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The State of the Ocean 2013: Perils, Prognoses and Proposals

Executive Summary

The scientific evidence that marine ecosystems are being degraded as a direct result of human activities is overwhelming; and the consequences both for the vital and valuable ocean goods and services we rely on, including for the maintenance of a healthy Earth system, are alarming. Recent assessments by the UN's climate change panel the IPCC, for example, show that these changes are progressive and relentless: whilst terrestrial temperature increases may be experiencing a pause this is not true for the ocean, which continues to warm regardless. For the most part, however, the public and policymakers are failing to recognize –or choosing to ignore— the severity of the situation and are not taking the action necessary to address it.

The International Programme on the State of the Ocean (IPSO) is publishing a set of five papers on ocean stresses, impacts and solutions by leading international experts to present the key findings of the workshops it held in 2011[1] and 2012* in partnership with IUCN and its World Commission on Protected Areas. The purpose of these workshops, and the papers published today, is to promote a holistic, integrated view of both the challenges faced and the actions needed to achieve a healthy global ocean for the future.

The central messages from the workshops are that the risks to the ocean and the ecosystems it supports have been significantly underestimated; that the extent of marine degradation as a whole is greater than the sum of its parts; and that it is happening at a much faster rate than previously predicted.

The 2012 workshop additionally reviewed new material and evidence, available since the workshop in 2011, and concluded that the threats to the ocean were even faster, bigger and closer than the first workshop set out: faster with an accelerated rate of change, bigger in scale, and closer in time in terms of the impacts being felt.

The five papers aim to contribute to actions to address the problems we now face by analyzing the effects and links between the major stressors – the climate change "deadly trio", our overexploitation of marine resources, in particular through fishing, and continued pollution and contamination of the ocean – and identifying the best available options for addressing them effectively. The titles of the five papers, which are explored in more detail later on, together with their key messages, are:

- **Climate change and the ocean – What does the future hold?**

The ocean is shielding us from the worst effects of accelerating climate change by absorbing excess CO_2 and heat from the atmosphere. The twin effects of this – acidification and ocean warming – are combining with increased levels of deoxygenation, caused by nutrient run-off from agriculture near the coast ,and by climate change offshore, to produce what has become known as the ocean's 'deadly trio' of threats whose impacts are potentially far greater because of the interaction of one on another. The scale and rate of this change is

[1] **The Summary of the conclusions and recommendations of the international Earth system expert workshop on ocean stresses and impacts was published in June 2011 and received widespread international attention.**

unprecedented in Earth's known history and is exposing organisms to intolerable and unpredictable evolutionary pressure.

- **Climate change impacts on coral reefs: Synergies with local effects, possibilities for acclimation, and management implications**

Coral reefs are extremely vulnerable to the impacts of climate change. It is imperative and urgent that emissions targets below 450 ppm CO_2e be agreed and implemented, combined with coordinated programmes at local and regional levels to reduce other stress factors and boost resilience; otherwise it is predicted that most reefs will be lost as effective, productive systems within a few decades.

- **Fisheries: Hope or despair?**

The global picture of ongoing depletions of fish stocks, the degradation of food webs, threats to seafood security and poor quality of most fishing management is alarming and demonstrates that recent more optimistic outlooks are misplaced. Reversing these global trends towards "despair" demands urgent, focused, innovative action to promote effective community- and ecosystem-based management.

- **Evaluating legacy contaminants and emerging chemicals in marine environments**

Protecting marine ecosystems and seafood resources from the adverse effects of complex cocktails of 'legacy' (already regulated) contaminants, emerging (unregulated) chemicals and natural chemicals (e.g. algal biotoxins) remains a critical, unresolved global problem. The economic and infrastructural challenges posed by such a wide variety of chemicals means that the most cost-effective approach is to implement a targeted, effects-based strategy that prioritizes key groups of chemicals of most concern.

- **Ocean in peril: Reforming the management of global ocean living resources in areas beyond national jurisdiction**

The current system of high seas governance is fraught with gaps, directly leading to the mismanagement and misappropriation of living resources, and placing our ocean in peril. It is time for a new paradigm that can only come about through the fundamental reform of existing organisations and systems, overseen by a new global infrastructure to coordinate and enforce the necessary action. Crucially, the authors call for the negotiation of a new implementing agreement for the conservation and sustainable use of biodiversity in areas beyond national jurisdiction.

Concluding Statement

Founded to investigate the impacts of anthropogenic stressors on the ocean and identify workable solutions to eliminate or remedy them, IPSO – with the support of IUCN – is unique in bringing together experts from a range of disciplines within marine science, as well as the legal, policy and communications arenas, in order to highlight the connectivity and synergy between the multiple stressors impacting the ocean and treat them collectively. This holistic approach is essential to developing viable, practical solutions that consider marine ecosystem health, socio-economic drivers, as well as the larger Earth system perspective. Achieving this integrated, ecosystem-based management of the ocean and its resources is an immensely complex challenge but these five papers all stress that we have a vast wealth of information, expertise, management tools and proven solutions at our disposal.

The two IPSO workshops showed that deferring action will increase costs in the future and lead to even greater, perhaps irreversible, losses. If we want to continue to benefit from the goods and services the ocean has provided for millennia, we must radically change the way we view, value, use and govern marine ecosystems.

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As a matter of urgency, IPSO urges that:

- There should be a significant reduction in global $C0_2$ emissions to limit temperature rise to less than 2^oC or below 450 CO_2e . Current targets for carbon emission reductions are insufficient in terms of ensuring coral reef survival, especially as there is a time lag of several decades between atmospheric CO_2 and CO_2 dissolved in the océan

- Effective implementation of community - and ecosystem-based management, favouring small-scale fisheries is achieved. Examples of broad-scale measures include introducing true co-management with resource adjacent communities, eliminating harmful subsidies that drive overcapacity, protection of vulnerable marine ecosystems, banning the most destructive fishing gear and combatting IUU fishing.

- The global infrastructure for high seas governance should be enhanced so that it is fit-for-purpose. A global high seas enforcement agency should be established to provide integrated and coordinated monitoring and enforcement for the full range of threats to ocean sustainability and global security. Most importantly, a new implementing agreement for the conservation and sustainable use of biodiversity in areas beyond national jurisdiction under the auspices of UNCLOS should be introduced urgently.

Summary of the Papers

1. Climate change and the ocean – What does the future hold?

We have been taking the ocean for granted. It has been shielding us from the worst effects of accelerating climate change by absorbing excess CO_2 from the atmosphere, and this has created a "deadly trio" of impacts – acidification, warming and deoxygenation – which are combining to dramatic effect on the flora and fauna of the ocean, and exacerbating the effects of other factors, such as pollution, eutrophication and overfishing. According to a flood of recent literature, most, if not all, of the Earth's five past mass extinction events have involved at least one of these three symptoms of global carbon perturbations, all of which are present in the ocean today.

More worrying still, the scale and rate of the present day carbon perturbation, and resulting ocean acidification, is unprecedented in Earth's known history. Today's rate of carbon release, at approximately 30 Gt of CO_2 per year, is at least 10 times faster than that which preceded the last major species extinction (the Paleocene Eocene Thermal Maximum extinction, or PETM, ca. 55 million years ago), while geological records indicate that the current acidification is unparalleled in at least the last 300 million years. We are entering an unknown territory of marine ecosystem change, and exposing organisms to intolerable evolutionary pressure. The next mass extinction event may have already begun.

Developed, industrialised human society is living above the carrying capacity of the Earth, and the implications for the ocean, and thus for all humans, are huge. It is now certain that the uptake of CO_2 into the ocean is outstripping its capacity to absorb it, resulting in a reduction in ocean pH (i.e. increase in acidity) coupled with a lowering of its CO_2 buffering capacity. Acidification is causing a substantial decline in carbonate ion concentrations and resulting in 800km^2 of the seafloor becoming exposed to waters that are unsaturated with respect to aragonite every year. The rate of acidification is 50% faster at high latitudes compared to sub-tropical waters because of the effects of temperature on ocean chemistry. Biological impacts are already being observed as acidification is a direct threat to all marine organisms that build their skeletons out of calcium carbonate, including reef-forming corals, crustaceans, molluscs and other planktonic species that are at the lower levels of pelagic food webs. If current levels of CO_2 release

continue we can expect extremely serious consequences for ocean life; at CO_2 concentrations of 450-500 ppm (projected in 2030-2050) erosion will exceed calcification in the coral reef building process, resulting in the extinction of some species and decline in biodiversity overall.

The second prong in the "deadly trio" is ocean warming. The average temperature of the upper layers of the ocean has increased by 0.6°C over the last 100 years, with direct and well-documented physical and biogeochemical consequences. The impacts which continued warming is projected to have in the decades to 2050 include: reduced seasonal ice zones, including the disappearance of Arctic summer sea ice; increasing stratification of ocean layers, leading to oxygen depletion; increased venting of the GHG methane from the Arctic seabed; and increased incidence of anoxic and hypoxic (low oxygen) events.

The biological implications encompass: sea temperature-driven range shifts and species invasions, in particular a projected movement poleward of 30-130 km, and 3.5 m deeper, by marine fish each decade; loss of 60% of present biodiversity of exploited marine fish and invertebrates, including numerous local extinctions; increased disease prevalence as a result of pathogen range expansions; increased extinctions, with ice-dependent polar species such as seals and penguins at greatest risk; and mass coral bleaching leading to increased coral reef mortality, and a predicted phase shift from coral domination to algal domination in the Great Barrier Reef and Caribbean reefs. The synergistic effect of acidification and warming are considered likely to lead to rapid and terminal decline of tropical coral reefs by 2050. All these changes will have massive economic and food security consequences, not least for the fishing industry and all those who depend on it. It is predicted that the redistribution of commercial fish species through range shifts will lead to a 40% decrease in catch potential in the tropics by 2050, and 30-70% increase in the high-latitude zones – where richer societies and more industrialised fisheries are located.

To complete the triumvirate, there is deoxygenation, the accumulating evidence that the oxygen inventory of the ocean is progressively declining. Predictions for ocean oxygen content suggest a decline of between 1% and 7% by 2100. This occurring in two ways: the broad trend of decreasing oxygen levels in tropical oceans and areas of the North Pacific over the last 50 years; and the dramatic increase in coastal hypoxia (low oxygen) associated with eutrophication. The former is caused by global warming, the second by increased nutrient runoff from agriculture and sewage. Impacts of the broad deoxygenation on marine species and ecosystems are varied, but include habitat compression for large ocean predators, such as marlin, which have a high oxygen demand, which is likely to increase the vulnerability of these large fish, which also include tuna species, to fishing pressure. Another symptom of climate change has been the incursion of anoxic (no oxygen) waters into the inner shelf adjacent to the upwelling zone along the west coast of North America, with such events occurring in 2006, 2007 and 2008 having negative effects and causing mortalities among marine fauna.

Oxygen depleted, or hypoxic, zones have spread since the introduction of industrial fertilizers in the 1940s, and since the 1960s the number of "dead zones" has doubled every ten years, concentrated in areas near human population centres and large water sheds. Inland seas and estuaries – including the Black Sea, the Kattegat, and Chesapeake Bay – are particularly badly affected, and number of hypoxic zones is thought to be underestimated as their occurrence is not reported in many geographic zones. Over long periods of time, hypoxia or anoxia will eliminate most benthic fauna within areas vulnerable to the formation of dead zones, causing ecosystems to become dominated by microorganisms (some of them pathogenic), and harmful algal blooms. Climate induced and eutrophication induced hypoxia may interact as elevated temperatures enhance stratification and may increase the likelihood of eutrophication-induced coastal hypoxia.

It is the simultaneous occurrence of the "deadly trio" of acidification, warming and deoxygenation that is seriously effecting how productive and efficient the ocean is, as temperatures, chemistry, surface stratification, nutrient and oxygen supply are all implicated, meaning that many organisms will find themselves in unsuitable environments. These impacts will have cascading consequences for marine biology, including altered food web dynamics and the expansion of pathogens. To make matters even worse, this is all happening to marine ecosystems already undermined by other human pressures such as

overfishing, eutrophication and pollution. The adaption of species to these altered conditions is in some cases possible – as is migration, though as warming demands a poleward migration while acidification encourages the movement to warmer more equatorial waters the "green pastures" will become increasingly scarce and competition for them fierce. Mass extinctions happen in the geological equivalent of overnight; we may already have entered into an extinction period and not yet realized it. What is certain is that current carbon perturbations will have huge implications for humans, and may well be the most important challenge faced since the first hominids evolved. The urgent need to reduce the pressure of all ocean stressors, especially CO_2 emissions, is well signposted.

2. Climate change impacts on coral reefs: Synergies with local effects, possibilities for acclimation, and management implications

Corals reefs are one of the most vulnerable ecosystems to climate change impacts, in particular to acidification and warming and the synergy between them. These factors also interact with local pressures from pollution, overfishing and shoreline alterations to further reduce the resilience of coral reefs and amplify the effects of climate change. This is a particular concern as a substantial number of the world's poorest people depend on coral reefs, including for reef-supplied food. Prior to the major warming-induced coral bleaching event of 1998, local factors such as nutrient runoff and destructive fishing practices were seen as the greatest threat to corals; since 1998 – when some of the most remote reefs, previously considered at low risk, were worst effected – the attention has shifted to climate change, but it is vital that the interaction between all factors is considered when making management decisions.

Coral bleaching follows anomalously high seawater temperatures, and such episodes have been increasing steadily over the past three decades in terms of both frequency and intensity. Ocean acidification is another direct threat to corals as increased bi-carbonate coupled with reduced calcium carbonate (a result of acidification) drastically reduces the growth of coral skeletons and eventually will dissolve existing calcified matter. Acidification has also been identified by some researchers as a trigger for coral bleaching and can slow down post-bleaching recovery. The ocean is already on average 0.1 pH units more acidic than in the pre-industrial period and this reduction in pH is expected to reach 0.4 pH units more acidic by 2100. At 450ppm CO_2e (associated with a 2^{o}C temperature rise) coral reefs will cease to grow, at 560ppm CO_2e (approx. 3^{o}C rise) they may start to dissolve. The response of corals to acidification may also be synergistic with other factors, notably temperature, to multiply and amplify effects. Interaction between coral bleaching, acidification and diseases are expected to negatively influence coral survival, growth, reproduction, larval development and species development.

The authors of this paper consider it unlikely that coral reefs can adapt or acclimatize to these fast changing environmental conditions, i.e. decadal rather than millennial rates of climate change. Responses to increasing episodic mass bleaching and mortality events that have already occurred indicate that adaptation is not happening fast enough to match the rate and frequency of warming events and hope that species will acclimatize appears to be misplaced. However, some species are more affected than others leading to fundamental changes in the composition of reef communities. In many coral reefs suffering from degradation, the structure of seabed ecosystems is already characterized by low coral cover and diversity and the dominance of seaweed, algae and soft-bodied invertebrates. It is vital that local efforts to reduce the impact of direct stressors such as pollution and fishing and aid reef recovery, are stepped-up. It is tempting to consider such local initiatives futile in the face of rising CO_2 levels, but evidence shows that reefs that have fewer local pressures (such as in the Chagos atolls) recover better from high temperatures than those where there are many additional pressures (such as in the Seychelles). This presents a strong incentive for local action to boost the resilience of coral reefs to global stressors.

At the global management level, the key message is that the current targets for carbon emission reductions are unrealistic in terms of ensuring coral reef survival, especially as there is a time lag of several decades between atmospheric CO_2 and levels of CO_2 dissolved in the ocean – a factor that appears to be beyond the grasp of most policy-makers. Put simply, the target to limit temperature rise to 2^{o}C, or remain below 450

CO_2e, is not sufficient for coral reefs to survive. Lower targets should be urgently pursued. Even more worrying, some socio-economic evaluations conclude that even the 2°C target is too hard to bear and are encouraging settling for a 650ppm CO_2e stabilization level. This "easy" economic compromise would be completely fatal for coral reefs. It is imperative that targets below 450 ppm CO_2e be agreed and implemented, combined with coordinated programmes at local and regional levels to reduce local stress factors and boost resilience. Without such dedicated action it is predicted that most reefs will be lost as effective, productive systems within a few decades.

3. Fisheries: Hope or despair?

We have drawn heavily from the ocean to feed millions of people over the millennia but have the last decades of increasingly intense and industrialised fishing done irreversible harm to its biodiversity? For the past ten years, fisheries worldwide have been generally reported as being in an extremely poor state with no improvement in sight and forecasts warning of the collapse of ocean fisheries as we know them. However, more recently, some studies have suggested that fisheries depletions have turned the corner, that things may have always been better than we thought and are now improving. Sadly, the authors of this review for IPSO conclude that this optimistic outlook is misplaced, largely because the analysis it is founded on was primarily based on evidence from better-managed, developing world fisheries. Deeper analysis of the status of the majority of world fisheries instead confirms the previous dismal outlook: serious depletions are the norm, management quality is poor, and catch per unit effort continues to decline.

The global picture for further fisheries species extinctions, the degradation of food webs and seafood security is alarming and the depressingly poor quality of fishing management is one key issue that challenges any claim that things have improved. A recent global assessment of compliance with Article 7 (fishery management) of the 1995 FAO Code of Conduct for Responsible Fisheries, awarded 60% of countries a "fail" grade and saw no country identified as being overall "good". Some of the worst compliance results were related to catch issues that should be straightforward to address, such as tackling bycatch, discard and the scourge of "ghost fishing" by lost fishing gear. All were awarded "fail" scores world-wide and remain hugely destructive problems. The Indian Ocean and the Mediterranean scored worst of all.

There has been widespread failure among the principal fishing countries to adopt the key features of ecosystem-based fishery management, and "silver bullet" approaches that rely heavily on one type of management solution (e.g. property rights, or marine protected areas) have been shown to be of only limited use. While there are some promising signs that the management of some fisheries in the developed world is improving, over 80% of the world's fish are caught elsewhere, in many cases in fisheries where stocks are not assessed. The analysis suggesting that fisheries status is improving was based on just 16% of world fisheries, mostly in Europe and North America. More recent, global analysis suggests that catch per effort is declining and in 2012 FAO determined that 70% of world fish populations are overexploited of which 30% have biomass collapsed to less than 10% of unfished levels. Meanwhile Illegal, unregulated and unreported (IUU) fishing remains a huge problem; the total extent of IUU fishing is uncertain but estimated to be at least 35% of the global catch. This phenomenon is related to another trend which is the dark side of improved fisheries management and control in the developed world; there has been an often uncontrolled redistribution of effort into poorer regions, causing serious overexploitation and the unethical sequestering of local benefits – including valuable sources of food - and biodiversity.

Some fisheries scientists warn that we are living through a major catastrophe in our exploitation of fish stocks and regard most of the management that is taking place to be working to support a globalized commercial enterprise marketing commoditized fish, at the expense of biodiversity and conservation, as well as long term food security. In most parts of the world there is very little science-based action to conserve the non-fished components of the ecosystem, whether top predators or low trophic level groups. Even where many fisheries are assessed, as in the developed world, there is almost no explicit inclusion of these non-fishing factors. Compounding this already dire situation, climate change is expected to continue to cause range shifts in important commercial species, reduce the actual body size of fishes, and make

management more challenging and unpredictable. While there are still gaps in our understanding of climate change effects on fisheries, there is already sufficient scientific information highlighting the urgent need to implement mitigation and adaptation policies to minimize the impacts.

A fundamental solution to many of these problems is to ensure effective implementation of community- and ecosystem-based management, favouring small-scale fisheries. Examples of broad-scale measures include introducing true co-management with resource adjacent communities, eliminating harmful subsidies that drive overcapacity, protection of vulnerable marine ecosystems, banning the most destructive fishing gear, and combating IUU fishing. The challenge is to effectively and ethically implement these solutions and this requires effort and cooperation at all levels from small communities to international bodies. There are examples that indicate that declining trends can be reversed but action needs to be urgent, focused, innovative and global if we are to avoid tipping us further, and irreversibly, onto the despair side of the hope/despair balance.

4. Evaluating legacy contaminants and emerging chemicals in marine environments

Complex mixtures – or "cocktails" – of 'legacy' contaminants (that are now subject to control, such as heavy metals and persistent organic pollutants), emerging chemicals (defined as chemicals that have been detected in the environment, but are currently unregulated, the fate and biological impacts of which are poorly understood) and natural chemicals (e.g. algal biotoxins) in marine ecosystems pose a threat to human health via the food chain, and represent important scientific, economic and health challenges. Protecting marine ecosystems and seafood resources from the adverse effects of chemical contaminants therefore remains an important issue.

Analytical chemistry plays a key role in evaluating to what extent regulatory steps (such as regional conventions controlling certain persistent, bioaccumulative and toxic, or PBT, chemicals) have been effective in leading to reduced emissions of these legacy contaminants into marine environments. Evidence suggests that a number of these regional conventions succeeded in reducing inputs and levels of certain PBT legacy contaminants in many areas, although problematic exposure scenarios do still exist, for example lingering high levels of polycyclic aromatic hydrocarbons (PAH) in UK estuaries. In parallel, the application of biomarkers and bioassays integrated with analytical chemistry has strengthened the evidence base to support an ecosystem approach to manage marine pollution problems. In recent years, however, the increased sensitivity of analytical chemistry, toxicity alerts and wider environmental awareness has led to a focus on emerging chemical contaminants (including brominated flame retardants, microplastics, nanomaterials and recreational drugs). High profile recent examples – such as the Prestige and Deepwater Horizon oil disasters in Spain and the US, and the ongoing pollution of the Pearl River estuary in China - have also highlighted the huge damage and cost that marine pollution can incur and helped focus public and political attention on the issue.

The challenges posed by chemical contamination and pollution can be met by initiating a programme of exposure assessments for priority chemicals, to establish a better understanding of the biological effects of these chemicals and to better understand the impacts of complex mixtures of substances on physiology. The economic and infrastructural challenges posed by such a wide variety of chemicals means that a targeted, effects-based strategy is needed.

In order to meet these challenges, and pursue cost-effective scientific approaches that can provide the evidence necessary to support policy needs, the authors of this paper support the widely held view that, rather than increasing the analytical chemistry monitoring of large numbers of emerging contaminants, it will be important to target key groups of chemicals of concern using effects-directed analysis. It is also important to evaluate to what extent existing biomarkers and bioassays can address various classes of emerging chemicals using the adverse outcome pathway (AOP) approach now being developed by the Organization for Economic Cooperation and Development (OECD) with respect to human toxicology and

ecotoxicology. These methods promise to be valuable tools for determining the most effective way to address complex chemical contamination mixtures that can threaten marine ecosystems and seafood resources.

5. Ocean in peril: Reforming the management of global ocean living resources in areas beyond national jurisdiction

The existing legal and institutional framework for governing and managing the resources of the high seas (the vast areas of the ocean that are not included in the exclusive economic zone, EEZ, or under the national jurisdiction of any state) is weak and poorly implemented. As a result, high seas living resources are not being used sustainably and the health of the marine environment is being compromised. The high seas is often referred to as the ''the global ocean commons", a common heritage of humankind but its biodiversity is exploited predominantly by vessels from developed States and it is also subject to global problems related to climate change, pollution and large-scale human activities such as shipping.

The previous paper has already shown that global fisheries as a whole are in crisis; many fish stocks caught largely in the high seas, including one third of highly-migratory tuna and more than half of oceanic sharks, are over-exploited or depleted. It has also been estimated that up to half of all illegal fish catches, in terms of value, take place in the high seas. Chronic mismanagement by regional fisheries management organisations (RFMOs), combined with excessive government subsidies spurring overcapacity in open-access fisheries, contribute to overfishing and IUU fishing in the high seas. The consequences are brought into stark relief by the recent collapse of the once highly productive jack mackerel fishery in the South Pacific in less than twenty years. While governments negotiated the creation of an RFMO in the region, and deliberated over interim measures, a "race to fish" before the agreement entered into force drove stocks from 30 million tons to just 3 million.

RFMOs are the institutions legally charged with managing high seas fisheries under UNCLOS, yet a recent assessment identified that 67% of stocks (for which the status is known) under the jurisdiction of the 18 existing RFMOs are depleted or being overfished. A major problem is that the rules and decisions adopted by each RFMO apply only to its own member States while vessels owned by other States are able to fish in the region. Nearly all RFMOs are comprised primarily of States with a direct economic interest in the fishery, with delegates representing commercial fishing interests hugely outnumbering those geared towards ecological concerns. There is also wide discrepancy between the effectiveness of different RFMOs – indicating what can be achieved where political will and pressure exist. For example, the Commission for the Conservation of Antarctic Living Marine Resources (CCAMLR) is widely praised, while the International Commission for the Conservation of Atlantic Tuna (ICCAT) has been labeled an international disgrace. At best, the pace of reform has been slow and uneven.

IUU fishing is a global phenomenon and an area where the advantages of an integrated global approach are already acknowledged. Persistent IUU fishing today is to a large extent due to the traditional reliance on flag States to enforce regionally agreed measures – based on the legal fiction that a ship is a floating piece of a nation's territory. This allows certain irresponsible States to evade their commitments, and encourages the practice of reflagging ships to evade enforcement action. The 2009 FAO Port State Measures Agreement sets the stage for a consistent international standard to replace ad hoc regional approaches but much more needs to be done to achieve compliance and enforcement. At the moment, illegal fishers remain too confident in their ability to escape detection and punishment. Marine living resources crime, in particular illegal fishing, needs to be integrated into wider efforts to suppress the other transnational crimes to which it can be connected, such as piracy, drug trafficking, terrorism and the illegal trafficking of people and weapons. The existing regional and international policing community, particularly INTERPOL and EUROPOL, should become more engaged in this issue and help implement measures to shift IUU fishing from a low risk, high reward activity to one that has high risks with few chances for rewards.

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The technology needed to implement effective monitoring, control and surveillance of fishing activities in the oceans already exists, which means that the ongoing inability to manage fisheries on the high seas comes down to gaps in governance and the ineffectiveness of the organisations charged with managing such fisheries, i.e. RFMOs. The authors of this paper warn that if no change is made the deterioration of the high seas will accelerate as more areas are targeted for fishing or other extractive activities. This may weaken ecosystem function, resilience and adaptive capacity and thereby exacerbate the effects of other marine stressors, such as warming and acidification. They therefore outline three possible avenues for: 1) a "soft" change through a series of UN General Assembly Resolutions, which is deemed insufficient as such resolutions often produce few practical results, can take years to negotiate and would still leave RFMOs as the primary institutions; 2) an enhanced regional approach focused on strengthening RFMO performance and capacity for ecosystem based management of living resources, which has the disadvantage of continuing with the regional "silo" approach and not introducing any globally agreed goals; and 3) an ambitious fundamental reform which would combine the two previous proposals with a global infrastructure to coordinate, ensure consistency and supervise, sanction and enforce the necessary changes.

The key elements of this enhanced global infrastructure for high seas governance could include the establishment of a global high seas enforcement agency to provide integrated and coordinated monitoring and enforcement for the full range of ocean security threats. Most importantly, the fundamental linchpin proposed is a new implementing agreement for the conservation and sustainable use of biodiversity in areas beyond national jurisdiction under the auspices of UNCLOS.

The current system of high seas governance that tolerates the mismanagement and misappropriation of high seas living resources is placing our ocean in peril. It is time for a new paradigm that promotes ocean health, resilience and integrity, to secure the well-being, diversity and productivity of the ocean for the benefit of present and future generations.

All five of these papers, and the report arising from the two seminal IPSO meetings, outline some of the most important steps that need to be taken to achieve a more holistic, ecosystem-based approach to marine management. Ultimately, however, this must be undertaken within a wider re-evaluation of the core values of human society and its relationship to the natural world on which we all rely. The future of humanity and the future of the ocean are intertwined.

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Authors:

Introduction to the special issue: The global state of the ocean; interactions between stresses, impacts and some potential solutions. Synthesis papers from the International Programme on the State of the Ocean 2011 and 2012 workshops

Dan Laffoley, IUCN (International Union for Conservation of Nature)

Alex D. Rogers Department of Zoology, University of Oxford, UK

Climate change and the oceans – What does the future hold?

Jelle Bijma Alfred-Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

Hans-O. Pörtner Alfred-Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

Chris Yesson Institute of Zoology, Zoological Society of London, UK

Alex D. Rogers Department of Zoology, University of Oxford, Oxford UK

Climate change impacts on coral reefs: Synergies with local effects, possibilities for acclimation, and management implications

Mebrahtu Ateweberhan Department of Life Science, University of Warwick, Warrick, UK

David A. Feary School of the Environment, University of Technology, Sydney, Australia

Shashank Keshavmurthy Biodiversity Research Centre, Academia Sinica, Taipei, Taiwan

Allen Chen Biodiversity Research Centre, Academia Sinica, Taipei Taiwan

Michael H. Schleyer Oceanographic Research Institute, Durban, South Africa

Charles R.C. Sheppard Department of Life Science, University of Warwick, UK

Evaluating legacy contaminants and emerging chemicals in marine environments using adverse outcome pathways and biological effects-directed analysis

Thomas H. Hutchinson Centre for Environment, Fisheries and Aquaculture Science, Weymouth Laboratory, Dorset, UK

Brett P. Lyons Centre for Environment, Fisheries and Aquaculture Science, Weymouth Laboratory, Dorset, UK

John E. Thain Centre for Environment, Fisheries and Aquaculture Science, Weymouth Laboratory, Dorset, UK

Robin J. Law Centre for Environment, Fisheries and Aquaculture Science, Suffolk, UK

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Ocean in peril: Reforming the management of global ocean living resources in areas beyond national jurisdiction

Kristina M. Gjerde IUCN Global Marine and Polar Program, Massachusetts, USA

Duncan Currie Globelaw, Christchurch, New Zealand

Kateryna Wowk NOAA, Washington, USA

Karen Sack The Pew Charitable Trusts, Washington, USA

Fisheries: Hope or despair?

Tony J. Pitcher Fisheries Centre, University of British Columbia, British Columbia, Canada

William W.L. Cheung Fisheries Centre, University of British Columbia, British Columbia, Canada