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Contents

1 INTRODUCTION

This report presents the results of activities carried out as a part of the Work Package 5.1.

The main goal of the activities carried out is to provide data needed for estimation of the present and future traffic and environmental load on ships under consideration and has to include data collection and analysis of:

- navigational features and restrictions of the project area (availability and suitability of the navigational marks, lights and aids, coverage of satellite navigation and radio communication systems, earth magnetic influences and existing navigation restrictions and dangers in open seas, coastal areas and port approaches);
- meteorological and oceanographic features (environmental and weather elements of the area including typical winds, waves, tides and sea currents characteristics, precipitation and fog frequency of occurrence and weather changing patterns);
- identification of possible new measures or change of the existing rules to improve the overall safety of navigation within the area, with the emphasis on the potential new routes and traffic load.

Activities carried out, as well as this Report, are based on the following assumptions:

- a legal framework regulating the safety of navigation and pollution prevention, both national (Croatia and Italy) and international, is assumed as it is at the time of the Report delivery
- ships considered in this Report comply with the requirements set forth by the provisions of the International Convention for the Safety of Life at Sea, 1974 (SOLAS 74), the International Convention for the Prevention of Pollution from Ships 1973/78 (MARPOL 73/78), the International Convention on Load Lines, 1966 (LOADLINE 1966), the International Convention on Tonnage Measurements of Ships, 1969 (TONNAGE 1969), as amended, or as required by the relevant and applicable technical rules of the recognized organizations;
- characteristics of yachts, boats and ships that are not subject to international conventions comply with requirements prescribed by the authorised administration of the respective flag states;
- ships' masters and crew meet the standards prescribed by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, as amended, as well as provisions of the International Safety Management Code, as defined in Chapter IX of the SOLAS Convention;
- actions of the master and crew of ships, yachts and boats are reasonable, and are carried out as a prudent seafarer would act; behaviour that significantly contradicts the rules of the profession or that is aimed at harming people or causing damage to the environment or property is not the subject matter of this study;
- ships, yachts and boats use the typical traffic routes; the use of other waterways, which ships, yachts and boats, depending on their size or own characteristics, do not use or use only on an exceptional basis, are not considered;

– communication devices used by ships, yachts and boats as well as other means of surveillance and data collecting correspond with the nominal effective range and required reliability.

The Report assumes working, management and technological presumptions of relevant and valid documents and recommendations of the International Maritime Organisation and other international expert bodies regulating marine safety and environmental protection.

The Report does not take into account internal procedures or instructions that maritime companies or other legal subjects in maritime traffic may prescribe to their employees.

The Report is mostly based on the most recent data available whenever possible or appropriate. Older sources are used in cases where there is a lack of data. When deciding between more reliable or current sources, as a rule, priority is given to sources of higher reliability.

This Report is written considering the available scientific and expert knowledge of the maritime traffic technology, and following the accepted rules of science, profession and skill.

2 NAVIGATIONAL FEATURES OF THE ROUTE AREAS

Navigational features of a particular waterway area include features enabling orientation at sea, such as determining the position of the ship in all conditions, managing and monitoring its movement (a determination of the course, speed and underkeel clearance), receiving information about navigational hazards (balisage marks), etc. In general, the navigational features can be divided based on their variability in time, into static and dynamic.

The static navigational features include all those features and factors that are not subject to significant changes and oscillations in values in shorter periods. The most critical static navigational features include those referring to lighthouses, coastal and harbour lights, topographic features and depths.

Dynamic navigational features include those that are more or less susceptible to change over time. The most critical dynamic features include density and frequency of ships in a particular area and VTS services.

2.1 Brestova-Porozina

The ro-ro passenger line Brestova-Porozina connects the port of Brestova on the eastern coast of Istria and Porozina seaport on the northwest coast of the island of Cres. The route crosses the Vela Vrata Strait, which connects Kvarner Bay and Bay of Rijeka.

The main entry-exit route through the Kvarner can be divided into two parts: the sea area at the entrance to the Kvarner and the smaller area of the Vela Vrata and the Bay of Rijeka.

The Kvarner Bay is an area between the eastern coast of Istria, from Cape Kamenjak to port of Plomin, and the western coasts of the islands of Cres, Unije, Lošinj and Ilovik, which leads from the open sea towards the Vela Vrata.

In the high sea area outside the Bay of Kvarner, sea traffic goes from and to the North Adriatic ports (Trieste, Koper and Venice) and to or from the Bay of Rijeka. Ships entering the Kvarner are crossing courses with vessels engaged in the coastal navigation. The open manoeuvring space in the area is large enough while angles at which the crossings take place are almost perpendicular.

In the passage of Vela Vrata (width 2.3 to 2.8 nm), a Traffic Separation Scheme (TSS) was established, determining the sailing direction. All vessels longer than 20 m in the north-eastern direction and entering the Bay of Rijeka must sail along the coast of the island Cres, i.e. have to use the eastern track of the TSS. Ships sailing in the southwest direction, i.e. sailing from the Bay of Rijeka must use the west lane of the TSS.

In the Vela Vrata area, ro-ro passenger vessels sail between the island of Cres and the coast of Istria, i.e. between the ports of Brestova and Porozina. Their route is almost perpendicular to the main navigational direction. The voyage time of ro-ro vessels is relatively short, i.e. about 30 minutes. Depths in the Vela Vrata strait are from 55 to 65 m.

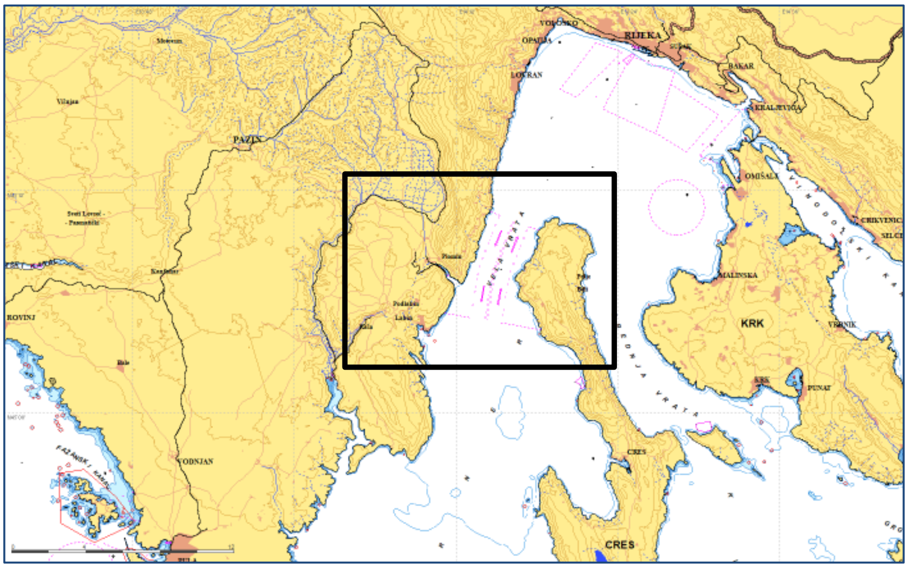

Figure 1 The Kvarner Bay, Vela Vrata (marked) and Bay of Rijeka

At the entrance to the Gulf of Rijeka, north of the Traffic Separation Scheme, vessels sailing from the Bay of Rijeka ports cross the routes of ships sailing to the ports in the Bay of Rijeka. The second crossing area is in the central part of the Bay of Rijeka, where vessels arriving through Vela Vrata and sailing to the Bay of Bakar or Omišalj oil terminal, cross with those used by ships coming to Srednja Vrata and navigating to the Rijeka and Opatija.

There are no obvious navigational hazards in the Kvarner Bay area. The only location in the Kvarner region that poses a particular danger to navigation (stranding) is the Galijola rock at the entrance to Kvarner Bay. The islet is well marked with light, RACON and AIS AtoN (E2744 HRID GALIJOLA), so it can be detected on time with vessels' radars and AIS systems. Ships sailing to the ports in the Bay of Rijeka area are sailing mostly west of Galijola.

During strong southerly winds, smaller vessels (length less than 120 m) usually use a sailing route between the islands of Unije and Lošinj. The Zaglav rock (about 0,6 nm from the west coast of Cres, south of Cape Pernat) is also well marked by a navigation light. Depths in the entire Kvarner Bay region are about 50 m.

Cargo vessels carrying dangerous goods, flammable cargoes or those that can contaminate the marine environment are prohibited from sailing through the Unije Channel[1].

2.1.1 Radar observations and aids to navigation

The entire coast of the area is predominantly high and steep. It may be effectively used to determine the position of the vessel by visual observation or by radar equipment in all weather conditions. Thanks to the excellent reflection of the coastline, the accuracy of radar positions is satisfactory, even at distances well over 30 nm (with sufficient radar antenna height).

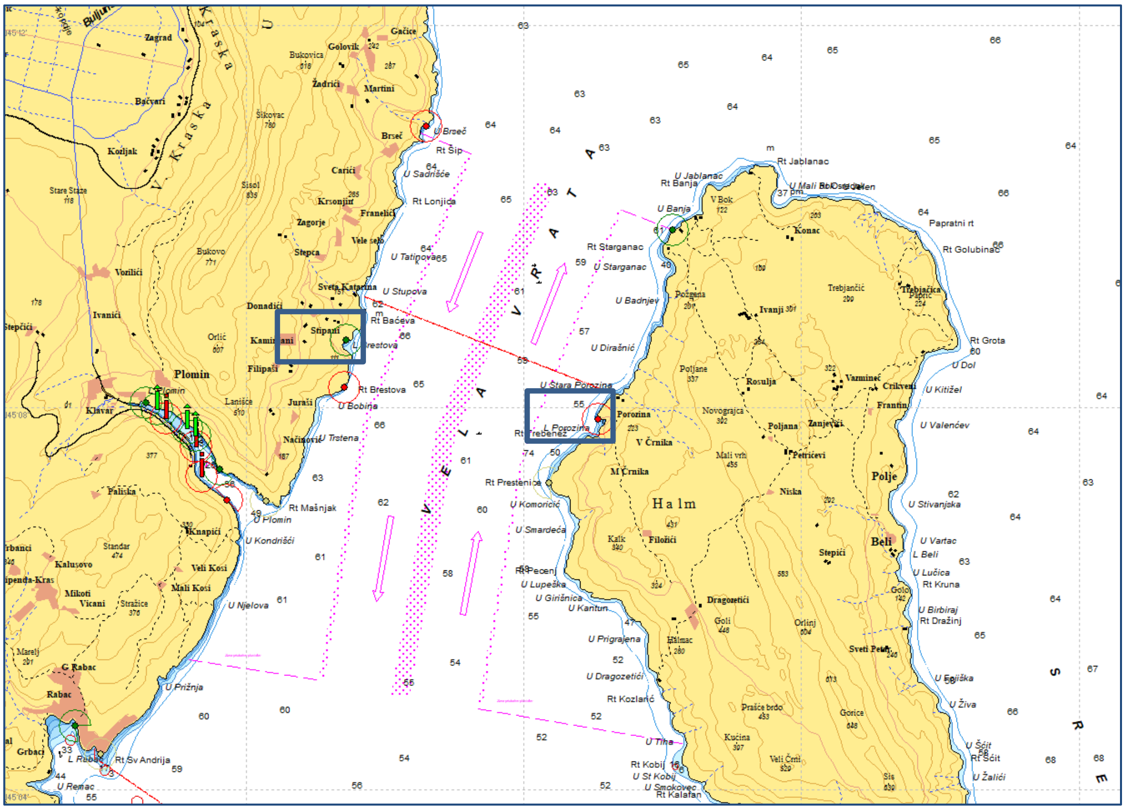

Figure 2 Brestova and Porozina - locations in Vela Vrata

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1 Order on navigation in the passage to Šibenik harbor, in the Pašman Strait, through the passage of Vela Vrata, Neretva and Zrmanja rivers, to ban the sailing through Unije canal and the Krušija canal, parts of the Middle Canal, the Murter Sea and the Žirjan canal (Official Gazette of the Republic of Croatia NN 9/07, 104/16, 53/19)

The Bay of Rijeka is a sea area between the northeast coast of Istria and the coast of Hrvatsko Primorje, including the Bay of Bakar, the west coast of the island of Krk, and the north coast of the island of Cres. The most notable orientation points on the west coast of the Bay are the bell tower in Brseč, Mošćenice and Mošćenička Draga, the tower on the Cesar, the church in Veprinac above Opatija, and Učka mountain (1,401 m) with an antenna column.

Orientation points on the north coast of the Bay are the belfry in Kastav, the buildings of the city of Rijeka, the tower and walls on Trsat, industrial facilities west of the entrance to the Bakar Bay, the Krk Bridge and the island of Sv. Mark at the entrance to the Tihi Kanal.

On the east coast of the Bay, along the island Krk, the most prominent orientation points are the belfry in Omišalj, the oil and petrochemicals facilities, Malinska and the Glavotok church.

Orientation points along the coast of Istria are the Porer lighthouse, with white light with a 25 nm range, the coastal towns of Medulin and Ližnjan, the Crna Punta lighthouse with a white light range of 10 nm, the deeply indented Bay of Plomin, the peaks of the Učka mountain and a series of harbour lights along the coast.

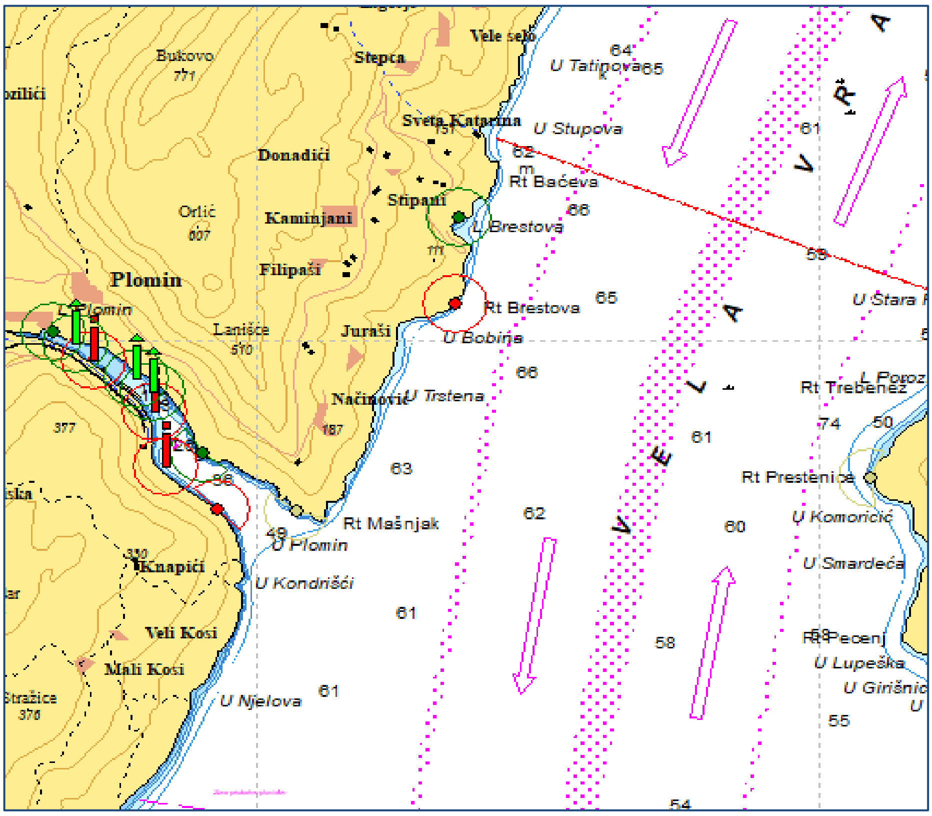

Figure 3 Navigational Lights in Vela Vrata (Brestova and Porozina area)

The coast of the island of Cres is very steep, and the chain of hills stretches along the entire length of the island. The highest peaks are Orlinj (604 m), Gorice (648 m), Sis (639 m) in the North part, and Helm (482 m) in the central part, while the South part of the island is of much lower altitude (60-80 m). Significant markings along the west coast of the island are the lights of the fish farm in Veli Bok bay (yellow lights with 2 nm range), signal lights at the entrance to the port of Cres on Cape Kovačine (red light with 8 nm range) and Cape Križice (green light with 4 nm range), the lighthouse on Zaglav cliff (white light with 10 nm range), the lighthouse on the island of Zeča (white light range 8 nm and red light range 6 nm) and lighthouse on the islet of Visoko (white light range 6 M).

At the entrance to the Vela Vrata on the coast of Istria, there is the lighthouse on Cape Sv. Andrija (white light with 5 nm range), the lighthouse on Cape Brestova (red tower with gallery, red flash (2), 12 s, 40 m, 13 nm), the lighthouse in Brestova Bay (green tower with gallery, green light, 2 s, 7 m, 4 nm), and the lighthouse on Cape Šip (red light with 8 nm range).

The coast of the island of Cres is marked by a lighthouse on the pier in the Porozina Bay (red tower with gallery, red flashing light, 2 s, 7 m, range 3 nm), lighthouse on Cape Prestenice (white light with 10 nm range) and lighthouse on Cape Starganac (green light with 8 nm range).

2.1.2 Satellite navigation

Global navigation satellite systems (GNSS) can be used throughout the Adriatic, including the Kvarner and Bay of Rijeka. Accuracy, availability, reliability, time between two consecutive vessel positions and system capacity fully meet international standards. In the observed area, as well as in the rest of the Adriatic, the differential GNSS support is not available.

2.1.3 Magnetic conditions

The elements of the Earth's magnetic field are magnetic variation, magnetic inclination, and the force of the total intensity of the Earth's magnetism, consisting of a vertical and a horizontal component. Of particular importance for navigation is the value of the magnetic variation and the value of the horizontal component of the earth's magnetic field. Magnetic variation in the Adriatic Sea area (2012) varies from approximately 2.5 °E in the Venice area to 3.5 °E in the Strait of Otranto area. The annual variation in magnetic variation is minimal, ranging from approximately 7.1' E in the north part to 6.2' E in the central and south Adriatic.

Magnetic anomalies in the Adriatic Sea are observed in the area of Lošinj – Rijeka and the central part of the Adriatic, close to the islands Jabuka - Svetac – Vis. The leading causes are the geological structure of coastal mountains and the eruptive rocks (Brusnik and Jabuka). In these areas, it is advisable to check the magnetic compass more frequently and to use means independent of terrestrial magnetism to determine the position of the ship, as possible.

In conclusion, the use of a magnetic compass as a navigational aid on waterways in the North Adriatic and the respective Brestova - Porozina route area, is sufficiently reliable and safe.

2.1.4 Communication coverage

In the area under consideration, ships may use the services of the three coastal radio stations (CRS) of the Republic of Croatia (Rijeka, Split and Dubrovnik). In the Adriatic Sea, the service is offered on VHF channel 16 and for vessels equipped with DSC VHF devices on DSC VHF channel 70. In the absence of urgent radio messages, all communications may be conducted on the working channels of the respective coastal radio stations.

The Rijeka Radio (Call Sign - 9AR) offers radio services in the Brestova-Porozina area. It uses the VHF radiotelephone on channels 04, 07, 16, 20, 21, 23, 24, 28 and 81, as well as appropriate MF radiotelephone frequencies.

Navigation notices, valid for the Croatian Adriatic coast and adjacent waters, are issued and published by the Croatian Hydrographic Institute from Split as national coordinator. Notices important for the safety of navigation are transmitted and repeated by coastal radio stations in English and Croatian language as long as they are in force or until being published in the Notices to Mariners.

Meteorological reports and warnings for the Adriatic Sea are published daily by the Maritime Meteorological Centre of Split, which provides a general weather situation and 24-hour weather forecast and warnings. These reports are usually transmitted together with navigation notices on the relevant working channels, in Croatian and English language. Daily weather reports with a weather map and weather forecasts for the next three days are available for all Croatian harbours. Besides, ships, yachts and boats with the capability to connect to a data network, either using satellite connections or GSM, may download the results of the weather numerical simulations (for example model Aladin), thus significantly increasing the information content available for decision-making.

In the respective route area, due to good coverage, GSM signal is available.

In conclusion, the communication services to ships sailing along the east Adriatic coast is adequately provided by the system of coastal radio stations Rijeka, Split and Dubrovnik on the MF and VHF frequencies.

2.1.5 Maritime traffic

The traffic through Vela Vrata is directed to and from ports and terminals in Bay of Rijeka. In the observed area, Rijeka is recognized as a port of international significance. Also, there are 27 ports of county significance and 76 ports of local significance[2]. Also, there is a total of 30 registered nautical tourism ports, of which ten are marinas, seven are dry marinas, five are moorings and eight anchorages.

Carriage of goods. Port facilities and terminals in the Bay of Rijeka include Rijeka, Sušak and Bakar basins as well as Brajdica container terminal. Crude oil and oil products are handled at the terminal in Omišalj and industrial ports of Bakar and Sršćica used by INA oil refinery Rijeka. There are several industrial shipyards in the area: 3. Maj, Viktor Lenac and Kraljevica.

Port basins Rijeka, Sušak, Bakar, container terminal Brajdica and Omišalj terminal are under the governance of the Port of Rijeka Authority and represent public ports of international economic significance for the Republic of Croatia.

The total quantity of cargo handled at ports in the Bay of Rijeka is approximately 13,000,000 tons, most of which is discharged at the oil terminal in Omišalj, with approximately 50% of the total quantity, followed by the INA terminal and bulk terminal in Bakar.

Table 1 Cargo throughput for Port of Rijeka Authority ports and terminals from 2015 to 2019[3]

Year	2015	2016	2017	2018	2019
Liquid (t)	6.595.537	7.325.173	7.997.836	8.628.586	6.637.726
Dry (t)	4.304.884	3.833.988	4.617.230	4.776.198	4.850.816
Container (TEU)	200.102	214.348	249.975	260.375	305.049

The number of vessels accommodated between 2014 to 2016 in the Bay of Rijeka area was about 4.700. For example, in 2016 there were 4.674 vessels, including approximately 900 foreign vessels. In general, domestic traffic includes fishing and passenger ships and tugs traffic in the port of Rijeka area. Foreign vessels are mainly cargo vessels (tankers, container carriers, bulk and general cargo vessels) heading towards berths in the Bay

2 The Order on the classification of ports open to public transport in the area of Primorsko-Goranska County (Official Gazette of the Republic of Croatia NN 3/2015))

3 Port of Rijeka Authority: available at https://www.portauthority.hr/en/traffic-statistics/

of Rijeka area (Rijeka and Sušak basins, container terminal Brajdica, berths in the Bakar Bay area, oil terminal Omišalj and shipyards Viktor Lenac and Kraljevica). The largest vessels entering the port of Rijeka bay are container ships up to 366 meters in length and crude oil tankers with deadweight of 330.000 tons, approximately 330 meters long and 60 meters wide.

Passenger traffic. Passenger traffic in the Bay of Rijeka is not significant. In 2014 it reached 234.416 passengers, with most passengers being transferred at the passenger terminal Rijeka (192,500 passengers). Most the passenger traffic refers to the HSC vessels connecting the port of Rijeka with islands Cres, Lošinj, Rab and Pag where 149.194 passengers were transported in 2014 and 140.825[4] in 2016. Two HSC passenger lines depart daily to these islands.

Among other ports in the Bay of Rijeka, the ports Opatija, Bakar, Kraljevica, Omišalj and Malinska have noticeable maritime traffic. Maritime traffic in these ports is primarily related to the fishing ships and smaller passenger vessels. At the same time, in the ports of Opatija and Krk (at the anchorage), there is also modest international traffic of cruise vessels.

Fishing vessels. Fishing in the Primorsko-Goranska County area is usually carried out in the Bay of Rijeka and the approaching waterways from the Kvarner area. In the Kvarnerić area, it is carried out in-between the islands of Krk, Rab and Cres. Generally, the area of Kvarner and the Bay of Rijeka can be considered as an area of relatively high fishing density, mainly purse seiner fishing vessels. The area of Vela Vrata has the lowest density of fishing vessels compared to the Kvarner and Bay of Rijeka area.

Port of Brestova is situated on the east coast of the Istrian peninsula in the Brestova bay in Vela Vrata Strait. The approach and orientation are facilitated by previously described aids to navigation. Berths are open to southerly winds and waves, especially from the SE direction, during which manoeuvring is demanding.

The port of Brestova is a public port with three ramps available for ro-ro passenger vessels. It is connected by state roads D402 and D66 (Rijeka – Pula) which leads to Pula or Rijeka. The port is primarily used for berthing the ro-ro passenger vessels serving the line between Brestova – Porozina, connecting mainland Istria and island of Cres.

Table 2 Passengers and vehicles transported between Brestova and Porozina from 2014 to 2018[4]

Year	2014	2015	2016	2017	2018
Passenger	500.114	545.700	575.893	589.337	602.591
Vehicles	218.248	218.006	226.189	229.648	234.561

4 Data provided by Coastal Liner Services Agency (Agencija za obalni linijski pomorski promet)

The use of the piers for other purposes and other vessels is generally prohibited, and possible only with permission obtained from the Port Authority of Rabac and the Harbour Master's Office Pula, Rabac branch.

On the ro-ro passenger line Brestova-Porozina in 2018, 602.591 passengers and 234.561 vehicles were transported. In 2017 there were 589.337 passengers and 229.648 vehicles according to Coastal Liner Services Agency.

Port of Porozina is situated on the island of Cres in Vela Vrata Strait. It is used primarily for ro-ro passenger ships and supporting activities and includes a fishing and leisure craft harbour. It is connected to the state road D100. The port has three ramps for ro-ro passenger ships which connect the island of Cres with the mainland coast of Istria and the port of Brestova. Berthing of ro-ro passenger ships is carried out at two berths.

The port of Porozina is open to the west winds, i.e. towards the shores of Istria. The port is exposed to the south and south-westerly winds. However, strong bora and sirocco can influence the safe mooring of ships by developing a swell in the port. The anchorage is located southerly in the Trebenež Bay with a sandy bottom. Usually, the anchorage is used only occasionally, by smaller vessels only.

2.2 Split-Ancona

Ro-ro passenger line Split-Ancona is an international line between the Republic of Croatia and the Republic of Italy. The line is operated by two shipping companies, Italian SNAV and Croatian Jadrolinija. The line is maintained the whole year around. In both directions, the ships are sailing through Drvenički Kanal, the channel between shore and the islands of Drvenik Veli and Drvenik Mali. The return trip is approximately 130 nm long.

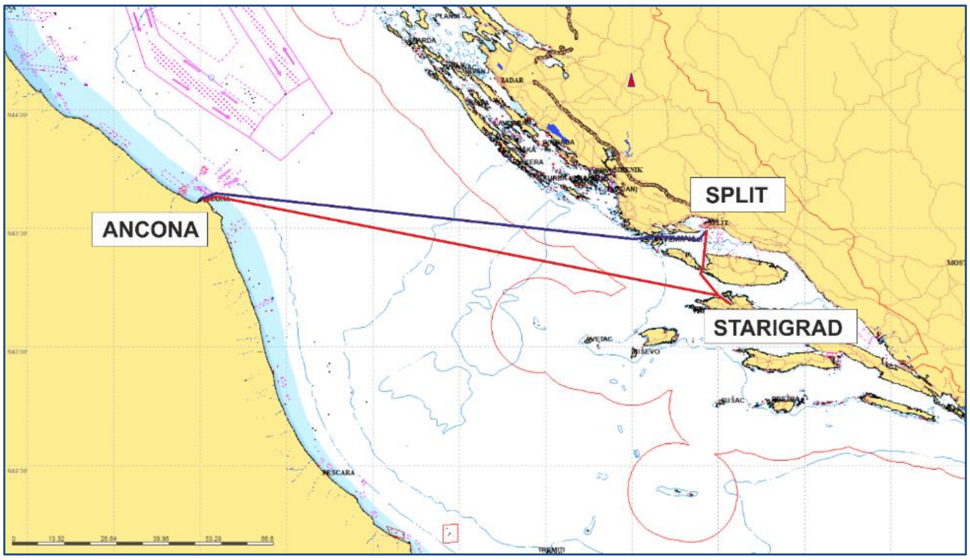

Figure 4 Split-Ancona (blue route) and Split-Starigrad-Ancona (red route)

During the high season only, the ships call one more port, Starigrad on the island of Hvar. In that case, the ships sailing between Split and Starigrad pass through Splitska Vrata, the passage between the island of Šolta and the island of Brač. The return line between these three ports is approximately 155 nm long.

2.2.1 Radar observations and aids to navigation

The eastern Adriatic coast is high and steep. It provides good radar reflections, so it is possible to undoubtedly and timely determine the position of the ship by visual observation or by use of radar devices, in all weather conditions. Also, geographical features and forms on all islands provide quick and accurate orientation. As a result, radar navigation methods can be continuously used in the east Adriatic area, and satisfactory radar position accuracy can be achieved typically on distances of over 30 nm.

In addition to a sufficient number of easily identifiable objects on the coast in the respective area, enabling safe navigation, there is a network of lighthouses, coastal lights, light buoys and other markings that additionally support safe navigation. It is estimated that the navigation aids positioned along the eastern coast of the Adriatic Sea meet the quite high standards, probably higher that can be found in areas where the natural conditions are not as nearly as good as those prevailing in the Adriatic Sea area. Approaches to each port are described more in detail in the following chapters.

2.2.2 Satellite navigation

Global Positioning System (GPS) and GLONASS can be used throughout the whole Adriatic Sea area. Accuracy, availability, reliability, time lag between two consecutive ship positions and system capacity fully meet international standards. There is no GPS enhancement system in the Adriatic.

2.2.3 Magnetic conditions

As mentioned in the previous chapter, the magnetic variation in the Adriatic Sea area (2012) varies from approximately 2,5 °E in the Venice area to 3,5 °E in the Strait of Otranto area. The annual variation in magnetic variation is minimal, ranging from approximately 7,1' E in the North part to 6,2' E in the central and South Adriatic. The use of a magnetic compass as a navigational aid on waterways in the respective Split - Ancona route area, is sufficiently reliable and safe.

2.2.4 Communication coverage

In the central Adriatic, there are coastal radio stations on Croatian and Italian side. Close to the eastern Adriatic coasts, ships can transmit all messages via SPLIT Radio coastal radio station (call sign 9AS, MMSI 002380100) – using VHF radiotelephony on channels 07, 16, 21, 23, 81. Closer to the western Adriatic Sea coast ships can transmit all messages via monitored coastal radio station ANCONA (Call sign IPA, MMSI 002470119). The preferred coastal radio stations in Italy are Rome Radio and Palermo Radio.

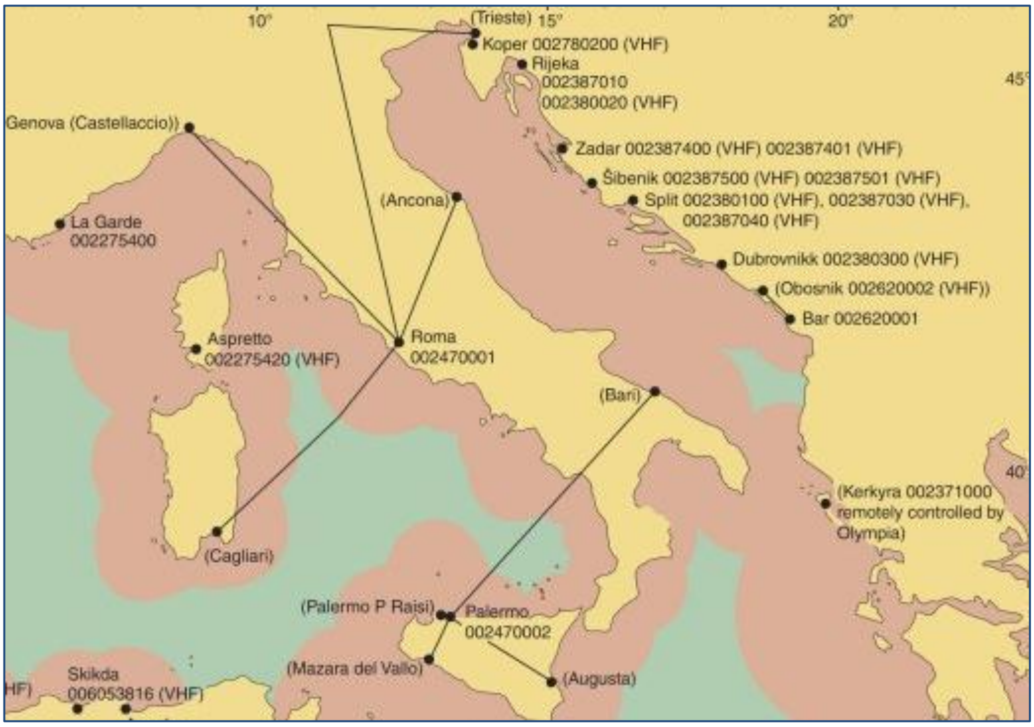

Figure 5 Digital selective calling (DSC) coverage (red area) and coastal radio stations[5]

Maritime Safety Information (MSI), i.e. notices vital for the safety of navigation along the Croatian Adriatic coast and in the adjacent waters, are issued and published by the Croatian Hydrographic Institute from Split as the national coordinator. Notices are transmitted and repeated by NAVTEX (station Q – international frequency 518 kHz) and coastal radio stations in English and Croatian until they are in force or until are not published in Notices to Mariners. Italian NAVTEX stations transmitting MSI on international frequency 518 kHz for the area are Trieste (station U) and Rome (station R).

5 From Global maritime distress safety system: www.gmdss.org

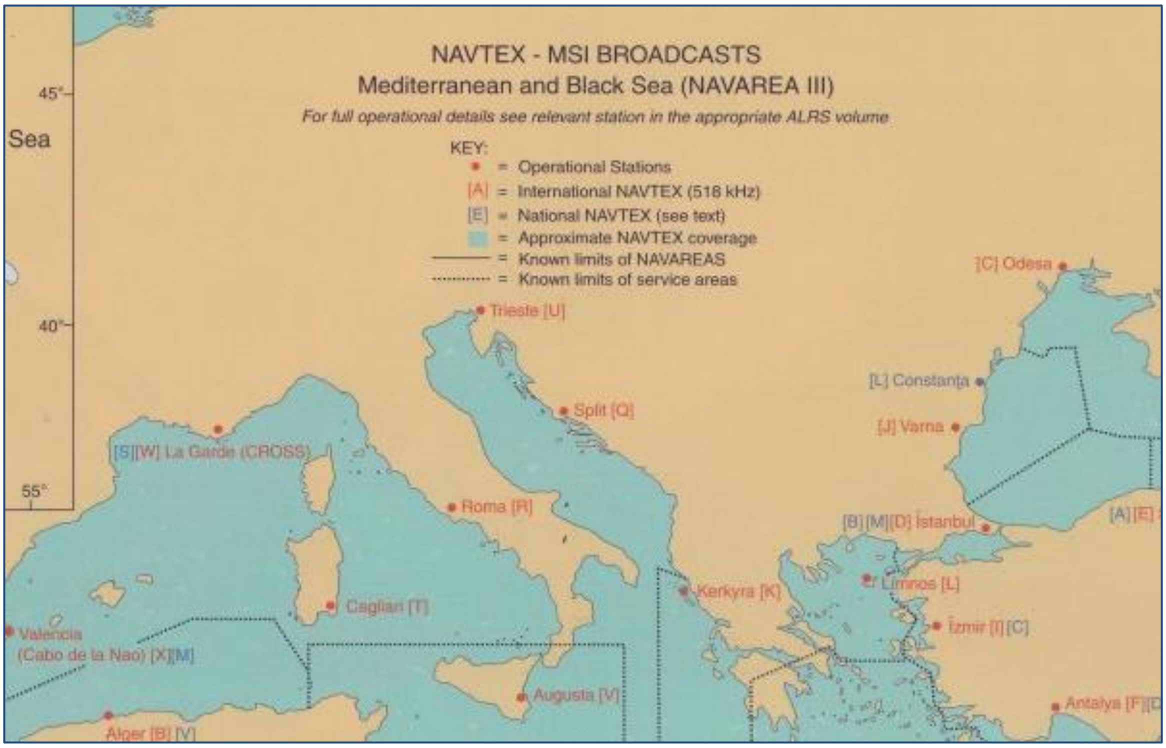

Figure 6 NAVTEX – MSI Broadcast stations[6]

Meteorological reports for the Adriatic Sea are published daily by the Maritime Meteorological Centre of Split, which provides a general description of the weather conditions and 24-hour weather forecast and warnings. These types of reports emitted by Croatian CRS (Rijeka, Split and Dubrovnik) are usually emitted together with navigation notices on the working channels in Croatian and English. Daily weather reports with a weather map and weather forecasts for the next three days are available in all Croatian harbours.

Italian radio stations transmit regular meteorological reports "Meteomar" several times daily, providing a general description, forecast, warnings and coastal observations.

Also, ships with access to the Internet can download results of numerical simulations (for example model Aladin published by Croatian National hydro-meteorological institute) is also available, thus significantly increasing the information content available to ships.

In conclusion, the communication connection of ships in navigation on the respective route is satisfactorily ensured by the system of coastal radio stations Ancona and Split, and NAVTEX stations (U, R and Q).

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6 From Global maritime distress safety system: www.gmdss.org

2.2.5 Port of Split - approach

If one excludes manoeuvring areas, only a smaller part of the sailing route between Split and Ancona is considered as coastal navigation. Namely, sailing through the Drvenički Kanal and the passage Splitska Vrata may pose a particular collision risk, particularly during summer. Both waterways are the alternative approaches to the port of Split.

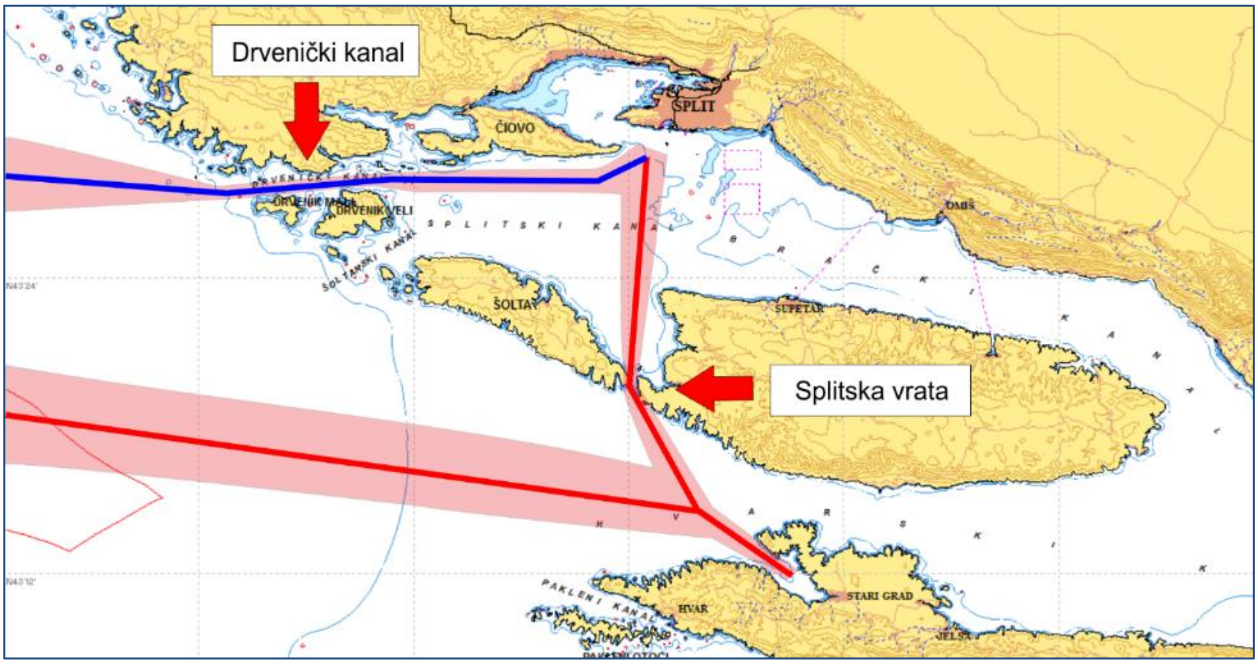

Figure 7 Split-Ancona (blue route) and Split-Starigrad-Ancona (red route) with navigation zones

Drvenički Kanal is a long channel, approximately 7 nm long, being the narrowest in the central part (approximately 0,5 M). It embraces numerous small islands and reefs, all well marked with navigational lights. The traffic in the channel includes approximately 2.000 one-way passes a year, of which from 200 to 300 are cargo ships at international voyages, about 500 ships a year are ro-ro passenger liners, and around 100 are vessels flying the national flag in cabotage. The rest are other vessels, of which cruise ships and larger yachts account for a significant share. The channel is the main route for ship carrying dangerous goods towards the port of Split and vice versa. Vessels carrying hazardous liquids, chemicals and liquefied gases are subject to coastal pilotage. In the central waterway, the depths are safe for navigation, varying from 50 to 70 m. In the central waterway are situated several shallows, not being dangerous for referent ro-ro passenger ships, varying from 15 to 20 m.

The significant navigational lighthouses are those at islet Muljica (white flash, 3s, 15 m, 5 nm), islet Murvica (ref flash, 8s, 15 m, 7 nm), islet Malta (white flashes (2), 8s, 11 m, 5 nm), islet Galera (white flash, 5s, 8m, 10 nm) and shallow Mlin (white flash (2), 10 s, 7 m, 8 nm).

Figure 8 Channel *Drvenički kanal*

Splitska Vrata passage is the busiest and narrowest approach to the port of Split. The available waterway width is only 0,3 nm in the narrowest part. Generally, it is the shortest approach to the port of Split from the high sea. The annual traffic in the passage in each direction counts over 10.000 crossings or 20.000 crossings in both directions. During winter season daily traffic reaches 20 to 25 ships, in both directions. During the summer high season, daily traffic is raising two to three times. The mentioned estimate is based on Croatian VTS AIS system monitoring, hence the total number of vessels passing through is probably much higher.

The predominant vessel types in the traffic structure include ro-ro passenger ships and high-speed craft (HSC) passenger liners. The traffic of cargo ships is estimated at around 500 per year in one direction. Along the central waterway, the depths are safe for navigation, varying from 10 to 40 m. There are no shallows, reefs or wrecks dangerous for navigation. On the northside of the passage is the isle of Mrduja, clearly marked with a navigation light.

The significant navigational lights from the north approach to the passage are isle of Mrduja (green flash, 3s, 14m, 4 nm), sector light on the island of Šolta (white flash (2), 5s, 11m, 8 nm) and sector light on the island of Brač (white flash, 5s, 17m, 13 nm).

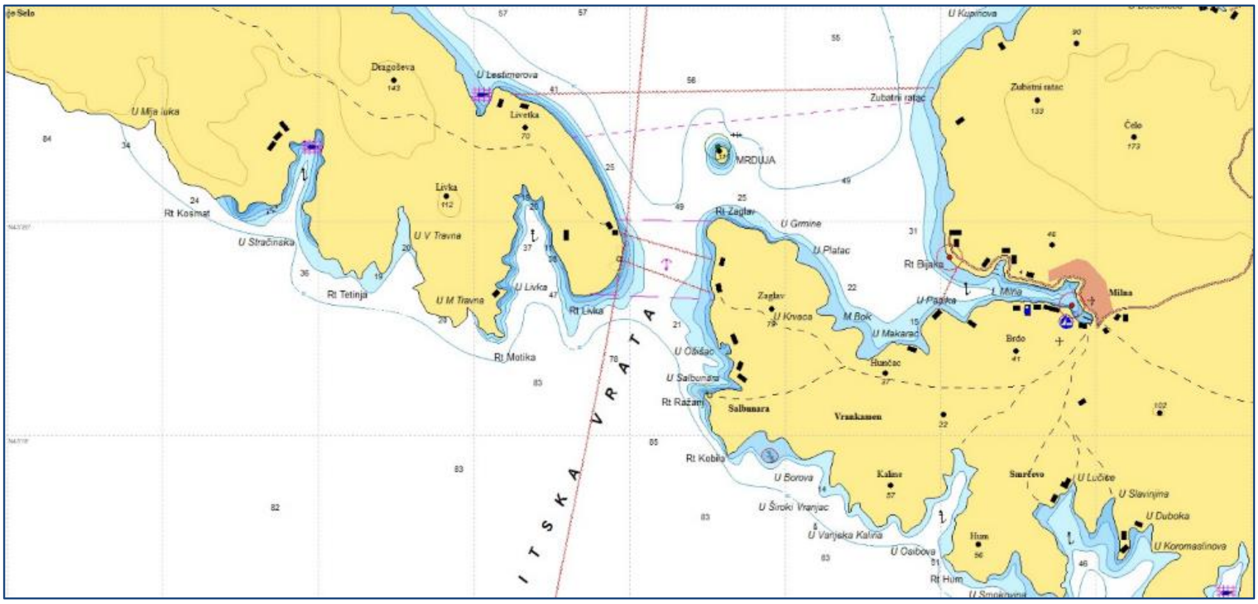

Figure 9 *Splitska Vrata* Strait

2.2.6 Open sea

The route connecting Split and Ancona lying outside the territorial seas of the Republic of Croatia and the Republic of Italy is approximately 70 nm long. While passing the area, ships are crossing the main longitudinal Adriatic waterway. The longitudinal Adriatic waterway connects the Strait of Otranto and the largest ports of the north Adriatic. The waterway through the central part of the Adriatic Sea along the northwest-southeast direction. It follows the longitudinal axis of the Adriatic Sea. The total waterway length is approximately 400 nm. This waterway, in its central part, rests between the island of Palagruža and the island of Pianosa. Close to the island Palagruža, the Republic of Croatia unilaterally established a traffic separation scheme within the boundaries of its territorial waters. The waterway divides in the North Adriatic in two directions, one towards the port of Venice (and the surrounding ports) and the other towards the port of Trieste and Koper. In the north part of the waterway a routing system, approved by the IMO, has been established.

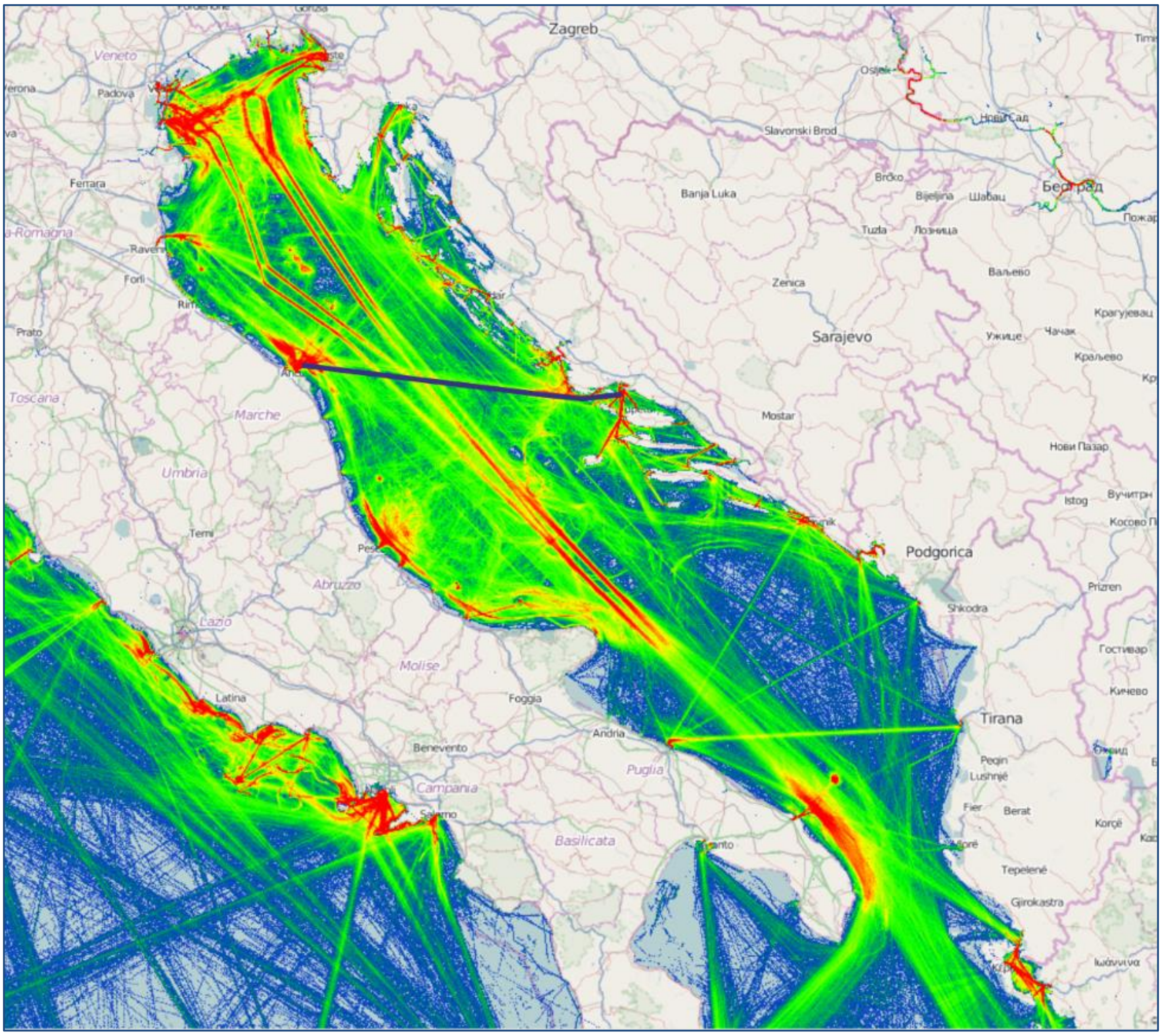

Figure 10 Main Adriatic waterways (based on AIS data) and the Split-Ancona line (blue line)

Total longitudinal waterway traffic may be estimated using the total number of ships calling the ports of the North Adriatic. According to the available data, approximately 22.000 ships annually call the most important ports of the North Adriatic accommodating ships on international voyages (Rijeka, Koper, Trieste, Venice, Monfalcone, Ravenna and Ancona). Assuming that 30-40% of the traffic are ships sailing between Adriatic ports, then the number of vessels sailing in the longitudinal waterway can be estimated at 50 to 60 ships per day. The number corresponds to the observations of the Croatian VTS.

The sailing conditions between Split and Ancona are usually favourite; there are no significant navigation hazards, depths are more than sufficient. However, due to crossing the longitudinal Adriatic waterway, there is a particular risk of collisions with head-on or crossing traffic. Also, adverse effects of inclement weather, particularly in case of strong SE winds may hinder the voyage schedules. Several platforms for gas exploitation, located in the EEZ of both states and along the route, are marked with aids to navigation.

2.2.7 Port of Ancona - approaches

While approaching or departing from the port of Ancona, ships have to follow a traffic separation scheme divided into two parts (inner and outer), both positioned within the territorial sea of the Republic of Italy. Ships arriving at the port must follow the North traffic lanes, while ships leaving the port must follow the south traffic lanes. The port of Ancona routinely accommodates cruise ships, ro-ro and ro-ro passenger vessels, different cargo ships, fishing vessels and other smaller vessels, particularly those serving nautical tourism.

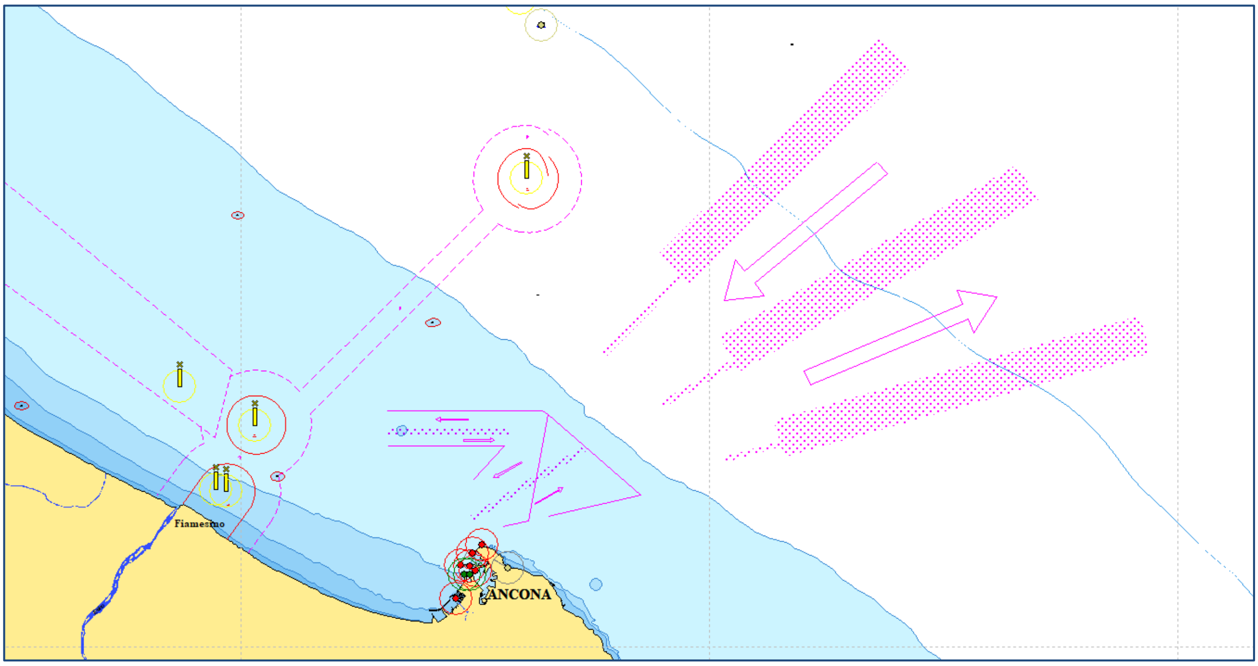

Figure 11 Port of Ancona approaches

The navigational lights used during approach are the two red port-lights, one on the quay (red flash, 1s, 5m, 3 nm), and one on the end of the north pier (red flash, 7m, 4 nm). Other important port-lights are on the very entrance to the port between the main breakwater (sector light red flash, 4s, 11m, 8 nm) and south quay “Molo sud” (green flash, 4s, 11m, 7 nm).

2.2.8 Maritime traffic

Port of Split. The total number of vessels accommodated in the port of Split is about 20.000. In 2018 altogether 20.382 arrivals were recorded, of which 18.237 were berthed in the city basin and 2.145 in the North cargo basin[7]. Ships accommodated in the city basin mostly include the local ro-ro passenger liners connecting the city with the numerous nearby islands (13.396 arrivals or 73% in 2018) and passenger ships (2.984 or 16% in 2018). The rest includes excursion ships, large cruisers, and yachts.

Table 3 Number of arrivals in the city port of Split in 2018

Vessel types	2018
National liners	13.396
International liners	243
Passenger ships	2.984
Excursion ships	1.231

During 2018, the port accommodated 5.422.589 passengers and 811.214 vehicles, which is 3% more than in the previous year, while vehicles increased by 5%. The majority of the throughput is generated by the national ro-ro passenger company Jadrolinija, counting for 3.614.059 passengers, which is 3% less than in 2017, and 769.102 vehicles which is 4% more than in 2017. The cruise ship passenger throughput in 2018 counted for 307.148 passengers, which presents a significant increase (32%) if compared to the previous year.

Table 4 Predominant cargo throughput for the port of Split in 2018

Cargo type	2018
Dry – cement (t)	904.793
Dry – grain (t)	201.259
Liquid (t)	521.191.
Ro-ro (trailers)	971.420

7 Split Port Authority, available at www.portsplit.hr

In 2018 the total cargo quantities in the port of Split was 2.998.013 tons, which is approximately 4% less than in the previous year. The predominant cargo shipped through the port of Split is cement (approximately 30%), as well as different cargo on trailers loaded/unloaded by ro-ro ships (approximately 30%), and oil and oil products (approximately 17%). The rest of the cargo includes mainly grain, scrap iron, salt, coal, wood and general cargo.

Port of Ancona. Annually approximately 4.000 vessels (cargo, liners and passenger ships) arrive in the port of Ancona (4.089 in 2017, 3.977 in 2018, and 3.819 in 2019).[8]

Passengers traffic include passengers in transit using ro-ro passenger liners (approximately 90% of the total), and passengers visiting Ancona with cruise ships (remaining 10%). The ro-ro passenger lines, with the considerable traffic of vehicles and passengers, are those connecting port of Ancona with Greece (Piraeus) and Croatia (Split and Zadar).

Table 5 Number of passengers and vehicles throughput for the port of Ancona from 2017 to 2019

No. of passengers/ vehicles	2017.	2018.	2019.
Passenger	1.090.639	1.151.266	1.189.441
Vehicles	230.463	249.671	261.547
Tir and trailers	148.660	147.650	143.874

Table 6 Predominant cargo throughput for the port of Ancona from 2017 to 2019

Cargo type	2017.	2018.	2019.
Liquid (t)	4.643.313	4.607.454	4.434.506
Dry (t)	581.810	305.619	386.948
Container (TEU)	168.372	159.061	176.193
Ro-ro (trailers)	4.706.345	4.770.397	4.693.531

8 Ancona Port Authority, available at www.porto.ancona.it

The total quantity of cargo handled in the port of Ancona is approximately 10.700.000 tons, most of which is shipped at the oil terminal (crude oil and products), with approximately 45% of the total quantity, and ro-ro terminal (trucks and trailers) also with approximately 45% of the total quantity. The rest of the cargo handled includes containers, dry and general cargo. The cargo quantities in the last few years are relatively steady, with rather small oscillations in total (1-4%). Considering cargo, the hub ports for the port of Ancona are port of Trieste and port of Goia Tauro in Italy and Piraeus in Greece.

3 METEOROLOGICAL AND OCEANOGRAPHIC FEATURES

The Adriatic Sea is a deeply indented basin of the Mediterranean Sea. The major axis is elongated in the northwest/southeast direction. It differs significantly from the rest of the Mediterranean Sea due to the sea and landmass distribution, partially protecting the Adriatic Sea from the colder air masses. Such distribution creates a relatively isolated environment with distinctive local weather. The Adriatic Sea area has substantial climatological differences between land and sea, due to different surrounding mountain chains, causing very rapid and sudden changes in weather, both in longitudinal and transverse directions.

3.1 Weather and climate conditions in the Adriatic Sea

Knowledge of the features of meteorological elements, especially wind, is essential for the safety of navigation. In the Adriatic Sea, the weather can change frequently and abruptly, causing sudden wind gusts, especially from NE (bora), SE (scirocco), or summer gale force and storms from SW, as well as the formation of associated surface waves. Such weather may substantially influence the navigation, making it difficult, particularly for smaller vessels.

Winds in the area generally depend on the distribution of baric systems, while the coastal masses in the region changes the direction and strength of winds. Although usually following similar paths, cyclones, anticyclones, and fronts generate different meteorological and oceanographic conditions.

The cyclone activity, with a clockwise direction airflow, is commonly influenced by the penetration of the Atlantic cyclones across the western Mediterranean region and Central Europe. They usually move quickly and cross the Adriatic following the east or northeast direction. The impacts of the Genoa cyclonic systems often occur as a result of the penetration of cold air masses over the Alps. The Genoa cyclone can last for several days over the Tyrrhenian Sea and the Apennine Peninsula, causing the sirocco wind to prevail on the entire Adriatic, causing undulating and heavy seas. Deepening and retention of the cyclone in the South Adriatic create strong cyclonic ("dark") bora, frequently causing cold weather and precipitations.

Anticyclones are caused by weaker airflow patterns than cyclones. Stable anticyclones are more common during the winter; they are caused by the strengthening Azores anticyclone. The weather over the entire Adriatic area, in this case, is calm or slightly windy, often accompanied by haze or fog, especially in the morning. Cold Siberian anticyclone systems frequently develop along with cyclone activity over the central and eastern Mediterranean. Such systems often cause anticyclonic ("bright") bora over the Adriatic, usually lasting for several days.

Atmospheric fronts, boundaries between different air masses, causes the rain formation influencing visibility on the waterway.

In the following subchapters, meteorological elements directly affecting the safety of maritime navigation, such as wind, waves, sea currents, tides and horizontal visibility will be elaborated. Other meteorological elements, not essential to navigational safety, will not be presented here.

3.1.1 Wind

The prevailing winds on the Adriatic Sea are bora (NNE to ENE), sirocco (ESE to SSE), mistral (WNW to NW), and westerly winds. The influence of the mainland, as well as the layout of coastal islands and channels significantly changes the direction and intensity of winds blowing in the coastal and inter-island areas.

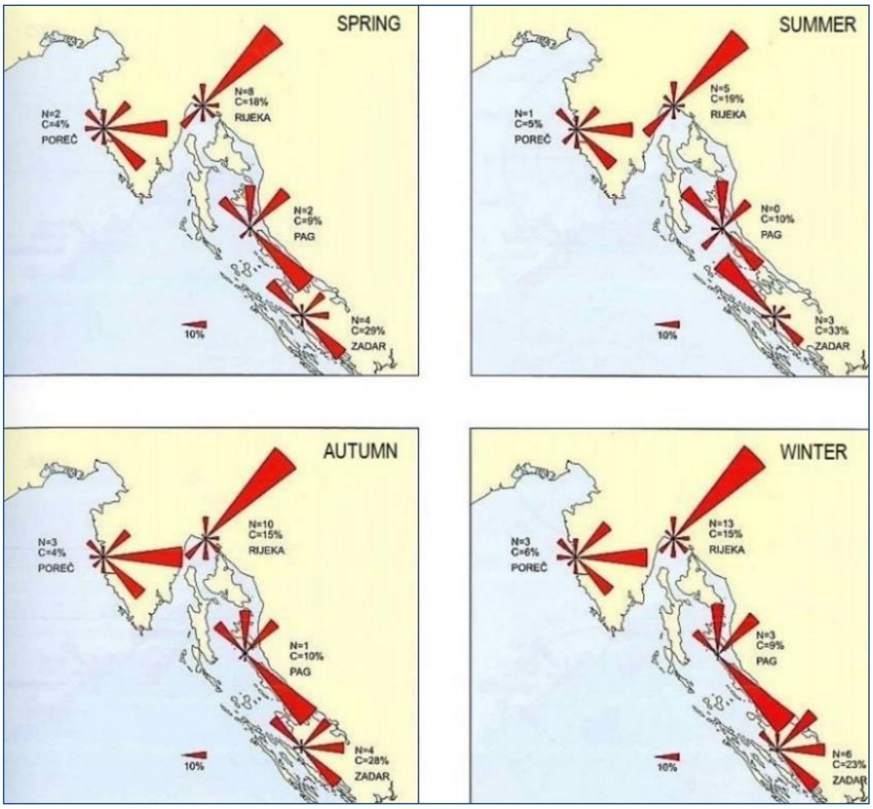

Figure 12 North Adriatic - Winds with force 8 Bf or greater (N) and occurrence of calm days (C)[9]

Along the coast, winds of 6 Beaufort scale (Bf) or more blow in average 25 to 40 days a year, but in open areas can blow more than 100 days a year. Gale-force winds (8 Bf or more) blow less frequently, usually from 2 to 10 days a year and most often from NE (bora), and less often from S (sirocco). The occurrence of northerly

9 Sailing Directions I – Adriatic Sea, Eastern Coast 5th edition 2012, corrected to 03/2020. Hydrographic institute of the Republic of Croatia

tramontana wind is also common, especially over the open sea. In the summer, the most common wind is mistral from NW, with the less frequent occurrence of the sirocco and bora compared to the winter period. From the presented wind polar diagram (Figure 12), local features of the winds can be observed, in terms of the direction and the occurrence frequencies. Such occurrence is primarily due to the landmass layout, as well as the layout of islands and inter-island channels.

Table 7 Yearly wind speed and direction distribution on the Adriatic Sea (in %)

Bf / Direction	<1	1-2	3	4	5	6	7	8	> 9	Σ
N	1,3	1,4	2,4	4,1	1,4	0,3	0,5	0,2	0,0	**11,6**
NE	0,5	0,5	1,7	1,5	3,4	2,2	1,4	0,2	0,0	**11,4**
E	0,6	0,6	1,7	2,6	1,4	0,7	0,5	0,0	0,0	**8,1**
SE	0,4	0,5	1,2	2,4	2,9	3,6	1,7	1,0	0,0	**13,7**
S	1,3	1,4	2,2	2,6	3,4	1,2	0,3	0,2	0,0	**12,6**
SW	1,8	1,8	1,5	1,4	0,9	0,3	0,3	0,0	0,0	**8,0**
W	1,8	1,8	2,2	2,9	0,7	0,3	0,2	0,0	0,0	**10,4**
NW	2,5	2,6	8,0	6,2	3,9	0,7	0,3	0,0	0,0	**24,2**
Σ	**10,2**	**10,6**	**20.9**	**23,7**	**18,0**	**9,3**	**5,2**	**1,6**	**0,3**	**100**

Bora is a katabatic wind, usually cold, with strong gusts. On the east Adriatic coast blows from the land towards the sea, from NNE to ENE directions. During gusts, wind speeds of 69 m/s at Maslenica, 59 m/s at Makarska and 54 m/s on the Krk bridge connecting the land and island of Krk, were observed. Since on the eastern Adriatic bora blows from the mainland to the sea and it has a relatively short wind fetch, bora does not create high waves (wave heights are up to 2,5 m). The short bora's fetch, being up to about 100 km, steep and frequently breaking waves occur, with periods usually between 5 and 7s[10]. Nonetheless, at 6,5 m/s or more, it causes significant amounts of seafoam.

10 Pomaro, A., Cavaleri, L., & Lionello, P. (2017). Climatology and trends of the Adriatic Sea wind waves: analysis of a 37-year long instrumental data set. International Journal of Climatology, 37(12), 4237-4250.

Generally, bora weakens away from the east Adriatic coast. However, it can reach west Adriatic coast creating strong winds, heavy rain and snow, storm surges and floods[11]. Strong bora can form distinctive jets over the offshore Adriatic from coastal areas of Trieste in Italy, and Bakar/Senj, Karlobag, and Drage in Croatia. These jets can create mostly strong or near gale, and even gale-force winds in offshore and coastal areas near Ancona. Bora jets and associated wind speeds presented on the following figure were obtained by using spaceborne Synthetic Aperture Radar (SAR)[12].

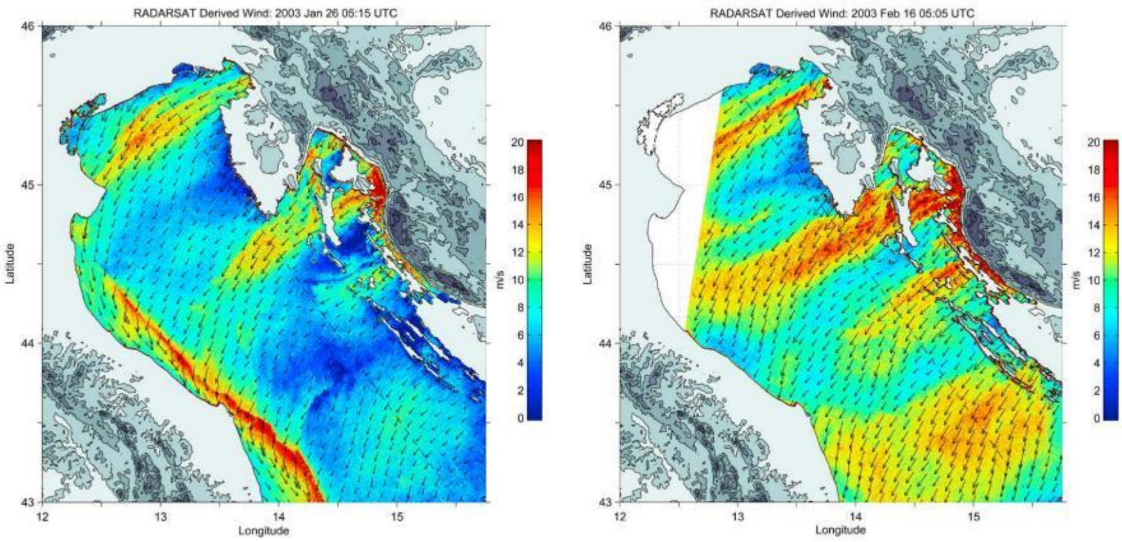

Figure 13 SAR-derived bora wind fields on 26 January 2003 (left) and 16 February 2003 (right)[12]

Besides bora, sirocco influences the safety of navigation due to the highest speeds and frequency of occurrence. Sirocco is the warm and moist wind, mainly blowing from the ESE to SSE directions. Extremely high wind speeds during the winds from south directions were measured at the island of Palagruža (57 m/s). Due to the considerably long fetch, especially from the SE direction, sirocco can create large waves. In the North Adriatic region wavelengths can reach approximately 100 m with wave heights of 10 m or over. In comparison, in the Central and South Adriatic areas wavelengths may reach approximately 80 m with wave heights over 10 m. Typical periods are between 7 and 10 s[10]. Therefore, in cases of long-lasting sirocco, navigation and vessel arrival times will be considerably affected. Usually, sirocco is developing several days until it reaches its maximum speed. Waves are generated in the South part of Otranto Strait, further developing along the Adriatic

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11 Stocchi, P., & Davolio, S. (2017). Intense air-sea exchanges and heavy orographic precipitation over Italy: the role of Adriatic Sea surface temperature uncertainty. Atmospheric Research, 196, 62-82.

12 Signell, Richard P., et al. High-resolution mapping of Bora winds in the North Adriatic Sea using synthetic aperture radar. Journal of Geophysical Research: Oceans 115.C4 (2010).

Sea, resulting in mid-range wave activity in South and Central Adriatic regions and highest significant wave heights in the North Adriatic[13].

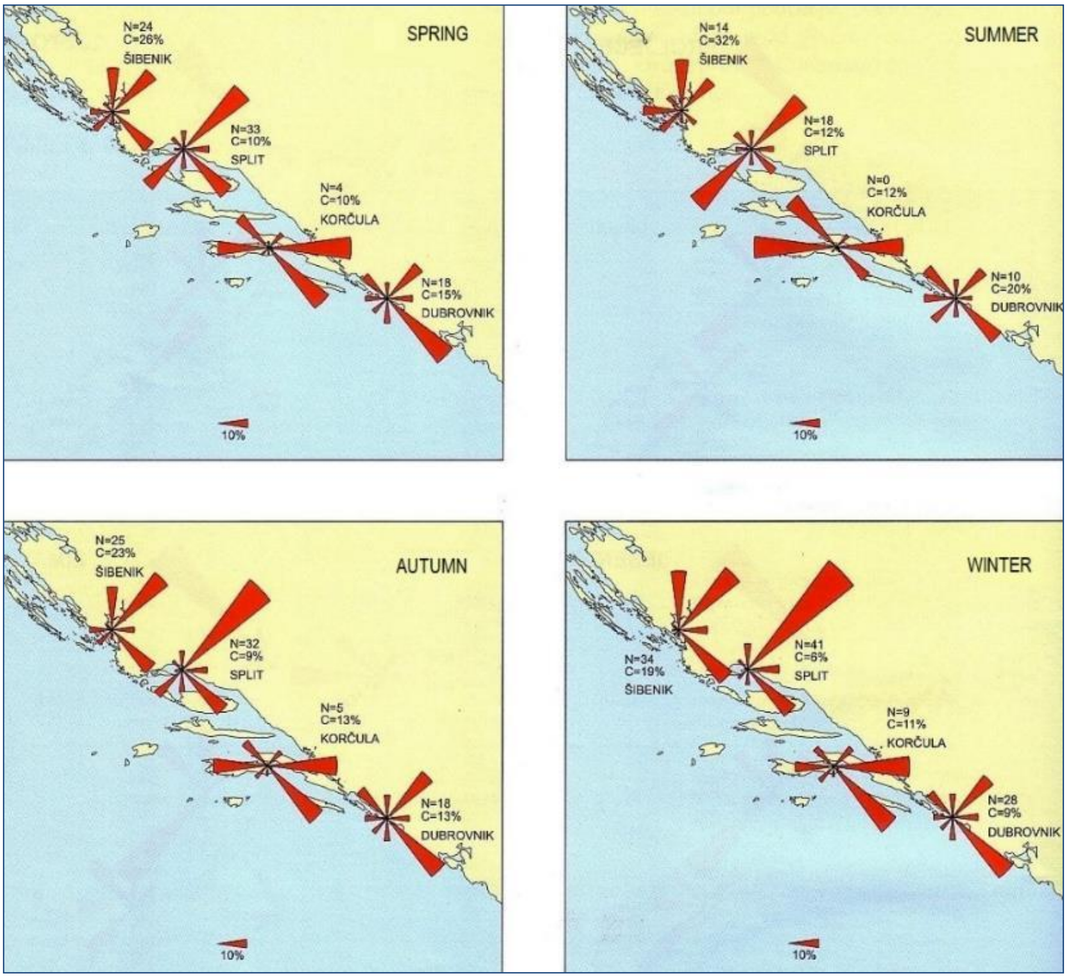

Figure 14 Central and South Adriatic - Winds with force 8 Bf or greater (N) and occurrence of calm days (C)

Besides bora and sirocco, south-westerly wind libeccio can also reach gale force. Its strength and resulting waves will generally be higher than the waves caused by the bora, but much less than the waves caused by the sirocco. It should be expected that only rarely the SW wind will impend vessel navigational safety and maritime traffic.

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13 Katalinić, M., & Parunov, J. (2018). Wave statistics in the Adriatic Sea based on 24 years of satellite measurements. Ocean engineering, 158, 378-388.

3.1.2 Waves

The sea waves are disturbances or oscillations of the sea surface, characterized by propagation direction, height, length, period and speed. They depend on the fetch length, strength and duration of the generating winds.

The main types of waves on the Adriatic Sea are wind waves caused by continuously blowing local winds. Swells are waves caused by more distant weather systems, not by local wind. They can propagate beyond the initial wind and fetch zone. Also, when a wind blowing direction changes, a new wave system develops, the so-called “cross seas” or “confused seas”. Such wave systems also form when wind and swell waves cross, as well as when wind or swell waves reflect from vertical obstacles. Wave height and propagation direction depend as well on wave reflections, refractions and diffractions on the propagation path.

Since the winds are the dominant cause of sea waves, the wind distribution also creates a correspondent distribution of waves over time, which in the case of long-term winds is crucial to the safety of navigation. The most frequent sea surface waves in the Adriatic Sea are caused by bora and sirocco in the winter period, and mistral in the summer period.

In general, significant wave heights less or equal than 1 m occur in 70% of sea states occurrences[14]. When analysing highest significant wave heights, throughout the whole Adriatic Sea, highest waves have been recorded in the North Adriatic. In general, bora wind waves are steep and with short periods while sirocco wind waves are less steep with more prolonged periods. Waves with a height of 2,4 – 3,6 m can be observed practically throughout the Adriatic with a variable occurrence probability. Higher waves of 3,7 to 6,9 m have the same spatial distribution as lower waves with approximately half the occurrence frequency. Waves with maximum heights of 6 m or above, can only be encountered in the Kvarner area during sirocco and in the Otranto Strait area during SE or S winds.

As presented, the severity of sea states in the Adriatic is much lower than in open oceans. However, sea states with significant wave heights above 5 m are considered heavy seas[15].

In the North and Central Adriatic, the wind direction is highly dependent on local topography. Therefore, the properties of the wave are considerably dependent on wind fetch area and hydrographic features. Consequently, in the observed area, the sirocco causes significantly higher wave heights than bora at the same wind speed and duration.

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14 Farkas, Andrea, Joško Parunov, and Marko Katalinić. "Wave statistics for the middle Adriatic Sea." Pomorski zbornik 52.1 (2016): 33-47.

15 Parunov, Joško, Maro Ćorak, and Marina Pensa. "Wave height statistics for seakeeping assessment of ships in the Adriatic Sea." Ocean engineering 38.11-12 (2011): 1323-1330.

In the open sea area on the North Adriatic during prolonged gale-force sirocco, the maximum wave height of H_{max} = 10,8 m was measured (with significant wave height $H_{1/3}$ = 6,0 m and mean wave period T_m = 8,5 s, with mean wavelength L_m = 112,3 m). For the periods of bora, the maximum measured wave height was 7,2 m (with significant wave height $H_{1/3}$ = 3,9 m, mean wave period T_m = 5,7 s, mean wavelength L_m = 51,3 m).

In the open sea area of the Central Adriatic, during gale-force sirocco, the height of the maximum wave of H_{max}= 8,4 m (significant wave height $H_{1/3}$ = 5,5 m, mean period T_m = 6,9 s, mean wavelength L_m = 74,9 m) was recorded. For the bora periods, the maximum measured wave height was H_{max} = 6,2 m (with significant wave height $H_{1/3}$ = 3,9 m, mean wave period T_m = 6,2 s, mean wavelength L_m = 60,3 m).

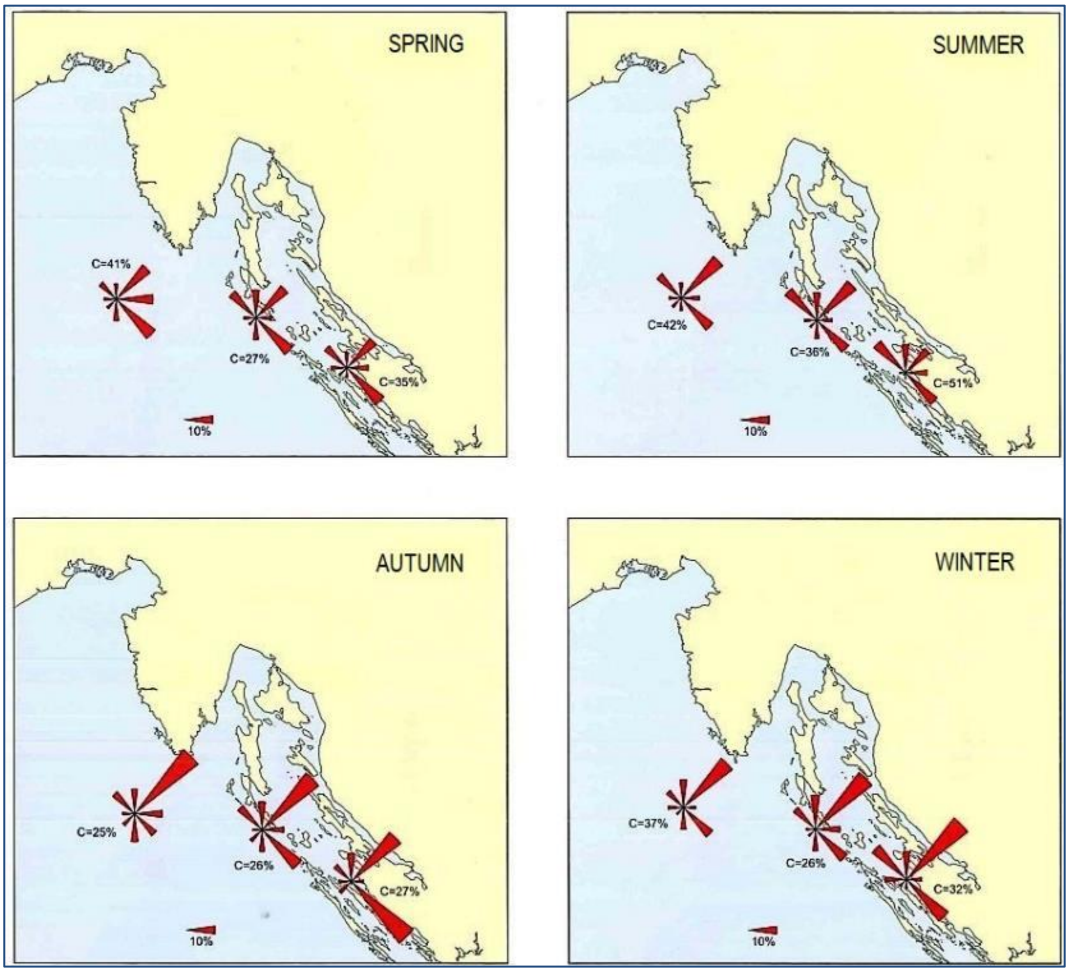


Figure 15 North Adriatic - Mean seasonal wave propagation and direction occurrences and calm seas (C)[9]

In the South Adriatic, during sirocco, the highest measured wave height was H_{max} = 8,9 m (with significant wave height $H_{1/3}$ = 6,6 m, mean period T_m = 7,0 s, mean wavelength L_m = 75,9 m). It is estimated that the characteristics of extreme sea state during the bora are very similar to those shown for the Central Adriatic.

Table 8 Wind waves parameters for North and Central Adriatic[9]

NORTH ADRIATIC								CENTRAL ADRIATIC							
SIROCCO				BORA				SIROCCO				BORA			
H_{max} (m)	$H_{1/3}$ (m)	T_m (s)	L_m (m)	H_{max} (m)	$H_{1/3}$ (m)	T_m (s)	L_m (m)	H_{max} (m)	$H_{1/3}$ (m)	T_m (s)	L_m (m)	H_{max} (m)	$H_{1/3}$ (m)	T_m (s)	Lm (m)
10.8	6.0	8.5	112	7.2	3.9	5.7	51	8.4	5.5	6.9	75	6.2	3.9	6.2	60

In the winter period in the North Adriatic region (close to Pula), dominant waves are from NE direction (approximately 27%). However, due to long wind fetch, the highest waves are expected from SE, S and SW direction. In this area, the average number of days with waves exceeding 2 m is four days per year. In the Central Adriatic region, dominant waves are from NE and SE direction with an average of three days per year with waves exceeding 2,0 m.

When observing seasonally, the incidence of waves from NE direction decreases during spring, while waves from SE and NW directions occur in the Central and South Adriatic region. During spring, the average number of days with waves exceeding 2,0 m is three days in the north and two days in the Central Adriatic. During summer, the highest frequency of waves is associated with NW direction, with 27% in the Central and 14% in the North Adriatic region. In the observed period, the average number of days with waves higher than 2,0 m is about four days per year the North and Central Adriatic region. In the autumn the predominant winds are from NE direction in the North Adriatic region. However, caused by increased synoptic disturbances over the Adriatic, the most frequent waves are from the SE direction for the Central and South Adriatic. The frequency of waves from NE direction in the North Adriatic area is 29% in the autumn while the frequency of waves from the SE direction is 28% in the area of the Central Adriatic. In autumn, on average four days per annum occur with waves of more than 2,0 m in the North and Central Adriatic region. In the South Adriatic region, such waves occur during seven days on average.

In the North and Central Adriatic region, the heights of the most common waves are in 0,5 to 1,5 m range, which is according to Douglas's scale considered as a sea state 3. Waves above 3.0 m are infrequent and are mainly from NE and SE direction.

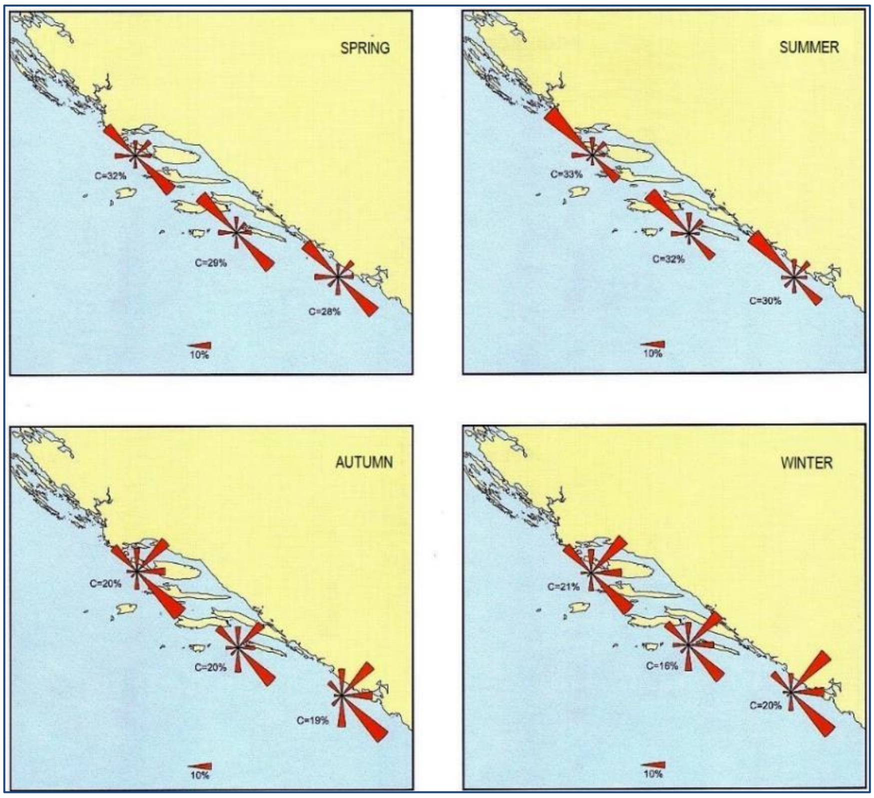
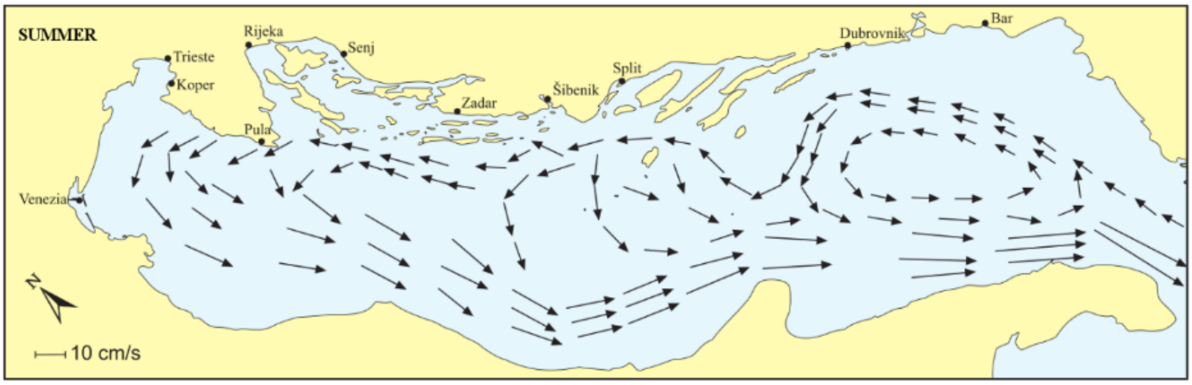


Figure 16 Central and South Adriatic - Mean wave propagation and direction occurrences and calm seas (C)[9]

To conclude, there is a limited number of days per year with sea surface waves that could significantly affect the navigational safety of referent ro-ro passenger ships in the North and Central Adriatic.

3.1.3 Sea currents

Sea currents represent the horizontal displacement of water masses. They can be classified by driving forces, depth, recurrence, seasonality or distance from the shore. Generally, according to the driving forces, currents can be divided as wind-driven currents, geostrophic currents, tidal currents and gradient currents.



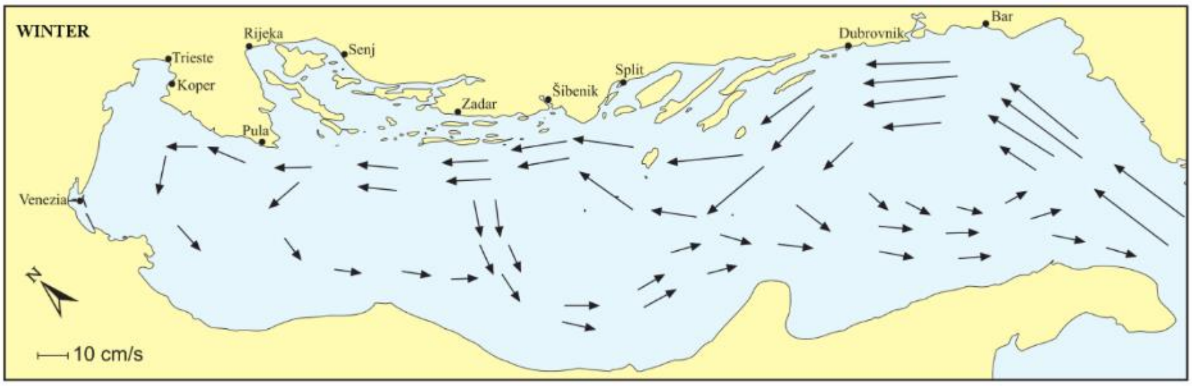


Figure 17 Prevailing currents in the Adriatic Sea[9]

Surface currents in the Adriatic do not have a significant impact on the safety of navigation in the open sea area. In the Adriatic Sea area, the currents along the east coast follow the NW direction while along the west coast follow SE direction. At several spots, currents switch from the east toward the west coast of the Adriatic (islands of Lastovo and Lošinj).

Such cyclonic flow in the Adriatic Sea prevails due to the sea density differences. The inflow of fresh water from the North Adriatic rivers influenced by Coriolis forces flow along the west coast towards Otranto strait, thus causing reverse flow along the east coast. In the area, the speed of the current usually decreases with the observed depth.

The general characteristic of the Adriatic currents is the variability in speed and direction. Current speeds change in certain areas and periods, and the mean speeds of sea currents are about 0,5 knots. Under certain conditions, especially in narrow passages and channels, the values of the current speed commonly increase. The surface sea currents of the coastal part of the eastern coast of the North and Central Adriatic, as well as in the area of inter-island channels show significant seasonal deviations in speed and direction throughout the year.

The influence of tides on the formation of currents on the Adriatic is more pronounced in the coastal areas, straits and along the eastern Adriatic coast. Such tide currents are generally cyclic, i.e. in one cycle of tides the direction changes by 360°. Wind drift currents are most pronounced when cyclones and anticyclones are governing winds over the Adriatic Sea, especially in case of prolonged gale-force winds. Only during periods of very strong boras, the surface layer can reach 3-4 knots. However, even at the relatively lower depths, it reduces to 1,5 knots. The surface current speed induced at medium and lower wind speeds does not exceed 0,5 knots.

Based on the presented, sea currents do not have a significant influence on navigation in the North and Central Adriatic.

3.1.4 Tides

Tides are periodic oscillations of sea level, mainly due to the tidal influence of the Moon and the Sun. In addition to astronomical forces, the height of the water is also affected by atmospheric pressure: at high pressures, the water height falls, and it rises during low atmospheric pressure. Furthermore, prolonged blowing of winds with a stable direction suppresses water masses, causing changes in the tidal wave parameters.

The tides of the Adriatic Sea are of mixed type with extreme inequality in height. However, during the syzygy, the tides are mostly semidiurnal type, while during quadrature they are diurnal. During transitional phases, they are of mixed type. During quadrature, tides coincide along the entire Adriatic Sea, while during syzygy there are delays, noticeably increasing clockwise along the Adriatic coast.

Tidal amplitudes increase from south to north. Mean amplitudes range from 0,22 m (port of Bar) to 0,68 m (port of Trieste). Increasing air pressure and long-lasting northerly winds (bora and tramontana) can cause sea level to decrease up to 0,60 m in the area of the North and up to 0,5 m in the central Adriatic. Oppositely, long-term southerly winds (Sirocco, Libeccio) can cause a sea-level rise of 1,5 m in the North Adriatic region, and up to 0,8 m in the Central and South Adriatic.

Tides must be monitored and considered to ensure safe berthing and accommodation. However, they do not have a critical impact on the safety of the ship underway.

3.1.5 Fog

In the Adriatic Sea area, fog occurs mostly in the winter period. It is more common in the North than in the South part, and are the most common in the Venetian Plain. In the North Adriatic region, the highest number of days with fog is in the Gulf of Trieste with over 20 days per year, and along the west coast of Istria with 10-20 days per year. In other areas of the Adriatic Sea, the probability of fog is low, and it occurs on average less than five days a year, except in the North Dalmatia and around the island of Palagruža.

Due to the low frequency in the North Adriatic region, the impact of fog on the safety of navigation is low or negligible. In the Central Adriatic, impact on the safety of navigation is estimated as negligible.

3.2 Brestova-Porozina area

3.2.1 Wind

Port of Brestova is situated on the east coast of Istra, about 1,5 nm from the entrance to Plomin Bay. Porozina is situated on the NW part of Cres island approximately 2,7 nm from Brestova. The locations are situated in Vela Vrata channel, connecting the Kvarner Bay and Bay of Rijeka.

The prevailing wind in the Kvarner area is bora. It blows from a broader range of directions. Close to the island of Cres, it blows from more northerly directions, while along the east Istrian coast it is coming from a more easterly direction.

It usually blows in the autumn and winter from November to March. The indication of bora is the formation of crownlike white clouds over Velebit mountain. The bora usually lasts 3-4 days, sometimes even more than a week.

The bora is also the strongest wind in this area with maximum wind gusts. It is strongest in winter or early spring, or somewhat more generally; in the colder part of the year. It is a gusty wind and can reach a mean hourly value of up to 30 m/s. Wind gusts of maximum speeds can significantly exceed the mean hourly values and can be up to 45 m/s. Weakening and cessation of the bora occur after the clouds from the top of Velebit are scattered. The probability of the occurrence of bora in the winter period is about 40%; in the summer period, it is about 20%. The direction and speed (strength) of the wind are very dependent on topography. For example, in the area between Plomin and Porozina in the same or similar conditions, a wind with different characteristics blows, mainly because of the channelling effect. Nevertheless, from a series of data obtained in the area, it is worth noting the regularity according to which the strength of the bora decreases going from Rijeka to Pula. In contrast, the sirocco decreases somewhat from the entrance to the Kvarner towards the Bay of Rijeka.

After bora, sirocco is a second according to the highest wind speeds and frequency in the observed area. It mainly blows from the ESE to S and for the most part in the winter months from October to March. During the sirocco, the highest waves are formed, since the Kvarner area is quite open to south-easterly winds. The sirocco also creates very rough seas. It usually blows for 2-3 days, but it can last for a whole week. An indicator of sirocco is a dark cloud cap formation over Učka mountain and fog on Osoršćica and Velebit mountains.

Significant wind in this geographical area is also a libeccio, generally blowing from SW which can also reach gale force. In summer, winds from the northwest direction prevail.

During the summer months, sudden local storms are possible. They occur as a result of local atmospheric disturbances, making them hard to predict. For the most part, these are sudden short-term gusts of south-westerly winds of sometimes storm force with speeds over 40 knots and accompanied by heavy rain.

Besides bora, sirocco and libeccio, during summer and commonly stable weather conditions, from noon to evening, mistral from NW direction blows. In general, mistral is weaker than other predominant winds. Likewise, during summer evenings and at night, close to the coast, burin can blow. It is weak wind from the mainland caused by the differences between land and sea temperatures.

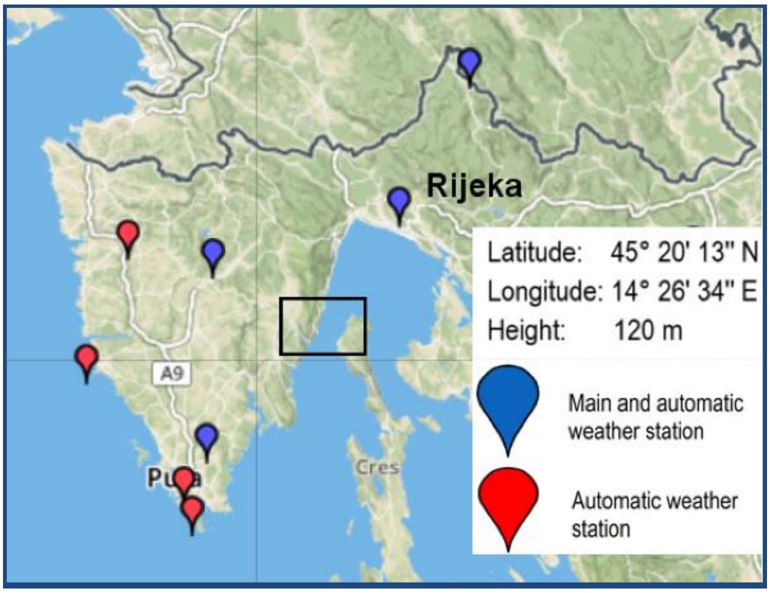


Figure 18 Locations of weather stations in proximity of Brestova-Porozina area[16]

An official weather station for the observed area is situated in Rijeka. Wind polar diagram for the Rijeka weather station with the occurrence frequency in 8 directions (in ‰) and mean wind speed in Beaufort scale, by months and for the year is presented in Figure 19. The data presented are collected at the weather station Rijeka at 07, 14 and 21 h CET (28 years data series, source: Rijeka-Kozala, weather station).

16 Croatian Meteorological and Hydrological Service: Surface meteorological stations - Main and automatic stations, available at www.meteo.hr

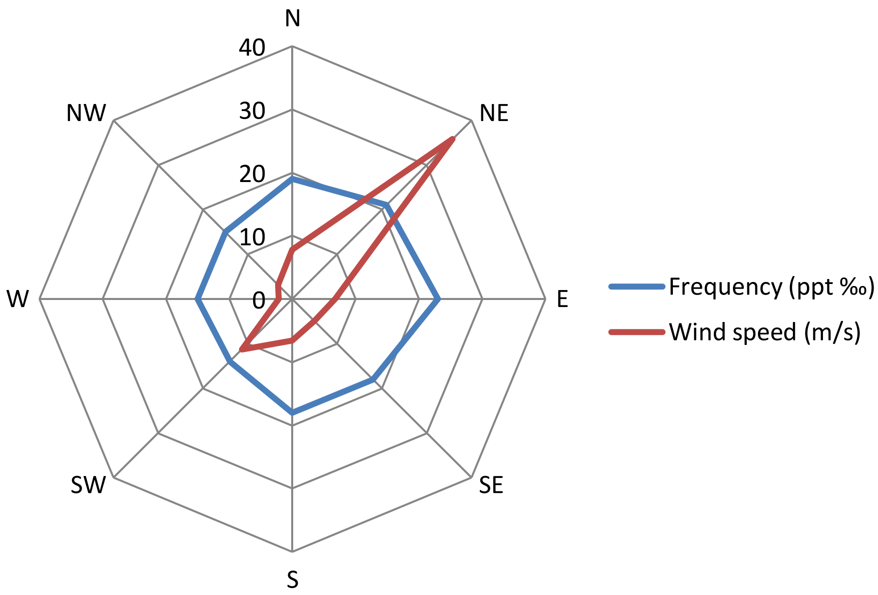


Figure 19 Annual wind polar diagram for weather station Rijeka[17]

The occurrence of calms ranges from 1,6% to 3,1% with an annual average of 2,2%. During the summer months in 80% of cases, the prevailing wind speed is between 0,3 and 3,3 m/s. During the winter months, winds of this speed range can be expected in 65% of cases.

Table 9 Number of days with strong (6 Bf or larger) and gale-force wind (8 Bf or larger) for Rijeka weather station

Days/month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Yearly
With strong wind	4	4	4	3	2	2	2	2	3	4	4	4	**38**
With gale force winds	1	1	1	0	0	0	0	0	1	0	1	1	**6**

The accompanying table shows the number of days with strong (6 Bf and above) and gale force winds (8 Bf and above) per month and year. Tables are derived from 28 annual series. Value of 0 in gale force winds means that the number of days in a month with gale-force winds is less than 0,5.

[17] The data is obtained from daily climatological meteorological observations at the weather station Rijeka at 07, 14 and 21 h CET, in 28 years. (Source: Rijeka-Kozala, weather station.

3.2.2 Waves

In the Kvarner area, waves from southerly directions with maximum heights of 7-9,1 m can be expected. In the vicinity, south from the entrance to the Kvarner Bay, 10,8 m wave was observed from the oil platform *Panon*.

The length of the waves induced by sirocco winds in the Kvarner area may range from 20 to 30 m, depending on the wind direction and strength. The maximum length has been produced by waves from the SW direction. When the wind stops blowing, the waves in the Kvarner and the Bay of Rijeka areas calm somewhat slowly, due to long wind fetch and steep and high coasts. Therefore, swelling occurs for a while.

Waves from W and NW winds can be expected to reach heights of up to 1 m. These winds in the North Adriatic are weak, and the waves they cause cannot reach more noticeable heights. In the Kvarner, the highest waves are expected during the prolonged blowing of the gale-force sirocco or oštro. The waves in the Kvarner area are affected by a partially limited wind fetch, particularly for waves from the east directions. The bora and levant can develop waves of up to 2,9 m height, while libeccio can develop waves up to 3,2 m.

The highest waves in the Bay of Rijeka are the waves of the sirocco. The wind fetch is open from S and SW (Mala and Vela Vrata channels). The waves coming from these areas change direction from SE to SW and can be expected to reach 3,5 m in height. Consequently, in Vela Vrata area, most significant waves could occur from NE and SW directions and reach approximate heights as in the Kvarner area.

3.2.3 Sea currents

Sea currents, together with wind and waves, influence the ship's motion and therefore safety of navigation. In the Kvarner area and Bay of Rijeka, the currents follow the general circulation patterns with speed up to 0,5 knots. Most of the time, they follow a counter-clockwise pattern.

The Adriatic Sea current enters in the Bay of Rijeka between the island of Sv. Marko and mainland, and to a lesser extent between the islands of Krk and Sv. Marko and between the island of Cres and Krk. The current exits throughout the Vela Vrata strait, usually with higher speeds close to the coastal part of Istria.

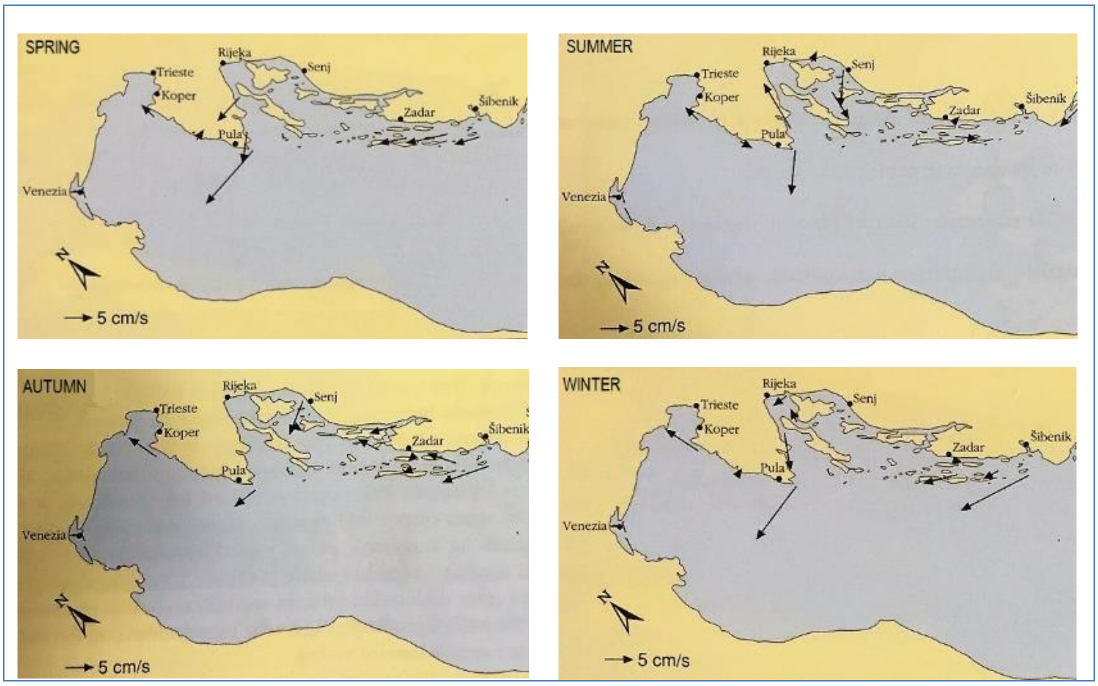


Figure 20 Seasonal distribution of sea surface currents in coastal areas of the east coast of North and Central Adriatic

Generally, it is assessed that the currents do not impact the safety of navigation of ro-ro passenger ferries between Brestova and Porozina

3.2.4 Tides

Tides in the Kvarner Bay and Vela Vrata area are similar to those in open sea areas of the Adriatic Sea. Only during prolonged sirocco, sea level may increase compared to the open sea area. Also, during prolonged and forceful boras, the sea level can decrease more than in the open sea. In both cases, the sea level is relatively easily predictable.

Therefore, tides will not affect maritime traffic in the Kvarner, Vela Vrata or Bay of Rijeka areas.

3.2.5 Fog

Fog in the area is rather seldom. In the Kvarner region, it can reduce visibility for up to an average of 8 days a year. In the Bay of Rijeka, fog can be expected an average of up to 6 days a year.

3.3 Split area

3.3.1 Wind

This subchapter deals with meteorological and oceanographic features along the route between Split and Ancona.

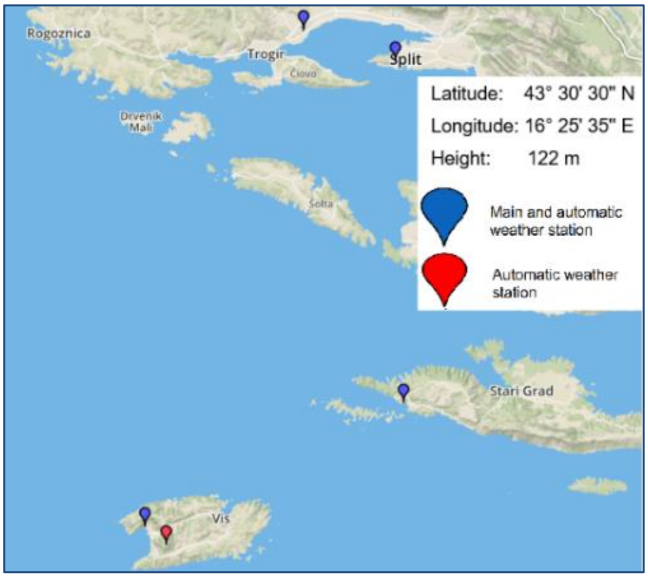


Figure 21 Locations of weather stations in proximity of Split area[16]

Split is situated in the Central Adriatic, and it is the largest port in the Dalmatia region. It is situated on a peninsula and with the island of Čiovo encloses Kaštela Bay. In the immediate hinterland, Mosor (1.339 m) and Kozjak (780 m) mountains are located. Dinaride mountain range extends in a west-east direction and coincides with the layout of islands and canals in this area. Access to the port of Split is through waterways of Drvenički, Šoltanski and Brač channels and Splitska Vrata strait. As in other Adriatic regions, the wind features are strongly dependent on local characteristics and orography.

In the area close to the port of Split, the dominant winds are bora and sirocco. The occurrence of bora and sirocco differs for at different stations as it can be observed in the following figures. Bora occurs more frequently in Split, dominantly in the winter.

Table 10 Average number of days with bora in cold and warm periods of the year

Station	Yearly	Winter	Summer	Percentage of the annual sum	
				Winter	Summer
Split	147,6	97,3	50,3	66	34
Hvar	37,4	27,9	9,6	74	26
Palagruža	54,4	41,7	12,7	77	23
Lastovo	54,2	44,5	9,7	82	18

Table 11 Average number of days with sirocco in cold and warm periods of the year

Station	Yearly	Winter	Summer	Percentage of the annual sum	
				Winter	Summer
Split	135,2	86,5	48,7	64	36
Hvar	107,2	70,0	37,2	65	35
Palagruža	104,5	71,8	32,7	69	31
Lastovo	98,7	69,9	28,8	71	29

The frequency of sirocco is slightly lower than the respective values for bora during the winter period and almost equal in the summer period. It can be seen that the total number of days with sirocco is higher than the respective values for bora.

The dominant winds by frequency and mean speeds are from NNE and ESE directions. However, WSW and SW winds can also cause higher waves, and occur more frequently in spring and summer.

Following wind polar diagrams and relevant wind data for the port of Split were obtained from the Croatian Meteorological and Hydrological Service wind climate data, collected in the period from 1966 to 2005 at the weather station Split, at the Marjan (height of 122 m).

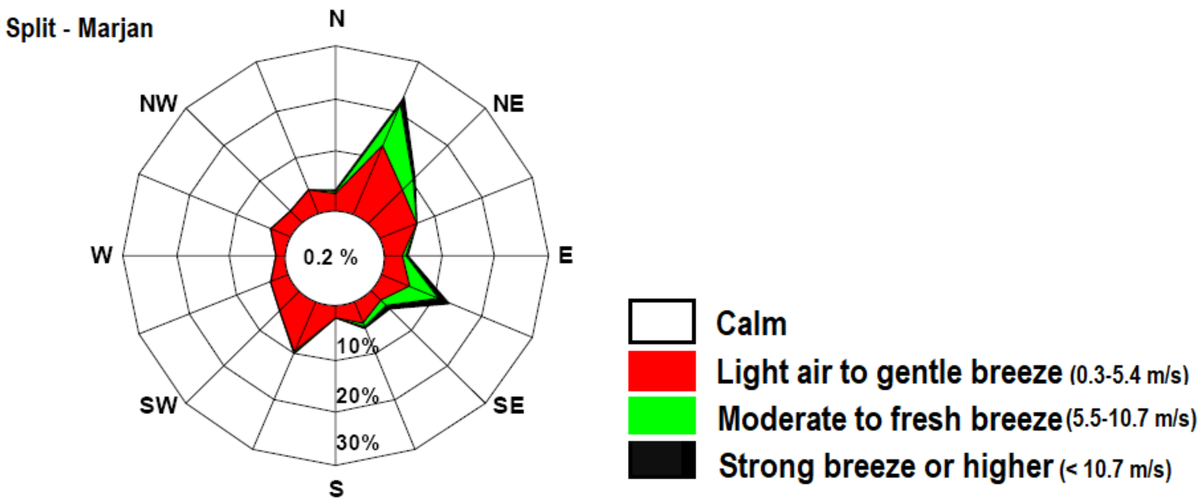


Figure 22 Wind polar diagram for the period from 1966 to 2005 for Split - Marjan weather station

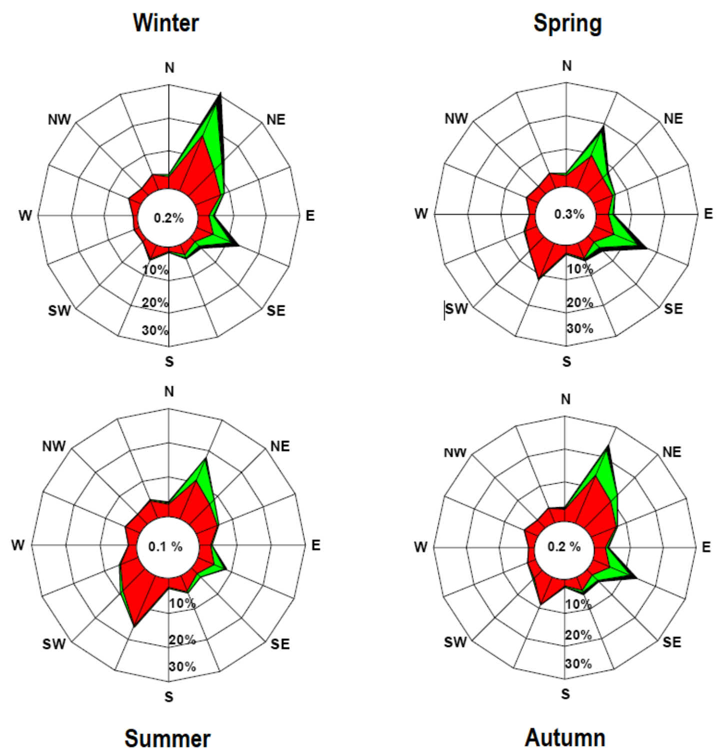


Figure 23 Seasonal wind polar diagrams for the period from 1966 to 2005 for Split - Marjan weather station

Some more recent observation and analysis of climatological elements were carried out for the period from 2003 to 2012 for the port of Split. In the observed period in the port of Split, strong winds (≥ 10,7 m/s) were most frequent from ENE direction. Also, on the average, there were 86,6 days with winds ≥ 6 Bf and 11,9 days with winds of ≥ 8 Bf.[18]

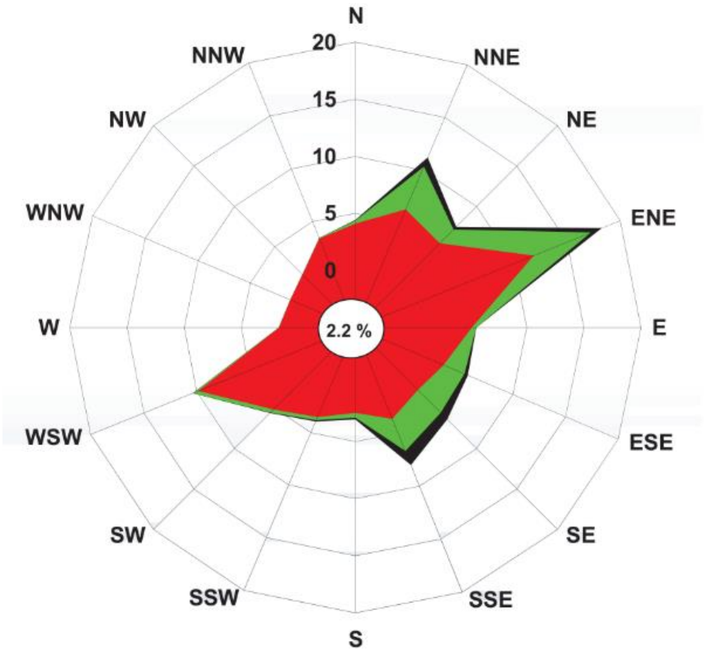


Figure 24 Wind polar diagram for the Split area in the period from 2003 to 2012[18]

As can been seen, in the observed period, there were more days with strong wind during autumn and winter compared with spring and summer. It is also observed for gale-force winds.

Table 12 Days with breeze and gale force winds for the port of Split from 2003 to 2012[18]

Days/month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Tot.	Aver.
Strong wind (≥ 6 Bf)	97	105	101	68	49	23	27	32	47	84	104	131	**868**	**86.8**
Gale force winds (≥ 8 Bf)	13	20	20	10	4	2	2	1	4	5	15	23	**119**	**11.9**

18 Popović, Ružica, Mirsad Kulović, and Tatjana Stanivuk. Meteorological Safety of Entering Eastern Adriatic Ports. Transactions on maritime science 3.01 (2014): 53-60.

3.3.2 Waves

The deep-water area is an area consisting of an area outside the port (between the mainland and island of Šolta and island of Brač) and city port basin. The area is open for the waves coming from the II and III quadrants in 5 sectors delineated by the wave directions. The first sector is for ESE and SE direction, second SSE and S, third for SSW, fourth SW and fifth for WSW.

The waves are derived by using Groen - Dorrenstein method based on wind data input and the length of the wind fetch for each sector. The predicted values of significant wave heights were obtained at the location in front of the entrance to the Split city port basin and are presented in the following table.

Table 13 Significant deep-water wave heights (Hs) for different recurrence periods (RP) in front of the Split city basin

RP	ESE-SE sector			SSE-S sector			SSW sector			SW sector			WSW sector		
	H_s	T_m	T_p	H_s	T_m	T_p	H_s	T_m	T_p	H_s	T_m	T_p	H_s	T_m	T_p
100	3,6	7,0	8,4	3	6,4	7,7	2,8	6,2	7,4	2	5,2	6,3	1,7	4,8	5,8
50	3,4	6,8	8,2	2,8	6,2	7,4	2,7	6,1	7,3	1,8	5,0	6,0	1,5	4,5	5,4
20	3,2	6,6	8,0	2,6	6,0	7,2	2,4	5,7	6,9	1,6	4,7	5,6	1,3	4,2	5,1
10	3,1	6,5	7,8	2,4	5,7	6,9	2,3	5,6	6,7	1,4	4,4	5,3	1,1	3,9	4,7
5	2,9	6,3	7,6	2,3	5,6	6,7	2,1	5,4	6,4	1,2	4,1	4,9	1,0	3,7	4,4

RP – Recurrence period (years); H_s – Significant wave height (m); T_m – Mean period (s); T_p – Peak period (s)

The distribution of wave heights inside the city port basin for the S, SE and SW directions was numerically modelled with existing port structures and for a recurrence period of 100 years. The determined reference value of the maximum significant wave height H_{smax} was 1,30 m, positioned directly in front of the St. Duje pier.

This reference maximum significant wave height is the result of the action of the incoming deep-water wave from the southerly directions and recurrence period of 100 years, with significant wave height H_s = 3,60 m and peak wave period T_p = 7,70 s.

3.3.3 Sea currents

Sea currents in the port of Split are influenced by the general Adriatic Sea currents, flowing along the eastern Adriatic coast in SE – NW direction. They are also influenced by tidal currents and local conditions caused by morphology, temperature and wind.

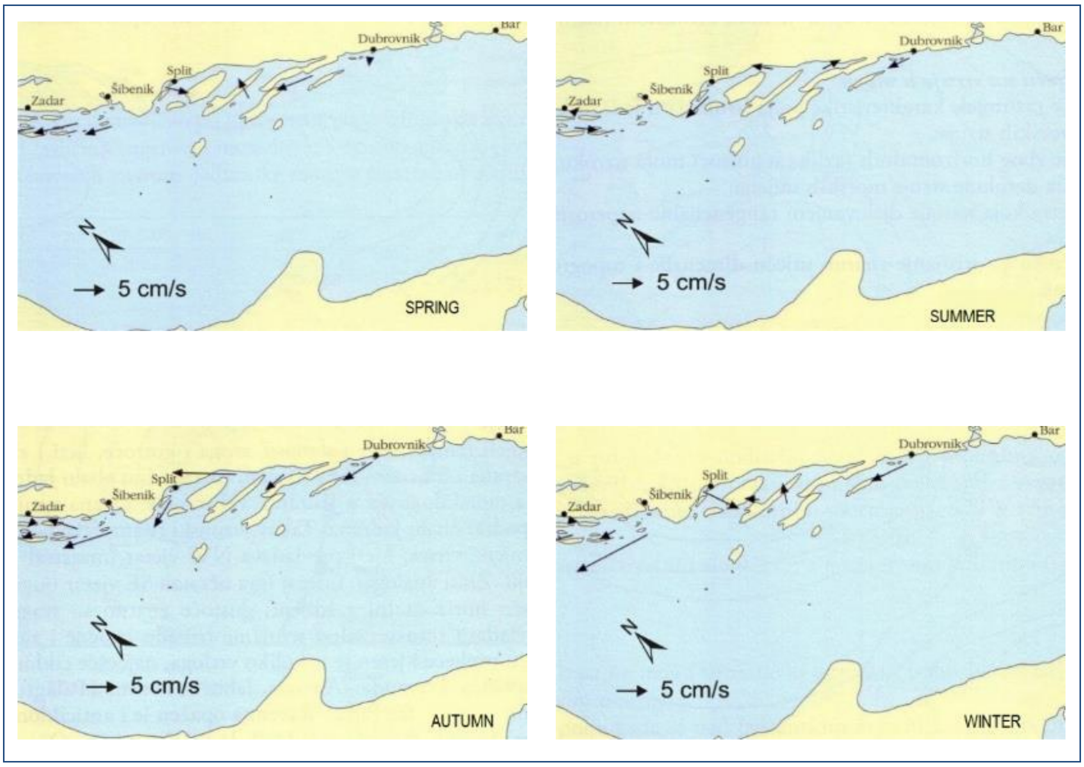


Figure 25 Seasonal distribution of sea surface currents in coastal areas of the east coast of Central and South Adriatic

At the entrance to the port of Split, the speeds of sea currents range from 0,1 to 0,4 knots. Consequently, these sea currents can be considered modest, with low impact on the level of maritime safety.

3.3.4 Tides

In the port of Split, the tide measuring device is installed (mareograph). Therefore, sea-level data for the port and nearby areas are highly reliable. Concerning the Tide Gauge Datum, the height of the Ordnance Datum for the port of Split is + 28 cm and the height of Chart Datum + 40 cm. Characteristic sea level values relative to Ordnance Datum and concerning Chart Datum are shown in the following table.

Table 14 Sea level values (in meters) for the port of Split

Relative to Ordnance Datum	Level	Relative to Chart Datum
1,20	Highest observed	**1,08**
0,49	Mean Higher High Water (MHHW)	**0,37**
0,31	Mean Sea Level	**0,19**
0,12	Chart Datum	**0,00**
0,00	Ordnance Datum	**- 0,12**
- 0,28	Tide Gauge Datum	**- 0,40**
- 0,33	Lowest observed	**- 0,45**

Based on presented data, water heights can be calculated for the long return period as shown in Table 15.

Table 15 Maximum water heights in Split city port basin (long-term return periods)

Return period in years	Highest High Water above Mean Sea Level (cm)
10	88,6
20	91,3
50	94,0
100	96,6

The mean amplitudes of tides are relatively small, ranging from 0,2 to 0,5 meters. During prolonged sirocco, the sea levels can increase and reach up to 0,6 m, while anticyclonic bora can reduce it by 0,3 m.

3.3.5 Fog

Horizontal visibility is affected by the time of day, precipitation and fog. Visibility can be significantly reduced by heavy rain, hail or snow. In the summer season, heavy rain during local storms, can significantly reduce visibility and cause manoeuvring delays.

Table 16 Days with fog in Port of Split from 2003 to 2012[18]

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total	Average
Days with fog	2	3	5	5	-	-	1	-	-	2	2	1	**21**	**2.1**

In the port of Split, it occurs on average two days per year, mostly in autumn and winter. The records of fog in the period from 2003 to 2012 confirmed the long-term average of 2 days[18].

3.4 Ancona area

3.4.1 Wind

The port of Ancona is located in the Marche Region of western Central Adriatic coast of Italy. The city is surrounded by slopes of promontory of Monte Conero, Monte Astagno and Monte Guasco. The weather station is located near S.Primiano dock - North wharf. The following wind analysis is based on hourly observations and presents results for the three years, from 2011 to 2014.

It can be noted that the significant winds are quite different if compared with winds recorded at sites along the east Adriatic coastal area.

The significant wind directions are from 3rd (from SE to SSE) and 4th quadrant (SW to WSW). Most occurring are moderate winds varying from 2-6 m/s (2-4 Beaufort scale), while stronger winds occur significantly less frequently. Calms occur approximately 3,6% of the time throughout a year.

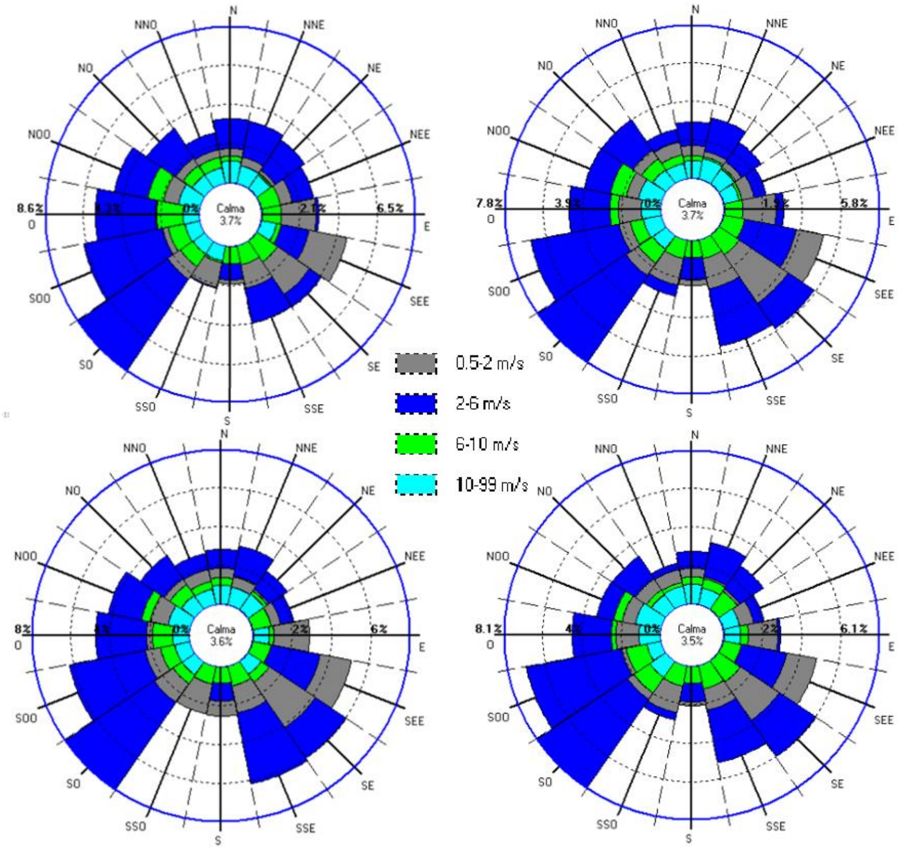


Figure 26 Annual wind polar diagram for the port of Ancona from 2011 to 2014 (hourly observations)[19]

3.4.2 Waves

Wave directions were recorded from 1999 to 2006 from a wave recording buoy situated offshore the port of Ancona. The significant wave directions are from SE (occurring in 20% of the time) and NE (occurring in 16% of the time). These directions correspond to the significant wind directions and storms of sirocco and bora. In most cases, the significant wave heights were between 0,25 m and 2 m (in 80% of the time). More massive waves occurred in significantly fewer cases, so waves higher than 2 m were recorded only in 10% of the time[20].

19 ISPRA – Istituto Superiore per la Protezione e la Ricerca Ambientale - The National Tidegauge Network data/analysis archive, available at: https://www.mareografico.it

20 Grottoli, E., & Ciavola, P. (2019). The role of detailed geomorphic variability in the vulnerability assessment of potential oil spill events on mixed sand and gravel beaches: the cases of two Adriatic sites. Frontiers in Earth Science, 7, 242.

3.4.3 Tides

The tidal rise is slight, being only 0,5 m during spring. The bora, a strong NE to N wind, may increase the height of the water level by as much as 0,9 m[21].

Recorded data of tidal levels from national tide gauge network in the period from 2011 to 2016 are presented in the following figure.

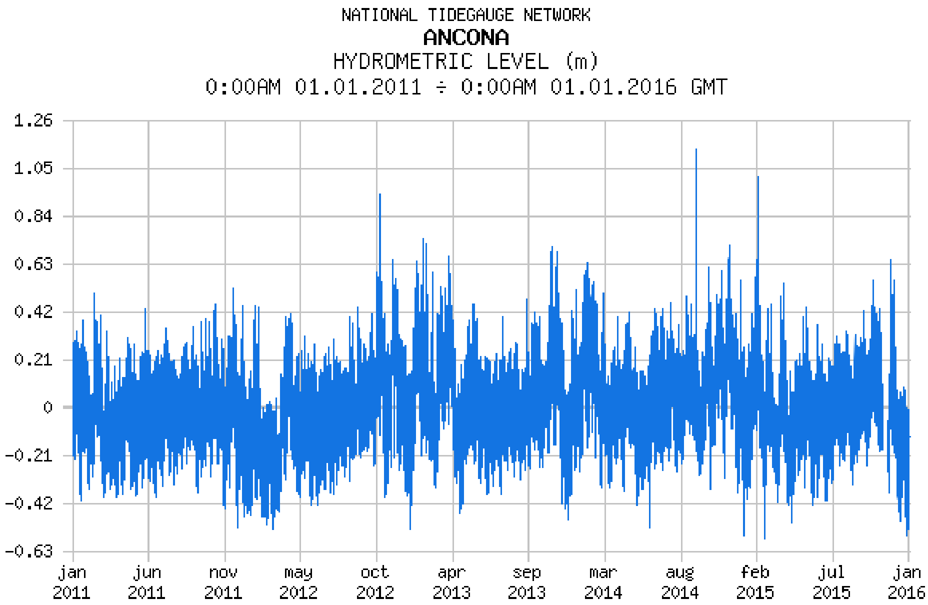


Figure 27 Tidal ranges in the port of Ancona

The average tidal oscillations are in the 0,5 m range. There are several occurrences of extreme values (approximately 1m). However, oscillations above 0,6 m are rather seldom.

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21 Sailing Directions Western Mediterranean (Enroute), corrected to NTM No. 5 of 2020, National Geospatial-Intelligence Agency, Springfield, Virginia, 2017.

4 MEASURES TO INCREASE THE SAFETY OF NAVIGATION

Measures to improve the safety of navigation may include the proposals to change the existing regulations in respect of the safety of navigation and environmental protection or proposals to add, change or improve the existing technical, technological or infrastructural elements in a particular navigational area.

Furthermore, the measures may be divided into two different groups:

- general measures applicable to any navigational area, i.e. applicable to the whole navigational safety system of a particular state (The Republic of Croatia or the Republic of Italy)
- dedicated measures applicable only within a clearly defined navigational area.

Throughout this Report, the possibility and justification to introduce a novel ro-ro passenger ship with electrified propulsion system is analysed in detail, considering different aspects, only for two selected ro-ro passenger lines. Likewise, the level of safety of navigation is analysed in detail for navigational areas used by the respective ro-ro passenger lines. Consequently, for this Project, the safety analysis does not include any general measures or proposals to change the existing statutory regulations of the project partner States. The analysis includes the measures applicable or justified only within the navigational area of the selected ro-ro passenger lines. The navigational area is considered as an area consisting of the part of the open sea, port approaches and manoeuvring areas, as well as ship-berth interface.

4.1 Brestova-Porozina

The Vela Vrata strait is the main waterway for larger ships to the ports and terminals of the Gulf of Rijeka. It is the waterway with the densest traffic in the North Adriatic, within the Croatian waters. In the strait, a mandatory traffic separation scheme has been established. Each traffic lane is 0,7 nm wide. The traffic of ro-ro passenger ships on the regular Brestova-Porozina line crosses the traffic separation scheme, that is, the main navigational route, at a right angle. Thus, the area is classified as an area with frequent maritime traffic crossings. The vessels following the main routes (north-bound or south-bound) do not need to change the navigational course significantly. During the summer season, maritime traffic is further increased by the passenger and leisure vessels often sailing in the inshore traffic zone.

According to Croatian legislation (The Order on navigation in the passage to Šibenik harbour, in the Pašman Strait, through the passage of Vela Vrata … NN 9/07, 104/16, 53/19), the navigation in Vela Vrata passage is arranged as follows:

- Navigation must be carried out according to Rule 10 of the International Regulations for Preventing Collisions at Sea and Article 13 of the Regulation for the safety of navigation in internal waters and territorial sea of the Republic of Croatia (Official gazette NN 79/13, 140/14).

– A ship and a yacht of 20 meters in length or more must use the separation lane of the separation scheme, by following the main waterway and navigating in the right separation lane.
– A fishing vessel can fish in the area of the Vela Vrata strait, but it must give way to the ship following the general direction of navigation.

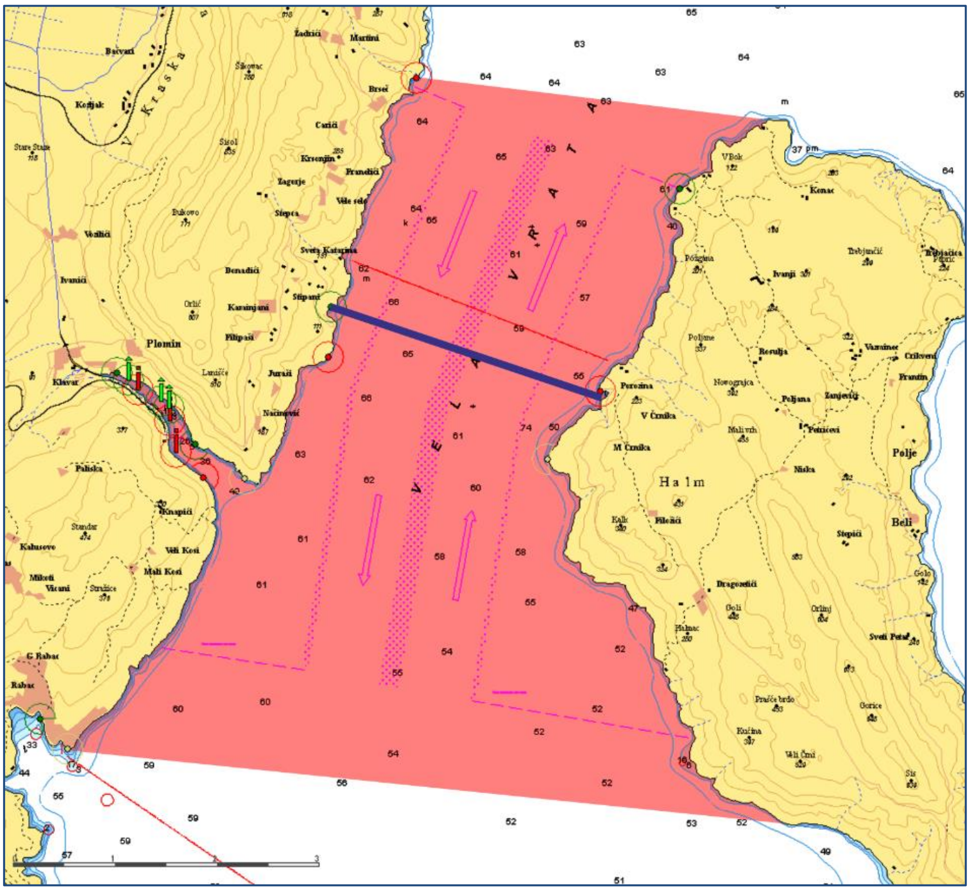

Figure 28 Vela Vrata strait and Brestova-Porozina ro-ro passenger line

According to the Croatian Regulation on maritime pilotage, the vessels of 40.000 BT or more carrying dangerous cargo in a liquid state (tankers carrying liquid cargo listed in Annex II of MARPOL Convention, oil tankers and liquified gas carriers), calling at the port of Rijeka, are required to embark the pilot while sailing through the Vela Vrata strait. The pilot station, for the listed ships, is approximately 10 nm south of the entrance to the Vela Vrata. The aids to navigation, covering the waterway, are satisfactory in the Adriatic area, as well as in the Kvarner area. They are considered as excellent in the Vela Vrata strait, i.e. in the area of the Brestova-Porozina line.

Outside port areas, the depths are varying between 50 and 65 m. There are no dangerous areas, such as reefs, wrecks, shallow areas, etc.

Consequently, the route between the ports is maintained in an area with no recognized hazards.

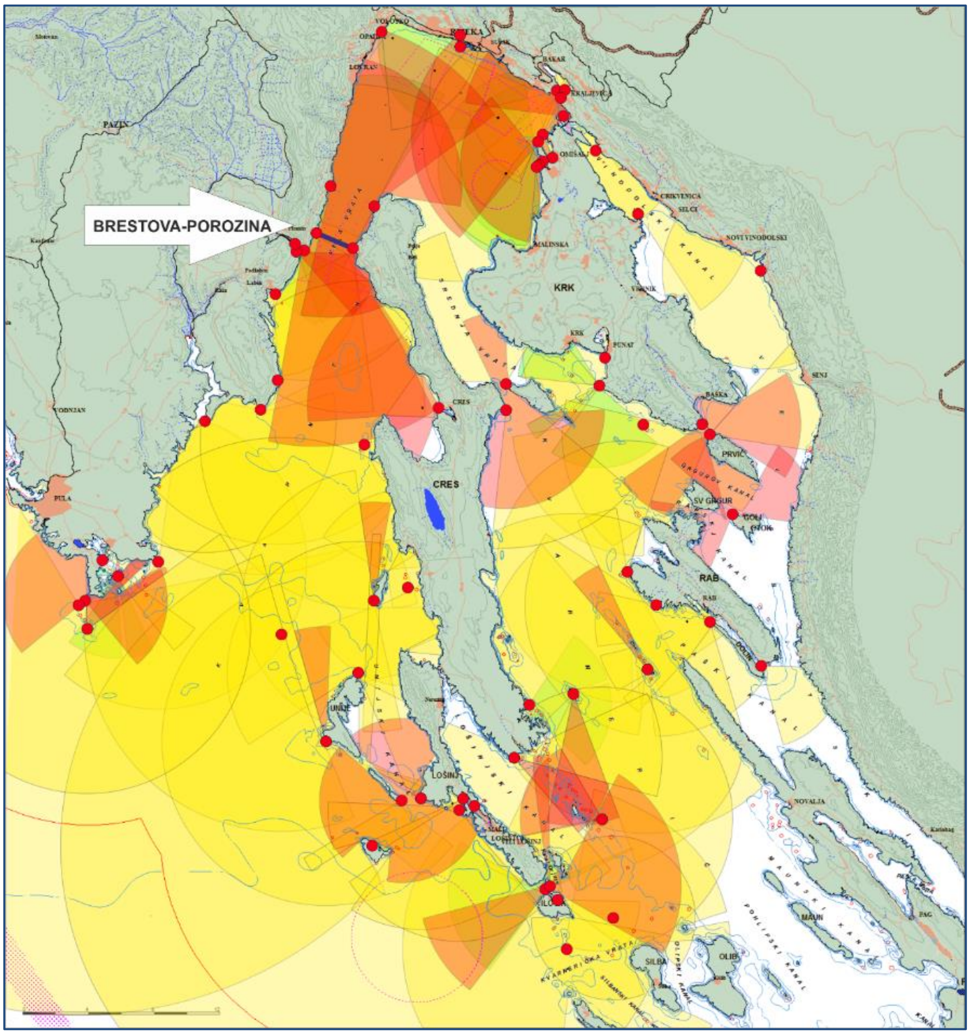

Figure 29 Navigational lights coverage – port of Rijeka area (light range > 5M)

The Croatian Vessel Traffic Service (VTS) started to provide services in 2015. Areas monitored and managed by Croatian VTS are divided into several sectors, as follows:

- Sector A (EEZ area),
- Sector B (territorial sea),
- six management sectors (internal waters) and
- seven manoeuvring sectors (port areas).

The relevant navigational area, Vela Vrata strait, is a part of the VTS management sector Rijeka, where the Croatian VTS provides Information Service (IS) and Traffic Organization Service (TOS). The area is continuously monitored by the radar and automatic identification system (AIS) network. All ships calling the port of Rijeka and passing through the Vela Vrata strait must report to the Croatian VTS on entering or leaving a specific sector. The communication of ships in manoeuvring sector Rijeka is maintained on VHF channels 14 or 62.

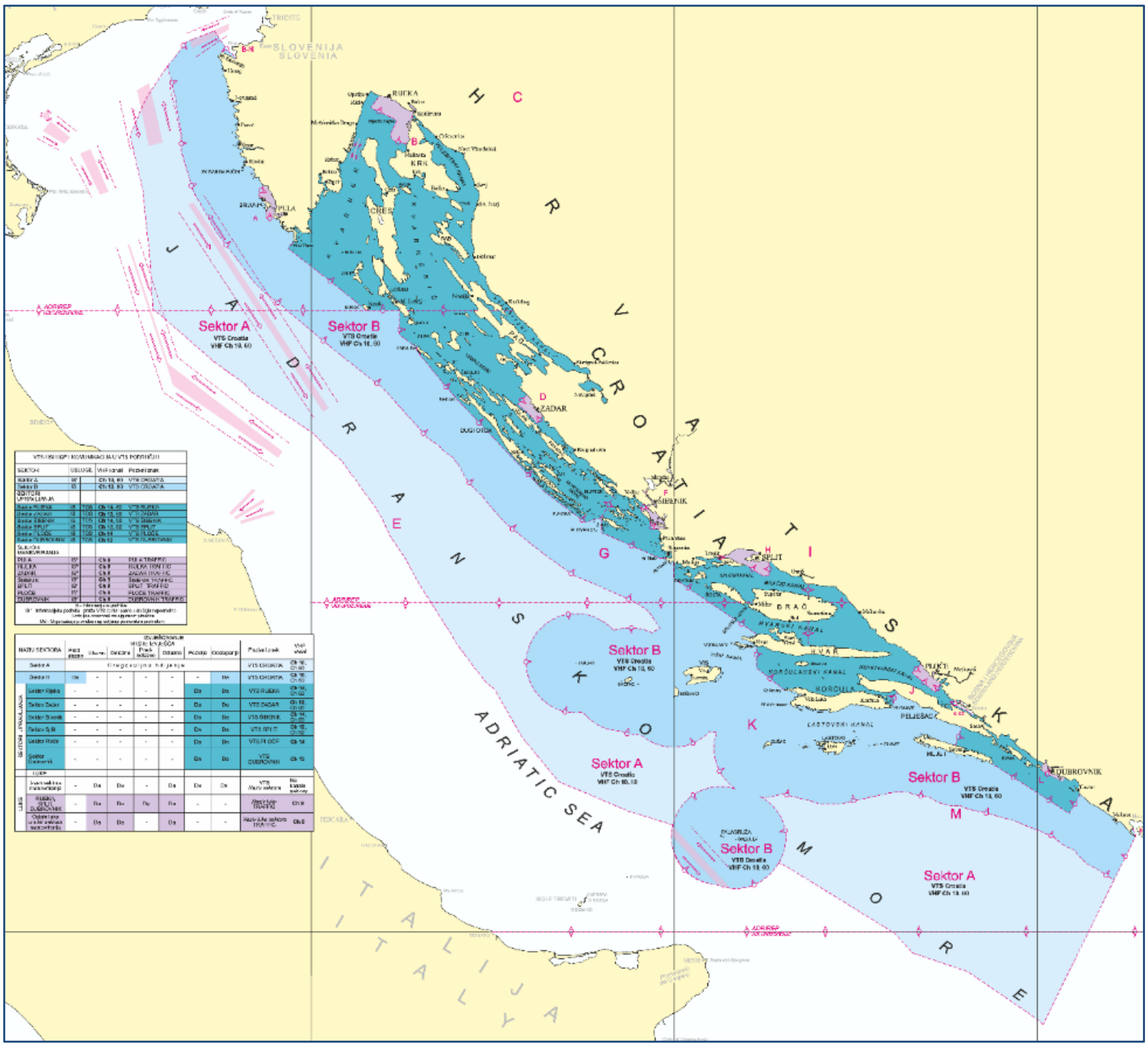

Figure 30 Croatian VTS sectors

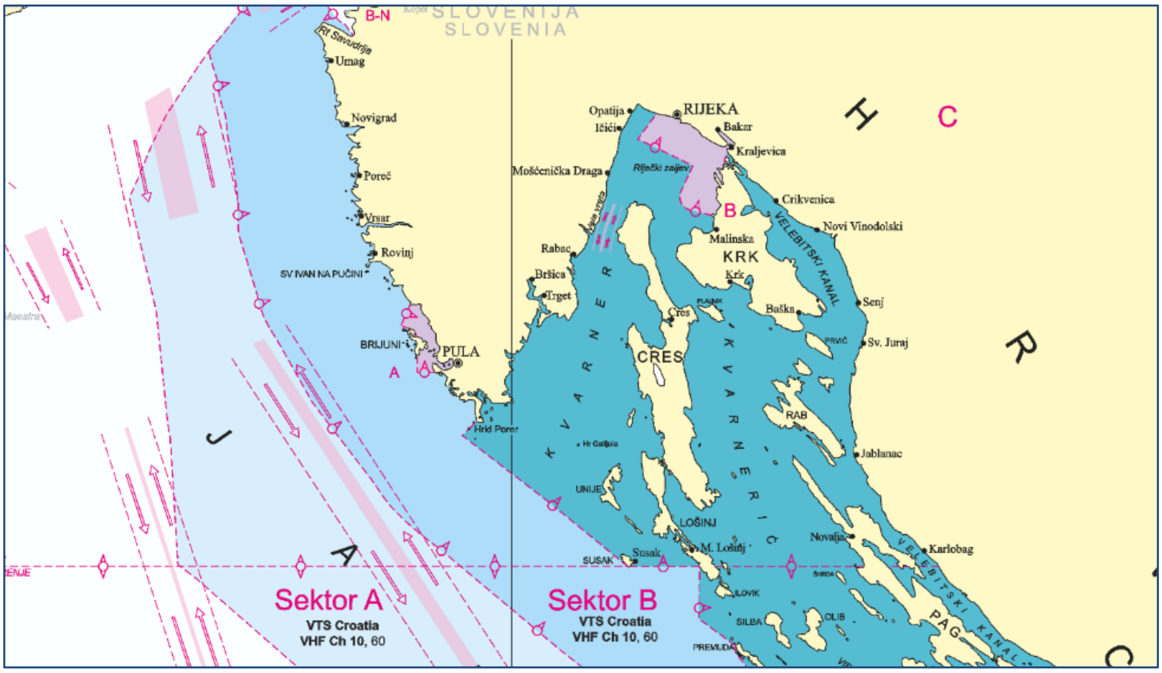

Figure 31 VTS – Sector A, Sector B and Rijeka Management sector (dark blue)

The merchant ships heading to or from ports in the Bay of Rijeka area are the most frequent in this strait, due to good coverage with the aids of navigation, sufficient depths, clear shore radar visibility and established traffic separation scheme. Consequently, no additional measures are needed to increase the safety of navigation during the passage between Brestova and Porozina.

Brestova. Port of Brestova is situated on the east coast of the Istrian peninsula. The depths inside the port area are varying between 3 m (berth) and 10 m (outer port area). The port consists of one berth for ro-ro passenger vessels. The berth has the front ramp and side quay with fenders and additional breasting dolphin. The berth (side quay with the dolphin) is approximately 65 m in length. The shore east from the berth is natural, rocky and not accessible, without any mooring infrastructure (bitts). Because of that, ships less than 65 m in length can be berthed safely, assuming it tied enough mooring lines (starboard and port bow-lines, forward and aft springs, forward and aft breast lines).

On the other hand, ships of 65 m or more cannot tie all mooring lines as required; hence the berth is less safe. For example, a ship of 100 m with the bow in (berthed on the starboard side) has its stern approximately 35 m away from the last berth bitt. Such ship on the stern side can use only aft springs.

Figure 32 Berth in the port of Brestova

Figure 33 Ship of 100 m berthed in the port of Brestova

In respect of wind sheltering, the port provides appropriate protection from the winds blowing from 3rd and 4th quadrants. On the other side, the ship alongside is exposed to winds and waves from the south directions, mainly the SE winds, due to which manoeuvring is becoming extremely difficult. During the NE and E winds, the ship alongside is partially protected. In those cases, the wind is following the shoreline and blowing nearly directly into the stern quarter of a berthed ship. In both cases, during strong winds, the ships are not considered safely berthed. To ensure the safety of ships 65 m long or more berthed alongside, the quay in the port of Brestova should be extended. In general, it is considered that the berth can accommodate a ship of the same length or smaller.

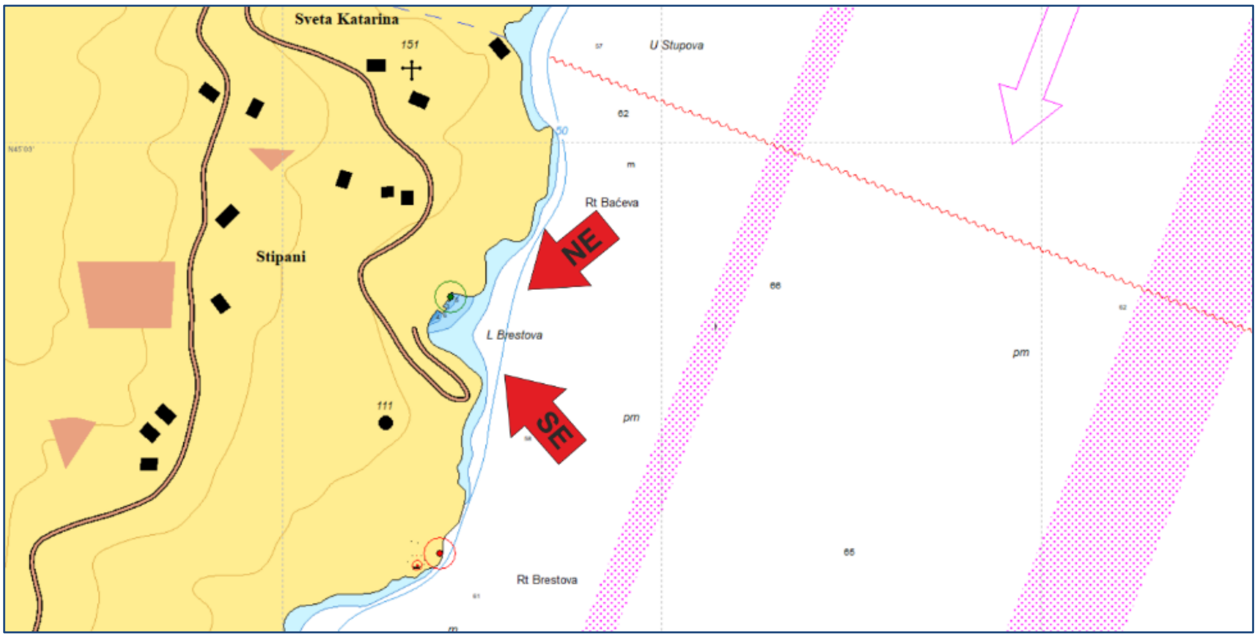

Figure 34 Direction of significant winds to the port of Brestova

Consequently, the port of Brestova can accommodate ships of a length over 65 m only during favourable weather conditions. To safely accommodate longer ships (100 m in length, as predicted by this project) and ensure safe manoeuvring of ships, especially during southerly winds, the port infrastructure should be improved. In general, the maritime safety of a particular port can be improved by:

- construction or upgrading of a breakwater(s)
- raising protection walls on an existing breakwater or quay to minimise effects of winds,
- realigning a berth within the port (reconsidering its height, length and position)
- adaptation or conversion of individual berths within the port,
- widening or dredging the area of the berth approach.

The suitable measures should be based on a detailed maritime safety study. Accordingly, the berth in the port of Brestova should be extended to at least 100 m to accommodate referent ships of 100 m in length. Additionally, one or more breasting dolphins should be constructed on the shore for stern lines, approximately 30 m abaft from the referent ship stern.

Porozina. The port of Porozina is situated on the west side on the North end of the island of Cres. The depths in the port are varying between 3 m (berth) to approximately 10 m (outer port area). The port consists of two berths for ro-ro passenger vessels. The smaller berth (west) consists of a front ro-ro ramp and a small jetty of approximately 40 m. The longer berth consists of a front ro-ro ramp and a jetty of approximately 80 m with four breasting dolphins. Ships of 80 m in length or more, when using the jetty, cannot position mooring lines as commonly considered as appropriate. Similar to the port of Brestova, they use starboard and port bow-lines, forward and aft springs, and occasionally forward breast line. The stern line cannot be adequately positioned because there is no place suitable for breasting dolphins; besides, the area between the jetty and shoreline is used to enter the inner port area with berths dedicated to local citizens.

Figure 35 100 m - ship of berthed in the port of Porozina on a berth long ~80m

Due to its geographical position, the port of Porozina is well protected from all waves coming from 1st and 2nd quadrant, i.e. dominant winds in the area. However, because of the topographic shape, the wind from NE can reach extreme speeds, blowing in the bow quarter when the ship is berthed, making manoeuvring rather demanding. The port is partially protected from winds and waves from 4th quadrant, thanks to the smaller 40 m long jetty acting as a breakwater. The port is not protected from winds in 3rd quadrant, especially SE, from where localized summer storms are typically coming. Fortunately, such summer storms are rather seldom.

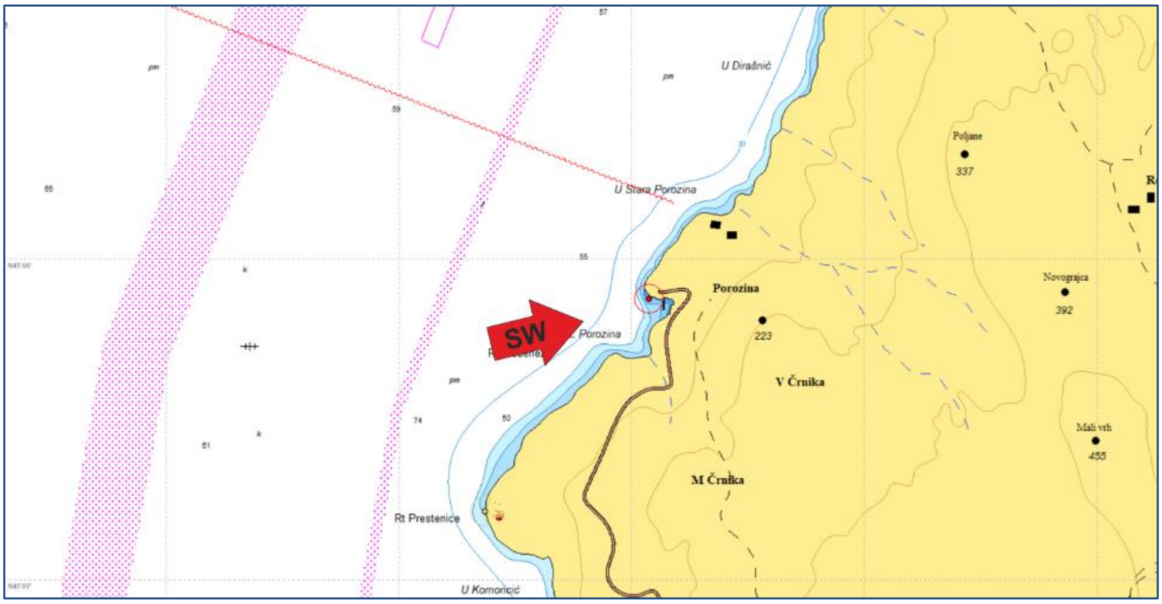

Figure 36 Direction of SW wind to the port of Porozina

In general, the port of Porozina is considered safer than the port of Brestova. However, some aspects of maritime safety should be improved, the most critical being to extend the berth enough to provide adequate mooring set up for the ship of 100 m in length.

4.2 Split-Ancona

The area used by the ships sailing between Split and Ancona is well covered with aids to navigation, i.e. navigational lights. Installation of additional equipment is not expected.

While sailing through Drvenički Kanal and Splitska Vrata strait, the ships can use at least three navigational lights at all times, which is evaluated as satisfactory.

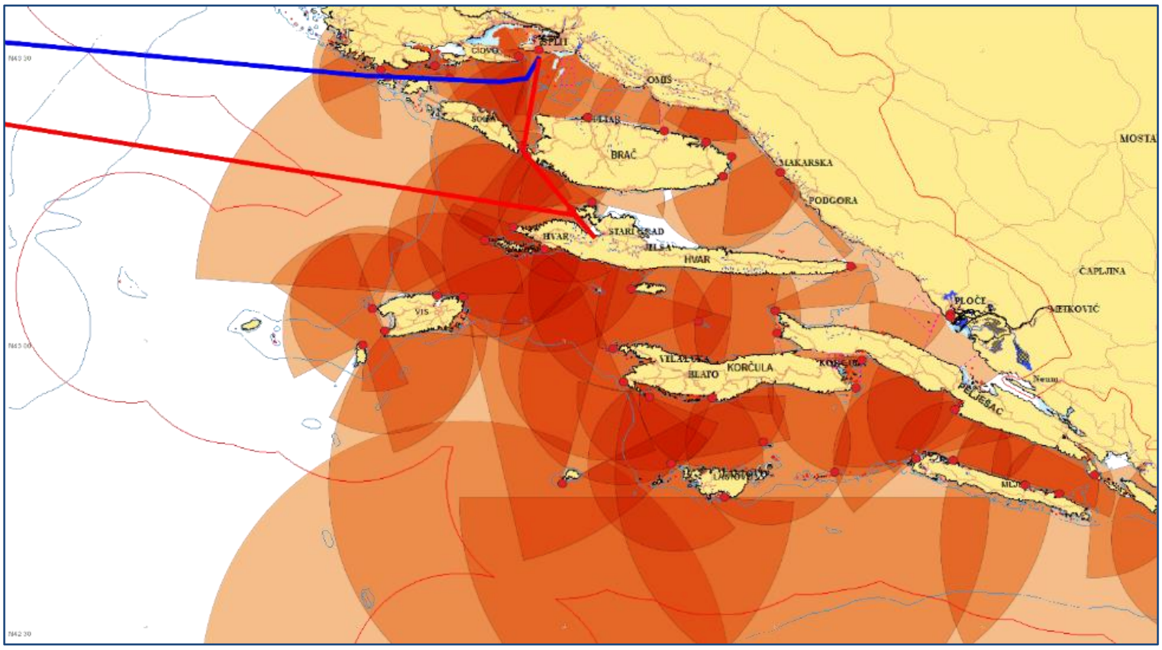

Figure 37 Navigational lights coverage – port of Split area (light range > 5M)

The sailing within internal waters of the Republic of Croatia is regulated by the Croatian VTS service, the VTS management sector Split. In the area, the Croatian VTS provides Information Service (IS) and Traffic Organization Service (TOS). The area is continuously monitored by the radar and automatic identification system (AIS) network.

Figure 38 VTS – Sector B and Split Management sector (dark blue)

The communication with ships in the manoeuvring sector Split is maintained using VHF channels 12 or 62. Once the ships leave the VTS manoeuvring sector, they remain under surveillance (via radar and AIS network) until they left the Sector B - territorial sea, and Sector A – EEZ. In both outer sectors, communications are maintained using VHF channels 10 or 60.

Split. The port of Split is divided into two parts, the cargo port and city port. The cargo port, northside of the city of Split in the Kaštelanski Bay, accommodates different cargo ships, mainly bulk carriers, container ships, ro-ro and general cargo ships. The city port accommodates cruise ships, passenger ships, ro-ro passenger ships and other smaller vessels serving nautical tourism.

The main city port area is dedicated to passenger ships. It has 27 berths of which 12 berths, dedicated to ro-ro passenger ships, are situated along the port breakwater and two adjacent jetties. The berths vary from 116 m to 150 m. The depths alongside are varying from 5 m to 10 m. The city port of Split is well protected by two breakwaters from winds and waves from all directions. From the maritime safety point of view, the port is evaluated as a well-protected port.

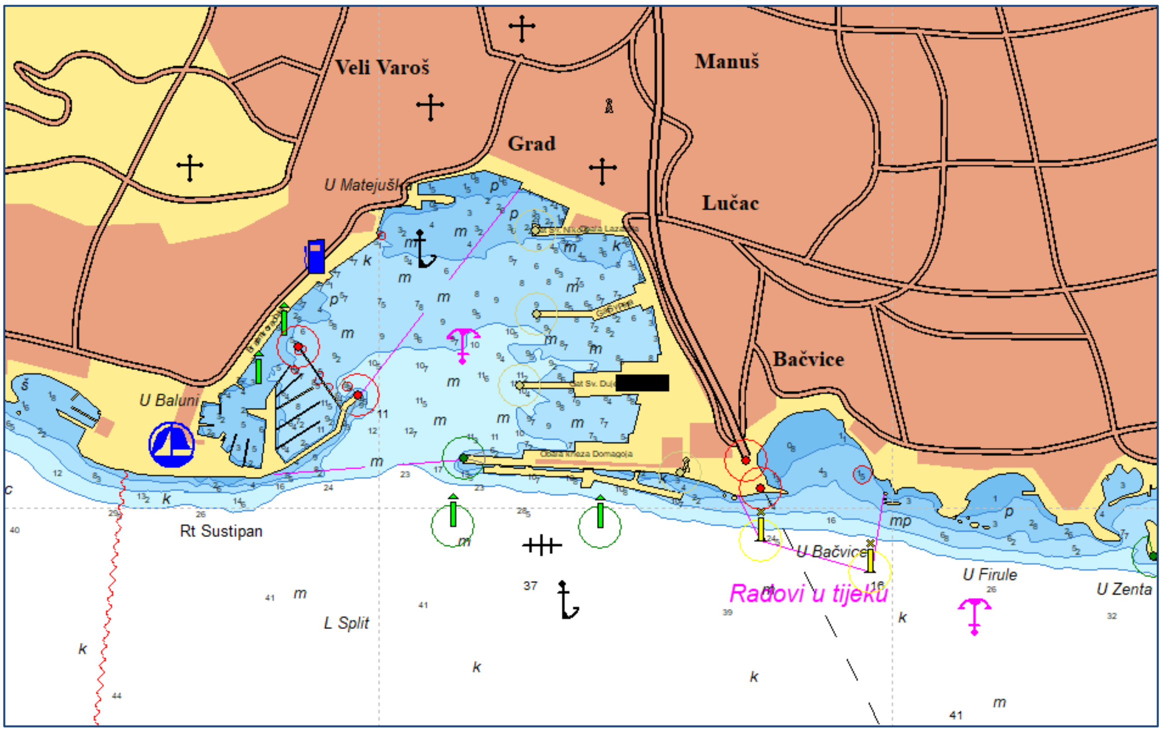

Figure 39 The city port of Split

Starigrad. Port of Starigrad is situated on the northwest area of the island of Hvar. The port is divided into two parts, the old town port and the new ro-ro passenger terminal situated outside of the port area. The part located close to the old town is dedicated to smaller passenger and ro-ro passenger ships on domestic voyages. The new ro-ro passenger terminal has three berths, of which one is approximately 50 m long, and two are approximately 130 m long. The depths on the main ro-ro passenger berths vary between 5 to 10 m. The port and ro-ro passenger terminal are naturally well protected from winds and waves from all directions, except partly from NW winds, which does not significantly affect the manoeuvring and safety of ships while berthed. From the maritime safety point of view, the port is evaluated as a well-protected port.

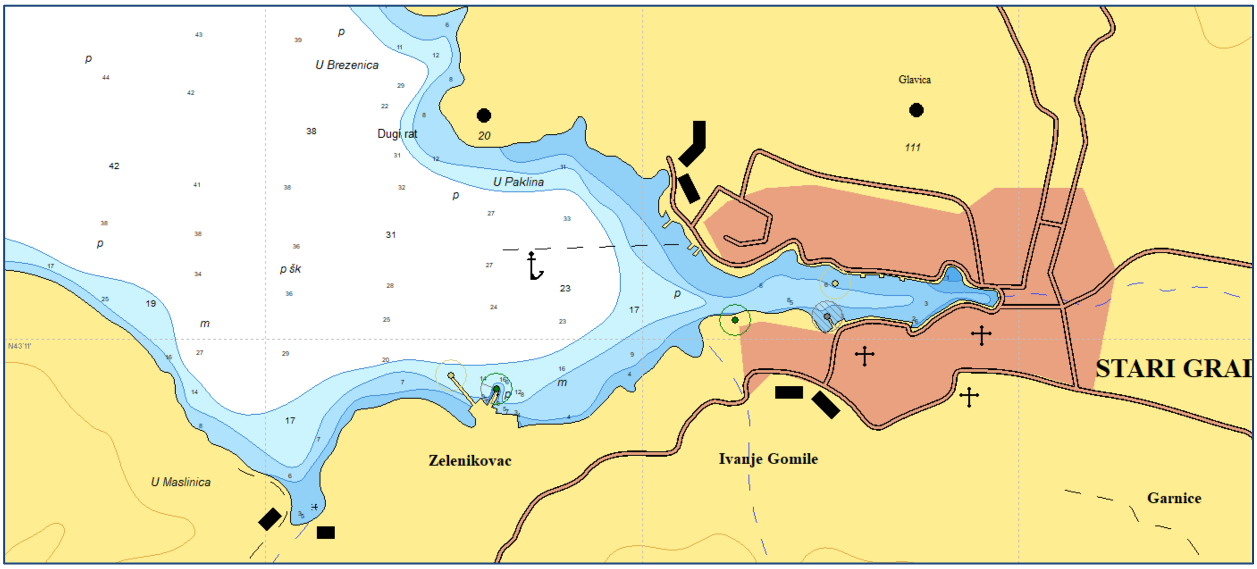

Figure 40 The port of Starigrad

Ancona. The main port area, dedicated for large vessels, has eight berths for ro-ro passenger vessels and 12 berths for cargo ships. The smallest berth for ro-ro passenger ships is 80 m long while the largest is 200 m long. The depths on ro-ro passenger berths vary between 8,5 and 10,5 m.

The port of Ancona is well protected from winds and waves from all directions by three breakwaters. Each breakwater has several navigation lights to ease the orientation and manoeuvring within the port area during the night. From the maritime safety point of view, the port is evaluated as a well-protected port appropriate for the current volume of traffic.

Figure 41 Port of Ancona

5 CONCLUSIONS

The main conclusions of this report are:

NAVIGATIONAL FEATURES

1) The Brestova-Porozina ro-ro passenger line connects the island of Cres and the coast of Istria. The voyage time is relatively short, i.e. about 30 minutes. Sea depths in the Vela Vrata strait may range from 55 to 65 m. There are no natural hazards on the waterway (shallows, reefs, etc.).
2) Ships maintaining the Brestova-Porozina ro-ro passenger line are crossing the Vela Vrata strait, the main waterway for ships' calling the port of Rijeka. In the strait, the mandatory traffic separation scheme is implemented. Hence, the passage must be conducted with precaution.
3) The entire coastline close to the Brestova-Porozina area and around approaches to the port of Split is predominantly high and steep and support the positioning of the vessels by visual observation or by radar equipment in all weather conditions. The accuracy of radar positions is satisfactory, even at over 30 nm distance from the shore.
4) The coast of the port of Ancona is relatively shallow. The predominant natural feature used for positioning in coastal navigation, by visual observation or by radar equipment, is the Monte Conero (800 m), located approximately 2 km south of the port of Ancona.
5) Global navigation satellite systems (GNSS) can be used throughout the Adriatic Sea, including all observed areas. Accuracy, availability, reliability, time between two consecutive vessel positions and system capacity fully meet international standards.
6) Magnetic variation in the Adriatic Sea (2012) varies from approximately 2,5° E in the Venice area to 3.5° E in the Strait of Otranto area. The annual variation in magnetic variation is small, ranging from 7,1' E in the North part to 6,2' E in the central and South Adriatic. The use of a magnetic compass as a navigational aid in observed areas is sufficiently reliable and safe.
7) In the area of Brestova-Porozina ro-ro passenger line, the ships can use the Rijeka Radio coastal radio station. The radio watch is maintained using VHF channel 16 and DSC VHF channel 70.
8) Ships maintaining Split-Ancona ro-ro passenger line can use the Split Radio coastal station. The radio watch is maintained using VHF channel 16 and DSC VHF channel 70.
9) Ships maintaining Split-Ancona ro-ro passenger line can use the Ancona Radio coastal station. The radio watch is maintained using VHF channel 16 and DSC VHF channel 70.
10) Maritime Safety Information (MSI), i.e. notices vital for the safety of navigation in the Adriatic Sea, are provided by coastal radio stations and NAVTEX stations: station Q (Croatia), station U and station R (Italy).

11) The Split-Ancona ro-ro passenger line follows the route through Drvenički Kanal, the channel between shore and the islands of Drvenik Veli and Drvenik Mali, and then directly to the Ancona, and vice versa. That route, from port to port, is approximately 130 nm long.

12) During summer, the ships serving the Split-Ancona ro-ro passenger line call the port of Starigrad on the island of Hvar. In that case, the ships follow the route through Splitska Vrata, the passage between the island of Šolta and the island of Brač, and then directly to the Ancona and vice versa. The route between these three ports is approximately 155 nm long.

13) In respect of the Split-Ancona ro-ro passenger line, the channel Drvenički Kanal and the Splitska Vrata strait are considered as areas of higher risk of collision or grounding, hence requiring additional precaution.

14) Open sea waterway of the Split-Ancona ro-ro passenger line (between territorial seas of the Republic of Croatia and the Republic of Italy) is approximately 70 nm long. The depths are sufficient, and there are no significant navigation hazards, except the risk of collisions with ships heading to or from North Adriatic ports. The risk is not considered as significant.

15) Ships approaching or departing from the port of Ancona are bound to follow the traffic separation scheme.

METEOROLOGICAL AND OCEANOGRAPHIC FEATURES

16) In general, meteorological and oceanographic conditions are favourable for safe navigation of referent ships. The situation is particularly favourable from spring to autumn. During the winter period, occasional adverse weather may have an impact on the safety of navigation.

17) Along the eastern coast of North Adriatic, winds of 6 Bf or more blow in average 25 to 40 days a year. In open sea areas, they can blow over 100 days a year. Gale force winds of 8 Bf or more blow less frequently, usually from 2 to 10 days, a year and most often from NE, and less often as S or SE.

18) In Vela Vrata strait significant winds are bora (NE) and Sirocco (SE). Winds from both directions can reach gale force and occasionally influence the safety of navigation and berthing. Bora is reaching gale force more frequently in winter.

19) Port of Brestova is open and unprotected form winds and waves from SE and partially NE directions, while the port of Porozina is open and unprotected from winds and waves from SW direction.

20) In Vela Vrata area, the occurrence of calms is 2,2% of the time on average. During the summer months in 80% of cases, the prevailing wind speed is between 0,3 and 3,3 m/s. During the winter months, winds of this speed range can be expected in 65% of cases. Winds of 6-8 Bf appear on average 38 days a year, while 8 Bf winds appear eight days per year.

21) The highest waves in the Vela Vrata are the waves from SW. The waves from this direction can reach 3,5 m in height.

22) In open Adriatic Sea area (Split – Ancona ro-ro passenger line) prolonged sirocco winds can create high waves due to long fetch. During gale-force sirocco, the height of the maximum wave of H_{max}= 8,4 m (significant wave height $H_{1/3}$ = 5,5 m, mean period T_m = 6,9 s, mean wavelength L_m = 74,9 m) was recorded.

23) In open Adriatic Sea area (Split – Ancona ro-ro passenger line) in case of the NE winds (bora) maximum measured wave height was H_{max} = 6,2 m (with significant wave height $H_{1/3}$ = 3,9 m, mean wave period T_m = 6,2 s, mean wavelength L_m = 60,3 m).

24) In the port of Split area, strong winds (≥ 10,7 m/s) were most frequent from ENE direction. Also, on the average, there were 86,6 days with winds of 6-8 Bf and 11,9 days with winds of 8 Bf or more.

25) The significant wind directions in the Ancona area are from 3rd (SE to SSE) and 4th quadrant (SW to WSW). Most occurring are moderate winds varying from 2-6 m/s (2-4 Beaufort scale), while stronger winds occur significantly less frequently. Calms occur approximately 3,6% of the time throughout a year.

MEASURES TO INCREASE THE SAFETY OF NAVIGATION

26) The Brestova-Porozina ro-ro passenger line is adequately covered with aids to navigation.

27) The Brestova-Porozina ro-ro passenger line is located within the VTS management sector Rijeka, where the Croatian VTS provides Information Service (IS) and Traffic Organization Service (TOS). All ships in the area are continuously monitored by the radar and automatic identification system (AIS).

28) The port of Brestova has one quay approximately 65 m long. The depths are approximately 3 m. The port is not protected from winds and waves from 2nd quadrant and only partially protected from winds and waves from 1st quadrant.

29) The port of Brestova is not considered safe, for referent ro-ro passenger ships of 100 m in length, in all conditions. Approximately 35 m of the referent ship's length would not lean on fenders, and there are no elements to safely moor a ship in case of significant 2nd quadrant winds.

30) The berth in the port of Brestova should be extended to at least 100 m. Additionally, one or more bitts should be constructed for fastening stern lines, approximately 30 m abaft from the referent ship stern.

31) The port of Porozina has two berths, a protective jetty of 40 m and main jetty of 80 m in length. The port is not protected from winds from 1st quadrant and wind and waves from 3rd quadrant.

32) The port of Porozina is considered partially safe for referent ro-ro passenger ships of 100 m in length. The referent ship is approximately 20 m longer than the jetty and ship cannot be safely moored in all conditions.

33) The berth in the port of Porozina should be extended to at least 100 m; alternatively, other arrangements ensuring safe mooring the ship with all mooring lines appropriately positioned should be made.

34) The Split - Ancona ro-ro passenger line is well covered with aids to navigation. While sailing through the channel Drvenički Kanal and Splitska Vrata strait, ships can use at least three navigational lights at all times.

35) In the internal waters of the Republic of Croatia, the Croatian VTS provides Information Service (IS) and Traffic Organization Service (TOS). All ships in the area are continuously monitored by the radar and automatic identification system (AIS).

36) In the territorial sea (VTS Sector B) and EEZ (VTS Sector A) of the Republic of Croatia, ships are monitored via radar and AIS network and provided with Information Service (IS).

37) The city port of Split has 12 berths reserved for ro-ro passenger ships. The berths vary from 116 m to 150 m. The depths are varying between 5 m to 10 m.

38) The city port of Split is well protected by two breakwaters from winds and waves from all directions.

39) The port of Starigrad has three berths on the new ro-ro passenger terminal. Two berths are 130 m long. The depths on the main ro-ro passenger berths are varying between 5 to 10 m.

40) The port of Starigrad and ro-ro passenger terminal is very well naturally protected from winds and waves from all directions, except partly from NW winds, which does not significantly affect the safety of ships.

41) The port of Ancona has eight berths dedicated to ro-ro passenger ships. The berth length varies between 80 m and 200 m with depths on ro-ro passenger berths between 8,5 and 10,5 m.

42) The port of Ancona is well protected from winds and waves from all directions by three breakwaters.

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