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One jurisdiction away from a healthier ecosystem? The impacts of jurisdictional zones on the health of large marine ecosystems

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ABSTRACT

The Law of the Sea (UNCLOS) divides the world ocean into different maritime zones. This division has led to situations where similar marine resources may be subject to different legal frameworks and requirements, even if they are, in ecological and geographical terms, part of the same Large Marine Ecosystem (LME). At least according to the environmental management literature, the mismatch between jurisdictional (maritime) zones and ecosystem boundaries is inherently harmful to marine ecosystems. This paper tries to validate this narrative by applying the Ocean Health Index (OHI) in relation to LMEs according to their 'jurisdictional situation.' Each of the five jurisdictional situations identified has different standings *vis-à-vis* UNCLOS. Thus, associating this concept with the OHI framework serves as the foundation to analyse whether or not the (mis)match of jurisdictional zones and LME boundaries has any measurable effects on an ecosystem's health. This paper settles on two conclusions: one idealistic and one realistic. Idealistically, empirical evidence suggests that the concept of jurisdictional zones is incoherent from an ecological perspective, since they represent a risk factor for ecosystem-based management. This is concluded because ecosystems in jurisdictional situations with fewer jurisdictional zone intersections tend to receive better ocean health scores on average compared to their counterparts in other situations. However, realistically speaking, the same evidence is simultaneously inconclusive in validating the literature's narrative. This is concluded considering that no direct correlation between the factors 'fewer jurisdictional borders' and 'healthier marine ecosystems' was attested; most likely, due to a vast number of cofounding biophysical, social-economic, and institutional considerations.

1. Introduction

The 1982 United Nations Convention on the Law of the Sea (UNCLOS) provides countries with a particular set of maritime zones. At the risk of oversimplification, the general idea of maritime zones is that coastal state sovereignty over marine areas and resources is strongest in waters closest to it and weakens when one moves further away toward to high seas. This legal-geographical setting has a pragmatical reason to exist. That is, maritime zones are the solution to two inseparable problems which arise when one considers the principle of national jurisdiction in sea areas; those being: "[1] What are the contents of this jurisdiction? [2] What are the boundaries of the area over which it extends?"[1] Notwithstanding its pragmatic function, it is a commonplace in the environmental management literature that the legal architecture visualised in Figs. 1 and 2 historically overlooks how marine ecosystems function and ignores how they are affected by this division of the ocean and seas.[2]

For example, in a 2020 study, Palacio-Abrantes et al. indicated that the advent of the 200 nautical miles rule in the 1980s "cut across" the distribution of marine species which are not evolutionarily constrained by human-made boundaries.[3] Craig goes further and states that the current model of fragmented ocean governance is a "regulatory chaos,"

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[1] Griffin [3], p. 553. As stated by Griffin [3], these two problems are inseparable because "the more absolute the coastal state's authority, the greater is the interest of other states in a narrow width of such authority. Conversely, the wider the area of the coastal state's authority, the greater is the interest of other states in reducing the content of the costal state's authority therein."

[2] On this, see, *e.g.*, Global 2000 Report [4], p. 109; Sherman [5], p. 355; Platjouw [6], p. 114–116; de Lucia [7], p. 5.

[3] Palacio-Abrantes et al. [8], p. 1.

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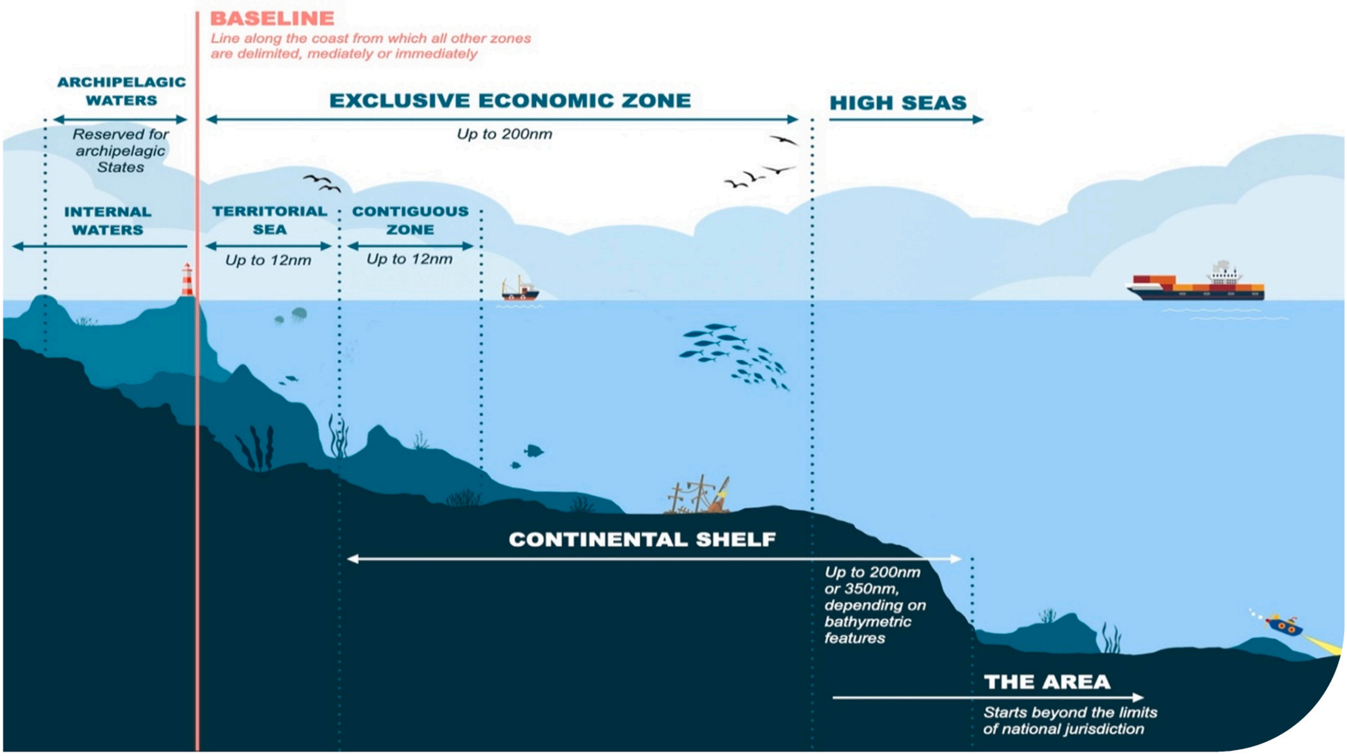

Fig. 1. Maximum breadths of the UNCLOS maritime zones.

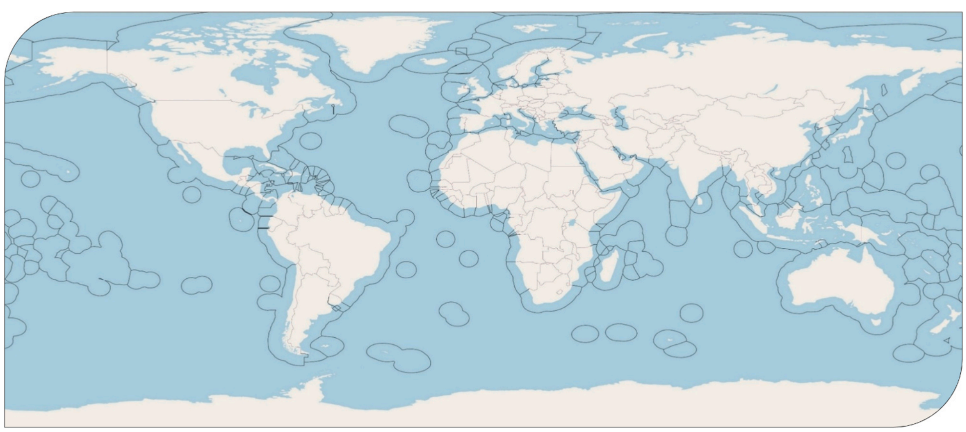

Fig. 2. Maritime zones of the world, represented by the maximum breadth of the world's Exclusive Economic Zones (EEZs). Designed using ArcGIS Pro (version 2.9.2). Map layers used: OpenStreetMap; Maritime Boundaries and Exclusive Economic Zones (200NM) (version 11), by Flanders Marine Institute (2019) (adjusted by Akraetschell).

since multiple national authorities often have conflicting individual priorities and yet regulate different aspects of the same (transboundary) marine environment.[4] As a result, the overall ecologically problematic consequence of this 'artificial' division of the world ocean seems to be that since each maritime zone has its own legal paradigm with varying degrees of state authority, the same type of marine living resource, such as straddling and highly migratory species can be subject to different legal requirements depending on where it roams. In other words, depending on which side of the imaginary nautical mile-lines a marine species finds itself on, might make the difference between strict legal protection or wanton capture.

This issue is further acknowledged by evidence suggesting that migratory marine species, such as marine mammals, turtles, sharks, and tuna, are among the most threatened species due to the pressures they encounter during their extensive movements through different maritime zones.[5] These pressures include, for example, differences in quota allocation, changes in the proportion of captures, and fishery newcomers in different countries' maritime zones.[6]

Although said differences do not necessarily mean that different countries cannot cooperate and synergise their regulatory efforts, Belsky considers that differing jurisdictional responsibilities for ecosystem management, more often than not, constrain comprehensive responses to ocean management issues.[7] That is because, paraphrasing Belsky, most bilateral and multilateral agreements related to transboundary

[4] Craig [9], p. 93.

[5] See Lascelles et al. [10].

[6] Palacios-Abrantes et al. [8], p. 1.

[7] Belsky, 1985, p. 739.

marine living resources:

"do not look to the whole ecosystem, or to the relation between species. Moreover, when they do address geographic areas, the agreement usually focus on economic and political issues, such as dividing resources, rather than on ecological issues, such as conservation of the resources."[8]

Noteworthy also is that climate change is likely to exacerbate the abovementioned concerns. For example, emerging issues such as sea levels rise and species "migration" towards higher latitudes due to rising ocean temperatures,[9] also challenge the current model of fragmented ocean governance in relation to biodiversity protection since they expose, yet again, a divergence between legal delimitations and ecosystem boundaries.

Now, are these concerns justified? Can it be said with confidence that the mismatch between legal and ecosystem borders negatively impacts marine ecosystems in the real world as much as the literature often claims?

This paper aims to validate these questions by applying the Ocean Health Index (OHI) framework, which is a comprehensive framework used to measure ocean health from global to local scales, and its relationship with the Large Marine Ecosystems (LMEs) concept, according to their jurisdictional situation. The jurisdictional situation concept describes the standing of an LME *vis-à-vis* UNCLOS legal-geographical setting, and, as will be seen in Section 3, each situation entails distinct challenges for LMEs. Thus, associating the aforementioned concept with the OHI framework serves as the foundation to analyse whether or not the (mis)match of jurisdictional zones and LME boundaries has any effect on an ecosystem's health.

Before this association, Section 2 outlines the three-step method used to identify which jurisdictional situation an LME represents. Based on this method, five jurisdictional situations were identified:

- **Jurisdictional Situation 1:** LME that exists solely within the maritime zones of a single nation-State;
- **Jurisdictional Situation 2:** LME that crosses over the maritime zones of two or more States;
- **Jurisdictional Situation 3:** LME that exists in the maritime zones of one or more States, and in the high seas;
- **Jurisdictional Situation 4:** LME not yet identified or potentially exists only on the high seas;
- **Jurisdictional Situation 5:** LME that exists solely within areas with unclear and/or undelimited maritime jurisdiction.

The value of classifying LMEs into distinct jurisdictional situations enables us, in an idealistic sense, to demonstrate how jurisdictional zones may be regarded as risk factors for the comprehensive ecosystem-based management of marine ecosystems. Notwithstanding this perspective, realistically speaking, comparing OHI scores in each jurisdictional situation also enables us to challenge long-standing concerns of the environmental management literature that the mismatch of UNCLOS' zones and LME boundaries are inherently harmful to marine ecosystems in every case.

2. Jurisdictional situations as a conceptual foundation

2.1. The problem of jurisdiction

Ecological border-related issues in the marine context are perhaps best evident in LMEs, which are relatively large regions characterised by distinct bathymetric, hydrography, productivity, and trophically dependent populations.[10] In simpler terms, the LME concept acknowledges differences in the physical characteristics of marine regions on the planetary scale, and thus, within those relatively large regions, distinct marine ecosystems are perceived to exist. At the time of writing, 66 LMEs have been identified worldwide – an ever-changing number considering that, paraphrasing Sherman, "the designation and management of LMEs is an evolving scientific and geopolitical process."[11]

This mutually dependent relationship between science and geopolitics is a paradox, which I refer to as the LME boundaries paradox: that is, if the designation of LMEs boundaries ideally follows "natural" boundaries and yet depends on an "ever-evolving scientific and geopolitical process," then are not LMEs boundaries in a way artificially made since they depend on human-made processes? Notwithstanding this paradox, the concept of LMEs as ecosystem-based 'units of management' has received strong international support since its inception in the 1980s[12] However, as described by Garcia and Hayashi, managing those units poses several challenges in practice, such as:

1. The herculean task of geographically delimitating all the components and functions of an LME across all scales of time and spaces.
2. The potential conflicts associated with juxtaposing the often many maritime zones that some LMEs encompass.
3. The absence of international agreements explicitly based on the LME concept.[13]

Once described as "the problem of jurisdiction,"[14] the abovementioned challenge 2, in particular, was raised even before UNCLOS came into effect.[15] Among those conflicts, concerns that the said juxtaposition may have negative impacts on the health of LMEs have not yet been validated. The following section provides a method that enables such a validation process by describing *inter alia* a visual tool on how to tell which jurisdictional situation an LME belongs to. Fig. 3.

2.2. Three-step method to identify the jurisdictional situation of LMEs

To the extent of the author's present knowledge, the first attempt to subdivide LMEs into different jurisdictional situations was made by Martin Belsky, in a 1985 study on the viability of developing a new rule of customary international law based on total ecosystem management regimes. Now, either in an attempt not to disregard the scope of his study or due to the lack of scientific data at the time, Belsky did not undertake the effort of classifying individual LMEs into the original four

8 Belsky, 1985, p. 742.

9 On this, see Fogarty [11].

10 Intergovernmental Oceanographic Commission (IOC, UNESCO), *Large Marine Ecosystems*.

11 Sherman [5], p. 352. For more information on the designation of process of (new) LMEs, see, *e.g.* Chapters 13 and 15 of Sherman, K; Alexander, L. M., Biomass yields and geography of large marine ecosystems. Routledge 1990."

12 On this, Garcia and Hayashi [12], p. 465–466 theorized that the reason for this support is because:

1) From the perspective of countries, LMEs may be used as a pretext for expanding the width of their respective jurisdictional authorities since, at least in theory, it would be easier to manage an LME if this was totally within the EEZ of one single country.
2) From the perspective of international researchers, the LME concept is helpful in securing funding from countries and organizations.
3) From the perspective of Non-Governmental Organizations, the aforementioned points 1 and 2 are strong assets in their campaign for a more holistic management of the environment.

13 Garcia and Hayashi [12], p. 465.

14 Belsky, 1985, p. 735.

15 See, *e.g.*, Global 2000 Report [4] and Sherman [5].

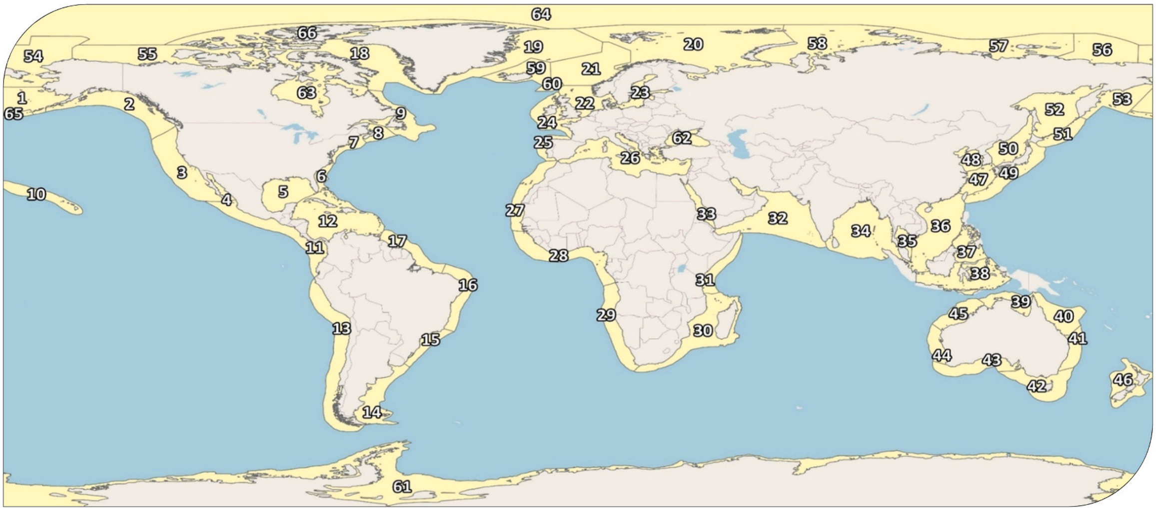

Fig. 3. World's Large Marine Ecosystems. Designed using ArcGIS Pro (version 2.9.2). Map layers used: OpenStreetMap; 66 LME Polygon Boundaries (GEF IW: LEARN Project).

Table 1
Nomenclature and approximate size of the world's large marine ecosystems[a].

Large Marine Ecosystem	Area (km^2)	Large Marine Ecosystem	Area (km^2)	Large Marine Ecosystem	Area (km^2)
01: East Bering Sea	1,193,601	23: Baltic Sea	396,838	45: Northwest Australian Shelf	911,812
02: Gulf of Alaska	1,491,252	24: Celtic-Biscay Shelf	766,550	46: New Zealand Shelf	980,420
03: California Current	2,224,665	25: Iberian Coastal	300,915	47: East China Sea	1,008,066
04: Gulf of California	216,344	26: Mediterranean Sea	2,528,398	48: Yellow Sea	438,619
05: Gulf of Mexico	1,530,387	27: Canary Current	1,120,439	49: Kuroshio Current	1,333,074
06: Southeast U.S. Continental Shelf	303,029	28: Guinea Current	1,958,802	50: Sea of Japan	1,054,305
07: Northeast U.S. Continental Shelf	308,554	29: Benguela Current	1,470,134	51: Oyashio Current	663,609
08: Scotian Shelf	412,676	30: Agulhas Current	2,615,294	52: Sea of Okhotsk	1,627,284
09: Newfoundland-Labrador Shelf	674,862	31: Somali Coastal Current	844,524	53: West Bering Sea	2,182,768
10: Insular Pacific-Hawaiian	975,493	32: Arabian Sea	3,950,421	54: Northern Bering – Chukchi Sea	783,245
11: Pacific Central-American Coastal	1,996,659	33: Red Sea	480,385	55: Beaufort Sea	664,752
12: Caribbean Sea	3,305,077	34: Bay of Bengal	3,657,502	56: East Siberian Sea	1,024,100
13: Humboldt Current	2,619,386	35: Gulf of Thailand	391,665	57: Laptev Sea	539,035
14: Patagonian Shelf	1,173,332	36: South China Sea	5,662,985	58: Kara Sea	970,089
15: South Brazil Shelf	566,397	37: Sulu-Celebes Sea	1,015,737	59: Iceland Shelf and Sea	1,176,522
16: East Brazil Shelf	1,073,210	38: Indonesian Sea	2,289,597	60: Faroe Plateau	151,005
17: North Brazil Shelf	1,034,575	39: North Australian Shelf	772,214	61: Antarctica	3,486,169
18: Canadian Eastern Arctic – West Greenland Shelf	359,422	40: Northeast Australian Shelf	1,299,112	62: Black Sea	461,398
19: Greenland Sea	521,237	41: East Central Australian Shelf	660,679	63: Hudson Bay Complex	1,247,246
20: Barents Sea	2,023,335	42: Southeast Australian Shelf	1,199,787	64: Central Arctic	3,522,239
21: Norwegian Sea	1,109,613	43: Southwest Australian Shelf	1,046,368	65: Aleutian Islands	220,000
22: North Sea	690,041	44: West-Central Australian Shelf	543,577	66: Canadian High Arctic – North Greenland	600,000

[a] Compiled using data available by One Shared Ocean Project at onesharedocean.org/lmes – Last accessed on 05 October 2022.

jurisdictional situations proposed in 1985.[16,17] In this section, I lay down the method used to fill the gap in Belsky's original framework regarding the categorisation of individual LMEs into their respective jurisdictional situation. Table 1.

2.2.1. Step 1: Data collection

The first step to identify the jurisdictional situation of an LME is collecting data on the coordinates of the jurisdictional and ecosystem borders to be analysed. Here, care should be taken regarding the reliability of the metadata used, as unprecise coordinates will be mispresented in a Geographic Information System (GIS) software. Attention should also be paid regarding the source of the data collected, as different data sources are often produced at different times by different professionals with different purposes in mind.[18] One should also keep in mind that some data, such as that used in Fig. 2, cannot necessarily be considered to be authoritative or legally binding, even if they include official data from States' databanks.

Moreover, in consonant with legal geography methods, it is important to consider the timeframe and scale to be analysed. In this context, 'timeframe' means the period in time that the analysis is aimed at, and

[16] Belsky's original jurisdictional situations were (Belsky 1985, p. 736–739):

- **Situation 1**: Controls over a total ecosystem that exists solely within the territory of a single nation-state;
- **Situation 2**: Controls over an ecosystem that crosses over the territories of two or more states;
- **Situation 3:** Controls over an ecosystem that exists solely within international waters;
- **Situation 4:** Controls over an ecosystem that exists in the territory of one or more nations, and in international waters.

[17] The reasoning behind adding a new fifth jurisdictional situation is further described in Section 3.2.5.

[18] On this, see Bailey [13], p. 30.

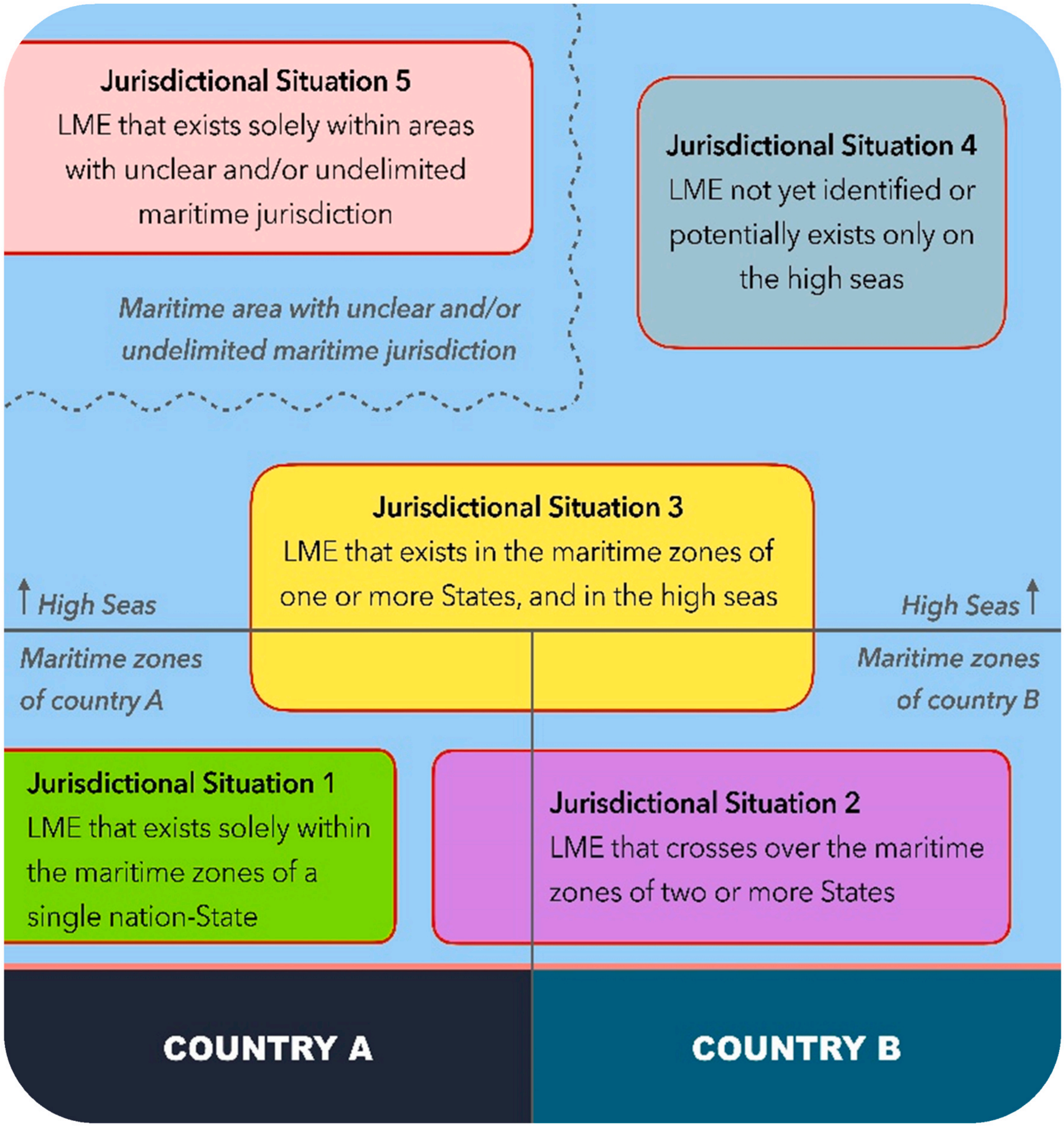

Fig. 4. Illustrative tool for determining the jurisdictional situation of LMEs.

the 'scale' determines the geographical extent or scope of the analysis. This consideration is noteworthy because the use of different timeframes and geographical scales may result in different data being collected, which in turn may affect the analyses in Step 3. The cartographical scale in the analysis is also important to be pinpointed. That is because a mismatch of LME and maritime zone borders could be visualised under finer scales on a map but could easily go unnoticed under greater regional or planetary scales.

Regarding the 'timeframe,' this factor brings to the equation the adaptive nature of LMEs. That is, LMEs are not static in time and constantly evolve under certain disturbances.[19] For example, it has been theorised that differences in ocean temperature and in ice conditions due to climate change will lead to a new restructuring of the LMEs of the Arctic.[20] This restructuring process usually takes a long time to unfold, and thus an analysis between two points in time 'before' and 'after' a restructuring process may (or may not) translate into different co-ordinates regarding ecosystem borders. Furthermore, the time factor can also be assessed from the perspective of maritime zones, as States' borders occasionally change over time. That is, a maritime zone that once belonged to one country may, at a different point in time, belong to another. Recent developments associated with the currently unsettled issue of maritime zones "shrinking" due to sea-level rise could be a variable within the time factor for future case analyses.

2.2.2. *Step 2: Overlay of jurisdictional and ecosystem boundaries*

As the name suggests, this step aims to overlay the data collected in

[19] As stated by Anker et al. [14] (p. 64), "[e]cosystems do not disappear when disturbance overwhelms their resilience. They overgo a shift to a new regime with a structure and function that differ from those of the preceding regime."

[20] Matishov et al. [15], p. 38.

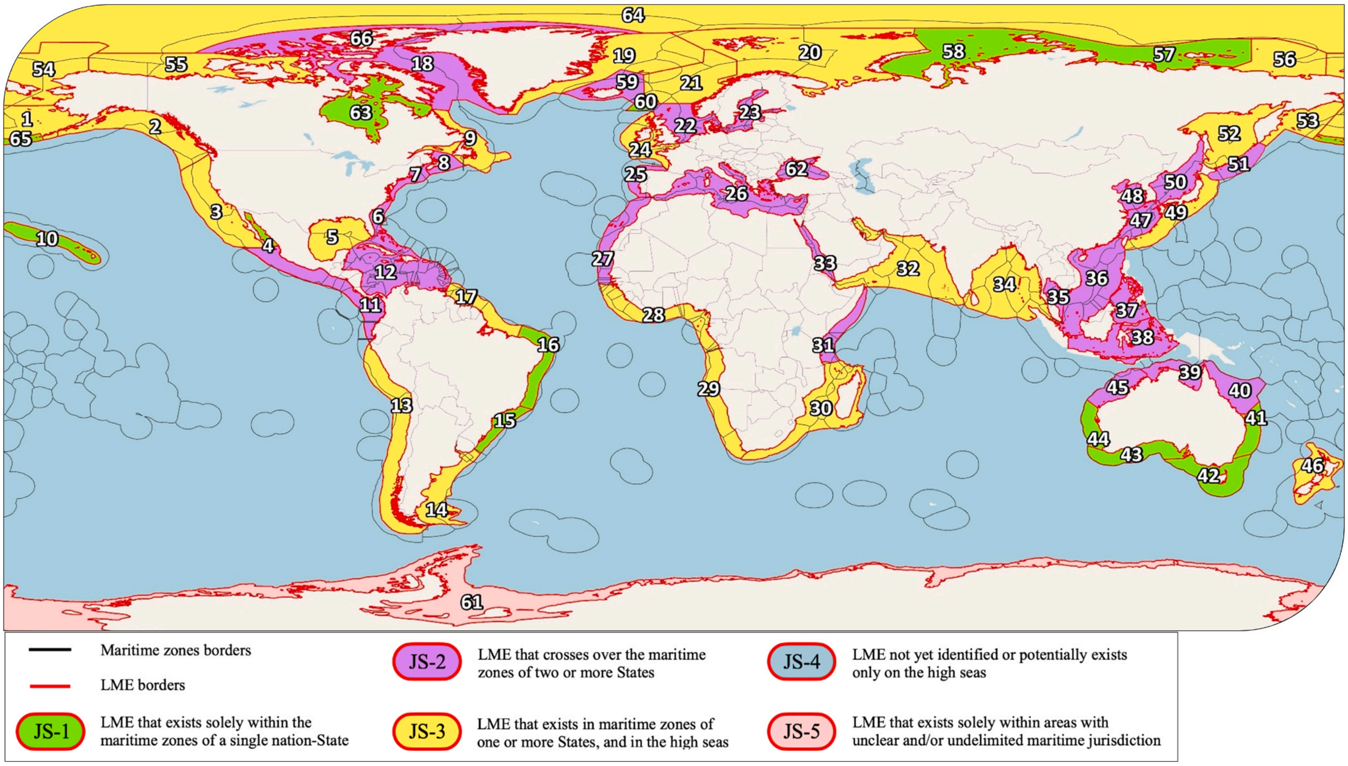

Fig. 5. Jurisdictional Situations of the World's Large Marine Ecosystems. Designed using the three-step method outlined in Section 2 and utilising ArcGIS Pro (version 2.9.2). Map layers used: OpenStreetMap; Maritime Boundaries and Exclusive Economic Zones (200NM) (version 11), by Flanders Marine Institute (2019) (adjusted by Akraetschell); 66 LME Polygon Boundaries (GEF IW:LEARN Project). Individual LMEs were colour-coded to their respective jurisdictional situation following a visual analysis from the overlay of maritime zones borders and LME boundaries at the scale of 1:100 000 000. Personal discretion was used in cases where identifying the jurisdictional situation was uncertain, dubious, or contentious.

the previous step into a single frame of reference, such as in an infographic map. This step is based on the traditional Map-Overlay Method, which many geographers are well familiar with.[21] This step is rather technical and requires some degree of familiarity with the use of GIS software and some graphic design skills.[22]

Finally, in managing the overlayed data, one should consider the following:

1. Which base map to use, depending on which content/variable one wants to include in an analysis;
2. Which colour codes and label structure to use in order to facilitate infographic map visualisation;
3. Developing a Data Management Plan.[23]

2.2.3. Step 3: Visual analysis

The last step to identify the jurisdictional situation of an LME is to visually analyse the (mis)match of ecosystem boundaries and maritime zone boundary intersections. On this, Fig. 4 serves as a visual tool to tell which situation an LME belongs to according to the overlayed boundaries. As seen later in Fig. 5, this exercise also serves as a powerful image to demonstrate the non-equitable and somewhat delicate position that jurisdictional zones leave marine environmental protection worldwide.

3. One jurisdiction away from a healthier ecosystem?

3.1. LME health

In a study published in 2016, Halpern et al. calculated the OHI scores of all the world's 66 LMEs. The full results of OHI scores for each LME are found in Annex Table 7-B of the said study.[24] Traditionally, the OHI index assesses the maritime zones health of coastal nations and

Table 2
Summary of Ocean Health Index values per risk category for LMEs.[281]

fx1

Risk category	Range of values (OHI score)
Lowest	> 72,5
Low	> 68,5 and ≤ 72,5
Medium	> 65,25 and ≤ 68,5
High	> 62 and ≤ 65,25
Highest	≤ 62

[21] As described by Bailey [13], p. 30–31, the rationality behind the map-overlay method is that, by integrating and synthesizing available factor maps, significant ecosystem units can be captured. One should always keep in mind, however, that various discrepancies do often appear when applying the Map-Overlay Method; on this, see Goodchild and Gopal 1989, p. 3–18.

[22] In theory, word processor software, presentation programmes, and even spreadsheets could be used to apply this step. However, those are relatively less accurate for this task and may compromise the reusability of the metadata.

[23] Although one could discuss the role of a data management plan in legal research, a well-designed plan for managing data could coordinate progress in applying this method in larger (international) research projects.

[24] Halpern et al. [16], Annex Table 7-B.

Table 3
OHI scores and risk categories per LME jurisdictional situation.

Jurisdictional situation		OHI Scores			Risk category based on the average OHI score
		Lowest	Highest	Average	
JS-1	LME that exists solely within the maritime zones of a single nation-State	61.10	75.80	69.30	Low risk
JS-2	LME that crosses over the maritime zones of two or more States	55.10	75.80	66.42	Medium risk
JS-3	LME that exists in the maritime zones of one or more States, and in the high seas	51.20	80.80	66.47	Medium risk
JS-4	LME not yet indentified or potentially exists only on the high seas	No data			
JS-5	LME that exists solely within areas with unclear and/or undelimited maritime jurisdiction	73.00			Lowest risk

territories, providing those areas with a score ranging from 0 to 100.[25] Using a new methodological approach, LME-specific scores were calculated by taking the proportion of overlap of EEZs in each LME and using them to calculate an area-weighted average of the EEZ score.[26] Although not a perfect methodology,[27] Halpern et al. scores make it possible to visualise a trend on how LME OHI scores negatively differ depending on the jurisdictional situation. These findings are presented next.

3.2. Ocean health scores per jurisdictional situation

Considering that individual LMEs can be categorised into five different jurisdictional situations, as identified in Section 2, and based on Halpern et al. OHI scores for each of the 66 LMEs, the average OHI score for each jurisdictional situation can be calculated. Table 3 summarises this finding by displaying the lowest, highest, and average scores received by each LME jurisdictional situation. Based on the previous, in Table 2 presented data, Table 3 also reveals that jurisdictional situations with fewer jurisdictional border intersections are perceived to be at "lesser risk", according to the Halpern et al. calculations.

Curiously, by inspecting the data set of all 66 LMEs, categorised according to their respective jurisdictional situation, one can visualise a slight trend regarding the LME OHI sores: LMEs in jurisdictional situations with fewer jurisdictional boundaries intersections tend to receive, *on average*, better OHI scores compared to their counterparts in other situations. Fig. 6 displays this finding in the form of a negative trend graph.

Although visible, it is important to note that, frankly, the decreasing OHI score trend observed in Fig. 6 is modest, thus making it statistically insignificant. In other words, no direct correlation between the factors 'fewer jurisdictional borders' and 'healthier marine ecosystems' can be attested for certainty. Yet, a negative trend exists and is, at least, intriguing.

This discussion will be returned to in Section 3.3. Beforehand, the OHI scores for each jurisdictional situation will be dissected. Additionally, this section also elaborates upon Belsky's original framework, as well as provides some observations in his writing, which, I hope, will redound on his credit.

3.2.1. Jurisdictional Situation 1 (JS-1)

The first jurisdictional situation is marked in green in Fig. 5 and symbolises LMEs that exist solely within the maritime zones of a single nation-State, excluding continental shelves.[29] At the time of writing, 13 LMEs can be classified into JS-1, those being: the (04) Gulf of California LME, the [13] Insular Pacific-Hawaiian LME, the [11] South Brazil Shelf LME, the [12] East Brazil Shelf LME, the [41] East Central Australian Shelf LME, the [42] Southeast Australian Shelf LME, the [43] Southwest Australian Shelf LME, the [44] West-Central Australian Shelf LME, the [57] Laptev Sea LME, the [58] Kara Sea LME, the [60] Faroe Plateau LME, the [63] Hudson Bay Complex LME, and the [65] Aleutian Islands LME. In total, JS-1 LMEs cover an area of approximately 9,4 million km^2 or about 11 % of the global LME area.

In the case of JS-1, those 13 ecosystems, as a group, received comparatively better scores than other jurisdictional situations. As seen in Table 3, on average, JS1–1 LMEs received a score of OHI 69,30, which qualifies them collectively as a *low-risk* category on the OHI scale. The lowest score in the JS-1 is held by the [17] Gulf of California LME (OHI 61,1), which is an LME under the complete jurisdiction of Mexico. The highest score in this jurisdictional situation (OHI 75,8) is held by three LMEs simultaneously, all under the jurisdiction of Australia: the [42] Southeast Australian Shelf LME, the [43] Southwest Australian Shelf LME, the [44] West Central Australian Shelf LME.

In this situation, Belsky notes that, as subjects to minimal limitations found in customary international law, nation-States are free to promulgate comprehensive management rules for an LME within their territory, as well as to not establish any management rule at all.[30] Now, suppose we are to consider that the legal-geographical separation of LMEs is inherently harmful to the marine ecosystems – again, as often claimed by the environmental management literature – then it stands to reason to infer that the maritime zone borders should match LME borders as closely as possible. By this reasoning, the green areas shown in Fig. 5 are, in theory, more "desirable" from a jurisdictional and ecological viewpoint as ecosystem borders and jurisdictional boundaries match each other. This theory will be further discussed in Section 3.3.

3.2.2. Jurisdictional Situation 2 (JS-2)

The second jurisdictional situation is marked in purple in Fig. 5 and

[28] Adapted from Halpern et al. [16].
[25] Ocean Health Index, "*What is OHI*?" Available at: https://oceanhealthindex.org/about/ - Last accessed on 05 October 2022.
[26] Halpern et al. [16], p. 242.
[27] Halpern et al. [16] acknowledge that "caution should be used if decisions are made solely on the basis of risk category assessment [of OHI scores]." (p. 242–243).

[29] Continental shelves borders were not included in this analysis for two main reasons: [1] this author considered that including those borders into this general analysis would make map visualization harder, and [2] it was unclear, at the time of writing, whether or not the slope angle associated with the continental slope was accounted for in LME boundaries displayed in Figs. 3 and 5. This is a factor that deserves further scrutiny in order to make a comparison between continental shelves boundaries and underwater LME boundaries viable.
[30] Belsky, 1985, p. 737.

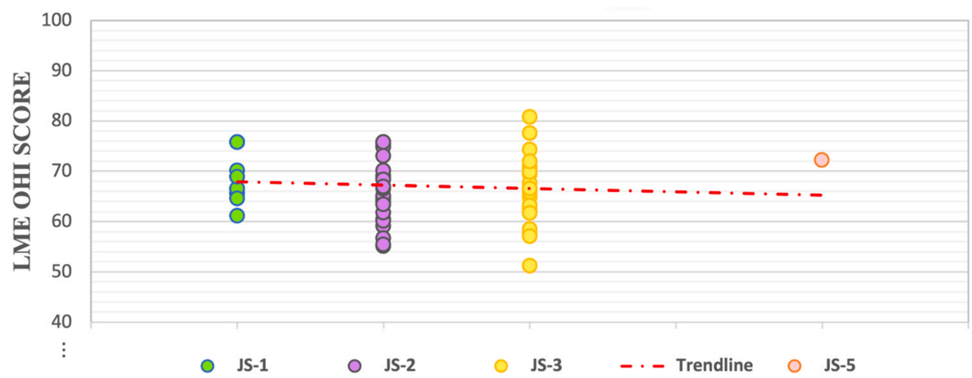

Fig. 6. OHI score-trend for LME jurisdictional situations.

symbolises LMEs crossing over the maritime zones of two or more states. At the time of writing, 27 LMEs can be classified into JS-2, those being: the [18] Southeast U.S. Continental Shelf LME, the [19] Northeast U.S. Continental Shelf LME, the [20] Scotian Shelf LME, the [21] Pacific Central-American Coastal LME, the [9] Caribbean Sea LME, the [3] Canadian Eastern Arctic – West Greenland Shelf LME, the [10] North Sea LME, the [22] Baltic Sea LME, the [23] Iberian Coastal LME, the [24] Mediterranean Sea LME, the [8] Canary Current LME, the [25] Somali Coastal Current LME, the [33] Red Sea LME, the [35] Gulf of Thailand LME, the [36] South China Sea LME, the [37] Sulu-Celebes Sea LME, the [38] Indonesian Sea LME, the [39] North Australian Shelf LME, the [40] Northeast Australian Shelf LME, the [45] Northwest Australian Shelf LME, [47] East China Sea LME, the [48] Yellow Sea LME, the [50] Sea of Japan LME, the [51] Oyashio Current LME, the [59] Iceland Shelf and Sea LME, the [62] Black Sea LME, and the [66] Canadian High Arctic – North Greenland LME. In total, JS-2 LMEs cover an area of approximately 30,8 million km^2 or about 36 % of the global LME area.

Following the analyses of the previous subsection, JS-2 LMEs received, as a group, lower scores on average compared to LMEs managed only by a single nation-State. As seen in Table 3, on average, JS-2 LMEs received a score of OHI 66,42, which qualifies them collectively as a *medium risk* category on the OHI scale. The lowest score in the JS-2 is held by the [25] Somali Coastal Currency LME (OHI 55,1), which is an LME found within the maritime zones of Somalia, Kenya, Tanzania, and Comoros. The highest score in this jurisdictional situation (OHI 75, 8) is held by two LMEs simultaneously: the [39] North Australian Shelf LME, which exists mainly on the maritime zones of Australia but is *de facto* shared with Indonesia and East Timor due to the unresolved dispute concerning the Timor Gap, and [45] Northwest Australian Shelf, which exists mainly on the maritime zones of Australia but has a small portion of the LME that found within the maritime zones of Papua New Guinea.

In this jurisdictional situation, Belsky notes that:

"[w]hen an ecosystem crosses over the territory of more than one nation, management of the total ecosystem can occur only with the explicit consent of each nation-state involved. Thus, each state may decide whether or not to set rules for management within its territory and may disregard completely any standards established by its sister states."[31]

In the real world, this dilemma can be observed in various JS-2 LMEs. Taking the [25] Somali Coastal Current LME as an example, a report published in 2020 by the International Waters Learning Exchange & Report Network (IW.:learn) found that, while Kenya and Tanzania have "extensive legal and institutional frameworks" to manage the water resources within the [25] Somali Coastal Current LME, political issues in their "sister state" Somalia makes it so that the country lacks specific laws and regulations to protect and preserve the marine environment[32] – which, again, is a JS-2 LME. Similar reports also narrate similar dilemmas even for JS-2 LMEs with better OHI scores. This is the case, for example, of the [3] Canadian Eastern Arctic – West Greenland Shelf LME, which albeit receiving an OHI score of 75,5, and thus falling into the *lowest risk category* within the OHI scale, still suffers from a historical enforcement problem due to the voluntary nature of compliance to existing bilateral agreements between Canada and Greenland, which jointly share jurisdiction over this LME.[33]

3.2.3. Jurisdictional situation 3 (JS-3)

The third jurisdictional situation is marked in yellow in Fig. 5 and symbolises LMEs that exist in maritime zones of one or more states and on the high seas. As of the time of writing, 25 LMEs can be classified into JS-3, those being: the [1] East Bering Sea LME, the [2] Gulf of Alaska LME, the [26] California Current LME, the [4] Gulf of Mexico LME, the [14] Newfoundland-Labrador Shelf LME, the [7] Humboldt Current LME, the [27] Patagonian Shelf LME, the [28] North Brazil Shelf LME, the [29] Greenland Sea LME, the [20] Barents Sea LME, the [16] Norwegian Sea LME, the [15] Celtic-Biscay Shelf LME, the [6] Guinea Current LME, the [5] Benguela Current LME, the [30] Agulhas Current LME, the [31] Arabian Sea LME, the [34] Bay of Bengal LME, the [46] New Zealand Shelf LME, the [49] Kuroshio Current LME, the [52] Sea of Okhotsk LME, the [53] West Bering Sea LME, the [54] Northern Bering – Chukchi Seas LME, the [55] Beaufort Sea LME, the [56] East Siberian Sea LME, and the [64] Central Arctic LME. In total, JS-3 LMEs cover an area of just over 42,1 million km^2 or about 49 % of the global LME area.

On average, JS-3 LMEs received a score of OHI 66,47, which qualifies them collectively within the *medium risk* category in the OHI scale. Even though JS-3 LMEs received, as a group, virtually the same OHI score as JS-2 LMEs, the lowest score in JS-3 LMEs is considerably lower than the previous two situations. The holder of this unfortunate statistic is the [6] Guinea Current LME, which exists within the maritime zones of some 16 countries and in four distinct areas of the high seas. This LME received a score of OHI 51,2. In contrast, the highest score in this jurisdictional situation – and of all LMEs, for that matter – is held by the [29] Greenland Shelf (OHI 80,8).

Regarding this situation, Belsky interestingly notes that whenever ecosystems exist within one or more nations' maritime zones and on parts of the high seas, jurisdictional responsibilities and limitations tend

[31] Belsky, 1985, p.737

[32] Heileman, S; Scott, L. E. P., II-5 Somali Coastal Current: LME #31 [20].

[33] Aquarone et al., XIX-58 West Greenland Shelf: LME #18 [26].

to "clash."[34] That is because, quoting Belsky:

"[u]nless a treaty or a customary rule [exists] which all states [follow], no state [is] forced to comply with those standards in dealing with parts of the ecosystem located in international waters. Moreover, because of nationalism, many states [oppose the] establishment of international standards which [restrict] their freedom to regulate activities within their territories or in international waters."[35]

This issue is seen in a number of JS-3 LMEs. For example, the [31] Arabian Sea LME (OHI 58,5) exists in the maritime zones of multiple countries, as well as a large expanse of the high seas, and although regional initiatives have reportedly made positive impacts on the protection of said LME, a holistic ecosystem approach – which, in principle, also includes the high seas – is missing.[36] Another example of this type of jurisdictional clash was seen in the so-called 'Donut Hole,' which is a high sea enclave partially within the [1] East Bering Sea LME (OHI 68, 8). Historical catches in that area of the high seas are reported to have been high and unsustainable,[37] a situation which only changed after the advent of the 1994 Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea.

In contrast to the previous examples, the [7] Humboldt Current LME (OHI 63,2) is a prominent example of what happens when – using Belsky's words – "enlightened states'[38] are able to look beyond the jurisdictional clash. Although this LME received a relatively poor OHI score, falling thus into the *high-risk* category within the OHI scale, this LME is covered by several international agreements, including the 2000 Framework Agreement for the Conservation of Living Marine Resources in the High Seas of the Southeast Pacific (Galapagos Agreement). Reportedly, these agreements are said to promote "fruitful regional cooperation" among the countries which share jurisdiction over the [7] Humboldt Current LME, as well as address the threat that uncontrolled exploitation of living marine resources in high seas areas adjacent to zones under national jurisdiction could entail for that LME. [39]

3.2.4. Jurisdictional Situation 4 (JS-4)

The fourth jurisdictional situation is marked in light blue in Fig. 5 and symbolises LMEs not yet identified or potentially existing only on the high seas. Since none of the existing 66 LMEs currently fall into this jurisdictional situation, JS-4 is, for now, a hypothetical situation; thus, explaining its absence in Table 3 and Fig. 6. In Belsky's 1985 work, this situation is described as the third jurisdictional situation and refers to the cases when "an ecosystem exists solely within international waters."[40] As will be clarified below, this paper extends the original 1985 description to include not only LMEs that (potentially) exist only on the high seas but also LMEs not yet identified, whether on the high seas or within national jurisdiction.

The reason for this extension is twofold. First, in the 1985 formulation, Belsky did not consider areas of the ocean within national jurisdiction outside of currently identified LMEs. That was an imprecise approach because, when applying the three-step method outlined in Section 2.2 to develop Fig. 5, it was noticed that areas *within* coastal States' maritime zones that are *outside* of the current 66 LME borders could not logically be classified to be "solely on the high seas". This is the case, for example, of the maritime zones in Micronesia, Polynesia, and some parts of Melanesia. No LME has yet been identified in (or around) said maritime zones, but by no means this entails that an LME "solely on the high seas" exist in those zones. This would be, of course, contradictory. Thus, in order to include Belsky's then-third situation in Fig. 5, the only option left was to broaden his original reasoning by also considering LMEs that have not yet been identified (more on this below).

Second, the original 1985 description failed to reflect on the dilemma I referred to in Section 2.1 as the LME boundaries paradox: how come LME boundaries are "natural" if they depend on "artificial" scientific and geopolitical processes? By this logic, one cannot disregard the notion that there may (or may not) be unidentified LMEs 'out there', yet to be identified by human-made processes. As food for thought, one could say that those undiscovered LMEs wait for further "scientific and geopolitical processes", which could one day identify the correct jurisdictional situation upon which they "naturally" belong to. This notion is further supported by the fact that LME numbers have only grown in the past decades. Being that as it may, it is by expanding the original 1985 JS-4 description to also include undiscovered LMEs that makes it possible to include JS-4 into a single frame of reference together with other jurisdictional situations without the contradictions previously noted. Hence, making this new description preferred over the original one.

Noteworthy also is that, since none of the 66 LMEs identified to date exists only on the high seas, it remains unclear what the jurisdictional risks that JS-4 LMEs may encounter are.

3.2.5. Jurisdictional Situation 5 (JS-5)

The fifth jurisdictional situation is marked in salmon colour in Fig. 5 and symbolises LMEs that exist solely within areas with unclear and/or undelimited maritime jurisdiction. At the time of writing, for reasons presented below, only the [61] Antarctica LME falls into this category. This LME covers an area just shy of 3,5 million km^2, or about 4 % of the global LME area, and received a 73,0 OHI score, thus falling into *the lowest risk category* on the OHI scale.¨.

JS-5 is not mentioned in Belsky's original framework, but it is logically deduced once we consider that:

1. Several maritime areas around the world have unclear maritime jurisdiction as a result *inter alia* of maritime zone overlaps and jurisdictional disputes;
2. Not all coastal areas are equally entitled to all maritime zones under UNCLOS.

Now, in the case of Antarctic waters, Malone notes that:

"[maritime] boundaries under UNCLOS, as important as they otherwise are, are significant for Antarctica only if they apply to Antarctica. Whether they do or do not is not evident on the face of [UNCLOS], as it never mentions Antarctica. Whether this glaring omission was intended to indicate exclusion, was inadvertent, or was a reflection of an inability to reach a consensus, necessitates a messy inquiry into the *travaux préparatoires* of the Convention and conflicting statements by state representatives as to coverage of Antarctica."[41]

It is not within the scope of this paper to undertake such a 'messy inquiry.' However, in the context of the discussion of LME jurisdictional situations, I argue that the [61] Antarctica LME should fit into a jurisdictional distinct from JS-4 for two main reasons: [1] the LME was

[34] Belsky, 1985, p. 738.

[35] *Ibid.* Although once could say that UNCLOS *is* the treaty that Belsky might have been refereeing to, it is important to note that UNCLOS rules concerning the conservation and management of living resources which exist on the high seas are relatively limited. In fact, Article 118 UNCLOS state only that States shall cooperate and enter into negotiations concerning *inter alia* the establishment of subregional or regional fisheries organizations to deal with living resources of the high seas. I argue, therefore, that until a legally binding treaty on biodiversity of areas beyond national jurisdiction is in force, jurisdictional responsibilities and limitations regarding JS-3 LMEs will continue to clash.

[36] Heileman, S.; Eghtesadi-Araghi, P.; Mistafa, N., VI-9 Arabian Sea: LME #32 [19].

[37] Aquarone, M. C.; Adams, S, XIV-45 East Bering Sea: LME #1 [17].

[38] Belsky, 1985, p. 749

[39] Heileman et al., XVII-56 Humboldt Current: LME #13 [18].

[40] Belsky, 1985, p. 737.

[41] Malone [22], p. 66.

Table 4
Seven-point scale of Coherence (adapted from Nilsson et al., 2017).

+3	Indivisible	The strongest form of positive interaction in which one objective is inextricably linked to the achievement of another.
+2	Reinforcing	One objective directly creates conditions that lead to the achievement of another objective.
+1	Enabling	The pursuit of one objective enables the achievement of another objective.
0	Neutral	A neutral relationship where one objective does not significantly interact with another or where interactions are deemed to be neither positive nor negative.
-1	Constraining	A mild form of negative interaction when the pursuit of one objective sets a condition or a constraint on the achievement of another.
-2	Counteracting	The pursuit of one objective counteracts another objective.
-3	Cancelling	The most negative interaction is where progress in one goal makes it impossible to reach another goal and possibly leads to a deteriorating state of the second. A choice has to be made between the two.

identified and [2] the borders of that LME also includes vast coastal areas of mainland Antarctica, thus contradicting the literal notion of the LME potentially existing "only in the high seas."[42] On a more theoretical note, even though claims of sovereignty in Antarctica are still an unsolved question due to the Article IV of the Antarctic Treaty, the competence of the Antarctic Treaty parties, attributed to them tacitly by third States, cannot legally be translated into maritime zones, since this would be, in my perspective, in contradiction to *pacta tertiis* rule.[43] This theory thus excludes the [61] Antarctica LME from jurisdictional situations 1, 2, and 3.

Consequently, in order to incorporate the [61] Antarctica LME into the list of jurisdictional situations, as identified by the three-step method outlined in Section 2, the only alternative left was to expand Belsky's framework and propose a new fifth jurisdictional situation. In a way, JS-5 could then be seen as the "last option" should an LME not fit in any other jurisdictional situation.

3.3. Discussion

As visualised in Table 3 and Fig. 6, the OHI scores for LME groups in different jurisdictional situations reveal an interesting trend: LMEs in jurisdictional situations with fewer maritime zone intersections have received better OHI scores on average in comparison to their counterparts in other situations. This is an interesting finding in itself, and, at first glance, this trend could be used to fuel concerns that UNCLOS' concept of maritime zones is incoherent from an ecological perspective since said zones inadvertently constraint (−1) the implementation of ecosystem-based management of transboundary LMEs; thus counteracting (−2) efforts towards the holistic management and sustainable use of transboundary marine resources. The main argument supporting these concerns is the fact the mismatch between legal requirements and ecological needs entails the fragmentation of naturally indivisible ecosystems.[44]

The negative scores in bold brackets above are hypotheses based on the seven-point scale of Coherence, which was originally developed by Nilsson et al. [23]. Since then, this framework has been applied by a number of scholars and international research projects[45] and is presented below (Table 4), since comparing different Coherence scores by analogy is, in my perspective, easier than analysing any score independently.

Now, the study of Coherence is not an exact science, and discussing its complexity further is not within the scope of this study. Notwithstanding, the negative scores, proposed two paragraphs above, give us a glance at how UNCLOS finds itself in a very difficult predicament: its jurisdictional zones enjoy an enormous historical and pragmatic value whilst inadvertently having an incoherent environmental one. This conclusion is, nevertheless, idealistic.

Realistically speaking, although LMEs with fewer boundaries *seem* to have higher OHI scores *comparatively* in relation to their counterparts in other jurisdictional situations, it is somewhat incongruous to note that the jurisdictional situation itself cannot be automatically considered the direct cause for good or bad OHI scores. In fact, not only is the decreasing trendline visualised in Fig. 6 statistically insignificant, one should always consider the vast number of biophysical considerations, such as ocean productivity and sea surface temperature, as well as other socio-economic factors, such as demographic trends and economic dependence on ecosystem services, that may, directly or indirectly, influence the health of an LME. Therefore, although the raw data presented in Fig. 6 can be interpreted in a manner suggesting a trend between the factors 'fewer jurisdictional boundaries' and 'healthier marine ecosystems', a direct correlation between these variables is not realistic. Moreover, even if there was a correlation between these factors, one cannot disregard the institutional or international process that might implicitly manage transboundary LMEs, such as the 1995 United Nations Fish Stock Agreement and other regional agreements

[42] As pointed out by Homan (2006, p. 76) [32], among many other things related to Antarctica, the question of whether or not Antarctic waters are to be considered part of the high seas is, at this point in time, a little more than "idle speculation." In the context of the LME discussion, the Author considers this speculation to be enough to distinguish the [61] Antarctic LME from other situations besides JS-5.

[43] For more on the tacit competence of the Antarctic Treaty parties to manage Antarctica on behalf of the commonweal of the international community, including third states, see: de Oliveira 2021, p. 42–48. For other views on this topic, see, *e.g.*, Churchill, Robin; Lowe, Vaughan; Sander, Amy, *The Law of the Sea*. Manchester University Press [17] 2022; Elferink, Alex G. O., Rothwell Donald. R., *The Law of the Sea and Polar Maritime Delimitation and Jurisdiction*. Brill 2001; and, Treves, T, *High Seas*. Max Planck Encyclopaedia of International Law 2009.

[44] On this, Platjouw [6], p. 135 states that since different countries' legal instruments tend to differ in geographical scope, and public officials are assigned with particulate mandates within the frame of their national legislation, the current fragmentation not only complicates governance of an ecosystem "as a whole" but also disable the possibility of ecosystem-based governance due to the demarcation of naturally indivisible ecosystems into different jurisdictional zones.

[45] *E.g.*: Nilsson et al. [24]; McCollum et al. [33]; Nilsson et al. [34]; Platjouw et al. [6]; Horizon 2020 FAIRWAY Project (2017–2021); and Horizon Europe CrossGov Project (2022–2025).

established *ex-ante* UNCLOS came into force.

All in all, proposing that the 'fewer jurisdictional boundaries an LME has, the healthier the LME is' is as illogical as proposing that the 'more jurisdictional boundaries, the less LME health can be expected' – which, in the real world, is not necessarily the case. In fact, the best OHI score was received by a JS-3 LME; that is, the [29] Greenland Sea (OHI 80,8). Once again, according to the environmental management literature logic that the UNCLOS legal-geographical setting is inherently harmful to marine ecosystems, JS-3 would be the least desirable situation for an LME to be in *vis-à-vis* UNCLOS. At least for the [29] Greenland Sea, this standing seems to have had little impact on its ecosystem health.

On an opposite spectrum, let us also not forget that JS-1, which, according to the literature logic, would be the most desirable situation, has received some terrible scores of its own; namely, the [17] Gulf of California LME (OHI 61,1) and the [60] Faroe Plateau LME (OHI 64,6). These scores were low enough to be classified respectively into the *highest* and *high-risk* categories within the OHI scale.

These examples serve to contradict, once again, claims that fewer jurisdictional zones entail better marine environmental protection for LMEs. Thus, in light of the presented arguments, I also settle with the realistic conclusion that the empirical data presented in this section is inconclusive to validate the narrative that the mismatch between legal and ecosystem boundaries invariably impacts the health of LMEs in a generic, negative manner.

4. Conclusions

This article attempted to validate long-lasting claims in the environmental management literature that the mismatch between UNCLOS jurisdictional zones and ecosystem borders negatively impacts marine ecosystems. In doing so, the paper expanded on the original 1985 conceptual framework on the LME jurisdictional situations and developed a new method to categorise which of the five jurisdictional situations identified an LME belongs to (Section 2). This categorisation is noteworthy because each situation entails distinct management challenges for marine ecosystems, thus representing the standing of each LME *vis-à-vis* UNCLOS. The method also facilitated the development of an infographic, displaying which jurisdictional situation of all the world's 66 LMEs fall into (Fig. 5). The infographic serves as a powerful image to demonstrate the non-equitable and somewhat delicate position that jurisdictional zones leave marine environmental protection in worldwide.

By using the abovementioned framework as a conceptual foundation, Section 3 applied the OHI in relation to LMEs according to their respective jurisdictional situation. This association enabled the visualisation of a trend on how the (mis)match of jurisdictional (maritime) zones and LMEs boundaries reflects but does not correlate to LME health (Fig. 6). Based on this finding, this paper settled on two conclusions regarding validating the environmental management literature claims: one idealistic and one realistic.

Idealistically speaking, jurisdictional zones represent a risk factor for ecosystem-based management (See Table 3). That is because, far from being neutral (see Table 4 and the discussion in Section 3.3), maritime zones as a legal-geographical concept constrain the ecosystem-based management of transboundary LMEs. As a result, by simply 'being there', said zones counteract efforts towards the holistic management and sustainable use of transboundary marine resources in transboundary LMEs. This conclusion is supported by a well-established Coherence framework, outlined in Section 3.3, and by a trend observed in Table 3 and Fig. 6: LMEs in jurisdictional situations with fewer jurisdictional zone intersections tend to receive better OHI scores *on average* compared to their counterparts in jurisdictional situations with more intersections.

However, – and this is a big 'however' – realistically speaking, the data provided in Section 3 is, at the same time, inconclusive to validate the literature concerns. Two main points support this conclusion. First, there seems to be no direct correlation between fewer jurisdictional boundaries and healthier marine ecosystems. In fact, there are so many confounding biophysical, social-economic, and institutional factors that need to be assessed when comparing different LME OHI scores, that trying to pinpoint the main variable providing better or worst LME OHI scores probably will lead somewhere between the realm of confusion and the unknown. Second, this realistic conclusion can also be supported by counter argumentation. For example, at the end of the day, if LMEs with fewer boundaries were 'as good as they say', then why is the state of marine living resources in most countries' maritime zones so deplorable after 40 years of UNCLOS? Also, if jurisdictional zones were so bad, why did an LME managed by three States plus the high seas' norms receive the best OHI score in the world?

All in all, although claims made by the environmental management literature that the mismatch between legal and ecosystem borders negatively impacts marine ecosystems is a compelling narrative and does deserve further investigation in the form of case analyses, as it stands, there is simply insufficient empirical evidence to confidently support said claims generically. Therefore, there is a need to conduct interdisciplinary analyses combining research on the distinct biophysical characteristics of LMEs[46] with an assessment of the policy incentives and legal requirements designed to foster transboundary legal coherence in LME management structures.

CRediT authorship contribution statement

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

Declaration of interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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