



Full length article



An Analysis of Policy Options Available to the International Maritime Organization to Protect the Costa Rica Thermal Dome: Building the Case for a Particularly Sensitive Sea Area

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ABSTRACT

Intense maritime traffic threatens marine habitats globally. The Costa Rica Thermal Dome (CRTD) is a biologically productive ocean region that experiences a high volume of maritime traffic, and its location is dynamic, representing a governance challenge for this marine area. The CRTD is a high seas upwelling system influenced part of the year by coastal jet winds off the coast of Nicaragua and Costa Rica. During parts of the year, the CRTD moves into the jurisdictional waters of the adjacent countries (Costa Rica, Nicaragua, Guatemala, and El Salvador). Because there is currently no cross-sectoral coordination or capacity to address multiple threats in high seas areas such as the CRTD, regulation must be implemented on a sector-by-sector basis. This document analyzes tools under the International Maritime Organization (IMO) to reduce the threats from international shipping in the marine environment, with particular emphasis on the CRTD. The IMO has the authority to regulate shipping activity globally and implement precautionary measures to avoid threats such as hazardous and noxious substances, ship-whale strikes, or underwater noise pollution. The following IMO tools were included in the analysis: ship routing measures and speed reductions, a Special Area under the International Convention for the Prevention of Pollution from Ships (MARPOL), and a Particularly Sensitive Sea Area (PSSA). The results of the analysis concluded that the implementation of a PSSA within the CRTD is the best option to address threats from international shipping, since it can combine a range of Associated Protective Measures under its single administrative structure.

1. Introduction

The Costa Rica Thermal Dome (CRTD) is a dynamic, nutrient-rich upwelling system that creates a complex and healthy food chain ranging from zooplankton to keystone predators like sharks, serves as feeding grounds for whale species, such as the blue whale (*Balaenoptera musculus*), and as a stopover along the migratory routes for sea turtle species like the leatherback (*Dermochelys coriacea*) [1]. The CRTD's location is predictable yet dynamic: located in the high seas, it might expand during certain years and seasons into the jurisdictional waters of Central American countries such as Costa Rica, Nicaragua Guatemala, and El Salvador [2]. Because there are only sectorial regulations to protect marine biodiversity in Areas Beyond National Jurisdictions (ABNJ), the CRTD is highly vulnerable to negative impacts of

anthropogenic activities like maritime traffic [1].

Maritime traffic is a threat to the marine environment and particularly to highly migratory species like whales. The International Maritime Organization (IMO) has the authority to regulate international shipping activity globally and implement precautionary measures to avoid negative impacts of maritime traffic, like underwater noise pollution, and implement area-based management tools, such as areas to be avoided (ATBA), Special Areas under MARPOL (Special Areas), and Particularly Sensitive Sea Areas (PSSAs) [3]. While Costa Rica and neighboring country Panama have implemented navigation measures, such as ATBA, vessel speed reductions, and Traffic Separation Schemes (TSS) to reduce the risk of whale-vessel strikes and noise associated with vessel propellers [4,5], the implementation of protective measures becomes more challenging when the area requiring such measures is

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located in ABNJ, such as the CRTD [2].

This document will analyze whether any of the IMO tools, or a combination of them, can help address the threats posed by the international shipping activity within the CRTD.

2. The Costa Rica Thermal Dome

The CRTD receives its name due to the “dome like” shape created by its thermocline (boundary between deep cold water and shallow warm water) [6]. The CRTD is an upwelling area located in the high seas off the Pacific Coast of Central America (Fig. 1) and its size changes according to variations in currents, winds, and movement of the Inter Tropical Convergence Zone (ITCZ) [1,7]. Despite its dynamic nature, the CRTD’s location and size are predictable throughout the year [8]. Early in the year, around January and February, the CRTD’s average diameter covers an area between 200 – 300 km. The CRTD significantly increases in size from July to October, and by November it reaches a diameter of approximately 1000 kilometers [1].

2.1. Importance of CRTD

The CRTD is an area of high primary productivity that serves as critical habitat for marine species, such as the endangered blue whale (*Balaenoptera musculus*), the humpback whale (*Megaptera novaeangliae*), and the gray whale (*Eschrichtius robustus*) [9]. The Eastern North Pacific Blue Whale population is the largest population of this species with an

estimated 300 individuals. These whales travel during the winter from the west coast of the United States and Canada to Baja California and to the CRTD to feed and give birth [10]. The presence of blue whales in the CRTD is associated with high concentrations of krill, the main food source for this species, making the region an important habitat for the population’s recovery [1].

The CRTD is also an important area for sea turtle species, such as the olive ridley turtle (*Lepidochelys olivacea*) and leatherback (*Dermochelys coriacea*), listed by the IUCN Red List as vulnerable and critically endangered respectively [1,11]. The olive ridley sea turtle shows a high presence in the CRTD while the leatherback uses it as part of its migratory route to nesting beaches and feeding areas [1].

Furthermore, the CRTD is an area of high economic relevance due its influence on adjacent populations of valuable commercial and sport-fishing species such as sailfish (*Istiophorus platypterus*), swordfish (*Xiphias gladius*), and blue marlin (*Makaira nigricans*), as well as keystone species such as the hammerhead shark (*Sphyrna lewini*) [1]. In Costa Rica, Panama, and Guatemala alone, sport fishing generates an estimate of USD \$25 million a year [1]. Tourism is also a profitable activity for CRTD-adjacent countries. In Costa Rica, it is estimated that one single hammerhead shark linked to shark observation can generate US \$1.6 million during its lifetime. Leatherback sea turtle observation by tourists generates around US \$1 million a year in one marine park on Costa Rica’s Pacific coast [1].

In 2013, Mission Blue declared the CRTD as a “hope spot,” which recognizes the importance of this marine space for the ocean’s health

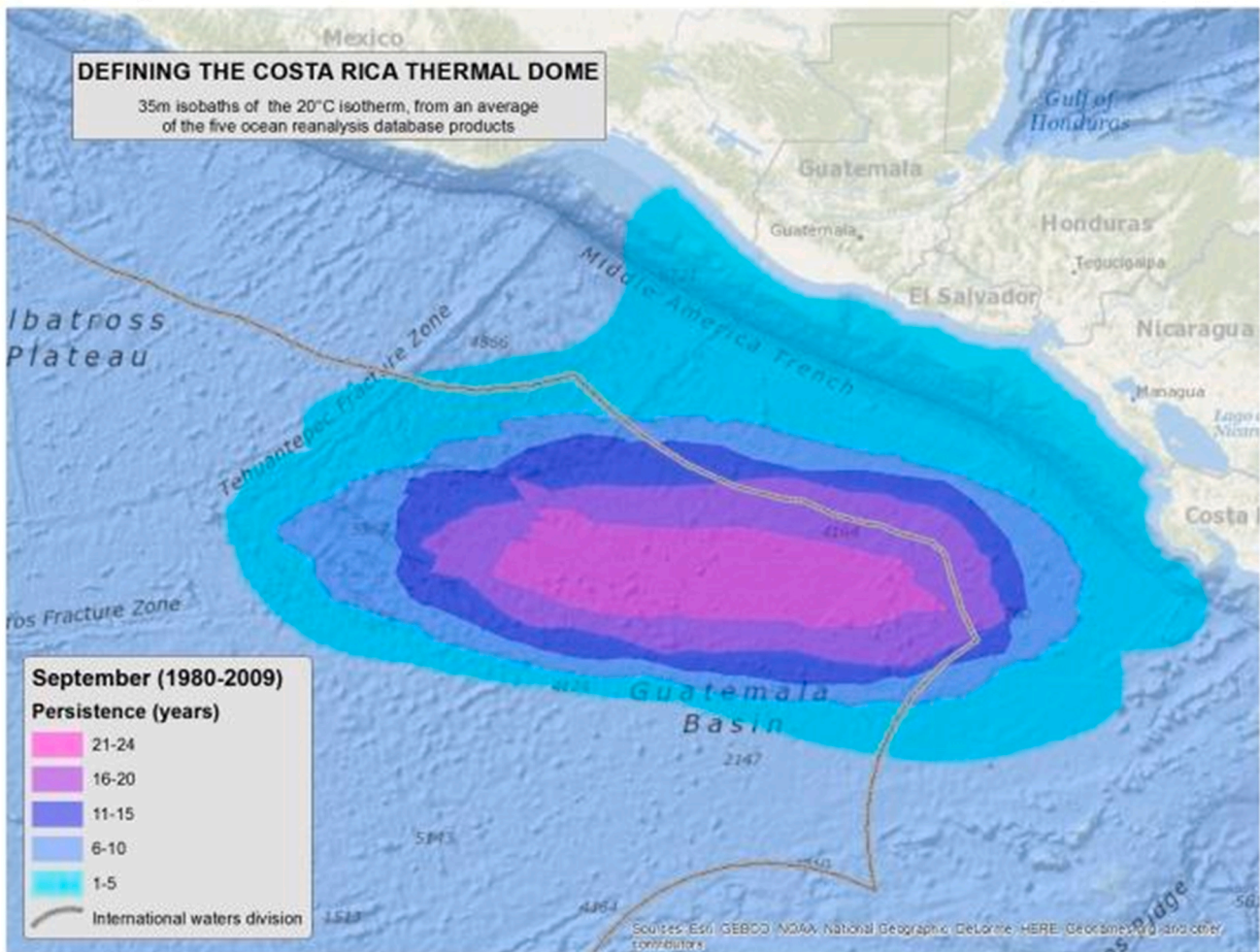


Fig. 1. Persistence of the Costa Rica Thermal Dome over the past three decades [1,8].

[12]. Furthermore, in 2014, part of the CRTD (the Papagayo Upwelling System and Adjacent Areas) was identified as an Ecologically or Biologically Significant Marine Area (EBSA) during the twelfth Conference of the Parties (COP) of the Convention on Biological Diversity (CBD), recognizing the ecological and biological importance of this area [13]. More recently, the CRTD was selected as an Important Marine Mammal Area (IMMA) candidate site [14].

2.2. Threats posed by maritime traffic in the CRTD

The CRTD is an area with high marine traffic due to its proximity to the Panama Canal. The Panama Canal connects some of the world’s most important trade routes: between Europe and Asia and the west coast of the American continent; between the east coast of the American continent and its west coast; between the east coast of the American continent and Asia; and between North and South America, all of which represents close to 5 % of the world’s maritime traffic [1] (Fig. 2). It is estimated that about two-thirds of this maritime traffic passes through the CRTD, potentially crossing important migratory routes and feeding grounds for endangered whale and sea turtle species [15].

Maritime traffic increases the exposure of marine species to underwater noise pollution, ship strikes, and other sources of pollution from ships [1]. The constant acoustic pollution caused by shipping is the largest source of low frequency sound in the ocean and ambient noise

has increased in the past decades as commercial vessels increase in size and number [17]. It is estimated that about 90 % of the anthropogenic noise in the ocean is caused by ship propulsion – i.e., sound from propellers [18]. Noise from ships causes stress in whales, affects whale’s ability to communicate and find mates, leads to displacement of habitats, and disrupts breeding and feeding behavior [18].

Moreover, noise from ship motors and propellers may affect cetaceans’ ability to avoid collisions [17]. Negative effects from ship-whale collisions range from behavioral change to severe physical injuries or death [3]. Despite the lack of exact statistics on ship-whale strikes in the CRTD, the humpback whale shows the highest record of accidents and deaths in the Eastern Pacific [1]. Shipping is responsible for other types of marine and air pollution, not only from oil spills, but also from normal ship operations such as washing cargo tanks at sea and discharging contaminated water in the ocean (e.g., sewage, ballast water or hull fouling) [19]. A significant part of the total inputs of oil into the marine environment is caused by these regular operational discharges, which negatively affect the marine ecosystems and may affect the CRTD [18]. Regarding greenhouse gas emissions, it is estimated that “if shipping were a country, it would be the world’s sixth-biggest greenhouse gas emitter” [18]. Therefore, international shipping activity represents a significant risk to the CRTD as a marine ecosystem and to the species that depend on it.

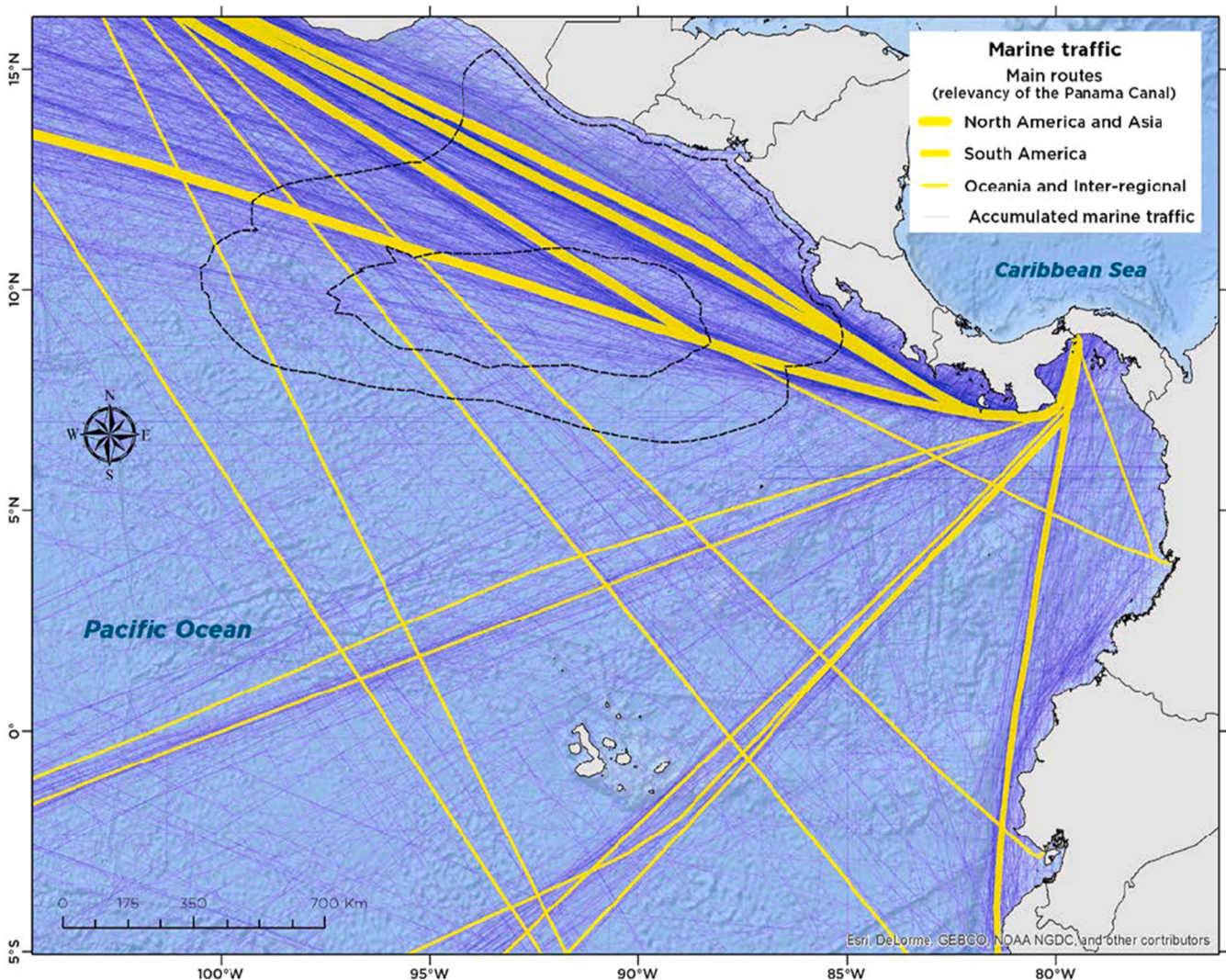


Fig. 2. Marine traffic and density through the Costa Rica Thermal Dome, indicated with a dotted line [1,16].

2.3. Governance challenge

The CRTD's location is dynamic and varies throughout the year. When analyzing the location of the CRTD's core between 1980 and 2009, Fiedler et al. [8] found that for over 20 years, the CRTD was located in ABNJ year round [2]. This study also shows the CRTD expanded into the jurisdictional waters of Costa Rica, Nicaragua, Guatemala, and El Salvador in at least 6 years over a span of 30 years [2] (Fig. 3).

The management of marine biodiversity is currently not regulated in ABNJ and there is currently no regional or global strategy for the management of the CRTD, representing a major governance challenge for the CRTD and its marine resources [1]. Part of this governance challenge includes the fact that there is no clear governance framework to protect biodiversity beyond national jurisdictions (BBNJ) and that part of the CRTD expands into jurisdictional waters of nearby countries [20]. Current efforts include the adoption and implementation of the Biodiversity Beyond National Jurisdiction Agreement (BBNJ Agreement), a comprehensive and legally binding instrument for conservation of biodiversity in ABNJ [21,22]. If approved, this agreement could serve as a future framework for the governance of the CRTD.

There currently are other initiatives that aim to overcome this governance challenge in the CRTD. The project *Contributing to a Hybrid Governance to Protect and Manage Remarkable Areas of the High Seas: Thermal Dome and Sargasso Sea (SARGADOM)* is funded (2022–2027) by the French Fund for Global Environment (FFEM) and aims to promote governance of the CRTD and the Sargasso Sea, being that they are two important ecosystems in the high seas. CRTD governance aspects of the project will focus on promoting a mixed governance model for regulation of fisheries and maritime traffic in ABNJ. This initiative focuses solely on the development of proposals and lessons learnt to inform UN negotiations related to the governance of ABNJ [23].

There are various legal instruments and international institutions that provide guidance on human activities and regulate ocean resource management by sector in ABNJ [24] (Table 1). Even though the United Nations Convention for the Law of the Sea (UNCLOS) does not directly regulate activities in ABNJ or provide guidance on the implementation of cross-sectorial coordination for area-based planning or management, it provides the legal framework for some activities in ABNJ through relevant sectorial authorities, such as IMO, Regional Fisheries Management Organizations (RFMOs) or the International Seabed Authority (ISA) [25,26]. The governance bodies represented in Table 1 vary greatly in terms of their mandate (which determines their geographic

scope, their objective, the legally binding nature of decisions they adopt, and whether they regulate one or several activities) and often overlap in geographical area [25]. The overlapping jurisdictions and fragmented governance approaches among organizations make it difficult to measure the real environmental impact of the activities (e.g., fishing, shipping, mining) in a given high seas area, such as the CRTD [24].

This article will focus on the management tools within the purview of the IMO to regulate international shipping given the risk associated with this activity within the CRTD. The IMO is the United Nations (UN) specialized agency designated as “the global standard-setting authority for the safety, security, and environmental performance of international shipping. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented” [28]. The IMO has the authority to regulate shipping activity globally, including ABNJ [29].

3. Tools available to the IMO applicable to the CRTD

The IMO has the regulatory capacity to implement precautionary measures to decrease the negative effects of international shipping in the marine environment [30]. This section will analyze regulatory tools under the IMO that can help address or minimize the identified risks of shipping within the CRTD in the high seas area. These measures include Special Areas under the International Convention for the Prevention of Pollution from Ships 1973/1978 (MARPOL); ship routing and speed reduction measures; and Particularly Sensitive Sea Areas (PSSAs).

3.1. International Convention for the Prevention of Pollution from Ships, 1973/1978 (MARPOL)

MARPOL Special Areas address different types of pollution through six technical annexes which regulate pollution from oil (Annex I), noxious liquid substances in bulk (Annex II), harmful substances in packaged form (Annex III), sewage (Annex IV), garbage (Annex V), and air pollution (Annex VI), and includes the possibility to identify “Special Areas” to be protected from shipping pollution [3]. Special Areas can increase restrictions or prohibit the discharge of oil, sewage, or noxious liquid substances. Special areas are defined as “areas where for recognized technical reasons in relation to [their] oceanographic and ecological conditions and to the particular character of [their] traffic, the adoption of a higher level of protection than (in other areas of the sea) is necessary” [3].

Special areas can be established to protect “the maritime zones of

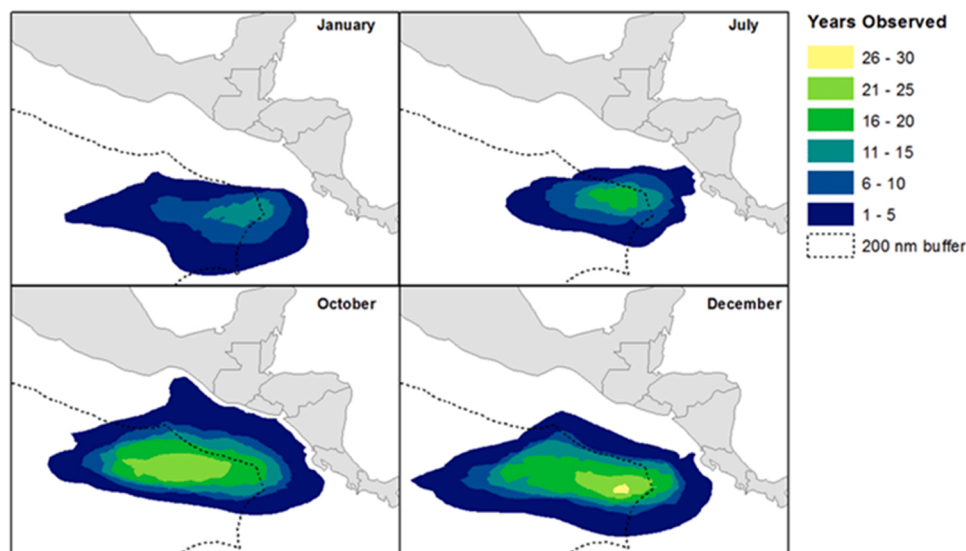


Fig. 3. Persistence of the Costa Rica Thermal Dome over the past three decades. The dotted line shows countries' Exclusive Economic Zone [2].

Table 1
Global organizations and instruments of relevance to global governance of ABNJ specific to the CRTD.

Sector	Name	Type	Area-Based Management Tools
General Ocean Governance	UN Convention on the Law of the Sea (UNCLOS)	Global Agreement	None
Shipping	International Maritime Organization (IMO)	Intergovernmental organization	1. MARPOL 'Special Areas'; and 2. Particularly Sensitive Sea Areas (PSSAs) and associated protective measures
Cable Laying International Cable Protection Committee (ICPC)	Cable Laying International Cable Protection Committee (ICPC)	Industry association	None
Marine Environmental Protection	Convention on Biological Diversity (CBD)	Global Agreement	No management mandate. However, it includes criteria for identifying Ecologically or Biologically Significant Marine Areas (EBSAs) which can help highlight the biological importance of a marine area.
	World Heritage Convention (WHC)	Global Agreement	World Heritage Sites, including natural properties and mixed sites, inscribed both as cultural and natural world heritage sites. The WHC does not have a mandate in ABNJ, however it is considering areas in ABNJ as potential World Heritage Site, but the mandate needs to be modified [27].
	Convention on International Trade in Endangered Species (CITES)	Global Agreement	None
	Convention on Migratory Species (CMS)	Global Agreement	The CMS guidance that relates to the development of instruments under the Convention is broad and permits the inclusion of area-based management tools
Fisheries Management	Regional Fisheries Management Organizations (RFMOs)	Country membership varies	Regional Fishery Bodies with a management mandate (called RFMOs) can adopt area-based management tools to avoid catching target species, non-target species or to avoid impact on sensitive habitats. The Inter-American Tropical Tuna Commission (IATTC) operates in the CRTD.

Source: Adapted from UNEP and WCMC [25].

several States, or even an entire enclosed or semi-enclosed sea area” [3]. Several Special Areas have been designated around the world to date. For example, the IMO designated the Wider Caribbean region including the Gulf of Mexico and the Caribbean Sea as a Special Area under MARPOL Annex V. Special Areas under MARPOL have also applied in the high seas, such as in the case of the Antarctic and the Mediterranean Sea (where coastal states have not claimed EEZs) [3].

Application to the CRTD: Considering that Special Areas under MARPOL have been implemented not only within countries’ jurisdictional waters but also in ABNJ, the designation of the CRTD as a Special Area could serve as an effective tool to protect it from shipping pollution [3]. However, Special Areas can only be designated if they meet all three conditions required by the “Guidelines for the Designation of Special Areas Under MARPOL” [3]. These conditions are: oceanographic conditions that favor the retention of harmful substances within the marine area in case of an eventual incident; ecological conditions related to presence of endangered species, critical habitats, fragile ecosystems, or areas of high productivity; and vessel traffic characteristics that render vulnerable the area to shipping discharges [3]. Further research may be needed to determine whether currents within the CRTD would cause the retention of harmful substances and their potential impact on the CRTD productivity. If so, a MARPOL Special Area might help address potential problems of operational discharges, sewage, or ballast water exchange in the CRTD.

3.2. Ship routing and speed reduction measures

Ship routing measures and speed reductions are used to reduce the risk of pollution or damage from shipping activity in environmentally sensitive areas [31]. Ship routing measures may include TSS, areas to be avoided (ATBAs), precautionary areas, and deep-water routes [32]. TSSs can be used to protect whales from ship collisions. For example, Panama implemented a TSS in the Gulf of Panama to reduce the risk of collision with humpback whales. The 65 nmi long TSS and a maximum speed of 10 knots during winter for vessels transiting the Gulf of Panama is expected to reduce whale-vessel collisions by 93 % [28].

A 10 knots speed limit to reduce whale-vessel collision is a common practice that has also been implemented in other latitudes. For example, the US has implemented measures such as 10 knots speed limits (or lower) to protect the North Atlantic right whales during migratory season along the US eastern coastline and applies to vessels 65 feet or greater. It is estimated that this vessel speed restriction measure has reduced ship-strike mortality risk by 80–90 % [33].

ATBAs have also been implemented as routing measures to protect marine life. For example, Costa Rica established an ATBA off its Pacific Coast to reduce the risk of humpback whale-vessel collision in this area. The ATBA applies to all ships 900 gross tonnage and upwards. In this specific region, there is also a TSS declared to direct marine traffic [34].

Application to the CRTD: While these tools have been implemented in jurisdictional waters, they are absent in high seas, even though they could be equally effective. The authors, therefore, consider relevant to assess their use in high sea areas of the CRTD. Considering the presence of humpback, blue, and gray whales within the CRTD, the establishment of ATBAs, TSSs, and speed reduction measures would represent an effective measure to reduce the risk of ship-whale collisions. Furthermore, these measures may help reduce noise pollution and pollution from operational discharges in the area. The speed reduction could help address ship strikes, noise pollution, greenhouse gas emissions, and other negative effects of maritime traffic in the CRTD area [35].

3.3. Particularly Sensitive Sea Area

According to the “Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas” (PSSA Guidelines), a PSSA is “an area that needs special protection through action by IMO because of its significance for recognized ecological, socio-economic, or

scientific attributes where such attributes may be vulnerable to damage by international shipping activities” [28]. For the identification and designation of a PSSA, the IMO will consider three main elements:

1. *the particular attributes of the proposed area,*
2. *the vulnerability of such an area to damage by international shipping activities, and*
3. *the availability of associated protective measures within the competence of IMO to prevent, reduce, or eliminate risks from these shipping activities* [28].

The significance of the area is based on its recognized ecological, socioeconomic, scientific, or educational attributes. The ecological attributes include criteria such as: critical habitat, productivity, or spawning and breeding grounds. The socio-economic criteria include human, social, or economic dependency and cultural heritage. The scientific and educational criteria refer to the area’s potential for research and education [28]. To demonstrate the significance of the proposed area as a PSSA, such an area needs to meet at least one of the established criteria [31].

Furthermore, to qualify for a PSSA designation, the attributes of the area should be at risk from international shipping activities. Risks associated with international shipping activity include “operational discharges; accidental or intentional pollution; and physical damage to marine habitats or organisms” [28]. Risks threatening the area can include operational factors, such as types of activities; types of vessels, substances carried by such a fleet and traffic’s characteristics (e.g., high traffic volume) [28]. Natural factors such as hydrographic and oceanographic characteristics can also be considered to assess the vulnerability of the area [28].

Associated Protective Measures (APMs) are measures that help address the risks from shipping and an essential element for the designation of PSSAs [31]. The sole designation of a PSSA does not provide protection to an area unless APMs are designed, approved, and implemented [28,31], and at least one APM must be specified for any PSSA proposal. PSSAs can include a variety of APMs that function under PSSA’s single administrative roof [31]. Therefore, protective measures should be implemented in a case-by-case modality according to the features of the area and the identified vulnerabilities [31]. APMs can be already existing IMO instruments, such as Special Areas under MARPOL, ship routing measures, or speed reductions. They can also be any measure that does not yet exist but could become available through amendment of an IMO instrument or by adopting a new IMO instrument [28,31].

To date, 17 PSSAs have been designated around the world including four in Latin America and the Caribbean: Malpelo Island in Colombia; Paracas National Reserve in Peru; The Galapagos Archipelago in Ecuador; and The Sabana-Camagüey Archipelago in Cuba [36]. All of them have been designated in jurisdictional waters and none in ABNJ.

Application to the Costa Rica Thermal Dome: The definition and criteria for the designation of PSSAs does not exclude their implementation in ABNJ [28–30]. According to the PSSA Guidelines, their criteria “can be used by IMO to designate PSSAs beyond the territorial sea with a view to the adoption of protective measures (...)” [28,31]. To be declared as a PSSA, the CRTD would need to meet only one of the required criteria for its designation, but more detailed studies on shipping traffic would have to be conducted. If declared as a PSSA, APMs can be designated to address the identified risks and new APMs could be added in the future according to identified needs [31]. Therefore, the designation of a PSSA and the implementation of APMs within the CRTD could help address possible negative impacts from international shipping in this area.

4. Analysis of IMO tools

The authors analyzed each of the tools described above against the

Table 2
Definitions and examples of criteria used to analyze IMO tools.

Criteria	Definition	Examples
Effectiveness	Refers to the ability of the tool to improve the environmental conditions of the CRTD by decreasing the negative impacts of the shipping activity.	High: Tool slows or stops the negative effects of international shipping and/or covers most of the identified negative effects from shipping. Low: Tool does not reduce or only minimally reduces the impacts from shipping in the CRTD.
Implementability	Analyzes the complexity of the implementation of each tool in terms of what is required to reduce or eliminate the risks from international shipping within the CRTD. Will consider technical feasibility, which refers to whether the infrastructure and technology to implement the tool exist or is available.	High: Tool does not require the involvement of many actors to achieve goals. Tool does not require the development of new technology or infrastructure to be achieved. Low: Complex tools that involve many actions or actors and/or the development of infrastructure or technology to achieve a goal.
Political viability	Refers to the level of acceptability the option may have among the main actors (e.g., IMO, shipping industry, Central American countries).	High: There are precedents of the application of the tool in a country or region. Low: There are no precedents. There is expected political opposition.

Table 3
Comparison of International Maritime Organization’s Tools.

	Option 1: Let present trends continue	Option 2: Special Area Under the MARPOL	Option 3: Ship Routing and Speed Reduction Measures	Option 4: Particularly Sensitive Sea Area (PSSA)
Effectiveness	Low	Low	Moderate	High
Implementability	High	Low	Moderate	Moderate
Political Viability	Moderate	Moderate	Low-Moderate	Low-Moderate

following criteria: effectiveness, implementability, and political viability to determine which is the most effective IMO tool to address the risks of international shipping in the CRTD. Definitions and examples of the criteria are described in Table 2.

The analysis of IMO tools against the criteria shown in Table 2 helps visualize the tool with the highest potential to address the impacts of international shipping in the CRTD (Table 3). Status quo is also presented as an option.

Under the first option “Let Present Trends Continue” (Status Quo) ships would continue to navigate the area without any special consideration or precautionary measures. Therefore, the Effectiveness of this option is low. The Implementability of this option is high since it would not require any action or the availability of technology from the countries, the IMO, or any actor involved in the process. The Political Viability of this option would be moderate since those countries and groups interested in addressing the impacts of shipping in the area would oppose the status quo.

Regarding the second option of “Special Area Under MARPOL,” the Effectiveness of this option is low. While this option can help reduce some sources of pollution from shipping, it does not address existing risks such as noise pollution or potential whale-vessel collisions. The Implementability of this option is low since Special Areas require adequate port reception facilities to enter into force, which may delay

the implementation of its measures if those facilities do not already exist. The CRTD would have to demonstrate that it meets all three aforementioned criteria required for the designation of a Special Area. Therefore, as an area in the open sea, it is necessary to conduct studies to demonstrate the CRTD meets the ecological criteria, which requires concentration or retention of harmful substances in its water or sediments in the area in case of discharges. Regarding Political Viability, the declaration of the Wider Caribbean Region as a Special Area under MARPOL sets a precedent for political acceptability of this option by Central American countries. However, groups like the shipping industry may oppose this option if port reception facilities are unavailable or inadequate. Additionally, this measure has not been implemented in the ABNJ. Therefore, Political Viability of this option is moderate.

The third option, “Ship Routing and Speed Reduction Measures” has the potential to address the identified impacts of shipping within the CRTD. Depending on the proposed measure, it can address threats such as noise pollution and whale-vessel impacts. However, this option by itself would not regulate other negative impacts such as those caused by pollution (e.g., discharges). Therefore, the Effectiveness of this option is moderate. Regarding the Implementability of this option, there is existing technology in place for vessel monitoring and tracking such as the Long-Range Identification and Tracking (LRIT) system and other systems [37]. However, not all of vessel tracking information is publicly available which makes the monitoring and enforcement challenging [38]. Therefore, the Implementability of this option is moderate. Regarding Political Viability, there are precedents of Ship Routing and Speed Reduction Measures in Central America, however, there are no precedents of the implementation of these measures in ABNJ. Ship routing measures may be opposed by the shipping industry depending on the proposed measure. For example, a considerable change in the route may increase ships’ fuel consumption and reductions in speed may increase ships’ travel time, both of which will not be perceived as favorable by the shipping industry [39]. However, a potential approval of the BBNJ Agreement discussed at the UN may raise the political viability of this option. Therefore, the Political Viability for this option is ranked as low to moderate.

The fourth option, “PSSA,” can help address multiple impacts of shipping in the CRTD. PSSAs will be as effective as their APMs and can include multiple APMs under their administrative roof according to the need for protection. APMs can be already existing IMO tools (e.g., routing measures, speed reduction, Special Areas, ATBAs); or, if the necessary tool to address a risk is not available under an existing IMO instrument, such tool can become available by adopting a new instrument or by amending the existing instrument [28,31]. The possibility of including multiple APMs makes the PSSA a well-rounded and effective tool to protect this marine space. Therefore, the effectiveness of this option ranks as high. The Implementability of this policy option will depend on the proposed APMs. The implementation of APMs such as speed reductions or ATBA may require technological instruments. Therefore, the Implementability of APMs under a PSSA is moderate. The Political Viability is low under present conditions. Currently, there is no precedence for PSSAs in ABNJ. However, countries can influence the implementation of measures in ABNJ such as APMs in the CRTD by opposing or supporting such measures [38]. The shipping industry will likely oppose the designation of the CRTD as a PSSA depending on the proposed APMs [39]. While the Political Viability is low, the upcoming approval of the BBNJ Agreement [40] may increase the political viability of a PSSA from low to moderate. It is apparent that the designation of the CRTD as a PSSA is the best option available to the IMO to address most of the possible threats from shipping. Furthermore, a PSSA will help raise awareness about the CRTD, its economic and ecological value, and the species that depend on this marine ecosystem. APMs should be those that best address the identified risks posed by maritime traffic that may affect the CRTD.

5. The Costa Rica Thermal Dome as a PSSA

Based on the result of the analysis of IMO tools in the previous section, here the authors analyze the CRTD’s potential to qualify as a PSSA and its challenges and opportunities. This section will study 1) the CRTD’s potential to meet the PSSA criteria based on its attributes; 2) vulnerability of the CRTD to international shipping; and 3) availability of APMs to address the risks from international shipping within the CRTD.

5.1. CRTD’s potential to meet PSSA criteria

The criteria for the designation of a PSSA are similar to the ecological criteria for the description of an EBSA [41]. An assessment of characteristics of the Papagayo Upwelling System (part of the CRTD) against CBD’s criteria for the description of an EBSA confirm the area’s uniqueness, importance as a critical habitat and breeding ground for endangered species, its vulnerability, and its biological productivity [9]. The fact that part of the CRTD met the criteria to be designated as an EBSA means that the CRTD may also have the potential to meet the criteria identified by the IMO for the designation of a PSSA [41]. For example, as previously mentioned, the CRTD serves as feeding and breeding grounds for blue whales and as a part of the migratory route for endangered sea turtles. This information can help demonstrate ecological criteria, such as critical habitats and spawning or breeding grounds. Furthermore, the CRTD as a biologically productive marine area, has the potential to serve as a hub for future marine research. A preliminary assessment of how the CRTD meets the criteria for the designation as a PSSA by the IMO is provided in Table 4.

5.2. Vulnerability of the CRTD area to international shipping

The CRTD is an area that combines high marine traffic and important migratory routes for species such as the blue, gray, and humpback whales, and leatherback sea turtles. Whales are particularly vulnerable within the CRTD due to the risk of colliding with vessels. Ship collisions with large whales, such as blue whales, have been documented farther north in Pacific [42]. One documented example includes the finding of four blue whale carcasses that were discovered off the California coast showed signs of injury that were clearly consistent with ship strikes, which triggered a “Unusual Mortality Event” under the US government

Table 4
Criteria for the designation of a Particularly Sensitive Sea Area (PSSA) and the potential of the Costa Rica Thermal Dome (CRTD) to meet these criteria.

PSSA Criteria Category	Criteria	Does CRTD have the potential to meet PSSA criteria?
Ecological Criteria	Uniqueness or rarity	Yes
	Critical habitat	Yes
	Dependency	Further Research Needed
	Representativeness	Yes
	Diversity	Yes
	Productivity	Yes
	Spawning or breeding grounds	Yes
	Naturalness	Further Research Needed
	Integrity	Further Research Needed
	Fragility	Further Research Needed
	Bio-geographic importance	Further Research Needed
Social, cultural, and economic criteria	Social or economic dependency	Yes
	Human dependency	Yes
	Cultural heritage	No
Scientific and educational criteria	Research	Yes
	Baseline for monitoring studies	Yes
	Education	Yes

[43]. In many cases, however, whale collisions with large vessels can go unnoticed and therefore unreported [44]. Because the CRTD is critical habitat for a population of blue whales, its presence amidst high maritime traffic represents a risk for this endangered whale species not only in terms of strikes but also underwater noise pollution and pollution from operational discharges [10]. Further research on whale-ship strikes, levels of underwater noise, and other sources of pollution from ships in the CRTD specifically needs to be conducted to assess the overall risks of shipping to marine life in this marine space [38].

Marine species are also vulnerable to noise and operational discharges from maritime traffic. Even though most studies have focused on the negative effects of noise on cetaceans, emerging studies indicate that noise pollution may be also negatively impacting other forms of marine life such as fish, birds, or turtles, which are present within the CRTD. Regarding the discharge of substances in the marine environment, a significant part of the total inputs of oil is caused by regular operational discharges, which negatively affects marine ecosystems. Discharged substances may have a negative impact when discharged in sensitive marine areas such as the CRTD [18]. Further studies will need to be conducted to determine the potential damage operational discharges may have in the CRTD based on variables such as type of substances discharged, the amount discharged, and the time of the year.

5.3. Availability of APMs applicable to the CRTD

A PSSA functions as a single administrative roof under which multiple APMs can be designated to protect an area [31]. Considering the characteristics of the CRTD, the most effective APMs in addressing the risks of ship strikes, underwater noise pollution, and other sources of shipping pollution in the CRTD are ship routing systems (e.g., ATBA, TSS) and speed reductions.

Ship Routing Measures can help reduce the risks of ship strikes or pollution from ships in sensitive areas. A TSS can be designed in the CRTD to maintain vessels at a safe distance from areas of high concentration of whales or environmentally sensitive areas [45]. Re-routing marine traffic can help reduce the risk of pollution (e.g., noise pollution) by directing the marine traffic away from areas of high concentrations of marine life.

An ATBA can be established as an APM to organize and redirect marine traffic to protect sensitive areas and should not prohibit vessels' access or transit through an area. ATBA are also an effective tool to protect endangered whale species and have proved effective even in cases when they were based on recommendatory actions [45]. ATBAs have been implemented in PSSAs, such as Papahānaumokuākea Marine National Monument in Hawaii, where they apply to all vessels over 300 gross tonnage or greater [46].

Likewise, ATBAs may be established in a specific or vulnerable section of the CRTD. Special Area under MARPOL may help address possible pollution occurring within the CRTD, if further research determines the CRTD meets all three required criteria for its designation.

To address the threats from shipping in a well-rounded manner, it is necessary to implement a combination of the described APMs. Noting the CRTD's seasonal presence of some species, APMs can be requested seasonally or in specific areas of the CRTD. For example, the presence of blue whales increases within the CRTD during winter (November-February) when a population migrates from the north to the west section of the CRTD to feed and breed [10]. Preliminary studies indicate that blue whales aggregate to the west of the CRTD's nucleus, in the high seas, but more data must be collected [1]. An ATBA could be in place in a section of the CRTD when and where the presence of blue whales increases. Speed reduction could be implemented permanently to reduce noise pollution that may affect those cetacean species present all year. More studies must be conducted to better understand exact location where APMs should be implemented. Further studies should also identify the nature and extent of shipping traffic, such as types of vessels, vessel speeds, and routing patterns using Automatic Identification

Systems and other remote sensing data.

Because a PSSA in the CRTD will require the implementation of APMs in ABNJ, there would be no clear entity responsible for its implementation and enforcement [31,38]. According to Kachel [31], interested States could "negotiate a cooperation agreement aimed at setting up an administering body to govern the PSSA. Subsequently, this body would need to seek consensual appointment by IMO member states to manage the area". The establishment of a regional body to govern a PSSA in ABNJ does not imply an extension of these States' sovereignty, but a protective role in which States would advocate to reduce harmful impacts of shipping in the marine environment while maintaining the freedom of the high seas [47].

6. Conclusion

The CRTD is a dynamic upwelling system which serves as an important habitat for marine species. The CRTD is also socio-economically important for Central American countries that depend on its resources for tourism activities, sport and commercial fishing, and educational programs. The CRTD's location in the high seas and its seasonal influence of Central American countries' jurisdictional waters represents a governance challenge. Under the present governance options, regulations need to be implemented on a sector-by-sector basis.

Because of the CRTD's proximity to the Panama Canal, maritime traffic represents an immediate risk to this marine ecosystem and to the species that depend on it. The IMO has the authority to regulate the shipping sector and implement precautionary measures to address the threats by the international shipping activity in ABNJ and in the adjacent jurisdictional waters of the Central American countries. The definition and criteria for the designation of PSSAs does not exclude their implementation in ABNJ, which helps build the case for the implementation of this tool in the CRTD. Establishing a PSSA represents a well-rounded option to address the identified shipping threats in the CRTD. PSSAs work as an "umbrella" designation under which various APMs can be included and, therefore, represent an opportunity to address various risks from international shipping in a marine area. Potential APMs for the CRTD include Ship Routing and Speed Reductions, ATBAs, or other APMs under the PSSA's administrative roof.

This analysis showed that the CRTD has potential to meet the criteria for the designation of a PSSA. Future research should address the intensity of the shipping activity in this area, identifying ships' country of origin and destination, flag States, type of material being carried, and size, and whether the implementation of APMs would impact the shipping industry. Consultations with relevant stakeholders will shed light on which APMs would provide the best protection of the CRTD and result in the lowest impact on the shipping industry and Central American countries' port activities.

CRedit authorship contribution statement

Richard Castillo Rodríguez: Conceptualization; Data curation; Formal analysis; Methodology; Project administration; Writing- original draft, review, editing; **Jorge Jiménez:** Conceptualization; Resources; Validation; Writing – review and editing; **Katherine Arroyo Arce:** Resources; Validation; Writing- review & editing; **Katie R. Thompson:** Investigation; Validation; Visualization; Writing- review and editing.

Declarations of Competing Interest

None.

Data availability

Data will be made available on request.

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