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The role of geographical and legal features in optimizing security and control of semi-enclosed seas: A case study of the eastern Adriatic Sea

Uloga geografskih i pravnih obilježja poluzatvorenih mora u optimizaciji sigurnosti i nadzora: studija slučaja istočnog Jadranskog mora

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Written by:

Tomislav Sunko¹ <https://orcid.org/0000-0002-9287-5642>**Mihael Dedo²** <https://orcid.org/0000-0002-5968-3171>**Ružica Popović³** <https://orcid.org/0009-0004-5989-8676>**Toni Mišković⁴** <https://orcid.org/0000-0002-5032-034X>**Marin Delić⁵** <https://orcid.org/0009-0009-9575-270X>**Lovro Strnad⁶** <https://orcid.org/0009-0005-0478-875X>

Abstract

Semi-enclosed seas are geographic areas specifically defined by their general geometry. Geographical characteristics heavily influence the possibilities and challenges of surveillance, security and navigation of semi-enclosed seas. This paper analyses specifications and typical challenges that occur within the semi-enclosed seas, firstly by defining them and secondly by comparing different challenges that occur within different geographical areas. The causality of typical challenges is then correlated to geomorphological, geopolitical and

Sažetak

Poluzatvorena mora su geografska područja posebno definirana svojom općom geometrijom. Geografske značajke snažno utječu na mogućnosti i izazove nadzora, sigurnosti i navigacije u poluzatvorenim morima. Ovaj rad analizira specifičnosti i tipične izazove koji se javljaju u poluzatvorenim morima, prvenstveno njihovom definicijom, a zatim usporedbom različitih izazova koji nastaju u različitim poluzatvorenim morima. Uzroci tipičnih izazova potom se povezuju s geomorfološkim, geopolitičkim i hidrometeorološkim svojstvima poluzatvorenih

¹ PhD., Asst. Prof., Ministry of Defence of the Republic of Croatia, Croatian Defense Academy "Dr Franjo Tuđman", Zagreb, Croatia. Email: tsunko@morh.hr

² University Magister of Engineering in Naval/Maritime Traffic, Ministry of Defence of the Republic of Croatia, Croatian Defense Academy "Dr Franjo Tuđman", Zagreb, Croatia. Email: mihael.dedo@morh.hr

³ PhD., Croatian Meteorological and Hydrological Service, Regional Meteorological Office Split, Split, Croatia. Email: r.popovicstzg@gmail.com

⁴ Master of Engineering in Electrical Engineering, Transmitters and Communications Ltd., Zagreb, Croatia. Email: toni.miskovic@oiv.hr

⁵ Bachelor of Engineering in Nautical Studies / Nautical Science, Split Ship Management, Split, Croatia. Email: deliae_0212@hotmail.com

⁶ Student, Rectory, Dr. Franjo Tuđman Defense and Security University, Zagreb, Croatia. Email: lovro.strnad@student.sois-ft.hr



hydrometeorological properties of semi-enclosed seas. Heavy focus is on the problematics arising on the eastern coast of Adriatic. These are further compared to the general properties of challenges occurring in the semi-enclosed seas analysed by comparison of different regions, resulting in not only a correlation between semi-enclosed sea properties, but also a clear systematizations and categorization of those problems which will enable further research on combating them.

Keywords: Semi-enclosed sea, security, surveillance, Adriatic.

mora. Poseban naglasak stavljen je na problematiku koja nastaje na istočnoj obali Jadrana. Ona se dalje uspoređuje s općim obilježjima izazova prisutnih u poluzatvorenim morima analiziranim usporednim prikazom različitih regija, što rezultira ne samo utvrđivanjem povezanosti između svojstava poluzatvorenih mora i samih problema, već i jasnom sistemizacijom i kategorizacijom tih problema koja će omogućiti daljnja istraživanja u svrhu prevladavanja istih.

Ključne riječi: Poluzatvoreno more, sigurnost, nadzor, Jadran.

Introduction

The precondition for achieving a higher level of maritime security for coastal states with access to semi-enclosed seas is the effective implementation of sea control and protection to reduce threats and risks at sea. The analysis of the maritime situation is defined as a process, an examination of the situation, its elements and their relationships. Early detection and neutralization of threats posed by vessels is one of the key tasks of coastal state services in the context of control and protection of maritime traffic, as well as critical infrastructure.

For the purpose of maritime security, control and protection systems are organized depending on: the sea surface area, geostrategic position, and meteorological-oceanographic conditions of the coast and islands. Given the demanding task of maritime traffic surveillance and control of the state border at sea, the spatial features of semi-enclosed seas have been defined and analysed with the goal of improving the effectiveness of existing management models and future deployment of resources by state administration bodies.

First section of this paper provides a detailed analysis of the features and properties of semi-enclosed seas, with focus on Adriatic. Furthermore, analytical comparison of different challenges of various semi-enclosed seas worldwide helps to correlate specific challenges to specific properties and provide a systematic overview linking typical causes to typical problems.

Second section analyses how the nature of semi-enclosed seas influences navigation and surveillance on the Adriatic. Moreover, an analysis of the common problems of eastern Adriatic is compared and categorized within the systematic framework that was presented in the first section, further strengthening the systematic framework as well as providing additional information and findings that might in future help to find easier ways to combat said challenges. All abbreviations used in the preparation of this paper are listed in the nomenclature table.

Table 1.
Nomenclature

RC Republic of Croatia	NtM Notices to Mariners
SAB State Administration Bodies	VHF Very High Frequency
RI Republic of Italy	MF Medium Frequency
RG Republic of Greece	DSC Digital Selective Calling
IW Internal Waters	NAVTEX NAVigational TElex
TS Territorial Sea	INMARSAT International Maritime Satellite Organization
EEZ Exclusive Economic Zone	CRS Coastal Radio Stations
CS Continental Shelf	IMO International Maritime Organization
UNCLOS United Nations Convention on the Law of the Sea	

Methodology

This paper adopts a qualitative and comparative case-study approach to examine the challenges of maritime surveillance along the eastern Adriatic coast. The methodological choice stems from the recognition that surveillance difficulties on eastern Adriatic arise not from a single variable but from the interplay of

geomorphology, hydrometeorology, legal frameworks, and institutional structures. Rather than seeking quantifiable performance measures of technical systems, the study employs interpretive analysis to identify recurring patterns and categories of constraints.

The primary unit of analysis is the eastern Adriatic, understood as a part of a semi-enclosed sea system under the definition of the UNCLOS. Within this framework, the paper investigates both the legal-institutional context (border disputes, maritime spatial planning, institutional fragmentation) and the technical-environmental context (impacts of geomorphology and hydrometeorology on surveillance).

A comparative method is applied by situating Croatia's challenges within the broader category of semi-enclosed and indented seas. Comparative references include the Baltic, the Aegean, and selected chokepoints such as the Strait of Hormuz and Bab el-Mandeb. These examples are not used to provide exhaustive regional surveys, but to highlight the structural similarities that arise when semi-enclosed geography and fragmented governance intersect.

Finally, the limitations of the methodology must be acknowledged. The analysis is based on open-source academic and legal material; classified technical or operational naval data are not included. The findings therefore remain conceptual and structural in nature, oriented toward understanding patterns rather than evaluating the performance of specific systems.

Literature review

The materials for this study consist of legal documents, academic literature, and applied case studies.

At the international level, UNCLOS provides the legal definition of semi-enclosed seas, as well as principles relevant to cooperation and surveillance. European Union frameworks on maritime spatial planning further inform the legal-institutional context, establishing requirements for coherence and integration across member states.

At the national level, Croatian legislation and policy documents relating to maritime spatial planning, concessions, and jurisdiction form a crucial material basis. Scholarly work has emphasized the persistence of institutional fragmentation and the underdevelopment of GIS infrastructure in eastern Adriatic maritime governance. While regional GIS applications exist, the absence of a comprehensive national framework reduces integration and limits cross-sectoral coordination.

The geomorphological features of the Adriatic are a further focus of the literature. The eastern Adriatic is characterized by its highly indented coast and large number of islands and islets, creating permanent challenges for surveillance and monitoring. This geomorphology complicates not only technical coverage but also legal clarity, as shown in dispute over Piran Bay, which underscores how natural coastal configurations intersect with questions of sovereignty.

The hydrometeorological literature provides critical insights into the Bora and Sirocco winds, which directly affect maritime operations. The Bora, a cold and gusty wind from the northeast, introduces instability and operational risk, while the Sirocco, a moist southeasterly wind linked to cyclonic activity, produces reduced visibility and hazardous sea states. Both winds have been shown to degrade the reliability of radar and optical surveillance, introducing environmental uncertainty into an already complex geomorphological setting.

Comparative material includes research on other semi-enclosed and indented seas. The Baltic and Aegean Seas illustrate how geographic constraints and overlapping jurisdictions complicate surveillance, while the Strait of Hormuz exemplifies a chokepoint where geomorphology and geopolitics converge. These cases are used as analytical mirrors to situate the Adriatic, underscoring both the commonalities and the distinctiveness of Croatia's maritime challenges.

Together, these materials constitute a layered foundation for the analysis. Legal sources define the framework of governance, technical and environmental studies reveal the natural constraints, Adriatic-focused literature provides regional specificity, and comparative cases situate the Croatian experience within a wider category of maritime surveillance environments.

The concept and features of semi-enclosed seas

According to the United Nations Convention on the Law of the Sea, "...a closed or semi-enclosed sea means a gulf, basin or sea surrounded by two or more States and connected to another sea or ocean by a narrow outlet or consisting wholly or primarily of the territorial seas and exclusive economic zones of two or more coastal States." (UNCLOS, 1982).

Coastal states bordering a closed or semi-enclosed sea should cooperate with each other in exercising their rights and fulfilling their duties under the Convention. To this end, they endeavor, directly or through an appropriate regional organization:

- To coordinate the management, conservation, exploration, and exploitation of the living resources of the sea;
- To coordinate the exercise of their rights and the fulfilment of their duties with respect to the protection and preservation of the marine environment;
- To coordinate their scientific research policies and, where appropriate,
- To undertake joint programs of scientific research in that area.

Spatial features of semi-enclosed seas

A characteristic of semi-enclosed seas is limited communication with adjacent seas or oceans, in contrast to "semi-open seas" such as the North Sea or the China Sea or "open seas" with long undefined boundaries with the ocean, like the Andaman Sea.

As a result of the development, expansion and definition of international law of the sea, the specific characteristics of individual marine areas, the seabed and subsoil, and even the coast are increasingly taken into account when formulating new rules for the spatial features of semi-enclosed seas. The spatial features of selected semi-enclosed seas around the world are presented in Table 2.

Table 2.
Spatial features of selected semi-enclosed seas in the world

Ocean	Name of the sea	Continent	Area (km ²)	Volume (km ³)	Connection to oceans/seas	Countries with Sea Access
Pacific Ocean	1. Yellow Sea	Asia	380,000	17,000	East China Sea	3
	2. Sea of Japan		978,000	1.360,4000	Pacific Ocean	4
	3. Sea of Okhotsk		1.538,000	1.280,100	Pacific Ocean	2
	4. Gulf of California (Sea of Cortes)	North America	160,000	131,900	Pacific Ocean	2
Atlantic Ocean	5. Gulf of Mexico		1.550,000	2.332,000	Atlantic Ocean	3
	6. Gulf of St. Lawrence		155,000	30,200	Atlantic Ocean	2
	7. Hudson Bay	Europe	819,000	157,700	Labrador Sea	2
	8. Baltic Sea		386,000	21,700	Northern Sea	9
	9. Mediterranean Sea		2.501,5000	3.842,200	Atlantic Ocean	21
	10. Black Sea		422,000	547,000	Mediterranean Sea	7
Indian Ocean	11. Adriatic Sea	Africa	131,000	330,000	Mediterranean Sea	8
	12. Red Sea		450,000	215,600	Indian Ocean Mediterranean Sea	8
	13. Persian Gulf	Asia	241,000	6,000	Arabian Sea	7

Source: By the authors according to (Britannica, 2023; Lowe, 1990; Leppäkoski et al., 2009; Mikulski, 1981; Oguz, & Su, 2004; Sunko, 2024)

Semi-enclosed, marginal seas and the continental shelf can be classified in terms of their morphological structure into three different groups:

- Almost enclosed basins with very limited exchange with the open oceans (Baltic Sea, Mediterranean Sea, Black Sea, Red Sea, Arabian Gulf, Bohai Sea, Okhotsk Sea, Sea of Japan - East Sea),
- Partially enclosed basins with moderate interactions with the open oceans along one or two of their boundaries (North Sea, Yellow Sea, East China Sea, South China Sea) and
- Marginal seas that extend along continental margins and have strong interactions with the open oceans along two or three of their boundaries (northern marginal seas of the Indian Ocean, seas of outer Southeast Asia, marine areas around Australia and New Zealand) (Oguz & Su, 2004). The geographical locations of the world's semi-enclosed seas are shown in Figure 1.

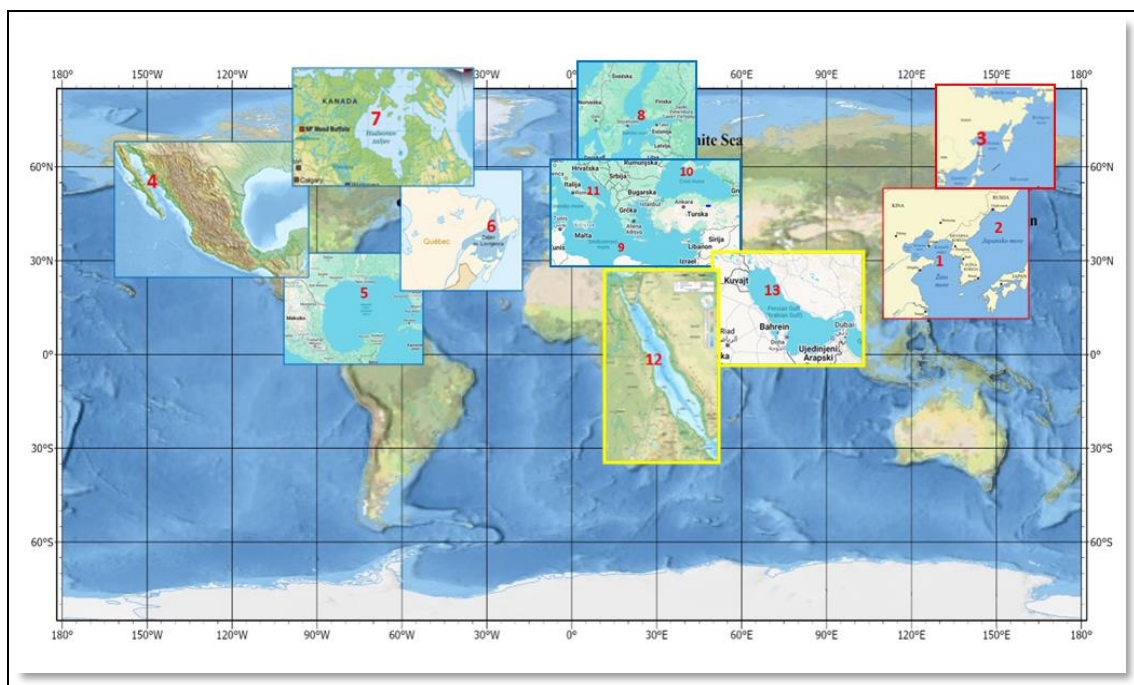


Figure 1. Geographical location of the world's semi-enclosed seas.

Source: By the authors according to (Britannica, 2023; Lowe, 1990; Leppäkoski et al., 2009; Mikulski, 1981; Oguz, & Su, 2004; Sunko, 2024)

According to Leppäkoski et al., (2009) semi-enclosed seas, due to their physical enclosure by landmasses and the strong influence of freshwater, tend to have lower salinity. For this reason, semi-enclosed seas are sometimes referred to as “brackish water islands”. The emphasis in the remainder of this work is on the eastern part of the Adriatic Sea.

Geographical features of the eastern part of the Adriatic Sea

The Adriatic Sea is a vast and elongated gulf in the eastern part of the Mediterranean Sea, bordered by the Apennine, Alpine, Dinaric, and Hellenic mountain ranges. It is located in the subtropical semi-arid zone of the southern part of the Northern Hemisphere and represents the northernmost indented part of the Mediterranean Sea into the European mainland and reaching up to $\varphi = 45^{\circ}47' N$ (Leppäkoski et al., 2009). It stretches in a northwest-southeast direction (parallel to the orientation of the land relief and islands, between longitudes $\lambda = 12^{\circ}15' E$ and $\lambda = 19^{\circ}45' E$ and latitudes $\varphi = 39^{\circ}45' N$ and $45^{\circ}45' N$) (Jardas et al., 2008; Croatian Hydrographic Institute, 2012). The southernmost point of the Adriatic is located at geographical coordinates: $40^{\circ}07' N$ and $\lambda = 18^{\circ}31' E$ in the Strait of Otranto, and the northernmost at $45^{\circ}47' N$ and $\lambda = 13^{\circ}35' E$ near Derina, the RI (Jardas et al., 2008). Entry and exit into the Adriatic Sea begins and ends in the Strait of Otranto, the southern boundary of the Adriatic Sea. According to the International Hydrographic Organization - IHO, the boundary between the Adriatic and Ionian Seas is the line connecting the Butrintit River (southern coast of Albania, $\varphi = 39^{\circ}44' N$), Cape Karagol (island of Corfu, $\varphi = 39^{\circ}45' N$), via Cape Kefali (Corfu) to Cape Santa Maria di Leuca (Vrdoljak et al., 2021). The Strait of Otranto in its narrowest part is 75 km wide (41 nautical miles), with a maximum depth of 741 m (Riđanović & Bičanić, 1993; Žabica, 1993). The greatest length of the Adriatic Sea along its longitudinal axis in the northwest-southeast direction, measured from the Marano Lagoon (Porto di Lido, Venice) in the

north to the mouth of the Butrintit River in the south, is 870 km or 470 M. The width of the Adriatic Sea along its transverse axis, measured from east to west, from the port of Omiš to the port of Vasto (RI) is 117 M (216.7 km). The average mean width of the Adriatic Sea is 86 M (159.3 km). The deepest point of measured depth in the Adriatic was measured in the southern part on the Fasano - Budva cross-section, in the South Adriatic Basin, and it measures 1,233 m. The average depth in the Adriatic Sea is 252 m (Vokić Žužul & Filipović, 2015). In Figure 2, the bathymetric division of the Adriatic Sea is visible.

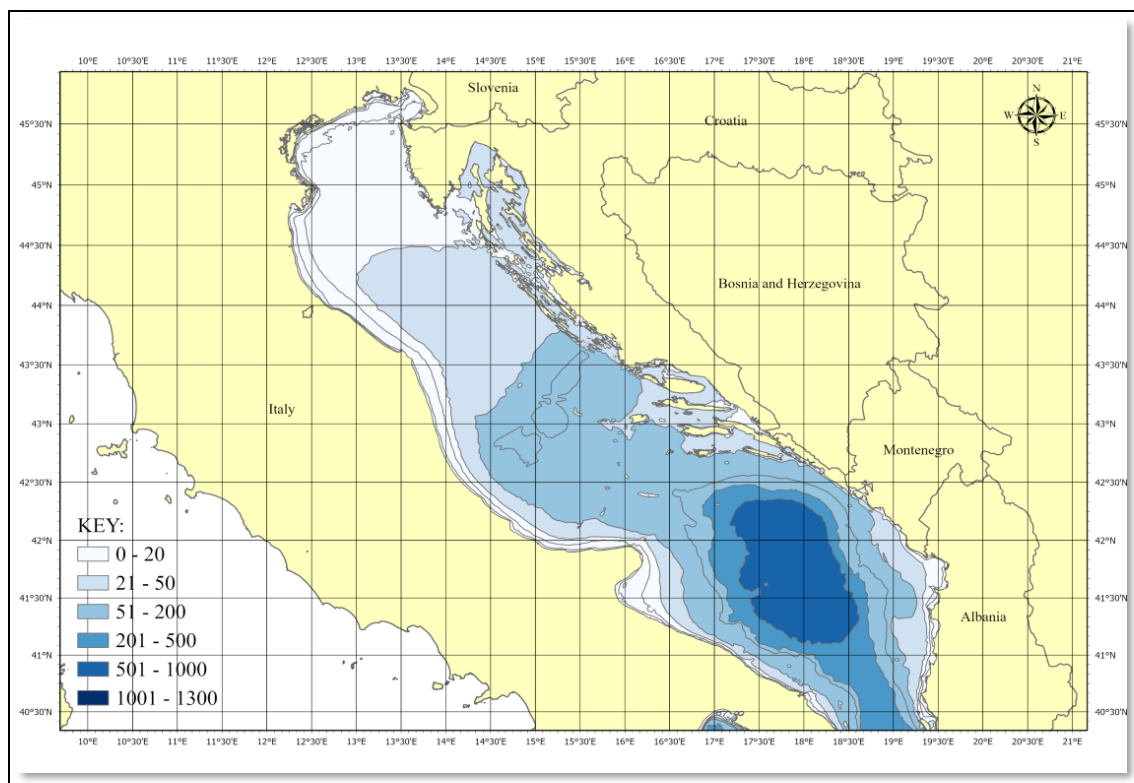


Figure 2. Bathymetric division of the Adriatic Sea.

Source: By the authors according to (Sunko, 2024; Vrdoljak et al., 2021)

Bathymetric analysis, including depth statistics, area and volume calculation, proves that the Adriatic is a shallow sea with an average depth of 253 m, with over 50 % of its surface shallower than 100 m. The Adriatic Sea can be considered according to its bathymetric and geographical divisions.

According to bathymetry, the Adriatic Sea is divided into three sub-basins:

- The Northern (extends to the line connecting the cities of Ancona and Zadar),
- The Central (extends between the Ancona - Zadar line and the line connecting Cape Gargano - Mljet Island - Pelješac Peninsula) and
- The Southern sub-basin (extends from the boundary line of the Palagruža Sill to the southern boundary of the Adriatic in the Strait of Otranto) (Vrdoljak et al., 2021).

Geographically, the Adriatic Sea is divided into three units:

- The Northern region includes the shallow northern Adriatic and extends to the line connecting Ancona and Karlobag,
- The Central Adriatic extends between the Ancona-Karlobag line and the line connecting Cape Gargano, Palagruža, Lastovo, Makarska, and Ploče,
- The Southern Adriatic extends from the Palagruža Sill to the Adriatic boundary at the Strait of Otranto (Marelić, 2016).

The Southern Adriatic, due to the open sea around the islands of Vis and Lastovo and around smaller islands (Palagruža, Svetac, and Jabuka), represents TS, which occupies the largest share of the total area of RC.

The western coast of the Adriatic Sea encompasses RI, and the eastern coast of the Adriatic Sea encompasses RC, Slovenia, Bosnia and Herzegovina, Montenegro, and Albania (Vokić Žužul & Filipović, 2015).

Hydrometeorological features of the Adriatic Sea

The Adriatic Sea is a moderately warm sea. In the Croatian part of the Adriatic, winds of great frequency are Bora (bura), Sirocco (jugo), and Mistral (maestral). The highest wind speed measured on the territory of the RC was recorded in December 1998 on the Maslenica Bridge when a Bora gust reached 248 km/h (69.0 m/s) (Croatian Hydrographic Institute, 2012; Volarić & Nikolić, 2014). The Northern Adriatic is an area with a very high frequency of Bora winds, while Sirocco is less represented. Generally, the intensity of the Bora decreases from the northern to the southern Adriatic, while the intensity of the Sirocco increases from the south to the north of the Adriatic, given that the windward direction coincides with the direction of the Adriatic Sea (SE). In March 1974, the strongest Sirocco gust of 205 km/h (56.9 m/s) was measured on Palagruža. Sirocco and Bora blow with the greatest intensity, with Sirocco developing higher waves than Bora. Mistral blows at a moderate strength and does not create waves dangerous for navigation, and usually blows from the western quadrant (WNW to NW direction), depending on the orography. In the winter period, Bora (NNE to ENE direction), due to its gustiness, represents an extremely dangerous wind for navigation, especially in the Velebit Channel area. Sirocco (ESE to SSE direction) blows with less intensity, but creates larger waves, given that the direction of Sirocco coincides with the direction of the Adriatic, thus creating enough windward area for waves to achieve full development. Until now, the highest wave in the Adriatic was officially confirmed at 10.8 m, measured in February 1986 on the PANON platform on the open sea of the northern Adriatic, also during a stormy Sirocco. However, the latest data indicate that the Croatian Hydrographic Institute measured a new maximum wave height on November 12, 2019, at 16:00. This wave was recorded in the waters of the city of Dubrovnik near the islet of Sv. Andrija. The maximum wave height was $H_{max} = 10.87$ m with a corresponding significant wave height $H_s = 4.75$ m. On the eastern coast of the Adriatic, fog most frequently occurs on the western coast of Istria, on average 8 days a year, while in the rest of the Adriatic, the occurrence of fog is much lower. The average speed of sea currents is around 0.5 knots. In Table 3 the maximum wind gusts [speed (m/s), direction and missing monthly data, for 2024 from 11 automatic meteorological stations along the eastern coast of the Adriatic are presented.

Table 3.
Maximum wind gusts for 2024 from maritime meteorological stations

MAXIMUM WIND GUSTS (m/s)													
mjesec	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	god
Poreč	33,4	26,3	26,5	32,5	22,4	23,5	23,7	22,0	25,8	-	-	33,6	33,6
	E	SE	SE	NE	ENE	ENE	NW	NNW	NNE	-	-	ENE	ENE
			2						2	744	720		1466
Rijeka	21,6	21,7	17,0	19,1	13,7	21,6	19,4	17,2	17,0	-	-	26,7	26,7
	NNE	SSE	E	ENE	WSW	NNE	NE	NNW	E	-	-	NNE	NNE
										744	720		1464
Senj	35,6	23,4	20,0	18,6	23,5	27,0	24,2	26,5	29,2	32,0	33,6	29,3	35,6
	NNE	E	NE	NE	NE	ENE	E	NE	NNE	NE	E	NNE	NNE
			418	588			19					3	1028
Mali Lošinj	17,8	-	22,3	21,2	20,	16,2	17,7	25,8	25,3	-	-	33,5	33,5
	NE	-	SSE	SSE	SW	SE	NW	NNW	W	-	-	NE	NE
		696					250			744	720		2410
Maslenički most	32,1	26,6	23,4	20,6	24,0	18,1	29,2	18,3	29,2	34,1	-	-	34,1
	NNW	NNE	N	E	WNW	N	NW	ESE	NW	N	-	-	N
			4				167	30		113	720	744	341
Zadar	16,9	25,5	20,6	23,0	19,4	15,2	18,3	25,3	17,6	19,1	20,1	24,2	25,5
	ESE	SE	SE	S	ESE	ESE	SSE	SW	W	SSE	SSE	NE	SE
		2	28		1	2			165	58			256
Split	27,6	24,8	30,1	31,8	24,2	18,6	19,0	16,6	23,8	17,8	24,7	29,1	31,8
	ENE	SE	SE	SE	SE	SW	NW	WSW	NE	SW	SSE	ENE	SE
					3	8		11	5	24		37	78
Hvar	22,0	-	25,5	27,1	20,4	15,5	15,8	13,3	19,6	21,3	22,5	22,9	27,1
	NE	-	ESE	ESE	ESE	ESE	ENE	NE	SW	SE	SSE	NE	ESE
		696				3		11		1			711
Vis	27,0	-	-	26,8	26,4	19,1	21,5	28,3	22,2	26,8	-	30,6	30,6
	SE	-	-	ESE	ESE	NW	NW	NNW	WNW	ESE	-	ESE	ESE
	34	696	744	99	38	89	17	156	163	11		40	1440
Palagruža	25,7	-	29,8	20,5	21,9	15,9	26,5	20,4	11,0	-	-	-	29,8
	SE	-	WNW	S	SSE	SSE	NW	SW	NNW	-	-	-	WNW
	88	696				396			660	744	720	744	4058
Dubrovnik	29,4	26,8	26,0	22,3	20,8	18,5	25,3	21,3	24,7	25,9	25,1	29,7	29,7
	NNE	SSE	SE	SE	NE	SE	WNW	SSE	SE	ESE	NNE	NNE	NNE
						3							3

Source: By the authors according to (Državni hidrometeorološki zavod, 2024)

As can be seen from Table 3., automatic measurement of wind speed is not the most reliable way, given the number of missing data.

Relationship of semi-enclosed sea features to maritime surveillance and security

Geomorphological features of the coastline, position of the surrounding states and the indentation scale of the coastline heavily influence national and regional surveillance and security policies in both legal and technical sense (Fuglesang Rye, 2021; Hayton, 2014; Do, 2024; International Crisis Group, 2025; International Maritime Bureau, 2019; Nyman et al., 2010; Pugh, 1994; Scovazzi, 2024; van Dyke, 2005). To establish a link between geomorphology of semi-enclosed seas and the problematic of surveillance and security, real life examples of various regional legal and technical challenges across the world are examined, analysed and taken into account. Problems, as well as characteristics of said problems are analysed in the following regions of the world that could be classified as semi-enclosed seas or indented areas: Nordic Fjords (Fuglesang Rye, 2021), South China Sea (Hayton, 2014), Pacific island states (Do, 2024) and Philippines (International Maritime Bureau, 2019), although not directly classified as semi-enclosed maritime area, do poses similar problems for similar reasons, Strait of Hormuz and the Persian Gulf (International Crisis Group, 2025), Baltic Sea (Nyman et al., 2010), Mediterranean (Scovazzi, 2024) and the Aegean Sea (van Dyke, 2005). Nature of said problems are thereby classified into legal or technical category (or both), main problem is listed and the cause of the problem is assessed. The summation of analysed problems yields a concrete link between the nature of semi-enclosed seas and the challenges that arise organically due to it.

Table 4.
Comparison of problems concerning semi-enclosed and indented seas by region

Region	Problem	Problem category (legal/technical/both)	Cause of the problem
Nordic fjords	Radar surveillance diminished	Technical	Complex geomorphology (complex terrain), hydrometeorological nuisances
South China Sea	Border disputes, grey zone tactics	Legal	Complex geomorphology, lack of cooperation
Pacific island states	Maritime crime and grey zones (lack of surveillance)	Technical	Complex geomorphology, lack of cooperation
Persian Gulf	General maritime security, asymmetric attacks	Both	Geomorphology (chokepoint, high traffic), regional instability
Philippines	Increased piracy due to AIS and radar gaps and blind spots	Technical	Complex geomorphology (multitude of islands)
Baltic Sea	Surveillance betterment needed, high risk of collisions to both human life and environment	Technical	Complex geomorphology
Mediterranean Sea	Lack of protection for underwater heritage sites, problem of navigation in environmentally sensitive areas	Legal	Lack of cooperative framework
Aegean Sea	Border disputes, traffic surveillance rights and right of passage questioned by contesting states	Legal	Complex geomorphology, lack of cooperation

Source: By the authors according to (Fuglesang Rye, 2021; Hayton, 2014; Do, 2024; International Crisis Group, 2025; International Maritime Bureau, 2019; Nyman et al., 2010; Scovazzi, 2024; van Dyke, 2005)

As visible in Table 4, all problems fall under either legal or technical category. Majority of them are due to complex geomorphology, i.e. steep and uneven terrain, fractal like nature of fjords, multitude of islands with multitude of blind spots present; hydrometeorological circumstances, such as frequent storms or high winds that disrupt the reflection pathway of electromagnetic radar waves and, as such, cause distortions in radar image; and regional instability due to border disputes, ongoing geopolitical tensions and conflicts as well as differing interests, made even more complex by the number of contesting entities on a limited natural resource base (hence, a term “chokepoint” is etymologically linked with overcrowding), intertwined with hardship presented by the sheer number of islands and similar features present especially in an indented coastal areas. The number of entities tasked with collective governance of a relatively narrow geographical area also induces challenges with respect to regional cooperation. To summarize, all semi-enclosed seas and indented or indented-like coastlines and areas share similar problems with surveillance and security that can be either legal or technical, and caused by either lack of cooperation, complex geomorphology or hydrometeorological circumstances, or combinations of said. To further simplify the systematization of challenges for semi-enclosed seas, a diagram is provided in Figure 3.

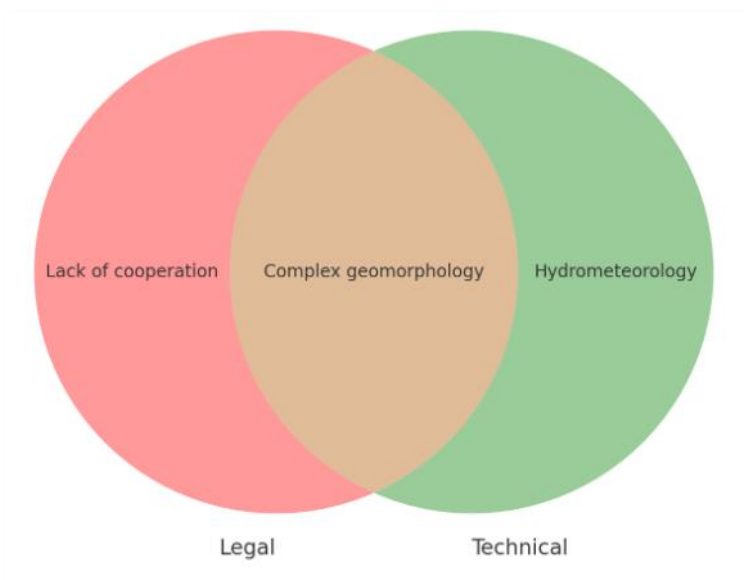


Figure 3. Systematic view of the challenges of maritime security and surveillance of semi-enclosed seas with regards to the challenge category and cause.
Source: By the authors

Results and discussion

The Adriatic Sea exhibits two distinctly different coastlines: a poorly indented and almost islandless western coast and a highly indented eastern coast with numerous islands. The total length of the Adriatic coastline is 8,282 km. The RC has the longest land coastline in the Adriatic Sea (48 % of the total land coastline of the entire Adriatic). The land coastline is 1,880 km long (29.9 % of the total land coastline of the RC). The length of the island coastline can be divided into: coastline of islands (3,573 km), coastline of islets (717 km) and coastline of reefs and rocks (107 km).

The total length of the coastline belonging to all islands, islets, reefs and rocks in the eastern Adriatic Sea in the RC is 4,398 km (70.1 % of the total island coastline of the RC; 97.2 % of the total length of island coastlines in the entire Adriatic). The total length of the Adriatic Sea coastline of RC is 6,278 km (75.8 % of the total length of the coastline of states in the Adriatic Sea). In terms of coastline length, the RC is the third country in the Mediterranean, after the RG and the Republic of Italy. The total marine area of the Adriatic Sea is 138,595 km² (accounting for 5.5 % of the total area of the Mediterranean Sea including island areas, and excluding the islands, the area is 135,418 km²) (Jardas et al., 2008). The marine area of the Adriatic Sea of the RC is divided into: the area of internal waters (12,498 km²), territorial sea (18,981 km²) and exclusive economic zone (23,870 km²).

The Adriatic Sea has a volume of 34,836 km³. The external boundary of the TS also represents the RC's maritime border. The total area of all islands, islets, reefs and rocks in the RC's Adriatic Sea is 3,259 km². The RC has 1,246 islands, islets, reefs, and rocks, including 79 islands, 525 islets, and 642 reefs and rocks. Cres Island has the largest area (405.70 km²), while Smokvica Vela (Kornati) has the smallest (1.04 km²). The islet Badija has the largest area (0.97 km²), while Galicija islet has the smallest (0.01 km²). The island of Pag has the longest coastline (302.47 km), while Vele Orjule Island has the shortest (5.89 km). Among the 79 large islands with an area exceeding one square kilometre, 66 are inhabited; 525 are islets with an area of 0.01 km² to one km²; and 642 are reefs and rocks with a total area of less than 0.01 square kilometres (Leder et al., 2004). The eastern Adriatic coastline, belongs among the most indented sea coasts in the world, and after the RG coastline, it is the most indented in the Mediterranean (Ridanović & Bičanić, 1993).

Marine and submarine area of the eastern part of the Adriatic Sea

According to Article 2 of the Constitution of the RC and the Maritime Code (Zakon Hr, 2019), the sovereignty of the RC at sea extends to its IW and TS, the airspace above them and their seabed and subsoil. In accordance with international law, the RC exercises sovereign rights and jurisdiction over the marine areas and seabed of the Adriatic Sea beyond the state territory up to the borders with neighbouring countries

through its EEZ and CS. The CS of the RC covers 44,844 km² (Sea Around Us, 2016). Waters from the baseline of the TS towards the land are considered to be part of the state's internal waters. States exercise full sovereignty over their IW, and IW is legally equivalent to land territory. The IW of RC include ports and bays along the mainland and island coast (Figure 3), as well as parts of the sea between the low-water line on the mainland coast and the straight baseline used to measure the width of the TS. Coastal state sovereignty extends beyond its land territory and IW to the adjacent belt of sea known as the TS. Every state has the right to establish the breadth of its TS up to a not exceeding 12 M, measured from the baselines determined in accordance with the United Nations Convention on the Law of the Sea. States exercise sovereignty in their TS, with the exception of the right to innocent passage, which is guaranteed by the Convention.

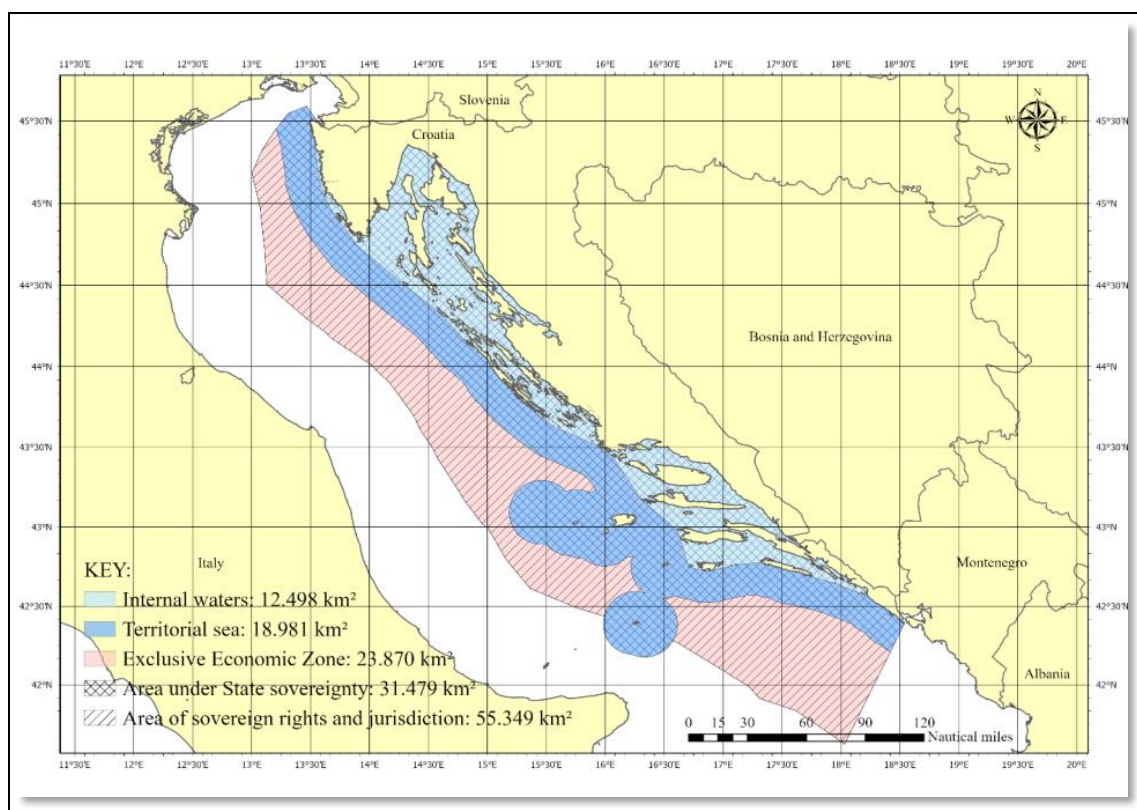


Figure 4. Marine and underwater areas of the Republic of Croatia in the Adriatic Sea.

Source: By the authors according to (Sea Around Us, 2016; Sunko, 2024)

In February 2021, the Croatian Parliament declared the EEZ of the RC in the Adriatic Sea in accordance with the United Nations Convention on the Law of the Sea, within the legal framework established in Part V of the United Nations Convention on the Law of the Sea and Chapter IV (Decision on the Declaration of the EEZ of the RC in the Adriatic Sea). The EEZ of the RC encompasses the maritime space extending from the outer boundary of the territorial sea in the seaward direction to its outer boundary permitted by general international law (Narodne novine, 2021). The outer boundaries of the EEZ of the RC will be determined through international agreements on delimitation with countries whose coasts lie opposite or adjacent to the RC, which has not been done to date. In October 2022, within the framework of the fifth meeting of the Coordinating Committee of the governments of RC and RI, a Treaty on the delimitation of the EEZ between RC and RI was signed. The treaty mutually determines the line of delimitation of the EEZ between the mentioned states, in accordance with international law. The line of delimitation of the EEZ is the already existing line of delimitation of the CS on the seabed and subsoil (Vlada Republike Hrvatske, 2022). The application of the legal regime of the EEZ of RC from Chapter IV. of the Maritime Code is carried out in accordance with Part V of the Convention and the legislation of the European Union. Unlike the EEZ, the rights of the coastal state to the CS do not depend on actual or fictitious occupation, nor on any explicit proclamation of the sea. For this reason, RC did not proclaim its CS in the way the EEZ was proclaimed, by decision of the Croatian Parliament (Narodne novine, 2021).

Fairways, separated and directed navigation systems in the Adriatic Sea

Due to its natural features, longitudinal, transverse, and coastal navigation routes have been established in the Adriatic Sea (Figure 4). The most important longitudinal navigation route in the open sea of the Adriatic Sea, takes place in a northwest-southeast direction, and represents the shortest sea distance between the Strait of Otranto in the southeast and maritime ports located in the northwest part of the Adriatic Sea.

Along the most important central navigation route in the open sea of the Adriatic, longitudinal navigation routes have been formed:

- Along the western coast of the Adriatic Sea (Strait of Otranto - Cape Gargano - traffic separation scheme of Ancona) and close to the the coast,
- Along the eastern coast of the Adriatic Sea, along the outer edge of a series of islands in the northern and central part of the eastern Adriatic coast and along the eastern coast of the Adriatic Sea,
- Along the inner edge of the outer series of islands.

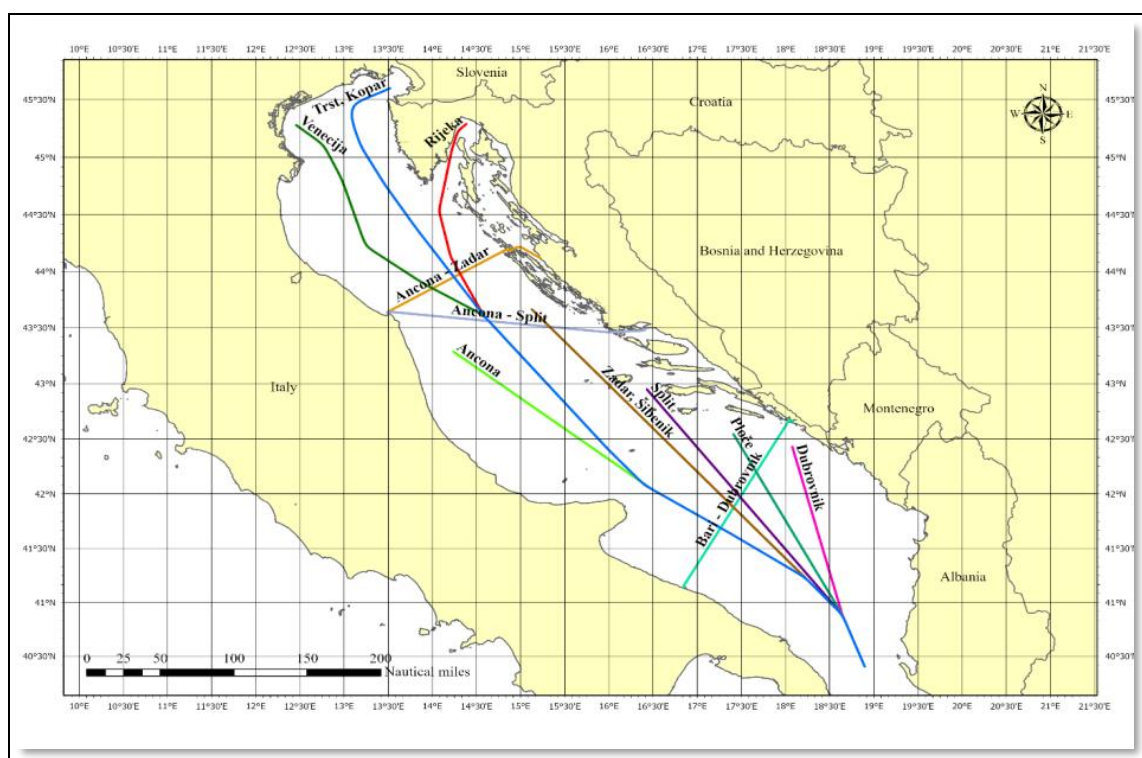


Figure 5. The main longitudinal and transverse navigation routes in the Adriatic Sea.

Source: By the authors according to (Sunko, 2024)

If hydrometeorological conditions (wind and waves) permit, navigation routes are most often established according to the criterion of the shortest distance. Along the immediate vicinity of the western (coast of the RI) and eastern (coast of Albania, Montenegro, RC and Slovenia) lines of the Adriatic Sea coastline, coastal navigation routes have been established. The vessel traffic routing scheme in the Adriatic Sea was approved by the IMO) in 2001 and has been in effect since 2002. In 2004, the IMO's Maritime Safety Committee adopted new and amended vessel traffic separation schemes and measures for routing navigation in the Adriatic Sea, which came into force in 2004 (Luttenberger & Zec, 2010). The system of directed and separated navigation for the area of the northern Adriatic was adopted at the IMO Marine Environment Protection Committee session MSC.139 (76) in 2006 (International Maritime Organization, 2006) and was published in NtM (Ćorić & Šantić, 2012; Hrvatski Hidografski Institut Split, 2007; Sveučilište u Rijec, 2016; Kos, 2018). Navigation is regulated by a separation scheme and reporting obligations with defined temporal and spatial components for the entry of ships into the Adriatic Sea. Between Pianosa Island on the Italian side and Palagruža Island on the Croatian side, within the boundaries of the territorial sea of RC, there is a vessel traffic separation scheme for the central Adriatic.

Navigation features of communication coverage of the Adriatic Sea

Due to the indented coastline, natural and artificial objects on the coast and at sea, numerous islands, islets, shoals, reefs, narrow passages, sea straits and channels, the eastern coast of the Adriatic Sea is ideal for using terrestrial navigation methods to determine the position of a ship. Terrestrial navigation in the Adriatic Sea is complemented by radar and satellite navigation (Sveučilište u Rijec, 2016). All components that enable orientation at sea and determination of the position of a ship in all navigation conditions represent the navigational features of a specific navigation area. Navigational support for ships in navigation enables the determination of ship positions, course and speed. All navigational features imply technological support.

With the establishment of the CROPOS system in 2008, the condition for the application of new geodetic datums and cartographic projections of the RC was met. The positional and altitude transformation accuracy in the area of continental RC was ± 0.05 m and in the area of the Adriatic Sea ± 0.10 m (Marjanović, 2011). The CROPOS system enabled real-time positioning with an accuracy of $\pm 2 - 4$ cm in the entire area of the RC (Premužić et al., 2018). The network solution of the CROPOS system currently includes 56 reference stations. The positioning service in the Adriatic Sea - eastern part is also offered by mobile telephone networks (Republika Hrvatska, 2024).

In accordance with the GMDSS, the Adriatic Sea - eastern part falls under the A1 Sea area in which the RC is obliged to provide coverage with a: VHF belt, through DSC and NAVTEX.

The basic terrestrial wireless networks for the needs of regular communication (voice and data transmission), safety, urgency and distress are defined by the frequency range they use. In the area of the Adriatic Sea - eastern part, four VHF simplex channels are mandatory (06, 13, 16 and 70). On VHF channel 16 (156.800 MHz) the watchkeeping service, calling and communication in case of distress and safety by radiotelephony, coordination of SAR actions and for providing other communication services are carried out. As part of radio traffic, ships navigating the eastern Adriatic Sea can also utilise CRSs of RC. All communications are carried out via the working channels of CRSs of the RC (Rijeka radio, Split radio and Dubrovnik radio). During navigation, constant ship radio – watchkeeping is organized on: VHF DSC channel 70, MF DSC frequency 2187.5 kHz, on MF/HF DSC frequencies (8414.5 kHz and on one of the following frequencies: 4207.5 kHz, 6312 kHz, 12577 kHz or 16804.5 kHz) or by means of INMARSAT ship station, and watchkeeping on VHF channel 16. The automated NAVTEX service of direct printing of navigational notices, maritime safety information, navigational and meteorological warnings, meteorological forecasts and other urgent safety messages to ships is part of the GMDSS system. NAVTEX messages are broadcast in the working frequency range of 518 kHz (international NAVTEX service) and 490 kHz (national NAVTEX service). The Croatian Hydrographic Institute is the national coordinator of the NAVTEX system in RC.

Surveillance and security challenges on the eastern part of the semi-enclosed Adriatic Sea

As presented in the previous section, challenges characteristic to semi-enclosed seas can be divided into either legal or technical category, with causes that influence them being either complex geomorphology, hydrometeorological circumstances or lack of cooperation. Although this systematization has been gathered by analysing problems occurring in semi-enclosed seas or similar geomorphological locations across the world, it is now used to classify problems of eastern Adriatic coast and thus create a connection between challenges that occur and the nature of semi-enclosed seas.

One of the problems that arises in the eastern Adriatic is the malfunction of radar surveillance systems and EO/IR (Electro-optic/infrared) surveillance equipment. The main cause of these problems are arising from the adverse weather conditions (Cosoli et al., 2010; Vujović & Kuzmanić, 2018). Electro-optical devices can be interfered with due to storms, hales, fog and rain, but also due to reflections of the sea surface, which can be especially challenging during high seas (Vujović & Kuzmanić, 2018). As the Sirocco wind, which is one of three main winds occurring in eastern Adriatic and which blows mostly in late winter period (January-March) is often considered the one causing storm surges and high waves due to its connection to the locations of cyclogenesis, as already discussed in previous section (Lionello et al., 2012). Therefore, it is to be expected that during this period EO/IR surveillance will be hindered the most. The problem of radar surveillance hinderance has not been directly tested on eastern Adriatic, however problems due to adverse weather did occur when a specific study was conducted using a shore-based high-frequency (HF) radar in northern Adriatic (Cosoli et al., 2010). The cause of the hinderance of the radar surveillance

is listed as the pulses of northeasterly wind, that is Bora, characteristic for it's high intensity in northern Adriatic especially, but as discussed in previous section, not uncommon within northern and mid part of the eastern Adriatic as well (Cosoli et al., 2010). All of these challenges can be described as caused by the specific hydrometeorological circumstances of semi-enclosed seas, such as Adriatic, and can be classed as technical problems in nature.

Another problem that arises on eastern Adriatic coast is a border dispute of Piran bay. The arise of dispute is at the same time complicated and simple. The Slovenian government claimed the corridor of Piran bay as part of it's inside waters, as opposed to Croatian territorial sea, in order to gain access to international waters (Degan, 2019). Similarly to one of many disputes arising in the Aegean Sea between Turkey and Greece discussed in previous section, main dispute arose from the unclear demarcation of the continental shelf (Degan, 2019; van Dyke, 2005). Although this problem has been subsequently solved, albeit after almost 30 years of dispute, unclear demarcation may cause an unclear authority on the location and therefore a threat to security. This challenge can, according to established systematization, be classified as legal and the causes of it complex geomorphology (unclear continental shelf demarcation) and lack of cooperation.

As eastern Adriatic is characterized by an indented coastline, mapping and creation of interactive charts can heavily simplify surveillance and surveillance planning. For this reason, in recent years there has been an increasing number of attempts to utilize GIS (Geographic Information System) to improve surveillance and security and also to solve legal issues of concessions, borders etc. However, this process is slowly implemented and still fragmented and not unified, creating possible gaps in surveillance and especially surveillance planning and maritime spatial planning as a whole (Kovačić et al., 2022). This issue is both technical and legal, legal in the sense that maritime spatial planning lack national framework and is caused by primarily complex geomorphology.

Some of the major problems regarding security and surveillance of eastern Adriatic can be directly correlated with the general geographic specifications of semi-enclosed seas. Simplified version of the analysis is provided in Table 4:

Table 5.

Analysis of problems arising in eastern Adriatic by systematization of challenges typical for semi-enclosed seas (Table 4)

Problem	Cause (hydrometeorology/ complex geomorphology/ lack of cooperation)	Category (legal/technical/both)
Electro-optical/radar surveillance difficult	Hydrometeorology	Technical
Pyran bay border dispute	Complex geomorphology, lack of cooperation	Legal
GIS system fragmented	Complex geomorphology	Both

Source: By the authors according to (Cosoli et al., 2010; Degan, 2019; Kovačić et al., 2022; Vujović & Kuzmanić, 2018)

Conclusion

Timely identification of processes and phenomena that can disrupt the security and interests of coastal states in semi-enclosed seas requires a multifaceted approach, recognizing events and occurrences in an environment of increased risks from illegal activities. In the context of the spatial distribution of systems and subsystems for controlling and protecting the rights and interests of coastal states in semi-enclosed seas, understanding the spatial structures of semi-enclosed seas is very significant. The spatial structures of controlled and protected maritime areas can significantly influence security strategies, control capabilities and protective measures. With the aim of more effective implementation of control and more efficient protection of the rights and interests of coastal states, there is a recognised need for an analysis of the spatial features of semi-enclosed seas. Physical-geographical features, and the environment of the coastal area is extremely important in the process of positioning control and protection systems, and thus reducing possible risks. Islands can serve as strategic points for monitoring outposts, radar installations and military maritime locations in order to improve the ability to track and respond to possible illegal activities.

The spatial features of semi-enclosed seas have been considered from several different perspectives to ensure an integrated approach that provides recommendations and guidelines for placing control and protection systems. Understanding spatial features and their implications is extremely important for the development of effective maritime security measures. By ensuring the security of maritime assets, coastal states protect their economic prosperity, environment and overall national security. In line with this, the paper conceptually and systematically presents the results of research on the spatial features of the semi-enclosed Adriatic Sea - eastern part. All geographical, marine, submarine, navigational, hydrometeorological and navigational features of the Adriatic Sea - eastern part were thoroughly studied and analysed. Previous relevant research was reviewed and a structural analysis of the determinants of national and international legal regulations by which the RC exercises jurisdiction in accordance with international law and national legal regulations in the Adriatic Sea - eastern part was performed.

Moreover, a comparison has been presented to other semi-enclosed seas worldwide, which constitutes that majority of the problems in security and surveillance arise from particular properties of said seas: complex geomorphology, hydrometeorology and lack of cooperation and can be classified as either legal or technical (or both). This systematization is them further applied to particular challenges on the eastern Adriatic, finding them to be in accordance with such systematization. This framework is developed not only to correlate properties of semi-enclosed seas with typical problems occurring in them, but also to be used in future to simplify problem-solving regarding these issues as well as aid future research regarding surveillance and security of semi-enclosed seas.

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