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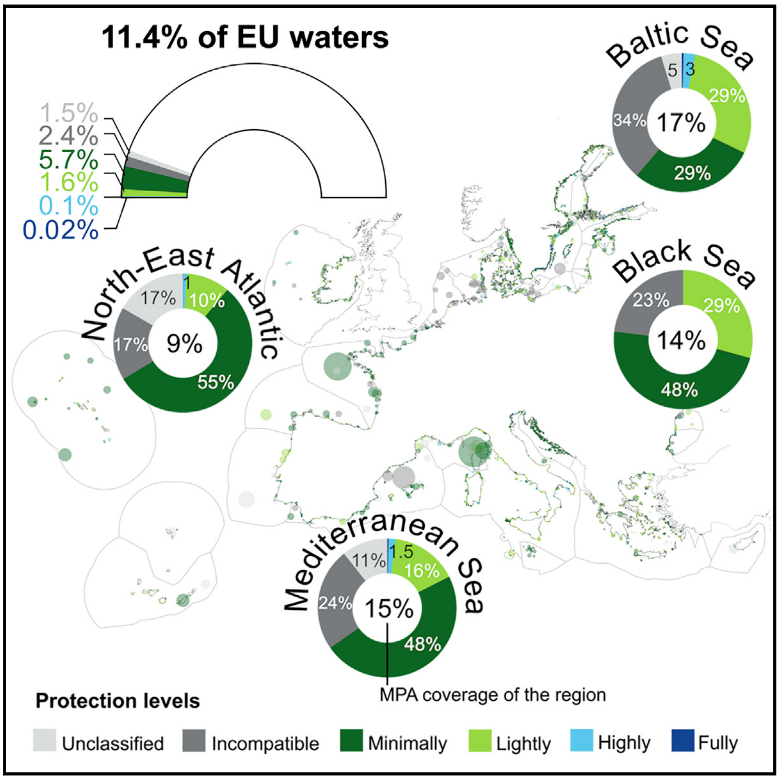
Article

Over 80% of the European Union's marine protected area only marginally regulates human activities

Graphical abstract



Highlights

- We assessed the level of protection of 4,858 EU MPAs based on the MPA Guide
- In 2022, MPAs covered 11.4% of EU waters, and 0.2% were fully or highly protected
- 86% of MPA area showed low protection levels or incompatibility with conservation
- Minimal protection was widespread across member states, regions, and MPA features

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In brief

The European Union has developed an ambitious vision for its marine protected areas (MPAs), aiming for 30% of MPA coverage and 10% strict protection per sea region. However, the protection levels of existing MPAs have not yet been assessed. We assessed their protection levels using the MPA Guide framework. MPAs covered 11.4% of EU national waters in 2022, of which 0.2% were fully or highly protected. Minimal protection was widespread across member states, regions, and types of MPAs.

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Over 80% of the European Union's marine protected area only marginally regulates human activities

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SCIENCE FOR SOCIETY Our oceans guarantee our food, climate regulation, and well-being, but they are largely threatened by heatwaves, overfishing, and ecosystem destruction caused by ever-expanding human activities. The European Union (EU) and its member states have designated marine protected areas (MPAs) as areas where the protection of marine biodiversity is a priority. We found that, in 2022, 86% of the 11.4% of EU waters covered by MPAs showed light, minimal, or no protection from the most harmful human activities, such as dredging, mining, or the most damaging fishing gears. For EU MPAs to protect marine biodiversity, it is urgent to expand their toolbox to reduce pressures on marine ecosystems by regulating activities more broadly, thus increasing their level of protection. Our results raise the question of how MPAs have been used and what decision-making processes would enable the definition of common rules that guarantee the future of our livelihood and our ecosystems within MPA boundaries and beyond.

SUMMARY

To address the ongoing deterioration of marine ecosystems and its consequences on livelihood, the European Union (EU) now aims to achieve 30% coverage of marine protected areas (MPAs), with 10% under strict protection per region. Here, we provide the first assessment of protection levels of EU MPAs, describing the level of legal restrictions of activities using the MPA Guide framework. While MPAs covered 11.4% of EU national waters in 2022, 0.2% were fully or highly protected. As much as 86% of MPA coverage showed low levels of protection or would not be considered compatible with conservation objectives, as they allow industrial activities. Most MPA coverage showed minimal protection across member states, sea regions, and legal types of MPAs. The EU MPA network likely provides limited ecological outcomes. Reaching the EU's 10% strict protection target will require radical changes to the regulation of activities in EU MPAs.

INTRODUCTION

Marine protected areas (MPAs) have been increasingly used worldwide as a conservation tool for maintaining marine ecosystem integrity, including through the regulation of human activities at sea.[1] Yet, the state of marine ecosystems has shown little improvement or continued deterioration.[2] These developments have led to growing concerns about the benefits of existing MPAs[3–6] and increasing calls for policies to focus not only on designating new MPAs but also on ensuring their effectiveness to maintain or restore ecosystems.[1,7] Indeed, MPAs can have a wide range of objectives, implemented through various governance systems and levels of regulation (e.g., from no-take to areas where most maritime activities can occur). MPAs can have many social (e.g., environmental knowledge, conflict management, participation, and economic benefits[8–10]) and ecological impacts. Enforced regulation of activities and active management are key for MPAs to contribute to restoring and protecting ecosystems and biodiversity (e.g., maintain habitats and their functions or increase biomass[10–16]).

The European Union (EU) is at the forefront of marine conservation policies,[17,18] and the 22 coastal member states have so far designated 12% of EU seas as MPAs.[19] MPA policies are driven by several EU legal instruments, notably the Marine Strategy Framework Directive (MSFD), and most importantly, the Birds and Habitats Directives that led all member states to designate MPAs under the Natura 2000 umbrella.[20,21] In each Natura 2000 MPA, member states must implement conservation measures relevant to the species and habitats for which it was designated.[22] Finally, in addition to EU legislation, regional sea conventions have also integrated MPAs in their strategies, leading to MPA designation under the umbrella of OSPAR (North-East Atlantic Ocean), HELCOM (Baltic Sea), and Barcelona (Mediterranean Sea) conventions. These different legal frameworks focus on ensuring large and ecologically representative MPA coverage; they do not require (regional sea conventions) or specify (EU directives) management measures for MPAs. Nature conservation laws also interact with other legal frameworks, including national legislation and the EU Common Fishery Policy, for which implementation varies by jurisdiction.[20] This multilayered legal framework resulted in a very heterogeneous network made of national and international designations and adapted to national priorities and administrative systems.

Despite these existing policies, ecological proxies indicate little or no improvements at EU scale (see, for example, assessments from the European Red List and the European Environment Agency notably based on reporting schemes of EU directives).[23–27] Insufficient enforcement, funding, and staff capacity; low political prioritization; limited participatory settings; and lack of restrictions on impactful activities hamper MPAs' ability to fulfill their socio-ecological objectives in the EU.[28–32] Many EU MPAs lack conservation measures, though they are mandatory at least in Natura 2000 MPAs at EU scale and through several national legal frameworks.[21,33–36] Existing measures are also difficult to assess, as they are rarely specified in management plans (national schemes may require management plans, but it is not mandatory under EU legislation.[37,38] Overall, the few existing assessments describe low protection levels in different parts of EU seas.[20,39–46]

For the first time, the European Commission defined clear but non-legally binding goals regarding regulation of activities in EU MPAs that should support the implementation of existing legal requirements. This was done first through the non-legally binding EU Biodiversity Strategy for 2030, welcomed by the Council of the European Union,[47] aiming at a 30% coverage of MPAs, and other effective conservation measures and at 10% of strict protection by 2030 for each sea region. It considers "strict protection" as "fully and legally protected areas [… where] natural processes are left essentially undisturbed from human pressures and threats to the area's overall ecological structure and functioning."[48] The OSPAR, HELCOM, and Barcelona conventions also committed to the 30% target, and HELCOM went further in aligning with the 10% target of strict protection. In addition, the European Commission released a non-legally binding action plan to protect and restore marine ecosystems, calling on member states to "phase out mobile bottom fishing" in Natura 2000 MPAs under the Habitats Directive by 2024 and in all EU MPAs by 2030.[49] This call was not supported by the European Parliament.[50] These policies brought an unprecedented focus on regulating human activities and, so, on protection levels. In early 2024, most member states have yet to present their pledges and action plans to the European Commission, including the definition and targeted coverage of strict protection for their national waters.[51]

While it would be necessary to monitor the effectiveness of MPA policies, there is no EU-wide assessment of MPAs' protection levels. Existing and accessible databases contain dispersed and limited information on MPAs' regulation of activities (e.g., Natura 2000, Marine Spatial Plans, EMODnet, and national databases) that have not yet been gathered to provide an overview at the EU level. Only a few studies have provided regional or national assessments[39–42] or analyses using proxies of protection levels, such as the presence of management plans, types of designations, IUCN categories, and number of overlapping MPAs.[42,43,52,53] Research on the link between these proxies and the levels of protection through regulation of activities is limited. The IUCN categories, for example, can be taken as one such indicator, and because they are defined based on main management objectives, they could be used as a proxy of protection levels (e.g., Jacquemont et al.[54]) or as an example of the definition of "strict" protection.[48] Management authorities may assign IUCN categories to their MPAs by following IUCN guidelines on activities compatible with each category,[55] but it is likely that current reporting does not reflect the levels of regulation on activities.[56,57]

This study therefore assesses the protection levels of EU MPAs based on the potential impact of activities allowed within their borders. As defined by the MPA Guide framework, MPAs were classified from minimally protected to fully protected or considered incompatible with conservation objectives if some highly impactful activities, such as mining, could occur (Grorud-Colvert et al. 2021[13]). To account for uncertainty on regulated activities, we computed two scenarios of potential impacts and resulting protection levels. In the first scenario, we considered the lowest impact for each activity, and in the second scenario, we considered the highest. We examined the distribution of protection levels across EU seas and countries, and we hypothesized overall low protection levels. Finally, we investigated the correlations between protection levels and various MPA features that have been used previously as proxies of protection levels, with the hypothesis that they are uncorrelated (i.e., age, protection focus, and reported IUCN categories). We also investigated the links between protection levels and legal MPA features (designation types and subtypes, the use of a zoning system with different regulations within MPAs, level of overlapping of multiple designation, and jurisdictions). We expected stronger protection levels in national waters and nationally designated MPAs, particularly because of the shared sovereignty over fishing rights in EU waters and the lack of specific requirements in Natura 2000 MPAs. While MPAs covered 11.4% of EU waters in 2022, we found that 0.2% were fully or highly protected. Eighty-six percent of EU MPA coverage was either lightly protected, minimally protected, or incompatible with conservation objectives. This pattern was consistent across member states,

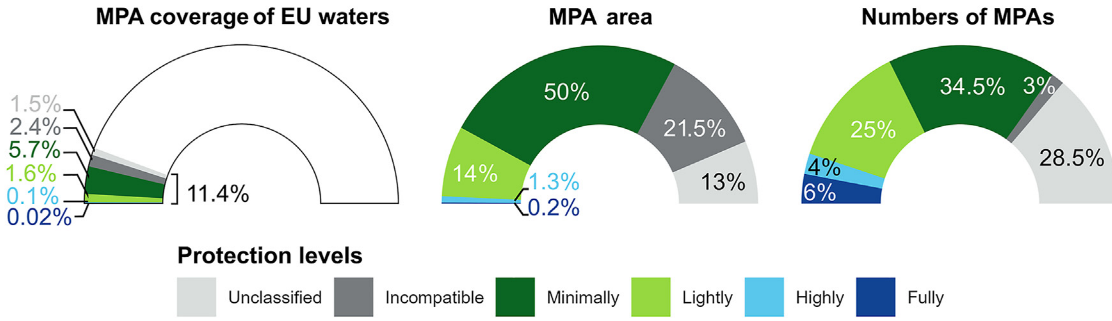

Figure 1. Distribution of protection levels across EU national waters relative to the area declared as MPA and relative to the number of MPAs

sea regions, and MPA features. These results show that current protection levels of EU MPAs are therefore far from the 2030 targets. For EU MPAs to provide the expected social and ecological benefits, their role in regulating human activities to limit their negative impacts should be questioned broadly.

RESULTS

For a clear understanding of the results, we first present a brief introduction to the 'experimental procedures' section that the reader can find at the end of the article. Protection levels were assigned following a decision tree based on the potential impacts of allowed uses within the MPA, following the MPA Guide framework.[13] MPAs were classified into four protection levels (i.e., fully protected [no extractive activities], highly protected [low-impact activities], lightly protected [moderate-impact activities], or minimally protected [high-impact activities]) or were classified as incompatible with biodiversity conservation when very impactful or industrial activities can occur within the MPA.[13] For simplicity, we also grouped protection levels into a two-level classification of MPAs: strong (full and high protection) and low (incompatible with conservation and minimal and light protection) protection. Because the scale and potential impacts of activities were not available at the EU scale, we considered two possible scenarios of impacts for each activity. Scenario 1 considered the lowest potential impacts and scenario 2 the highest (some data were sufficiently detailed to consider the same impact for both scenarios). In the Results section, when unspecified, we present results from scenario 1. To assess our range of uncertainty, we compared our results with two expert-based assessments (see the experimental procedures, describing the assessments from Horta e Costa et al. and Roessger et al.).[41,42]

We assessed protection levels of 4,858 EU MPAs (and their zones when identified) located in EU national waters (excluding overseas territories and extended continental shelf; i.e., all MPAs reported to the European Environment Agency [EEA] in 2022). We analyzed protection levels by regions, countries, and several MPA features. To analyze the correlation between protection levels and MPA features, we conducted chi-square tests. These tests allowed us to assess significant deviations from an independent distribution of MPA coverage and differences among features (e.g., distribution of area by protection level across different jurisdictions). When computing results in terms of MPA coverage, the highest level of protection was retained for areas where different protection levels overlapped. When providing results in numbers of MPAs, spatially identical MPAs were only counted once.

EU-wide low protection levels

In terms of coverage, 11.4% of EU national waters (610,078 km^2) were designated as MPAs as of January 2022. In terms of protection levels, 0.2% of EU national waters were covered by strong protection (0.14% of high and 0.02% of full protection), 9.7% by low protection (light or minimal protection or allowing activities that are incompatible with conservation objectives), and 1.5% were unclassified (Figure 1). Of the total EU MPA area, 1.5% was covered by strong protection, 85.7% by low protection, and 12.8% was unclassified (Figure 1 shows detailed protection levels and illustrates that, despite their low coverage, strongly protected MPAs constitute up to 8% of MPAs). These results changed significantly under scenario 2 (Supplemental experimental procedures). While low protection would cover a similar 9.9% of EU waters, strong protection would cover only 0.04%, and 72.9% of MPA coverage would be classified as incompatible with biodiversity conservation (instead of 21.5% in scenario 1).

Stronger protection levels in the Mediterranean and Baltic Seas

When analyzing protection levels for the four main sea regions, the largest MPA coverage was located in the Baltic (16.8%), followed by the Mediterranean (14.8%) and Black (14.2%) Seas, and the smallest in the North-East Atlantic (9.1%; Figure S1; Table S1). For each, most MPA coverage could be classified (>80% of classified MPA coverage). Low protection levels were predominant in the four main sea regions (>80% of MPA area; Table S1), and strong protection covered 0.5% or less of their area. The highest coverage of strong protection was found in the Baltic and in the Mediterranean Seas (3% and 1.9% of their MPA area, respectively) compared to 1% of the North-East Atlantic MPA area. No strong protection was described in the Black Sea. Figure 2 details the results for the subregions included in the main regions presented above (the Mediterranean Sea and the North-East Atlantic Ocean were subdivided following MSFD subregions).

Most MPA coverage was under low protection for all member states

The highest MPA coverage was located in Germany (45.3%), followed by France (38.9%), and Belgium (37.9%), while the lowest was in Ireland (2.4%), followed by Portugal (4.5%),

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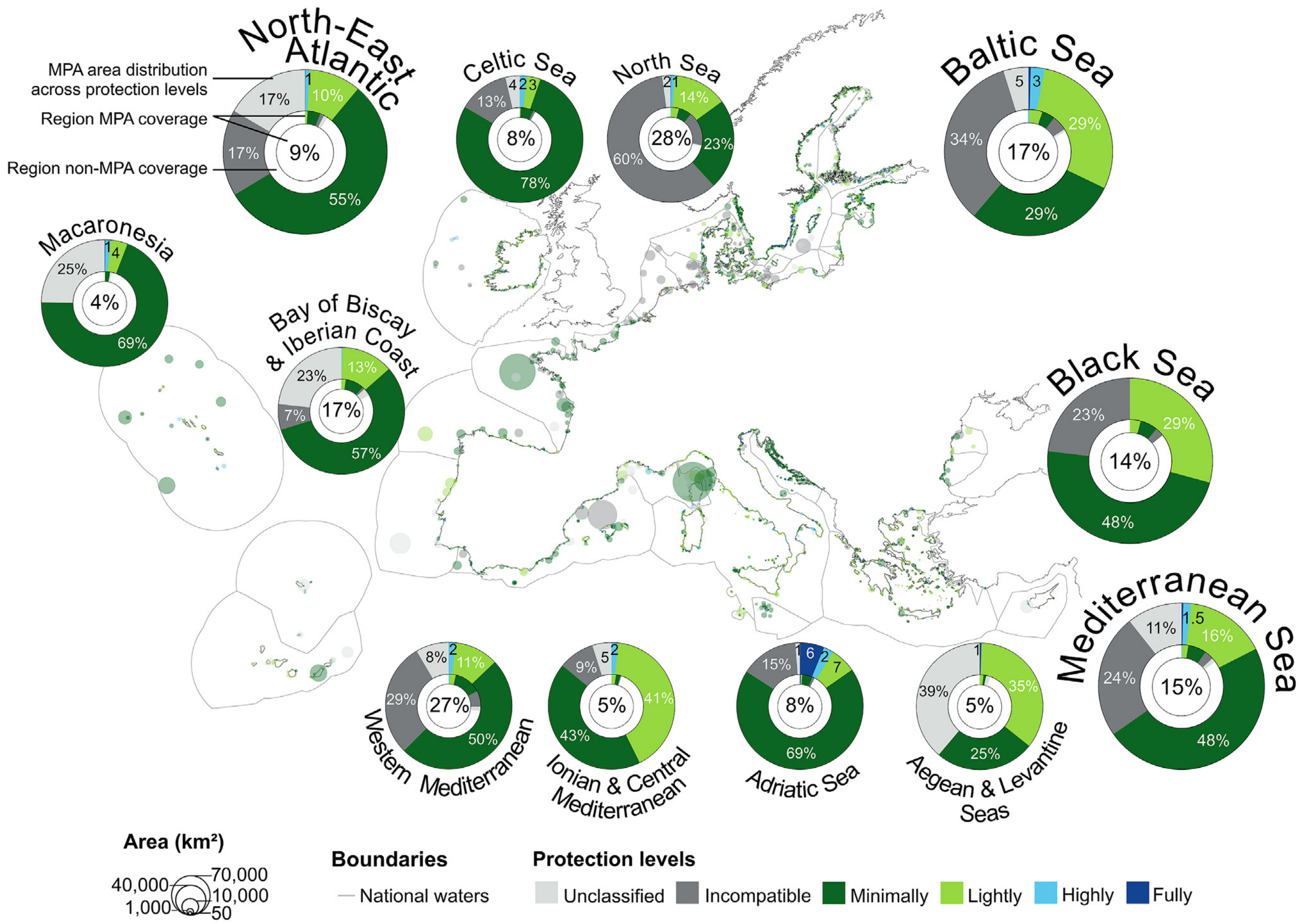

Figure 2. Protection levels of the 4,858 MPAs (and their zones when identified)

Distribution of protection levels for the main (bigger pie charts) and subregions (smaller pies). Only percentages equal or greater than 1% are displayed. Each pie chart consists of two parts: an inner pie chart that shows the distribution of protection levels across the entire region area (with the percentage of regional MPA coverage indicated at the center) and an outer pie chart that shows the distribution of protection levels within the area designated as MPA in the region. Subregions are based on MSFD reporting. The Mediterranean Sea includes the Western Mediterranean, Ionian and Central Mediterranean, Adriatic, and Aegean and Levantine Seas. The North-East Atlantic Ocean includes the Celtic Sea, the Bay of Biscay and Iberian Coast, the North Sea, and Macaronesia. Only EU waters are included in each region.

Greece (4.7%), and Slovenia (5.1%; Figure 3; Table S2). All but four countries designated MPAs classified as strongly protected, covering less than 1% of each of their national waters (Figures 2 and 3; see Table S2 for details). The highest MPA coverage under strong protection was described for Slovenia (18.0% of MPA area), Ireland (7.1%), Italy (5.7%), Sweden (4.9%), and Estonia (4.7%; see Figure S2 for results in numbers of MPAs). Twenty states were found to have more than 80% of their MPA area under low protection levels (Figure 3; most of the remaining area was not classified). Although all countries showed some differences when comparing scenarios (Figure S3), for 8 countries, all the MPA coverage under strong protection switched to a low protection level under scenario 2 (including Ireland and almost all strong protection coverage for Estonia; both showed among the highest strong protection coverage in scenario 1). For a broader perspective on national contexts, further information on national MPA networks (designation types, use of zoning within MPAs, and MPA sizes) and national waters (coverage and coast length) can be found in Figure S2.

MPA features: National designations and earlier designated MPAs showed stronger protection levels

The first EU MPA was designated in Sweden in 1909 and the EU MPA coverage started to rapidly increase in the 2000s (Figure 4). The relative coverage of low protection levels increased in later designations, accounting for at least 60% of the cumulative MPA coverage since the 1960s (Figure 4; Spearman correlation coefficient = 0.7, $p < 0.001$; Figure S4). Regarding jurisdictions, the majority of EU MPAs were located in nearshore waters (66.2%; i.e., up to 1 nm; experimental procedures), while most of the MPA coverage was located in territorial waters (30.1%; the 12-nm zone) and in offshore waters (54.6%; beyond 12 nm; Figure 2). Higher coverage of strong protection was found in territorial (2.1% of MPA coverage) and nearshore waters (5.0%; compared to 1% in offshore waters; Figures 5A; see also Figure S5, which shows significant deviations from an independent distribution of protection levels for each jurisdiction and differences among jurisdictions, chi-square = 48,560, df = 10, $p < 0.001$).

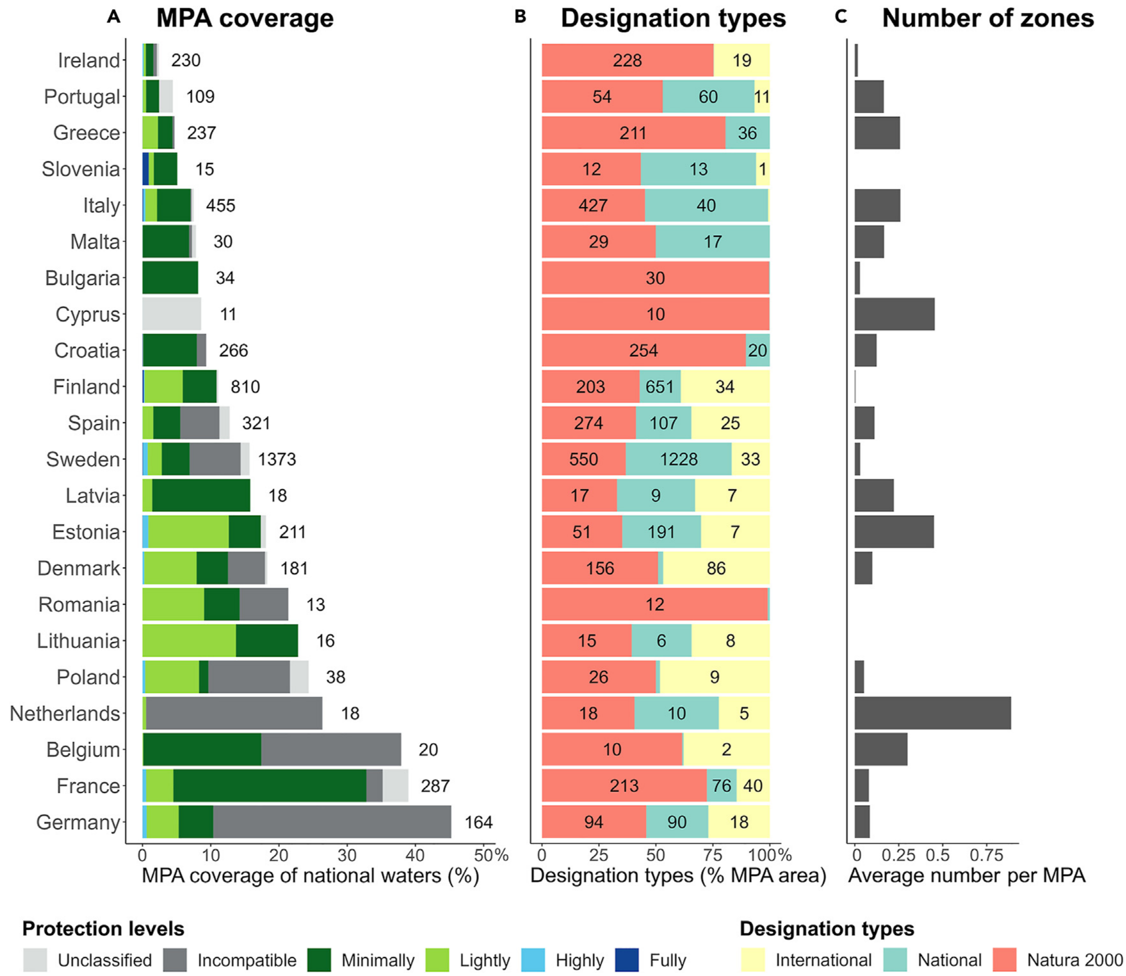

Figure 3. MPA characteristics for each EU coastal country

(A) Distribution of the protection levels per country.

(B) Distribution of designation types (overlapping designations are represented twice. International designations refer to MPAs designated under the OSPAR, HELCOM, or Barcelona conventions. The number of MPAs for each designation type is overlaid on the bar plots).

(C) Average number of zones per MPA.

Most MPA coverage was designated as Natura 2000 MPAs (72.1%; Figure 3B). National designations showed the highest coverage of strong protection (Figure 5; see also Figure S5, chi-square = 112,813, df = 10, $p < 0.001$; see Figure S6 for results in numbers of MPAs). Most of the area classified as incompatible with conservation objectives was found in MPAs designated both nationally and internationally (under regional sea conventions). As a result, almost no area was described as incompatible when excluding MPAs designated under multiple designations (Figure 5B, internal pies). Some subtypes of nationally designated MPAs showed higher coverage of strong protection (e.g., "sanctuary,", "biotope protection site," "private reserve," "reserve," and, to a lesser extent, "national park"; Figure S7). However, at the scale of each country, most of the subtypes showed significant coverage of low protection (Figure S8). MPAs were highly overlapping, with each MPA overlapping with three other MPAs on average. The accumulation of overlapping designations was not correlated with strong protection levels, though strongly protected MPAs were often fully included in other designations (Figure S9). MPAs were particularly found to be divided into multiple zones with different regulations in the Netherlands, Cyprus, Estonia, Belgium, Italy, and Greece (Figure 3C; note that, since zones were not reported in the European MPA database, we identified them from other data sources, and they could represent either MPA legal zoning or other spatial management tool within the MPA). Though it greatly varied between countries, only 11.9% of zone coverage was classified as strongly protected (e.g., overall, zones in Greece were fully protected; Figure S10).

Regarding MPA protection focus, higher coverage of strong protection was found in MPAs designated for ecosystems (focus summarized from management plans; Figure 5; chi-square = 26,080, df = 10, $p = 0.001$). Finally, we compared the protection levels described in this study with the IUCN categories reported to the World Database of Protected Areas by management authorities, which should illustrate MPAs' management objectives. MPAs from all IUCN categories showed a predominance of low protection levels (Figure 5). However, none of the MPA coverage

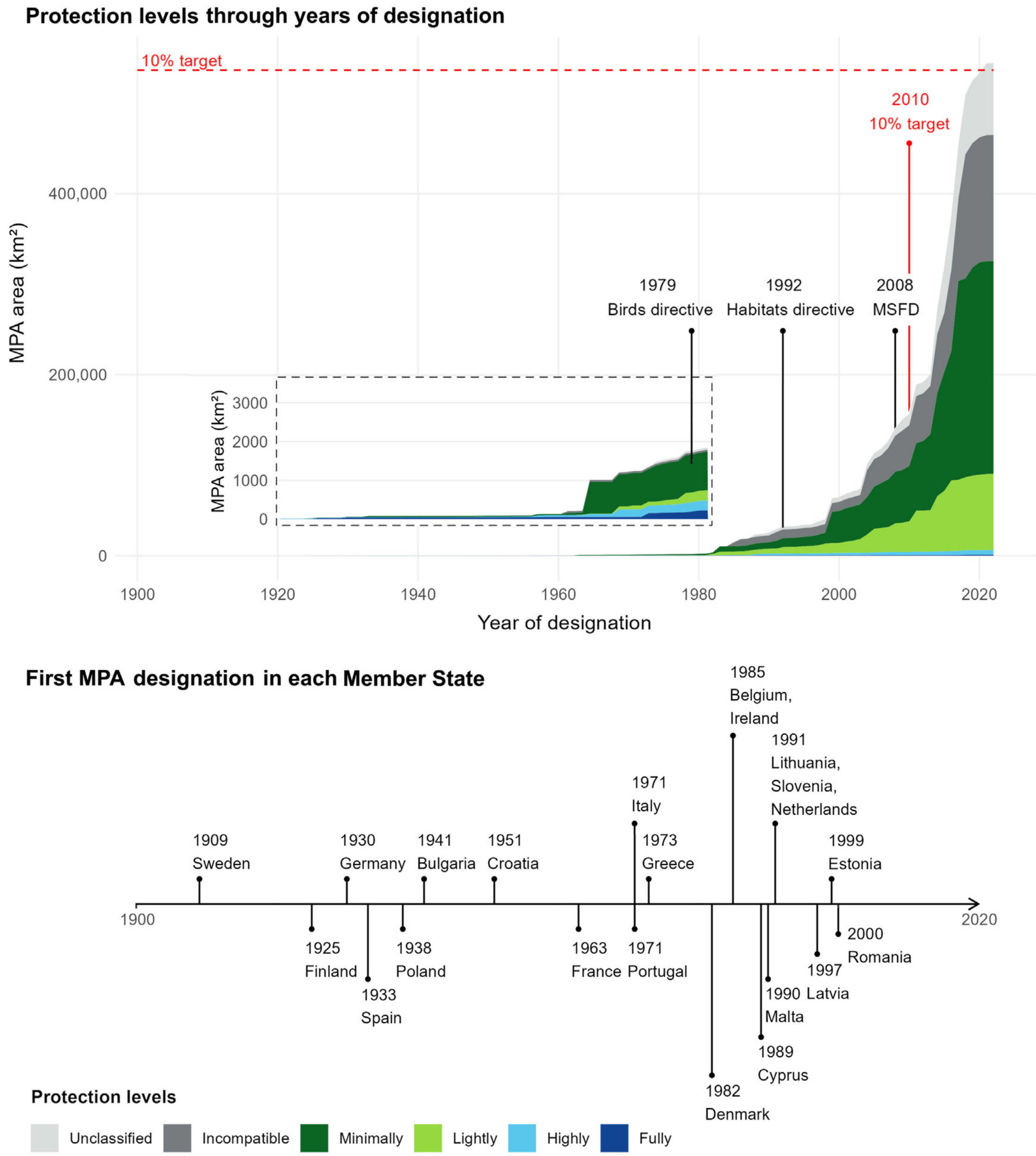

Figure 4. Area per protection level plotted against year of designation (the current protection levels are displayed for the 4,858 MPAs and their zones)

An overlay plot presents the MPA coverage for the 1920–1980 period for readability. Main EU policies are indicated in black (Marine Strategy Framework Directive [MSFD]). The dashed red line indicates the 10% coverage threshold for EU national waters, based on the United Nations Aichi target 11 toward 2020, adopted in 2010. The second plot shows the year of designation of the first reported MPA for each country. See Figure S4 for further analyses.

reported as IUCN category Ia or Ib was classified as incompatible with biodiversity conservation, and categories IV, V, and VI showed lower coverage of strong protection (Figures 5, S5, and S6; chi-square = 141,586, df = 35, p = 0.001).

DISCUSSION

Our study shows that the large majority of EU MPAs (62.2%) and MPA coverage (85.7%) are under low protection regimes (lightly, minimally protected, or incompatible with biodiversity conservation) across all member states, regions, and MPA features. We also show that only 1.5% of the MPA area is under strong protection (fully and highly protected), representing 0.2% of EU national waters.

Despite our efforts to gather the most up-to-date and detailed data, computed protection levels can only result from the current limited standardized reporting schemes regarding MPA regulations[58] and highly heterogeneous efforts across countries to integrate regulations in management plans or report them in MSPs and other databases, despite existing guidelines available[22,59]

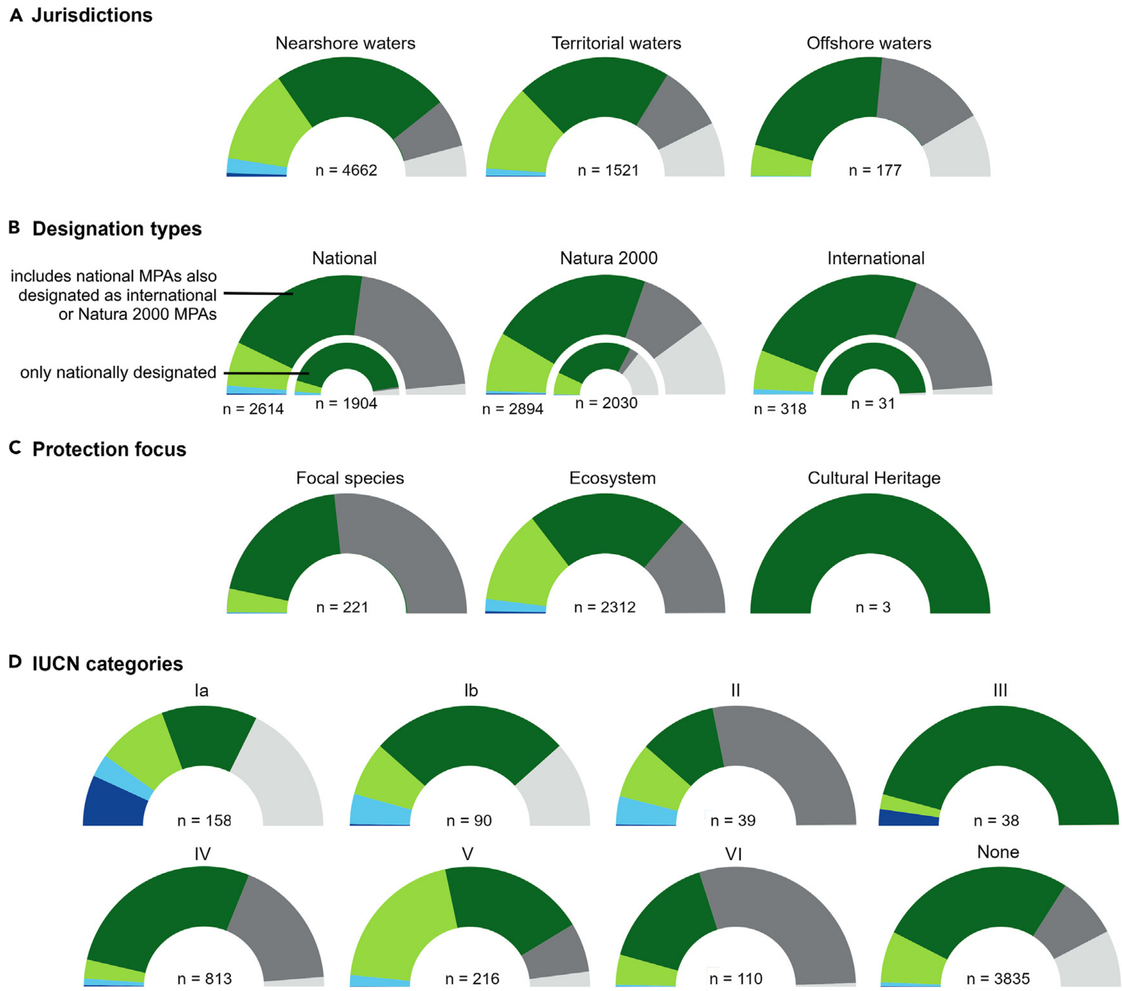

Figure 5. Distribution of protection levels (in relative MPA coverage) across MPA features

(A–D) Protection levels across (A) jurisdictions (note that MPAs can overlap multiple jurisdictions), (B) designation types (international designations refers to MPAs designated under the OSPAR, HELCOM, or Barcelona conventions), (C) protection focus categories, and (D) IUCN categories (in all plots, zones are included in coverage calculations). Numbers of MPAs are given inside of each plot. In (B), the external pie charts include all MPAs of the designation type of interest, the internal pie charts include only MPAs solely of the designation type of interest (i.e., MPAs designated only as national, international, or Natura 2000 MPAs, where the legislation is specific to that designation). In (C) jurisdictions are defined as nearshore (0–1 nm, though the delimitation varies significantly), territorial waters (1–12 nm), and offshore waters (up to 200 nm). In (D), IUCN categories were reported by states to the WDPA database (because we merged spatially identical MPAs, one MPA can have been reported under multiple IUCN categories) and theoretically correspond to MPAs managed: Ia as strict nature reserves, Ib mainly for wilderness protection, II for ecosystem protection, III to protect a natural monument/feature, IV to manage a habitat/species, V for seascape conservation and recreation purposes, and VI for sustainable use of natural resources. Statistical analyses are shown in Figure S5.

(J.A.-B., unpublished data). Our study also highlights that several descriptors of MPA objectives (i.e., IUCN categories and designation types) are likely not representative of regulations over activities and, as they are currently reported, cannot be used as indicators of protection levels. Overall, our study shows that, although member states already bear a heavy reporting load,[60] data collection and reporting schemes about regulations in EU MPAs have to improve rapidly to enable effective monitoring of the implementation of the EU strict protection target.

Given the current data availability, classification systems assigning levels of protection based on the legal framework are among the most accessible methods to evaluate some of the potential effects of MPAs at large scale (i.e., assessing activity regulation rather than *in situ* activity intensity; see also Sullivan-Stack et al. and Pike et al.[61,62]), notably because data on activities pressures and impacts is still insufficient to assess the actual ecological consequences of MPA policies in Europe.[63] In addition to the data limitations, such classification systems focus on fisheries and activities historically recognized as highly impactful, such as mineral extraction.[4,57,64,65] Other activities, including land-based ones, could impact marine ecosystems and should be better incorporated into the assessment and management frameworks of MPAs, especially since many (EU) MPAs include a terrestrial part. Finally, such a legally focused classification system cannot capture all of the social-ecological processes taking place in MPAs, including the level of enforcement, the tacit rules in place, or changes in practices driven by the implementation of the MPA.[8]

Our goal was to provide the most reasonably comprehensive study at EU scale as a basis for ongoing and future discussions on EU MPA protection levels. High rates of low protection levels in EU MPAs were expected.[20] Indeed, even based on the lowest range of impacts, our assessment showed that most of the MPA coverage would be minimally protected, while our second scenario, considering higher impacts, described most MPA coverage as incompatible with biodiversity conservation. The results from the second scenario seem to be more aligned with findings from former regional studies and other assessments of threats found in EU MPAs and seas.[39,41,66–68] Indeed, Roessger et al.[41] described 60% of OSPAR MPAs as "unprotected," and Claudet et al.[39] classified 72.6% of Mediterranean MPAs (including non-EU) as "unprotected" or "not regulated." The reality of what protection and regulations EU MPAs provide probably lies somewhere in between these two scenarios. Yet, both scenarios pointed to limited ecological outcomes from EU MPAs, even if MPAs with lower protection levels can, to some extent, provide ecological benefits[16,69] and can act as spaces of education, innovation, and collaboration.[8]

Our study highlights significant differences across regions and member states in data availability, protection levels, and the use of designation types and subtypes. The Mediterranean and Baltic Seas showed relatively higher coverage of strong protection compared to the North-East Atlantic Ocean, and we did not find any strong protection in the Black Sea. Most MPA coverage in the Black Sea was described as minimally or lightly protected, which might result from the later development of MPA designation and management in the region.[21,70] However, the identified critical lack of data in the Black Sea prevents us from drawing any firm conclusions,[71] as most activities, except fisheries, were poorly known.[71] The Atlantic part of EU waters showed low protection overall, and our estimation of 1% of strong protection could be an overestimation,[41] especially given than half of that coverage would be under a low-protection regime in the second scenario (e.g., all of it in Ireland). It is, however, worth noting that, in addition to MPAs, other fisheries management tools have been deployed in the region[72] (e.g., closure to bottom fishing gears in vulnerable marine ecosystems[73]). A relatively higher coverage of strong protection was expected in the Mediterranean,[21] where the implementation of strong protection may have been facilitated by the MPA design approach to divide MPAs into zones with different regulations (as illustrated by Greece in our results). This approach has been frequently used for the Mediterranean;[72] for example, to protect Posidonia meadows. We also found strongly protected MPAs that had no zoning system, notably in the Baltic, where the prevalence of strongly protected MPAs was mostly driven by Estonia, Sweden, and Finland (note that, for Finland, half of the area under strong protection in scenario 1 is downgraded to low protection in scenario 2 and 95% for Estonia). Though still showing high rates of low protection,[46] strong protection was expected to be found in Sweden and Finland, as their management systems include local units, and their long history of establishing MPAs has been documented.[30,74] Enforcing these stronger levels of protection to secure social-ecological benefits remains a recurring challenge[14] (in part due to under-capacity[28,29]), including in the Mediterranean and Baltic Seas,[30,75,76] where we described higher coverage of strongly protected MPAs.

National designations were the most frequently used to create strongly protected MPAs, as we described for all member states and as observed previously in the Mediterranean.[21] This was also clear in countries showing the highest rates of strong protection (relative to their MPA area [e.g., Sweden, Estonia, and Italy], although Natura 2000 special area of conservation [SAC] MPAs make up to 40% of Italian strongly protected MPAs), except in Greece, where Natura 2000 was the main MPA instrument,[21] including for strong protection. These countries and others relied on "reserves" to create strong protection, a type of MPA expected to show high restrictions.[77,78] Yet, designations referred to as "reserves" also showed high rates of light or minimal protection in most countries, and their objectives vary highly, given that they can be designated, for example, as private reserves in Finland[79] or fishery reserves in Spain.[80] This clearly shows how the nomenclature and the use of MPA subtypes to implement specific protection levels is highly country specific. In comparison to nationally designated MPAs, Natura 2000 (except for Greek and Italian MPAs, as described above) and international designations showed smaller coverage of strong protection, were younger and larger, and represented most of the MPA coverage in territorial and offshore waters. The legal frameworks of these designations (requirements from regional sea conventions or EU directives transposed into national law) did not initially set obligations to specifically regulate activities and continue not to.[37,81] At least in territorial waters, member states could have used similar (if not the same) legal tools to implement them as for nationally designated MPAs. Indeed, national MPAs and Natura 2000 designations very often overlap, without any additional protection in terms of regulations (rejecting the use of overlapping designations as a proxy for protection levels[43]). It is, however, worth noting that, in offshore waters, where most protection coverage is designated as Natura 2000 or international MPAs, states need to negotiate with other EU fishing fleets in their exclusive economic zone because of the Common Fisheries Policy.[20] These offshore MPAs have therefore been designated knowing that it might take time and substantial efforts (if even achievable under the current legal framework) to develop any relevant regulations on fisheries. So far, little effort to regulate fisheries in offshore EU MPAs has been deployed by member states under the EU policy framework.[20,21]

Reflecting on commonalities in EU MPAs and their policy context can help uncover reasons for low protection levels and inform future strategies. Many MPA-related policies were developed in the past decades, at the EU (directives, implementation guidance, rulings, and successive biodiversity strategies) and international levels, such as the current United Nations Global Biodiversity Framework, which aims at 30% MPA coverage. These policies led to the development of legal frameworks and institutions to create and manage MPAs[21,82–85] and resulted in relatively large MPA coverage.[20,86] However, it also contributed to the overall and increasing designation of MPAs that lightly or minimally regulate human activities. Strong protection levels were found in most countries but were restricted to small MPAs, which covered a very small area of EU waters. Although other factors could play a role, this trend of limited MPA protection is facilitated by the current legal and policy frameworks.

First, and as mentioned above, EU directives, like the Habitat Directive or the MSFD, were flexible when it came to setting up conservation measures in MPAs, in terms of what to regulate and when to reach objectives.[87,88] This likely contributed to limited prioritization to implement strongly protected MPAs across EU seas. The limited specificity and voluntary requirements from other international agreements, such as the Regional Sea Conventions and the Aichi targets, might also have contributed to low protection levels.[81,89,90] Even with this flexibility, member states have shown recurrent non-compliance.[91,92]

While we have so far focused on environmental policies in the EU, other maritime policies, such as the Common Fisheries Policy and "blue economy" initiatives, have a much more economic scope, often diverging from biodiversity protection.[20,93–95] Protection levels of EU MPAs revealed and resulted from deep-rooted conflicts between economic activities (including for livelihood) and biodiversity protection. Conflicts emerged from stakeholders' diverging values and interests on one hand (also due to limited support of capacity to change their activity), and perceptions and expectations of MPAs on the other.[31,75,96–99] In some contexts, stakeholders could converge toward implementing strongly protected MPAs (see, for example, Bennett et al.[100]), but in many EU MPAs, low protection levels could be the result of short-term conflict avoidance. In fact, EU MPAs cover so much of EU nearshore and territorial waters[19,33,101] that, if MPAs were meant to strictly restrict human activities, then conflicts would be inevitable.

Although MPAs and their contexts around the world differ greatly and cannot simply be compared to the EU context, MPA policies are increasingly important (e.g., 118 countries joined the High Ambition Coalition for Nature and People, aiming to protect 30% of the ocean). Some countries implemented relatively larger coverage of stronger levels of MPA protection compared to the world trend (e.g., South Africa and Palau; Kirkman et al.[102] and Gruby et al.,[103] see the MPA assessments reported in the MPAtlas; Marine Conservation Institute[104]), while others are now engaging in strengthening the restrictions of activities in their MPA network (e.g., the UK to ban bottom mobile gears in several MPAs; Pieraccini[105]). As we described in the EU, low levels of protection are still common,[4,61,62,106] and any large-scale action to strengthen their regulation will require significant resources to ensure conflict management, notably through stakeholder participation, the deployment of measures to ensure justice, and stakeholder' compliance and adaptation.[107–109] Such actions can be informed and accompanied by in-depth investigations, so far too limited, into the social (institutional, historical, political, and cultural) contexts of MPAs and their consequences for levels of protection.[8,31,110–113]

In conclusion, we found that protection levels were generally low across all EU seas and MPA features, likely providing limited ecological outcomes. There is now a growing push for stronger protection, as illustrated by the strict protection target set by the 2030 EU Biodiversity Strategy and the restriction of mobile bottom fishing gears in MPAs highlighted by the Action Plan. By putting pressure on member states to make decisions, these targets are contributing to repoliticizing protection levels of EU MPAs (e.g., for MSPs, see Tafon et al.[114]). Some EU states have already made commitments to strengthen regulations in their MPAs (e.g., France and Greece[115,116]). Actors are forming coalitions (e.g., "Blue up 2024!" for ocean protection or the European Bottom Fishing Alliance), gathering recognition and power to support their demands. Ultimately, these EU and national processes could lead to institutional and cultural change and set the context for improved MPA participation and enforcement.[117] This could lead not only to greater ecological outcomes but to increased social benefits (e.g., social and economic capital), as illustrated by several smaller scale examples.[80,118] It now really depends on member states to address threats to marine ecosystems through different tools, including strongly protected MPAs and means to manage current conflicts.

EXPERIMENTAL PROCEDURES

Resource availability

Lead contact

Requests for further information, resources, and reagents should be directed to and will be fulfilled by the lead contact, Juliette Aminian-Biquet (juliette.biquet@lilo.org).

Materials availability

The main material generated in this study (MPA list and polygons with protection levels and studied features) and the R code to analyze and plot the data have been submitted together with the manuscript.

Data and code availability

The data and code on protection levels generated for this study were made available in Figshare (https://doi.org/10.6084/m9.figshare.25103450; https://figshare.com/s/6a2c54f68567fff1c3b0).

The full database has been submitted as a publication in Data in Brief available as a preprint (Regulations of activities and protection levels in Marine Protected Areas of the European Union: a dataset compiled from multiple data sources, J.A.-B., unpublished data), including all data sources and data formatted by activity.

Scale of analysis

We investigated protection levels at (1) EU, (2) regional, and (3) national scale (the Pelagos international designation was excluded from national analyses). For (2) regional analyses, we reported protection levels for the four main regions considered in the MSFD; i.e., the Black Sea, Mediterranean Sea, North-East Atlantic, and Baltic Sea and their subregions (Figure 2). For national analyses, we considered "national waters" as the fusion of three jurisdictions (Table S2): nearshore waters[119] (0–1 nm, but their delimitation varies significantly[120]), territorial waters (up to 12 nm for most member states[119]), and offshore waters of the exclusive economic zones (EEZ; beyond 12 nm up to 200 nm[121]). All polygons used have been filtered with MSFD polygons to extract their marine area.[122] For this, we excluded MSFD areas from non-EU states and high seas (excluding the Portuguese extended continental shelf).

When computing results in terms of coverage, polygons were merged by protection levels so that no area would be counted multiple times (the strongest protection levels were retained for areas where different levels of protection overlap). All analyses were run in QGIS and R, notably using the sf and ggplot2 packages.[123–125]

EU MPA list and marine sea regions

We extracted 6,414 MPA polygons listed in the 2023 MPA database in EU states' national waters from the EEA, including national, Natura 2000, and international designations (MPAs designated up to January 2022 and database accessed in February 2023[126]). So-called international MPAs included MPAs designated in national waters under the OSPAR in the North-East Atlantic and HELCOM in the Baltic Sea and Mediterranean Sea Conventions, including the national and international parts of the Pelagos sanctuary. This analysis excluded MPAs in the extended continental shelf and MPAs' overlapping part with Monaco waters. Overlapping MPAs were merged into one MPA if they both shared at least 90% of their area or if they shared more than 70% and had the same name (whatever their designation; J.A.-B., unpublished data), resulting in 4,858 MPAs after

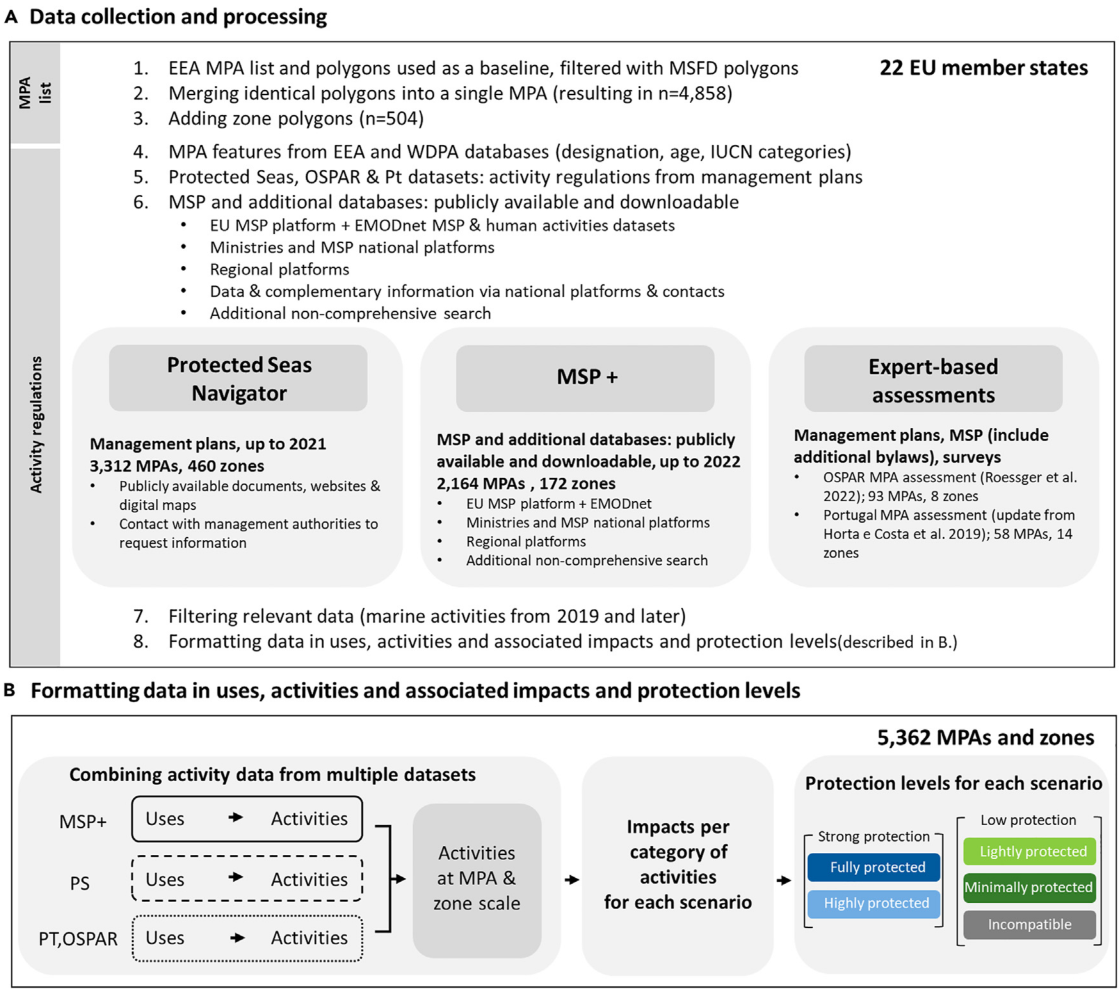

Figure 6. Data sources and general protocol

(A) Data collection, datasets summary, and data cleaning procedure (see Figure 7 for the activities reported in each dataset).

(B) Protocol to compute protection levels, starting from uses, to activities, to impacts, to protection levels (for more details on each step, see Figures 7 and S13).

merging (Figure 6; this merging only influences results in terms of numbers of MPAs).

Finally, we extracted 504 zones identified in the MAPAMED database,[127] the Protected Seas Navigator[128] (2021), from the assessment of OSPAR MPAs (see Roessger et al.[41]), and from the Portuguese assessment presented below (based on Horta e Costa et al.[42]). We considered as zones the polygons from these databases that were completely included in EEA MPAs without matching any of the EEA MPA polygons. These zones could represent either MPA legal zoning or another spatial management tool fully included in an MPA (e.g., fishery restriction zone).

Datasets on human activities in EU MPAs

To compute protection levels, we searched for activity regulations in EU MPAs for the seven activities considered in the MPA Guide: mineral extraction (mining), dredging and dumping, anchoring, infrastructure (e.g., harbors and wind parks), aquaculture, fisheries, and non-extractive uses. When available, detailed types of use (e.g., fish or alga aquaculture) were gathered in these activities (Figure 6).

We gathered information from four different sources (Figure 6; J.A.-B., unpublished data) on activity allowances and prohibitions or restrictions, independent of the on-the-ground implementation of the regulation or whether the activity was indeed occurring. First, we used the Navigator data gathered by Protected Seas (PS), gathered up to 2021.[128] It included regulation of some activities (especially fisheries) explicitly mentioned in the management plans as allowed, restricted, or prohibited, and fisheries were formatted as a level of fishing protection score.

To overcome the lack of data from MPA-related legal texts, we gathered regulations available and downloadable as geospatial data from (1) national marine spatial plans (MSPs) extracted from national web pages and (2) additional national or regional databases.[121,129,130] Data searches were conducted between April 2022 and September 2022. Data were filtered for activities overlapping with MPAs (in case of polygons about allowances, it should cover at 10% of the MPA area, 90% in case of polygons about prohibitions) from 2019 or later (2016 for harbors and ports). This dataset is referred to as MSP+.

Finally, we used two document- and expert-based assessments. The OSPAR MPA assessment (hereafter called OSPAR) was based on management plans, geospatial databases provided by some managers, and surveys conducted by Roessger et al.[41] between 2020 and 2021. The Portuguese MPA assessment (hereafter called PT) was based on management plans and MSP analyses conducted up to 2022 (based on Horta e Costa et al.[42]).

Combining datasets for each activity

For each dataset, we grouped detailed uses into the seven activities considered in the MPA Guide (Figure 7A). If one of the types of uses was allowed, then the activity to which it belonged was considered as allowed. We then combined datasets for each activity (when available for a given MPA or

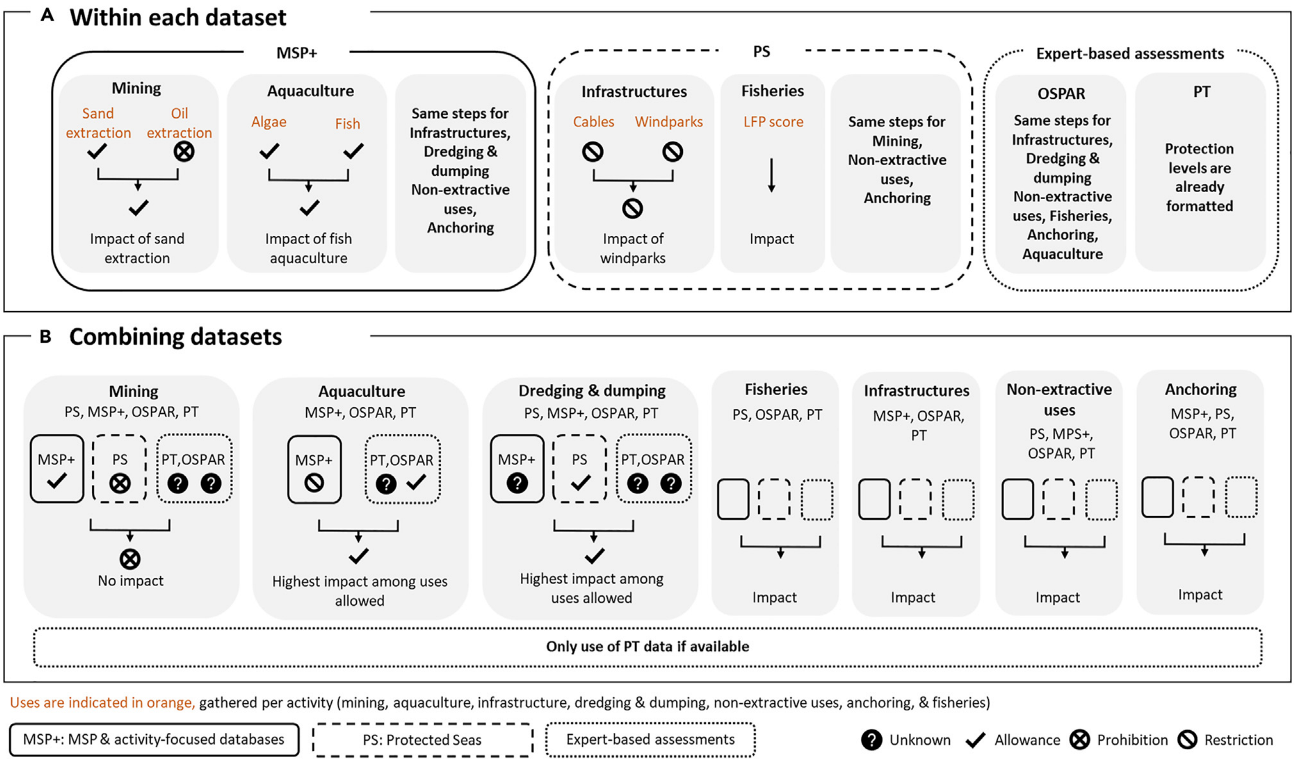

Figure 7. Protocol for computing impacts and protection levels
(A) Protocol for categorizing uses by activity.
(B) Protocol to combine data for each activity from the four datasets. We computed two scenarios of potential impacts.

zone; Figure 7B). When combining datasets, if one dataset reported an activity as prohibited, then it was considered as prohibited (i.e., even if another dataset reported it as allowed; Figure 7B). When available, data from the PT dataset were prioritized over other datasets as the most recent and more detailed assessment.

The scale and potential impacts of activities were not available at EU scale. We therefore considered two possible scenarios of impacts for each use. Scenario 1 considered the potential lowest impacts and scenario 2 the highest (they could be the same if information was detailed enough). Within each scenario, if an activity was considered as allowed, then its impact was computed as the highest impact among the allowed uses of this activity for the two scenarios of impacts (e.g., if aquaculture was allowed, then its impact would be that of fish aquaculture and not of alga aquaculture if both are allowed; Figure 7). Maps of impacts under scenario 1 are provided in Figure S11.

Finally, when mining, dredging/dumping, or infrastructure were reported as restricted within an MPA or zone (and no other dataset indicated an allowance), we considered that their allowance could be dependent on the approval from another authority, potentially leading to their prohibition. These activities have therefore been considered as allowed under scenario 1 and as prohibited in scenario 2.

Classifying protection levels based on two scenarios

Protection levels were computed following the decision tree from the MPA Guide,[131] adapted to the scales of impacts known for each activity, presented for the two scenarios in Figures S12 and S13. MPAs were classified into protection levels, from fully protected to minimally protected, or were classified as incompatible with biodiversity conservation (Grorud-Colvert et al.[13]). We also grouped protection levels in a two-level classification of MPAs: strong (full and high protection) and low (incompatible with conservation and minimal and light protection) protection. The classification does not consider the combined impacts of multiple activities allowed simultaneously (e.g., if mining and fishing were allowed, then the protection level was based on mining activities only). Unknown activities did not downgrade the protection level, as if they had been prohibited.

Protection levels were computed for MPAs where (1) regulations over fisheries were known (any level of impacts), (2) dredging/dumping was known as allowed, or (3) mining was known as allowed, independently from the level of information about the other activities. This is because (1) was one of the most regulated activities in MPAs and because if (2) and (3) were allowed, then the MPA could only be classified as minimally protected or incompatible with biodiversity conservation, regardless of regulations on other activities (Figures S12 and S13). The remaining MPAs were not classified, as their level of information was not sufficient to assign a protection level.

To estimate the range of uncertainty when assigning a protection level, we compared the resulting classification from the two scenarios. A total of 6.3% of MPAs were assigned the same MPA guide protection levels under the two scenarios (Figure S14A). When considering a two-level classification of MPAs, in strong (full and high protection) and low (incompatible with conservation and minimal, and light protection), 92.4% of MPAs were classified equally among the two scenarios. Scenario 1 resulted in higher rates of stronger protection.

Comparison of protection levels with previous assessments

To estimate uncertainty among dataset and scenarios, we compared protection levels obtained using PS and MSP+ datasets (the only datasets available for most MPAs) with protection levels obtained using PT and OSPAR assessments (n = 74). This comparison first showed that 39.2% of the MPAs assessed in the PT and OSPAR assessments could not be assigned a protection level using PS and MSP+ datasets due to a lack of data (Figure S14B). Of those that could be classified, 26.7% (scenario 1) and 8.9% (scenario 2) ended up with the same protection levels as in the expert-based assessments. Overall, scenario 1 described higher protection levels than the expert-based assessments (60.6% of classified MPAs), while the second scenario described lower protection levels (80.5%). When considering the two-level classification, 60.0% (scenario 1) and 82.2% (scenario 2) of protection levels corresponded to the expert-based assessments. Results from scenario 1 are emphasized in the main text for simplicity, assuming a bias toward stronger protection levels (see supplemental information for more scenario 2 results).

MPA features

We investigated the relationships between protection levels and several MPA features, including age, jurisdictions, designation types and their overlap, design in zones, and MPA objectives. We extracted the MPA year of designation from the EEA database (and kept the oldest if fully overlapping MPAs had been merged; $n = 4{,}788$). For Natura 2000 sites from the Habitats Directive, we used the year of recognition as a SAC and, if not available, the year of designation as a site of community importance (see below). We distinguished MPAs in three jurisdiction zones: nearshore waters, territorial waters, and offshore waters of the EEZ (see Scale of analysis).

We differentiated three designation types (Natura 2000, International from the Regional Sea Conventions, and National). We extracted and simplified MPA subtypes from the World Database of Protected Areas (WDPA[132]). We considered 29 MPA subtypes ($n = 4{,}570$ MPAs) like reserves and national parks (subtypes within national designations; Figure S7). Natura 2000 MPAs included three subtypes: Special Protection Areas (Birds Directive) and Sites of Community Importance (SCI), which turn into Special Areas of Conservation (SAC) after the approval of the European Commission (Habitats Directive). We investigated the links between the protection levels and the designation overlap (including all designation types), which is highly common in Europe.[19,53,133] We considered whether multiple designations were merged, the number of overlapping designations, and the level of overlap (for non-merged designations; considering no overlap, 30% of the MPA area overlaps with another MPA, 30%–60%, 60%–90%, and above; Figure S9).

Finally, we used two proxies of MPA objectives: the protection focus reported in PS (at three levels: focal species, ecosystem, or cultural heritage; n = 2,536 MPAs) and the IUCN categories reported in WDPA (n = 1,450; MPAs managed: Ia as strict nature reserves, Ib mainly for wilderness protection, II for ecosystem protection, III to protect a natural monument/feature, IV to manage a habitat/species, V for seascape conservation and recreation purposes, and VI for sustainable use of natural resources[55]).

The links between protection levels and categorical MPA features (IUCN categories, designation types, jurisdictions, and protection focus) were tested using chi-square tests (test of independence, modeling protection levels as a categorical variable and using square kilometers as the quantitative measure). The effect of year of designation on protection levels was tested by comparing the relative area of low and strong protection (in percentage of the MPA area accumulating over years) using Spearman correlation tests (Figure S4).

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.oneear.2024.07.010.

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AUTHOR CONTRIBUTIONS

Conceptualization, J.A.-B., J.C., J.Y., and B.H.eC.; methodology, J.A.-B., J.C., J.Y., and B.H.eC.; investigation, J.A.-B., A.L., N.V., J.S., T.V., and B.H.eC.; writing – original draft, J.A.-B.; writing – review & editing, J.A.-B., S.G., J.C., J.Y., and B.H.eC.; funding acquisition, J.A.-B., B.H.C., J.Y., and J.C.; supervision, J.C., J.Y., and B.H.eC.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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