Living on the Margin in the Anthropocene: Engagement arenas for sustainability research and action at the ocean–land interface

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Living on the Margin in the Anthropocene: engagement arenas for sustainability research and action at the ocean–land interface

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The advent of the Anthropocene underscores the need to develop and implement transformative governance strategies that safeguard the Earth's life-support systems, most critically at the ocean–land interface — the Margin. The seaward realm of the Margin is the new frontier for resource exploitation and colonization to meet the needs of coastal nations and humanity overall. Here, we spotlight the pivotal role of the Margin for planetary resilience and sustainability, highlight priority issues, and outline a research strategy which aims to: (a) better understand Margin social-ecological systems; (b) guide sustainable development of Margin resources; (c) design governance regimes to reverse unsustainable practices; (d) facilitate equitable sharing of Margin resources; and (e) evaluate alternative research approaches and partnerships that address major Margin challenges.

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Introduction

Human activities dominate key global processes in a new era that scientists now call the Anthropocene [1,2]. Environmental thresholds are being approached or have already been transgressed [3], imperiling planetary health and human well-being. Hence it is imperative to better understand both the Earth's resilience and fragility, and to institutionalize governance strategies that safeguard foundational life-support systems and unlock opportunities for sustainable development. Nowhere is this undertaking more compelling and urgently needed than at the ocean–land interface — the Margin — because of the unprecedented acceleration of demands for space and resources, and the systemic weaknesses of prevailing governance regimes. We use a broad definition of the 'Margin,' comprising coastal lands inward from the seashore that influence and are influenced by the sea and extending outward to the continental shelf and slope. It is thus a relatively narrow band within which humans live, work, recreate and exploit coastal and marine resources (Figure 1). One well-recognized anthropogenic hazard unique to the Margin is the threat from warming-induced sea-level rise and human-induced coastal land subsidence [4], while other more localized disasters have occurred as risk increases with intensifying Margin use, as illustrated in the following examples. The human quest for more resources is exemplified by the rapid expansion of drilling to greater depths for oil and gas, for example in the Gulf of Mexico since the 1970s (Figure 2a), or as planned in the Arctic Ocean more recently. Disasters, such as the 2010 BP-Deepwater Horizon oil spill [5], are likely to occur with increasing frequency within the Margin because of accelerating development pressure in this

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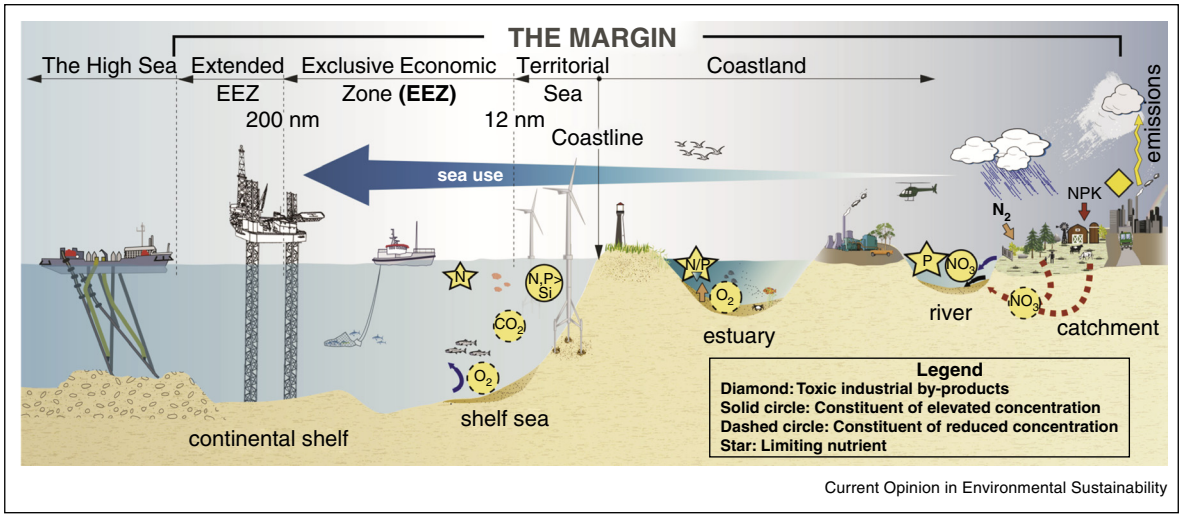
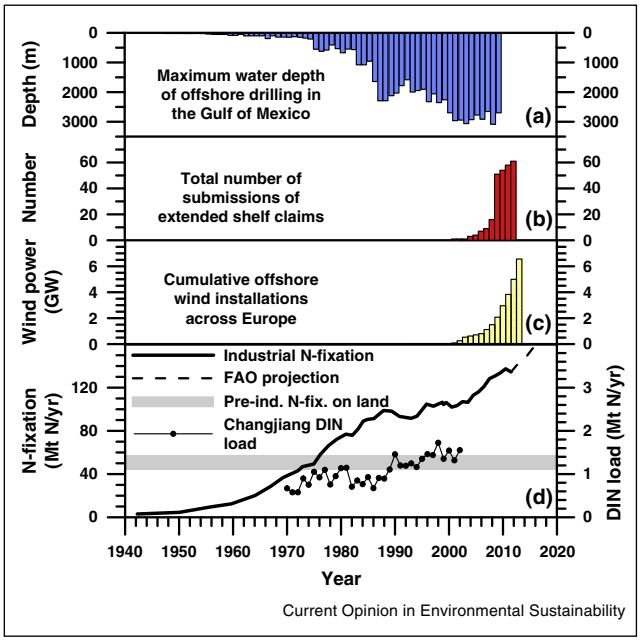
Figure 1



The Margin. The 'Margin' has a broader definition than 'continental shelf' as it includes coastal land down to the seashore extending outwards to the continental shelf and slope. It is thus a relatively narrow band where humans live, work, recreate and exploit coastal and marine resources. Different zones of the Margin with schematics showing multiple stressors — NPK: fertilizers; N (NO_3), P, Si: nutrient loading in water bodies; O_2: consumption of dissolved oxygen; CO_2: production of carbon dioxide, which may cause acidification. [This figure has been modified from Figure 1.3b of [47].]

Figure 2



The Margin under stress. Anthropogenic stressors on the Margin: **(a)** Maximum water depth drilled in the Gulf of Mexico. **(b)** Total number of submissions of claims on extended continental shelves to the United Nations [10]. **(c)** Cumulative offshore wind power generation across Europe [48]. **(d)** Global industrial nitrogen fixation, which, according to FAO, has surpassed the pre-industrial natural level of nitrogen fixation on land [49]. A significant fraction of the fixed nitrogen is discharged to the coastal waters via rivers and groundwater seepages. The dissolved inorganic nitrogen (DIN) load of Changjiang (aka the Yangtze River) is shown as an example [30]. [See electronic supplement for more details of data sources used in the plots.].

realm and the elevated risks associated with ever deeper drilling into the seafloor and intensified exploitation of remote and fragile Margin resources. There is also escalating disaster risk on the landward side of the Margin, viz. the 2011 Tōhoku earthquake and tsunami and Fukushima Daiichi nuclear disaster [6] or Typhoon Haiyan that devastated the Philippines in 2013 [7], due in part to increasingly dense human settlement of coastal lands which are uniquely susceptible to hazard impacts of oceanic, atmospheric or terrestrial origin, especially in this era of climate change.

The recent declaration of sovereignty by Russia of the continental shelf of the Sea of Okhotsk, off Russia's southeast coast near Japan — an additional 52,000 square kilometers that is about the size of Switzerland — illustrates another aspect of the Margin which increases its vulnerability: large areas of it are still unexplored and unexploited or only lightly so. Sergei Donskoy, Russian Minister of Natural Resources and Environment, described the acquisition as 'Ali Baba's cave' — a treasure trove of exploitable natural resources that includes minerals and more than a billion tons of hydrocarbon reserves that promises massive economic benefits [8,9]. This acquisition is one step in Russia's campaign to secure rights to the entire continental shelf, including the Arctic shelf, based on the Lomonosov and Mendeleev Ridges being extensions of the Siberian continental shelf. If this campaign is successful, Russia will secure 1.2 million square kilometers of Arctic territorial waters. This campaign is just one of the many international legal manoeuvres by various nations to secure exclusive rights to explore and exploit the natural resources of the Margin, especially in

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this specific region as Arctic ice recedes. The total number of submissions of extended shelf claims [10] swelled in the 21st century (Figure 2b). This prevailing frontier mentality does not augur well for Arctic sustainability nor for the sustainability of the world's Margin.

Below, we explain the Margin's essential role in securing global resilience and sustainability, identify priority issues, and outline a five-point research strategy to facilitate the transition towards sustainability based on research in three engagement arenas: knowledge and understanding of dynamic Margin processes; development, innovation and risk at the Margin; and governance for sustainability of Margin resources.

The pivotal role of the Margin

Human interests, activities, impacts and future prospects fuse at the Margin — the slender ocean–land interface that extends from *ca* 1 to 100 km inland (where human population centers, ports and industries are concentrated and growing), and out to continental shelves and slopes (including the Exclusive Economic Zone and beyond 200 nautical miles where appropriate)[13] bordering the deep ocean. Depending on one's choice of landward and seaward boundaries, the Margin comprises only up to 14% of the earth's surface [[11], see electronic supplement]. However, Martinez *et al.* [12], using a definition of coastal regions including areas within 100 km landward of the shore and to a depth of 200 m in offshore waters, determined that the goods and services of coastal ecosystems comprise 77% of the total economic value of global ecosystem goods and services, highlighting their disproportionately high productivity and value. More than 40% of humans live within 100 km of the shoreline, more than 500 million people are concentrated in delta regions, two-thirds of the world's megacities are coastal, and much of the world's global economic activity occurs here [12,13]. Exponential human population growth and associated pollution and resource consumption are outstripping the carrying capacity and resilience of Margin ecosystems [14]. Accelerating efforts to exploit Margin resources are pushing ever deeper and further seaward to profit from abundant, previously inaccessible resources on the continental shelf and slope (Figure 2a). These offshore realms of the Margin constitute the new frontier for resource exploitation, colonization and industrialization in the Anthropocene, and will play a fundamental role in sustaining the burgeoning populations of some 150 coastal nations and humanity as a whole.

[13] This broad definition of the Margin enables consideration of an array of issues, some of which may transcend specific and evolving jurisdictional boundaries as specified for example by the United Nations Convention on the Law of the Sea. Furthermore, the landward extent of the Margin may extend more or less than 100 km depending on the extent to which direct and indirect land-sea interactions occur.

The global expansion of human population, resource exploitation and economic activity has been described as 'The Great Acceleration' [15]. As human stressors gain momentum seawards, any transition towards sustainability in the Margin must confront a 'quadruple squeeze' [16] that grips coastlines and the seaward domain (Box 1). Resolution of these issues is hampered by a paucity of knowledge and understanding about the characteristics and functioning of social-ecological systems [29•] and of how to transition from unsustainable to sustainable practices [34•]. In the face of accelerating efforts to exploit resources on the Margin, there is a narrow window of opportunity for innovative research efforts to enable sustainable Margin development. Key here, firstly, is mobilization of new, transdisciplinary research that melds the natural and social sciences. Secondly, effective governance arrangements need to be designed and implemented to prevent over-exploitation at the Margin's seaward reaches, as has already happened along much of the landward edge.

Towards a research strategy for the Margin

This article emerged from discussions of the Continental Margins Working Group, a joint committee of the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) and the Future Earth Coasts [formerly Land-Ocean Interactions in the Coastal Zone (LOICZ)] international projects sponsored originally by the International Geosphere-Biosphere Program, Scientific Committee on Oceanic Research, and International Human Dimensions Program (respectively, IGBP, SCOR, and IHDP). It aligns the research strategies of IMBER and Future Earth Coasts (formerly LOICZ) for the Margin, and aims to contribute to the global sustainability research agenda of the new Future Earth program (URL http://www.icsu.org/future-earth/media-centre/relevant_publications/future-earth-research-framework). Building upon three research themes identified by Future Earth (http://www.futureearth.org/science), we focus on three priority engagement arenas for research that converge at the Margin (Figure 3): first, knowledge and understanding of dynamic Margin processes, including '*observing, explaining, understanding and projecting social-ecological trends, drivers and their interactions*'; second, development, innovation and risk on the Margin to '*address the most pressing needs of humanity, including sustainable, secure and fair stewardship …, and other ecosystem functions and services*'; and third, governance for sustainability, including '*transformations…. in values, technologies …. (and practices) across sectors and scales*'. More than identifying research 'themes', we emphasize the need for engagement in and coordination between these arenas because the natural environment of the Margin is being confronted with imminent, massive human impacts. At the same time, this environment is characterized by deficits in effective governance for sustainability [e.g., [35]]. As outlined below, the aim of any future research endeavor geared

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Box 1 Quadruple squeeze at the Margin.

Population growth, development intensification and rising demands for energy-intensive resources: Activities in the Margin, including maritime transport, communication infrastructure, fishing and oil and gas drilling, have long impacted shelf ecosystems down to a depth of about 200 m. Exploiting and expanding their Exclusive Economic Zones (EEZ), many nations push into ever deeper and more remote waters, including the Arctic and other fragile areas (Figure 2a and b). In addition, the increasing demand for space in the marine domain of the Margin [17•], such as for wind farming (Figure 2c), competes directly with traditional uses, such as fisheries. Landwards, already stressed coastal 'hotspots' are subject to accelerating pressures [4,13,14,18,19] with particular challenges faced in deltas (where fluxes of water and sediment are depleted, pollutants are concentrated, impacts are severe, and the need to safeguard ecosystems and associated dependent livelihoods is urgent and compelling [20,21]); urbanizing coasts and coastal megacities (where people are concentrated [22]); low-lying coasts and small island developing states (which are vulnerable to an array of coastal hazards compounded by climate change [4,23]); and Arctic coasts (where climate change is causing systemic change in the state of social–ecological systems [24]).

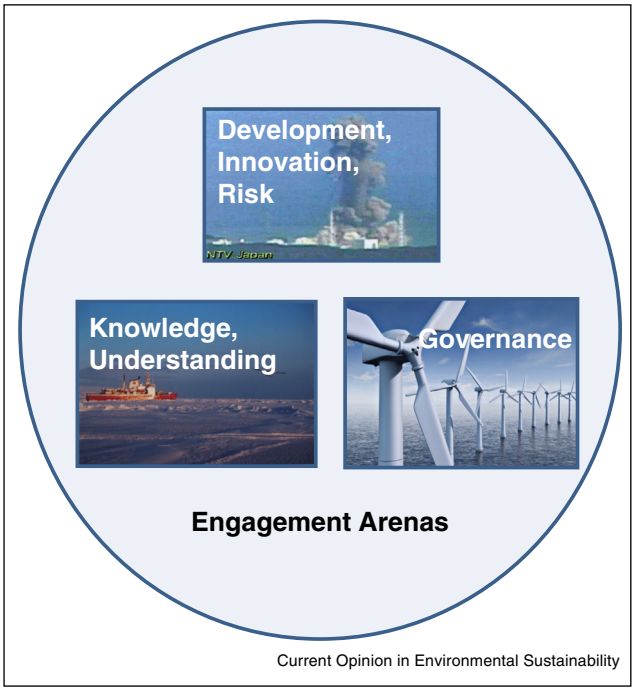
Ecosystem degradation and loss: Interacting human stressors occurring within the Margin, such as habitat destruction and transformation from building and other development, resource extraction, over-fishing, pollution, eutrophication and hypoxia, are profoundly impacting wetland, estuarine, continental shelf and deep slope ecosystems within the Margin [3,13,25•,26]. Our understanding of Margin ecosystems, their responses to individual and combined stressors, and effects on ecosystem goods and services remains poor, especially in remote and unmonitored regions.

Rising CO_2, climate change and alteration of biogeochemistry of Margin ecosystems: Human activities outside the Margin can also have significant impacts. Rapidly rising atmospheric greenhouse gas concentrations are transforming aquatic systems with the prospect of irreversible impacts on Margin ecosystems (e.g., estuaries, coral and oyster reefs) and industries which rely on their support (e.g., aquaculture and ecotourism), as well as on freshwater and marine systems beyond its boundaries [27]. Air and surface water temperatures and sea level are rising, the ocean is acidifying (particularly in the Arctic Margin [28]) and losing oxygen [26], and eutrophication/hypoxia [29•,30] is spreading (Figure 2d). Effects may compromise the continued ability of these ecosystems to sustain coastal communities and livelihoods, and resilience to global environmental change on the Margin may be waning.

Ecosystem tipping points and rapid and irreversible changes in social–ecological systems and societal responses: Complex, non-linear interactions between physical conditions, biogeochemical cycles, ecosystem structures and functions, and societal trajectories create positive and negative feedbacks that elicit cumulative and synergistic impacts which may transgress system thresholds. Burgeoning coastal communities face increasing exposure and vulnerability to coastal hazards exacerbated by climate change [4,14]. Exploring and nourishing resilience is necessary to reduce disaster risk [31] and avert potentially catastrophic shifts in state that imperil the Margin's interacting systems. The potential long-term societal and environmental impacts and risks are profound [32], but the ability of prevailing governance regimes to enable sustainability is at best variable and precarious [33].

towards enabling the transition to Margin sustainability must be to develop robust knowledge and understanding that can be channeled into practical actions to safeguard terrestrial and marine ecosystems of the Margin, to

Figure 3



The Margin — an engagement arena for global sustainability. The three priority engagement arenas for research on the Margin. **(a)** Knowledge and understanding: We know relatively little about the social–ecological trends of the Margin, especially the vulnerable and critical Arctic margin; **(b)** Accompanying development and innovation are risks, which may strike as surprises often with grave consequences, such as the Fukushima nuclear accident [6], which happened precisely because of its locality on the Margin; **(c)** The Margin as a whole lacks comprehensive and effective sustainability governance, which includes transformations in values, technologies and practices across sectors and scales.

support economic development and sustainable livelihood opportunities, and to deepen the connections many people have with their coasts and oceanic environments.

Knowledge and understanding as an engagement arena: Many of the Margin's diverse and complex physical, geological, chemical, biological, ecological, social and human characteristics, processes and interactions are scarcely understood [e.g., [29]], especially in deeper and more remote realms, and in areas of the developing world with limited resources for monitoring and research [36], where capacity development is crucial to the success of the following proposed approach [37]. It is imperative to improve understanding of Margin ecosystem structures, functions, dynamics and anticipated changes in response to anthropogenic forcings, and the goods and services they yield, the communities and societies they sustain, and associated governance challenges, opportunities and risks. Priority topics include: (i) understanding the range and value of ecosystem goods and services (for example, storm surge mitigation by coastal wetlands is

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a well-defined service, but local specifics are largely unknown); (ii) improving monitoring of the Margin by establishing environmental baselines, developing systems for monitoring trends and changes, and maintaining and expanding networks of observing systems [29]; (iii) developing processes and tools to understand and anticipate thresholds and tipping points and to predict, manage and mitigate human impacts; (iv) identifying barriers, risks, costs and benefits, opportunities and options for sustainability governance that enable mitigation, adaptation and resilience in the face of uncertainty, change and surprise; (v) understanding human values and perceptions that shape behavior; (vi) enhancing public awareness and understanding, and science-policy dialogue about the Margin; and (vii) creating practical ways to overcome cognitive, social, institutional and other barriers for translating sustainability knowledge into action. Informative inter-disciplinary programs that explore such issues, and need to be integrated in order to develop an holistic understanding of the Margin as a whole, include the Japanese Satoyama Satoumi Assessment [38] and the Large Marine Ecosystem program [39].

***Development, innovation and risk as an engagement arena*:** The Great Acceleration of innovative development underway at the ocean-edge of the Margin is rife with risks characterized by scientific uncertainty, complexity and ambiguity [e.g., [29]]. New technological and business innovations have enabled exploitation of resources in ever deeper and remoter waters. Globalization and international trade extract Margin resources in response to distant sources of demand and create waste products and impacts in the Margin from distant sources of supply [40,41]. Despite innovations in governance, prevailing governance regimes have not kept pace with these technological innovations, and have even encouraged unsustainable high risk ventures. The BP Deepwater Horizon oil spill disaster is a case in point. The US President's National Commission created in 2010 to analyze this disaster recognized that systemic reform is needed in the structure of arrangements for regulatory oversight and internal decision-making processes to provide the requisite political autonomy, technical expertise, and full consideration of environmental concerns to secure public safety and sustainability [5]. However, it is questionable that adequate steps have been taken to this end [42]. Transformative change is needed in these technologies, practices and in the supporting institutional architecture to enable the transition to sustainability [34,43,44•]. Priority topics include: first, understanding and addressing these multi-dimensional risk problems including new modalities of research and action to deal with 'unknown unknowns' and even 'unknowable unknowns'; second, evaluating how risk is created, who bears the risk and how risk is shared, viz. the 2010 BP-Deepwater Horizon oil spill disaster and emerging risk problems arising from exploration and exploitation of resources at depth on continental shelves and slopes, and in fragile systems like the Arctic; and third, implementing social and governance innovations to facilitate risk reduction and sustainability at the Margin.

***Governance as an engagement arena*:** Environmental governance consists mainly of issue-based responses to problems such as the impact of climate change on biodiversity, over-exploitation of fisheries, and managing the risks facing coastal communities. There are few interactions between issue-based governance networks or with other global governance regimes developed for other societal sectors such as trade. Governance deficits or mismatches are particularly pronounced at the ocean-edge of the Margin where *de facto* unregulated access and technological innovations facilitate accelerating exploitation of previously inaccessible continental shelf, slope and seabed resources [44•]. The prevailing Law of the Sea appears incapable of resolving the challenges of the Anthropocene because its historical and ideological foundation has fueled the exploitative practices that led to the Industrial Revolution and which characterize contemporary management practices. Hence the need for reforms that emphasize *responsibility and accountability* for the seas over simply *freedom* of the seas [45]. Priority issues include: first, investment reform to advance sustainability: currently investors may knowingly engage in 'lethal but profitable activities' with impunity [46]; second, risk reduction: some coastal states, such as Pacific Island states, may be exposed to high risk ventures and many others are actively engaged in the exploration and exploitation of Margin resources, including the USA, Canada, Russia, China, Japan, Brazil, New Zealand and several EU member states. Current governance arrangements — including mostly disconnected, sectoral institutions and networks governing fisheries, conservation, energy development, and marine transportation — are ill-suited to deal with the escalating risk and the global sustainability implications arising from intensifying Margin use, and this necessitates focused research that enables effective governance for sustainability; and third, jurisdiction, equity and fiscal responsibility: the cost burden and equity implications for coastal states *versus* those lacking access to the Margin's bounty need to be better understood, rationalized and institutionalized. The transition towards sustainability in the Anthropocene goes beyond business as usual. It requires a transformational change in human values emphasizing sustainability, as well as technologies and practices that integrate and transcend socio-economic sectors and span multiple geographic and temporal scales.

These three engagement arenas require new research partnerships and programs that bring together previously unconnected trajectories of research and associated science-society actors and networks.

As intensified development proceeds seawards towards the ocean-edge of the Margin, we are reminded of the

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unsustainable exploitation of ecosystems that has already occurred and continues along the landward edge of the Margin and in shallow seas. A new, pluralistic scientific agenda is needed as the Great Acceleration unfolds on this new frontier to prevent repeating mistakes of the past. Specifically, innovative research in these Margin engagement arenas is needed to inform policy and practice and lead to societal actions that foster ocean and coastal sustainability by:

(a) building knowledge and understanding of the Margin's social-ecological systems (including coupled physical, biological, cultural, economic, social, political and administrative aspects) that spans the spectrum from ecosystem functioning to exploitable resources, societal values, institutional frameworks and governance regimes;
(b) enabling innovative methodologies, strategies, guidance and good practices that identify opportunities to utilize the resources of the Margin on a risk averse, sustainable basis, and to determine those areas which should remain undeveloped and protected;
(c) designing inclusive, reflexive, adaptive and enforceable governance regimes in order to prevent or stop unsustainable practices occurring within the Margin;
(d) evaluating alternative place-based institutionalized structures and processes for securing equitable distribution of costs and benefits from sustainable use of Margin resources; and
(e) experimenting with and establishing new research epistemologies, partnerships and practices for the Margin — the frontier of the sustainability crisis in the Anthropocene.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cosust.2015.06.003.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- of special interest

1. Crutzen PJ, Stoermer EF: **The Anthropocene**. *Global Change Newslett* 2000, **41**:17-18.

2. Zalasiewicz J, Williams M, Steffen W, Crutzen P: **The new world of the Anthropocene**. *Environ Sci Technol* 2010, **44**:2228-2231 http://dx.doi.org/10.1021/es903118j.

3. Rockström J, Steffen W, Noone K, Persson Å, Chapin FS, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ *et al.*: **A safe operating space for humanity**. *Nature* 2009, **461**:472-475 http://dx.doi.org/10.1038/461472a.

4. Nicholls RJ: **Planning for the impacts of sea level rise**. *Oceanography* 2011, **24**:144-157 http://dx.doi.org/10.5670/oceanog.2011.34.

5. National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling: *Deep Water — The Gulf Oil Disaster and the Future of Offshore Drilling. Report to the President*. 2011:380.

6. Holt M, Campbell RJ, Nikitin MB: **Fukushima nuclear disaster**. *R41694 In CRS Report for Congress. Congressional Research Service 7-5700*. 2012:12.

7. Lum T, Margesson R: **Typhoon Haiyan (Yolanda): U.S. and International Response to Philippines Disaster**. *R43309 In CRS Report for Congress. Congressional Research Service 7-5700*. 2014:32.

8. News report on March 12th, 2014: URL http://www.dailymail.co.uk/news/article-2626193/Russia-wins-oil-rich-territory-big-Switzerland-without-violence-handed-Ali-Babas-cave-natural-resources-arctic.html (accessed 04.06.14).

9. News report on March 19th, 2014: URL http://www.marinelink.com/news/treasure-okhotsk-russias365743.aspx (accessed 04.06.14).

10. Suárez-de Vivero JL: **The extended continental shelf: a geographical perspective of the implementation of article 76 of UNCLOS**. *Ocean Coast Manag* 2013, **73**:113-126 http://dx.doi.org/10.1016/j.ocecoaman.2012.10.021.

11. Jahnke RA: **16. Global synthesis**. In *Carbon and Nutrient Fluxes in Continental Margins: A Global Synthesis*. Edited by Liu K-K, Atkinson L, Quiñones R, Talaue-McManus L. Springer; 2010:597-615. IGBP Book Series.

12. Martinez ML, Intralawan A, Vazquez G, Perez-Maqueo O, Sutton P, Landgrave R: **The coasts of our world: ecological, economic and social importance**. *Ecol Econ* 2007, **63**:254-272 http://dx.doi.org/10.1016/j.ecolecon.2006.10.022.

13. Moser SC, Williams SJ, Boesch DF: **Wicked challenges at land's end: managing coastal vulnerability under climate change**. *Annu Rev Environ Resour* 2012, **37**:51-78 http://dx.doi.org/10.1146/annurev-environ-021611-135158.

14. Millennium Ecosystem Assessment (MEA): *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press; 2005.

15. Steffen W, Broadgate W, Deutsch L, Gaffney O, Ludwig C: **The trajectory of the Anthropocene: the great acceleration**. *Anthropocene Rev* 2015, **2(1)**:81-98.

16. Rockstrom J, Karlberg L: **The quadruple squeeze: defining the safe operating space for freshwater use to achieve a triply green revolution in the Anthropocene**. *Ambio* 2010, **39**:257-265 http://dx.doi.org/10.1007/s13280-010-0033-4.

17. • Emeis K-C, van Beusekom J, Callies U, Ebinghaus R, Kannen A, Kraus G, Kröncke I, Lenhart H, Lorkowski I, Matthias V *et al.*: **The North Sea — a shelf sea in the Anthropocene**. *J Mar Syst* 2015, **141**:18-33 http://dx.doi.org/10.1016/j.jmarsys.2014.03.012.
It is likely that the southern North Sea will be re-zoned as riparian countries dedicate increasing sea space for offshore wind energy generation. Responding to such a potential change, the authors provide an up-to-date review and synthesis of observational and model data of the North Sea (mainly from the southeastern part) to identify and describe effects of natural variability, of secular changes, and of human impacts on the North Sea ecosystem, and outline developments in the next decades in response to environmental legislation, and in response to increased use of shelf sea space.

18. Newton A, Carruthers TJB, Icely J: **The coastal syndromes and hotspots on the coast**. *Estuar Coast Shelf Sci* 2012, **96**:39-47.

19. Newton A, Weichselgartner J: **Hotspots of coastal vulnerability: a DPSIR analysis to find societal pathways and responses**. *Estuar Coast Shelf Sci* 2014, **140**:123-133.

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20. Renaud FG, Syvitski JPM, Sebesvari Z, Werners SE, Kremer H, Kuenzer C, Ramesh R, Jeuken AD, Friedrich J: **Tipping from the Holocene to the Anthropocene: how threatened are major world deltas?** *Curr Opin Environ Sustain* 2013, **5**:644-654.

21. Giosan L, Syvitski J, Constantinescu S, Day J: **Protect the world's deltas**. *Nature* 2014, **516**:31-33.

22. Pelling M, Blackburn S (Eds): *Megacities and the Coast: Risk, Resilience and Transformation*. Routledge; 2014. Earthscan.

23. Nurse LA *et al.*: **Small islands. In Climate Change**. In *Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Edited by Barros VR *et al.*: Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014:1613-1654.

24. Forbes DL (Ed): *State of the Arctic Coast 2010 — Scientific Review and Outlook*. Geesthacht, Germany: International Arctic Science Committee, Land-Ocean Interactions in the Coastal Zone, Arctic Monitoring and Assessment Programme, International Permafrost Association. Helmholtz-Zentrum; 2011. 178 p. http://arcticcoasts.org.

25. • Barbier EB, Moreno-Mateos D, Rogers AD, Aronson J, Pendleton L, Danovaro R, Henry LA, Morato T, Ardron J, Van Dover CL: **Protect the deep sea**. *Nature* 2014, **505**:475-477.
The authors illustrate how seriously continental margins are impacted by human activities and call for governance and funds for deep-sea reserves and the restoration of ecosystems damaged by commercial interests.

26. Rabalais NN, Turner RE, Díaz RJ, Justic D: **Global change and eutrophication of coastal waters**. *ICES J Mar Sci* 2009, **66**:1528-1537 http://dx.doi.org/10.1093/icesjms/fsp047.

27. Hoegh-Guldberg O, Bruno JF: **The impact of climate change on the world's marine ecosystems**. *Science* 2010, **328**:1523-1528 http://dx.doi.org/10.1126/science.1189930.

28. Shadwick EH, Trull TW, Thomas H, Gibson JAE: **Vulnerability of polar oceans to anthropogenic acidification: comparison of arctic and antarctic seasonal cycles**. *Sci Rep* 2013, **3** http://dx.doi.org/10.1038/srep02339.

29. • Levin LA, Liu K-K, Emeis K-C, Breitburg DL, Cloern J, Deutsch C, Giani M, Goffart A, Hofmann EE, Lachkar Z *et al.*: **Comparative biogeochemistry-ecosystem-human interactions on dynamic continental margins**. *J Mar Syst* 2014 http://dx.doi.org/10.1016/j.jmarsys.2014.04.016.
Comparing time-series observations from continental margins of different types, the authors demonstrate how such a comparison can illuminate the contrasting behaviors of different margins and enable attribution of different drivers that cause the observed changes, but also reveal the widespread gaps in data availability, which call for more support on sustained observational programs in continental margins.

30. Liu K-K, Yan W, Lee H-J, Chao S-Y, Gong G-C, Yeh T-Y: **Impacts of increasing dissolved inorganic nitrogen discharged from Changjiang on primary production and seafloor oxygen demand in the East China Sea from 1970 to 2002**. *J Mar Syst* 2015, **141**:200-217 http://dx.doi.org/10.1016/j.jmarsys.2014.07.022.

31. Adger WN, Hughes TP, Folke C, Carpenter SR, Rockstrom J: **Social-ecological resilience to coastal disasters**. *Science* 2005, **309**:1036-1039 http://dx.doi.org/10.1126/science.1112122.

32. Stojanovic TA, Farmer CJQ: **The development of world oceans and coasts and concepts of sustainability**. *Mar Policy* 2013, **42**:157-165 http://dx.doi.org/10.1016/j.marpol.2013.02.005.

33. Young OR: **Effectiveness of international environmental regimes: existing knowledge, cutting-edge themes, and research strategies**. *Proc Natl Acad Sci USA* 2011, **108**:19853-19860 http://dx.doi.org/10.1073/pnas.1111690108.

34. • Talaue-McManus L: **9. Examining human impacts on global biogeochemical cycling via the coastal zone and ocean margins**. In *Carbon and Nutrient Fluxes in Continental Margins: A Global Synthesis.* Edited by Liu K-K, Atkinson L, Quiñones R, Talaue-McManus L. Springer; 2010:497-514. IGBP Book Series.
The author provides a synoptic overview of human impacts on the biogeochemical transformations that coastal ecosystems perform for ecosystem integrity and human well-being. She first introduces how humans have transformed the planet's behavior through their activities along the catchment–coast continuum. Then she gives assessments of large-scale ecosystem impacts resulting from these activities. Finally, she examines approaches and innovations that may enable human institutions to enhance human well-being as well as ecosystem health across the water continuum through governance arrangements. As examples she provides comparisons of governance issues with respect to the Mekong and the Mississippi river systems and how they impact environmental conditions in the deltaic and outflow regions.

35. Costanza R, Andrade F, Antunes P, van den Belt M, Boesch D, Boersma D, Catarino F, Hanna S, Limburg K, Low B *et al.*: **Ecological economics and sustainable governance of the oceans**. *Ecol Econ* 1999, **31**:171-187 http://dx.doi.org/10.1016/s0921-8009(99)00077-4.

36. Swaney DP, Hong B, Paneer Selvam A, Howarth RW, Ramesh R, Purvaja R: **Net anthropogenic nitrogen inputs and nitrogen fluxes from Indian watersheds: an initial assessment**. *J Mar Syst* 2015, **141**:45-58 http://dx.doi.org/10.1016/j.jmarsys.2014.09.004.

37. Morrison RJ, Zhang J, Urban ER, Hall J, Ittekkot V, Avril B, Hu L, Hong GH, Kidwai S, Lange CB *et al.*: **Developing human capital for successful implementation of international marine scientific research projects**. *Mar Pollut Bull* 2013, **77**:11-22 http://dx.doi.org/10.1016/j.marpolbul.2013.09.001.

38. See http://archive.ias.unu.edu/sub_page.aspx?catID=111&ddlID=1485 (accessed 28.05.15).

39. See http://lme.edc.uri.edu/ (accessed 28.05.15).

40. Deutsch L, Graslund S, Folke C, Troell M, Huitric M, Kautsky N, Lebel L: **Feeding aquaculture growth through globalization: exploitation of marine ecosystems for fishmeal**. *Glob Environ Change — Hum Policy Dimens* 2007, **17**:238-249 http://dx.doi.org/10.1016/j.gloenvcha.2006.08.004.

41. Lassaletta L, Billen G, Grizzetti B, Garnier J, Leach AM, Galloway JN: **Food and feed trade as a driver in the global nitrogen cycle: 50-year trends**. *Biogeochemistry* 2014, **118**:225-241 http://dx.doi.org/10.1007/s10533-013-9923-4.

42. Boesch D: **Deep-water drilling remains a risky business**. *Nature* 2012, **484**:289.

43. Leach M, Rockstrom J, Raskin P, Scoones I, Stirling AC, Smith A, Thompson J, Millstone E, Ely A, Arond E *et al.*: **Transforming innovation for sustainability**. *Ecol Soc* 2012, **17** http://dx.doi.org/10.5751/es-04933-170211.

44. • Merrie A, Dunn DC, Metian M, Boustany AM, Takei Y, Elferink AO, Ota Y, Christensen V, Halpin PN, Osterblom H: **An ocean of surprises — trends in human use, unexpected dynamics and governance challenges in areas beyond national jurisdiction**. *Glob Environ Change — Hum Policy Dimens* 2014, **27**:19-31 http://dx.doi.org/10.1016/j.gloenvcha.2014.04.012.
The authors argue that surprise shifts in the ocean could be driven by both established and emerging users taking opportunities to chase lucrative resources enabled by development of new technologies. Rapid development due to the multiplication of users could present a problem given the current lack of a unified institutional framework for governance connecting the different user groups. Then the authors demonstrate trends in human use of oceanic areas beyond national jurisdiction in order to begin to mobilize an adequate governance response to changing conditions and uses of areas beyond national jurisdiction. Finally they present a set of institutional design principles as a first tentative step in this direction.

45. Vidas D: **The Anthropocene and the international law of the sea**. *Philos Trans R Soc A — Math Phys Eng Sci* 2011, **369**:909-925 http://dx.doi.org/10.1098/rsta.2010.0326.

46. Ehrlich PR, Ehrlich AH: **Can a collapse of global civilization be avoided?** *Proc R Soc B — Biol Sci* 2013, **280** http://dx.doi.org/10.1098/rspb.2012.2845.

47. Crossland CJ, Baird D, Ducrotoy J-P, Lindeboom HJ:: **Chapter 1. The Coastal Zone - A Domain of Global Interactions**. In *Coastal Fluxes in the Anthropocene.* Edited by Crossland CJ, Kremer HH, Lindeboom HJ, Marshall Crossland JI, Le Tissier MDA. Springer-Verlag; 2005. IGBP Book Series.

48. EWEA: *The European Offshore Wind Industry — Key Trends and Statistics 201*. The European Wind Energy Association; 2014.

49. Vitousek PM, Menge DNL, Reed SC, Cleveland CC: **Biological nitrogen fixation: rates, patterns and ecological controls in terrestrial ecosystems**. *Philos Trans R Soc B — Biol Sci* 2013, **368**:0119 http://dx.doi.org/10.1098/rstb.2013.0119.

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