Chapter 8.1 Cumulative Human Impacts in the Open Ocean

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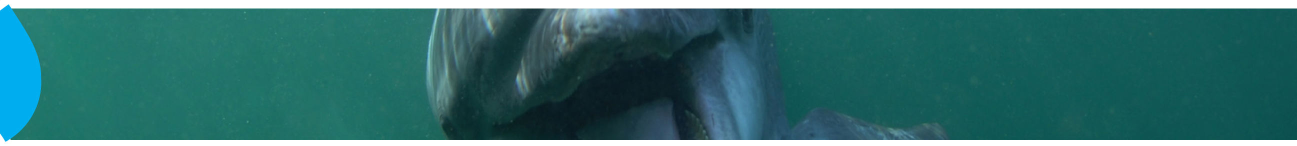
Chapter Citation:

Halpern, B.S., Frazier, M. (2016). Chapter 8.1: Cumulative Human Impacts in the Open Ocean.
In UNESCO IOC and UNEP (2016). The Open Ocean: Status and Trends. United Nations
Environment Programme, Nairobi, pp. 289-296.

Integrated Assessment



8.1 Cumulative Human Impacts in the Open Ocean

8.1.1 Summary and Key Messages

Marine ecosystems experience a wide range of stressors associated with human activities. These multiple stressors cumulatively impact systems in ways not always known, but their combined impact is always greater than the individual stressors. Recognition of the ubiquitous role of multiple stressors in marine ecosystems motivates management to focus on ecosystem-based management and marine spatial planning.

Assessing and mapping the cumulative impact of human activities on marine ecosystems provides a unique perspective and understanding of the condition of marine regions, and of the relative contribution of different human stressors to creating that condition. By focusing on the combined impact of multiple stressors within a common assessment framework, one that allows direct comparison among stressors and regions, cumulative human impact (CHI) assessments can feed directly into a wide range of possible policy decisions. In fact, the same approach has been applied to the Large Marine Ecosystem (LME) theme of the Transboundary Water Assessment Programme (TWAP), allowing for direct comparison between the LME and Open Ocean Assessment themes. CHI assessments can, for example, inform policy that aims to identify stressors with the greatest impact, rank regions most or least impacted, or highlight stressors that originate from one location but have key impacts in another region.

Stressors affecting the open ocean (also called high seas) regions largely fall into three main categories: climate change, commercial fishing, and commercial activity (such as shipping). A fourth category – land-based pollution – has essentially no effect on the high seas via watershed processes due to the large distance between land and the high seas, although may have impacts via atmospheric deposition of pollutants. To understand the relative importance of each stressor to a location, CHI assessments draw on data and information that map the location and intensity of stressors associated with human activities and the unique vulnerability of each habitat type to each stressor. The global assessment (which includes LMEs) draws on data for 19 stressors and 20 marine habitats from a variety of sources that provide globally-consistent outputs, with most data reported in 2011 or 2012 for inclusion in analyses of impact scores for the reporting year 2013. In the high seas, only 11 stressors and four habitats are present and thus relevant for the assessment.

Averaged across the area within each of 18 high seas regions (defined by FAO reporting regions), a relatively modest range of cumulative impact scores exists. In general, northern hemisphere high seas regions have higher impact scores, while polar regions tend to have lower scores. Several key results and messages emerge from the global analysis of cumulative human impact to high seas regions:

Key Messages

1. The most heavily impacted high seas regions are northern and central Atlantic and the northwest and western central Pacific, regions in closest proximity to Europe and China, where LME scores are also the highest (see the TWAP LME Technical Assessment Report, Chapter 7.2.4.);

2. The least impacted high seas region is the Arctic. Because this indicator does not project into the future, these results do not reflect any of the changes in condition that are expected to occur in the near future that will heavily impact these regions;
3. Stressors associated with climate change, most notably ocean acidification and increasing frequency of anomalously high sea surface temperatures, are the top stressors for nearly every high seas region. In part, this result emerges from the scale of assessment. At smaller scales, other stressors, such as commercial fishing, play a dominant role;
4. Commercial shipping and demersal commercial fishing that use gear on the seafloor (demersal fishing) are the other two main stressors at the scale of the high seas region. Stressors associated with these activities tend to affect different parts of the ecosystem, such that where they overlap in space, cumulative impacts are *likely* to directly affect the entire food web; and
5. Estimates of impact are *likely* conservative, as many stressors exhibit synergistic interactions with each other, where the total impact is greater than the sum of the individual impacts.

Efforts to manage marine ecosystems at the scale of high seas regions will require global coordination among countries, not only because the high seas are beyond the jurisdictions of national Exclusive Economic Zones (EEZs) but also because the key stressors are global in nature. Coordination among sectors will also be key to successful management because, the cumulative impacts on the system are much greater than what can be identified and addressed through single-sector management. Cumulative human impact (CHI) assessments provide a tool for transparently and quantitatively informing such policy processes and decisions.

8.1.2 Main Findings, Discussion and Conclusions

For millennia, humans have used the oceans for a wide range of purposes, including obtaining food through fisheries, getting rid of wastes, and navigating the planet. In the last century, due to rapid human population growth and the industrial revolution, these uses have become much more intense, widespread, and overlapping. We now live on a planet where no single patch of ocean remains untouched by human activities (Halpern et al. 2008), and a vast majority of marine ecosystems experience the impacts of multiple human uses simultaneously.

Even though high seas regions of the ocean are far from land and human populations, these regions still experience stressors related to commercial fishing, climate change, commercial shipping, and likely others. To understand the condition of high seas regions, one must therefore address the cumulative impacts of multiple stressors – any single-issue indicator, by default, will give an incomplete picture of the overall condition.

Managing for multiple stressors is inherently a transboundary challenge, as most stressors cross boundaries, including atmospheric pollutants produced by one nation and deposited elsewhere, fishing that targets fish stocks outside EEZ boundaries; and the global nature of commerce that connects patches of ocean to countries far away. The transboundary nature of multiple stressors is amplified in the high seas, where no country has jurisdiction of the regions and thus no responsibility or authority to manage any individual stressor let alone all of them. High sea regions thus provide a valuable lens through which to view these challenges and identify key opportunities for conservation and mitigation solutions.

Cumulative human impact (CHI) assessments track the change in intensity of human drivers and their associated stressors and model the expected change in ecosystem condition in response to these stressors. As such, CHI assessments capture stages 2-4 in the Conceptual Framework (see Section 2), spanning both the human and natural system. In combination with the Ocean Health Index (see the following Chapter 8.2 for more detail), measures of ecosystem service valuation, and governance assessments, a complete picture of high seas condition emerges.

Results

Most of the high seas regions have similar CHI scores, with all but one within one standard deviation of the average score (3.265). The highest scores are in the northern and central Atlantic and the northwest and western central Pacific, regions in closest proximity to Europe and China (See Figure 8.1), where LME scores are also the highest (see the TWAP LME Technical Assessment Report, Chapter 7.2.4). The lower range of scores included the three Antarctic (southern) Ocean regions and the southeast and eastern central Pacific. Only the Arctic has a relatively *low* average CHI score (0.743). This is not surprising as most of the Arctic high seas region has been under permanent sea ice until very recently, and even now it is generally too risky for most human use and exploration of the region.

Three stressors related to climate change – ocean acidification, changing sea surface temperature (SST), and increasing UV radiation – contributed most to the cumulative impact score for each high seas region (Table 8.1). In fact, these three stressors accounted for >80% of cumulative impact for all regions, and in over half of the regions accounted for >95% of cumulative impact.

The other main stressors in the high seas are shipping and ocean-based pollution, which are derived from the same input data source (commercial shipping traffic). Global shipping routes that pass through the high seas primarily occur in the northern hemisphere, connecting Europe and North America and Asia and North America. Thus, shipping impacts are primarily concentrated in the northern Atlantic and northern Pacific regions.

Commercial fishing has relatively *low* impact scores for nearly all high seas regions. The one exception is the western central Pacific high seas region, where demersal non-destructive (both high and *low* bycatch) and pelagic *low* bycatch fishing have significant impact. Although commercial fishing in the high seas can be intense in certain locations, only six nations actively fish the high seas (White & Costello 2014) and catch is relatively *low* compared to coastal areas within EEZs.

Figure 8.1. Map of open ocean regions (by FAO fishing area) and their average cumulative impact score

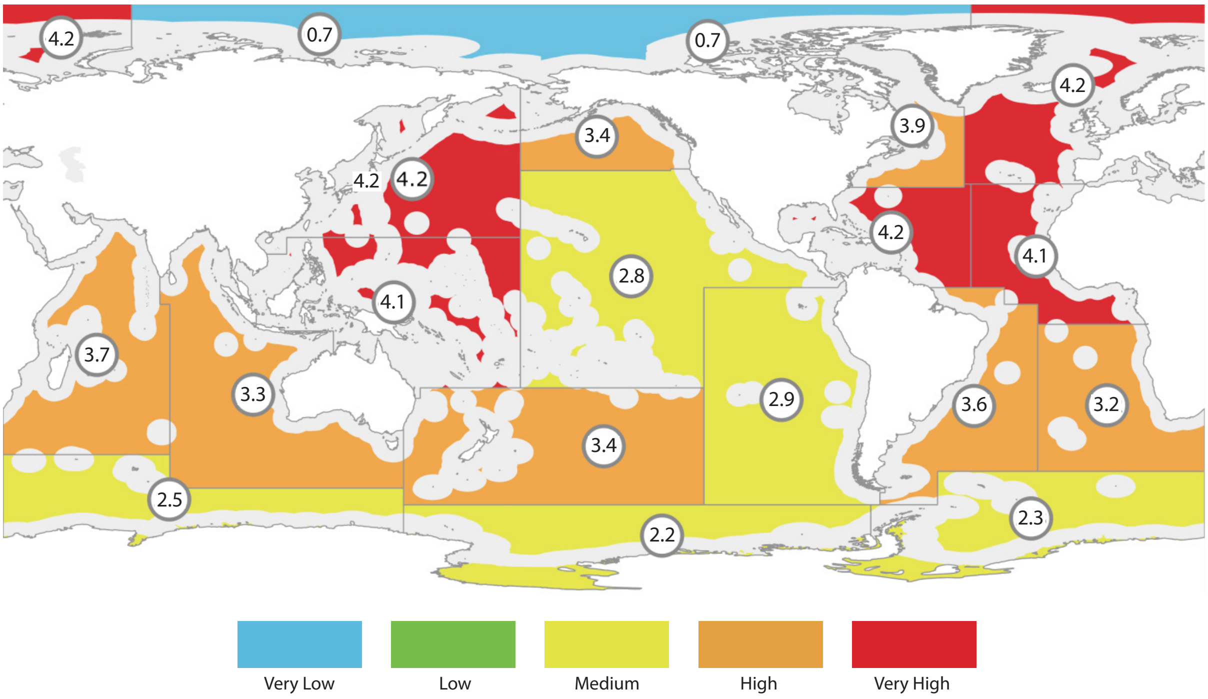


Table 8.1 Full results of CHI and individual stressor impact scores for each high seas region. True zero values are indicated by zeros without decimal points; zero values with decimal points are extremely low but non-zero scores.

FAO region	Name	CHI	Climate Change				Industry		Commercial Fishing				
			SST	UV	Ocean Acidification	SLR	Ocean-based pollution	Shipping	Demersal Destructive Fishing	Demersal Non-destructive High Bycatch Fishing	Demersal Non-destructive Low Bycatch Fishing	Pelagic High Bycatch Fishing	Pelagic Low Bycatch Fishing
18	Arctic Sea	0.743	0.017	0.015	0.708	0.000	0.001	0.001	0.000	0.000	0	0	0
21	Atlantic, Northwest	3.887	1.351	0.818	1.138	0.002	0.344	0.210	0.017	0.004	0.002	0	0.001
27	Atlantic, Northeast	4.200	1.817	0.730	1.126	0.000	0.310	0.196	0.017	0.001	0.003	0	0.001
31	Atlantic, Western-Central	4.217	1.799	0.743	1.251	0	0.250	0.147	0.003	0.003	0.009	0.005	0.005
34	Atlantic, Eastern Central	4.104	1.911	0.742	1.168	0.000	0.149	0.086	0.001	0.001	0.018	0.004	0.024
41	Atlantic, Southwest	3.634	1.633	0.795	1.092	0.000	0.058	0.032	0.010	0.004	0.003	0.005	0.003
47	Atlantic, Southeast	3.237	1.306	0.789	1.030	0.000	0.069	0.038	0.000	0.000	0.003	0.000	0.002
48	Atlantic, Antarctic	2.274	0.788	0.720	0.736	0	0.015	0.008	0.001	0.000	0.005	0	0.000
51	Indian Ocean, Western	3.689	1.601	0.743	1.146	0.000	0.087	0.049	0.010	0.008	0.017	0.002	0.024
57	Indian Ocean, Eastern	3.265	1.296	0.787	1.043	0.000	0.057	0.031	0.004	0.014	0.013	0.006	0.015
58	Indian Ocean, Antarctic & Southern	2.452	0.907	0.799	0.721	0.000	0.016	0.009	0.001	0.000	0.000	0.000	0.000
61	Pacific, Northwest	4.177	1.720	0.777	1.090	0	0.276	0.160	0.013	0.064	0.060	0.000	0.016
67	Pacific, Northeast	3.420	1.113	0.836	0.929	0	0.335	0.197	0.002	0.002	0.003	0	0.003
71	Pacific, Western Central	4.118	1.602	0.694	1.148	0.000	0.133	0.075	0.020	0.103	0.146	0.000	0.198
77	Pacific, Eastern Central	2.813	0.727	0.732	1.083	0	0.152	0.086	0.001	0.006	0.009	0.005	0.012
81	Pacific, Southwest	3.440	1.532	0.815	1.018	0.000	0.044	0.024	0.002	0.002	0.001	0.000	0.001
87	Pacific, Southeast	2.916	1.028	0.773	0.961	0.000	0.045	0.024	0.003	0.031	0.037	0.001	0.012
88	Pacific, Antarctic	2.186	0.710	0.750	0.703	0.000	0.011	0.006	0.002	0	0.000	0	0.003

Note: Eight of 19 stressors included in the CHI assessment are coastal and thus do not affect open ocean systems. They all had zero impact on all FAO high seas regions; they include: artisanal fishing, nutrient pollution, organic pollution, inorganic pollution, light pollution, oil rigs, invasive species, and direct human impacts

Discussion and Conclusions

Nearly all high seas regions are experiencing *moderate* to *high* levels of cumulative impact, primarily due to impacts from climate change. Therefore, managing the high seas and mitigating human pressures by necessity requires addressing climate change. Climate change stressors are the only ones that are truly global, and thus have the potential to impact every square kilometre of the high seas. This global scale contributes to climate change consistently being the highest scoring stressor. The addition of information on stressors that currently do not have global data, in particular atmospheric deposition of key pollutants and marine debris, would increase the cumulative impact for at least some of the high seas regions, but would unlikely change the result that climate change stressors are the dominant impact to high seas regions.

The issue of scale of assessment has important implications for how results presented here can inform policy and management actions. For actions at the scale of entire high seas regions (or entire ocean basins), such as allocating funding among different oceanic regions, these results are useful for identifying high seas regions most in need of conservation and mitigation resources. Within a high seas region, however, these results will have more limited relevance, and decisions would benefit from a regional analysis focused on smaller scale outputs. For example, decisions about where or how to allocate funds to particular locations within a high seas region, or which stressors to mitigate first for particular locations, would all require finer-scale analyses.

The only high seas region to have relatively *low* scores was the Arctic, where sea ice has covered nearly the entire area until very recently. As climate change stressors continue to alter the Arctic, in particular by melting the sea ice, this region's cumulative impact score is *likely* to jump much higher. Careful and strategic management of shipping, fishing and other uses of the area will be important to help prevent overall cumulative impact from getting too high for the region.

The social and economic implications of these results are challenging. Most of the main stressors at the scale of entire high seas region are driven primarily by global forces that are external to the region. Climate change is fueled by global emissions, and commercial shipping by global trade and trade routes. To mitigate these stressors requires truly global efforts. This global need is even more pronounced in the high seas where countries lack jurisdictional authority.

Results from CHI assessments only capture half of what needs to be known and understood for measuring the condition of high seas regions. CHI assessments measure and indicate human activities, their associated stressors, and the expected impact on ecosystems. Missing from these assessments is how the change in ecosystem condition affects the delivery of services to people and how that in turn affects governance and management decisions. Connecting CHI assessments to the scale and location of service delivery (instead of the entire high seas region) would *likely* produce very different results and potentially be much more informative.

Cumulative human impact (CHI) assessments were also done for LME systems, providing an opportunity to directly compare all regions of the world's ocean with the same indicator. Similar CHI assessments have been done for river systems (Vorsmarty et al. 2010). As such, CHI assessments within LMEs provide a powerful tool for linking the assessment of these three water systems in TWAP.

Cross-system comparisons are made possible by the fact that CHI assessments are quantitative and measured in the same, universal metric of impact to ecosystems. Because CHI assessments are fully transparent in their methods and process, they can easily be repeated (to check results or to update with new data) and they are more amenable to policy and management decisions. Transparency and repeatability are hallmarks not only of the scientific process but are also essential for decision-making if it is to be trusted by all involved and effected.

All indicators rely on the underlying data that informs them. Uncertainty in CHI assessments is thus dependent on the quality and certainty of all of the input data, including information on habitat extent and the location and intensity of human stressors. Uncertainty is highest at the finest resolution of assessments permitted by these data ($1km^2$), with resulting '*medium* certainty' in cumulative impact scores at this resolution. At larger scales, in particular at the scale of an entire high seas region, certainty is '*high*' for overall scores, and especially for the relative quantitative difference in scores among regions. A full discussion of assumptions and caveats to CHI assessments is provided elsewhere (Halpern and Fujita 2013).

Recommendations

Much of the area far offshore but still within EEZs is essentially identical to the high seas in terms of component ecosystems and the pressures and impacts to those ecosystems. Managing high seas regions will benefit greatly from coordination with surrounding countries. Because relatively few human activities occur in the high seas, the dominant stressors to the regions result from climate change, although the remoteness of the high seas means they are poorly monitored, limiting our understanding of the location and types of habitats and the extent and intensity of key stressors such as atmospheric pollution and commercial fishing. Meaningful management and stressor mitigation in the high seas must focus on global approaches to reducing carbon emissions, and will also benefit from improved monitoring and assessment.

8.1.3 Notes on Methods

Full details on data sources and processing are provided in extensive supplementary information provided in Halpern et al. (2015). In summary, data layers were developed as follows. Sea surface temperature (SST) and UV layers were based on satellite time series data, and both were processed to assess the number of values that exceeded one standard deviation above the long term average. Ocean acidification and sea level rise (SLR) were both modeled globally and processed as the difference between current and historic values. The five commercial fishing layers were based on spatially-allocated FAO catch data assigned to one of the five fishing gear types. Commercial shipping was based on voluntary monitoring data from ships and processed into shipping tracks across the ocean. Annex A summarizes key attributes of each data layer. Key stressors missing from the analysis include atmospheric pollution and marine litter, and high resolution data on the location and types of habitats in the high seas remain limited.

Intensity values for each stressor and presence/absence for each habitat layer are processed to be at $1km^2$ resolution, requiring down-scaling for some layers (for example: finer resolution is modeled for data at coarser native resolution). All stressor layers are normalized to their reference, or maximum, value to allow direct comparison of stressors measured in very different units. Finally, normalized stressor intensity values are multiplied by the habitat vulnerability weight unique for each stressor-habitat combination to create a modeled impact score, and these impact scores are summed by habitat type to create a per-habitat cumulative impact score and averaged across habitats to create a final per-pixel cumulative impact score.

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Annex A

Summary of data layers used to calculate CHI. Only layers relevant to the high seas are included.

Data Type	Layer	Native resolution	Source
Stressors			
Fishing	Demersal, destructive	half-degree	Sea Around Us
	Demersal, non-destructive, high-bycatch	half-degree	Sea Around Us
	Demersal, non-destructive, low-bycatch	half-degree	Sea Around Us
	Pelagic, high-bycatch	half-degree	Sea Around Us
	Pelagic, low-bycatch	half-degree	Sea Around Us
Climate Change	SST	~16km^2	NOAA
	UV	half-degree	NOAA
	Ocean acidification	half-degree	Halpern et al. 2008
	Sea Level Rise	quarter-degree	Nicholls & Cazenave 2010
Ocean-based	Shipping	~25km^2	VMS AIS data
	ocean-based pollution	1km^2 (modeled)	Shipping + port volume
Habitats			
Offshore	Seamounts	1km^2 (modeled)	Halpern et al. 2008
	Hard shelf (60-200m)	1km^2 (modeled)	Halpern et al. 2008
	Soft shelf (60-200m)	1km^2 (modeled)	Halpern et al. 2008
	Hard slope (200-2000m)	1km^2 (modeled)	Halpern et al. 2008
	Soft slope (200-2000m)	1km^2 (modeled)	Halpern et al. 2008
	Hard deep (>2000m)	1km^2 (modeled)	Halpern et al. 2008
	Soft deep (>2000m)	1km^2 (modeled)	Halpern et al. 2008
	Pelagic surface (0-60m)	1km^2	Halpern et al. 2008
	Deep pelagic (>60m)	1km^2	Halpern et al. 2008