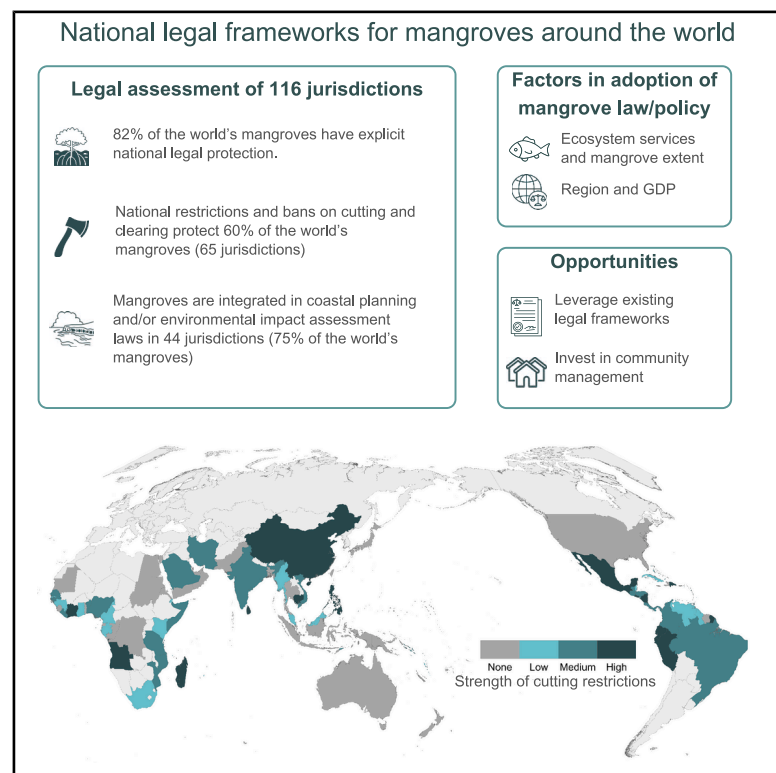


# Quantifying the presence and potential of national legal frameworks for global mangrove protection

## Graphical abstract



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## In brief

National legal frameworks are important for mangrove conservation. Slobodian et al. assess laws and policies in all 116 jurisdictions containing mangroves. They find that mangrove ecosystem services and GDP predict the adoption of different laws and identify opportunities to use existing laws and community management frameworks to protect mangroves.

## Highlights

- 82% of the world's mangroves have explicit national legal protection
- 60% of all mangroves are protected by laws restricting cutting or clearing
- 83% of mangroves are in jurisdictions with legal frameworks for community management
- Adoption of mangrove laws is associated with mangrove extent and ecosystem services

## Article

# Quantifying the presence and potential of national legal frameworks for global mangrove protection

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**SCIENCE FOR SOCIETY** Mangroves represent a highly valuable and complex ecosystem that delivers critical ecological services. They protect coastlines from storms and erosion; they purify the air and lock in carbon; and they harbor beautiful species and provide homes for fish and crabs, which in turn provide food and livelihoods. Protecting mangroves is a vital strategy to advance human well-being and mitigate climate change and biodiversity loss. National laws are a key tool for mangrove conservation, but studying them can be challenging. In this article, a multidisciplinary team of researchers from around the world analyzes the laws and policies of 116 countries and territories—every jurisdiction in the world that contains mangroves—to understand what kinds of mangrove laws exist and why they are adopted in some places but not in others. We find more mangrove laws than we expected; more than 80% of the world's mangroves are subject to some form of explicit legal protection, from direct prohibitions and restrictions on cutting or clearing (60%) to requirements for considering mangroves in environmental impact assessments or coastal planning (75%). Jurisdictions with high-value mangroves supporting fisheries or protecting coastlines or locking in carbon are more likely to have laws and policies protecting mangroves. The types of laws adopted also depend on geographic region and wealth. Lower-income countries are more likely to have frameworks for community management of mangrove areas, while higher-income countries are more likely to integrate mangroves into coastal planning. This highlights the opportunities to leverage existing laws for mangrove conservation, including through investing in community-managed mangrove areas. In addition, countries where mangroves are providing valuable ecosystem services like fisheries and coastal protection may be amenable to legal reform to strengthen mangrove protection.

## SUMMARY

Legal protection of mangrove ecosystems supports biodiversity conservation and climate mitigation and adaptation, but evaluating the global extent and level of protection provided by national mangrove laws is challenging. We assess national laws and policies in the 116 countries that contain all the world's mangroves and use Bayesian multivariate regression to model the probability of the adoption of mangrove laws based on geopolitical and ecological factors. We find that 82.2% of the world's mangroves are in jurisdictions with explicit national legal protection. Jurisdictions with a high extent of mangroves that provide significant ecosystem service values are more likely to have mangrove laws; jurisdictions with lower GDP are more likely to employ provisions for community management, environmental impact assessment, and cross-sectoral coordination; those with higher GDP were more likely to include mangroves in coastal planning laws. Our analysis can inform efforts to implement existing laws and target legal reform.

## INTRODUCTION

Mangrove governance is complex—it involves multiple stakeholders spanning jurisdictions and is regulated by multiple, often overlapping, legal regimes.<sup>1–8</sup> Legal tools for mangrove protection include national prohibitions on mangrove cutting and clearing, environmental impact assessment (EIA) and permitting requirements for projects affecting mangroves, integration of mangroves in coastal planning and management, and frameworks for community management of mangrove areas, in addition to legal frameworks for protected areas.<sup>2,9</sup> While some jurisdictions have specific national mangrove laws and regulations, legal protections for mangroves are commonly found in general laws on forestry, environmental protection, coastal management, or regulation of specific industries (tourism, logging, aquaculture, etc.).<sup>2</sup> This complexity poses significant challenges to global assessment of legal protection. However, if appropriately designed and implemented, national level legal protections are a critical element of mangrove conservation,<sup>3,5</sup> particularly outside the boundaries of protected areas.<sup>10</sup> Our goal is to ascertain the nature and coverage of different types of mangrove laws and policies and what factors determine whether and where they are adopted.

Mangroves are among the most valuable ecosystems on the planet in terms of carbon storage, coastal protection, biodiversity conservation, and fisheries production, among other services.<sup>1,11–14</sup> Mangrove conservation can support achievement of the Sustainable Development Goals,<sup>15,16</sup> the Global Biodiversity Framework (including targets to conserve and sustainably manage ecosystems by 2030),<sup>17–19</sup> and climate targets under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement.<sup>20–22</sup> National governments are integrating mangroves into National Biodiversity Strategy and Action Plans under the Convention on Biological Diversity (CBD)<sup>23</sup> and Nationally Determined Contributions under the Paris Agreement.<sup>24,25</sup> Despite increasing attention from both donors and policymakers, global mangrove coverage continues to decline, albeit at a decreasing rate.<sup>26</sup>

To date, global assessments of mangrove conservation and management, such as the State of the World's Mangroves Report, have primarily focused on protected areas.<sup>27</sup> Global targets for mangrove conservation are framed in terms of area of coverage—the Mangrove Breakthrough, launched by the Global Mangrove Alliance and partners in 2022, aims to double the

area-based protection of mangroves by 2030.<sup>28</sup> While important, protected areas are only one component of the array of legal and policy tools deployed for mangrove conservation and sustainable use.

National legal protections for species and ecosystems can have a significant positive impact on conservation,<sup>29–31</sup> and they can complement area-based conservation and environmental policy by providing legal certainty and consistency over entire jurisdictions.<sup>2</sup> Within particular countries, protection laws and policies have played a key role in reducing mangrove deforestation and promoting restoration. For instance, increasing socioeconomic and environmental impacts from mangrove loss in the Philippines drove the establishment of a National Mangrove Committee, community-based forest management, and mangrove cutting prohibitions, which have helped stem mangrove loss.<sup>32</sup> Although similar efforts may have contributed to global reductions in mangrove loss rates in recent years, the lack of global analyses makes it challenging to understand how national legal protections impact mangrove conservation. As a consequence, national laws and policies that can help conserve mangroves may be under-utilized relative to area-based conservation interventions.<sup>3,5,10</sup>

Assessments of non-area-based measures for mangrove conservation have been limited, but promising. A global review of case studies characterized mangrove governance systems as top-down (state-led), bottom-up (community-based), or co-managed (coordinated state and community led), and it identified key governance principles that shape environmental outcomes across these systems.<sup>33</sup> Other work has identified policy challenges and potential solutions within Southeast Asia, based on extensive work in the region.<sup>34</sup> A study in Australia identified legal frameworks at the national and state levels that could work to protect coastal wetlands and maintain ecosystem services, but it found that governance complexity and inconsistency impeded their implementation.<sup>7</sup> Another study found that in Mexico, a national prohibition on cutting mangroves contributes to declining rates of deforestation, but mangrove degradation may be expanding, complicated by the lack of an accepted national definition of degradation.<sup>35</sup> These studies offer glimpses of the potential obstacles and opportunities for legislative and policy instruments to support mangrove conservation. In this article, we seek to expand this view through a global analysis of the coverage and nature of legal frameworks protecting mangroves.

We address two fundamental questions. First, what is the global coverage and nature of national legal protections of mangroves? We analyze the following: (1) national restrictions on cutting and clearing (cutting restrictions) at various levels of protection; (2) national EIA and coastal zone planning and management laws; (3) community management frameworks; (4) national management plans and national regulations, focused specifically and entirely on mangroves (mangrove policies); and (5) national mechanisms for coordinating management and decision-making (coordination mechanisms). Second, what geopolitical and economic conditions are associated with the adoption of mangrove policies and laws? In this regard, we (6) model the probability of the adoption of mangrove laws based on national indicators, such as gross domestic product (GDP) and ecosystem services provision. Our objective is to build an understanding of where mangrove laws and policies exist and what they look like in order to inform mangrove conservation management and policy initiatives around the world.

## RESULTS

Globally, 82.2% of the world's mangroves spanning 75 jurisdictions (countries and territories) are subject to some form of explicit national legal protection. These include cutting restrictions, coordination mechanisms, EIA requirements, and coastal planning processes embedded across myriad sectoral statutes, decrees and regulations, as well as national mangrove laws and policies specifically directed at mangroves.

### National cutting restrictions apply to most of the world's mangroves

Over half of the world's mangroves (59.8%) are covered by national laws, explicitly restricting cutting, clearing, or conversion (Figure 1). These laws—present in 65 jurisdictions—provide protection to mangroves that store 12,121 Mt CO<sub>2</sub>e, provide protection to 13 million people and 40 billion USD worth of coastal property vulnerable to coastal storms and flooding, generate fisheries underpinning 87 million fisher days per year, and contain 60% (~2,300) of mangrove tourist attractions (Figure 1B). Of global mangroves within protected areas, 65.0% are also subject to national cutting restrictions (Figure 1B). The oldest mangrove cutting restrictions date back to the 18th century,<sup>36</sup> but we identified only three jurisdictions with cutting restrictions in place prior to 1950, 8 that adopted new cutting restrictions between 1950 and 1989, 18 between 1990 and 1999, 10 between 2000 and 2009, and 26 that adopted restrictions since 2010 (Figure 1C).

We classified mangrove cutting restrictions based on the level of protection: (1) “high” protection prohibiting all cutting or clearing of mangrove ecosystems (14.1% global mangroves) either directly (13.8%) or by legally classifying mangroves as protected species or ecosystems (0.3%); (2) “medium” protection banning some uses but allowing or requiring a permit for others (27.5% global mangroves); and (3) “low” protection that requires a permit for some or all activities (18.3% global mangroves) (Figure 1; Table 1).

At least seven jurisdictions provide a clear exception from their cutting restrictions for traditional or subsistence use, either in

general or pursuant to community management agreements. For example, Ecuador prohibits all mangrove cutting but allows ancestral communities to enter into agreements for sustainable use and custody of mangroves with the Ministry of Environment (Executive Decree no. 772, 2003).

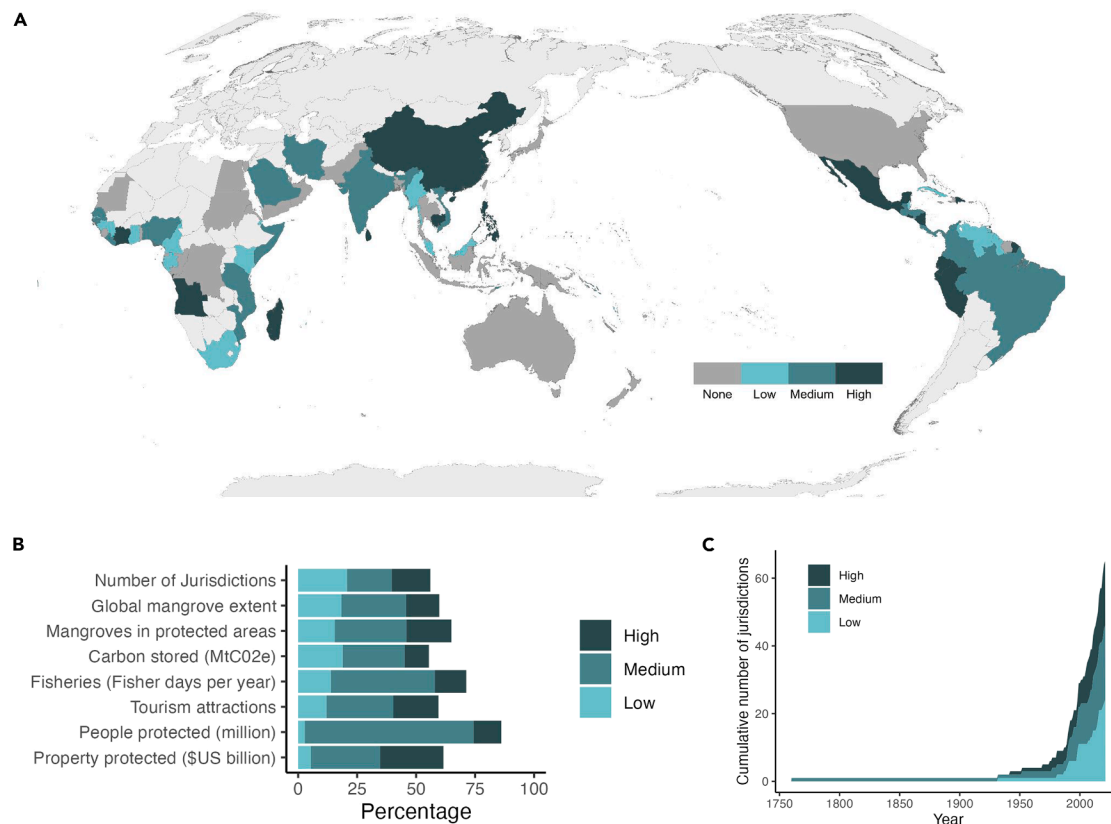
### Mangroves are broadly integrated in EIA and coastal zone planning laws

Three-quarters (75.0%) of the world's mangroves are in jurisdictions that explicitly mention mangroves in either EIA laws or coastal zone planning laws or both. At least 29 jurisdictions (40.5% global mangroves) explicitly address mangroves in the context of EIA requirements (Table 2). Most of these (17 jurisdictions; 22.3% global mangroves) require an EIA for any project involving clearing mangroves, either explicitly (e.g., Vanuatu EIA Regulations 2011, Schedule 1) or by defining all mangroves as special areas where an EIA is required (e.g., in Mexico, an EIA is required in coastal ecosystems, which is defined to include mangroves, Law of General Ecological Balance and Protection of the Environment 2018). In nine jurisdictions (17.8% global mangroves), an EIA is required for certain activities or impacts of a certain size. In three jurisdictions (0.4% global mangroves), mangroves are considered as part of the screening process to determine whether an EIA is required.

We identified 29 jurisdictions—containing 56.5% of global mangroves—that explicitly reference mangroves in their coastal zone planning and management frameworks (Table 3). These provisions range from requirements that mangroves be included in coastal planning processes to restrictions on zoning in mangrove areas. For example, the National Planning for Coastal Zone Management Law of Brazil stipulates the prioritization of conservation of mangroves and other coastal forests in zoning processes (Law no. 7.661, 1988). Most of these jurisdictions (21 jurisdictions) also address both coastal development and agriculture or aquaculture, while five address mangroves and coastal development only, and one addresses mangroves and agriculture or aquaculture only.

### Over 80% of mangroves are in jurisdictions with frameworks for community management

We found 53 jurisdictions (83.2% global mangroves) with national legal frameworks that allow for community management or governance of mangrove areas (Table 4). Some of these frameworks explicitly use the word mangrove; others do not but could be applied in mangrove areas. In a few jurisdictions, the framework explicitly gives rights to communities to manage mangrove areas, such as the 1997 Philippines Indigenous Peoples' Rights Act (Table 4). In others, legal frameworks provide for concessions or conservation agreements to allow communities to access natural resources and take on stewardship responsibilities. In Ecuador, traditional users of mangrove resources can enter into sustainable use and custody agreements under which the communities guard the mangroves from illegal logging and can use mangrove areas for shellfish fisheries. As of October 2023, there were 53 such agreements in force covering >50,000 ha of mangroves in Ecuador.<sup>9</sup>



**Figure 1. Explicit restrictions on mangrove cutting and level of protection provided**

"High" protection indicates all cutting and clearing of mangroves is prohibited. "Medium" protection indicates that cutting, clearing, or conversion is prohibited for some but not all uses, species, tree heights or diameters, or sizes of mangrove areas. "Low" protection indicates that cutting, clearing, or conversion of mangroves requires a permit for some or all uses. See Table 1 for examples.

(A) Global distribution of mangrove cutting restrictions, assessed for the 116 jurisdictions containing mangroves globally.

(B) Percentage of jurisdictions, mangrove extent, mangroves within protected areas, and mangrove-derived ecosystem service value globally covered by mangrove cutting restrictions.

(C) Cumulative number of jurisdictions with cutting restrictions through time.

### Half the world's mangroves are in jurisdictions with mangrove-specific national policies

Of the 116 jurisdictions where mangroves are found, 21 have adopted mangrove-specific national policies (Figure 2A; 51.2% global mangroves). We defined mangrove-specific policies as binding or non-binding instruments adopted by national legislatures, executives, or government agencies, which use the word "mangrove" or a synonym in the title. While provisions for mangrove protection are common in more general or sectoral legal instruments (e.g., forest protection, EIA, or coastal zone planning instruments), mangrove-specific national laws and policies are relatively rare.

Mangrove-specific national policies vary widely in content, but we identify two main types: non-binding national mangrove plans and binding national mangrove laws or regulations. Not all of the national policies identified fall cleanly into one of these categories, and some jurisdictions have multiple instruments. Eight countries have non-binding national mangrove plans. Such plans typically establish time-bound targets for mangrove management, conservation, and restoration and/or sustainable

use and strategies for achieving such targets. Examples include Mozambique's Mangrove Management Strategy 2020–2024 (2020), Thailand's Mangrove Management Master Plan (2019), and Brazil's Mangrove National Action Plan (2019). At least 12 countries have legally binding mangrove-specific laws or regulations that create special protections, processes, or designations for mangrove areas. For example, the Colombian Law for the Protection of Mangrove Ecosystems creates a system of mangrove zones, including zones for preservation, restoration, and sustainable use, and it establishes a participatory process for zoning. It also provides resources for mangrove education and research and monitoring, and it sets up a process for creating a national plan for mangrove restoration and designates 26 July of each year as National Mangrove Day (Law 2243, 2022).

The number of mangrove-specific national policies increased significantly in the 1990s (Figure 2B). The earliest policy we identified is the Order of August 5, 1932, regulating the exploitation of mangrove stands, adopted in Madagascar and still in force in Comoros. In total, we found two jurisdictions with policies



**Table 1. National mangrove cutting restrictions**

Category	Definition	Jurisdictions	% global man- groves	Includes	Example
Low protection	cutting, clearing or conversion of mangroves requires a permit for some or all uses.	Barbados, Belize, Brunei, Cameroon, Comoros, Cuba, Djibouti, Gabon, Gambia, Ghana, Guinea, Guyana, Kenya, Kiribati, Malaysia, Mauritius, Myanmar, Sao Tome and Principe, South Africa, The Bahamas, Tuvalu, US Virgin Islands, Vanuatu, Venezuela	18.3	-permit required for aquaculture operations in mangrove areas -no mangrove clearing without a license -authorization and environmental assessment required for projects affecting mangrove areas	"A person shall not alter, allow or cause to be altered any mangrove, unless the alteration is carried out pursuant to a permit." Belize Forests (Protection of Mangroves) Regulations 2018 art. 3(1)
Medium protection	cutting, clearing or conversion of mangroves is prohibited for some but not all uses, mangrove species, tree heights or diameters, or sizes of mangrove areas.	Benin, Brazil, Cayman Islands, Colombia, Costa Rica, Guatemala, Guinea-Bissau, Honduras, India, Iran, Liberia, Mozambique, Nigeria, Palau, Panama, Saudi Arabia, Senegal, Solomon Islands, Somalia, Tanzania, Timor-Leste, Vietnam	27.5	-no aquaculture in mangrove areas; other activities may be allowed -permit required in mangrove areas; permit must be denied for activities affecting listed species -mangrove clearing only allowed for tourist development, which requires a permit	"In ecologically sensitive areas such as ... mangroves ... construction of beach resorts or hotels shall not be permitted." Nigeria National Environmental (coastal and marine area protection) Regulations (2011) art. 10
High protection (Direct)	All mangrove cutting and clearing is prohibited directly, with a possible exception for traditional use.	Angola, Cambodia, China, Cote d'Ivoire, Dominican Republic, Ecuador, France, Madagascar, Marshall Islands, Mexico, Nicaragua, Peru, Philippines, Sri Lanka	13.8	-no cutting or clearing of mangroves, with the exception of traditional use -cutting or clearing mangroves listed as a crime	"Cutting, reclaiming, digging out, clearing, burning or occupying flooded forests and mangroves is prohibited...Doing so is punishable by 3–5 years imprisonment". Cambodia Fisheries Law (2006) [Unofficial translation Fisheries Administration/ WWF/UNDP 2007]
High protection (Legal classification)	All mangrove cutting and clearing is prohibited because all mangroves are legally classified as protected ecosystems or species.	Antigua and Barbuda, El Salvador, Aruba, Bermuda, Trinidad & Tobago	0.3	-Killing or destroying of listed species prohibited, and all mangrove species are listed. -All mangroves are special conservation zones, and cutting or clearing special conservation zones is prohibited.	"Mangroves and reefs are ecological reserves, therefore no alteration in them will be permitted." El Salvador Environmental Law (1998) art. 74. [translation by author]
TOTAL		65	59.8	–	

Assessment of presence/absence and category of protection for explicit restrictions on cutting or clearing mangroves in the 116 jurisdictions containing mangroves globally. See [Methods S3](#) for notes on interpretation of the categories

**Table 2. Integration of mangroves into EIA laws**

Category	Jurisdictions	% global man- groves	Includes	Example
EIA required for all projects and mangroves	Benin, Brunei, Costa Rica, Cote d'Ivoire, El Salvador, Gabon, Ghana, India, Madagascar, Mexico, Mozambique, Myanmar, Nicaragua, Tanzania, Timor-Leste, Vanuatu, Venezuela	22.3	-EIA required for projects affecting mangroves -EIA required for projects in special areas, where all mangrove areas are legally classified as special.	"Activities requiring preliminary environmental assessment: ...(I) the clearance of any mangroves or the disturbance of any other coastal/ estuarine ecosystems..." Vanuatu Environmental Impact Assessment Regulations (2011) Schedule 1
EIA required for some projects/ mangroves	Angola, Belize, Cameroon, Colombia, Malaysia, Nigeria, Panama, Philippines, Thailand	17.8	-EIA required for projects above certain size -EIA required for certain industries/activities.	"Mandatory Study Activities ...5(c) Land based aquaculture projects accompanied by clearing of mangrove swamp forests covering an area of 50 hectares or more...6 (d) Conversion of mangrove swamps for industry, housing or agricultural use covering an area of more than 10 hectares. (e) Clearing of mangrove swamps on islands adjacent to national marine parks." Nigeria Environmental Impact Assessment Act (1992) Schedule
Mangroves considered in screening	Fiji, Micronesia, Palau	0.4	-mangroves considered in threshold for whether detailed report is required.	"Initial Assessment Environmental Checklist ... 4.a. Destruction of any upland or mangrove forest communities?" Micronesia Environmental Impact Assessment Regulations (2016) App. B
Total	29	40.5	–	–
EIA laws that explicitly reference mangroves assessed for the top 80 jurisdictions globally by mangrove extent (99.96% global mangroves)				

**Table 3. Integration of mangroves into coastal zone planning laws**

Category	Jurisdictions	% global man- groves	Includes	Example
Mangroves only	Kenya, Benin	0.4	-coastal areas with mangroves zoned as strictly protected -Mangroves explicitly included in scope of coastal planning -Mangroves to be considered in coastal development -Agri/aquaculture zoning restricted in mangrove areas.	"The National Coastal Zone Plan should provide for zoning of uses and activities in the coastal zone and prioritize the conservation and protection of ... coastal forests, mangroves and submerged grasslands." Brazil National Planning for Coastal Zone Management Law (1988) [translation by author]
Mangroves and coastal development only	China, Gambia, Philippines, Sri Lanka, Venezuela	4.6	–	–
Mangroves and agriculture/aquaculture only	New Caledonia	0.2		
Mangroves and coastal development and agriculture/aquaculture	Brazil, Cayman Islands, Colombia, Costa Rica, Cote d'Ivoire, Cuba, Ecuador, Fiji, France, India, Indonesia, Madagascar, Mozambique, Nicaragua, Nigeria, Panama, Republic of Congo, Saudi Arabia, South Africa, Thailand, Vietnam	51.3		
Total	29	56.5	–	–
Coastal zoning planning laws that explicitly reference mangroves assessed for the top 80 jurisdictions globally by mangrove extent (99.96% global mangroves)				



**Table 4. Legal frameworks for community management**

Definition	Jurisdictions	% global man- groves	Includes	Example
Legal framework that allows for community management or governance of mangroves, either explicitly or in practice.	Australia, Bangladesh, Belize, Benin, Brazil, Cambodia, Cameroon, China, Colombia, Congo DRC, Cote d'Ivoire, Dominican Republic, Ecuador, Equatorial Guinea, Eritrea, Fiji, France, Gabon, Gambia, Guatemala, Guinea, Guinea-Bissau, Guyana, Honduras, India, Indonesia, Jamaica, Japan, Kenya, Liberia, Madagascar, Mexico, Mozambique, Myanmar, New Zealand, Nicaragua, Panama, Papua New Guinea, Peru, Philippines, Republic of Congo, Senegal, Sierra Leone, Solomon Islands, South Africa, Sri Lanka, Suriname, Tanzania, Thailand, Timor-Leste, Vanuatu, Venezuela, Vietnam	83.2	-general framework for locally managed marine areas that could be applied in mangrove areas -procedure for setting up community management areas in mangrove areas -stipulation that communities have the right to manage mangrove areas	"Ancestral domains or portions thereof, which are found to be necessary for critical watersheds, mangroves, wildlife sanctuaries...shall be maintained, managed and developed for such purposes. The ICs/IPs concerned shall be given the responsibility to maintain, develop, protect and conserve such areas with the full and effective assistance of government agencies." Philippines Indigenous Peoples' Rights Act (1997) Section 58.

Legal frameworks for community management that can be applied in mangrove areas assessed for the top 80 jurisdictions globally by mangrove extent (99.96% global mangroves)

adopted before 1990, six between 1990 and 1999, five between 2000 and 2009, and eight in 2010 or later.

#### Few jurisdictions have adopted mangrove-specific coordination mechanisms

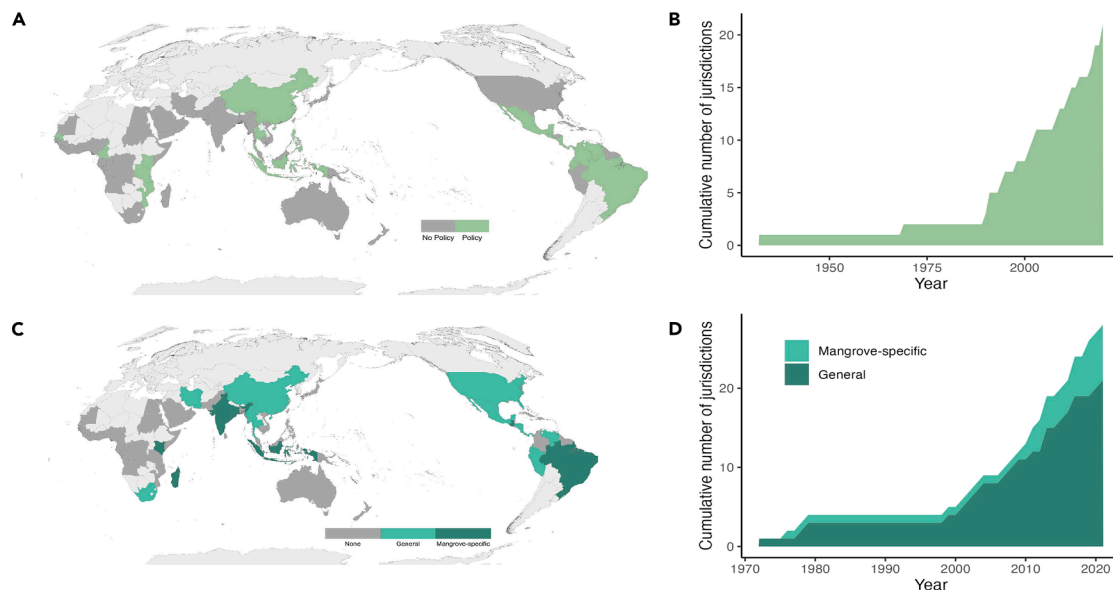
At least seven jurisdictions have national interagency or cross-sectoral coordination mechanisms specific to mangroves, with these jurisdictions containing around a third (33.0%) of the world's mangroves (Figure 2C). This is driven by Indonesia (20.0% global mangroves) and Brazil (7.8% global mangroves). All but one of these mangrove-specific coordination mechanisms were adopted in or after 2010, with the National Mangrove Committee of India the only exception, established in 1976 (Figure 2D). An additional 21 jurisdictions have general wetland or coastal ecosystem coordination mechanisms that apply to mangrove areas, covering 19.3% of global mangroves (Figure 2C).

These coordination mechanisms take various forms, from legal requirements or processes for consultation, coordination, or joint decision-making among government agencies to committees or institutions charged with harmonizing national mangrove decisions. Institutional coordination mechanisms are typically embedded in an existing sectoral agency. For example, the Timor-Leste Department of Management of Coastal and Mangrove Areas, which is responsible for coordination and collaboration on mangrove management, is part of the National Directorate of Hydrographic Basins and Mangrove Areas, itself a subunit of the Ministry of Agriculture and Fisheries (Ministerial Order no. 2/2020). In contrast, Madagascar's National Committee for Integrated Management of Mangroves is hosted by the Ministry of Agriculture and Fisheries but co-chaired by the Ministry of Environment and Sustainable Development (Decree 2015-629).<sup>37</sup>

In most jurisdictions, a special order or regulation sets up the coordination mechanism, such as the Brazilian Ministry of Environment Order No. 185, creating the Technical Committee on Mangroves (2011). The complexity of mangrove governance in Indonesia led to the re-establishment of the national mangrove working group by Ministerial Regulation, which had been dissolved by Presidential Regulation.<sup>8,14</sup> In Guatemala, the Regulation for the Sustainable Management of Forest Resources of Mangrove Ecosystems establishes a mandate for the National Institute of Forests and the National Protected Areas Council to coordinate with public institutions, municipalities, civil society, and local communities to achieve the purposes of the regulation (2019, art. 9).

#### Jurisdictions with high mangrove extent and mangrove-derived ecosystem services are more likely to have mangrove laws

We applied a framework for spatially explicit models of social-ecological systems<sup>38</sup> to quantify the contributions of ecological, geopolitical, and economic factors influencing mangrove law and policy uptake. Factors considered include the extent of mangroves in a jurisdiction relative to a jurisdiction's shoreline length and area, mean mangrove ecosystem service value per ha for the jurisdiction (including fisheries, coastal protection,



**Figure 2. National mangrove policies and coordination mechanisms**

"Mangrove specific" includes laws or policies with the word "mangrove" or a synonym in the title. Assessed for all 116 jurisdictions containing mangroves globally.

(A) Jurisdictions with mangrove-specific national policies.

(B) Cumulative number of jurisdictions with mangrove-specific national policies through time.

(C) Jurisdictions with mangrove-specific or general coastal/wetland coordination mechanisms.

(D) Cumulative number of jurisdictions with mangrove-specific or general coastal/wetland coordination mechanisms through time.

and carbon stocks), type of government, and geographic region (see [Methods](#)).

Ecological, geopolitical, and economic factors explain a high proportion of variance in adoption of mangrove cutting restrictions (68.7%), coordination mechanisms (86.6%), EIA (80.8%), community management (82.6%), and specific policies (65.9%) ([Figure 3A](#)). We used probability of association to explore directionality of relationships between factors and mangrove laws and policies ([Figure 3B](#)).

Jurisdictions with a high relative extent of mangroves are more likely to have mangrove-specific national policies (97.3% probability of association) and address mangroves in EIA laws (79.1% association) and coastal planning laws (82.6% association). High value from mangrove-related fisheries is associated with the adoption of mangrove-specific national policies (96.5% association), cutting restrictions (91.4%), coordination mechanisms (93.7%), and EIA laws (88.9%). Jurisdictions with significant mangrove carbon stocks are more likely to have mangrove-specific coordination mechanisms (95.1%) and national policies (82.1%) and to address mangroves in EIA laws (99.7%). High coastal protection from mangroves is associated with explicit consideration of mangroves in coastal planning laws (91.3%) and EIA laws (82.0%) and in the adoption of specific mangrove policies (75.8%). We tested the sensitivity of these results to gaps in ecosystem service data and found the results were robust ([Methods S5.2](#)).

Geopolitical and economic factors like GDP per capita (GDPpc), government type, and geographic region are also associated with the adoption of laws and policies protecting mangroves ([Figures 3B and 3C](#)). Jurisdictions with lower GDPpc are more likely to have in place community management frameworks

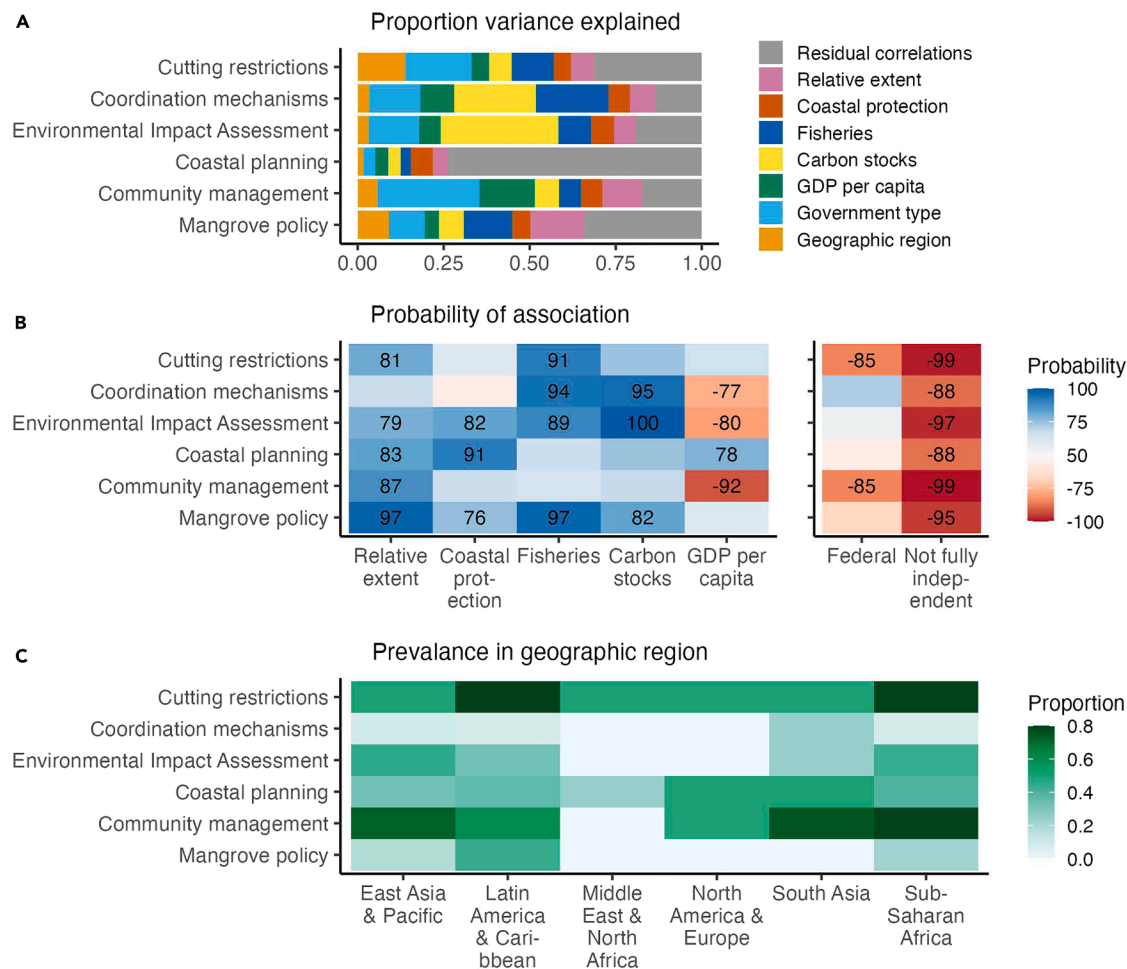
(92.1%), EIA (79.9%), and coordination mechanisms (76.6%); in contrast, those with higher GDPpc were more likely to have coastal planning laws (78.5%). Federal states, where significant governance authority is held by subnational states or provinces, are less likely to have national community management frameworks (84.6%) relative to unitary independent states, where governance authority is ultimately held at the national level. Federal states may have laws and policies protecting mangroves at the subnational level, which were not included in this analysis. Relative to unitary independent territories, territories that are not fully independent (only 0.5% of global mangrove cover) are substantially less likely to have any national law or policy explicitly protecting mangroves, including laws of the metropole.

Our analysis reveals differences in the prevalence of mangrove laws and policies across regions ([Figure 3C](#)). Geographic region accounts for a high proportion of variance in the adoption of cutting restrictions (13.7%) and in community management (5.8%) ([Figure 3A](#)). Cutting restrictions were more prevalent in Latin America and the Caribbean and in Sub-Saharan African countries, whereas community management was more prevalent in Sub-Saharan Africa, South Asia, and East Asia and the Pacific.

## DISCUSSION

### Explicit national legal protection of mangroves is more prevalent than previously recognized

Our research shows that explicit recognition of mangroves in national laws and policies is now widespread globally. These laws create frameworks for conservation and sustainable use of mangroves that extend beyond protected areas.



**Figure 3. Ecological, geopolitic, and economic factors associated with adoption of national mangrove laws and policies**

Analysis is based on the top 80 mangrove-containing jurisdictions. Explanatory factors considered are as follows: relative mangrove extent; mean or median jurisdiction mangrove ecosystem service value per unit area for coastal protection, fisheries, and carbon; GDP per capita; and type of government.

(A) Proportion of variance explained for the presence or absence of laws/policies.

(B) Probability of association between mangrove laws/policies and explanatory factors. Types of government are unitary independent, federal independent, or not fully independent, with probability of association shown for federal independent or not fully independent relative to unitary independent.

(C) Proportion of evaluated mangrove-containing jurisdictions by geographic region that have adopted mangrove laws/policies.

The extensive integration of explicit mangrove provisions in national legal frameworks indicates awareness and political will at the national level to prioritize mangroves. As an ecosystem at the intersection of land and water and in forestry and fishing and multiple other sectors, mangroves can fall through the cracks of governance—under the authority of multiple regimes yet prioritized by none.<sup>2,3,6</sup> The existence of laws addressing mangroves by name shows that legislators and policymakers are giving mangroves active consideration.

The increase in mangrove laws over the past three decades correlates to some extent with the increase in international attention to mangroves. Increasing adoption of national mangrove laws and policies in the 1990s roughly corresponds with the 1992 UN Conference on Environment and Development (Rio Conference) and the adoption of Agenda 21, which represents a broad global commitment to address biodiversity and climate

change, and calls for action on mangroves explicitly.<sup>39</sup> The Rio Conference also culminated in the UNFCCC and the CBD, whose expansive regimes have encompassed myriad resolutions, initiatives, and commitments on mangroves.

Mangrove laws have not been widely incorporated in global targets or indicators of mangrove conservation, which often focus on indicators like percentage of mangroves within protected areas.<sup>27</sup> The data we have gathered can serve as a baseline and first step for tracking progress in legal protections for mangroves beyond protected areas. A next step is to evaluate implementation and ecological outcomes of these laws.

### Existing laws represent opportunities for strengthening effectiveness of mangrove protection

The laws and policies assessed in our research represent significant opportunities for protecting mangroves and associated

ecosystem services worldwide. For organizations committed to conserving mangroves, investment in implementing these existing frameworks may be more impactful than legal reform.

Prohibitions and restrictions on cutting and clearing can potentially protect most of the world's mangroves and mangrove-associated carbon sinks, valuable fisheries, and vulnerable coastal populations. The permitting process will be an important intervention point for strengthening mangrove protection, and civil society organizations can play a powerful role by increasing transparency, facilitating public participation, and building capacity and awareness of all involved.<sup>2,14</sup>

The prevalence of legal frameworks for community management applicable to mangrove areas creates a key opportunity. Community management is effective in protecting mangroves.<sup>26,33,40</sup> Supporting implementation of community management arrangements for the 83.2% of mangroves in jurisdictions with legal frameworks for community management could be an efficient way to ramp up global mangrove protections.<sup>41</sup> Community management frameworks were more common in jurisdictions with lower GDPpc, suggesting that international financial and technical support may be particularly warranted.

National legal frameworks can strengthen and reinforce protected areas.<sup>42,43</sup> National mangrove policies can include strategies and targets for designating protected areas, while coastal planning and EIA laws can impose higher standards for projects affecting protected areas and coordination mechanisms can incorporate protected area management bodies. Building capacity of protected area managers and civil society organizations to understand applicable national legal protections and to engage with coordination mechanisms and planning processes could improve conservation outcomes both within and beyond protected areas.

Implementation of laws and policies can vary among and even within jurisdictions and is difficult to assess.<sup>44,45</sup> Governance quality, which influences implementation, is an important factor in mangrove protection.<sup>10,26</sup> Studies of the relationship between mangrove policy and shrimp farming in Vietnam have found a lack of compliance with mangrove policies<sup>46</sup> as well as potential economic and social impacts of shrimp farm regulation on local communities, which could undermine their effectiveness.<sup>47</sup>

Even with full implementation, our categorization of cutting restrictions as low, medium, and high protection is not a perfect indicator of the effectiveness of the provision for mangrove protection. A low level of protection that requires a permit for all mangrove activities and heavily restricts destructive activities could be stronger than a medium level of protection that prohibits some activities but allows other destructive activities without a permit or a high level protection that is so rigid that it undermines its own legitimacy or becomes impossible to implement. More detailed evaluation at the national level is needed to evaluate the effectiveness of protection in practice.

### Understanding ecological and geopolitical factors can inform strategic legal reform

Global organizations and initiatives like the Global Mangrove Alliance and the Mangrove Breakthrough are seeking to leverage financial and technical resources for mangrove conservation, including the creation of new legal frameworks. Understanding

the factors associated with the adoption of mangrove laws can help prioritize these efforts.

Our analysis of the associations between legal frameworks and social, political, and ecological factors suggests options for expanding legal frameworks.<sup>38</sup> Jurisdictions with high relative mangrove extent and high ecosystem services are more likely to have mangrove laws and policies. Similarly, situated jurisdictions may be more receptive to developing new legal frameworks, given appropriate resources and support.

Cutting restrictions and community management frameworks are both more likely in jurisdictions with higher relative mangrove extent but are more popular in different regions. This may indicate that social, political, and cultural factors in jurisdictions in Sub-Saharan Africa, South Asia, and East Asia and the Pacific are conducive to community management. Therefore, jurisdictions in these regions that do not have community management frameworks in place may be amenable to following the example of their neighbors. It could also suggest that there is an opportunity to introduce community management frameworks in Latin America and the Caribbean, where they are less familiar, through regional support and targeted sharing of experiences.

The negative association between GDP and community management, EIA, and coordination mechanisms indicates that lower-income jurisdictions may be more experienced with—and politically amenable to—laws that allow for community involvement and flexible implementation. Pushing for strict bans on mangrove cutting or clearing in such jurisdictions may not be appropriate without additional information about the specific legal, social, and political contexts. At the country level, knowledge about the present status of mangrove laws in a jurisdiction can inform decisions about whether to invest resources in creating laws or in supporting implementation of existing laws.<sup>48</sup>

## METHODS

To evaluate the global coverage and nature of national cutting restrictions, mangrove policies, and coordination mechanisms for mangroves, we gathered information from 116 jurisdictions, containing 100% of the world's mangroves as mapped by Global Mangrove Watch.<sup>49</sup> Full details regarding the methods can be found in the [supplementary methods](#). For the analysis of EIA laws, coastal planning, and community management, we collected information from the top 80 jurisdictions by mangrove extent—containing 99.96% of the world's mangroves ([Methods S1](#)). We defined jurisdictions in accordance with the World Bank list of Countries and Economies.<sup>50</sup> While most of the jurisdictions we analyzed are unitary and fully independent countries, we also included 12 federal countries (e.g., Australia, Brazil) and 14 territories not fully independent from another jurisdiction (e.g., New Caledonia, Puerto Rico).

To identify mangrove laws or policies, we searched legal databases and online search engines following predetermined search criteria ([Methods S2](#)). We developed and followed a structured desk assessment to assess and record mangrove laws and policies in a structured way, using a standardized template ([Methods S3](#)). With the exception of community management frameworks, we included only laws and policies that explicitly refer to mangroves, using the word “mangrove,” a synonym,



or a species name. In the case of mangrove-specific national policies, we included only policies with the word “mangrove” or a synonym in the title (Methods S2). We used this strict interpretation to improve consistency, recognizing the limitations of a desk assessment to accurately interpret legal nuance.

To contextualize our findings, we calculated expected ecosystem service provision from mangroves under legal protection (Methods S4). To identify which geopolitical, economic, and ecological conditions are associated with the adoption of mangrove policies and laws, we gathered data on seven national level indicators: (1) relative extent of mangroves expressed as total mangrove extent multiplied by the ratio between jurisdiction shoreline length and total jurisdiction area, (2) average total carbon storage per unit area of mangrove, (3) median number of mangrove fisher days per year per unit area of mangroves, (4) coastal protection represented by the average number of people and value of property protected by mangroves per unit area of mangroves, (5) GDPpc, (6) governance type in terms of federal vs. unitary and fully independent vs. not fully independent, and (7) geographic region (Methods S5). We fitted a Bayesian multivariate regression model to identify associations between the adoption of mangrove laws or policies and national ecological, geopolitical, and economic covariates (Methods S5).

### Limitations

Our analysis has several key limitations. Our assessment is limited to national legal frameworks, although subnational frameworks can be important, particularly in jurisdictions that delegate or decentralize governance of natural resources.<sup>3</sup> We only included policies, cutting restrictions, coastal laws, and EIA laws that explicitly referred to mangroves, using the word “mangrove” or a synonym or species name, leaving out legislation that might apply to mangroves but does not call them out specifically, such as protection of “marine plants” (Australia), or “submerged forests” (Vietnam), or general cutting restrictions for forests (e.g., Thailand). We did not include cutting restrictions that apply only within designated protected areas or general references to mangrove protection that do not create legally enforceable restrictions, as in Indonesia (Law no. 27 Concerning Coastal and Small Island Management, 2007). Our legal analysis was based on a desk study. We were not able to work with lawyers qualified in every jurisdiction we reviewed, although we did seek the advice of national legal experts when we noted questions or ambiguities. We did not evaluate implementation or effectiveness of mangrove laws and policies in practice. Despite these limitations, this is the most comprehensive global overview to date of mangrove laws and policies and their potential to contribute to conservation.

### Conclusions

Our assessment provides a first-of-its-kind view of legal frameworks for mangrove conservation at the national level. Prior assessments have assessed key policy barriers for mangrove conservation through non-systematic approaches<sup>43</sup> or examined typologies of mangrove governance,<sup>33</sup> but no study has conducted a systematic review of legal frameworks across all mangrove holding countries and territories. We identify a wide variety of legal frameworks and policies, including mangrove-

specific cutting restrictions and incorporation of mangroves into coastal plans. Other frameworks, such as interagency coordinating mechanisms, are less commonly applied but may benefit mangrove conservation if adopted more widely. Although our analysis suggests the widespread use of mangrove-specific legal frameworks and thus a large role for national law to play in mangrove conservation, understanding the precise impact of legal protections on mangrove ecosystems will require further research. The data we have gathered can provide important input into this research, including a baseline for a time-series analysis of policy change, which will allow future researchers to determine whether laws make a difference to the health and coverage of mangrove ecosystems. The method we have used to quantify and analyze legal information can be applied in other fields where legal protections involve multiple mechanisms, instruments, and sectors.

### RESOURCE AVAILABILITY

#### Lead contact

Requests for further information and resources should be directed to the lead contact, Lydia Slobodian ([ls27@georgetown.edu](mailto:ls27@georgetown.edu)).

#### Data and code availability

The database of national laws and policies and other input data used in analyses are stored on GitHub: <https://github.com/cabuelow/global-mangrove-legal-protection> and are archived on Zenodo: <https://doi.org/10.5281/zenodo.15401068>.

The code to run the analyses and reproduce the figures is available on GitHub: <https://github.com/cabuelow/global-mangrove-legal-protection> and is archived on Zenodo: <https://doi.org/10.5281/zenodo.15401068>.

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### AUTHOR CONTRIBUTIONS

Conceptualization, L.S., C.J.B., M.P.T., D.A.A.-B., J.B.-J., R.H.C., and N.H.; methodology, L.S., D.A.A.-B., S.C.B., C.A.B., C.J.B., J.V.-R., M.F.A., R.M.C., R.A.F., N.H., and A.C.V.V.; investigation, L.S., S.C.B., S.A., K.C.W., C.A.B., and A.R.W.; resources, A.A.A., J.J.B., R.M.C., E.J.G., F.S., and N.H.; writing – original draft, L.S., D.A.A.-B., and C.A.B.; writing – review & editing, J.V.-R., C.J.B., M.F.A., A.A.A., J.J.B., J.B.-J., A.C.V.V., R.H.C., R.M.C., E.J.G., R.A.F., N.H., F.S., M.P.T., and A.R.W.; visualization, C.A.B., J.V.-R., L.S., D.A.A.-B.; funding acquisition, D.A.A.-B., M.P.T., and C.J.B.

### DECLARATION OF INTERESTS

C.J.B. is co-lead of the Global Mangrove Alliance Science Working group, an organization that promotes mangrove conservation. J.J.B. is a science advisor for Carbon Direct, a for-profit company engaged in carbon dioxide removal.

### SUPPLEMENTAL INFORMATION

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