coastal economies.

The programmes’ institutional structure varies from region to region, from “light” secretariats or Regional Coordinating Units (RCU) to more developed Regional Activity Centres (RAC) that fight land-based pollution, inventory threatened marine habitats, make environmental forecasts, and so forth. These structural differences affect the nature of regional arrangements, and depend on their age, levels of funding and cooperation, and the number of countries involved. Cooperation will prove more regular and sustained if the structure maintains ties between countries, promotes new cooperative steps, and provides technical assistance for meeting obligations.

The Mediterranean Action Plan (MAP) boasts one of the most complete institutional structures, resulting from thirty years of cooperation. Based in Athens, its Regional Coordinating Unit serves as its nerve centre, ensuring coordination between six Regional Activities Centres, each specializing in a critical domain. The Programme for the Assessment and Control of Pollution in the Mediterranean and the Mediterranean
A REGIONAL APPROACH TO MARINE ENVIRONMENTAL PROTECTION: THE “REGIONAL SEAS” EXPERIENCE

Commission on Sustainable Development (MSCD) complete the structure. The MSCD provides a means for signatory countries and non-governmental organizations (NGOs) to discuss issues and make proposals. In 2008, a Compliance Committee was created to oversee compliance with legal obligations under the Convention and Protocols. In addition to benchmarks – ratification of legal instruments, policy declarations – the regional system’s energy shows in the day-to-day work of its permanent bodies: workshops and conferences, topical reports, technical assistance. All combine to durably link stakeholders working to preserve the Mediterranean basin.

CLOSER, FURTHER, FASTER

The Regional Seas Programmes have a simple and ambitious goal: uniting all countries bordering a given ecosystem in concerted action to protect the marine environment. Such arrangements can be summarized by the watchwords: “Closer, further, faster.” A regional approach takes the uniqueness of a marine ecosystem into account, applying appropriate legal and management tools. It goes beyond general principles to fight specific threats to nearby marine areas, whether these are oil spills from ships or land-based wastewater pollution. The programmes steer their efforts toward the most important pollution sources and most threatened ecosystems. For example, the coastal countries around the Baltic Sea have recently committed to fighting eutrophication, an especially important problem in the region (Helcom 2007). In the same vein, the Coordinating Unit for the South-East Asian Region concentrates on coral reef conservation. Even though threats to regional ecosystems appear identical, their intensity and effects differ greatly, inviting a regional response tailored to each natural environment.

Regional arrangements sometimes surpass global protection requirements, further preserving their ecosystems. The dismantling of offshore oil platforms in the OSPAR (Oslo and Paris Conventions) Commission-managed North-East Atlantic Region provides a good example of how a regional agreement can advance legal progress. In 1995, the British government authorized Shell Oil Company to sink the Brent Spar oil-drilling platform off the coast of Scotland. The applicable 1972 International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention)
required only that such an operation obtain a permit (UNCPMP 1972). Pressure from non-governmental organizations drove OSPAR Commission member-states to prohibit sinking disused offshore platforms weighing less than ten thousand tonnes (OSPAR 1998), representing 80% of North Sea installations (Vendé 1997), and to strictly regulate sinking heavier works.

Furthermore, regional arrangements create a joint stake in the same ecosystem, one that member countries come to regard as a “shared region” (ROPME 1978) or “common heritage” (UNEP 1976). At a practical level, this “collective appropriation” leads the regional community to watch over the environment and, sometimes, to compel better environmental policy-making at the national level. The Greek sea turtle story reveals how regional arrangements can influence recalcitrant countries: Xakynthos Island in the Ionian Sea harbours one of the key nesting areas for the Mediterranean sea turtle, Caretta Caretta. During the summer, the island welcomes egg-laying sea turtles on its beaches along with hordes of tourists, posing co-habitation problems for both species. For the turtles, noise pollution from the airport, light pollution from ocean installations, beaches crowded by humans night and day, and marine pollution generally disrupt nesting activities and threaten reproduction (Mabile 2001). Starting in the mid-1980s, environmental groups pleaded for better tourism regulation and improved protections for turtles and their nesting areas. Only in 1999 did Greek authorities create a national park to preserve the most important nesting sites, under pressure from the NGOs and the European Union, via the Natura 2000 network, the Mediterranean Action Plan and its 1995 Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA and Biodiversity Protocol) (UNEP 1995). Even though some problems remain (MEDASSET 2009), the regional programme’s insistence on the issue raised Greek official awareness and compelled action to protect this special area.

More generally, a regional approach makes cooperative action easier than a global one does, where plural stakeholders with diverse interests complicate negotiations. Disputes between developed and developing countries have stalled legal and protective measures for high seas biodiversity (Le Courrier de la Planète, 2008). By contrast, in 1995 the Mediterranean states adopted the SPA and Biodiversity Protocol, promoting the creation of high seas protected areas. A completely new initiative – the Pelagos Sanctuary for Mediterranean Marine Mammals – came out of an international agreement signed in Rome on 25 November 1999. It covers nearly 88,000 square kilometres (55,000 sq. miles) of French, Italian and Monaco territorial waters and adjacent high seas.

**INTRINSIC LIMITATIONS**

**THE REGIONAL APPROACH: A REFLECTION OF FRAGMENTED INTERNATIONAL GOVERNANCE.** Although the Regional Seas Programme aims to preserve the marine environment, some strategic sectors – such as fisheries management – remain outside their

1. See the paper about Natura 2000 by Germain in this volume.
cooperative mandate, evidence of fragmentation in the international governance framework. While marine protection comes under UNEP's purview, implementation of fisheries' technical, regulatory, economic and legal rules falls under the mandate of the Food and Agriculture Organization (FAO) and its regional units. As we mentioned in our introduction, two types of regional structure therefore overlap: Regional Seas and Regional Fisheries Management Organizations (RFMOs). Theoretically, biodiversity conservation in all its forms would make a natural link between them; however, the negotiations and decisions that each sponsors may follow different and even conflicting logics. Within RFMOs, many states strive to maintain (or minimally reduce) capture volumes for their national fishing industry. Experts from Fisheries rather than Environmental Ministries most often lead negotiations; ecological concerns sometimes take a backseat as a result. The RFMO framework may still include marine biodiversity conservation measures – for example, banning certain fishing practices, such as high-seas driftnet fishing and deep-sea bottom trawling, or closing fish nurseries to fishing. Yet these regional organizations and their member countries have failed to halt overfishing, as a single statistic will show: 75% of the world’s fish stocks are currently fully- or over-exploited (FAO 2009). Regional Seas programmes alone lack the authority to curb such overfishing. For example, the Mediterranean Action Plan cannot manage bluefin tuna stocks that depend on an inter-governmental fishery organization, the International Commission for the

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**FIGURE 2. REGIONAL GOVERNANCE: OVERLAPS IN REGIONAL SEAS AND RFMOS**

Source: FAO (2009); UNEP (1982, updated 2010)
Conservation of Atlantic Tunas (ICCAT). This reflects the fragmentation of ocean governance schemes, divided between several institutions in certain sectors. It also illustrates the difficulties countries face in conducting coherent sectoral policies, and the permanent tension between exploitation and conservation within various administrations (see Fig. 2).

In the same way, regional arrangements can only marginally address international shipping and the risks it poses. While coastal states can establish rules to fight hydrocarbon pollution, they cannot suspend or unilaterally stop ships from navigating their waters—even in ecologically fragile, high-risk areas. If countries want further ship traffic controls to improve navigation safety, they must ask the International Maritime Organization (IMO) to intervene. These examples further highlight the fragmented legal and institutional regimes that oversee the marine environment. The “silo effect” that separates jurisdictions and authorities sometimes poses great problems, notably when they must reconcile free high seas navigation (under IMO purview) and environmental protection.

The Strait of Bonifacio perfectly illustrates the complexities involved. The Strait separates the French island of Corsica from the Italian island of Sardinia; it is a particularly rich zone ecologically. It also serves as a vital international shipping route from Barcelona, Spain, and French Mediterranean ports to southern Italian ones (Naples, Palermo, Gioia Tauro, etc.) and to the Suez Canal. Its geographic position naturally exposes the area to heavy maritime traffic and undeniable environmental risks. At the beginning of the 1990s, concerns grew among French and Italian authorities about the risks of increased shipping activity in this area. In 1996, the cargo ship Fenès, carrying a 2,600-tonne grain cargo and sailing under a Panamanian flag, sank near the Lavezzi Islands in the Marine Reserve of the Bouches de Bonifacio. Part of the grain cargo escaped from its damaged hull and buried under-water vegetation, notably the Poseidon sea grass meadows that provide refuge and food for many ocean species.

A specific UNCLOS-defined legal regime\(^2\) covers international shipping straits. Coastal states cannot prohibit ships’ passage, but they may designate shipping lanes and prescribe traffic separation systems. Nothing prevents countries from barring ships flying under their own flag from these risk-prone areas: French and Italian authorities did exactly that from 1993 onward, banning their merchant ships from transporting dangerous cargoes. In 1998 the IMO followed through with new shipping rules, setting up recommended two-way traffic routes along with improved lighting and signalling systems. But however exemplary the French and Italian approach might be, their ban remains limited to ships registered under their flags. Obviously, these are not the only ships traversing the straits: protecting the marine environment requires curbs on all maritime traffic in the area, an option recently supported in a joint declaration by French and Italian environmental ministers (French Government 2010). Only the IMO, and not the Mediterranean Action

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\(^2\) UNCLOS Part III.
Plan, has the authority to create such legal restrictions. While not impossible in theory, reconciling environmental and shipping objectives depends on coordination between these two institutions, whose priorities – protecting the coast versus free international commerce – differ significantly.

THE REGIONAL APPROACH CANNOT REPLACE GLOBAL NEGOTIATIONS. In some cases, a regional approach cannot substitute for international negotiations. As Friedheim (1999) has noted, “the class of problems characteristic of the world’s oceans are collective action problems... Although some ocean problems are amenable to a bilateral or regional solution, many are not.” For example, the legal status of high seas biodiversity reveals a large doctrinal divide\(^3\) that regional arrangements alone cannot permanently resolve. Global negotiations will need to address the most problematic questions, e.g. the use of marine genetic resources or appropriation of living organisms via patents\(^4\). In the same way, climatic geo-engineering of the ocean, e.g. iron fertilization and carbon sequestration, requires the international community to respond worldwide, rather than simply multiplying regional policies and actions. We believe that the nature of these problems and the scale of their resolution are fundamentally global.

CHALLENGES TO OVERCOME

OPENING NEW SPACES. For a long time, Regional Seas initiatives have remained within the confines of territorial waters and Exclusive Economic Zones; recently, cooperation has extended to new spaces. The Protocol Concerning Specially Protected Areas and Biodiversity in the Mediterranean (Barcelona Convention; see UNEP 1976) provides for Marine Protected Areas in waters beyond national jurisdictions; this strengthens protections for ecosystems and threatened species previously excluded from regional initiatives. Similarly, the Mediterranean Action Plan recently filled a “black hole” in regional regulations – its coastal areas. The new law establishes “a common framework for integrated management of coastal areas around the Mediterranean Sea,” requiring conservation of coastal ecosystems, regulation of seaside activities, strategic planning for coastlines, and risk management in coastal policies. We would recommend that other regions study the political and judicial feasibility, the scientific and geographic relevance of such laws, and commit themselves to preserving spaces too long excluded from cooperative protections\(^5\).

REGULATE NEW CHALLENGES. The Regional Seas provide an effective framework to fill international regulatory gaps and address emerging issues – a direction to encourage in coming years. We would argue, for example, that regional cooperation

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3. See e.g. Germani and Salpin in this volume.
4. See e.g. Leary in this volume.
5. We note that the last meeting of the signatory Parties to the Nairobi Convention proposed designing a Specially Protected Area Protocol for the Western Indian Ocean Region (Billé and Rochette 2010), and that similar discussions are underway for the Black Sea.
could advance regulation of offshore oil drilling. The April 2010 explosion of the Deepwater Horizon oil rig, 70 kilometres (43 miles) off the coast of New Orleans, proved a tragic reminder of international dependence on fossil fuels in general and on deep-sea drilling in particular. Since the event, several experts have highlighted gaps in international deep-water drilling regulation. While UNCLOS Part VI recognizes the right to exploit resources on the continental shelf, countries follow their own laws when licensing international drilling companies. This situation raises questions about the adequacy of current governance, and makes increased regional cooperation an option worth studying.

While awaiting action from the international community as a whole, Regional Seas could themselves adopt measures to regulate offshore drilling. Although the Mediterranean countries adopted a relevant Offshore Protocol in 1994 (the Protocol for the Protection of the Mediterranean Sea Against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil; see UNEP 1994), its adoption has not led to further action. Recent events call for appraisal of such efforts in regions affected by oil exploration, such as the West African or Wider Caribbean Regions. In addition, we believe other emerging issues also require stronger regional initiatives – e.g. damage to marine biodiversity from acoustic pollution (Papanicolopulu 2008) or climate change adaptation through integrated coastal management (Rochette et al. 2010) – an issue surfacing only recently.

REINFORCE INSTITUTIONAL COOPERATION. The absence of a global governance regime for the ocean means that legally competent entities must find ways to cooperate. For example, no single international body may create Marine Protected Areas on the high seas; these require joint actions by the IMO, RFMOs and Regional Seas Programmes. Integrated protections covering all threats to vulnerable ecosystems must engage multiple institutional “strata” or levels of action. Efforts to improve coordination are underway; currently, the OSPAR Commission, along with the North-East Atlantic Fisheries Commission, the IMO and the International Seabed Authority, designs management plans for newly-created Marine Protected Areas. However, this appears to be an isolated case. Effective sharing of knowledge and joint management of regional ecosystems will require much more frequent and thorough coordination.

CONSOLIDATE COOPERATION FRAMEWORKS. Some observers believe that Regional Seas often result from “cooperation without implementation” (see e.g. Kutting 1994). Indeed, although the regional initiatives have promoted significant progress, too many conventions and protocols have been – and remain – dormant, due to a lack of energy in regional cooperation. For example, the Western Indian Ocean region has faced difficulties in recent years. Its Convention Secretariat lacks needed human resources, and unlike the MAP, the region has no Regional Activity Centre. The

6. See e.g. Hamilton or Chabason in this volume.
Convention’s day-to-day activities, technical assistance and implementation support remain limited. Similar situations occur in other regional arrangements, e.g. the West African one. Reactivating dormant arrangements requires – at the very least – increased funding to improve performance of Coordinating Units, or to create Regional Activity Centres and ensure robust regional cooperation.

Even the most advanced Programmes could benefit from strengthened compliance; this means, in the first instance, regular status reports to Coordinating Units on how nations implement the relevant convention and its protocols. Currently, compliance monitoring as prescribed in the conventions has little coercive power. International law thus appears imperfect “because of the obvious insufficiency – if not complete absence – of sanction mechanisms” (Weil 1982). The issue is particularly complex. On one hand, it appears difficult to “coerce moral or political actions” or to “cooperate in confidence with the same states” (Chabason 1999). On the other hand, avoiding the pitfalls of “Paper Protocols” – adopted and ratified but insufficiently implemented – means rethinking regional arrangements as well.

CONCLUSION
For the last forty years, the regional approach to marine conservation has constantly expanded; today it involves approximately one hundred countries. It has gradually established its regulatory effect, moving closer, further and faster than global legal frameworks. From an environmental point of view, Regional Seas Programmes have had – and continue to have – many important successes. For example, regional cooperation in the Baltic Sea has significantly restored the ocean's environmental quality. In the Mediterranean and Caribbean Seas, Marine Protected Areas have multiplied. In the West Indian Ocean, countries should soon have common regulations for coastal development. Nevertheless, regional initiatives too often suffer the same difficulties as global mechanisms: poor institutional coordination, insufficient funding for cooperative efforts, disregard of legal instruments. Regional Seas must overcome these challenges in coming years to retain their value and effectiveness within international oceans governance architecture.

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The Large Marine Ecosystem (LME) approach is a strategy based on an integrated management of land, water and living resources (Sherman and Duda 1999). It recognizes that humans are integral to many ecosystems, and promotes conservation and sustainable use of natural resources. It also acknowledges that complex and dynamic ecosystems require adaptive management. In a strong endorsement of this approach, the Global Environment Facility (GEF), together with five United Nations agencies, several participating countries and other donors, has invested US$1.8 billion in sixteen LME projects. These initiatives aim to help coastal nations better manage their resources, and to mitigate climate change effects that may otherwise lead to 200 million “climate refugees” by 2050 (IAASTD 2008).

Begun in 2007, the Agulhas and Somali Current Large Marine Ecosystem (ASCLME) Project is a five-year scheme built on the LME approach: it provides a framework for marine and coastal resource management by nine countries in the Western Indian Ocean (WIO) region (see Fig. 1). It encompasses the Somali Current LME that extends from the Comoros Islands and the northern tip of Madagascar up to the Horn of Africa, and the Agulhas Current LME that stretches from the northern end of the Mozambique Channel to Cape Agulhas. The Project also watches the effects of the South Equatorial Current that drives these two main LME currents: it defines much of the ecosystem structure in terms of biology, physics and chemistry, with related influences on weather and climate, not only along the eastern seaboard of Africa, but also as far away as the North Atlantic. Scientists affiliated with the project have recently confirmed the current flows indicated in Figure 1.

The ASCLME region is very diverse, ranging from unique kelp forests off the coast of Somalia to important tropical ecosystems, including coral reefs, mangrove swamps and seagrass beds, and subtropical and temperate marine habitats in the south. It supports important populations of charismatic species such as seabirds, turtles, dugong and the elusive coelacanth, alongside thousands of smaller species. This diverse ecosystem echoes a similarly complex socio-political landscape: an estimated 50 million people depend on resources from the two LMEs, comprising populations along the coasts of Kenya, Mozambique, Somalia,
South Africa and Tanzania and on the islands of the Comoros, Madagascar, Mauritius and Seychelles.

Local governments favor the project, although the introduction of adaptive and integrated resource management poses very real challenges. The affected countries are mostly poor; a small pool of skilled and experienced environmental managers works to establish sustainable resource-use regimes. The LME approach enables them to adopt a science-driven, ecosystem-based process and provides access to funding, pooling of scarce technical and human resources, and joint action to address environmental problems on a regional scale.

Like the ecosystem approach, the LME concept is holistic, combining data about productivity, fish and fisheries, pollution and ecosystem health with socioeconomic and governance indicators. In the past, management has tended to focus quite narrowly on individual species of interest rather than considering (and managing) them as part of an entire ecosystem with physico-chemical drivers and a human element. The LME concept also recognizes that managing resources at national levels does not adequately reflect the function of the ecosystem as a whole, since species often range outside of a nation’s Exclusive Economic Zone (EEZ) and many factors affecting productivity arise outside national jurisdictions. LMEs are defined along ecological boundaries of bathymetry, hydrography, productivity and trophically-dependent populations rather than human territorial boundaries. For example, the Benguela Current Large Marine Ecosystem encompasses the EEZs of Angola, Namibia and South Africa: the latter two nations have moved towards managing shared hake stocks by undertaking joint research surveys.

A key objective of the ASCLME project is to compile existing and new information about the Agulhas and Somali Currents, i.e. how they interact with and influence the region’s climate, biodiversity and economies. A series of cruises on the Norwegian research vessel *Dr Fridtjof Nansen* and the South African vessel *FRS Algoa* have revealed a wealth of new information about the physical and biological characteristics of the ASCLME region. These findings will form a vital
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comprehensive baseline dataset that the countries can use as a springboard for future research, ecosystem monitoring and adaptive management purposes.

Data captured so far indicate that pollution, overfishing and environmental degradation seriously threaten the region’s marine resources (UNEP/Nairobi Convention Secretariat 2009). Moreover, human-created climate change is affecting key environmental variables, causing elevated water temperatures and changes in storm frequency that affect fish catches and species composition. Figure 2 shows that, of all the countries of the ASCLME region, the small island states of Comoros, Madagascar, Mauritius and Seychelles are particularly vulnerable to climate change impacts. This is especially serious for coastal populations where poverty and reliance on marine resources are high.

However, by working together through the ASCLME Project, WIO countries have already gained a better understanding of the environmental challenges they face; in time they will negotiate and ratify a Strategic Action Programme (SAP) to address issues together on a regional scale. The SAP will formally set forth the institutional mechanisms, policies, laws, reforms, investments and actions required to address management priorities and problems identified through the Project. The long-term monitoring and early warning system that the Project has initiated shows how countries stand to benefit from credible ecosystem information. Figure 1 illustrates the location of oceanographic equipment used to monitor ecosystem variability in real-time: it provides the foundation for an early warning system for climate change impacts.

Many of these instruments are already in place, with further deployment and maintenance planned for 2010 and beyond. Combined with onshore coastal studies and supplemented by remote sensing data from satellites, this network will provide accurate indications of specific climate change impacts at the ecosystem level. When coupled with comprehensive mathematical models, these data can potentially provide accurate, reliable predictions and periodic management advice for the WIO region countries. This will inform their decisions on how best to avert disasters and mitigate climate change’s worst effects.

Scientific information generated by the ASCLME Project will be synthesized into a Transboundary Diagnostic Analysis (TDA), a science-based assessment that identifies and quantifies the causes of environmental problems in a geographic region – a key tool for the creation of the SAP. With the ultimate goal of preparing governments in the ASCLME region to better manage marine and coastal resources and respond to climate change impacts, the ASCLME Project is at the cutting edge of global efforts to improve the link between science and governance.

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The European Union (EU) has adopted a flagship policy, Natura 2000, to implement the Convention on Biological Diversity, a community-wide commitment made at the 1992 Earth Summit in Rio de Janeiro. Natura 2000 currently covers 18% of Europe, protecting 26,000 areas that constitute the largest network of natural sites on any continent (see Fig. 1). Based on the EU’s 1979 Birds Directive (EU 2009a) and 1992 Habitats Directive (EU 1992), Natura 2000 aims to ensure the survival of Europe’s most representative and threatened species and habitats, on both land and sea. This network rests on two principles. The first is scientific: site selection is based on objective criteria for habitat preservation and/or species protection. The second principle is subsidiarity, i.e. devolving decisions to the lowest practical level. This means that the EU sets common goals and objectives, but each member state decides how it will achieve them. It took nearly fifteen years for landowners, politicians, businesspeople, and other parties to accept Natura 2000 as a vital public policy, preserving habitats and species on land. The current challenges lies in motivating people to do the same for seas, given the lack of scientific and technical knowledge about the marine environment, and resistance from fishermen, industrialists and other affected parties.

The system’s true power comes from an assessment that takes place every six years, and the EU’s reminders and censures as member states gradually transfer new sites into the protection of Natura 2000’s network, a process that structures European land and marine spaces. However, the network’s extension to ocean areas has been slow enough that their protection has lagged significantly. Objectives set by the Birds and Habitats Directives have only barely been met since 1997, when the EU issued a strong reminder, and Natura 2000’s key indicators for transferred areas show striking differences between countries (see Fig. 2). The slow participation rate can be explained in part by the fact that Natura 2000’s twin founding principles work well on land, but confront major challenges when applied to marine areas. In this paper, we will review the major issues and differences affecting protection of...
FIGURE 1. EXTENSION OF EUROPE’S NATURA 2000 NETWORK: 2000-2010

Source: Based on data from the European Topic Center on Biological Diversity (2010)
marine versus inland areas, and look toward future solutions.

MARINE PERIMETRES MUST BE DEFINED DESPITE A LACK OF KNOWLEDGE

On land, animal and bird species and their habitats have a long research history; Natura 2000 has drawn on this to select and delineate sites for preservation. But when the policy first took effect, farmers and other interested parties overwhelmingly rejected it: they felt excluded from initial site selections made by entirely by experts. However, successive phases of regional and local species inventories have refined the process, with local actors sharing in decision-making. Habitat definitions remain in the realm of specialists, but their basis in scientific criteria and precise species lists allows for verification and discussion, and promotes their acceptance by rural residents, governments and businesses.

On sea, the gaps in scientific knowledge create a very different situation. Lack of precise data means that habitat and species selection cannot occur with the finesse now achieved inland. Choices depend upon the “best scientific knowledge available” and are validated by the relevant scientific community. On land, areas protected under the Habitats Directive are defined precisely, for example using plant association characteristics or highly explicit forest profiles. However, all the marine areas in question lack proper species inventories and habitat profiles; simply defining them, let alone selecting them, therefore becomes more difficult. For these areas, member states must use imprecise habitat definitions such as “reefs” or “bays and shallow creeks.” Marine experts turn to other criteria, such as the presence within a network of all types of sub-habitats, e.g. reefs covered by algae, coral reefs, beach reefs, underwater *zostera* or *posidonia* (seagrass) beds, etc. They also consider the functional value of certain parts of habitats or specific criteria, such as the presence in bays of aquatic plants that signify fish nurseries.

The European Commission (EC) has acknowledged the gaps in marine habitat knowledge; in practice, it allowed a “marine exception” on this account until 2006, and has launched vast marine research programmes, largely financed by the EU.

Some member states, notably Ireland, Spain and Italy, have yet to transfer a sufficient number of marine sites into the Natura 2000 network. Furthermore, most other states have transferred only coastal areas in territorial waters. There is still not enough scientific data to determine whether the current network will ensure sufficient habitat for threatened species’ survival, and the EC has agreed to conduct complementary research before designating more sites. This contrasts with the programme’s application on land, where any habitat insufficiency is litigated. The lack of knowledge not only impedes objective marine site selection, but threatens acceptance by critical stakeholders and decision-makers – commercial and recreational fishermen, other recreational users, energy and resource extraction industries, local and regional governments. These interested parties had little time to learn about marine site-selection criteria and process before they faced very large transfers to Natura 2000 – up to 70% of German territorial waters and 40% of French (Fig. 3). It is understandable that these stakeholders wonder about the legitimacy of site selections, especially when the choices may affect their livelihoods and remain unsupported by recent maps or species inventories.

Public education and explanations alone will not suffice for extending Natura 2000 to marine areas, since important habitats and species may seem trivial or useless in the eyes of certain stakeholders. This increases the need for further marine inventories, defining the issues and stakes – even if perimeters are subsequently modified – so that decisions reflect precise data and therefore become less open to criticism. European and national research programs and the scientific community all strive to provide state-of-marine-areas studies; this will take years, however,
Once the Natura 2000 network is fully in place, the European Commission will probably pay closer attention to member states’ efforts to conserve habitat and species and to evaluate projects that affect these resources. How should states fulfill their commitments, while giving appropriate weight to economic, social and cultural activities in selected sites?

In France, for example, those with economic interests in a designated site – inland or marine – can participate in a steering committee and help write an objectives document. In response to local elected officials, the French government has prioritized a local process for land sites; this decentralizes responsibilities so that towns or regions can draft the objectives document if they choose. For marine sites, the philosophy remains the same, but with one noteworthy difference: the French government and state retain authority over marine areas and relevant objectives documents, since marine areas are in the public domain and not subject to property rights. The state and the steering committee choose a consulting representative body (e.g. an organization of fishermen or group of other technical experts) to outline suitable objectives and actions for habitat and species preservation, on a case-by-case basis. In some instances, as with the Plateau du Four (see Box 1), the “consultant” is a group of fishermen, while in others it may be the town’s or region’s officials, especially if many economic stakes – fishing, leisure, industrial, tourist – depend on coastal management. In cases of conflict, the French government delegates responsibility for objectives to the French Marine Protected Areas Agency, a neutral public organization.

**CONCLUSION**

Natura 2000’s experience on land has taught us that marine area stakeholders and decision-makers must mobilize and participate in the process. This mobilization takes place in a context of major local, national and European reforms, influenced by increased awareness about environmental issues and changes in uses of marine spaces, e.g. sharing fishing areas with marine energy projects or extractive industries. The rapidly-changing socioeconomic landscape must leave room for biodiversity preservation and restoration. While this imperative has provoked stormy debates between Natura 2000 policy-makers, industry and representatives of user groups, some projects have already explored means to accommodate the latter without sacrificing the aims of the former (see e.g. Box 1).

Gradual changes to fishing, tourism, extractive industries and other activities will visibly affect the marine environment only in the middle- or long-term, but they have already shown fruit in the 2008 European Marine Strategy Directive and the recent Common Fisheries Policy reforms (see e.g. EU 2009). The Marine Strategy Directive forecasts reaching a “good environmental status” for ocean waters in 2020 (EU 2008) and the Common Fisheries reform should ensure an ecosystem-based approach to marine resource management. ■

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The Plateau du Four exemplifies the difficulties encountered in transferring marine areas. The site traces a square around the plateau’s reef, several thousand nautical miles from the coast. Professional and recreational fishermen as well as divers frequent the ecologically rich site. The maritime prefecture delegated the drafting of objectives to the regional fishing committee. The committee acts as the technical representative body, taking the opportunity to lead the process rather than be subject to it. But its true challenge is to remain neutral vis-à-vis other interested parties, recreational fishermen in particular, since the goal is to take care of habitats and species rather than the interests of the fishing industry.

The French Marine Protected Areas Agency has launched an area inventory that aims to deliver real-time data to the technical representatives (the fishing committee). The local government inventories the area’s human activities and organizes local participation, so that fishermen can participate in the inventory alongside amateur divers. This permits a shared diagnosis of the site’s status that, in a later phase, will inform decisions about appropriate measures.
Eighty percent of global marine and coastal pollution and degradation comes from land-based sources and activities (LBSA). Such pollution has severe consequences for biodiversity, livelihoods, economies and human societies. This paper reviews the governance issues of marine and coastal pollution and discusses the appropriate scale of intervention. Using the example of the Western Indian Ocean (WIO) Region, we will argue that the regional scale works best for tackling pollution concerns.

Over time, a range of technical and scientific solutions have been sought to remedy land-based marine and coastal pollution, with varying levels of success partly due to financing problems. However, governance arrangements for these environments, including the adoption of global and regional conventions and national laws, pose continuing challenges. Global, regional and national interventions could all address the issues, but we will argue that the best strategy combines them, with a strong emphasis on the regional approach, using the WIO Region as an example.

LAND-BASED SOURCES OF POLLUTION AND DEGRADATION IN THE WIO REGION

The WIO Region also includes the Eastern and Southern Africa region bordering the western Indian Ocean. The region comprises a wide array of marine and coastal settings, ranging from small island states to large countries with extensive coastlines, and from tropical to subtropical climates. It is recognized for its high ecological and economic value, and is considered a distinct division of the tropical Indo-West Pacific, the world’s largest marine bio-geographic province (UNEP/NCS/WIOMSA 2009). It sustains a high level of biodiversity, including inter alia more than 2,200 species of fish, over 300 species of hard coral, 10 species of mangroves, 12 species of sea grass, over 1,000 species of seaweed, and 3,000 species of mollusks (UNEP/NCS/WIOMSA 2009). Important sources of land-based pollution threaten this exceptional environment. Eight key sectors directly account

1. The continental coastal states are: Kenya, Mozambique, Somalia, Republic of South Africa and the United Republic of Tanzania. The island States are: Mauritius, Comoros, France- Reunion, Seychelles, and Madagascar (see Figure 1).
for most of the LBSA pollution in the region: urbanization, tourism, agriculture, industry, mining, transportation (including harbours), energy production, and aquaculture.

Rapid and often uncontrolled urbanization, including tourism development, has occurred in coastal areas of the Region. Over 60 million people inhabit the coastal areas, mostly settled in the major urban centres such as Mombasa (Kenya), Dar es Salaam (Tanzania), Maputo (Mozambique) and Durban (South Africa), which support populations of 2 to 4 million each. In the Island states, urbanization pressures are significant in Port Louis (Mauritius), Moroni (Comoros) and Victoria (Seychelles) (UNEP/NCS/WIOMSA 2009). These coastal settlements are also centres of economic activity with important international shipping harbours. Such developments usually lead to an increase in municipal wastewater, municipal solid wastes and atmospheric emissions, e.g. those from fossil fuel combustion and traffic. Industries are also responsible for pollution and degradation through inappropriate disposal of similar wastes (Fig. 1).

Agricultural activities also contribute heavily to marine pollution; this means that the problem is not confined to coastal areas, but spreads through river basins flowing to the Indian Ocean. Agricultural pollutants usually enter marine areas through river discharges, although agriculture near coastal areas can directly contaminate adjacent waters through surface or sub-surface run off. In most countries around the region, soil erosion in river basins, and the subsequent coastal impacts of suspended-solid loading and siltation, currently raise greater concern than agrochemical pollution. Impacts from soil erosion are especially notable along the coasts of Kenya and Madagascar (UNEP/NCS/WIOMSA 2009).

Pollutant loads from such sources and activities are typically deposited in the coastal zone, where they affect some of the most productive areas of the marine environment, such as estuaries and near-shore waters. Moreover, contaminants that pose risks to human health and living resources can be transported long distances by water courses, ocean currents and atmospheric processes.

**LEVELS OF INTERVENTION: GLOBAL, REGIONAL, AND NATIONAL**

While there is no global LBSA convention as such, the most significant global legal instrument is the 1982 UN Law of the Sea Convention (UNCLOS), which provides an important framework and basis for regional instruments. UNCLOS has two main environmental objectives: to prevent, reduce and

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**BOX 1. THE GLOBAL PROGRAMME OF ACTION TO FIGHT AGAINST POLLUTION OF OCEANS**

The Global Programme of Action (GPA) is an intergovernmental programme that addresses linkages between freshwater and the coastal environment and has a close working relationship with the UNEP Regional Seas Programme (RSPs). The GPA has a coordination office presently based in the UNEP, Nairobi. The GPA has identified at least nine pollutant or source nodes across most of the UNEP’s RSPs. These include municipal wastewater, heavy metals, litter, nutrients, oil, physical alterations and destruction of habitats (PADH), sediment mobilization, and persistent organic pollutants (POPs).

The GPA helps states achieve tangible results within the limits of their respective policies, priorities and available resources. The GPA is primarily implemented by governments in close partnership with all stakeholders, including local communities, public organizations, non-governmental organizations and the private sector. It also has initiated or assisted in the drafting of LBSA protocols for several RSPs treaties, including the Mediterranean, Southeast Pacific, Black Sea, Ropme Sea Area (Kuwait Convention), the Wider Caribbean, PERGSA (Red Sea and Gulf of Aden), and the WIO. In the WIO, the GPA worked mainly through one of its demonstration projects, namely the 2005-2010 project entitled “Addressing land-based activities in the Western Indian Ocean” (referred to as “WIO-LaB” in short), executed under the Nairobi Convention and funded by the Global Environment Facility (GEF).

Source: UNEP/GPA (2010)
control marine pollution, and to conserve and manage marine living resources (UNCLOS 1982). In 1995, two additional key documents were adopted to complement UNCLOS: the Washington Declaration on the Protection of the Marine Environment from Land-based Activities, and the Global Programme of Action (GPA), a soft-law agreement reflecting the international resolve to address the impacts of LBSA.

The GPA plays a central role in the WIO region mainly because its efforts through the Nairobi Convention help tackle LBSA in the region. With others, the GPA also takes part in regional capacity-building: its WIO LaB Project-supported “Educational Needs Assessment” shed light on education and awareness programs relevant to LBSA (Uku and Francis 2007). However, one could argue that the GPA’s impact in the WIO Region remains limited, mainly because it is spread out across many parts of the world, has broad mandates concerning all aspects of LBSA, and therefore lacks specific and dedicated attention to the WIO Region. Moreover, it necessarily relies heavily on the governments and the frameworks of relevant RSPs for any interventions, lessening its direct impact or visibility.

Generally, a regional approach to the protection, management and development of shared ecosystems is preferable to a global one. The latter tends to lack specificity, making it difficult to achieve desired results. National approaches are likewise limited because many countries, including those in the WIO region, lack adequate regulatory and other means to manage threats to their coastal zones, including those shared with other countries. Both biodiversity and many LBSA impacts cross national boundaries, and are usually dispersed regionally. In fact, in the WIO Region, the main LBSA causes of pollution are as transnational as their effects. Dynamic forces such as winds, currents, rivers and tides exist on scales larger than geopolitical entities, and over-exploitation, habitat destruction or degraded water quality in one part of the WIO region may affect the other areas. Furthermore, problems identified in one country

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**FIGURE 1. URBAN POLLUTION SOURCES IN NAIROBI CONVENTION COUNTRIES**

Sources: UNEP/WIOMSA (2009); CIESIN (2010)
may resemble those in other countries of the region, reinforcing the case for a shared strategy.

Key WIO regional interventions have sought to improve both the knowledge base and the management of marine and coastal ecosystems. The foremost example is the 1985 Action Plan, comprised of the Nairobi Convention and its two protocols (UNEP 1985), which entered into force in 1996. All countries of the WIO Region have signed and ratified or acceded to the instruments, with South Africa becoming the latest Contracting Party in 2003.

The relative robustness of the Nairobi Convention framework in recent years, along with other global environmental and development efforts, have strengthened regional governments’ management of their marine and coastal environments; the WIO region has also benefitted from a range of related donor-supported projects and programmes. The most recent developments underline the importance of the regional approach. On 31 March-1 April 2010, in Nairobi, Kenya, the Contracting Parties adopted the Amended Nairobi Convention (UNEP 2010), a new LBSA Protocol (UNEP/NCS 2010a) and a Strategic Action Plan (SAP) (UNEP/NCS 2010b). These negotiated agreements define key actions – policy, legal and institutional reforms, and the investments needed to address priorities identified in the WIO’s Transboundary Diagnostic Analysis (TDA) (UNEP/NCS/WIOMSA 2009). Such efforts demonstrate that despite the challenges, regional efforts to protect the coastal and marine environments are alive and well in the WIO region.

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The ocean cargo shipping industry owes its formidable economic efficiency to a unregulated and globalized system, provoking the question: how can it assume its environmental responsibilities? Seaports provide levers for action: the source of a growing number of regulations, they help manage fragile coastal areas that are increasingly coveted for various competing purposes.

**MARITIME SHIPPING AT THE CROSSROADS OF ECONOMIC AND ENVIRONMENTAL CHALLENGES**

Everyone buys products “Made in China.” They spring from multinational companies’ research centres, include components manufactured in several East Asian countries, and are often assembled in Shenzhen, China’s special economic zone. Their financing, manufacture and sale involve many intermediaries in Hong Kong and potent marketing campaigns to consumers around the world. These products and their parts – packed in cartons, placed in containers, transported by trucks and ships – travel several thousands of nautical and land kilometres. They go from one factory to the next, from warehouses to retail shelves, in measured flows and quantities to meet production and distribution constraints. The odyssey of China’s goods illustrates a core reality: our global economy has never before created such flows of materials and information. Ocean freight shipping forms the backbone of international trade, accounting for 80% to 90% of all volume: globalization could not occur without it. Increasing concern about sustainability in all forms – environmental, social and financial – requires a closer look at the profile of this industry.

**OCEAN FREIGHT SHIPPING PROVIDES GLOBALIZATION’S BACKBONE**

SPECIALIZATION, RELIABILITY AND ECONOMIES OF SCALE. Shipbuilding innovations account for much of the historic growth of maritime trade. Large iron-hulled sailing ships – clippers – carried commodities across the entire world for the colonial system during the nineteenth century (Pétré-Grenouilleau 1997). After the clippers came the steamers and further technical innovations: Frédéric Sauvage’s shortened-screw
propeller, followed by Augustin-Normand’s three-bladed one, with diesel replacing steam engines in 1914. The steamship reigned until the 1950s, ferrying millions across the ocean – third-class immigrants carried by their hopes to a new world, and a first-class high society of (already) global businesspeople and the rich (Fremont 1998).

Planes ended the ocean liner era. Marine vessels became progressively more specialized during the twentieth century: tanker ships to hold liquids, primarily oil, and dry-bulk cargo ships to carry mineral ores, coal and grain, reaching their peak in the post-war years (1945-1975). Most dry-bulk cargo ships provide tramp services: unlike scheduled cargo liners, tramp ships carry all kinds of cargo loads whenever and wherever users charter them.

Since the mid-1960s, container ships have transported other merchandise (Doovan and Bonney 2006; Levinson 2006), typically packed into 20- or 40-foot long containers (6 to 12 metres) and piled on ships that follow precise itineraries and the rhythms of the industry. Highly standardized in scale and volume, container ships carry an infinite variety of cargo: mass-market products, parts and commodities, fresh food in refrigerated containers, liquids and chemicals in tanks. Containerization allows shippers to make door-to-door deliveries from a factory to an inland destination warehouse by train, truck and/or barge without handling the merchandise: this “intermodal” transportation facilitates and accelerates trade (Frémont 2007).
Specialized port terminals for each kind of vessel also dramatically increase handling productivity. Tankers and bulk cargo ships remain in port for two or three days to unload, while a container ship takes only 10 or 20 hours to transfer thousands or tens of thousands of tonnes of cargo. The ships’ accelerated turn-around time improves returns on capital and labor costs. Further specialization increases ships’ cargo capacity. Oil tankers started the race toward gigantic ships in the post-war period, until the 1973 and 1979 oil shocks abruptly halted this development. These crises signaled the end of an economic growth model based on heavy industry: today’s largest oil tankers and cargo ships do not exceed a 350,000-tonne capacity. Containerization also evolved to gigantic proportions, and the trend toward ultra-large container ships (ULCCs) has continued unchecked. At the end of the 1980s, shipowners surpassed the Panama Canal’s lock-induced length limit of 32 metres (105 feet);¹ the largest ships currently have a capacity of more than 10,000 TEU,²

1. The Panama Canal, 48 miles of water connecting the Atlantic and Pacific Oceans, is undergoing a $5.25 billion expansion that is scheduled to be completed by Aug. 15, 2014, 100 years to the day after it opened. The expansion, though it still will not allow the canal to accommodate the largest of the ships, will enable products made in Asia to be sent directly to the East Coast of the United States instead of being unloaded on the West Coast and then sent east by train or truck (Severson 2010).

2. TEU or “Twenty-feet Equivalent Units” is a measurement that quantifies the number of containers based on one twenty-foot container: one TEU equals one 20-foot container; one 40-foot container equals two TEUs.
i.e. more than 100,000 tonnes of cargo. Increased ship size leads to economies of scale that reduce per-unit shipping costs (Stopford 2009). Even when ground links are included, ocean cargo shipping’s share of overall product cost is marginal – only a few pennies on the dollar.

Coordination along the transport chain ensures reliability – encompassing shipowners, freight forwarders who organize door-to-door shipping, longshoremen, customs officers and all the servicers who handle steering, hauling, docking, handling, provisioning. Computerization also provides essential services. The reliability and low cost of international transportation links make it possible for manufacturers and distributors to plan for global production and distribution systems.

GROWTH AND CRISIS. International seaborne trade increased from only 550 million tonnes in 1950 to more than eight billion tonnes in 2008 (Fig. 1). In 1979, oil made up more than half of all shipments. Since then, containerized shipping has grown immensely, and represents more than 40% of all traffic. More than 500 million TEUs moved through the world’s seaports in 2008, compared to 83 million in 1990, 35 million in 1980, and slightly more than 4 million in 1970: ocean cargo’s average growth rate exceeded 10% per year.

In 2009, the economic crisis resulted in a 10% contraction of world trade (UNCTAD 2009), a decline unprecedented since the Second World War. The maritime shipping industry suffered immediate repercussions: rates fell through the floor; ships were pulled out of circulation; orders for new ship construction faltered and seaport traffic dropped by 10% to 20%. Maritime shipping’s lag between supply and demand amplifies such crises, and as a result, mergers of shipowners are expected to occur. The economic crisis may also strongly affect ship construction, with Chinese shipyards pulling even further ahead of South Korean and Japanese ones. The latter will probably accelerate their ocean liner- and ferry-building activities, to the detriment of European shipyards that have specialized in such vessels.

OCEAN SHIPPING ROUTES AND CHINA’S EMERGENCE
Ocean freight shipping follows specific routes. North America, Europe and East Asia account for more than 80% of oil imports: East Asia relies on the Persian Gulf for 80% of its supply, while North America and Europe draw less than 20% from the region. Most of Venezuela’s oil is exported to North America, and North Africa’s to Europe. West Africa’s oil is split three ways, going to Europe, Asia and North America’s eastern coast. A few key passages dominate oil routing: oil tankers carrying more than 280,000 deadweight tonnage (DWT) pass through the Straits of Ormuz, Malacca and Lombok, and smaller vessels use the Suez Canal and Straits of Gibraltar and Pas-de-Calais (Frémont 2008).

China’s massive entry into shipping routes is the signal maritime event of the last twenty years. It increases East Asia’s role in global trade, and reflects the emergence since the 1970s of the so-called “Asian Tigers” – the rising economies of Hong Kong, South Korea, Singapore and Taiwan, and of the more recent “Tiger Cub Economies”
– Malaysia, Thailand, Philippines, Indonesia and China.\(^3\) East Asia has been at the heart of the worldwide containerized system since the mid-1980s, structured by North-South route that runs from Japan to Singapore (Fig. 2). The two biggest trade routes in terms of total traffic, the trans-Pacific and the trans-Indian Ocean route to Europe, originate in East Asia. The intra-Asian market boasts the highest volumes in the world, reflecting the area’s regional integration dynamic (Cullinane et al. 2007). The North Atlantic artery, dominant from the nineteenth century until the 1970s, completes the round-the-world freight circulation routes, with lesser traffic. North-South trade links are increasing in terms of absolute value of transported goods, but only account for 20% of all cargo traffic.

Of the world’s 50 largest seaports, seven are located in North America, six in Europe and 26 in East Asia, including 11 in China (Fig. 3). The long distance

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3. Asia continues its ascendancy in bulk cargo shipments. It is the world’s third largest importer: 27% of its imports (by value) are oil and mineral ores. In 2008, China imported 6% (by value) of all oil worldwide, compared to less than 3% in 2000 and 0.3% in 1990. It imported 53% (by volume) of worldwide iron ore in 2008 (UNCTAD 2009).
between major seaport cities along North America’s three coasts, i.e. the Atlantic, Pacific and Gulf of Mexico, underlies the relatively low density, in contrast to the Northern Europe seaport chain or that of the Japanese megalopolis. Singapore, Hong Kong, Busan (South Korea) and Kaohsiung (Taiwan) form the backbone of the Asian ocean freight-shipping route. China joins the axis with the Yangtze Delta ports of Shanghai and Ningbo, and the Pearl River Delta ports of Shenzhen and Guangzhou. However, China’s northern seaports around the Bohai Gulf – Dalian, Qinhuangdao, Tianjin and Qingdao – remain apart from this network.

Outside of these large seaport and harbor areas, intermediary and smaller ports are found along the coast of developing countries or places specializing in commodities exports. In addition, transhipment ports branch out along the container-traffic “highway,” attracting freight from peripheral regions. Such ports are located on each side of the Panama Canal, in the Mediterranean along the Suez-Gibraltar route (Algeciras, Gioia Tauro, Piraeus, Damietta), and the Red Sea to Singapore route, i.e. Dubai, Colombo in Sri Lanka and Port Klang in Malaysia.

THE WORLDWIDE FLEET ON TRIAL: TRUE OR FALSE ACCUSATIONS?

THE ACCUSED. The ships involved in the most serious marine pollution accidents are engraved in memory: Torrey-Canon (1967), Amoco Cadiz (1978), Exxon Valdez (1989), Erika (1999), Levoli Sun (2002), Prestige (2002). These names evoke catastrophe: oil slicks, spoiled coastlines, long and complex trials where culpability, the value of damages and who should receive compensation have proven difficult to ascertain. These catastrophes throw sand in the well-oiled wheel of ocean shipping, revealing the sometimes-immoral workings of a system that supplies gasoline every day to an oblivious public in rich countries. These accidents often occur along the
coasts of importing or exporting countries, in hard to navigate passages such as crowded straits or capes. Europe, on its Atlantic-English Channel coast, is especially vulnerable. Human error often leads to accidents, raising doubts about crews’ capabilities; ship quality can also prove suspect, as in the Erika oil tanker spill.

However, the majority of accidental spills involve small quantities of less than seven tonnes, and occur during loading and unloading operations (Fig. 4). The number of spills has decreased since 2000 even while oil tanker traffic has increased, surpassing shipping levels achieved in the 1970s. The most serious marine pollution arises from intentional oil discharge, e.g. when debalasting, washing out tanks, draining fuel solids or water from holds. All ship types are guilty of these practices, following their owners’ deliberate avoidance of portside waste treatment facilities in order to save money. Unlawful, hidden out of sight at night and in international waters, such gangster-like practices highlight the dark side of ocean cargo shipping – where anything goes, as long as it increases profits.

Ballast waters pose another huge problem: water transfers are estimated to reach three to 10 billion tonnes annually (IMO 2002). They help spread invasive species such as the zebra mussel, a small fresh-water mollusk from Europe introduced into the Great Lakes around 1986, following the debalasting of a Black Sea ship. Zebra mussels now inhabit most navigable waters in the eastern United States, and continue to spread westward, affecting the aquatic food chain and waterways’ ecological balance, blocking pipelines and locks, attaching to boat hulls and hindering motors. They also infest swimming areas; combating them cost the United States nearly a billion dollars between 1989 and 2000.

Global warming concerns raise questions about ships’ worldwide share of carbon dioxide emissions, estimated to be between 1% and 4% – comparable to the levels of a single country such as Germany. Even worse, freighters and tankers use heavy, unfiltered fuels, producing high emissions of nitrogen dioxide (NO$_x$) and sulfur dioxide (SO$_x$). These pollutants concentrate in large port cities, around islands, and in countries with long seaport and harbor coastlines near the largest shipping routes. Although ocean freight currently consumes the least fuel per tonne and
per kilometre, its share could increase if ocean traffic keeps growing and other modes of transportation improve their fuel efficiency.

**HOW CAN THE WORLD’S MERCHANT FLEET BE REGULATED?** The seas and ocean are spaces of free circulation. For shipowners, evading the most constraining national laws is both a principle and a necessity, due to the fierce competition such lack of regulation permits. By using open registry, shipowners can freely choose which country’s flag to sail under, exploiting tax advantages and recruiting crews that require lower outlay in employment benefits. Crewmembers from developing nations earn good salaries relative to their countries’ standard of living, at the cost of unremitting work in often-difficult conditions, as they labor below decks to feed the engines of globalization.

The use of flag-of-convenience registries has steadily risen since the 1970s (Fig. 5). At that time, American shipowners used them to remain competitive with other countries’ merchant ships, who then rushed to copy the practice. Two-thirds of the ships sailing under flags of convenience are actually controlled by developed countries, whose share of the world’s fleet remains practically the same as it was in 1970.

Shipping fleets have come under increasingly complex and sophisticated management. Since the end of the 1970s, the big oil companies disposed of their tankers to avoid first-line liability in the event of spills. To minimize their risks, independent shipowners – mostly Greek or Scandinavian – based their companies in tax havens and run their ships through various geographically-scattered legal entities. Shipping services, such crew recruitment and maintenance, are systematically subcontracted to benefit from the lowest price on the market. Oil companies use short-term charters, renting a ship for a single trip, for example, or long-term charters, e.g. for a year. The ocean shipping market is completely deregulated and globalized, and astonishingly efficient.

Regulation of ocean shipping should *a priori* take place at the international level, via the International Maritime Organization (IMO). This entity proposes conventions aiming to ensure shipping security, minimizing environmental risks while preserving the industry’s organizational freedom. Its two foundational conventions include SOLAS (International Convention for the Safety of Life at Sea) and MARPOL (International Convention for the Prevention of Pollution from Ships). These conventions have been updated several times; a convention on ballast water followed in 2004 (International Convention for the Control and Management of Ships’ Ballast Water and Sediments), supplemented by a ship-recycling project (Ship Recycling Convention) and most recently by discussions about crew quality (International

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5. The term flag of convenience describes the business practice of countries permitting the registration of ships owned by non-residents; usually occurs in a country whose tax on the profits of trading ships is low or whose requirements concerning manning or maintenance are not stringent. Sometimes referred to as a flag of necessity (ISL 2008: 419).
Convention on Standards of Training, Certification, and Watchkeeping (STCW) (see IMO 1974-2010). All of the conventions result from compromises among nations affected by the marine cargo industry and its pollution. Once adopted, the laws apply to everyone.

Questions remain as to when and how such laws will take effect. Their ratification requires thirty signatory states representing at least one-third of the world shipping fleet, suggesting very long timelines for implementation. This near-paralysis motivates states to create their own laws. After the Exxon Valdez spill, the United States enacted the Oil Pollution Act in 1990: it delineates the liability of various parties – shipowners, oil companies, classification societies6 – in the event of an accident, and progressively requires double-hulled tankers. Europe is divided between liberal states that have their own flags (United Kingdom, Holland, Greece, Denmark, Malta, Cyprus) and more interventionist states. Repeated oil spills led to the First and Second Maritime Safety Packages (Erika I and Erika II) directives, adopted by the European Union in 2003 (EU 2002). These measures strengthen

6. Classification societies are nongovernmental organizations that establish and apply technical standards in relation to the design, construction and survey of marine related facilities including ships and offshore structures. The vast majority of ships are built and surveyed to the standards laid down by classification societies (IACS 2010).
inspections of vessels and classification societies, gradually eliminate single-hulled tankers, implement a community-wide system for maritime traffic supervision, inspection and information, and create an indemnity fund for damage due to hydrocarbons in European waters. The European Maritime Security Agency, set up in 2003, implements the policy. The Third Maritime Safety Package (Erika III) will complete the directives in 2012: it increases shipowners’ liability and asks each member state to ensure that ships flying their national flag conform to international standards.

In addition to the work done by states, large oil companies actively eliminate “garbage ships” via vetting services that decide which vessels to charter. The companies have high incentives for care since oil spills tarnish their brands for long periods. In developing countries, public opinion and legislative pressures lead to rectifying ships’ quality problems and improving industry practices. The future may well see further technological progress that curbs ships’ air pollution. Creating emissions permits could be a powerful motivating factor, even if their implementation on an international scale faces many obstacles. What is more certain is that increases in energy prices will motivate shipowners to reduce their ships’ energy consumption.

But such measures remain a prerogative of the rich: the more distant the market, the cheaper and more hazardous the shipment, the less secure the areas served – the more likely that transactions will be the province of dubious companies, headed by corsairs and pirates of the twenty-first century. They stand to gain or lose fortunes by using garbage ships, disregarding crew dignity, and running the risk of environmental catastrophe. In 2006, the itinerary of the freighter Probo Koala, filled with toxic residues, ended in the Abidjan dump: its discharges killed seventeen people and poisoned thousands of others. The current economic crisis has led to the abandonment of many ships and crews in the Bosphorus Straits. These incidents illustrate the difficulty of regulating the worldwide fleet; laws collide with the world’s inequalities, which in turn drive shipping’s vitality as the handmaiden of globalization.

THE ECONOMIC, SOCIAL AND ENVIRONMENTAL CHALLENGES OF SEAPORTS

INCLUSION IN SUPPLY CHAINS. A seaport’s traffic depends largely on the wealth of its hinterlands and its location relative to the main ocean shipping routes (Vigarié 1979). In Europe, for example, Antwerp (Belgium) and Rotterdam (Holland) lead as principle seaports, serving its economic heart. They are major gateways to Europe’s trade backbone, the so-called “Blue Banana” – a curved corridor of urbanization that runs from the Thames Basin in London through Germany’s wider Rhine Valley and the Alps, terminating near Milan, Italy. The two seaports’ success derives from their geographic location, and especially their ability to fit into international logistics chains (Wang et al. 2007).

While small compared to the ocean’s immensity, large seaports extend over several thousand hectares with a succession of terminals and industrial buildings, forming vast seaport-industrial zone complexes. Despite the economic crisis, many have projects for new container terminals completed, underway or planned. These
multi-million-Euro projects are usually publicly financed: inland freight distribution requires large-scale infrastructure.

A distinction should be made between bulk cargos and containers. Bulk cargo is mainly processed in the seaport-industrial zones, to avoid adding ground shipment costs to negligible sea freight expenses. It is the reason many heavy industries have moved to the coasts in developed countries during the postwar period. Such bulk traffic is captive for the most part, ensuring regular earnings for the ports. In contrast, containerized traffic is less reliable, whether originating in or going to large metropolitan areas (Hayuth 1981). Because of its flexibility, trucking plays a larger part in carrying goods inland compared to other modes of ground shipping, requiring increasingly dense highway systems. However, freight volumes have increased to the point where shipping by waterways or rail makes logistical sense. Large ports take care to avoid ground congestion, to ensure that the system continues to function. The Rhine River in Germany carries two million containers per year. In North American, the east-west railroad line through Chicago carries loads of containers on double-stack trains that are several kilometres long. The Ports of Rotterdam in Holland and Long Beach near Los Angeles have dedicated freight rail lines: Rotterdam’s Betuwe Line runs directly to the German border, and Long Beach’s rail freight moves along the Alameda Corridor to inland sorting centers. These cases demonstrate the high investments made in infrastructure. Inland sorting, warehousing and distribution centres join with logistics platforms; such sites are sometimes called Inland Ports or intermodal hubs. Thus railways (and waterways) create true port corridors, reducing congestion and enlarging inland port capabilities: they also reduce inland costs (Notteboom et al. 2009).

Infrastructure is useful only when it fits market needs. Shipowners, freight handlers and forwarders must organize and run door-to-door transport chains, developing global maritime networks, terminals and agencies to meet shippers’ overall demands. These networks concentrate around the world’s three main economic points – East Asia, North America and Europe – and deploy in a looser fashion in the rest of the world. On land, railroad companies extend their networks across North America. The European Commission liberalized rail freight to create similarly-sized operators in Europe (Debrie and Gouvernal 2006). Fierce competition in the trucking industry, fueled by industry decentralization and legislative differences between European countries, furnishes another variable to ensure the system’s efficiency. Transport companies link networks to increase freight-carrying modes and destinations. They act individually, doing as much as they can afford alone, but also link with others, expanding via complex relationships of competition and coordination. The container – the intermodal box – has opened the door to vertically integrated transport chains.

As a result, the “landlord port,” serving its varied tenants, becomes the dominant model. Port authorities, who own the port’s major facilities, shipping access channels, basins and quays, concentrate on maintaining security, order and rules, but do not participate in running the shipping networks. Freight handling companies lease port
terminals for long periods of time. International terminal freight services companies, i.e. forwarders, consolidators and Customs brokers, etc., oversee the organization and coordination of land and sea services; their strategies directly determine the future of large seaports. Ports are pawns, an expendable link among others in complex and, in some ways, interchangeable transport chains (Slack 1993). Ports constantly adapt to supply chain needs, reinforcing the “landlord port” model and the trend toward “always providing more” in developing seaport and inland infrastructure. The risk is that a port may become dependent on a dominant shipping line or terminal services company: public policy-makers, acting through port authorities, must ensure competition and referee issues as needed, e.g. when tenant companies’ special interests differ from those of ports.

MEETING SOCIAL AND ENVIRONMENTAL DEMANDS. Seaports are situated in complex coastal territories, where urban and industrial activities mix with shipping activities. They usually adjoin vast, multi-million-dollar urban areas. They must contend with fishing, tourism and rich yet fragile ecologies, on sites near wetlands, estuaries and deltas. Other users of these territories increasingly contest port activities, questioning their economic and social utility (Frémont 2009). The industrial-port zones no longer provide as many jobs as in the past, having suffered industry’s restructurings since the 1970s. Containerization furnishes a source of economic growth if logistics or international trade activities settle in a port, or nearby. Otherwise, the port is simply a technical passageway, perceived as a money-making machine for international shippers, without providing any real benefit to local residents.

Even worse, seaports harbor many pollution sources and dangers with their concentrated petro-chemical installations, usually containing hazardous substances with the potential to contaminate vast areas (see e.g. the 1976 Seveso incident\(^7\)). Such concerns have increased pressure from many non-profit environmental groups and, in turn, from public institutions, leading to stronger protections for coastlines. In Europe, for example, all large ports come under the Natura 2000 network, a European Union policy to protect critical natural habitats and species: the Port of Le Havre on the Seine River, Antwerp on the Escaut River, Rotterdam at the mouth of the Meuse and the Rhine, Bremerhaven on the Weser, Hamburg on the Elbe, and Fos near the Carmargue wetlands.

A contradiction has emerged between development imperatives: greater worldwide seaport growth on the one hand, founded on competition between transport chains, and increasing economic, social and environmental constraints on the other. Every port expansion project faces concerns or, most often, strong opposition that crystallizes around competition for space in the port, at the port-city interface, and inland.

\(^7\) The “Seveso” accident occurred in 1976 in Seveso, Italy, at a chemical plant manufacturing pesticides and herbicides – substances similar to those carried through and stocked at seaports. A dense vapour cloud was released, containing what is commonly known as dioxin, a poisonous carcinogen. More than 600 people had to be evacuated from their homes and as many as 2000 were treated for dioxin poisoning (Wikipedia 2010).
Confronted with a lack of space, port authorities design projects ever further from city centers whenever possible. For example, the new South Korean Port of Busan is situated ten kilometres (six miles) west of the current port, completely outside of the city (Fig. 6); and Rotterdam’s Maasvlakte II project reclaims land from the sea to increase the port’s capacity. However, seaports can no longer avoid dialogue with surrounding stakeholders: new port projects now face public scrutiny and negotiation, breaking with the post-war period when simply pouring concrete sufficed to increase traffic. Port development projects must go through planning reviews and assessments that ensure that they also benefit local residents rather than just a single interest. These reviews last at least ten years in democratic countries, a long process. Even China – where short-term economic interests prevail – cannot continue to open gigantic port terminals in record time without soliciting local acceptance. This is the critical urban planning role for port authorities facing dual objectives: integrating the port into transport chains on the one hand and into its local context on the other, through a balance of economic, social and environmental development. Port authorities, having long considered only traffic volumes, must undergo a cultural revolution if they are to embrace their new mission.

**CONCLUSION**

Maritime shipping is the backbone of globalization. Its efficiency allows it to support growth in international trade. The latter depends on the health of the global economy. Three principal economic poles – North America, Europe, and East Asia – will structure worldwide ocean cargo flows, even as new growth areas emerge in South America, Africa and Southeast Asia. Their emergence will lead to more complex shipping networks in the future, and a stronger role for transhipment ports.

Could other forces break the logic of the maritime shipping system, such as a significant rise in energy costs? Shipping fuel costs are marginal on a merchandise unit cost basis, due to large economies of scale. However, higher fuel costs, combined with an international tax on ships’ emissions and more draconian legislation to reduce in-port air pollution, would motivate shipowners to reduce their vessels’ fuel consumption. That combination could also drive innovation in shipbuilding yards, which should focus on creating the “green” ship of the future. In addition, improving occupational regulations for crewmembers would certainly reduce accidents at sea. But even if the political will existed, what international organization – governmental or not – could regulate an international activity that has long benefitted from extreme organizational freedom? One outcome is certain: at the local level, in the ports of rich countries, ocean shipping will confront increasing regulation, as states strive to manage fragile coastal spaces – increasingly coveted, increasingly used for contradictory and diverse purposes.
WORKS CITED


Fishermen bypassing fishing regulations compromise fish stocks management efforts. Countering this lawlessness requires strengthened cooperation between countries and Regional Fisheries Management Organizations. It would entail systematic and truthful captures documentation, information exchange, and the creation of an Interpol-like agency for marine activities.

ON THE CURBING OF ILLEGAL, UNREPORTED AND UNREGULATED (IUU) FISHING

A number of studies have shown the progressive devastation of marine fisheries around the world (Pauly et al. 1998; FAO 2007); the Food and Agriculture Organization of the United Nations (FAO) believes that only about 25% of commercial stocks, mostly of low-priced species, are currently under-exploited. The FAO maintains that the “issue of illegal, unreported and unregulated fishing in world fisheries is of serious and increasing concern” (FAO 2001). The FAO goes on to state that IUU fishing undermines attempts to manage world capture fishery resources, with negative effects on world food security and environmental protection (FAO 2001). It has been recently estimated that the IUU catch of marine capture fishery resources may be as much as 12 million tonnes per annum, with a value in the order of US$10-$11 billion (Agnew et al. 2009). To put these figures into perspective, we can state, on the basis of FAO, World Bank and academic research estimates, that total reported marine capture fisheries catch per annum is in the order of 85 million tonnes, with a value around US$80-$85 billion (Sumaila et al. 2007; FAO 2009; Kelleher et al. 2009).

In discussing this issue, we shall first clarify definitions of illegal as opposed to unregulated and unreported fishing. We will then briefly examine the economic

1. FAO provide estimates of the volume of total and marine capture fisheries production, but only of the value of total capture fisheries production (marine plus inland).
drivers of IUU fishing, followed by an example of a developing fishing state that ultimately succeeded in reducing IUU fishing to tolerable proportions. Next, we briefly discuss the situation of tuna in the Mediterranean Sea, where IUU fishing remains a large problem. This, in turn, introduces the valuable analytical tools supplied by game theory as they apply to cooperative action among the affected states. We shall conclude by examining the serious threat that IUU fishing poses to the management of shared fishery resources, in particular those found in the high seas.

**IUU FISHING DEFINED**
As a preliminary, we must make a distinction between ocean fishery resources under coastal state jurisdiction and those found in the high seas. Fishery resources under coastal state jurisdiction are essentially those encompassed by the coastal state 200-nautical-mile Exclusive Economic Zone (EEZ). The EEZ regime emerged as a consequence of the 1982 United Nations (UN) Convention on the Law of the Sea (UNCLOS).

With respect to fishery resources in the high seas, we must distinguish between those under the jurisdiction of Regional Fisheries Management Organizations (RFMOs) and those beyond their jurisdiction. RFMOs are international organizations established by the UN Convention on the Law of the Sea (UNCLOS) to manage and conserve fishery resources in their areas of jurisdiction. RFMOs are composed of states parties to the relevant convention and are tasked with the management and conservation of fishery resources within their respective areas.

**Box 1: IUU Fishing Definitions**

- **Illegal fishing** is conducted by national or foreign vessels in waters under the jurisdiction of a state without its permission, or in contravention of its laws and regulations. Illegal fishing includes fishing conducted by vessels flying the flag of states that are members of an RFMO, but which operate in contravention of the conservation and management measures of that organization (RFMO), and by which the states are bound or relevant provisions of the applicable international law. Finally, illegal fishing is in violation of national laws or international obligations, including those undertaken by states cooperating with a relevant regional fisheries management organization.

- **Unregulated fishing** occurs within the high seas under the management jurisdiction of an RFMO, by a flagless vessel, or vessel flying the flag of a state or entity not a party to the RFMO, in a manner inconsistent with the conservation and management measures of the RFMO. If the state in question is a party to the 1995 UN Fish Stocks Agreement, then it is bound not to allow one of its vessels to operate in the high seas area under the management jurisdiction of the RFMO, unless the state is a member of the RFMO, or unless it has agreed to abide by the conservation and management measures of the RFMO (Munro, Van Houtte and Willmann 2004). If the state in question is not a party to the 1995 UN Fish Stocks Agreement, then it is not at all clear that the state is so bound. Also, unregulated fishing is deemed to occur in high seas areas, not under the management jurisdiction of a RFMO, where fishing is undertaken in a manner inconsistent with the relevant state’s obligations under international law (FAO 2001, para. 3.3.2). Such a state is governed by Part VII of the 1982 UN Convention on the Law of the Sea, which pertains to the high seas. While Article 87 puts forth the freedom of the high seas for fishing, this right is circumscribed by Articles 116-120, and in particular by Article 117, which requires states fishing on the high seas to cooperate with other states for the purpose of conserving the high seas fishery resources (UN 1982, Part VII). Part VII of the 1982 UN Convention is deemed part of customary international law (Lodge et al. 2007).

- **Unreported fishing** is defined as fishing that has not been reported, or has been misreported, to the relevant national authority or to the relevant RFMO (FAO 2001, para. 3.2). It is very difficult to distinguish between unreported fishing on the one hand and illegal and unregulated fishing on the other. Any vessel engaged in illegal and/or unregulated fishing can be expected either not to report the activity, or to misreport it.
ON THE CURBING OF ILLEGAL, UNREPORTED AND UNREGULATED (IUU) FISHING

Chapter 9

TACKLING IUU FISHING

A SUCCESS STORY: A DEVELOPING COASTAL STATE CASE STUDY – NAMIBIA

Namibia has an extensive coastline bordering the highly productive northern Benguela Current ecosystem, dominated by pelagic (upper water) fishes, mainly sardine, anchovy and horse mackerel. The demersal (lower water) ecosystem is dominated by the valuable stocks of hake. The food web off the Namibian coast is mainly represented by seals as the top predators; hake, squid, snoek, and chub mackerel as the piscivorous (fish-eating) species; horse mackerel, round herring, saury, sardine and anchovy as the main pelagic prey; and lightfish, lanternfish and goby as the main demersal prey (Shelton 1992; Palomares et al. 2004).

Prior to independence in 1990, there was no Namibian EEZ. In the high seas off Namibia, distant water fishing states (DWFSs) were subject to the high seas provisions of the UNCLOS (UN 1982, Part VII). The weakness of these provisions became manifest as unregulated fishing off Namibia grew rampant. It is estimated that by the mid-1980s, there were sixteen DWFSs engaging in unregulated fishing off Namibia. Sumaila and Vasconcellos (2000) demonstrate the huge and negative impacts, resulting in the over-exploitation by distant water fleets; as a consequence, the newly-independent Namibia inherited an altered ecosystem whose productive potential was severely reduced (Willemse et al. 2004). In addition, the country suffered huge socio-economic losses during this period due to the activities of DWFSs.

Fishing activities in Namibian waters were not effectively regulated, so the reporting of catches was very poor, and this led to the development of a “free-for-all” situation. This implied that all the direct drivers of IUU fishing were skewed in favor of fishers who wanted to undertake IUU fishing activities – what we call “the IUU Fisher’s Paradise.” The potential for gaining additional revenue from IUU fishing without any risk of being caught was high. Penalties were non-existent, and the violators engaged in avoidance activities with zero cost while benefitting highly.

Namibia gained independence in 1990, and promptly established an EEZ. What had hitherto been unregulated fishing now became illegal fishing. Namibia was not slow to exercise its power. During 1990 and 1991, eleven Spanish trawlers and one Congolese trawler were arrested for illegal fishing and successfully prosecuted; most...
of the vessels were forfeited to Namibia by the Namibian courts. The World Wildlife Fund (WWF 1998) has recently reported that with the announcement of the EEZ regime by the independent government, there followed a decrease of more than 90% in the number of unlicensed foreign vessels fishing in the area.

Namibia achieved this feat by rapidly adopting a fisheries management system with a strong monitoring, control and surveillance component (Bergh et al. 2004), with a primary goal of restricting fishing only to those entitled to do it, and ensuring that such fishing was carried out within legal and administrative guidelines (MFMR 1994). By so doing, the government of Namibia quickly moved the IUU fishing environment from an IUU Fisher’s Paradise to an IUU Fisher’s Hell. Suddenly, the chances of being caught engaging in IUU fishing increased, and the penalty violators faced turned positive – immediately affecting fishers’ risk calculations and inclinations to engage in IUU or not. More concretely, the annual running cost of the Fisheries Observer Agency (FOA), the organization responsible for providing observer services to the Ministry of Fisheries and Marine Resources (MFMR), increased to about NAD 20 million (personal communication, Mr. Hafeni Mungungu, CEO of FOA, June 2002).

There are many reasons for Namibia’s post-independence success in tackling its huge IUU fishing problem. Some of these are specific to the country while others can be generalized to other countries. A key positive factor for Namibian fisheries is their major contribution to the country’s national wealth. It is estimated that fisheries contribute over 10% of the country’s national income (Lange 2003). This prominence accords the fishing sector high national priority, which allows the MFMR to fund and implement an effective MCS system. Secondly, because it attained nationhood only recently, Namibia could draw from a number of negative examples from around the world, and learn how not to manage its fisheries. This opportunity appeared to have been used effectively - to the extent that the Namibian Constitution itself contains sustainability requirements. The legal system was also designed to give the courts the power to deal with illegal fishing activities.

The geography of Namibia also played a part. The coast of Namibia is shielded from the population by a strip of harsh desert land, resulting in only two major fishing ports; this meant that coastal fishing communities have never really developed. This had a positive socio-cultural consequence on the management of the resources: there was no coastal community with long-term claims to fishing rights to pacify. Finally, the country undertook drastic and dramatic initial enforcement of fisheries regulation in its EEZ, sending a clear signal to potential violators, with a huge positive effect on keeping IUU fishers out of the country’s EEZ.

**IUU FISHING: THE MEDITERRANEAN BLUEFIN TUNA AND GAME THEORY**

An internationally shared capture fishery resource is one that is exploited by two or more fishing states (or entities). The FAO estimates that up to one-third of marine capture fishery catches are accounted for by such resources (Munro et al. 2004). There are two major categories: transboundary fish stocks that move between or among
two or more EEZs, and straddling fish stocks, found in the waters of the EEZ and the adjacent high seas (Munro et al. 2004). Straddling stocks are exploited by coastal states and by distant water fishing states (DWFSs). The 1995 UN Fish Stocks Agreement calls for straddling stocks (broadly defined) to be managed through RFMOs, whose members include relevant coastal states and DWFSs with a “real” interest in the resource or resources (UN 1995; Munro et al. 2004). In passing, an RFMO may also involve so-called cooperating non-members. A good example of a shared stock is the Mediterranean bluefin tuna (BFT), which is targeted by several countries.

IUU fishing is widely recognized as one of the biggest concerns in BFT management in the Mediterranean Sea and Atlantic Ocean areas. The WWF (2006) found huge gaps between national reports on BFT trade and catch reports to the International Commission for the Conservation of Atlantic Tunas (ICCAT), indicating that a large amount of IUU fishing takes place in the region. The cited study estimated that the total BFT catches in the East Atlantic and the Mediterranean Sea were approximately 45,000 tonnes in both 2004 and 2005, 40% above the total allowable catch limit (TAC) of 32,000 tonnes set by ICCAT. If one includes catches for domestic markets by national fleets in Spain, France, and Italy, the total could be well above 50,000 tonnes per year (WWF 2006).

ICCAT is also fully aware of this IUU problem. In 2006, based on the number of vessels operating in the Mediterranean Sea and their catch rates, ICCAT estimated the total catches in the early 2000s to approach 43,000 tonnes. In 2008, a new evaluation by ICCAT suggested a 2007 catch of 47,800 tonnes for the Mediterranean Sea and 13,200 tonnes for the East Atlantic. These numbers were estimated from ICCAT’s list of BFT vessels, catch rates and stock information. This new evaluation indicates a total catch of 61,000 tonnes from both areas, which is higher than WWF’s estimate. ICCAT’s IUU estimates are also supported by the mismatch between reported data and various measures of market sales data. (ICCAT 2008). The shared nature of BFT in the Mediterranean Sea means that tackling IUU fishing is many times more difficult than in the Namibian case. The reasons for this level of difficulty will be developed below.

**WHY IS TACKLING IUU FISHING MORE DIFFICULT FOR SHARED STOCKS?** The chief characteristic of any internationally shared fish stock is the strategic interaction that almost invariably occurs among the states (entities) exploiting it. Consider the simplest case, that of two coastal states sharing a transboundary stock. The catching activities of one coastal state will have an impact upon the opportunities available to the other – hence the strategic interaction. Economists have known for over thirty years that the economics of these resources’ management cannot be analyzed without recourse to the theory of strategic interaction, better known as game theory (Bailey et al. 2010). The theory rests on two broad sub-sections: the theory of non-cooperative or competitive games, and cooperative games.
Competitive game theory helps answer the question of what consequences will ensue if the states (entities) sharing the fishery resource do not cooperate in managing it. The assumption is that each state would manage its share of the resource to the best of its ability.

Perhaps the most famous of all competitive games is one known as the Prisoner’s Dilemma, named for a story that the author of the game uses as an illustration. The point is that in a competitive game, “players” will be driven to adopt courses of action, “strategies,” that each knows is sub-optimal if not damaging. The Prisoner’s Dilemma applies with great force to the shared fish stock case. Non-cooperation carries the risk that the sharing states will adopt policies that sharply reduce the economic returns from the fishery, and that may damage the resource (Bailey et al. 2010; Munro et al. 2004).

Straddling stocks provide a case in point. The opaque nature of Part VII of the 1982 UN Convention, pertaining to the high seas segments of straddling stocks, led to uncertainty about the rights and duties of coastal states as opposed to those of DWFSs; this made it extremely difficult to establish stable cooperative management regimes for these resources. The competitive fishery games that emerged based on these resources had sufficiently destructive consequences that the UN felt compelled to convene the 1993-1995 UN Fish Stocks Conference, which would give rise to the RFMO regime. In any event, the analysis, validated by experience, has taught us that with few exceptions, cooperation does indeed matter.

Cooperative game theory, which is really a theory of bargaining, devotes a great deal of attention to the conditions that must be met for such games to remain stable over time. If the cooperative regime is unstable, the “players” will revert to competitive behavior with all the consequences that implies.

One fundamental condition – a common-sense one – is that every “player” must be convinced, now and in the future, that it receives an economic return from the cooperatively managed fishery at least equal to what could be expected under competitive circumstances. As the FAO has noted, this condition, which should be obvious, is often ignored in practice (FAO 2002). Of course, allocations of the economic returns among the “players” must be seen as equitable. This condition, however, is not sufficient.

Consider the following situation: a strictly transboundary fishery resource is shared by three neighboring coastal states, A, B and C. Suppose that there is agreement on the allocation formula. Compliance monitoring among the three, however, is lax. Suppose that A is convinced that B and C have cheated extensively, and that

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2. The prisoner’s dilemma demonstrates why two people might not cooperate even if it is in both their best interests to do so.

3. In the theory of cooperative games, this is referred to as the Individual Rationality Constraint.
such cheating is uncontrollable. Applying the IPOA-IUU criteria, it can be said that
B and C vessels are engaged in illegal fishing (unregulated fishing is irrelevant in
this case). State A could well conclude that it is actually worse off than it would
be under competitive conditions. Its willingness to cooperate will vanish. The only
sensible strategy for A is to join in the “illegal” fishing. The cooperative regime will
disintegrate.

Now consider now a straddling fish stock that is under cooperative management
through a RFMO, such as the Northwest Atlantic Fisheries Organization (NAFO), or
the Western Central Pacific Fisheries Commission (WCPFC). As with the manage-
ment of transboundary stocks, the cooperative regime will founder if the members
of the RFMO do not comply – if they engage in illegal fishing, to use the FAO defini-
tion. The cooperative management of straddling fish stocks does, however, differ
from that of transboundary stocks in at least two fundamental ways.

First, cooperative game theory concludes that the difficulty of achieving a stable
regime rises almost exponentially with the number of “players.” Monitoring behav-
iour among the “players” to prevent illegal fishing, for example, obviously becomes
more difficult as the number of regime members increases. Typically, the number of
“players” in the cooperative management of strictly transboundary stocks is small.
Cooperative management regimes for such stocks commonly involve no more than
two states. The typical RFMO, by contrast – having both coastal states and DWFSs
as “players” – has a large number of members.

Secondly, there is the problem of unregulated fishing, compounded by the so-called
“new member” issue. Unregulated fishing, fishing by non-members, is what game
theory refers to as “free riding.” Free riding can have exactly the same impact upon
the stability of the cooperative management regime as non-compliance among its
members. The same fundamental condition must be met once more, if cooperation
is to prove stable over the long run: every “player” must believe that it will be at
least as well-off as it would be without cooperating.

Let Z be a DWFS that is contemplating becoming a “charter” member of a RFMO
governing a straddling stock that had been overexploited in the past. It is the objec-
tive of the RFMO to invest in the resource by restricting current catches in the hope
of future economic benefits. Suppose that unregulated fishing is uncontrollable. Z
will anticipate making present sacrifices through reduced catches, but will see “free
riders” taking much of the future economic benefits of the resource investment. The
chances are high that Z will calculate that it would actually be better off by joining
the “free riders.” Cooperation will unravel, and with it the opportunity for effective
management of the resource.

A recent analysis has applied state-of-the-art cooperative game theory to manage-
ment of straddling stocks. The analysis concludes first that stable cooperation among
the “players” is more likely if they are heterogeneous, differing, for example, in terms
of fishing costs. It then demonstrates that even with heterogeneous “players,” no
cooperative straddling fishery game with more than seven potential players will be
stable as long as unregulated fishing remains uncontrolled. This will hold regardless
of how flexible and imaginative the formula for allocating the fishery's economic benefits may be (Pintassilgo et al. 2010). It can be added in passing that a RFMO with only seven potential “players” is a small one indeed.

In 2006, an independent panel was established, based at the Royal Institute of International Affairs (Chatham House), London, to create recommendations for improving RFMO improved governance. In its report, popularly known as the Chatham House Report, the panel states that “a core conclusion is that the success of international cooperation [in fisheries] depends largely on the ability to deter free riding” (Lodge et al. 2007). In its recommended best practices for RFMOs, the panel further states that “in each RFMO, members should recognize the grave threat to the stability of the cooperative regime posed by IUU fishing and work vigorously towards the suppression and elimination of such fishing” (Lodge et al. 2007).

The so-called “new member” issue arises because the terms of the 1995 UN Fish Stocks Agreement require RFMOs to consider accepting new members (UN 1995, Articles 8, 10, 11). In all but exceptional cases, the prospective new member will be a DWFS that was not a “charter” member of the RFMO, but which now professes a “real” interest in the fishery and a desire to join. There is, of course, the implicit threat that, if the DWFS is blocked, it will be tempted to engage in unregulated fishing, in disregard of the 1995 UN Fish Stocks Agreement.

To date, the new member issue has not been dealt with satisfactorily. In a study on RFMO practices, Willock and Lack (2006) point out that there have been two broad approaches to this issue. The first is to welcome new members and grant them total allowable catch (TAC) allocations at the expense of “charter” members, which the latter justifiably view as a form of implicit free riding (Kaitala and Munro 1997). Some RFMOs adopting this practice attempt to mask the pain to “charter” members by simply adding the new member catch allocations to the existing TAC, leading in most cases to excessively large TACs – a repudiation of good resource management. The other approach is to welcome new members, but advise them that the relevant fisheries are already fully subscribed and that they can look forward to catch allocations only from “new” fisheries. Willock and Lack aptly describe this approach as “effectively closing the door on new members” (Willock and Lack 2006).

It takes little imagination to see that the “closing the door” approach acts to stimulate unregulated fishing. If we return to the expected net benefits from IUU equation, the $m&f$ variable, moral standing and fairness, now becomes positive – fairness violated.

One approach, presently only at the discussion stage, is that of effectively granting “charter” members collective property rights to the relevant fishery resources, and then establishing tradable catch quota rights for each of them. The rights would be tradable not only among the “charter” members, but also between these members and prospective new ones. New members would then be allowed to enter the fishery by leasing or buying quota. The FAO considered this approach in 2002, as did the Chatham House independent panel in 2007 (FAO 2002; Lodge et al. 2007). According to the Organization for Economic Cooperation and Development (OECD), at least
one RFMO is currently discussing this strategy, the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) (OECD 2009).

**DRIVERS OF IUU FISHING**

To provide a framework for our examination of IUU fishing, we adopt the straightforward model developed by Sumaila, Alder and Keith in their 2006 analysis (Sumaila et al. 2006). The model ultimately rests upon economic models developed by Gary Becker on the economics of crime (Becker 1968). The basic idea is that a vessel contemplating engaging in IUU fishing will undertake a subjective cost-benefit analysis. The expected net return from engaging in IUU fishing will depend upon:

- (i) the net monetary returns from harvesting and selling the fish,
- (ii) the expected penalty, which will in turn depend both upon the actual penalty if apprehended, and the probability of being apprehended,
- (iii) the cost of engaging in avoidance activities.

Sumaila et al. then add in negative non-monetary drivers, namely:

- (iv) the vessel owner’s moral sense, and
- (v) his or her social standing in society.

Thus, if the vessel owner has a strong moral conscience, s/he will be deterred from engaging in what are seen as morally reprehensible activities (Sumaila et al. 2006). We shall modify (iv) to address both moral standing and sense of fairness.
It will be seen that, in the case of high seas fishing and RFMO regimes, the concept of fairness can act as a positive driver of IUU fishing.\textsuperscript{4}

The prospective IUU fisher must weigh the revenues from harvesting against its costs, along with the expected costs of penalties incurred, plus his/her pangs of conscience and the impact upon his/her standing in the community. A foreign-flagged vessel engaged in illegal fishing in a coastal state EEZ could expect severe penalties if apprehended. Furthermore, the vessel's home state could be seriously embarrassed, and could be expected to ensure that the vessel owner shared the consequences. This can be contrasted with a vessel engaged in unregulated fishing in high seas under RFMO jurisdiction, where the vessel flies the flag of a non-member of the RFMO, one which has as yet to ratify the 1995 UN Fish Stocks Agreement.

**DEALING WITH IUU FISHING**

Figure 1 understates the extent and the magnitude of the problem, because it focuses on illegal fishing. Data on unregulated fishing is very limited. That understatement is even more significant given that unregulated fishing presents the most difficult component of IUU fishing overall and, we would suggest, poses the greatest risk to the management of world capture fishery resources. We must now ask what if anything can be done about this threat to the emerging RFMO regime.

In broad terms, we have now seen that two requirements are necessary. The case of Namibia demonstrates what can be done when unregulated fishing becomes illegal fishing. With regard to RFMOs, the first requirement is that the provisions of the 1995 UN Fish Stocks Agreement achieve the status of customary international law. This would, in effect, create the necessary legal transformation in the high seas under RFMO governance. The second general requirement is that the “new member” issue be satisfactorily resolved. Otherwise, it will continue to act as powerful stimulus to unregulated fishing.

More specifically, other actions can be taken and are already underway. The equation of expected net benefits from IUU fishing equation is designed to provide negative incentives, by increasing the penalties, the probability of detection, and (where possible) the shame factor. The Chatham House Report on RFMO governance discusses in detail the measures that can be, and have been, applied (Lodge et al. 2007). Vessels that a RFMO finds engaged in unregulated fishing can be blacklisted. Member states can then be called upon to deny port facilities to all such vessels, and to impose trade restrictions on all fish products arising from blacklisted vessels' catches.

\textsuperscript{4} This model in equation form can be expressed as: $ENB = [ph(A, e, x) - T(e, A)] - \theta(e, A, R)F \pm m&f(e)$ -ts(e), where $ENB$ denotes expected net benefits, $h$ denotes the catch from IUU fishing, $p$ the price of caught fish, $e$ IUU fishing inputs, $x$ the biomass of the fish stock being exploited, $A$ the level of avoidance activity being undertaken, $R$ the set of regulations in place, $F$ the penalty faced, if apprehended, $\theta$ the probability of being apprehended, with $0 \leq \theta \leq 1$; $m&f$ the vessel owner's moral standing and sense of fairness, and $s$ the vessel owner's social standing. The expression $T(e, A)$ denotes the total cost of IUU fishing, excluding penalties incurred (Sumaila et al. 2006).
One obvious lesson is that actions by RFMOs, taken in isolation from one another, are wholly inadequate. If intra-RFMO cooperation is essential for effective capture fishery resource management, inter-RFMO cooperation is also very important. One of the strongest recommendations from the Chatham House Report is that such cooperation be strengthened (Lodge et al. 2007).

Let two examples suffice. The RFMOs of the North Atlantic (NAFO) and the Northeast Atlantic Fisheries Commission (NEAFC) have a joint blacklisting agreement. If a vessel is blacklisted by NAFO, it is automatically blacklisted by NEAFC and vice-versa (Lodge et al. 2007). The second example concerns trade restrictions on IUU-caught fish. Vessel owners will, of course, attempt to circumvent the trade restrictions by “laundering” the catches. This laundering may be countered by catch documentation schemes. These schemes can only hope to succeed through cooperation extending far beyond any one RFMO.

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) provides a second example of what may be done in the face of very difficult circumstances. Their focus is on the potentially very valuable Patagonian toothfish fishery. The species is a slow-growing groundfish, fished primarily in the Antarctic, with most of the final sales of the catch in the Northern hemisphere, particularly the Japanese, American and European markets (Österblom and Sumaila 2010).

By the late 1990s, CCAMLR realized that IUU Patagonian toothfish activity had reached a crisis. It was estimated that as much as 75% of the total catch was accounted for by IUU fishing. A significant portion of this 75% was misreported as “legal” catch taken in FAO Areas 51 and 57 (Indian Ocean), outside of the CCAMLR convention area (Mooney-Seuss et al. 2007). Clearly, unless drastic measures were taken, cooperative management of the resource would collapse. It was argued within CCAMLR that the crisis threatened the very credibility of the RFMO (Österblom and Sumaila 2010).

Action was taken by the CCAMLR member states, but also, importantly, by non-state “players”. Non-governmental organizations (NGOs) from Australia and Norway, for example, undertook intelligence operations and discovered that several vessels engaging in IUU fishing were flying the flags of CCAMLR members. Evidence of this illegal fishing was brought forward, to the embarrassment of those CCAMLR members. The NGOs were joined by fishing companies involved in legal fishing of the resource. The latter arrived in time (2003) to establish the Coalition of Legal

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5. Return to the Sumaila et al. equation cited above. The joint blacklisting increases both the probability of apprehension and the penalties, both monetary and non-monetary.

6. For a thorough and detailed discussion of the actions taken through CCAMLR see: Österblom and Sumaila (2010).
Toothfish Operators (COLTO), which gained observer status within CCAMLR. The NGOs and industry were to play an important role in implementing the catch documentation scheme introduced by CCAMLR in 2000 (Österblom and Sumaila 2010).

The war against IUU fishing required that CCAMLR seek cooperation beyond the “charter” members of CCAMLR. Thus Mauritius and Namibia, for example, were identified as important transhipment centres for IUU-caught toothfish. Both states were invited to become observers at CCAMLR, and eventually to become full members. In addition, the cooperation of the city-states of Hong Kong and Singapore had to be obtained to curb the laundering of IUU-caught toothfish (Österblom and Sumaila 2010).

The crackdown also involved state cooperation, in what amounted to military operations in pursuit of vessels engaged in IUU fishing. Such operations were undertaken by Australia, New Zealand, South Africa, Norway and France, on the one hand, and the South African Development Community states (South Africa, Namibia, Mozambique and Kenya), on the other (Österblom and Sumaila 2010).

To what extent has the war against IUU fishing of Patagonian toothfish succeeded? It is not possible to give precise estimates. That said, in their world survey of the extent and the trends in IUU fishing, Agnew et al. (2009) maintain that illicit catches of Patagonian toothfish reached their peak in the late 1990s and have declined significantly since (Agnew et al. 2009). The war has not yet been won, but it is moving in the right direction.

This experience brings us back to inter-RFMO cooperation. Such cooperation is vital not just for joint blacklisting catch documentation schemes, but also for the sharing of knowledge. The lessons learned by CCAMLR, for example, should be made universally available among RFMOs.

CONCLUSION

IUU fishing continues as a major danger to the sustainable management of the world’s capture fishery resources. Its greatest threat is to the stability of the emerging RFMO regime. While IUU fishing can never be eliminated entirely, it can be reduced to tolerable proportions. The first requirement is that the 1995 UN Fish Stocks Agreement achieve the status of customary international law. Unregulated fishing must, in effect, come to be seen as illegal fishing. The second requirement is that cooperation become the norm not just within individual RFMOs, but between and among RFMOs on a global level. What is required is a marine equivalent of Interpol.

Despite the continued and serious threat, there is no cause for unrelied pessimism. The experiences of Namibia and of CCAMLR demonstrate what can be done to curb IUU fishing, even under the most difficult of circumstances.

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Fish-landing quays provide strategic locations between land and sea where donors may assist coastal economic and social development. The French development agency, AFD (Agence Française de Développement), financed quay construction in Senegal between 1997 and 2007, helping spur economic growth and improved fishing practices (see Box 1).

With those of Morocco, Mauritania and Guinea Bissau, Senegal's territorial waters cover one of the richest fishing areas in the world: 2.5 million tonnes of fish are taken each year in West Africa, equivalent to half of all catches in the European Union. The fishing sector in Senegal provides employment for 15% of active workers and contributes strongly to food security: on average, fish provide 70% of animal proteins in the Senegalese diet.

AFD's quay-building project aimed to help the artisanal fishing sector: local small-scale fishermen accounted for 88% of the 415,000 tonnes of fish caught in the previous decade. The project's objective was to reduce post-catch losses, which could reach 10% when landings occurred directly on sandy beaches. Essential fish-landing and selling facilities were built: quays and a covered wholesale auction hall, parking areas for wholesalers, places to store equipment, as well as signage and lighting to help fishermen to find their way around and to improve night security. The facilities included processing areas for fish and shellfish going to the local market – a major innovation.

Beyond meeting its initial objective of reducing post-capture losses, the project also improved the workings of the fishing market. For example, the open auction hall changed the balance of power between fishermen and buyers: previously the fishermen were scattered along the coastline, leaving them in a weaker position. Improvements extended beyond the fish-landing quays to include the wholesalers, merchants and brokers (often women) who serve as the first link in an economic value chain joining fishermen to the hinterland. Other links – fish processing, exports and retail sales – also gained strength, adding value to the final product. The fish-landing quays attracted formal and informal investments, further contributing to the growth of other activities, such as gas stations, ice manufacturers, stores and restaurants.

More broadly, this new infrastructure made new
market rules possible, leading to important changes in fisheries regulation and management. The landing quays made it easier to follow and supervise fishing activity; they provided a central place where regulators could record volumes and prices, enforce rules (such as minimum allowable catch size), and curb illegal fishing by checking boat and fishing licenses. Donors did not anticipate these supplementary effects in the project’s initial phases, but have since found in them strong reasons to accelerate similar projects elsewhere.¹

Beyond its original aims, the project also helped structure the fishing sector. In the 1990s, professional associations were disorganized: hundreds of more or less formal fishermen’s groups existed, primarily to gather investments for fishing equipment. The project encouraged various groups to merge in an “Industrial and Economic Interest Group” that helped reorganize the sector. With training and other assistance, such groups matured and now represent a major force in negotiations with local and national officials. Their members have the tools needed to manage the landing quays’ accounting and finances: they collect user fees, including very high ones for the largest quays (more than €100,000 annually in Mbour per 40,000 tonnes landed), pay for maintenance, operations and employment benefits for quayside workers, and manage revenue and sales taxes.

Most strikingly, improving fishing quays in Senegal had major social and economic impacts, quickly restructuring the profession, the economic value chain, and local development. Somewhat to donors’ surprise, the project’s supplementary effects address fishing-sector challenges such as managing fish stocks and fighting illegal fishing. Fishing quays thus become an obligatory point of passage on the road to developing coastal countries.

¹. AFD and Millennium Challenge Corporation financed a more advanced project in Morocco: fish landings and sales take place in central fish markets and auction halls, bringing buyers and sellers together for best-price transactions.
Between 1997 and 2007, AFD supported two projects to improve fish landing facilities on two sites along the coast of Senegal. The first, from 1997 to 2001, concentrated on Senegal’s Great Coast, where €3.4 million in financing built facilities at sites in Saint Louis (Guet Ndar, Gokhou Mbathe, Fass Boy, Kayar, Yoff, Hann-plage). A second project, supporting artisanal fishermen along the southern coast and known as “Papasud,” took place in 2002-2007. This €3.1 million project concentrated on Mbour and the processing area of M’Balling, Joal, Djifer/Palmarin, Diamnaddio and Dionewar; the Sine Saloum (Foundiougne, Ndangane Sambou) and the Casamance (Ziguinchor, Cap Skirring, Diembering, Kafoutine, Elinkine). Other sites in Senegal benefited from European Union and Senegalese financing (italics indicate those financed by AFD).
Fisheries agreements made between the European Union (EU) and non-EU countries have often proven controversial. This essay will review the genesis and significance of the major agreements for all contracting parties. Since their revision in 2004, such agreements have failed to meet their stated aim, improved management of fish stocks – indeed, they have contributed to fisheries’ degradation. We will survey the agreements’ effects in contracting countries, and show the gulf between stated intentions and actual results.

The EU’s Fisheries Partnership Agreements (FPA) owe their official origins to a November 1976 European Council resolution, one that created a 200-mile fishing zone along the Northern Atlantic and North Sea coastlines for the European Economic Community (EEC). The agreements assumed two forms: one granted reciprocal access rights to shared or adjoining fisheries and fish stocks, and the other defined conditions for non EEC-member countries to purchase access rights. The FPAs replaced bilateral agreements negotiated between EEC member-states and non-member states; the number of agreements increases each time a new country joins the EEC1 (Fig. 1).

1. This chapter presents some of the results of studies on fishing agreements and commerce from the “Responsible Fishery” research programme, financed by the UK Department for International Development (DIFID). To examine certain elements in more detail, the authors also received financial support from the European International Cooperation Research programme ECOST, i.e. Ecosystems, Societies, Consilience, Precautionary Principle programme to develop assessments of social costs in best fishing practices and public policies. see www. ecost-project.org. The chapter does not reflect DFID’s nor the European Commission’s views or future fisheries policy.
A CRITICAL REVIEW OF FISHERIES AGREEMENTS

CHAPTER 9

FIGURE 1. EU-AFRICA FISHERIES PARTNERSHIP AGREEMENTS
The EU’s budget for fisheries agreements increased from the equivalent of €5 million in 1981 to €163 million in 1990, reaching €300 million in 1997 before decreasing to approximately €200 million in 2009. Shipowners’ fishing-license fees average 20% of receipts generated by the agreements for non-member countries, a percentage that should increase in the future. Approximately 700 EU ships have temporary or permanent licenses for the Exclusive Economic Zones (EEZ) of signator partner countries. Another 1,700 vessels operate through reciprocal “Northern” agreements for the North Sea and Northern Atlantic, out of 80,000 total EU ships (EU 2008). EU tuna boats boast annual captures of approximately 400,000 tonnes, nearly 80% (320,000 tonnes) of which is caught in waters adjoining partner-countries’ EEZs. Schools of tuna migrate great distances, crossing several national EEZs; the eleven tuna agreements currently in force allow EU vessels to cross borders in pursuit of stocks moving through the Indian and Pacific Oceans (Fig. 1). The “mixed agreements” do the opposite: they seek to base EU trawlers – a large segment of its long-distance fleet – along the continental shelf inside partner countries’ EEZs, providing access to a wide range of fish stocks.

FISHERIES PARTNERSHIP AGREEMENTS WITH AFRICAN, CARIBBEAN AND PACIFIC COUNTRIES

The Fisheries Partnership Agreement protocols originally covered short two- to three-year terms, and are now negotiated for four or five years. The renewal process runs more or less smoothly, depending on the type of agreement. Africa-EU tuna negotiations generally conclude quickly, since all tuna (and most other highly marketable species) go into export markets or are captured by foreign fleets. Mixed-species agreements provoke the stormiest discussions, since the technologically advanced EU vessels compete with partner-country fleets, particularly small-scale artisanal fishing boats (Fig. 2) for increasingly scarce fish stocks. For example, in West Africa, scarcity has led to lower captures of the main fish species, and shellfish and cephalopods catches fell 25% to 40% between 1997 and 2006 (Fig. 3).

The increased scarcity of desirable fish has two major consequences for the African market: their price rises steeply, beyond the average person’s means, while variety and choice decline, increasing peoples’ vulnerability to any factor that lessens captures (see e.g. ECOST 2010). All African fish stocks show full exploitation or chronic over-fishing, a measure of competition in West African waters. The European ships’ technological advantages over African national ships only aggravate the problem.

THE NEW AGREEMENTS: TOO LITTLE REFORM

The first Fisheries Partnership Agreements had ambiguous objectives, as do the newest ones. They aim to promote sustainable fishing in contracting countries, and must be implemented on a long-term and exclusive basis. They attempt to link negotiations to coastal states’ fisheries resource management, and to monitoring and control of all ship activity in national EEZs. Two important characteristics of the EU Common Fisheries Policy (CFP) emerge from this approach: the illusion of a rational management of marine resources-, and the illusion of the effectiveness of state control. The successive fisheries closings in the North Sea show the weakness of the model, and CFP’s failures are also evident in overfishing data: 88% of stocks in EU waters are fished beyond their capacity to reproduce, and many fisheries rest on young fish caught before they reach sexual maturity (European Commission 2010).

Other problems affect the agreements. The EU Directorate-General for Marine Affairs serves as an adviser to partner-countries – a conflict of interest, since he appears as both judge and plaintiff in disputed cases. European advisers write fishing policies and national management plans but also negotiate Fisheries Partnership Agreements, another potential conflict of interest. In cases that call for reduced fishing intensity, the uniform application of rules makes no distinction between flag states; the partner-country must reduce catches just as much as the EU states. The surplus issue disappears, despite its intended centrality in states’ decision-making. Furthermore, the new partnership agreements make it possible to circumvent UNCLOS rules (see e.g. Article 62.2, UNCLOS 1982).

The new fisheries agreements also allow countries to evade World Trade Organization (WTO) subsidies guidelines. Subsidies carry a “red” classification
if they contribute to an increase in overfishing, or “green” if they help restructure the European fishing industry. However, once ships arrive in a partner-country’s or sub-region’s waters, they increase fishing intensity and participate de facto in overfishing. Thus Fisheries Partnership Agreements prove to be green subsidies from the European point of view, but remain red ones for the ship’s host country. Nonetheless, the APC group of countries (Africa, Caribbean and the Pacific) opposed including fisheries agreements in the list of WTO subsidies. The financial compensation gained from fisheries represents a large stake for these countries, a critical source of revenue for some governments. Resource conservation is not yet integrated in policy-makers’ financial decisions, whether in the West African sub-region or in Europe (Fig. 4).

**TOWARD COHERENT PUBLIC POLICIES**

The EU fisheries agreement negotiations perfectly illustrate a short-term view of the situation: financial contributions from fisheries licenses and sales contribute greatly to public revenue in partner-countries, even as they harm national fleets and marine ecosystems. In addition, EU agreements with the APC countries have certainly improved trade from West Africa to Europe, but do nothing to generate national added value or sustainable profits. Furthermore, ten-year studies by the European Development Fund show that fisheries investments chiefly concentrate on improving debarkation and fish-storage facilities, along with the technical and sanitary aspects of fish packaging, with little to nothing invested in on-site fish processing. Such short-term thinking prolongs and aggravates long-term problems of sustainable economic and environmental development in Europe’s partner-countries.

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**FIGURE 2. PRACTICES IN COMPETITION WITH LOCAL ARTISANAL FISHING**

Source: Failler and Gascuel (2008)

**FIGURE 3. EUROPEAN FISHING IN AFRICA**

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>FLEETS</th>
<th>VOLUME CHANGE (1997-2006)</th>
<th>EXPLOITATION LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demersal species (groupers, sole, snapper, etc.)</td>
<td>CV - GUI, MA - MO, SEN - ES</td>
<td>- 26%</td>
<td>Moderately to intensely overfished</td>
</tr>
<tr>
<td>Cephalopods (squid, octopus, calamar)</td>
<td>MA - MO, SEN - ES</td>
<td>- 31%</td>
<td>Moderately to intensely overfished</td>
</tr>
<tr>
<td>Pelagic species (sardines, ardinella, ethmalosa, etc.)</td>
<td>CV - MO, NL - SEN - UKR</td>
<td>- 20%</td>
<td>Fully exploited to moderately overfished</td>
</tr>
<tr>
<td>Shellfish (lobster, crab, shrimp)</td>
<td>FR - IT, MO - SEN - ES</td>
<td>- 38%</td>
<td>Fully exploited</td>
</tr>
</tbody>
</table>

*Moritania, Senegal, Cape Verde, Gambia, Guinea-Bissau, Guinea, Sierra Leone
**FIGURE 4. IMPACTS ARE CASH POSITIVE BUT NEGATIVE FOR LOCAL FISH STOCKS**

<table>
<thead>
<tr>
<th>Affected sectors</th>
<th>Maurita</th>
<th>Cape Verde</th>
<th>Senegal</th>
<th>Gambia</th>
<th>Guinea Bissau</th>
<th>Guinea</th>
</tr>
</thead>
<tbody>
<tr>
<td>National value added</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Public receipts</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>−</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Exports</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
<td>+</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>Jobs</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>National markets' supply</td>
<td>○ ○</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Coastal demersal fish stocks</td>
<td>−</td>
<td>○</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Deepwater demersal fish stocks</td>
<td>−</td>
<td>○</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
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<tr>
<td>Small pelagic fish stocks</td>
<td>−</td>
<td>−</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Large pelagic fish stocks</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Ecosystems</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>

Source: Failler (2010)

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A moratorium on catching whales allowed certain stocks to recover. For some, that proved the need to stop whaling entirely, while others saw the benefit of simply limiting and regulating it. Despite the paralysis of formal negotiations, in this interview representatives of each view discuss the issue and agree on the need to open the debate to other causes of whale deaths, such as water and sound pollution.

**PERSPECTIVES ON THE WHALING CONTROVERSY**

In 2007, the International Whaling Commission (IWC) launched a three-year Future of the IWC process to create consensus out of long-standing, strongly-held opposing views on whale conservation and whaling among its member states. In June 2010, at the 62nd meeting of the IWC held in Agadir, Morocco, that process concluded in a stalemate, with no consensus and no agreement for further discussions. Joji Morishita, Japan’s IWC chief negotiator, and Rémi Parmentier, Senior Policy Advisor to the Pew Environment Group, were both actively engaged in the process. Their perspectives address the key issues and differences involved – views that suggest that the process, despite the lack of accord, could still offer a solid foundation for renewed, good-faith efforts by member states and other stakeholders to find a way out of the stalemate.

**In 1986, a commercial whaling moratorium entered into force within the framework of the IWC. How did the international community reach such a position?**

**Joji Morishita:** The 1946 International Convention for the Regulation of Whaling (ICRW 1946) defined principles for the conservation and sustainable use of whale stocks that are still valid more than 60 years later. The first meaningful whale management system established under the ICRW was the so-called Blue Whale Unit (BWU). The BWU was defined as the amount of whale oil that one blue whale can supply, and the total harvest of whales was managed by this unit. The purpose of this system was not the conservation and management of whale stocks but the regulation of oil production. Therefore, the major flaws of the BWU were the lack of biological considerations based on relative abundance of whale species and the lack of management by individual species. The result was depletion of whales in order of size, starting with blue whales.
Rémi Parmentier: The blue and humpback whales were protected in 1967 and 1965 respectively once they had been severely depleted, but despite scientists’ warnings, the Blue Whale Unit was not abandoned until the early 1970s. Nevertheless, concerns grew that the same pattern of over-exploitation would repeat itself with other species – especially with sperm whales, which had been over-exploited by distant fleets since the seventeenth century for lighting oil and later for other industrial purposes, and with fin whales and other rorquals (sei and Bryde’s whales).

Pressure on the IWC increased after the UN Conference on the Human Environment held in Stockholm in 1972 called for a ten-year moratorium on commercial whaling. Because amendments to IWC rules require a three-quarters majority to pass, it took ten years to adopt the indefinite moratorium in 1982, effective in the 1985-86 season. However, interim measures were also adopted that began a more positive shift in the IWC. The IWC’s Scientific Committee developed a new approach to whaling management to replace the disastrous Blue Whale Unit. The “New Management Procedure” (NMP), implemented in the mid-1970s, was applied on a stock-by-stock basis, and quickly brought many species and populations under protection, notably the Antarctic fin and sei whales.

Joji Morishita: Theoretically, the NMP was a valid approach to prevent over-harvesting of whales. However, this system required detailed scientific data on biological parameters, such as natural mortality rates, which were not available or not accurate enough at that time. Because of the lack of scientific information and the consequent uncertainty, the NMP gave the fledgling anti-whaling movement a rationale to call for the prohibition of whaling. Before the NMP could produce the originally intended outcomes, the IWC imposed its moratorium on commercial whaling in 1982.

Rémi Parmentier: Yes, the moratorium was an early manifestation of the precautionary principle. I remember we used to say at the time that whales, not the whalers, should get the benefit of the doubt.

Today there are three main whaling nations – Japan, Norway, and Iceland. Has this always been the case?

Rémi Parmentier: I suppose Joji will tell us that at the beginning of the IWC, Japan was less active in whaling than the UK, the Netherlands and Norway, especially in the great Antarctic whaling grounds. However, this does not deny former whaling countries the right to be advocates of whale protection; one can even say that it increases their legitimacy. By the 1960s Japan, along with the USSR, was the dominant whaling country, with a large domestic whale meat market at the time. Japan also actively supported whaling outside the aegis of the IWC, with land stations in Brazil, Peru, Chile, Spain, South Africa and South Korea, where whale catchers dropped prey for flensing and packaging before exporting the products to Japan. Japan also became the main export market for Icelandic and, to a lesser extent,
Norwegian whale meat. At that time no one had coined the acronym “IUU” for Illegal, Unregulated and Unreported fishing, but that’s exactly what was happening with whales, with the active involvement of Japanese interests. The most flagrant case was a Japanese and South African consortium set up to operate at least two combined whale catchers and factory ships; these roamed the West African coast for several years, using the ports of Las Palmas and Porto to transfer the frozen meat onto Japanese freighters. The fact that IUU whaling could operate in Europe as recently as the end of the 1970s gives an idea of the lack of enforcement and control at the time, in whaling as well as global fisheries at large.

The Japanese connection to IUU whaling was documented and publicly exposed in 1979, leading Japan to adopt domestic legislation to ban the import of whale products from non-IWC countries; the US also passed a law allowing fisheries sanctions on countries whaling outside of the IWC. This precipitated the entry of several “outlaw” whaling countries into the IWC (Spain, Brazil, Peru, South Korea, Chile). This helped Japan to maintain its blocking minority in the short term, but it also brought these countries’ whaling operations under control. 1979 also saw a ban on the use of factory-ships for whaling all species except the smaller minke whale, a result of several combined factors: a number of pro-whale delegates adopted an “activist” approach; Japan was on the defensive because of the IUU whaling scandal, and had not had time to coordinate properly with the five whaling countries who had just joined the commission. Finally, in the same year a whale sanctuary was declared in the Indian Ocean, proposed by the then very young Republic of the Seychelles. Complementing these events, the Convention on International Trade in Endangered Species (CITES) held meetings in the late 1970s and early 1980s and eventually placed all great whales on its Appendix 1, prohibiting trade in their products (CITES 1973).

**Why does Japan oppose the moratorium?**

**Joji Morishita:** Japan opposes the moratorium because it was adopted without a unanimous recommendation from the Scientific Committee. It should be clearly understood, however, that Japan does not seek unregulated and unlimited whaling. As with any other marine living resource, we support science-based conservation and management. In other words, Japan supports regulated and controlled utilization of abundant whale species, such as minke whales, while supporting the protection of endangered whales that have declined drastically due to past excessive hunts, such as blue whales or right whales. The issue is not a simplistic choice between protecting all whales with the moratorium or hunting all whales.

Contrary to common perception, the commercial whaling moratorium does NOT permanently prohibit whaling NOR characterize whaling as evil or wrong. The moratorium temporarily suspends whaling during a comprehensive scientific assessment of whale populations. This decision was made because scientific data for whaling management remained uncertain in the 1980s, and there was a clear timeline for the assessment. The language of the legal decision that established the
moratorium is clear: it provides “catch limits for the killing for commercial purposes of whales from all stocks for the 1986 coastal and the 1985/86 pelagic seasons and thereafter shall be zero. This provision will be kept under review, based upon the best scientific advice, and by 1990 at the latest the Commission will undertake a comprehensive assessment of the effects of this decision on whale stocks and consider modification of this provision and the establishment of other catch limits” (IWC 1982)

Japan’s research whaling was initiated to contribute to this comprehensive assessment. The legal basis for research whaling is also unequivocal. Article VIII of the ICRW grants its signatories the right to assign themselves whaling quotas for research purposes (IWC 1946). The quota is calculated, within a sustainable level, to obtain statistically and scientifically meaningful data. The research objectives, statistical bases for the sample size, and all results are provided to the IWC and made publicly available (GOJ 2004, 2005, 2010; ICR 2010) – again, contrary to common perception. Hundreds of scientific papers have been submitted to the IWC Scientific Committee and some published in peer-reviewed scientific journals (GOJ 2010). After research and data collection, the meat is released to the Japanese commercial market, in accordance with the requirement of Paragraph 2 of Article VIII which reads: “Any

![Hunted Whale Types and Populations](image)

Source: Based on Antarctic and Southern Ocean Coalition poster (2010)
whales taken under these special permits (scientific whaling) shall so far as practicable be processed...” (IWC 1946). The utilization of carcasses is not only legal, but obligatory under the Convention.

Rémi Parmentier: Everything Joji has just said is interesting because it speaks volumes to the influence of policy on scientific advice, and to the role of value judgements often conditioned by political instructions or, at the very least, political considerations. Disagreements within the Scientific Committee should therefore not come as a surprise. In keeping with the precautionary principle, disagreements should not lead to paralysis; it is the role of policy-makers to assess and resolve them.

**Since this moratorium entered into force, what is the status of whales stocks?**

Joji Morishita: Many whale species and stocks are now abundant, increasing and recovering from past over-harvesting. The IWC’s website (IWC 2010a) provides population figures agreed by its Scientific Committee. In 1990, the Scientific Committee agreed that there were 760,000 minke whales in the Antarctic. This estimate is currently under re-evaluation. Even if the new estimate shows lower abundance, a large number of minke whales may still be utilized sustainably. The Scientific Committee also agrees that humpback whales are increasing at about 10% per year. These estimates clearly show that under strict quotas whaling would be sustainable.

Past commercial whaling did result in over-harvesting. However, much has been learned in the interim about the science of whales and of resource management. The IWC’s Scientific Committee has developed a risk-averse method of calculating catch quotas, adopted by the IWC as a whole in 1994. This “revised management procedure” (RMP), together with a monitoring and inspection scheme, would ensure the sustainability of commercial whaling and the enforcement of regulations. Furthermore, past commercial whaling reflected a worldwide oil market that regarded whales as industrial material, resulting in over-harvesting to support industrial developments. However, whaling is now a food catch with limited markets and demand. Over-harvesting will not be repeated. As to the stock status of different species of whales, the IWC website (IWC 2010b) provides a good summary.

The introduction of the moratorium reduced the catch of whales substantially. Around 40,000 whales were caught annually in the Antarctic Ocean in the 1950s and 1960s; recent takes by Japan’s scientific whaling run to several hundred per year. A recent New York Times article (Broder 2010) also indicates the drastic decline of catches from over 6,000 in 1985 to less than 2,000 in 2009 (Fig. 2). Additionally, the recent catch is mainly of abundant minke whales. To equate the current catch level to the past over-harvest is inappropriate.
Rémi Parmentier: Unfortunately, this is our current situation: a moratorium still exists on the books, but three countries (Japan, Iceland and Norway) are seeking to kill approximately 4,000 whales annually for commercial purposes, with self-allocated catch quotas (even though in recent years they have caught less than half that number, for a variety of reasons); meanwhile, there is no international control whatsoever. This is what I call the whaling paradox.

The minke whales caught by Japan in the Southern Ocean are thought to be relatively abundant, although there are currently no agreed population estimates, despite years of effort by the Scientific Committee. But other species still being caught, such as fin, sei and sperm whales, are classified as endangered on the IUCN Red List, and were determined by the IWC to be depleted and protected (IWC 2010b). Even the so-called Sea of Japan stock of minke whales, caught by Japanese and Korean vessels (Pew 2009; IWC 2010b), is very depleted. The good news, though, as mentioned by Joji, is that certain whale species and populations show signs of recovery, especially some populations of humpback whales. The slow humpback whale recovery provides two lessons: international whale conservation efforts and campaigns have been far from futile or useless, but such efforts must be maintained over very long periods of time (the IWC began protecting humpback whales as early as 1965).

Finally, the IWC Scientific Committee failed to evaluate the moratorium’s effects on whale stocks by 1990, as required by the original 1982 decision; they attributed this failure to insufficient available data and noted that the moratorium had not been in force long enough for visible results. Evidence now exists that some populations of whales have begun to recover, but these species (e.g. gray, humpback) had IWC protection long before the moratorium was agreed – an indication of the many decades needed for these slow-reproducing animals to rebuild their numbers.

In another way, the moratorium’s main effect was to freeze the appetite for whales, in both the figurative and literal sense. Figuratively, the majority of countries engaged in commercial whaling at the time of the moratorium have abandoned the practice (USSR/Russia, Spain, Peru, Chile, Brazil and South Korea1). Literally, the consumption of whale meat in Japan has decreased considerably, despite the efforts of Japan’s Fisheries Agency (JFA). JFA says that whale meat consumption would increase if the moratorium were lifted, but this may be wishful thinking: public opinion polls show that younger Japanese have really no taste for whale meat, and meanwhile the country possesses large stockpiles of frozen meat. There is even a school of thought – led by Atsushi Ishii, a professor at Tohoku University studying his country’s attitude to whaling and whale conservation – suggesting that if the moratorium were lifted

1. However, in Korea there has been an increase in minke whale entanglements in nets, which is believed not to be a coincidence (see e.g. Pew 2009).
now, and subsidies for “scientific” whaling removed as a result, the private sector would give up whaling altogether.

**It seems that the situation that led states to adopt the moratorium has changed to such an extent that they may now consider abolishing it.**

**Rémi Parmentier:** For many years, the IWC has been atypical among multilateral fora and fisheries organizations. In the run-up to the moratorium, voting was the rule, not the exception. And in the period that followed the 1982 adoption, we saw two realignments: on the one hand, the number of whaling countries diminished considerably (with former whaling countries from Latin America and Spain becoming ardent defenders of the moratorium); on the other hand, tension increased as Japan solidified and increased its scientific whaling strategy after 1987, including incentivizing the IWC membership of developing countries in a bid to gain a voting majority. This trend culminated in 2006 at the IWC annual meeting held in St. Kitts and Nevis, where the pro-whaling nations obtained a simple majority for the first time since 1981. While the St. Kitts Declaration, promoted by Japan and adopted by simple majority, spoke of “normalizing the IWC,” Japan announced a scaling-up of its scientific whaling programme, including a proposed kill of fifty humpback whales per year in the Southern Ocean (IWC 2006). St. Kitts was also a wake-up call for the pro-moratorium countries, who then also scaled up their effort to regain the majority (countries from the European Union and Latin America were encouraged to join the IWC). At the following annual meeting (Anchorage, Alaska, 2007), the IWC went back into stalemate, and the newly-appointed US Chair encouraged everyone to adopt a more constructive attitude; the so-called Future of the IWC process was launched, and Japan announced that it was postponing (not cancelling) its plan to catch fifty humpback whales.

**Joji Morishita:** To be exact, the Future of the IWC process specifically agreed to keep the moratorium in place during the ten-year interim agreement period. The public perception was that the agreement would lift the moratorium and resulted in unregulated and unlimited whaling. The proposed agreement would have achieved the exact opposite: it would bring all existing whaling activities under the control of the IWC with strict quotas and enforcement measures to prevent over-harvesting. It is perfectly logical to

**FIGURE 2. WHALE CAPTURES SINCE 1985**

![Graph showing whale captures since 1985](image)

*Source: IWC (2010b)*
keep the moratorium while allowing controlled whaling, because the moratorium was NOT intended as a permanent ban, as I already explained.

Some anti-whaling countries were willing to accept controlled and limited whaling, at least during the ten-year period, because they recognized that some whaling will continue in the future; it is better to control these activities by accepting their existence, rather than sticking to a total ban that simply results in no control over them. The Future of the IWC proposal is not a perfect solution for the anti-whaling countries, but better than the current situation. The USA and New Zealand supported this approach while keeping their basic opposition to commercial whaling.

From Japan’s perspective, the proposed compromise solution was unsatisfactory in many respects. However, given Japan’s position of supporting science-based conservation and management of all marine living resources, we saw merit in the proposal. We believe that the acceptance of regulated whaling by the IWC while keeping the moratorium will help restore the IWC as a functional resource management organization, in accordance with the ICRW. In light of this, Japan offered a number of substantial compromises toward a consensus: reduced quotas, international observers on board whaling vessels, satellite-based real-time vessel monitoring systems (VMS), registers and market monitoring with DNA “fingerprints,” conservation programs, among other measures – provided that compromises come from all member countries and that the final outcome is fair and balanced.

The anti-whaling countries had two options at the Agadir meeting:
(a) Keeping the status quo. (No agreement. The moratorium remains but no control exists over current whaling).
(b) Accepting the Chair’s proposal. (The moratorium remains, contrary to public and press perception. All existing whaling comes under IWC control. This carries the risk of mistaken public outcry: “The moratorium is lifted!” and “Whaling will be resumed!”).

Apparently, public pressure deterred many anti-whaling countries from accepting option (b). Unless this situation changes, it would be very difficult, if not impossible, to expect the IWC to accept a similar proposal.

Rémi Parmentier: To be exact, there was a third option that both “anti-whaling” and “pro-whaling” countries should have exercised: negotiating improvements to the Chair’s proposal.

The last IWC meeting saw a divide within the environmental community between “pragmatists” and “fundamentalists.” After three years of negotiations that the media dubbed a “whale peace process,” disagreement persisted on the best strategy: whether to maintain the moratorium intact on paper, knowing full well that the three whaling countries would continue to exploit loopholes (scientific whaling and objections): to continue whaling with less control than ever; or to seek agreement on exemptions to the moratorium, in order to bring all whaling activities back under the control of the IWC. The “fundamentalists” prevailed in Agadir, but it is unclear what will happen in the future.

There are at least three reasons to seek a solution to the present stalemate: (1) the
current situation is not good for whale conservation; (2) it provides the foundation for the Japanese government’s subsidies to “scientific whaling;” and (3) it does not provide a good example of international stewardship. If we cannot resolve this stalemate with relatively few interests in play, what does it say about our political will to resolve wider challenges of marine biodiversity conservation, let alone climate change?

I think that in Agadir, Japan came to practice judo – they genuinely came to seek a compromise. But some other countries thought they were in a boxing ring, not on a tatami mat. In a negotiation, no one envisages a compromise at any cost; hence it is very difficult to find the right balance. Japan offered too little, too late to win over a sufficient number of pro-moratorium countries. Some NGOs, together with the Government of Australia, have celebrated the collapse of the negotiations in Agadir. Others, such as New Zealand, the USA, and the coalition formed by Pew, Greenpeace and WWF, which argued for three main elements: the abandonment of scientific whaling, an end to Antarctic whaling, and prohibition of the international trade in whale products, were much more cautious (Pew et al. 2010). When the dust settles, we will see whether the negotiation can be rescued. This will largely depend on Japan.

The moratorium vs quota allocation issue was at the heart of the Agadir meeting.

Rémi Parmentier: First, strictly speaking, the moratorium is a quota (or catch limit) allocation set at zero: it is spelled out in Paragraph 10(e) of the IWC Schedule, which says: “[…] catch limits for the killing for commercial purposes of whales from all stocks for the 1986 coastal and the 1985/86 pelagic seasons and thereafter shall be zero.” (IWC 1982). The dilemma is whether it is better for whale conservation to maintain the integrity of the moratorium, knowing that uncontrolled whaling by Japan, Iceland and Norway will continue, or whether whale populations and the international whale conservation regime would in fact benefit if agreed exemptions brought those three countries back under IWC control. In Agadir, some delegates (Australia and the Latin American countries) believed that this would reward “bad behaviour;” others (the US, New Zealand, Sweden, inter alia) believed, albeit reluctantly, that under the right terms and conditions, it could become a pragmatic solution.

Joji Morishita: To characterise this issue as “moratorium vs quota allocation” is incorrect, even though I recognize that this is the public perception. Paragraph 10(e) Rémi just mentioned also states that “catch limits for the killing for commercial purposes of whales will be kept under review, based upon the best scientific advice.” (IWC 1982). A straightforward reading of this provision is that when a comprehensive scientific assessment of a whale stock identifies a sustainable catch quota, a non-zero catch limit can be established for that stock. Therefore, quota allocation is still consistent with this “moratorium” language. 10(e) did not introduce...
a permanent ban on commercial whaling, nor did it establish a value judgement to
the effect that commercial whaling is wrong or illegal. The negotiation history of the
10(e) language supports this argument. But the public perception that the morato-
rium means a permanent ban and even a criminalization of commercial whaling was
the main cause the breakdown of the Future of the IWC process. Ms. Yasue Funayama,
Japan’s Vice-Minister of Agriculture, Forestry, and Fisheries, recognized in her Agadir
statement at the IWC’s 62nd meeting that “some hold the opinion that ‘No whaling
is acceptable, except for indigenous subsistence whaling,’ and ‘Not a single whale
should be taken’[…] However, adherence to such positions and repeated requests
for the elimination of whaling mean the breakdown of our visionary efforts in the
Future of the IWC process” (IWC 2010c).

Rémi Parmentier: At the end of the meeting in Agadir, it was reported that
Japan had agreed privately to reduce their catches in the Southern Ocean to 150
minke whales. Had the conservation community
been able to present a more united front, I believe
this could have been further reduced, maybe to
zero. Instead, with no agreement in Agadir, Japan,
Iceland and Norway went home with the assurance
that they can continue to catch as many whales as
they want, where they want, with no international oversight.

I don’t think anyone won anything in Agadir. There was nothing to celebrate. What is
clear is what has been lost: the IWC whale conservation regime comes out of
Agadir weakened and hurt, and the opportunity to put commercial whaling back
under international control has slipped away again. This does not look good. The
IWC was created to regulate and control all whaling activities. As long as it cannot do
that, it is at an impasse. For the time being, the only activities the IWC still controls
are indigenous subsistence whaling activities, in the Arctic and on the Island of
St. Vincent and the Grenadines. This clearly reflects a governance failure. In the
meantime, the IWC’s Scientific Committee and the recently formed Conservation
Committee continue to do useful work. But the results are hampered and limited
as long as the whaling controversy remains unresolved.

Beyond the moratorium vs quota allocation discussion, many experts emphasize that
the IWC has not sufficiently considered other causes of whale death (collision, noise
pollution, chemical pollution, fishnets…).

Rémi Parmentier: That’s what we term IWC’s need to move into the twenty-first
century. Commercial whaling is a thing of the past, even if three countries still
believe that it has a future. Contemporary threats to whales include the effects of
climate change, especially in the polar regions; entanglement in fishing nets – with
overfishing pressuring their food supplies, cetaceans are attracted to nets to look for
food, and can get trapped in them; collision with ships – with the increase of inter-
national trade in the globalized economy, ever-faster, larger and more numerous
merchant vessels collide with whales; noise pollution from seismic testing for oil and
gas offshore exploration, military activities, and shipping; increased concentrations of organic substances and heavy metals in cetaceans’ bodies, with related threats to their health and reproductive capacity. It has been suggested many times that the word “whaling” should be dropped from the name of the IWC, and replaced by the word “whale.” That would help broaden its horizon, I suppose.

Joji Morishita: We also have an interest in addressing other whale mortality causes because healthy and abundant whale stocks are the prerequisite for whaling. In the present controversy, however, we often hear the argument that with so many other threats to whales, such as pollution and climate change, no whaling at all should be permitted. This attitude is unfortunate, because sustainable-use and anti-whaling countries could work together on these issues, with the common goal of healthy whale stocks for the future. If the Agadir meeting had produced agreement, other whale mortality causes could have received more appropriate treatment through cooperation from all IWC members. The controversial nature of whaling issue prevents the IWC from addressing many such important issues. This is another reason for promoting the Future of the IWC process.

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In 1919, the Hungarian engineer Karl Ereky coined the term “biotechnology” as a shorthand term to “refer to methods and techniques that allow the production of substances from raw materials with the aid of living organisms” (Sasson 2005). In essence, biotechnology “is based on the search for and discovery of exploitable biology” (Bull et al. 2000). Novel biotechnology is, at its core, intimately connected to biodiversity. The search for and industrial-scale exploitation of natural products and of novel properties of naturally-occurring substances – often referred to by the shorthand term bioprospecting – emerged only in the past fifty years, along with an emphasis on the novel potential of marine biodiversity in particular.

The systematic investigation of the biotechnology potential of the marine environment began in the early 1950s. The first marine bioactive compounds, spongouridine and spongothymidine, were isolated from the Caribbean sponge Cryptotheca crypta and by the mid-1960s were proven to have anti-cancer and anti-viral activity (Leary et al. 2009). Both these drugs were developed from compounds derived from sponges found off the coast of Florida (Foresight Marine Panel 2005). By the 1970s – paralleling rapid developments in biochemistry, biology, ecology, organic chemistry, and pharmacology– the modern marine biotechnology industry began to emerge (Leary et al. 2009), and by the end of the decade, the search for novel biologically active agents was well underway (Cragg et al. 1997).

Marine biodiversity offers considerable promise for biotechnology while posing challenges for regulating access and sharing the benefits of bioprospecting. Although some countries, such as Norway and Australia, prove exemplary in their territorial waters, many issues remain unresolved on the high seas.
This chapter considers the links between marine biodiversity and bioprospecting in the marine environment that have led to the development of marine biotechnology. It examines a number of key questions. What is marine biotechnology? How much bioprospecting occurs in the marine environment? Where do companies’ interests lie? What is the scale of commercial activity? Are products developed from marine biodiversity patentable? What is the environmental impact of this activity, and is it being sustainably managed?

**CURRENT KNOWLEDGE ON THE DEVELOPMENT OF MARINE BIOTECHNOLOGY**

The list of newly-discovered marine natural products grows year by year. For example, in the most recent published survey of literature, Blunt et al. note that in 2008, 371 scientific articles describing some 1065 new compounds were published (Blunt et al. 2010). Recent reviews of patent data (discussed below) also highlight this trend. Marine flora and fauna provide a vast source of novel lead compounds for the development of pharmaceuticals in particular, with more than 52% of those leads coming from sponges (Blunt et al. 2010).

A recent detailed study of bioprospecting suggests that the development of natural-product marine biotechnology covers several broad categories, including medical research on substances with an anti-cancer and anti-tumour function; substances for treating HIV-AIDS; applications against other infectious diseases, such as fungal infections and malaria; and other medical applications such as anticoagulants (Leary et al. 2009). Other areas of research include the development of new DNA polymerases for use in research and diagnostics; development of novel enzymes for use in industrial and manufacturing processes; treatment of waste and industrial effluents; bioremediation, biomining and bioleaching, to name but a few (Leary 2007). Other forms also involve the production of novel products from marine raw materials, including chitin and related compounds from shellfish waste; omega-3 and other fatty acids from fish oils; carotenoids, pigments and flavourings; compounds derived from marine algae such as alginates and carageenans, and other nutritional supplements (Leary 2008).

While natural products remain at the forefront of developments in biotechnology, the past decade has seen a paradigm shift in biological research and development, with greater use of “genomics” i.e. approaching the biology of organisms through their genetic blueprints, and new research methodologies (Bull et al. 2000). Previously, the methodology of so-called “traditional biology” prevailed, involving a search strategy based on collecting individual specimens and experimenting on each in the laboratory. More recently, such research increasingly draws on the newer methodology of bioinformatics. Bioinformatics is a computer-driven search strategy that examines data from a large volume of samples, which it screens and evaluates in order to identify a few promising substances for closer examination (Bull et al. 2000).

The wholesale screening of large collections of microorganisms is now a widespread research and development strategy in the biotechnology industry, with many...
companies establishing collections of microorganisms and other biota from a variety of sources, including marine ones (Ferrer et al. 2005). These are then screened, and candidates selected for their abilities to synthesize pharmacologically active metabolites, along with a range of other uses (Ferrer et al. 2005).

THE COMMERCIAL SCALE OF INTEREST IN THE MARINE ENVIRONMENT

While there is clearly significant commercial interest in marine biotechnology, to date it has been very difficult to quantify this in dollar terms due to a lack of clear global data on the market value of marine biotechnology (Leary et al. 2009). There have been a number of studies of the commercial value of marine biotechnology, but it is difficult to arrive at accurate figures, since assessment methodologies vary considerably. Some studies have attempted to give a global view of the marine biotechnology industry. For example, one recent study estimated that in 2004, marine biotechnology globally was valued at €2.2 billion, excluding aquaculture, seaweed and processing-related industries (European Commission 2005). Other studies have focused on specific market values of industries commonly using marine genetic resources, and on approximate annual sales of selected marine-based products (Leary et al. 2009) For example, one cancer-fighting agent alone derived from marine sources had annual sales of US$1 billion in 2005 (Leary et al. 2009).

Regardless of its true commercial value, marine biotechnology is certainly a substantial market. Examples of specific products in the pharmaceuticals sector shed some light on this value. For example, in 2005 sales of a herpes remedy derived from a sea sponge were estimated at between US$50-$100 million per annum (Leary et al. 2009). More spectacularly, anti-cancer fighting agents developed from marine sources were estimated at more than US$1 billion in 2005 (Leary et al. 2009). But the lack of clear data on the market value of marine biotechnology suggests a need for an authoritative valuation of marine genetic resources and their commercial use (Pisupati et al. 2008).

One should not forget, however, that the path from sample collection to profitable drug or other product can take many years and involve the expenditure of vast sums of money, often in the range of hundreds millions of dollars, with no guarantee that a successful product will result. As one researcher in the field has commented:

[Marine biotechnology] is only truly successful when someone manages to profitably sell a finished product to a customer. To successfully develop a product it takes a lot more than just good research. There has to be a market for the product and the market has to be willing to pay a price for the product that allows a profitable return on the research, development, production, transport, marketing and sales costs of the product... Most products fail, so a company based on a single technology is also likely to fail (McKenzie 2003, 50).

The process of product development starts with the selection of appropriate biological materials, followed by screening for a desired attribute; this leads to the selection
of the best option from among a short list of positive hits, and culminates with the development of a commercial product or process (Bull et al. 2000). But there are many points along the way where product development can grind to a halt. As Firn (2003) has suggested, the process of developing a new drug beyond screening raises many questions. These include:

- “Will the drug be safe to use? (e.g. are there adverse side effects due to the chemical having more than one effect?)
- Is the drug clinically useful? (e.g does the effect found in the test tube translate into a positive outcome for the patient?)
- Can the chemical be extracted, synthesized or produced by fermentation on an industrial scale economically?
- Can the drug and its derivatives be adequately protected by patents?
- Is the market big enough to repay the typical $500 million development costs for the drug?” (Firn 2003, 209)

Despite these obstacles, there are now many companies active in research, development and commercialisation of marine biotechnology. Table 1 below (based on descriptions of these companies drawn from their own marketing material) gives some examples of the diverse range of companies involved.

THE KEY ISSUES CURRENTLY UNDER DEBATE

The status of marine-derived biotechnology is emerging as a significant issue of international debate. In terms of international law, the debate centres on who has the right to control access to marine biodiversity for the purposes of developing biotechnology, and who has the right to share in any profits that may ultimately arise. This is often referred to as the debate over “access and benefits sharing.”

This debate pivots on the interaction of two key international treaties: the 1992 Convention on Biological Diversity (the “CBD”) and the 1982 United Nations Convention on the Law of the Sea (UNCLOS 1982; CBD 1992). The CBD has three main objectives: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from the utilisation of biodiversity, genetic resources in particular. It is a framework treaty that sets out several obligations aimed at implementing these objectives. UNCLOS is the main treaty dealing with the oceans and divides the ocean space into a number of discrete jurisdictional zones. Under the provisions of UNCLOS, the coastal state has clearly defined jurisdiction over ocean space, including the twelve-nautical-mile territorial sea (which is regarded as sovereign territory), and the 200-nautical-mile exclusive economic zone (“EEZ”) (where states possess certain sovereign rights, including the right to regulate access to marine biodiversity) (UNCLOS 1982, Part V).

Within the territorial sea and the EEZ (and to a limited extent on the continental shelf, at least with respect to sedentary species), access and benefit sharing issues are regulated by the provisions of the CBD, which recognises the rights of the coastal state to regulate within national jurisdiction (CBD 1992, Article 4).
### TABLE 1. EXAMPLES OF MARINE BIOTECHNOLOGY COMPANIES

<table>
<thead>
<tr>
<th>Company</th>
<th>Products(s) and areas of research and development interest related to marine biotechnology</th>
<th>Location, Country</th>
<th>Web address</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/F Protein Inc &amp; A/F Protein Canada Inc.</td>
<td>Develops antifreeze proteins from Arctic and Antarctic fish species for the control of cold-induced damage in medical, food, and cosmetic products.</td>
<td>USA and Canada.</td>
<td><a href="http://www.afprotein.com">www.afprotein.com</a></td>
</tr>
<tr>
<td>Aquapharm-Bio-discovery</td>
<td>This company has a substantial collection of unique marine bacteria and fungi isolated from diverse and extreme marine habitats, including the Arctic and the deep sea, and uses these to develop new biologically active natural products for pharmaceutical, nutraceutical and industrial applications. Its core product areas are: anti-infectives (new antibiotic and antifungal development), carotenoid pigments (novel high yield fermentation), new enzymes (bio-transformations), and functional molecules. In addition, it also makes its library of marine bacteria and fungi available to third parties for research and development purposes.</td>
<td>Based in Scotland (United Kingdom)</td>
<td><a href="http://www.aquapharm.co.uk">www.aquapharm.co.uk</a></td>
</tr>
<tr>
<td>Biotec Pharmacon ASA</td>
<td>Biotec Pharmacon develops, manufactures, and markets immune modulating compounds and molecular biology grade enzymes, based on its own research in immunology and marine biotechnology.</td>
<td>Norway</td>
<td><a href="http://www.biotec.no">www.biotec.no</a></td>
</tr>
<tr>
<td>Magellan Bioscience Group Inc.</td>
<td>Main field of operation is in microbial extracts for drug discovery, agrochemical, enzyme, and specialty chemical research. Magellan has a collection of over 13,000 unique marine microbes and 60,000 diverse fungal strains sourced from the Arctic and Antarctica as well as from shallow reefs, marine caves, deep (&gt;1000M) ocean sediments, and tropical and temperate waters.</td>
<td>USA.</td>
<td><a href="http://www.magellan-bioscience.com">www.magellan-bioscience.com</a></td>
</tr>
<tr>
<td>New England Biolabs.</td>
<td>Enzymes and polymerases, including those isolated from deep sea hydrothermal vent ecosystems.</td>
<td>USA.</td>
<td><a href="http://www.neb.com">www.neb.com</a></td>
</tr>
<tr>
<td>Pharma Mar</td>
<td>PharmaMar is a biopharmaceutical company founded in Spain in 1986, and its main business focus is on exploiting the potential of the oceans as a source of novel medicines for improved cancer treatment. The company has a unique marine organism library containing over 85,000 specimens. PharmaMar’s Research, Development, and Innovation Department has discovered 700 new chemical entities and identified 30 new families of compounds. As a result of this work, PharmaMar has over 1800 patents that either have been awarded or are in the processing stage. Yondelis®, developed by PharmaMar and initially approved by the European Commission in 2007 for the treatment of soft tissue sarcoma, and in 2009 for the treatment of relapsed ovarian cancer, is the first in a new generation of anti-tumour drugs developed from marine compounds. Since that time, Yondelis® has been approved in 21 countries of Asia, Central and South America, as well as in Switzerland and Russia. PharmaMar’s other pipeline compounds, Aplidin®, Irvalec®, Zalypsis®, and PM01183 are in different phases of clinical evaluation.</td>
<td>Spain and USA.</td>
<td><a href="http://www.pharmamar.com">www.pharmamar.com</a></td>
</tr>
<tr>
<td>Pronova Biopharma (previously known as Pronova Biocare)</td>
<td>Pronova BioPharma develops and manufactures marine-originated, omega-3-derived pharmaceutical products, especially focusing on treatments for cardiovascular diseases.</td>
<td>Norway and Denmark</td>
<td><a href="http://www.pronova.com/">www.pronova.com/</a></td>
</tr>
<tr>
<td>Unilever</td>
<td>This company is a large food manufacturer that has developed antifreeze proteins derived from Arctic eel pout for use in making ice cream.</td>
<td>Company has world-wide operations.</td>
<td><a href="http://www.unilever.com/">www.unilever.com/</a></td>
</tr>
<tr>
<td>Verenium Corporation (previously known as Diversa Inc.)</td>
<td>Verenium Corporation develops cellulosic biofuels and enzymes. Verenium has a broad library of unique enzymes for commercial development sourced from extreme environments including the Arctic, Antarctica, volcanoes, rain forests and deep sea hydrothermal vent microorganisms. Verenium is also involved in anti-biotic and other drug research.</td>
<td>Company has operations world-wide.</td>
<td><a href="http://www.verenium.com">www.verenium.com</a></td>
</tr>
<tr>
<td>Zymetech ehf.</td>
<td>Zymetech concentrates on research in the field of enzymes and their use in the development and production of pharmaceuticals and cosmetics. The company is primarily involved in development, production and marketing of marine enzymes and products derived from such enzymes. Products marketed by this company include PENZIM, a product containing purified enzymes that purportedly brings relief to people suffering from a variety of skin conditions, rheumatic or arthritic diseases, swelling, and muscle pains, among other problems.</td>
<td>Iceland</td>
<td><a href="http://www.zymetech.is">www.zymetech.is</a></td>
</tr>
</tbody>
</table>

Source: Adapted and updated from Leary (2008) and companies’ websites.
Since the negotiation of the CBD, many states have developed domestic laws and policy regulating access and benefit sharing, some of which have extended to bioprospecting in the marine environment. For example, in Australia, the six State and the Northern Territory governments have jurisdiction over access and benefit sharing from the coast to three nautical miles out, while the area beyond that mark to the outer edge of Australia’s EEZ is regulated under the provisions of the Commonwealth’s Environment Protection and Biodiversity Act 1999 (Australia EPDA 1999) and associated regulations. Under this regime, permits are required for taking native species’ biological resources for research and development on their genetic resources or biochemical compounds. The Australian government has subsequently developed model access and benefit sharing agreements under this regime, which provide the basis for most arrangements where Australian Federal law applies. This regime applies in the marine environment as a whole, although permits for specific locations, such as the Great Barrier Reef Marine Park and Australia’s Antarctic Territory, are handled by separate authorities.

Like Australia, Norway has also recently adopted domestic legislation with provisions that specifically regulate access and benefit sharing. The Marine Resources Act (Act of 6 June 2008 no. 37 relating to the management of wild living marine resources) aims to “ensure sustainable and economically profitable management of wild living marine resources and genetic material derived from them, and to promote employment and settlement in coastal communities” (Section 1) and recognises that “wild living marine resources belong to Norwegian society as a whole” (Norway MRA 2008, Section 2). As the Norwegian Research Council has observed:

The new legislation is seminal in that it establishes the legal right of the [Norwegian] State to claim financial or other compensation when Norwegian marine genetic materials are commercially exploited (Norwegian Research Council 2010).

Moves by countries such as Australia and Norway to regulate access and benefit sharing within their areas of national jurisdiction provoke little controversy, because they are perfectly consistent with these countries’ rights under the CBD and UNCLOS.

However, in areas beyond national jurisdiction, controversy has recently emerged concerning the status of marine biodiversity subject to bioprospecting. UNCLOS and the CBD do not clearly regulate bioprospecting in those waters. A hotly contested debate has arisen over the extent to which existing international organizations, such as the International Seabed Authority (ISA), should regulate bioprospecting both on the sea floor and in the water column or high seas above. The ISA already has a role to play in managing minerals extraction in the deep sea beyond national jurisdiction, or the “Area” to use the UNCLOS definition. The “Group of 77” countries (i.e. developing countries such as Argentina, India, South Africa, Indonesia and China), supported by a number of their academic commentators (see e.g. Armas Pfirter 2006), have argued in recent years that access and benefit sharing should be brought within its mandate. This position rests on a questionable interpretation
of international law, one that extends the concept of the “common heritage of mankind”\(^1\) to marine genetic resources in the Area beyond the ISA’s existing clearly defined minerals mandate. The debate in the current context is whether the “common heritage of mankind” concept (and all of the legal consequences and structures under UNCLOS tied up in that term mentioned above) should be applied to marine genetic resources or not. The UN General Assembly has set up a process to consider a resolution of this question (and other issues associated with marine biodiversity in areas beyond national jurisdiction), the Ad Hoc Open-ended Informal Working Group: its mission is to study a range of issues relating to the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction.

This issue has also been debated extensively in the recent meetings of the United Nations Informal Consultative Process on the Law of the Sea (for a detailed overview of this process, see Ridgeway [2009]). These issues are canvassed elsewhere in this book and so will not be examined in this chapter. But as debate in this forum and others has shown, resolving the status of these resources may be some way off. Simply put, there is no international agreement on whether or not the common heritage concept has any bearing on this issue, and whether in future the ISA should play any role in regulating access and benefit sharing in the oceans beyond national jurisdiction.

**LINKAGES WITH INTELLECTUAL PROPERTY RIGHTS**

A fundamental flaw in the “common heritage” argument is that it ignores the crucial role that patents play in biotechnology development. As noted above, biotechnology research and development is a very expensive and time-consuming process with limited likelihood of success. Patents are granted as a monopoly on exploitation of an invention in exchange for its disclosure; they reward the inventor for the time, effort and expense entailed in developing the new invention.

Under the provisions of Article 27(1) of the international treaty known as the Agreement on Trade-Related Aspects of Intellectual Property Rights (the “TRIPS Agreement”), “a patent may be granted for any invention, whether product or process, in any field of technology, provided that it is new, involves an inventive step, and has industrial application” (WTO 1994). Under Article 27(2) of the TRIPS Agreement, “States may exclude inventions from patentability on the grounds of *ordre public* or morality (including to protect human, animal or plant life or health, or to avoid serious prejudice to the environment), provided that such exclusion is not made merely because the exploitation is prohibited by their law.”

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1. The term “common heritage of mankind” is used here rather than the equivalent gender-neutral “common heritage of humankind” because it denotes a specific concept defined by international law, established before gender neutrality was a concern. As reflected in UNCLOS, it has three core elements (1) non appropriation of the deep seabed beyond national jurisdiction by States; (2) common management of the mineral resources of the deep seabed beyond national jurisdiction by the ISA and (3) benefit sharing in relation to any profits that may come from the exploitation of deep sea minerals.
The granting of patents for products derived from marine biodiversity has proven controversial. As Salpin and Germani (2009) have recently observed:

There is an ongoing public debate about whether naturally occurring organisms and substances isolated from their natural surroundings are inventions or discoveries; whether they meet the criteria of being capable of industrial application; whether the extension of patent protection to genetic material is justifiable on ethical grounds; and on the impacts of permitting patent claims that are very broad in scope (Salpin and Germani 2009, 18).

Despite this controversy, many such patents have been granted around the world, and for the time being the patentability of such inventions seems beyond doubt. A number of recent surveys have highlighted this increasing trend. For example, in a 2007 study, the present author signalled at least 37 patents granted for inventions isolated from species associated with deep sea ecosystems (such as hydrothermal vents). These range across a diverse series of applications, including biological sciences research, medicine and diagnostics (Leary 2007). In a similar vein, Arico and Salpin (2005) note that patents have been granted for a number of applications (including pharmacology, agrichemistry and cosmetics) where the active ingredient has been sourced from a range of marine organisms, e.g. “bacteria, fungi, algae, sponges, cnidaria, echinoderms, molluscs and tunicates” (Salpin et al. 2009 citing Arico et al. 2007). More recently, another study identified at least 135 patents granted from 1973 to 2007, derived from marine biodiversity with applications in chemistry, pharmacology, cosmetics, food and agriculture (Leary et al. 2009). Table 2, drawn from data contained in that study, provides some examples of those patents.

Article 28 of the TRIPS Agreement clarifies a patent’s rights of ownership and third-party limitations. In the case of a product, it prevents third parties from making, using, offering for sale or selling, or importing the patented product for those purposes, without the owner’s consent. If the subject of the patent is a process, Article 28 prevents the same acts applied (as a minimum) to the product obtained by that process.

Once the patent is granted, it is irrelevant whether or not access to the original natural product complied with any applicable access and benefits sharing regime. The patent is a stand-alone monopoly, enforceable against the world! There clearly is a major missing regulatory link between the CBD and TRIPS.

IS BIODIVERSITY CONSERVATION COMPATIBLE WITH THE PATENTABILITY OF LIVING ORGANISMS?

Quite aside from issues associated with access and benefit sharing and intellectual property rights, developments in marine biotechnology also have a potentially significant environmental impact. Many new products, especially pharmaceuticals, rely upon the availability of sufficient quantities of their originating natural products. In a recent publication, a representative of the leading Spanish company PharmaMar (de la Calle 2009) has highlighted clearly what this can mean in terms of the potential environmental impact of new drug development. He has observed:
A serious obstacle to full development of most marine natural products is the problem of supply. The concentrations of the majority of highly active compounds for marine invertebrates are very often minute, sometimes accounting for less than $10^{-6}$ % of the wet weight. For example, in order to obtain approximately 1 g of the promising anti-cancer agent Yondelis©, close to 1 metric ton (wet weight) of the ascidian tunicate *Ecteinascidia turbinata* must be harvested and extracted. In other cases, such as halichondrin B, a powerful cryostatic polyketide of sponge origin, the ratio of biomass to final product is even less favourable. In order to obtain as little as 300 mg of a mixture of two halichondrin analogues, 1 metric ton of the sponge *Lissodendoryx* sp. must be collected and extracted. Other anti-cancer compounds, such as the dolastatins, have been isolated from the sea hare *D. Auriculata*, where the concentration of pure compounds is less than 1 mg per 1 kg (wet weight). A large number of similar cases can be found in the literature (de la Calle 2009, 214).
The larger the quantity of source biota needed to produce the new drug or other product, the larger the environmental impact will be. To some extent, this environmental impact can be minimized by chemical synthesis during the research and development process, or through culture in the laboratory where the original source is microbial in origin. Even where only small samples are originally required for research and development, “the fact that you may only require the celebrated ‘teaspoonful’ of the exciting [organism] is no guarantee that you will not trash a larger area in getting it” (Hemmings 2009, 60). For many new products, and especially some promising drug leads series, the environmental impact of bioprospecting urgently needs to be considered.

Within areas of national jurisdiction, this can be managed under national environmental legislation. In Australia, for example, assessing the environmental impact of biological sampling for research and development purposes is a pre-condition of permits for bioprospecting, as mentioned earlier in this chapter.

In areas beyond national jurisdiction, no international regulation of the environmental impact of bioprospecting currently exists. Surprisingly, this issue has received little if any attention in the international fora where bioprospecting has been discussed. In any future international legal or governance regime, managing the environmental impact of bioprospecting will prove a key issue. So far, no detailed study has been undertaken on the nature and scale of these environmental concerns, and clearly this must be a first step in designing a future response (Leary et al. 2009). Well-established concepts – such as environmental impact assessment and management, the precautionary principle, and ecosystem-based management – should play a central role in any such future regime (Leary et al. 2009).

However, designing such a regime will not be easy, especially given the very close relationship between marine scientific research and bioprospecting. To date there is no clear agreement on the difference between the two, a necessary distinction if existing high seas freedoms, such as marine scientific research, are to be maintained. Future bioprospecting may require a separate access and benefit sharing regime that clearly separates it from the special status accorded marine scientific research under international law.

CONCLUSION
Marine biodiversity holds great promise for future developments in biotechnology. From treatments for illnesses such as cancer, to development of new enzymes for use in a range of chemical and industrial processes and applications, the oceans now offer us many new and exciting prospects. But as discussion in this chapter has shown, these developments unfold rapidly in an environment without adequate regulation, whether of access and equitable sharing of potential benefits, or in managing a still vaguely-understood environmental impact. The challenge now is for policymakers to show leadership on these unresolved concerns.
WORKS CITED


THE STATUS OF HIGH SEAS BIODIVERSITY IN INTERNATIONAL POLICY AND LAW

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While the biological bounties of the water column have been known for centuries, it is only in the past forty years that the deep sea – once thought of as a desert from a biological point of view – has been recognized as host to many new species. In fact, discovery of unique species and organisms has recently accelerated, outstripping even the advance of technologies that give access to the deep seas, some of the most remote areas of Earth. Such organisms have drawn the attention of interested groups – governments, science, industry, academia and lawyers. This is due to their diversity, uniqueness and direct value on the one hand (e.g., to food security, with fish; to science and industry, with genetic resources) and indirect value on the other – for example, as parts of properly functioning marine ecosystems that play a role in carbon assimilation. This article will focus on current issues in international law and policy-making concerning marine biodiversity in areas beyond national jurisdiction. In particular, it will address the challenges and accomplishments of the United Nations and other relevant organizations in this field.

Policy-makers and lawyers have invested considerable time and resources in marine biodiversity, especially beyond areas of national jurisdiction. The former have by and large focused on balancing political, economic, social, environmental and ethical interests. In international policy-making fora, many states have promoted the equitable and sustainable use of marine biodiversity and genetic resources, while at the same time seeking to protect surrounding ecosystems from extraction risks. This includes advancing marine scientific research and clear regulatory frameworks, while counterbalancing the significant financial investment and advanced technology needed for deep-sea activities, and clarifying resource exploitation rights and sharing of benefits.

*The views expressed herein are those of the authors and do not necessarily reflect the views of the United Nations.*
International lawyers seek to identify the relevant legal principles and rules governing the conservation and sustainable use of marine biodiversity beyond areas of national jurisdiction. A patchwork of international instruments applies – first and foremost, the United Nations Convention on the Law of the Sea (UNCLOS) – yet none of those instruments directly or specifically addresses this issue. One of the particular sticking points in the legal discussions concerns marine genetic resources and whether the common heritage of humankind or the freedoms of the high seas apply to them. This question also relates to matters of legal interpretation, in particular whether Part XI of UNCLOS applies only to the mineral resources in the Area¹ or also to its biological resources. Another issue concerns the legal implications of conservation tools, such as marine protected areas, in the specific jurisdictional and institutional context governing areas beyond national jurisdiction.

In recent years, international fora have seen intense discussion of these and other questions – including appropriate management and conservation tools, enhancing the capacity of developing states, and the necessity of additional scientific information. In 2004, the UN General Assembly, which performs an annual review and evaluation of UNCLOS implementation and other developments relating to ocean affairs and the law of the sea, mandated an Ad Hoc Open-ended Informal Working Group (the “Working Group”) to study issues related to the conservation and sustainable use of marine biodiversity beyond national jurisdiction, including scientific, technical, economical, legal, environmental and social issues. The Working Group also surveys relevant activities of the United Nations and other relevant international organizations, identifies key issues and questions requiring more detailed background studies, and indicates possible approaches for international cooperation and coordination. This broad mandate demonstrates the widespread and growing interest of states in this field, including issues related to marine genetic resources.

Other intergovernmental organizations and bodies also take part in this discourse through their areas of competence. For example, the Food and Agriculture Organization of the United Nations (FAO) and regional fisheries management organizations address the impacts of destructive fishing practices on vulnerable marine ecosystems and biodiversity beyond national jurisdiction. The International Seabed Authority (ISA)² has adopted regulations targeting the environmental impacts of mining activities. The United Nations Educational, Scientific and Cultural Organization (UNESCO) and its Intergovernmental Oceanographic Commission have added valuable scientific input with the development of the Global Open Oceans and Deep Seabed Biogeo- graphic Classification. The scientific and technical work undertaken by the Convention on Biological Diversity and by the United Nations Environment Programme (UNEP) has also catalyzed international debate. One should finally mention the contribution of non-governmental organizations, which are very active in bringing relevant issues and proposals to the attention of states.

In the General Assembly, states are negotiating a coordinated approach to the measures and proposals discussed in these institutions and aim to identify possible solutions. A number of states focus on practical measures to address existing implementation gaps, and to enhance the conservation and sustainable use of marine genetic resources. Such measures include the promotion of marine scientific research and development of codes of conduct, methodologies for carrying out environmental impact assessments, area-based management tools (including protected areas), and mechanisms for cooperation, sharing of information and knowledge, discussion of practical options for benefit-sharing and consideration of intellectual property aspects of genetic resources beyond areas of national jurisdiction.

While open to considering practical measures, other states stress the importance of discussions on the legal regime for genetic resources beyond areas of national jurisdiction (UN 2008). In February 2010, the Working Group recommended that the General Assembly call upon states to make progress

¹. The Area is the seabed and ocean floor and subsoil, thereof beyond the limits of national jurisdiction (see Article 1 (UNCLOS 1982)).

². The International Seabed Authority is an international organization established under UNCLOS to organize and control activities in the Area, particularly with a view to administering the mineral resources of the Area.
in the discussion on the relevant legal regime for, and implementation gaps in, the conservation and sustainable use of marine genetic resources in accordance with international law, UNCLOS in particular, and taking into account states’ views on its Parts VII and XI (UN 2010). The recommendation reflects the differing views of states on the legal status of marine genetic resources beyond areas of national jurisdiction. In fact, while states recognize that UNCLOS provides the framework for all activities in the oceans and seas, their views diverge on the relevant legal provisions for these specific resources. Developing countries hold the view that the common heritage of humankind, as set out under Part XI of UNCLOS, not only applies to mineral resources but also to the biological resources of the Area. Developed countries, generally, hold the view that Part XI only encompasses mineral resources, while marine genetic resources fall under the high seas regime set out in Part VII of the Convention; the freedom of the high seas would therefore govern their collection and exploitation. By and large, those positions reflect the respective capacity of each group of states to access and exploit those resources, taking into account varying degrees of capacity within each group. The Working Group recommended that the General Assembly convene another meeting in 2011 to elaborate further recommendations (UN 2010).

Both in the short and longer term, a number of challenges exist for advancing the international debate, and for finding measures that would both satisfy the urgency of making progress on the ground and the varying interests of states. Given the broad range of issues and interests at stake, certain states advocate for their “pet” issues, such as furthering area-based management tools, including marine protected areas, and environmental impact assessments; others prefer continued discussion of the legal regime for marine genetic resources. Increasingly, negotiations have been treated as a “package,” polarizing rather than coordinating the interests of conservation and those related to utilization and access. This does not even account for states that engage in the discussions while apparently favouring the status quo – that is, continuing activities not already specifically regulated, without definite rules for conservation and sustainable use.

Many differing perspectives remain under discussion amongst states and will call for future reconciliation. These include following a global approach in policy development and guidance, versus adopting regional approaches; and focusing on implementation of existing legal and institutional frameworks, versus developing new ones to fill perceived governance and legal gaps. Adequate leadership and follow-up at the national level will be required to protect this large portion of the planet’s biodiversity, and to ensure its sustainable use for present and future generations.

WORKS CITED


In 2009 and 2010, an Indo-German scientific expedition dusted the ocean with iron to stimulate the biological pump that captures atmospheric carbon dioxide. Two onboard scientists tell the story of this controversial project. Besides raising the polemic on using geo-engineering to combat global warming, the expedition provided unprecedented knowledge about the oceans’ biogeochemistry.

OCEAN IRON FERTILIZATION

Oceans play a key role in shaping global climate by regulating atmospheric concentrations of the planet-warming greenhouse gas, carbon dioxide (CO₂). However, given that fossil fuel burning has swamped the natural carbon cycle, geoscientists face the challenge of manipulating those natural processes to increase ocean uptake of CO₂ from the atmosphere. One such technique, ocean iron fertilization (OIF) seeds certain ocean regions with trace amounts of iron to stimulate growth of the microscopic plant-like organisms known as phytoplankton, which then die and sink. A vital scientific experiment, designed to further understanding of this process and its potential, generated considerable controversy and stiff opposition from some environmental groups because of its perceived dangers, even as it revealed important new findings about plankton ecology and the limitations of OIF as a way to enhance oceans’ CO₂ sequestration. This paper will describe the challenges the authors faced when conducting the OIF experiment known as LOHAFEX in the southwest Atlantic Ocean in early 2009, and present its key findings.

The oceans’ special role arises because they help absorb CO₂; they currently contain about fifty times the amount present in the atmosphere. During the past century, atmospheric carbon dioxide concentrations – the leading greenhouse gas – have risen by one-hundred parts per million/volume (ppm/v), equivalent to about 200 gigatonnes (Gt = 10⁹ tonnes) or nearly one-third of the total carbon in all terrestrial vegetation. Even extensive reforestation – highly unlikely in the face of increasing use of land for food and biofuels – would have only a limited effect on
present-day excess CO$_2$ levels. To mitigate ongoing global warming beyond curbing additional emissions, we advocate research on reducing atmospheric CO$_2$, because natural processes removing anthropogenic (human-caused) CO$_2$ (largely uptake by the oceans) will take thousands of years. Such endeavors, including techniques to cool the planet, are termed “geo-engineering.” A recent report by the UK Royal Society recognizes that no single measure will suffice and that it will be necessary to use a portfolio of techniques to address the growing problem (The Royal Society 2009). One possible measure is to fertilize nutrient-rich regions of the ocean with trace amounts of iron to stimulate phytoplankton growth. After blooming, the phytoplankton die and sink out of the surface layer, transferring carbon to the deep ocean and sea-floor sediments, a process called the “biological carbon pump.”

Ocean iron fertilization (OIF) experiments represent a powerful new tool to study and quantify ecological and biogeochemical processes in the ocean. The first OIF experiments were carried out in the mid-1990s: they clarified the paradox of low phytoplankton productivity in three extensive, nutrient-rich areas of the ocean at both tropical and polar latitudes (the sub-arctic Pacific, the Equatorial Pacific and the Southern Ocean). Martin (1990) proposed that phytoplankton growth rates in these regions, in particular the entire Southern Ocean, were limited by the low supply of iron (Fe) from continental sources. The hypothesis had an interesting second part related to climate: at the height of the last Ice Age, 20,000 years ago, northern
Europe and North America were covered by three-kilometre thick ice sheets; sea levels were 100 metres lower and atmospheric CO$_2$ concentrations were 100 ppm/v lower than those of a century ago. Martin (1990) argued that the much higher input of iron-rich dust to these regions during the cold, dry Ice Ages would have stimulated productivity and hence sequestered more CO$_2$ in the deep ocean than during subsequent warm, wet periods. A corollary of this “iron hypothesis” is that artificial iron fertilization of surface waters in these regions would enhance the uptake of CO$_2$ from the atmosphere.

The iron hypothesis was partially confirmed by a dozen experiments in all three major low-productive but nutrient-rich regions; these studies stimulated phytoplankton blooms dominated by diatoms, a group of algae with a protective shell made of silica (Boyd et al. 2007). Although natural diatom blooms are known to die and sink en masse, a separate experiment (the European Iron Fertilization Experiment, or EIFEX) was required to verify the fate of the iron-fertilized algal bloom. It was carried out in the closed core of a hundred-kilometre oceanic eddy that extended to the sea floor at approximately 3,500 metres. Following the iron addition, a massive bloom developed, comprised of most of the diatom species present in the surface layer. A large portion of the phytoplankton cells subsequently formed detritus flocks that sank rapidly through the deep-water column of the closed eddy core. Grazing pressure on the diatoms was surprisingly low, despite the large populations of zooplankton (tiny invertebrates) that feed on them.

Previous OIF experiments had been carried out in low-productive waters far removed from natural sources of iron, investigating the response of “oceanic desert” communities inhabited by large, spiny, thick-shelled (and hence grazer-protected) diatoms. A joint Indo-German OIF experiment, LOHAFEX,$^1$ conceived in 2005, focuses on the response of a very different diatom population, one that inhabits the productive Southwest Atlantic sector of the Antarctic Circumpolar Current, which is influenced by iron-enriched coastal waters. The diatoms in these waters are smaller, thinner-shelled and faster-growing than those of the oceanic deserts: they are known to sink en masse following blooms. A detailed investigation of these species’ distribution in the region’s underlying sediments had revealed coastal diatom species extending eastward to about 10°W (Abelmann et al. 2006). Sediments deposited during the last glacial period showed an even more extensive distribution to the east, across the entire Atlantic sector; this suggests that these diatom communities helped sequester the “missing” glacial carbon from the Ice Ages.

In 2006, we submitted the LOHAFEX proposals and, following peer-review by a number of reputed scientists in India and Germany, the project secured ship access and the necessary US$4 million in funds, with both countries sharing the costs. Subsequently, the Alfred Wegener Institute in Germany and India’s National Institute of Oceanography prepared a memorandum of understanding (MoU) for their joint experiment. The heads of each institute’s parent organization (the Helmholtz

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1. Loha is the Hindi word for iron.
Association and the Council of Scientific and Industrial Research, respectively) signed the MoU during a visit by the German Chancellor to India in October 2007. In addition, scientists from five institutions in Italy, Spain, the United Kingdom, France and Chile were invited, and joined, the expedition. The LOHAFEX interdisciplinary team was comprised of forty-nine scientists, with physicists, chemists and biologists participating in about equal proportions.

Open ocean experiments offer unique opportunities to study processes at space and time scales (days and kilometres) not normally investigated in standard oceanographic research cruises, which tend to be carried out along transects. A transect is a path along which one records and measures occurrences of the phenomena or processes being studied. Such processes include mixing rates of water masses, turnover rates of various chemical compounds (including climate-active gases produced by plankton), and patterns of interaction between the various groups of organisms comprising the planktonic ecosystems. This information is vital for programming complex models of ocean ecosystem functioning; developing such models will help predict how ongoing climate change will affect oceans and their biota. Organizing the various groups who will measure these processes requires careful planning and coordination. To this end, a two-week training course was held at the National Institute of Oceanography (NIO) in Goa in January and February 2008, followed by a pre-cruise preparation workshop for all participants, hosted by the NIO in April 2008.

OPPOSITION TO OIF

Shortly after the first successful OIF experiments conducted in the mid-1990s, some companies announced their intent to use OIF to acquire carbon credits on the market, as per the Kyoto Protocol. Scientists were rightfully concerned about the possible negative effects that large-scale and long-term OIF could have. These concerns – directed at commercial-scale enterprises – were voiced in opinion pieces in prominent journals (Chisholm et al. 2001; Lawrence 2002) and received considerable coverage in the media. Although the media reports were by and large accurate, the fundamental distinctions between small-scale, scientific experiments and large-scale commercial enterprises were not always stressed, resulting in a negative view of OIF amongst the informed public.

Earlier reports of heavy metals pollution and excessive phytoplankton blooms in coastal waters caused by eutrophication (Smetacek et al. 1991) had strengthened the public’s concern about humans harming fragile marine ecosystems. Eutrophication occurs when water bodies are fertilized with nitrogen and phosphorus, causing excessive plant growth: over-fertilization caused by human activities often affects animal and plant populations, and degrades water and habitat quality. These concerns are entirely justified, since toxic metal pollution harms aquatic (and terrestrial) organisms, while excessive plant growth – in the form of intense surface-layer blooms followed by subsequent decay – takes up oxygen from subsurface water layers, asphyxiating local organisms. Blooms of toxic phytoplankton resulting in animal
deaths are another facet of eutrophication. Since human health is also affected, via water quality and consumption of contaminated cultivated species (mussels, fish, etc.), most developed countries had a strong incentive to adopt and pass legislation curbing pollution and eutrophication. These laws have abated the ill effects in many regions but, for largely unknown reasons, the pre-eutrophication annual cycles of plankton have not been re-established. This demonstrates how poorly we still understand the factors and processes shaping planktonic ecosystems (Smetacek and Cloern 2008). In any case, we see no justification for drawing parallels between light, small-scale additions of iron in the deep open ocean and constant, heavy doses of metals, phosphorus and nitrogen in shallower coastal areas, which definitely lead to environmental contamination and eutrophication.

In contrast to the over-fertilization and pollution of coastal areas, the open ocean often finds vital elements in short supply. All organisms require trace elements for proper metabolism – in particular iron, but also zinc, copper, cobalt, etc., in addition to macronutrients such as nitrogen and phosphate. Iron plays a key role in many basic metabolic pathways, such as synthesis of chlorophyll, reduction of nitrate to a usable form, and energy transfer. However, because of its insolubility in seawater, iron occurs at very low concentrations in a dissolved state, but abounds in sediments and soils. In coastal waters, iron concentrations are close to or even exceed their solubility maximum (a few tens to hundreds of micrograms per cubic metre); here, the supply of nitrogen is generally responsible for the limits on phytoplankton growth. However, in the open ocean, iron-limited regions where deep, nutrient-rich waters are brought to the surface by upwelling, the dissolved iron is insufficient to permit use of the other nutrients. To use a terrestrial analogy, adding iron to such regions is equivalent to watering a parched landscape where water shortage limits plant growth. All experiments have shown that iron-limited phytoplankton will increase their chlorophyll levels (i.e. become green, as do drought-stricken land plants when watered) and their photosynthetic efficiency increases, implying previous stress due to an iron shortage. Interestingly, just as the atmosphere supplies water to land via rain, it also transports iron-rich dust to the oceans (Cassar et al. 2007) with rain generally settling such dust on the oceanic surface.

As amply demonstrated by bottle experiments in the laboratory, as well as open-ocean experiments, the effects of adding iron artificially closely resemble those of natural dust input or contact with sediments. In addition to stimulating phytoplankton, added iron also acts on organisms that depend on organic matter provided by primary algae production – e.g. bacteria and various algae-feeding zooplankton, ranging from unicellular protozoa to mosquito-sized crustaceans; such organisms also increase their activity levels (Boyd et al. 2007), feeding and egg production rates. The analogy between open-ocean iron seeding and rainfall in parched land areas also holds for animals and plankton: as long as the iron dose remains light and sporadic, it mimics natural processes and does not harm the environment.

Another environmentalist concern is whether OIF could lead to blooms of toxic species, analogous to those implicated in the mass mortality of coastal animal species.
in particular fish, marine birds and mammals. We believe the risk involved must be considered in a broader environmental perspective. The vast majority of toxic phytoplankton species belong to the algal group known as dinoflagellates. Although there are many oceanic dinoflagellates, the toxic species typically occur in shallow waters, and form resting stages as spores on the sediment surface to survive unfavorable conditions. These species are more or less absent in the open ocean. However, the widespread common diatom genus *Pseudo-nitzschia*, which has some toxic species, has indeed been stimulated in OIF experiments. In a study that the Alfred Wegener Institute conducted in 2000, this genus contributed up to 25% of bloom biomass, but measurements of frozen plankton samples showed that the toxin in question – domoic acid – was absent² (Assmy et al. 2007). Blooms of toxic species of this genus regularly occur in many coastal upwelling regions: detrimental effects on marine shellfish and animals have been reported from the West and East Coasts of the United States, and off the eastern Canadian province of Prince Edward Island (WDFW 2010; CIMWI 2010). Other reports of toxic algal blooms, e.g. in the Gulf of Mexico or off the coast of Portugal, have not been linked to ill effects on marine mammals and birds; at this stage, only further experiments will show whether these toxic species pose a risk in OIF conditions.

A further environmental concern pertains to the release of trace gases in OIF experiments; we have examined and discounted the effects in greater detail elsewhere (see e.g. Smetacek and Naqvi 2008).

During 2007, unexpected developments in the international arena began to threaten the future of OIF research. The aforementioned and much-publicized announcements of corporate OIF plans alerted environmental groups, governmental and inter-governmental organizations to unregulated and premature attempts to create OIF geo-engineering. One such company aborted its plan to carry out an OIF experiment in 2007 when faced with opposition from many quarters, including nongovernmental organizations (NGOs) such as Greenpeace, the media, and governmental agencies of the countries involved. As a result, at its ninth meeting held in Bonn in May 2008, the Conference of the Parties to the Convention on Biological Diversity (CBD) adopted a resolution that:

“…urged other Governments … to ensure that ocean fertilization activities do not take place until there is an adequate scientific basis on which to justify such activities, including assessing associated risks, and a global, transparent and effective control and regulatory mechanism is in place for these activities, with the exception of small-scale scientific research studies within coastal waters.” Such studies “… should also be subject to a thorough prior assessment of the potential impacts of the research studies on the marine environment, and be strictly controlled, and not be used for generating and selling carbon offsets or any other commercial purposes.” (CBD 2008, IX/16)

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2. The domoic acid toxin is not destroyed by freezing (or cooking).
The CBD statement, interpreted by some as a *de facto* moratorium on all OIF activities, had several major flaws, as noted in June 2008 by the *ad hoc* Consultative Group on Ocean Fertilization created by the Intergovernmental Oceanographic Commission (IOC). The group expressed its concern that the CBD statement “places unnecessary and undue restriction on legitimate scientific activity” by not specifying what was meant by “small-scale,” among other things. The group further stated that “the restriction of experiments to coastal waters appears to be a new, arbitrary, and counter-productive restriction” and “there are good scientific reasons to do larger experiments” (IOC 2008). As for the regulation of OIF activities, the Consultative Group stressed that manipulative scientific experiments provide rare insight into ecosystems and “should be promoted with minimum additional bureaucratic burden;” such research should be distinguished from activities aimed at introducing additional CO$_2$ into the ocean (IOC 2008).

The CBD statement also “urged Parties and other Governments to act in accordance with the decision of the London Convention” (LC 1972) on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (IMO 2008). The Thirtieth Consultative Meeting of Contracting Parties to the LC and the Third Meeting of Contracting Parties to the London Protocol (LP 1996) examined issues related to ocean fertilization. It passed a resolution on 31 October 2008, which stated: “...given the present state of knowledge, ocean fertilization activities other than legitimate scientific research should not be allowed” (IMO 2008). While recognizing the need for legitimate scientific research, the attendees agreed that “scientific research proposals should be assessed on a case-by-case basis using an assessment framework to be developed by the Scientific Groups under the London Convention and Protocol” (IMO 2008). Until such a framework had been developed, Contracting Parties were “…urged to use utmost caution and the best available guidance to evaluate the scientific research proposals to ensure protection of the marine environment consistent with the Convention and Protocol” (IMO 2008). Significantly, this resolution did not seek to restrict fertilization experiments to “small-scale” and “coastal waters.” In light of the repeated references in the CBD resolution to LC/LP decisions, we – as the co-Chief Scientists of LOHAFEX, with the support of our institutions – interpreted it to mean that such restrictions no longer applied. Moreover, our proposals had gone through peer review and scrutiny by government bodies (including India’s Planning Commission). In any case, both the CBD and LC/LP resolutions are non-binding; and by November 2008 we had reached a logistical point of no return for the LOHAFEX experiment. We went ahead accordingly.

The LOHAFEX research vessel, the RV Polarstern, left Cape Town, South Africa, on 7 January 2009. The next day – to our utter surprise and dismay – an international NGO, the ETC Group (Action Group on Erosion, Technology and Concentration) wrote a letter of protest to the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (the host of the CBD meeting), claiming the LOHAFEX expedition contravened international agreements. Another NGO in Germany (Aktionskonferenz Nordsee, active in the 1990s against eutrophication
and pollution but dissolved in 2009) mobilized its former supporters to send protest emails to the Alfred Wegener Institute and the German government. The Environment Ministry responded by prevailing upon the German Federal Ministry of Education and Research to suspend the expedition. The ministries agreed to send the LOHAFEX proposal to independent research institutions (the British Antarctic Survey [BAS] in Cambridge, UK and the Leibniz Institute for Marine Sciences [IfM-GEOMAR] in Kiel, Germany) for assessment of its potential environmental impact, and to three respected legal authorities (professors of international law at German universities) for its legitimacy vis-à-vis international conventions. The proposal and the risk assessment prepared on board the research vessel and at the AWI received excellent scientific reviews from BAS and IfM-GEOMAR, and all three legal authorities argued that it did not violate international law; the German government therefore allowed the LOHAFEX expedition to continue.

THE EXPERIMENT
Following the successful technique employed in EIFEX, we had planned to fertilize a stable eddy with a closed core; this would prevent the fertilized patch from being pulled apart by currents and would maintain it over the underlying deep-water column. We made use of our enforced hiatus to examine various eddies identified from satellite images. The only suitable eddy influenced by coastal water in the entire region was centered on 16°W and 48°S. We surveyed the eddy on 25 January 2010 and received permission to go ahead with the experiment on 26 January. The next day we began fertilizing an area of approximately 300 square kilometres with ten tons of granular iron sulphate dissolved in seawater. This commercially-available ferrous sulphate is used as a lawn additive and is free of noxious impurities: the recommended dosage on land is 20 g/m². The amount needed to generate a phytoplankton bloom is 0.05 g per square metre of ocean. This yields a concentration of about 100 micrograms of iron per cubic metre over a 100-metre thick water column, well within the above-mentioned range of natural concentrations occurring in unpolluted coastal waters. Given that 10% of sea salt is sulphate, the amount added via iron sulphate (FeSO₄) is extremely small. We tracked the fertilized patch and monitored the biogeochemical and ecological processes for thirty-eight days. The patch revolved within the eddy for twenty-three days before being ejected, after which it became elongated and diluted.

The results of LOHAFEX experiments in the productive waters of the Southwest Atlantic differed significantly from the OIF experiments in non-productive waters discussed earlier. We made six key findings: (1) diatoms were conspicuously absent due to low ambient silicate levels, and phytoplankton biomass was dominated by small (<10 µm) flagellates; (2) phytoplankton biomass did not build up beyond 1.7 milligram chlorophyll a per cubic metre, presumably due to intense grazing by zooplankton (concentrations of this pigment, a convenient measure of phytoplankton biomass, are approximately twice as high in big natural blooms and in previous OIF experiments in the Southern Ocean); (3) although primary productivity almost
doubled in response to fertilization, bacterial biomass and production remained low; (4) CO$_2$ uptake inside the patch was modest (<15 micro-atmosphere, a unit equivalent to ppm/v in the atmosphere), while organic carbon accumulated in the surface layer in particulate and dissolved forms; (5) there was little export of particulate organic matter to the deep sea; and (6) iron fertilization had little effect on the production of other climatically-important greenhouse gases, such as nitrous oxide and ozone-destroying halocarbons (carbon and halogen compounds).

The LOHAFEX experiment results have two important implications. First, although phytoplankton production in the Southern Ocean is iron-limited, supplying iron in the absence of adequate dissolved silicon for diatoms does not build up large biomass, due to top-down control by grazers. However, our results did not exclude bottom-up control due to limitation by other micronutrients, e.g. cobalt. Cobalt is an essential element required for vitamin B-12 and its concentrations reached limiting levels at the end of the experiment. Second, because silicon appears only in low concentrations over 65% of the Southern Ocean, OIF's potential for sequestering anthropogenic CO$_2$ is substantially smaller than previously believed. Earlier estimates, based on utilization of available nitrate, were in the order of one Gt carbon (about two ppm/v) per year; the amount of nitrate that could be used before silicate limits are reached now works out to be less than half this figure.

The LOHAFEX experiments provided novel insights into plankton ecology that would not have been achieved had research halted. However, several important issues concerning OIF remain unanswered (Buesseler et al. 2008; Smetacek and Naqvi 2008). Such questions include the role of cobalt and other trace elements, the effect on phytoplankton at times of the year when zooplankton stocks are lower, and whether longer-term OIF will affect zooplankton predators and the rest of the food chain. Like most marine scientists, we strongly oppose OIF commercialization: it is profit-oriented and less likely to respond to unforeseen negative developments – certainly less than research conducted by an international, non-profit agency under the United Nation's umbrella, closely monitored by independent scientific bodies (Smetacek and Naqvi 2008). Such an agency could be funded by the proceeds from a carbon tax rather than from a carbon credit market. We also strongly favor using this promising research methodology to address hypotheses that otherwise remain untestable. Preventing highly-controlled future OIF research, out of misplaced concerns about its environmental impacts and possible commercialization, is tantamount to throwing out the baby with the bathwater.


On 2 August 2007, Russians planted their national flag more than 4500 metres deep in glacial waters near the North Pole, claiming Russian sovereignty over the Arctic and its immense fossil fuel reserves. The absence of any governance regime represents a blind alley in a race for energy that will inexorably lead to the fragile Arctic environment’s degradation.

THE ARCTIC GOVERNANCE CHALLENGE

If you ask a person in the street of almost any country about the Arctic, he or she will generally mention ice, polar bears, Inuit peoples, and perhaps explorers. Few will think of an enormous expanse of water the size of Russia, one of the five great oceans of the world. The Arctic Ocean is the sometimes-forgotten child of the marine world, as the smallest, shallowest, and most remote of the world’s oceans. Until recently, it was covered in ice most of the year and inaccessible to the developed world, but also home to hundreds of thousands of indigenous peoples. However, it now has increasing significance as a 14-million-square-kilometre region of paramount strategic importance – one undergoing profound change and, perhaps most importantly, one with the capacity to affect the everyday lives of people all around the world.

How? The Arctic Ocean is arguably the single most important and most sensitive regulator of the global climate system, due to its role in regulating albedo (white ice that reflects almost all incoming energy), its critical position in the North Atlantic Thermohaline Circulation system (commonly but incorrectly called the “Gulf Stream”), and its role in buffering changes in the global carbon cycle over long periods of time (WWF 2009). The fastest-changing part of the planet as a result of climate change, the Arctic has warmed at more than twice the global rate over the past few decades. It has already lost 40% of its summer sea ice and perhaps as much as half its thickness, or 80% of its volume, and it is still decreasing fast. It is also a potential source of massive amounts of trapped carbon dioxide: if released through melting, that gas could induce rapid and irreversible warming. A notable arctic ecologist, Dr. Martin Sommerkorn, recently and starkly expressed the risks to me: “If the Arctic is the canary in the coal mine, it’s already dead.”
Beyond the physical impacts of climate change, the Arctic has become a region of heightened strategic interest for many powerful stakeholders. Considered an empty wilderness with limitless resources in the early nineteenth century, it emerged as a key balancing region for the Cold War superpowers, a periphery where strategic resolve and technology (for example submarine navigation and detection systems) were tested beyond public view. As climate change opens up new parts of the ocean, the Arctic takes on different roles again: a region of opportunity for many parties with differing interests; a previously unreachable source of hydrocarbons; a place where new alliances and approaches may be considered. Whatever the outcomes, the resources of the Arctic Ocean – fish, oil and gas, minerals, transport routes, and possibly others – are attracting interest from around the world.

These disparate factors make managing the Arctic Ocean difficult from a strategic and environmental perspective. The sources of the problems and drivers of change are far away, the solutions inherently complex, and the stakes very high. How, for example, can you develop a conservation plan for polar bears and walrus when you know that they depend upon rapidly disappearing sea ice? How do you develop marine conservation reserves when species are migrating because of climate change? How do you control irresponsible development of oil and gas resources that are out of the world’s sight and mind? Perhaps most importantly, how do you protect the Arctic Ocean from warming caused by actions in cities half a world away?
THE GOVERNANCE CONUNDRUM

Environmental governance gaps have been recognized for years by Arctic nations, who launched the Arctic Environmental Protection Strategy in 1991, later developing into the Arctic Council.\(^1\) This unique body (which includes indigenous groups with ostensibly but not effectively the same rights as nation-states) has provided a forum for cooperation and exchange on a range of mainly technical issues, with little political interference or interest until a couple of years ago. It has had, perhaps ironically, almost no impact on environmental quality or regional conservation because it lacks decision-making power. The Council’s stated role provides for no supra-national authority or policy-development role: in short, it has and imposes no legally binding obligations. Similarly, it is not an operational body – the member states have chosen not to use the Council as the venue for collective commitments to act, preferring that it remain an informal cooperation body. Its working groups are excluded from considering major resource-use arenas, such as fishing, and it has failed to implement effectively its own strategies on conservation. Finally, the Arctic Council has limited participation, excluding countries and other stakeholders with legitimate interests in the region. In spite of these limitations, however, political reality has finally dawned: the record sea ice melt in 2007 (NSIDC 2007) and the growing push to exploit resources coincided with humanity’s last great territorial expansion through application of the UN Convention on the Law of the Sea. Under UNCLOS, countries may claim large areas of the “Extended Continental Shelf” (which in the Arctic Ocean means most of the region), a land-grab made much easier by the melting of the arctic sea ice.

Other international forums, such as the International Maritime Organization (IMO) or the regional fisheries management bodies, have shown no appetite for taking on the Arctic despite its evident importance. For example, guidelines for commercial vessel construction and operation in icy waters remain voluntary, meaning that a single-hulled, flag of convenience oil tanker can quite legally be driven across the Arctic, something that would be completely illegal in many other regions of the world. Foreign ministers and presidents have finally shown interest: ex-US Vice President Al Gore and French ex-Prime Minister Michel Rocard provided keynote addresses at the Arctic Council Ministerial in Tromsoe in 2009, highlighting the environmental and human security risks of climate change in the Arctic. In April 2009, Hilary Clinton addressed the inaugural Arctic Council/Antarctic Treaty System

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1. The Arctic Council was established in 1996 as a high-level forum by the governments of Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the USA, with a number of indigenous groups as “permanent participants.” Its role is to provide a means for promoting cooperation, coordination and interaction among the Arctic States, in particular on issues of sustainable development and environmental protection. Six expert working groups carry out the Council’s scientific work, focusing on such issues as monitoring, assessing and preventing pollution in the Arctic, climate change, biodiversity conservation and sustainable use, emergency preparedness and prevention, in addition to the living conditions of the Arctic residents. A ministerial meeting is held every two years, while senior bureaucrats meet twice each year.
plenary to celebrate the fiftieth anniversary of the Antarctic Treaty, and very recently, the Russian Prime Minister Putin opened a highly significant Russian-organized Arctic futures conference in Moscow (see Box 1). Prime Minister Stephen Harper of Canada has also made Arctic sovereignty a national security and identity issue in 2010 – an unprecedented occurrence.

As the ice retreats, the stakes for the surrounding five countries become larger: how can they best secure their (often unmapped) territories? How can they prevent others from using or abusing what is rightfully theirs? How can they simply and justly manage enormous and inhospitable areas that change so rapidly? A steady stream of major strategic policy announcements has flowed from Arctic and non-Arctic players in recent times: Canada, Denmark, Norway, Russia, the USA, the European Union, the Nordic defense organization, NATO, and others. This is unprecedented, and not just for the Arctic. It is an example of rich, stable countries being destabilized by the impacts of global warming. Notably, few of these issued statements discuss the fragility of the environment and ways to manage it.

Despite this sabre-waving, cooperation usually remains the name of the game in the Arctic. There are positive developments on specific issues, such as search and rescue, ship design, and scientific research. Arctic Council member states have chosen, for example, to work within International Maritime Organization processes to secure new regulations improving shipping safety, and have established a Task Force to develop a Search and Rescue Agreement (the first formal international agreement ever developed under Arctic Council auspices once signed, perhaps in 2011). They actively promote (but do not fund) collaborative research on a variety of issues in the region. However, there is little progress on the really important issues, such as defence, navigation rights, fishing, oil and gas, and conservation. One example both illustrates the complexity of the problem and partially motivates the Extended Continental Shelf land-grab: oil and gas.

OIL AND GAS: WHERE ENERGY SECURITY MEETS CLIMATE CHANGE

There are already more than 400 documented oil fields in the Arctic, containing about 10% of the world’s oil, mostly onshore. A recent study (Gautier et al. 2009) has expanded this figure: about one-third of the remaining oil and gas (mainly gas) on Earth is now thought to lie in and around the Arctic Ocean basin – with most of the resources lying offshore under less than 500 metres of water, and therefore accessible to drilling. The extensive, relatively shallow Arctic continental shelves may constitute the largest unexplored prospective area for petroleum remaining on Earth.

Production of oil and gas from the offshore Arctic remains limited, but exploration is booming. The oil industry has poured billions of dollars into exploration in the Canadian Arctic in the past three years, and NunaOil, Greenland’s national oil company, expects the number of active offshore licenses in Greenland to double in

2. The Deepwater Horizon accident, by comparison, occurred at a depth of 1500m.
the next 12 to 18 months. A lease sale in the US Chukchi Sea region in 2008 raised $2.7 billion. The Russian Shtokman gas/condensate field in the Eastern Barents Sea is one of the world’s largest prospects, but also one of the most challenging technically, lying in water depths over 300m and sited 600km north of the Kola Peninsula, in waters frequently infested with floating ice.

However, an additional and arguably even more dangerous practice has emerged: the transport of oil via routes through the Arctic Ocean (see Fig. 1). There have been no massive oil spills in the Arctic as yet; but according to the US Minerals Management Service (MMS 2007), the probabilities of a major spill over the lifetime of a block of exploration leases in Alaska are as high as one in five. We do have some knowledge of how bad they might be: the 1989 Exxon Valdez spill in Alaska occurred in sub-arctic waters, with no ice. Unlike spills in tropical environments, oil in (and near) the Arctic does not break down quickly: there is still a vast amount of oil in near-pristine state buried shallowly beneath the beaches and sea floor of Prince William Sound, off the south coast of Alaska.

Arctic ecosystems are especially vulnerable to catastrophic damage from oil because their fauna rely heavily on oil-soluble fats for metabolism and insulation. Moreover, there are enormous technical difficulties in the clean-up of any potential spill in icy waters: it simply is not possible in the vast majority of Arctic situations (WWF 2007). Skimmers either have major problems in recovering oil or fail to work entirely; burning may work on small spills in open water, but cannot scavenge oil in and underneath ice, or in certain types of ice. Furthermore, dispersants have not been developed sufficiently for arctic conditions and have catastrophic ecological effects: they remove the insulating properties of feathers and fur. An industry and government research programme completed in 2010 (the so-called “JIP,” or Joint Industry Programme, financed and undertaken by AGIP KCO, BP, Chevron, ConocoPhilips, Shell, StatoilHydro, and Total, led by SINTEF) is the largest R&D program on oil spill contingency ever initiated. JIP has taken some very small steps in developing new technology in laboratory conditions, but the results, presented to observers at an Arctic Council forum, were widely seen as showing very little progress indeed.

If one conjoins the basic technical difficulties and the highly sensitive nature of arctic ecosystems with huge problems in deploying the necessary equipment, often in dark and stormy conditions – the so-called “response gap,”– the likelihood increases that an Arctic spill would require days or even weeks before clean-up could begin. The amount of boom and dispersant currently warehoused around the Arctic Ocean would be grossly insufficient to deal with even a moderately-sized spill, and it is doubtful that transport options (helicopters, ships, etc.) would be available to reach most of the region. Even around Svalbard, one of the most accessible and well-resourced islands in the Arctic, the range of the few available rescue helicopters is limited. On these grounds, NGOs have publicly and repeatedly called for a...
moratorium on further oil and gas development in the Arctic until countries could
demonstrate that they could effectively clean up oil spills in the region. While the
industry has dismissed these calls, it has yet to demonstrate any capacity to clean
up a spill. Such positions and attitudes no longer hold water, especially when the
industry has failed so spectacularly in “easy” environments with readily available
response capacity, such as the Gulf of Mexico.

OIL AND FISH DON’T MIX
The five Arctic coastal states have all begun leasing large areas for oil and gas explo-
itation without putting in place the necessary safeguards, in a race for energy security
or, in the case of Greenland, for political independence. The industry, inherently
international, often works in consortia with unclear accountabilities and different
standards. The “trust us” rhetoric pervades both national and corporate communi-
cations. But what happens, for example, if a spill in the Russian part of the Barents
Sea affects the Norwegian fishing grounds? Or a Beaufort Sea spill affects Canadian
Inuit hunting areas? Or a spill occurs close to one of the four disputed boundary
regions? How do you reconcile oil and gas exploitation with clear international
commitments to protect polar bear habitat that prohibit any signatory from under-
taking activities that endanger it?

There are numerous legal instruments for protecting the Arctic marine environ-
ment (Koivurova and Molenaar 2009). However, the framework remains incoherent
and incomplete. UNCLOS is a very high-level treaty with no operational clauses or
agencies, no sanctions, and only one clause, Article 234 (ice-covered waters) specifi-
cally applicable to the polar regions. At the more operational level, there are serious
gaps that are too large and complex to be filled by simple adjustments of the existing
legal and institutional system. The governance framework is too focused on either
individual issues or sites to cover the entire Arctic. It does not take into account the
reality of ecosystems that cross sectoral and geographic boundaries, or that change
over time. It also fails to take into account the cumulative effects of different offshore
activities, such as fishing, shipping, and oil and gas.

The lack of a coherent governance regime covering important Arctic fisheries
resources has serious potential consequences. Taking the agencies responsible
for managing fisheries and simply extending their geographical coverage further
south is inappropriate: they have no mechanisms to cope with the Arctic's massive
environmental and biological changes. This illustrates the direct consequences of
climate change for environmental governance, and reflects the considerable opposi-
tion within the Arctic Council to active involvement in fisheries management and
conservation: it is considered by most states to be a national issue covered under
existing regimes. There is no single Regional Fisheries Management Organization
(RFMO) covering the region, a massive expanse including at least eleven Large
Marine Ecosystems. Many NGO observers, including Greenpeace, WWF and others,
consider the current approach to fisheries exploitation to be “managing based on
collapse,” only protecting a fishery after it has dwindled or disappeared, as in the
case of cod off the Atlantic coast of Canada. No nation presently addresses climate change effects in setting quotas or targets for fishing. Perhaps this state of affairs is not unusual: globally, the Food and Agriculture Organization of the United Nations (FAO) estimates that more than a quarter of marine fish stocks are overexploited (19%), depleted (8%), or recovering from depletion (1%), while more than half are fully exploited (FAO 2010).

The Arctic region supports rich fish stocks of significant international economic importance, supplying about 70 percent of the world’s total white fish supply and about half the fish eaten in Europe and North America (Fig. 2). The high biological productivity of the Barents Sea (1100 kg/km2, more than four times higher than the productivity of the world’s other oceans) arises from the fundamentals of Arctic marine ecology and the inflow of the Gulf Stream. The Barents Sea holds the last of the large cod stocks (the annual legal catch is around 450,000 tonnes, more than half the Atlantic cod available on the global market). Fishing is also big business in the Bering Sea: Alaskan pollock is the world’s second most important species, with annual quotas averaging 1 million tonnes, down from almost 3 million tonnes in 2006. These are large catches: in comparison, the world’s most-caught fish, the Peruvian anchoveta, leads with about 7.6 million tonnes taken in 2007. The North Sea produces about 2 million tonnes of fish each year, across all species. Illegal
fishing remains a large problem in the Arctic, but appears to be declining thanks to policing and better regulation. Fisheries resources are also extremely important to Arctic regional and coastal communities.

Data availability for Arctic fisheries management remains poor, according to the International Council for the Exploration of the Sea (ICES) Arctic Fisheries Working Group, and modelling the future behaviour of stocks has just begun. The impacts of climate change on this enormous fish resource are still unknown. While warmer Arctic surface and water temperatures, reductions in sea ice coverage and thickness, reduced salinity, increasing acidification and other changes will certainly affect Arctic marine ecosystems, accurate predictions cannot be made. The composition of these ecosystems will undoubtedly change – qualitatively, quantitatively, spatially and temporally.

The USA has recognized some of these risks: through the North Pacific Management Council, it recently (August 2009) announced a unilateral federal government moratorium on commercial fishing in most of its waters north of the Bering Strait, pending greater understanding of the potential impacts of climate change. This action, however, has not been mirrored by other Arctic coastal states.

Given the pace of change in the Arctic, prospects for coherent and sustainable oceans management appear small, unless an institution emerges with the legal and political mandate to enact protective changes. Rules, especially non-binding ones, are hardly enough to govern the “new sea” emerging from the sea ice.

**INTERLOPERS OR STAKEHOLDERS?**

Besides the Arctic Council members, many other states have real interests in the region. China, for example, can save almost half the time and fuel to transport goods to Europe by shipping via the North-East Passage. Europe has both commercial interests (fishing, shipping, oil and gas) and significant stakes in environmental protection. There is, however, currently no venue for discussing their concerns outside the UN General Assembly. Meanwhile, the Arctic “Coastal Five” (USA, Canada, Greenland/Denmark, Norway, and Russia) are closing ranks on the grounds of “collaboration,” while excluding other stakeholders and doing little beyond cementing their territorial claims.

**BOX 1. 2010 INTERNATIONAL CONFERENCES DEVOTED TO THE ARCTIC**

There are a plethora of conferences discussing the Arctic marine environment and governance, as a result of the growing interest in the region. Some recent arctic conferences include:

- Arctic Frontiers Conference, Tromsø, Norway, January 2010
- State of the Arctic Conference, Florida USA, March 2010
- Arctic Leaders Summit, Moscow, April 2010
- International Polar Year Oslo Science Conference, Norway, June 2010
- Arctic Science Conference: Water - Integrating Health, Habitat and Economy, Alaska September 2010
- Conference of Parliamentarians of the Arctic Region, Brussels, September 2010
- International Arctic forum The Arctic: Territory of Dialogue, Moscow, September 2010
- Environmental Security in the Arctic Ocean, Cambridge University, October 2010
- Arctic Council Senior Arctic Officials meeting, Faroe Islands, October 2010
- International Polar Foundation Arctic Futures Symposium, Brussels, October 2010
We therefore face something of a stalemate that will lead, inevitably, to an ever-decaying Arctic Ocean environment. Without clear leadership or a commonly-agreed agenda, the governance of the region drifts in response to everyday issues, events, and tensions. The simplest and most logical forum for this discussion is the Arctic Council, if the five Arctic coastal states would permit open discussion of these challenges. This could lead to exciting new developments in environmental governance, including formal “state” standing for indigenous peoples, the agreement of common goals for an entire ocean, shared responsibilities for management, and a true stewardship mandate on behalf of humankind that does not infringe national sovereignty. Such an outcome does not seem likely at present; instead, we see heightened tensions arising from nationalist statements and actions and a complete lack of leadership.

Who could lead? The USA (which still has not ratified UNCLOS) has proven unwilling to play a leading role in this debate, and Norway, the most neutral and conciliatory of the Five (and immediate past president of the Arctic Council) has been conspicuously silent for the last year. Canada effectively disqualified itself by making the Arctic a populist nationalist political issue while throwing stones at everyone within range, and Greenland is more focused on independence than regional leadership, even if it had the capacity to pursue the latter. Russia has therefore picked up the baton (perhaps to the shock and chagrin of the other four members) and for the past few months has clearly set the agenda. What direction will the Council now take? Perhaps the Five (USA, Canada, Greenland, Norway, and Russia) might step up and create a new institution driven by powerful common interests, a new form of stewardship and a voice for the Arctic. This would be less desirable than reforming the Arctic Council, but could be the rational solution in today’s nationalist Arctic world.

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On 20 April 2010, the British Petroleum Company’s Deepwater Horizon oil rig caught fire and sank into the Gulf of Mexico, in United States territorial sea. The accident killed eleven people and caused one of the largest oil spills in history. During the 85 days before the leak was stopped, an estimated 4.9 billion barrels of oil escaped, seriously damaging the surrounding ocean and approximately 400 kilometres (250 miles) of coastline.

DEEPWATER HORIZON: ONE OF THE LARGEST OIL SPILL IN HISTORY
The Deepwater Horizon spill was not the first in the history of offshore oil drilling, although it was one of the largest ever. Whatever the scale of such accidents, however, offshore drilling activity accounts for only 9% of marine hydrocarbon pollution: 68% of all oil spills are caused by maritime traffic incidents (Kloff and Wicks 2004). Nonetheless, the depth of the Deepwater Horizon’s drilling – 1,500 metres or 5,000 feet below sea level – contributed to the seriousness and exceptional size of the oil leak, preventing direct human intervention and making repairs complex, chaotic and slow. Strikingly, the growing offshore drilling industry has an economic vitality matched only by the risks it poses; it threatens marine and coastal environments because of ever-deeper wells and the difficulty of managing accidents at great depths. Moreover, offshore drilling is expanding considerably in the waters of countries lacking any means of monitoring or intervention. In this essay, we will propose that stronger international rules and regulations are the only way to address weaknesses in the current regulatory system.

Offshore oil drilling flourishes, providing 30% of the world’s oil production; its percentage of the total increases yearly. Deepwater offshore drilling, at depths of more than 500 metres or 1,650 feet, is expanding rapidly, driven by major technological progress in “seismic profiling and underwater installations” (Serboutoviez 2010) and higher crude oil prices that make it profitable. The Deepwater Horizon accident raises questions about this expansion. The ecological, human and financial costs and difficulties abruptly raised awareness about the large risks...
involved in deepwater oil exploration and drilling, motivating public and governmental questioning of the industry’s future.

**A DRILLING MORATORIUM’S TWIN DESTINIES**

As American officials investigated conditions leading up to the accident, the United States, Canada, European Union and the OSPAR (Oslo-Paris) Commission proposed two types of moratorium, on new drilling in currently-exploited areas and on opening new areas to oil exploration and/or exploitation. Although China and the West African states have an equal stake in offshore drilling, neither proposed suspending operations. Immediately after the oil rig explosion, President Obama’s administration ordered a six-month moratorium on deepwater drilling in the Gulf of Mexico and postponed a review of several large drilling projects off the coast of Alaska. After several political debates and judicial twists and turns, the American government lifted and then re-established a partial moratorium on drilling projects in the Atlantic and Gulf of Mexico, effective until 2017. In Canada, which has one deepwater drilling installation (operating at a depth of 2,500 metres or 8,000 feet), the Senate Committee on Energy, the Environment and Natural Resources held fact-finding hearings on issues raised by the Deepwater Horizon accident. The senators’ report concluded: “The Committee wishes to assure Canadians that Canada’s offshore oil and gas industry is in good hands, that we could not identify any justification for a temporary or permanent ban or moratorium on current offshore operations” (Senate of Canada 2010). The European Commission proposed a moratorium on new deepwater drilling licenses for European waters pending a draft of new regulations in 2011. The European Parliament rejected that proposal; the Commission

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1. OSPAR is the mechanism by which fifteen Governments of the western coasts and catchments of Europe, together with the European Community, cooperate to protect the marine environment of the North-East Atlantic.
then reiterated its position in favour of a moratorium, without further resolution by the year’s end. As this summary suggests, responses to the moratorium proposal varied widely, both among stakeholder countries and within European institutions. The economic clout of the offshore industry and its vital contribution to oil market stability have apparently deterred serious efforts to curb its growth.

THE NEED TO STRENGTHEN REGULATIONS
Governance of offshore oil drilling depends on self-regulation by drilling operators and oil companies. The industry’s use of advanced technology means that operators must monitor their own security measures, since public authorities lack the technical knowledge to perform detailed inspections. Furthermore, conflicts of interest are rampant in the industry: energy ministers, who sometimes double as oil ministers, often have contradictory dual mandates – to encourage oil production on one hand and to oversee security and inspections on the other. Within this governance framework, resting for the most part on private actors, all oil-producing countries and the European Union have agreed on the need for stronger national (and European) regulations and security for deepwater drilling operations.

TOWARDS INTERNATIONAL RULES FOR OFFSHORE OIL DRILLING
The current offshore international regime rests on the United Nations Convention on the Law of the Sea (UNCLOS 1982), and a few of its very general articles – e.g. 194, 288, 214. These address polluting activities on sea floors under national jurisdiction, as well as removal of oil drilling platforms at the end of their productive life. The offshore industry must also follow specific environmental protection conventions and regional agreements on preservation of marine biodiversity. Other activities related to offshore drilling, such as crude oil shipping and waste management, are regulated by much more specific conventions that require cooperation and reciprocal notice if an accident occurs. Only one international legal instrument specifically controls offshore oil drilling: the 1976 Barcelona Convention for the Protection of the Mediterranean Sea Against Pollution. Along with its 1994 Madrid Protocol, it aims to control pollution arising from exploring and drilling in the continental shelf, seabed and subsoil. The Madrid Protocol contains very strict clauses for drilling installations and operators’ obligations for pollution prevention and cleanup; it was ratified by six countries – Albania, Cyprus, Libya, Morocco, Syria, Tunisia – the minimum number required for it to take effect. Unfortunately, no European country except Cyprus has ratified the Protocol at present; once again, the gap between Europe’s professed good intentions and its actions proves evident.

AN URGENT NEED FOR REGULATION
Elsewhere, the international community has not seen the need to address ocean pollution caused by the offshore industry, leaving its management to operators, and coastal states. Companies continue to push the boundaries of the ecumene (human-inhabited world) with sophisticated technologies, under increasingly perilous environmental conditions, all the while extolling the virtues of sustainable and responsible development. Europe’s ratification of the Madrid Protocol would take a vital first step towards controlling such expansion and the pollution it entails. Other primary measures would include an independent audit of drilling platforms, as well as a systematic assessment of national authorization and control practices. Beyond these initial steps, a project to develop appropriate international regulations deserves the support of all stakeholder countries.
WORKS CITED

Plastic waste is increasingly found in marine environments. Entire plastic items appear regularly on beaches, accumulate on the sea bottom in both shallow and deep waters, or float at or below the ocean surface (Barnes et al. 2009). Many larger items, together with discarded fishing gear, are ingested by marine mammals, seabirds, turtles and fish, and can also entangle or smother them. Just as large debris presents a direct threat to large species (Gregory 2009), microplastics may prove hazardous to smaller species that inadvertently ingest them, including small planktivorous fish and filter feeders (sponges, corals, clams, etc.). These plastic items and fragments appear to be ubiquitous in the world's oceans, although the quantities found vary markedly according to ocean circulation patterns, river inputs, population density and level of industrialisation (although even unindustrialized areas receive current-borne debris). Of course, plastic debris is just one of many threats facing marine ecosystems (Allsopp et al. 2009), but one that nonetheless demands far greater attention in both research and policy terms. Paradoxically, although almost everyone aware of this pollution finds it alarming and unacceptable, relatively few make the immediate connection to their own excessive use and disposal of plastic goods. The present paper will examine the source and extent of plastics pollution in the ocean and outline its many threats to global marine life.

Since the mid-twentieth century, the global plastics market has grown steadily from around 1.5 million tonnes per annum to 250 million tonnes, representing current-borne debris). Of course, plastic debris is just one of many threats facing marine ecosystems (Allsopp et al. 2009), but one that nonetheless demands far greater attention in both research and policy terms. Paradoxically, although almost everyone aware of this pollution finds it alarming and unacceptable, relatively few make the immediate connection to their own excessive use and disposal of plastic goods. The present paper will examine the source and extent of plastics pollution in the ocean and outline its many threats to global marine life.

Since the mid-twentieth century, the global plastics market has grown steadily from around 1.5 million tonnes per annum to 250 million tonnes, representing...
a raw material demand equivalent to approximately 8% of global oil consumption (Plastics Europe 2009). Per capita use ranges from a high of some 100 kg annually in Western Europe and North America to 20 kg in developing Asian countries, where the industry sees the greatest potential for growth. Although plastics find their way into many products, over a third of production is used for short-life packaging purposes: true recycling of plastic wastes remains limited (accounting, even in Europe, for less than a quarter of post-consumer plastics in 2008). Accordingly, much of the waste plastic generated (about 10% of all solid waste on average) enters landfill sites, is burned as a source of energy in various industrial and waste disposal operations, or is simply discarded (Plastics Europe 2009). Plastics are extremely long-lived, although how long is a matter of debate – estimates range from hundreds to thousands of years. It has been suggested that, leaving aside incineration and fuel use, most plastic remains in the environment in its original form or as plastic fragments and particles. Studies carried out worldwide show that plastic items make up the bulk of marine litter found on beaches (Derraik 2002), as well as on the seafloor of urbanized coastal environments.

Plastic items may travel long distances before sinking under the weight of biofouling (colonization by barnacles and diverse organisms) or becoming stranded on the shore. It is often difficult to ascertain where an item entered the sea: it may have been thrown overboard from a ship or fishing vessel; identifying labels may have fallen off, and/or prevailing currents may have carried the item for some time. Smaller particles resulting from mechanical or photochemical degradation, or from the spillage of plastic pellets and powders, can also be ingested by marine animals, causing a variety of ill effects. Plastic particles also release added or adsorbed toxic chemicals that fish and other organisms can bioaccumulate (Teuten et al. 2007, 2009), with the potential for impacts along the food chain. Plants and animals colonize the surfaces of floating plastics and are consequently transported long distances into new environments; while not native to these habitats, they may nonetheless thrive and become invasive (Gregory 2009).

Some parts of the sea bottom seem to act as “sinks” of the areas sampled to date, the Mediterranean has the highest densities of sunken plastic debris, due to high human populations, high levels of shipping activity and relatively low tidal dispersion. Large-scale residual ocean circulation patterns also determine underwater accumulation sites, as is the case for areas of the North Sea and Atlantic Oceans (Barnes et al. 2009).

Just as sunken plastics tend to accumulate in specific places, so does floating plastic debris. The North Pacific Central Gyre (Moore et al. 2001) appears to be one such area (probably one of many): ocean and atmospheric circulation patterns bring together high densities of plastic debris. This gyre is not a permanent physical feature but rather a region of high atmospheric pressure in the North Pacific between California and Hawaii. It weakens and moves further south in winter, but nonetheless entrains and concentrates debris from a wider area of the Pacific Ocean. It has been estimated that the most intensively sampled core area of the gyre, approximately 1000 km in diametre, could contain as much as three million tonnes of floating plastic debris (Moore 2008) or approximately 5kg of plastics per square kilometre, with a high proportion of this total mass distributed as a widely dispersed suspension of fine “microplastic” fragments. The media calls these areas the “Eastern Garbage Patch” or “Pacific Trash Vortex.” Already there is some evidence for accumulations of a similar nature in other parts of the Pacific, including the “Western Garbage Patch” within a smaller gyre south of the Kuroshio Current near Japan (NOAA 2010). Some recent observations also note an “Atlantic Garbage Patch” centred on the Sargasso Sea (a region already long known to be an accumulation zone for floating biogenic material): the vast majority of individual fragments are less than 10mm in size and weigh less than 20mg (one fiftieth of a gramme) (Morét-Ferguson et al. 2010), although the long-term fate of debris in this region remains poorly understood.  

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2. Law et al (2010) note that, despite increases in global production of plastics in recent decades, levels of plastic debris in the Western North Atlantic and Caribbean appear to have remained relatively constant since the mid 1980s, indicating the existence of significant but so far undocumented pathways of loss from the water column.
The term “Pacific trash vortex” suggests an entire region covered by a large, obvious and easily visible patch of floating litter, one that could be detected from satellites or through aerial photography – in extreme terms, a “literal blanket of trash” (NOAA 2010). In reality – despite numerous relatively large items of debris, visible to observers on vessels or even from low-flying aircraft – these conspicuous items only rarely form larger agglomerations in the open ocean. However, their presence indicates a less visible but far more abundant and pervasive phenomenon: high concentrations of small fragments of plastic, detectable only by towing nets some distance through surface waters. Therefore, while aerial surveillance identifies large pieces of debris in other areas, such as in the North Pacific Tropical Convergence Zone (Pichel et al. 2007), such studies document only one extreme of the wide range of floating plastic debris.

It remains to be seen just how well the sample averages cited above represent the distribution of so-called “microplastic” debris across the gyre as a whole, and how that region compares to other similar convergences. Debris distributions appear to be inherently heterogeneous, both spatially and temporally. Despite a growing recognition and research interest in the issue over the past decade, the number, geographical extent and comparability of quantitative debris surveys remain remarkably limited to date. Given this paucity of basic descriptive data, assessing biological consequences is a considerable challenge.

While the consequences of entanglement and ingestion involving larger items and species are relatively simple to observe and document, microplastics ingestion research remains in its infancy: its physiological impacts and wider ecological significance urgently require study. A growing body of research documents both plastic-item ingestion by albatrosses and other seabirds and entanglement of dolphins, whales and turtles; however, few systematic surveys of smaller plastics exist, beyond those conducted along beaches in accumulation zones (most notably Hawaii). Moreover, researchers lack techniques for estimating the effects of smaller plastic fragments.

How can we address the known and as yet unknown threats to marine life posed by plastics pollution? Costly schemes aimed at collecting and recovering floating debris can only be effective at the local level, in shallow and enclosed in-shore waters. Beach-cleaning programmes fight a losing battle by treating the symptoms rather than the cause. Strategies such as recycling, taxing plastic bags, and using bio-based and biodegradable plastics may all play larger roles in the future, but will only ever address a fraction of the problem. Such strategies will work only if we are also willing and able to rethink our attitude to plastic consumption, to see it for the high-value, long-lived and non-disposable material it is, and to use plastic products and packaging sparingly and wisely.
FIGURE 1. CURRENTS CREATE THE PACIFIC VORTEX

Source: Adapted from NOAA (2010)
WORKS CITED


The ocean plays a crucial role in the planet’s climate system and its ability to sustain life. Human-caused climate change affects the ocean, preventing it from functioning properly. This poses serious threats to marine and coastal ecosystems, as well as to human societies along the coastlines – and everywhere.

CHANGING CLIMATE, CHANGING OCEAN, CHANGING PLANET

Over the next several decades, human-driven climate change will profoundly affect the sea and the marine resources upon which so many depend for food and livelihood. As we move into a more uncertain future, we require a much better scientific understanding of the complex ocean climate system to inform adaptation and mitigation strategies. The ocean plays a critical role in Earth’s climate system and in the planet’s ability to sustain life. It helps to regulate global cycles of heat, freshwater and carbon, as well as the magnitude and regional patterns of land temperature and precipitation. However, this ability is threatened by increasing anthropogenic carbon dioxide in the atmosphere and the resulting changes to global and regional climate patterns (Meehl et al. 2007). Observations show that climate change is already affecting the ocean in significant ways, diminishing its capacity for further climate change mitigation and imposing some unavoidable constraints upon marine biodiversity, ecosystem services, and human societies in the future (Allsopp et al. 2009).

Satellite data and in-situ measurements over the last several decades provide clear evidence that surface and subsurface waters are warming, ice shelves are disintegrating, sea-ice and glaciers are retreating in both the Arctic and along the Antarctic Peninsula, and freshwater is being redistributed on basin-wide scales. Climate change also affects river discharges to the ocean and alters global wind and ocean circulation patterns—all of which will have untold additional impacts on the planet’s interlinked physical, chemical and biological systems. Sea-level rise and associated impacts, such as submersion, salinization and so forth, also pose major threats to coastal natural and human systems.
All projections of Earth’s future climate rely on an accurate understanding of how the ocean will respond to warming. It presently removes about a quarter of all the carbon dioxide released by the burning of fossil fuels and deforestation and slows the rate of warming in surface temperature. However, the ocean also provides the largest reservoir for storing the excess heat generated by greenhouse gases. Globally, the average temperature of the surface ocean has already warmed by about 0.4 degrees Celsius since the 1950s; substantial warming clearly penetrates through the upper 750 metres of the water column and has even been found in bottom waters (Arndt et al. 2010). Under future climate scenarios, the ocean may prove less effective in removing excess atmospheric carbon dioxide and heat, resulting in an acceleration of already-observed atmospheric warming.

This chapter will examine these threats. It starts by exploring the two main direct consequences of atmospheric changes on the ocean – beyond simply warming – namely sea level rise and ocean acidification. It then shows how these changes will impact ecosystems and human systems, focusing in particular on polar regions, coral reefs, coastal areas and biodiversity. It concludes by highlighting some crucial challenges in both research and implementation.

**CLIMATE CHANGE INCREASES SEA LEVEL AND ACIDIFICATION**

**SEA LEVEL RISE** There is a growing scientific consensus that global sea level will rise by 0.5 to 1 metre by the end of this century, given current projections of future atmospheric greenhouse gas levels and climate warming. At the global scale, ongoing glacial melting and the thermal expansion of warming seawater drive rising sea level; it may rise even more if there is substantial melting of the ice sheets in either Greenland or west Antarctica. At the local scale of coastal ecosystems and human communities, a range of additional factors such as storm surge and land use will further affect coastline inundation rates.

**THERMAL EXPANSION AND LAND SUBSIDENCE CONSEQUENCES ON LOCAL SEA LEVEL RISE**

Roughly speaking, two types of causes influence local sea level: those that actually raise water levels, and those that lower land levels. Oceanic thermal expansion and exchanges of water between the ocean and other reservoirs are the two main factors raising water levels. Thermal expansion occurs when water is heated and its volume expands, elevating the surface level – a phenomenon influenced, obviously, by the increased average ocean temperatures that climate change brings. The second factor, water exchange, leads to sea level rise when the amount of water entering the ocean exceeds the amount lost through evaporation. Warmer average air temperatures lead to partial melting of the main reservoirs of freshwater, e.g. glaciers and ice sheets (primarily those in Greenland and the Antarctic). The two principle causes
of altered land levels are rising or subsiding tectonic plates and human-caused land subsidence, or sinking – a phenomenon resulting from groundwater extraction and/or the weight of built-up urban areas.¹

Sea level changes and impacts are not (and will not be) the same around the globe. In the first place, factors affecting surface elevation have differing local effects. Secondly, other local phenomena, such as ocean currents and atmospheric pressure, also change sea levels. Finally, the causes of land subsidence are highly local. Consequently, both global and local factors should inform assessments and adaptation strategies for coastal ecosystems and human-built infrastructure.

AN OLD PHENOMENON POSES NEW RISKS Rising sea levels are not a new phenomenon. For example, at the end of the last glacial period 25,000 years ago, the average sea level elevation measured 120 metres lower than at present. Ten thousand years ago, sea levels rose approximately two metres per century, or two to four times more than twenty-first century projections, if one excludes the prospect of substantial ice sheet melting. While projected sea levels for the coming century remain controversial, the amplitude or the speed of changes now appears less noteworthy than human societies’ vulnerability to them, due to development and urbanization along the coasts. We also note that progressive increases in average ocean elevation may worsen the effects of extreme weather events (e.g., hurricane generated storm surge), whose frequency and intensity may increase due to climate change.

Sea-level rise combined with climate change will have many negative effects on ecosystems and human societies. These will vary according to local conditions – beach erosion, groundwater salinization, heavier coastal flooding, and receding or disappearing deltas, estuaries and mangroves. In such cases, the effects of rising sea levels and climate change add to existing stresses. Deltas, for example, suffer from human activity: urbanization, agriculture and dam construction have had and probably will continue to have as destructive effects than those expected from climate change.²

ACIDIFICATION The chemical composition of seawater strongly influences the distribution of marine life and the productivity of the sea. For example, ocean phytoplankton require nutrients and inorganic carbon to grow, and animals need oxygen for respiration. However, human activities are changing ocean chemistry, often in fundamental ways (Doney 2010). Fossil-fuel combustion increases the level of carbon dioxide gas in the atmosphere, and about a quarter of this excess carbon dioxide subsequently dissolves into the ocean. The uptake of anthropogenic (human-caused)
carbon dioxide alters ocean chemistry, causing seawater to become more acidic; this makes it harder for some corals, mollusks and other marine life to build shells and exoskeletons from carbonate minerals (Doney et al. 2009). The current rate of ocean acidification is roughly 100 times higher than natural trends over at least the past several million years, and the extent to which marine organisms can adapt to such rapid change is unclear. Based on recent data, Figure 1 illustrates the extent of ocean acidification expected by 2050.

The biological effects of ocean acidification have been studied in the laboratory and through short-duration experiments at sea. The results suggest that ocean acidification may directly harm some ocean microbes, plants and animals while benefiting others. Less is known, at present, about how natural populations will respond or adapt to rising carbon dioxide levels in the wild or how this will alter marine communities. Key questions involve possible feedbacks through marine food webs, impacts on commercially important fisheries, and local and regional differences in the timing and intensity of effects. Nevertheless, the potential for acidification damage, to ocean life and ecosystems and coastal and marine biodiversity in general, remains highly troubling in light of the compounding anthropogenic pressures: pollution, overfishing, physical degradation (mechanical destruction of habitats) of coastal ecosystems due to erosion, loss of wetlands, and trawling. Coral reef ecosystems may be especially at risk. Finally, the combined impacts of acidification,
climate change and more local human activities may prove far worse than each threat in isolation.

**ECOSYSTEMS AND HUMAN SYSTEMS IN JEOPARDY**

**COASTAL AND MARINE BIODIVERSITY** Coastal and open-ocean ecosystems provide a range of services vital to societies and to the planet. Key services include (but are not limited to) providing food, cleansing and recycling water, supplying nutrients and chemicals to plants and animals, supporting recreation and tourism, regulating climate, and protecting infrastructures and populations against erosion and flooding.

The climate change impacts outlined above (rising sea levels, warming temperatures, ocean acidification, and altered ocean circulation) threaten and degrade ocean ecosystems – as do other human impacts (including enhanced coastal erosion, excess nutrient inputs, overfishing, and pollution). These changes can dramatically affect the growth, reproduction or distribution of marine species; this in turn may destabilize the structure of ocean biological communities, disrupt food chains, diminish the production of harvestable living resources, and reduce the biodiversity that plays a fundamental role in maintaining a healthy ocean.

Climate change effects are already observed in historical fish survey data. For coastal regions such as the North Sea and the east coast of North America, the geographical ranges of individual marine species have moved poleward and offshore to deeper waters over the last several decades, apparently in response to warming (see e.g. Nye et al. 2009). Most commercial fisheries species around the globe will probably see further and even more rapid poleward shifts over the 21st century, with the ranges of fish living in the water column more likely to change than those of bottom-dwelling fish (Cheung et al. 2010). This may result in significant changes in community structure and marine biodiversity; the Arctic and Southern Ocean may see an invasion of warm-water species, while the tropics and subpolar domains may experience high local extinction rates. Predicting the effect of climate change on fish population size is more challenging because warming and altered circulation patterns influence many factors – food supply, growth rates, disease, predation, seasonality or phenology – sometimes in opposite directions. Marine parasites and diseases are spreading poleward with warming waters. Moreover, the productivity of phytoplankton, the base of the marine food web, is projected to decline in the tropics and subtropics and remain constant or increase somewhat at higher latitudes (Steinacher et al. 2010).

**POLAR REGIONS** Earth’s polar regions appear to be some of the most sensitive ecosystems to the effects of climate change (ACIA 2004; Meehl et al. 2007), and understanding the role of the ocean in these regions is crucial. The evidence of dramatic recent environmental changes in the Arctic and Antarctic Peninsula is now widely
acknowledged: Arctic air temperatures are rising about twice as fast as the planetary average; sea ice and land-based glaciers are melting, in some cases more quickly than models project, and permafrost on surrounding land areas is thawing (Arndt et al. 2010; National Research Council 2010). Strikingly, the amount of sea-ice in the Arctic during late summer has shrunk by 30-40% in the last three decades (Fig. 2); computer models now suggest that the Arctic will be ice-free in summer by the middle of this century. On the Antarctic Peninsula, several large marine ice shelves (including the Larsen and Wilkins shelves) have collapsed either partially or fully, opening up large regions of new open water.

Such changes have already had startling and profound effects on marine and terrestrial ecosystems, and inevitably, on human populations (Anisimov et al. 2007). Changes in the distinctive marine ecosystems of the high latitudes have already been observed, with ramifications for such iconic species as polar bears, walruses and penguins, as well as for important commercial fisheries that feed millions of people worldwide. Many polar animals depend on sea-ice for food, habitat and breeding during part or all of their life cycles. The rapid disappearance of sea-ice has substantially reduced some populations, in some cases leading to local extinctions and replacement by species from more sub-polar environments (Ducklow et al. 2007). Climate change and retreating sea ice were key factors in polar bears’ “threatened” status listing under the U.S. Endangered Species Act.
At the same time, a decrease in Arctic summer sea ice may lead to a greatly expanded human presence in the Arctic, to wider exploitation of polar marine resources such as fisheries, oil and gas reserves, and the expansion of shipping routes into these fragile and poorly-understood areas. Evaluating the impact of these activities poses key challenges for the research community: it will need to develop improved observation systems and greater insight into polar climate and ecosystem dynamics. In particular, better information is needed on the sensitivity of polar ecosystems to increased human perturbations to better anticipate and evaluate their impacts.

**CORAL REEFS** Coral reefs cover nearly 600,000 square kilometres (373,000 sq. miles) of the planet; they are among the richest ecosystems in terms of biodiversity, and provide shelter to juvenile fish in particular. Beyond this intrinsic value, the thousands
FIGURE 4. THREATS WEIGHING ON CORAL REEFS

Source: Based on data from Wilkinson (2008)
According to a 2008 European Union report (Billé and Rochette 2008) on coping with rising sea levels, three main types of adaptation are usually favored, over and above non-action: protection, “accommodation” and strategic retreat. Table 1 summarizes some of the advantages and drawbacks. On this basis, we further explore examples of strategies to promote the conservation of coastal ecosystems and the protection of human installations.

Two examples of protective strategies for the conservation of coastal ecosystems:
(1) Allow environments to adapt on their own, i.e. do not let present or future infrastructure create irreversible pressures on the local environment; this would require moving some existing infrastructure and avoid building new infrastructure by creating buffer zones (no buildings or other structures allowed). Climate change should also be integrated into environmental impact studies and into land-use and town-planning documents.
(2) Strengthen the ability of coastal habitats and species to adapt on their own: climate threats exacerbate existing phenomena (fragmentation of ecosystems, pollution, over-exploitation, etc.). This increases the need for protected areas that are larger, better located, better managed, and more interconnected (networks of protected areas, corridors, greenbelts, etc.), as well as the need to reduce or move sources of occasional pollution (urban and industrial), diffuse pollution (agricultural) and habitat degradation (dredging, bottom trawling).

Four examples of strategies for protecting human installations:
(1) Plan the strategic retreat: move coastal installations inland to protect them from coastal hazards, i.e. make the coastal zones less artificial. Of course, it may be difficult to get the different players involved to accept this, but experience shows they can understand the process and rationale, at least when the stakes are quite low.
(2) Manage the risk by introducing risk prevention plans, town planning programmes, and regulations to limit or prohibit building on strips near the coast. The size of such “buffer zones” will depend on local topography, subsidence rates, erosion rates and projected sea-level rise over some time horizon (e.g., for 100 years, 2 metres altitude, etc.).
(3) Use insurance and compensation mechanisms, which are sometimes more effective and less costly than other types of measures. Use the price of insurance and even the impossibility to insuring property to create economic incentives for relocation.
(4) Use strong defenses to protect the coast when there is no other alternative (an environment that is highly urbanized, a very active economy that cannot be moved, critical infrastructure with long lifetimes such as power plants, etc.). Finally in certain contexts, artificially replacing sand on beaches may be less expensive than other options, but once again it must be thought through according to the specificities of the local context (size of the grains, the area where to put new sands, erosion patterns and downstream effects, etc.).

**TABLE 1. ADVANTAGES AND DRAWBACKS OF DIFFERENT ADAPTATION OPTIONS**

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Advantages</th>
<th>Drawbacks</th>
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</thead>
<tbody>
<tr>
<td>Protection</td>
<td>Efficiently solves local problems</td>
<td>High cost The erosion phenomenon is simply moved to other sectors Disruption of sediment function</td>
</tr>
<tr>
<td>Freeze coast line (dikes, rock-armor) or deal with causes of erosion (breakwaters, jetties, re-depositing sand)</td>
<td>Very socially acceptable</td>
<td></td>
</tr>
<tr>
<td>“Accommodation” (adjustment of natural or human systems to a new or changing environment)</td>
<td>A gain of space and conservation of natural shore condition Local policy Low cost Compensation and extra cost of protecting shore are avoided</td>
<td>Local measures and inconsistent applications Measures do not meet long-term imperatives</td>
</tr>
<tr>
<td>Adapt to the phenomenon by enacting construction regulations (zoning, raising foundations, etc.), and measures to compensate for destroyed property or systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategic retreat</td>
<td>More efficient in the short and long-term No maintenance No impact on sedimentary function</td>
<td>A need for space inland and land where infrastructures and activities can be moved to Difficult to implement in zones where socio-economic interests are important or infrastructures and urbanization are extensive Not very socially acceptable</td>
</tr>
<tr>
<td>Move the objects threatened further inland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-action</td>
<td>Preserve natural functions</td>
<td>Implementation limited to low-interest natural spaces</td>
</tr>
<tr>
<td>Decide to take no action</td>
<td></td>
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</tbody>
</table>

Source: Adapted from Paskoff (2001) and according to Carreno et al. (2008) in Billé and Rochette (2008: 2-3)
of reef species provide a primary food source for about thirty million people. In addition, coral reefs have several other functions – primarily, protecting coastlines by buffering them from ocean swells. They also possess substantial economic value, for example from tourism. Today, coral ecosystems face serious threats from human activities as well as from climate change and ocean acidification.

Coastal communities frequently overfish the reefs, taking larger catches than the ecosystem can naturally replenish. Land-based pollution – from deforestation, sediment erosion and/or urban, industrial and agricultural waste – degrades water quality, affecting the highly sensitive coral polyps that build the reefs. These stresses have already considerably harmed marine biodiversity; they exacerbate the impact of climate warming and of natural phenomena, such as the episodic warming of surface ocean waters in the eastern tropical Pacific known as the El Niño Southern Oscillation or ENSO. In 2008, the Global Coral Reef Monitoring Network estimated that 20% of the world’s reefs were definitively destroyed; nearly 50% were in threatened to very threatened condition, and only 30% were not yet at risk (Figs. 3-4) (Wilkinson 2008).

The trend toward urban development along coastlines worldwide suggests that pressure on coral reefs will not lessen: global climate-change effects only add to the local and regional threats. Beyond possibly intensifying storm activity, climate change’s three primary processes will also affect reefs’ survival: higher surface water temperatures, increased ocean acidification and rising sea levels. Coral animals (polyps) are very sensitive to temperature variations: coral bleaching – the loss of color from symbiotic algae under stressful conditions – has been linked with unusually high water temperatures. The zooxanthellae (tiny single-celled algae that live in symbiosis with polyps) abandon the polyps, depriving them of needed nutrients and causing their colors to bleach out. The polyps may also die because of changes in the ocean’s chemistry, resulting in bleaching as well. Seawater becomes more acidic as levels of dissolved carbon dioxide increase, harming the polyps’ ability to construct their limestone structures. Rising sea levels force coral to either grow taller or die since their zooxanthellae need to be near surface light to photosynthesize. No one knows precisely how coral will react to rising ocean levels, but three hypotheses have been advanced: (1) they will grow at the same rate the water rises; (2) they will go through a relatively agonizing period and then catch up to the higher levels; (3) they will not be able to keep up and will die.

COASTAL AREAS Over and beyond their menace to reefs, climate change and the growing local and regional human footprint also threaten the coastal environments

HUMAN POPULATIONS ACROSS THE GLOBE WILL THUS HAVE TO ADAPT TO IMPACTS THAT WILL GROW IN MAGNITUDE WITH TIME

3. ENSO involves both the ocean and the atmosphere: it perturbs global atmospheric circulation, modifies various regional climatic conditions (particularly hurricane tracks and numbers) and increases the risk of flooding east of the Pacific and drought to the west. ENSO is also known to collapse fisheries.
upon which we depend for so many resources. Rising sea levels caused by climate change threaten low-lying coastlines and communities (Nicholls et al. 2007), and further projected rises this century will have wider socio-economic and environmental impacts. Half of Earth’s people live near the coast, on less than one-fifth of its land mass. Two-thirds of the world’s largest cities are on the coast. Low-lying regions and island nations are threatened with inundation and are more vulnerable to storm surges and flooding.

In coastal areas, as elsewhere, climate change is clearly not the only threat, but rather adds to other existing human stresses. For instance, the combination of coastal development, pollution, climate change and sea-level rise can destroy valuable salt-marsh, estuarine, sea-grass and mangrove ecosystems that serve as key marine nurseries for large commercial fisheries. Likewise, excess nutrient runoff from land-based agriculture is a particular problem for many coastal and estuarine regions, producing low-oxygen hypoxic zones (“dead zones”) that harm fish and marine invertebrates. In some coastal upwelling regions, shifts in ocean circulation and wind patterns also enhance the frequency and severity of coastal hypoxia (Doney 2010). The burden of adapting to such coastal changes will fall disproportionately on poor and lesser-developed countries (See Box 1).

**CHALLENGES**

The urgency of climate change threats, especially those exacerbated by other human activities and natural processes, calls for immediate action to mitigate further change and reduce other environmental pressures on the ocean and coasts – overfishing, nutrient eutrophication, and wetland destruction. The prospect of future progress in ocean science should not be an excuse for postponing decisive political action. It seems clear now that we have committed the planet to a substantial level of climate change – whatever action is taken to reduce both current and future greenhouse gas emissions – and decisions made in the next several decades will affect Earth’s climate for centuries or even millennia (Solomon et al. 2009; National Research Council 2010). Human populations across the globe will thus have to adapt to impacts that will grow in magnitude with time, particularly if the will to pursue mitigation measures remains as low as it does today. Coastal areas and communities are clearly vulnerable to changing environmental conditions and will have to prepare for and adapt to their effects.

Some important adaptation options already exist: developing well-managed aquaculture in specific areas instead of increasing the harvest of wild stocks; building resorts and housing relatively far inland instead of destroying coastal dunes; developing consumer awareness about fish and fisheries. More generally, three main factors are crucial when developing adaptation strategies. First, it is important to consider how climate change will affect human society in the future and not simply the present, even if this adds to the complexity. This will require long-term integrated projections, for example in population growth, coastal urbanization, and food demands. Second, every solution is relevant only within the context in which
it is developed. A “good practice” for climate adaptation under one specific set of conditions could prove detrimental under another; it could create irreversibility or reinforce non-climate related stresses. Third, climate adaptation strategies must also fit within both economic and (geo)political constraints; they must account for incentives driving the actions of individuals, businesses, organizations and governments that could either advance or undermine the adaptation strategy’s objectives.

At the same time, a network of global, regional and national institutions is desperately needed to support a climate services program. Such an effort would gather and synthesize climate and ocean information, data products and services, and would foster dialogue between providers and users. Most importantly, however, politicians, policy-makers and an informed public must show a willingness to act on the best information that the ocean science community has to offer. Enhancing scientific knowledge should thus be a priority.

This commentary is partly based on a white paper prepared by the Marine Biological Laboratory and Woods Hole Oceanographic Institution for the Oceans Day held at the UNFCCC COP-15 in Copenhagen, December 2009. See http://www.woodsholeconsrtium.org for more information about the Woods Hole Consortium. It is also based on the main results of the CIRCE research project (“Climate change and impact research: the Mediterranean environment”) funded by the European Union (DG Research). For more details, see http://www.circeproject.eu/
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