D2.1
Report on Environmental Risk Assessment

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NAMIRS North Adriatic Maritime Incident Response System

CEI CENTRAL EUROPEAN INITIATIVE

Index

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1. Introduction

This report describes the activities carried out in the framework of the Activity 2.1 – Environmental Risk Assessment of NAMIRS. According to the project proposal, the goals and scopes of the Activity were to perform an Environmental Risk Assessment. The report showcases a methodology to conduct the oil spill risk assessment by integrating different tools such as the identification of particularly sensitive areas and the assessment of their vulnerability, the statistical and expert-based analysis of the ship traffics and oil spill probability, and a numerical oil spill model statistically assessing the oil spill hazard. The vulnerability assessment was done through stakeholder involvement following a participatory approach, as detailed in the report in order to assign scores (weights) to the different receptors. Through the assessment model developed, environmental damages in case of ship accidents (collision/sinking/grounding) are studied, taking especially into account the impact of oil-spill in marine sensitive areas and their secondary but relevant impact on the economy, and on the life of people living on the shore. The results of Activity 2.1. will help in contingency planning which is the main outcome expected from NAMIRS.

The activity was led by OGS, coordinated by URSZR in the wider context of NAMIRS WP2, and saw the active collaboration of the University of Ljubljana (UL-FPP) for most activities, and of ATRAC for the organization of the stakeholders' workshop in Croatia.

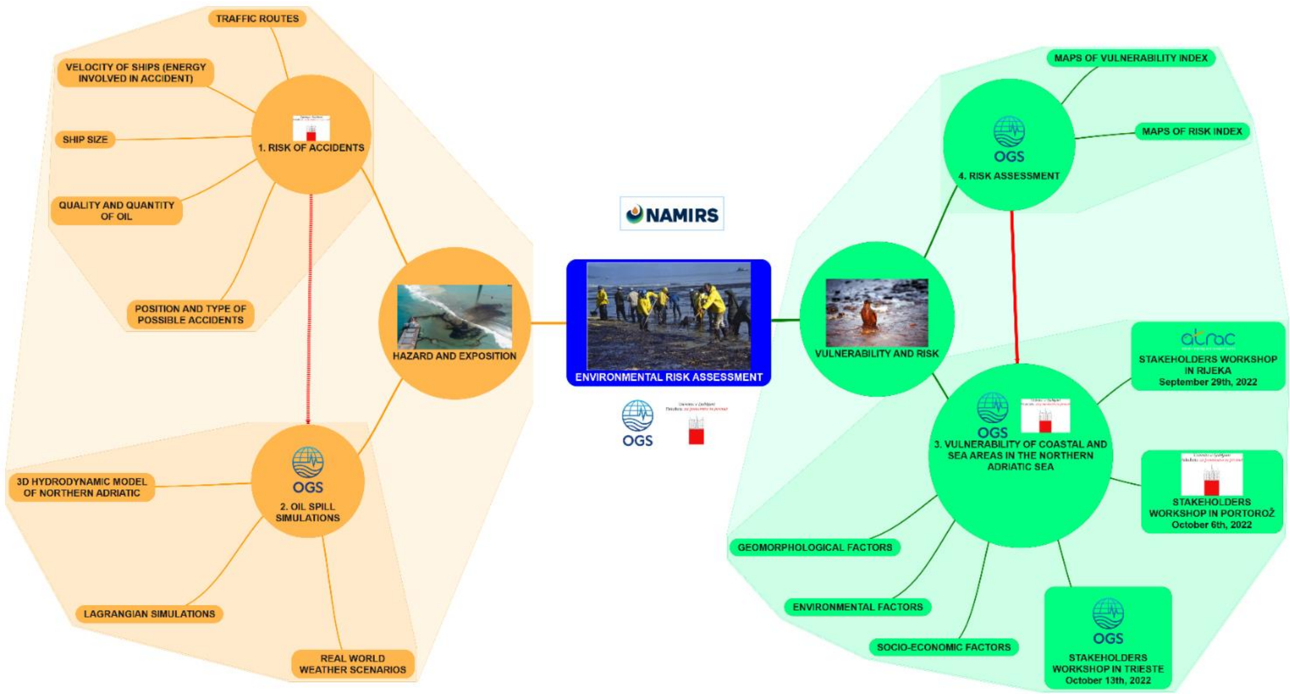

Figure 1: Schematic representation of Activity 2.1, its division in 4 tasks, and the related specific subtasks. The logos of the partners indicate the main responsibility for each Task or subtask, but all three partners actively collaborated during the whole Activity 2.1.

For operative purposes, activity 2.1 was subdivided into four tasks (Fig. 1):

1. Risk of Accidents
2. Oil Spill Simulations
3. Vulnerability of coastal and Sea Areas in the Northern Adriatic Sea

4. Risk Assessment

The four tasks are devoted to the definition of the hazard (Task 1), exposition (Task 2), and vulnerability (Task 3) of the area of interest, while the risk assessment is computed in Task 4 is the risk, as a function of hazard, exposition, and vulnerability, is computed.

The organization of the report is as follows: Section 2 is devoted to the description of the activities of UL-FPP for the analysis of the risk of accidents in the Northern Adriatic Sea (Task 1); Section 3 to the description of the activities of OGS regarding oil spill simulations (Task 2); Section 4 to the description of the activities regarding the stakeholders involvement, i.e. to the preparation of the questionnaires and to the activities regarding the stakeholders' workshops on behalf of UL-FPP, ATRAC and OGS; Section 5 to the vulnerability mapping and assessing in the coastal areas of the Northern Adriatic Sea; Section 6 to the description of the activities for the computation of the final risk index and the production of the relative mappings; Section 7 brings some general final remarks and suggestions for possible future developments of the work.

2. Traffic data analysis and hazard estimation

The Faculty of Maritime Studies of the University of Ljubljana, as a partner in the NAMIRS project, was commissioned to study maritime traffic in the northern Adriatic from the point of view of the risk of maritime accidents resulting from the significant oil release (Task 1 of Activity 2.1).

2.1 Introduction

The aim of the Section is to examine the nautical risks, focusing on potential accidents occurring during the vessel en-route to and from one of the major ports in the northern Adriatic Sea. The risk assessment is carried out for actual traffic conditions and comparative simulations, including traffic separation systems. The focus of the risk assessment is on commercial vessels, but fishing and recreational vessels are also considered to some extent.

Marine casualty risk assessment is one of the bases for implementing measures to reduce the number of marine casualties, but also one of the bases for improving the overall risk management of such casualties. This includes the analysis and design of the response measures available in the region, which measures and how they should be improved in order to achieve a balanced and satisfactory response to disasters, thus reducing the consequences in terms of human lives, environmental pollution and economic damage.

Neither Italian, Slovenian nor Croatian legislation do prescribe approaches or methods for assessing the risk of accidents at sea. Based on the international scientific and technical literature, the recommendations of the International Maritime Organization (IMO) and of the European Maritime Safety Agency (EMSA), and the Emergency Response Centre for Marine Pollution in the Mediterranean (REMPEC) combination of qualitative and quantitative approaches were applied. This is particularly important in order to obtain the most realistic assessment possible, given the local situation, as in some parts of the risk assessment it is practically impossible to give a quantitative assessment based on the local situation, simply because there are no statistics or relevant events (e.g. the assessment of the probability of a major spill of hazardous substances on the water cannot be based on the frequency of events in our area, as this has not yet happened).

The collision and stranding frequency calculations are based on historical event statistics and near misses. These are based on vessel movement data via AIS. The consequences of accidents are described in qualitative terms. The identification of risk sources includes the screening of all hazardous substances on board ships in transit that could be released into the environment and thus cause adverse effects.

2.2 AIS data

Near offshore traffic and coastal traffic along with confined waters traffic can be easily monitored using shore AIS base stations. The system, called AIS (Automatic Identification System), is primarily for ships. It allows a vessel to detect another vessel in time, even in poor visibility when radar is unable to indicate all hazards in the water, and to obtain the necessary information about the sighted vessel without establishing a radio link. Maritime industry stakeholders built the AIS with the goal of improving maritime safety, security, and their assessment. The AIS was launched as a joint effort of the International Maritime organization (IMO), the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), the International Telecommunication Union (ITU), and the International Electrotechnical

Commission (IEC). Originally, AIS was introduced on certain types of International Convention for Safety of Life at Sea (SOLAS) ships to assist the Officer of the Watch (OOW) in making decisions in the event of a collision. Naturally, the AIS system was immediately used in Vessel Traffic Service (VTS) systems for vessel traffic control. Officially, AIS was first recognized in 1998 by a resolution of the International Maritime Organization (IMO) adopted at the 69th session of the Maritime Safety Committee (MSC). The AIS device is capable of transmitting information to vessels and coastal authorities automatically, with the required accuracy and using only the designated radio frequencies. AIS operates in the VHF frequency band. It has been assigned two channels: AIS 1 (161.975 MHz - marine band channel 87B) and AIS 2 (162.025 MHz - marine band channel 88B). The nominal reporting intervals for data transmission vary from 2 seconds to 6 minutes and depends on the type of AIS station, the group of messages, the navigational status, the speed and the course change of ships (Burmeister et al., 2014). Slower ships send kinematic data every 10 seconds, medium speed ships every 6 seconds, high speed ships every two seconds. If the ship changes heading, the transmission intensity increases by a factor of 3 (for slower and medium speed ships). Table 1 shows the transmission intensity of static and dynamic information for Class A and B and for Single and Dual Channel Transceivers. AIS Transponders can receive all transmission information from both AIS channels simultaneously and combine the information from both channels into a single data stream. The standards of transmission, types, the format of messages and symbols, make it simple for users to identify, monitor, and track targets detected by AIS.

Table 1: Transmission period of dynamic data (IALA, 2016).

AIS Class A Transponder - Ships Dynamic Conditions	Dual Channel	Single Channel
Ship at anchor or moored	3 min	6 min
SOG 0-14 knots	10 sec	20 sec
SOG 0-14 knots and changing	3.3 sec	6.6 sec
SOG 14-23 knots	6 sec	12 sec
SOG 14-23 knots and changing course	2 sec	4 sec
SOG >23 knots	2 sec	4 sec
Ship Static Information	6 min	12 min
AIS Class B Transponder - Ships Dynamic Conditions	**Dual Channel**	**Single Channel**
SOG <2 knots	3 min	6 min
SOG >2 knots	30 sec	1 min
SOG		
Ship Static Information	6 min	12 min

The AIS system must be capable of processing at least 2000 messages per minute when used as a ship reporting system. The technical characteristics of AIS, such as variable transmission power, operating frequencies, modulation and antenna systems, are specified in the ITU (International Telecommunication

Union) standards. The envisaged capacity of 4500 telegrams per minute is assumed to be sufficient for unrestricted ship-to-ship (2S) and even ship-to-shore (4S) use, with a typical range of 20 nautical miles (NM) between ships and up to 40 NM between ship and shore. The theoretical range of the system is given by the following equation:

$$d_{min} = 2.5\left(\sqrt{height_{TX\ ant}[m]} + \sqrt{height_{RX\ ant}[m]}\right) = range[Nm]$$

The main AIS receiving antenna in Slovenia is located on Slavnik, while in Croatia (for the northern Adriatic Sea) it is located on Učka. Both antennas are on excellent locations, so there is also good monitoring of shipping traffic. For example, a VHF antenna at 1030 metres receiving data from a large merchant vessel with a VHF antenna at 49 metres has a range of 100 NM:

$$2.5\left(\sqrt{1026} + \sqrt{49}\right) \approx 100Nm$$

Today's applications of AIS data have shifted from use for collision avoidance, identification, and tracking to monitoring shipping routes, maritime traffic trends, risk analysis, marine accident investigations, near-miss investigations, search and rescue operations, waterway planning, management and maintenance using AtoNs (Aid to Navigation), traffic simulation, and forecasting, fisheries monitoring, environmental monitoring, prevention of illegal activities at sea.

Fig. 2 shows the current ship status in the Northern Adriatic, while Fig. 3 shows yearly based traffic density. This information is available from the MarinTraffic provider, which collects AIS data on a voluntary basis.

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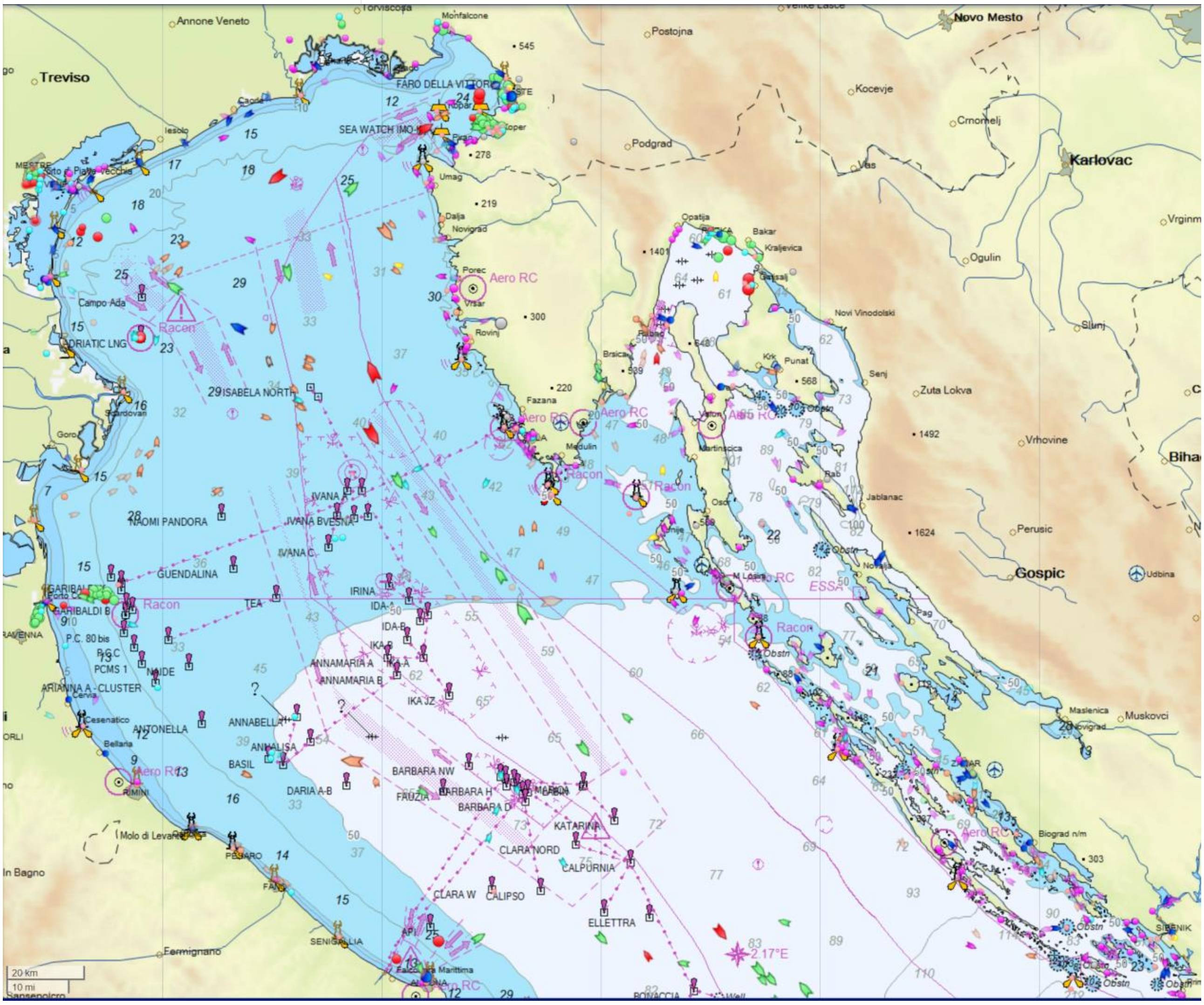

Figure 2: Example of the vessel position on 07.09.2022 at 08:25 in the study area. (Source: MarineTraffic)

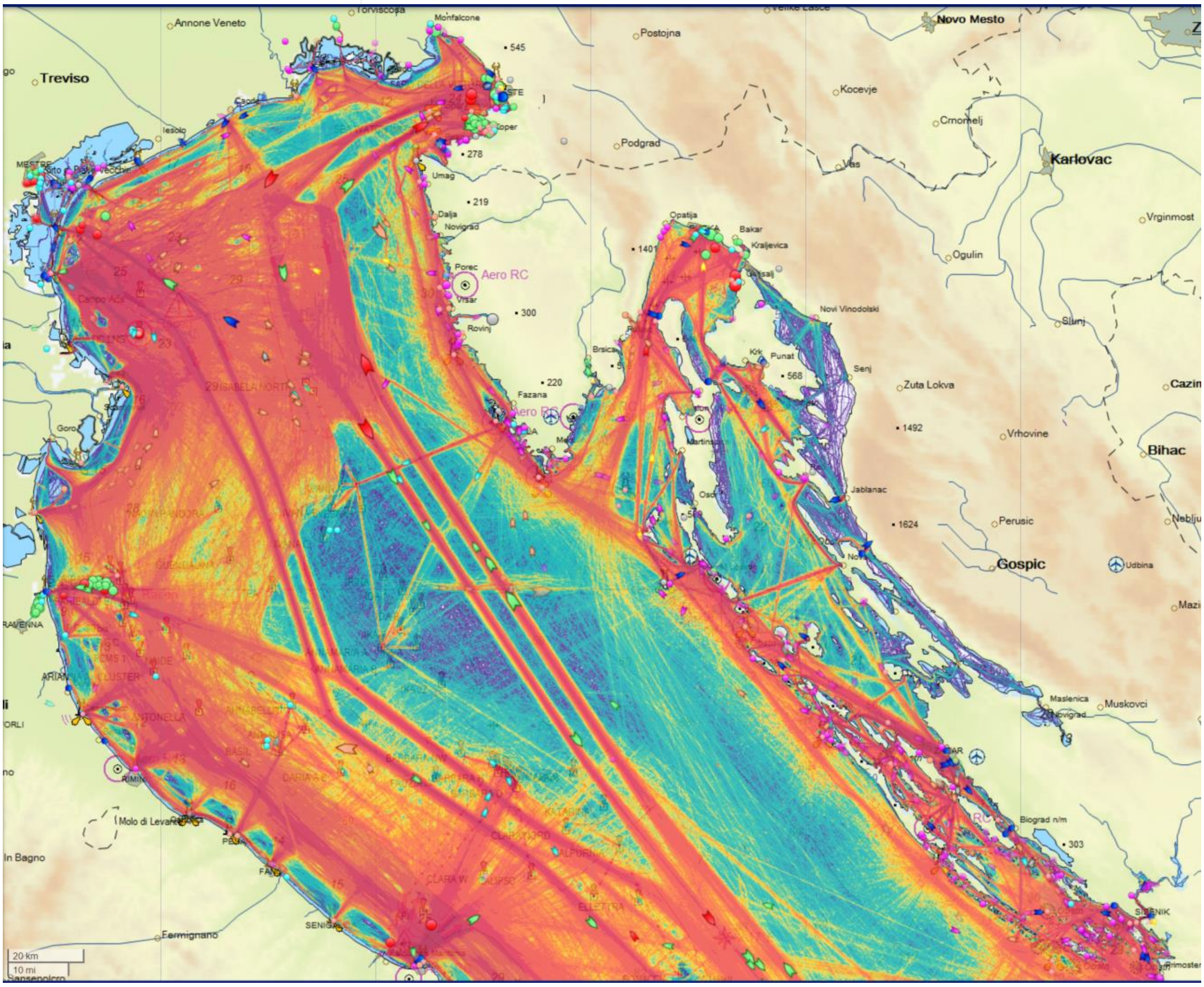

Figure 3: All ships traffic density in 2020-2021 in the study area. (Source: MarineTraffic)

The Slovenian Maritime Administration integrates AIS from the following sources:

1. **AIS BS SLAVNIK - MMSI 002780201:**
   Latitude= 45°32.028947' --> 45.53381578°
   Longitude= 13°58.517946' -->13.97529910°
   MSL= 1025.68m
2. **AIS BS IZOLA - MMSI 002780202**
   Latitude= 45°32.669470'
   Longitude= 13°41.204462'
   MSL= 135.88m
   MSL_{GPS} = 135.88+44.477=180.357m
3. **AIS BS KOPER - MMSI 002780203 (MSL=54.387 m)**

4. **AIS BS POORTOROŽ - MMSI 002780204 (Installed by UL FPP and shared with the MarineTraffic system)**
5. **MARES stream -** display of AIS data extracted from the national AIS systems of the Mediterranean countries. The main service provided by the AIS server is the collection and transmission of AIS data in real time and its storage in databases.

The AIS storage is done with the commercial software of Transas/Wartsila "TranDB", which writes the data into a MS SQL database, where due to the amount of data the messages are recorded in a separate table for each message type and each day:

Table 2: AIS messages grouped.

Name of the table
dbo.part_(YYYY-MM-DD hh:mm)_MsgPos
dbo.part_(YYYY-MM-DD hh:mm)_MsgPos2
dbo.part_(YYYY-MM-DD hh:mm)_Msg5
dbo.part_(YYYY-MM-DD hh:mm)_MsgOther1
dbo.part_(YYYY-MM-DD hh:mm)_MsgOther2
dbo.part_(YYYY-MM-DD hh:mm)_MsgNonAIS

Table 3: explanations of the abbreviations in Table 2.

YYYY	Year
MM	Month
DD	Day
Hh	Clock
mm	Minute
msg	Message
Other	Other messages

Up to 250 million AIS messages are recorded monthly only for the Northern Adriatic area. Commercial devices do not allow the export of large amounts of data from AIS without disrupting the ongoing AIS recording. Therefore, we set up a parallel offline server on the UL-FPP with identical (commercial) software and synchronized the databases with those available on the UL-FPP. To export data from a specific area and time period, we used a Python 3.6 script that uses the pymssql library and writes the desired data to CSV files for further processing. When exporting, the geographic coordinates must also be recalculated since they are not in the standard notation. The data is exported to a separate file for each month, as this makes the most sense given the number of records.

For further processing, we used the Pandas tool for Python to import the data. This allows to quickly filter the data by various criteria once it is loaded into memory. To process the large amount of AIS data, we developed three batch processing programs. During the pre-processing, only data limited to the desired geographical area is extracted, the original SQL database record is exported as a csv file for a time period of

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two months. The files were read using the Pandas library for Python. As the ship trajectories are given at different sampling rates, depending on the ship speed and navigation status (Table 1), all trajectories were resampled to a period of 10 s. This simplified or speeded up the calculation steps.

When no information about a ship was available for more than 120 s, it was assumed to be stationary. The resampling was performed by linear interpolation of velocities and positions between known points.

In addition to the pre-processing of the input data, a grid was defined for the calculation by setting the longitude and latitude step.

Fig. 4 shows vessel density due to all traffic in 2019 in the northern part of the Northern Adriatic Sea. The largest number of messages (maximum 13,105,332 messages) is in the ports and terminals marked in purple (e.g., the Rovigo LNG terminal).

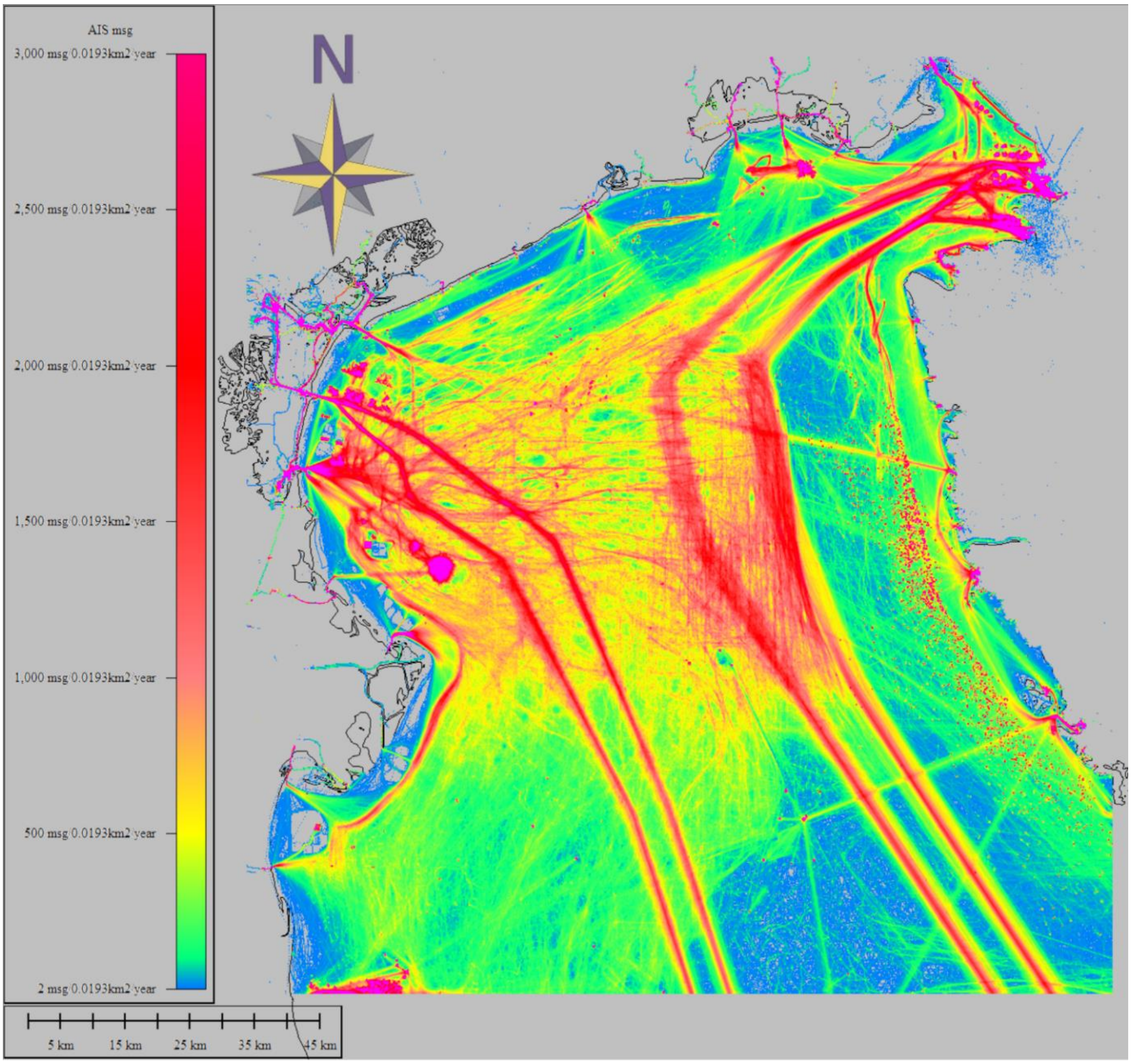


Figure 4: High resolution traffic density chart in 2019, main routes, ports are terminals are clearly identified.

2.3 Traffic data – spatial distribution analysis

The shipping densities are discussed in more detail below. First, ships are classified into size classes, small ships less than 50 meters in length, which includes all fishing boats, pleasure crafts and service vessels, then up to 150 meters, which includes mainly coaster ships, ships up to 230 meters, and ships up to 300 meters in length, and ships larger than 300 meters, which includes mainly container ships. For all these size classes, density maps are then produced for the distribution of average ship size, number of ships, occupancy time of ships and speed distribution.

Fig. 5 showing the distribution of average ship lengths within the 50-meter class clearly identifies the positions of the larger service ships close to 50 meters in length i.e., the red lines connecting the offshore platforms. Fig. 6 shows the distribution of ships (number of ships in each cell) in a class within 50 meters of the ship's length. The highest density of small vessels is in the coastal zone on the Croatian side, while Italian fishing boats sail all the way to the border zone. Fig. 7 shows the distribution of occupancy time (in seconds) in each cell, for ships less than 50 meters in length. This figure accurately depicts the locations of fishing boats, especially the stationary locations along the Istrian coast. In addition to the obstacles in the way shown in the previous figures, shipping speeds are also important. Fig. 8 shows the distribution of these, which are highest on service vessel courses, up to 15 knots on average.

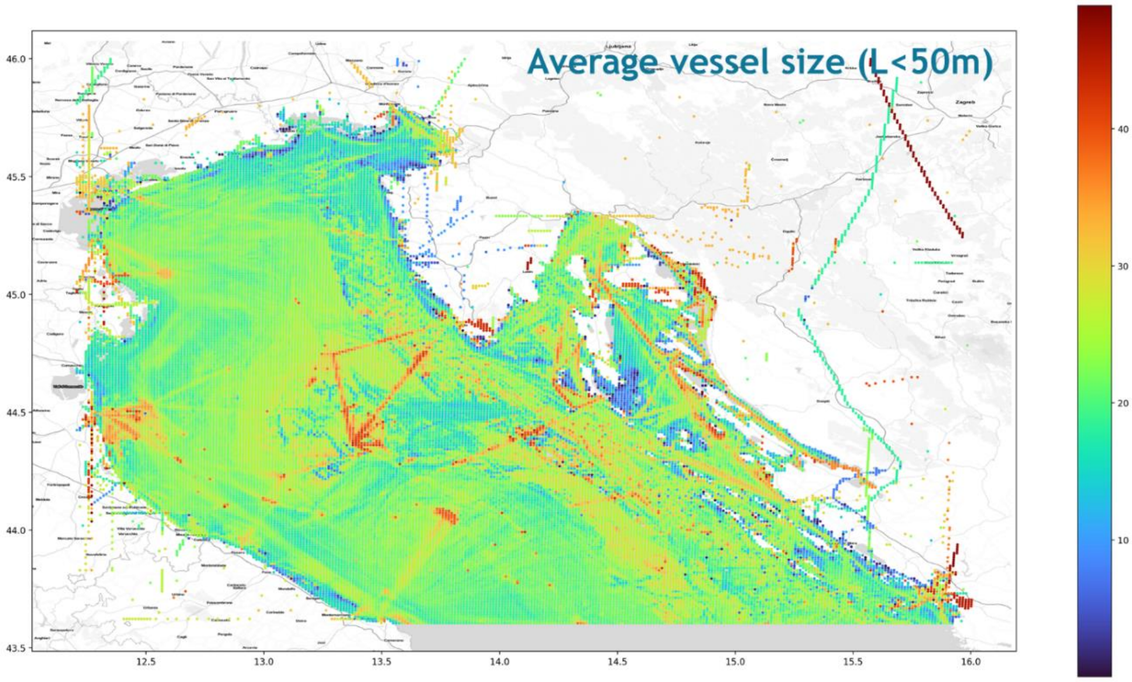


Figure 5: Average vessel size distribution (L<50m)

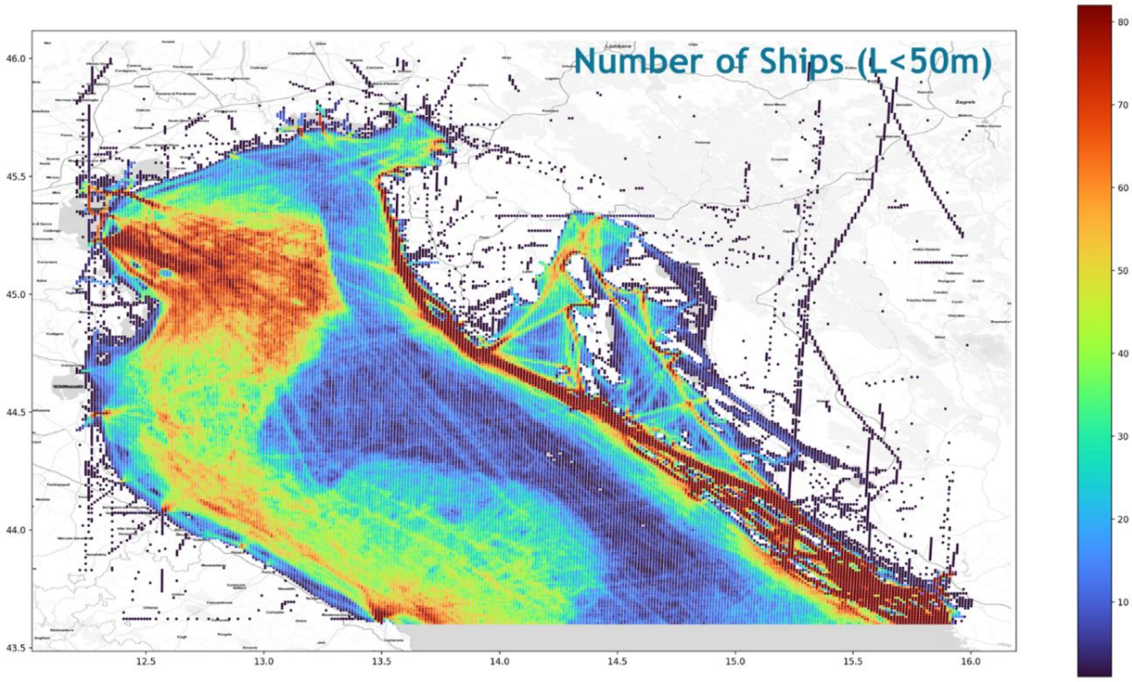


Figure 6: Ships position distribution (L<50m).

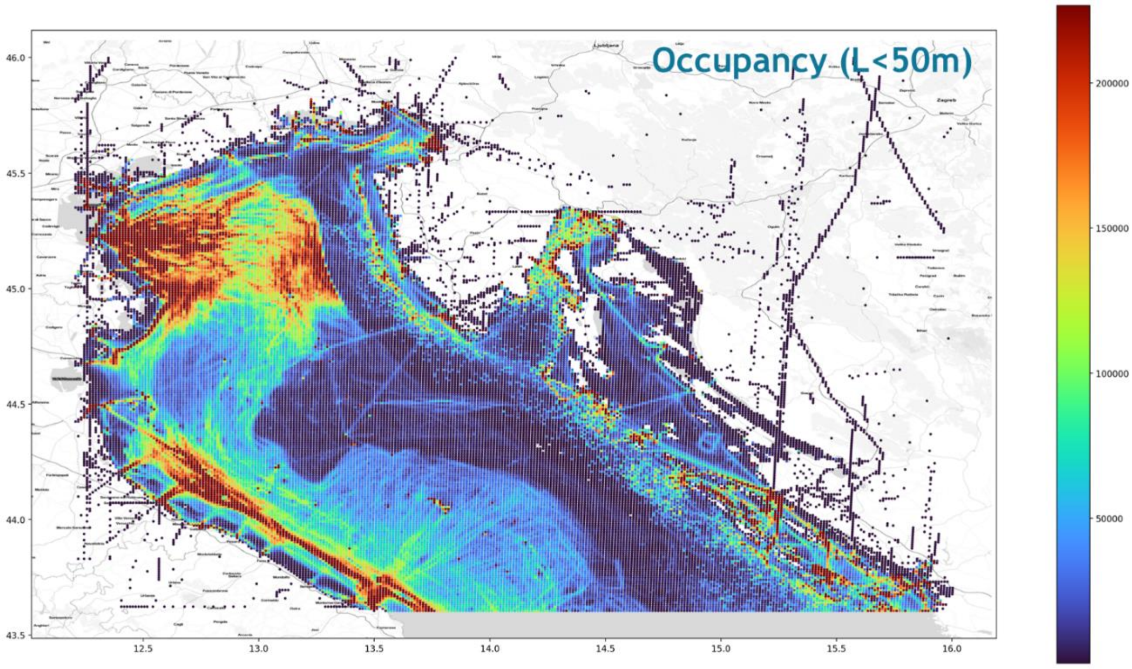


Figure 7: Temporal distribution (L<50m).

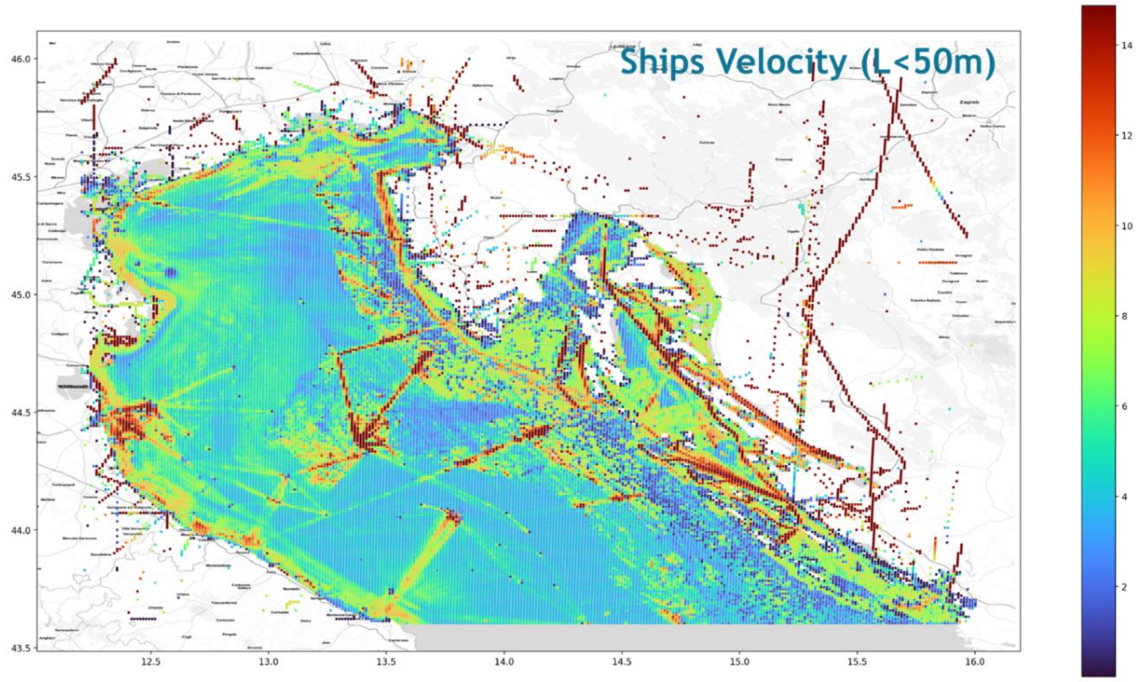


Figure 8: Ship velocity distribution (L<50m).

In the class of ships up to 150 meters in length, the distribution of ship average length is almost equally spread over the whole area except for the part dedicated to the offshore industry (Fig. 9). The figure gives a slight indication of the main traffic flows.

The distribution of vessels (number of vessels in each cell) in a class within 50 and 150 meters of length is shown Fig. 10. The highest density of coastal vessels is in the main lanes leading to major regional ports.

At first glance, the temporal distribution for this class of vessels (Fig. 11) looks like the positional distribution, but a closer look clearly shows anchorages that could obstruct ships as they navigate or be a potential location for collisions between ships.

The distribution of ship speeds also evidences the anchorages (Fig. 12), but also the courses of the larger offshore supply vessels. Furthermore, the figure shows that smaller merchant ships move on average steam at less than 15 knots.

As in the previous length class, the distribution of the average length of vessels in the 150 to 230 meter class is not evenly spread over the whole area. Fig. 13 gives a better indication of the main traffic flows.

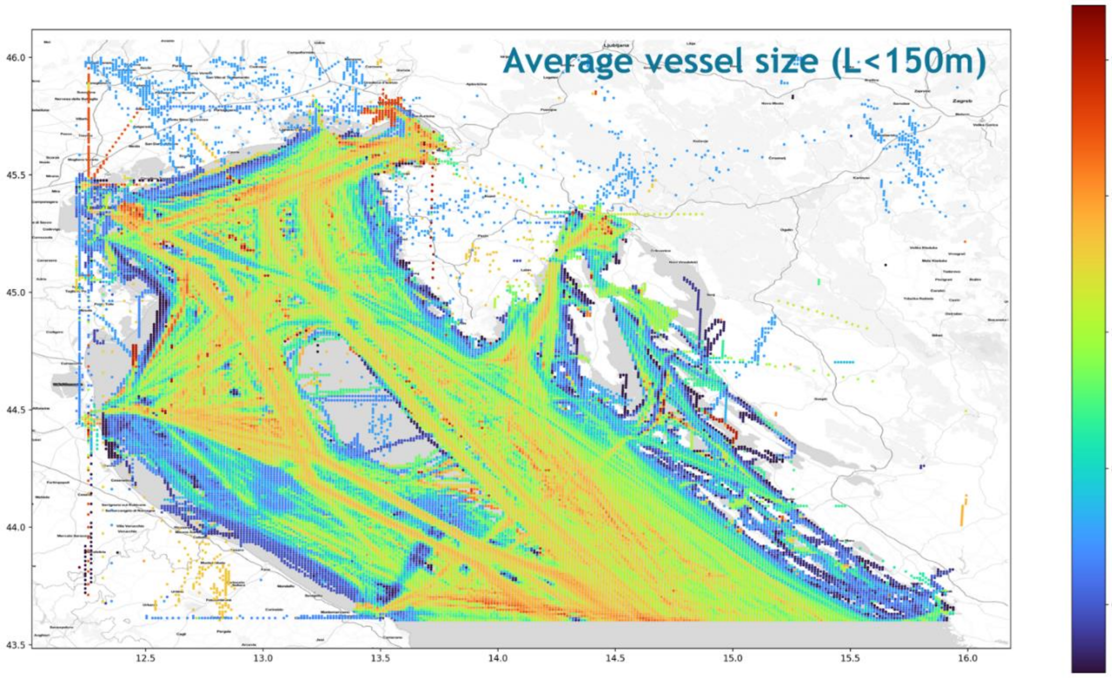


Figure 9: Average vessel size distribution (50<L<150m).

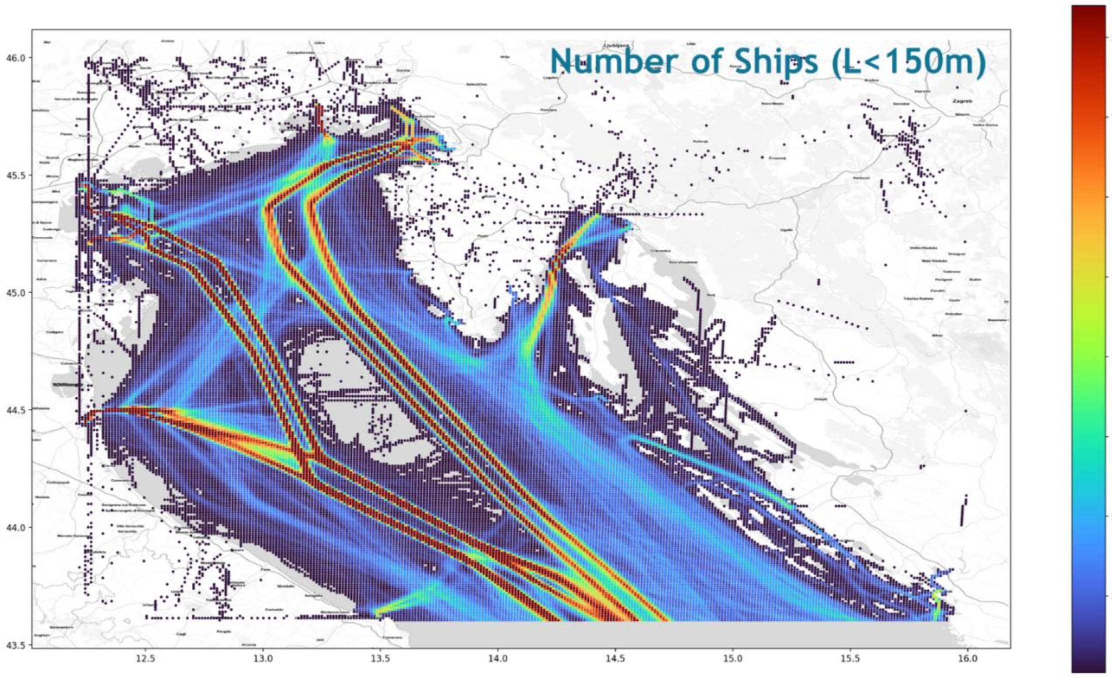


Figure 10: Ships position distribution (50<L<150m).

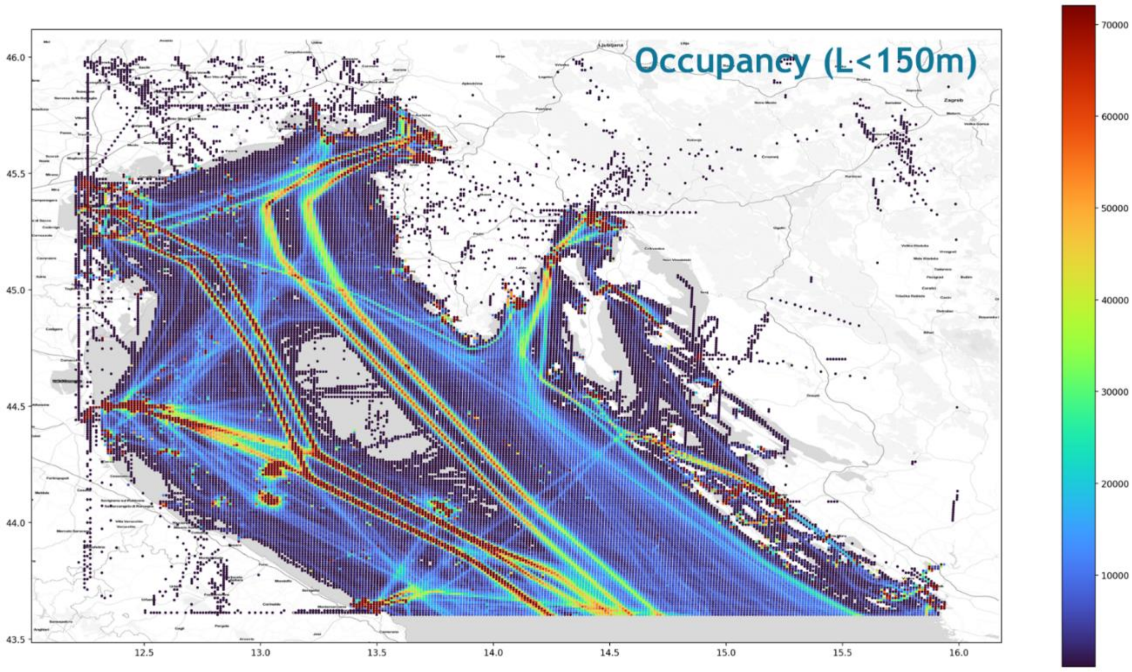


Figure 11: Temporal distribution (50<L<150m).

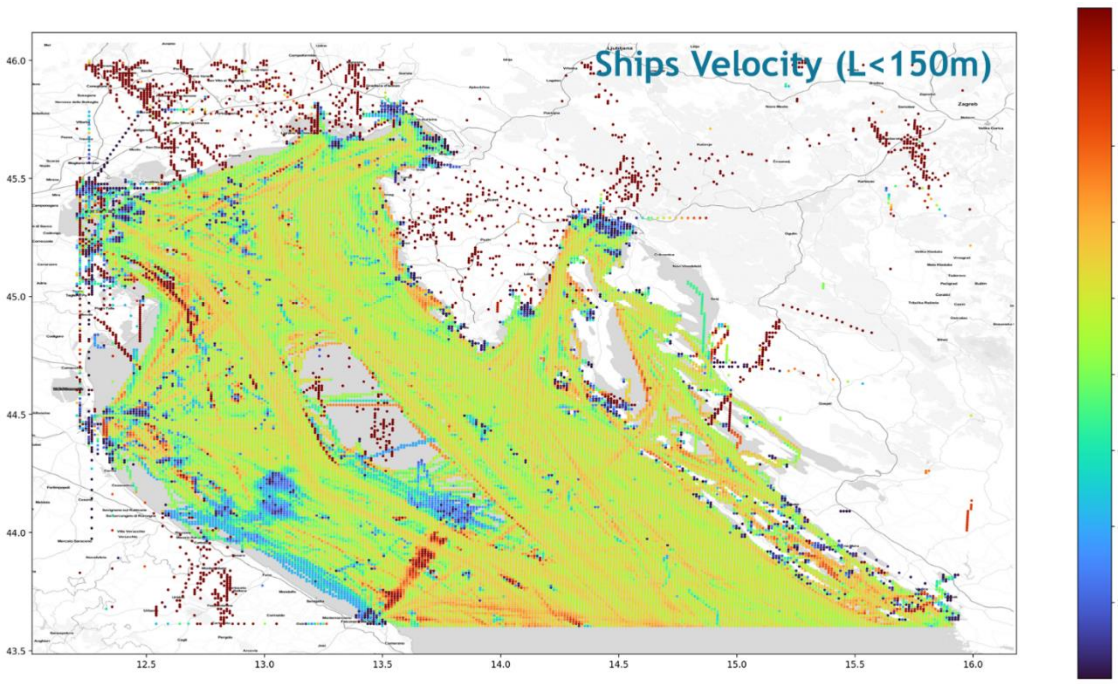


Figure 12: Ship velocity distribution (50>L<150m).

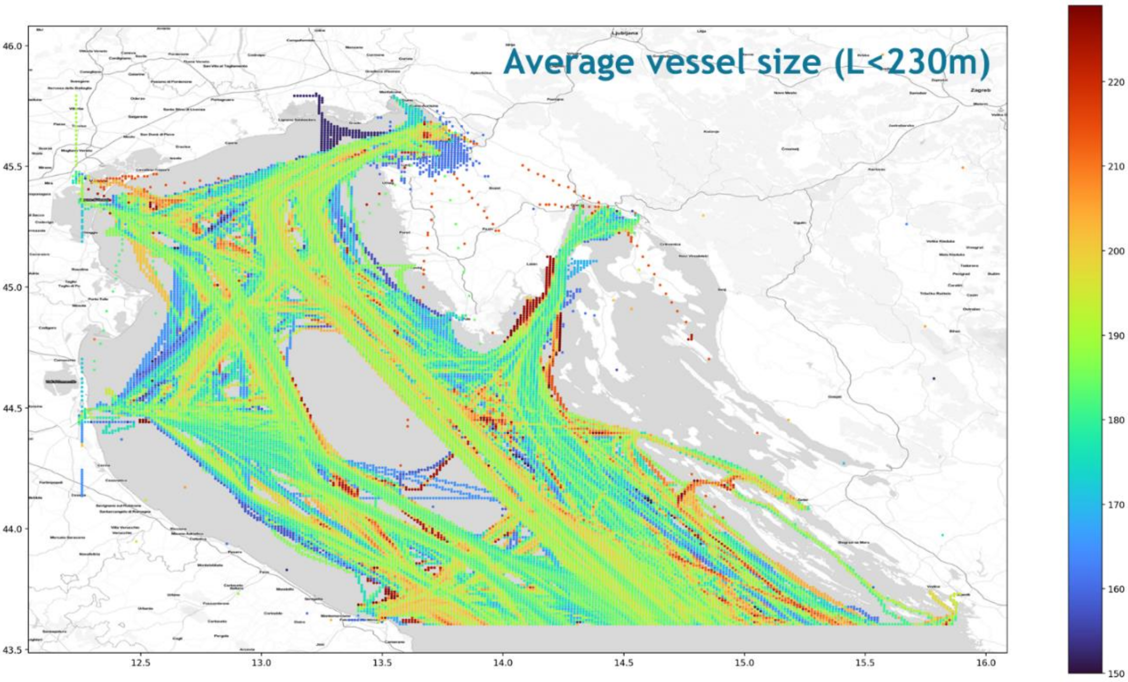


Figure 13: Average vessel size distribution (150<L<230m).

The distribution of ship positions in this length class shows more clearly the shipping lanes in relation to the previous class, and it is also clear that there are more ships, with the number of ships in each cell reaching up to 270 ships (Fig. 14). The distribution of the occupancy of the individual cells in the 150-230 meter class is indeed illustrative of the fairways (Fig. 15), there are no more visible anchorages of larger superyachts in this class. The locations of the main ports can be clearly seen. In this class, the speed distribution chart also shows shipping lanes where the speed of the ships is slightly higher compared to ships in the previous class (Fig. 16): on the fairway, average speeds reach 17 knots.

The distribution of average ship lengths in the 230 to 300 meter class occupies a much smaller area, with occupied cells concentrated around waterways and ports (Fig. 17). It is interesting to note that in this class the average length of the ships calling Venice is slightly greater than that of the ships calling Koper, Trieste and Monfalcone, mainly due to the cruisers.

The distribution of the number of ships (Fig. 18) shows that traffic to the Gulf of Trieste is significantly higher than traffic to Venice. The spatial distribution of ships is, of course, similar to the distribution of average ships lengths.

The occupancy of each cell is concentrated around traffic lanes, anchorages, and harbours (Fig. 19). This spatial distribution is also consistent with the other distributions in this class.

Larger vessels do also have slightly higher speed (Fig. 20), which in the event of a collision means a higher energy of penetration of the ship's plating and a higher probability of fuel or cargo release.

The biggest ships in the region, i.e., those exceeding 300 m, are the container ships - the motherships that regularly operate the liner service, Koper, Trieste, Rijeka (Fig. 21). There is also a share of ships that calls

Venice, mainly cruisers (Fig. 22). The spatial distribution of occupancy per cell provides similar information than the distributions of the other relevant quantities (Fig. 23). However, the occupancy is lower than that of other classes of vessels because there are fewer of them, and they are much faster (Fig. 24). In the event of a collision, the energy released is enormous, and if any ship collides with a large container ship, the amount of bunker fuel that can be spilled is significant.

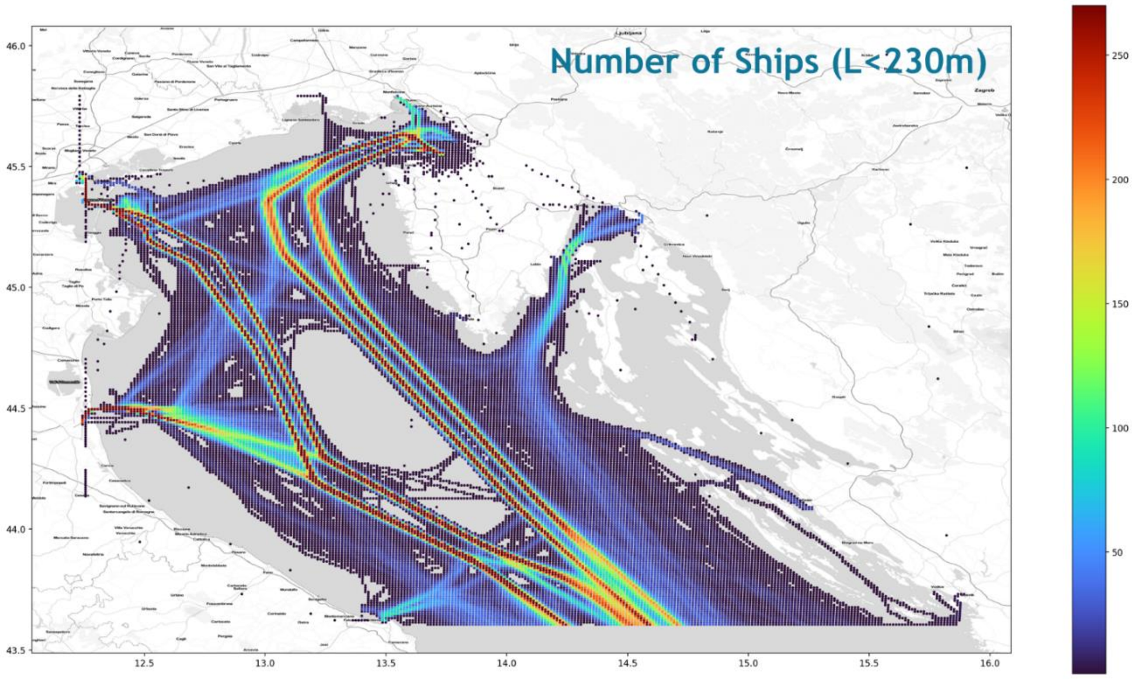


Figure 14: Ships position distribution (150<L<230m).

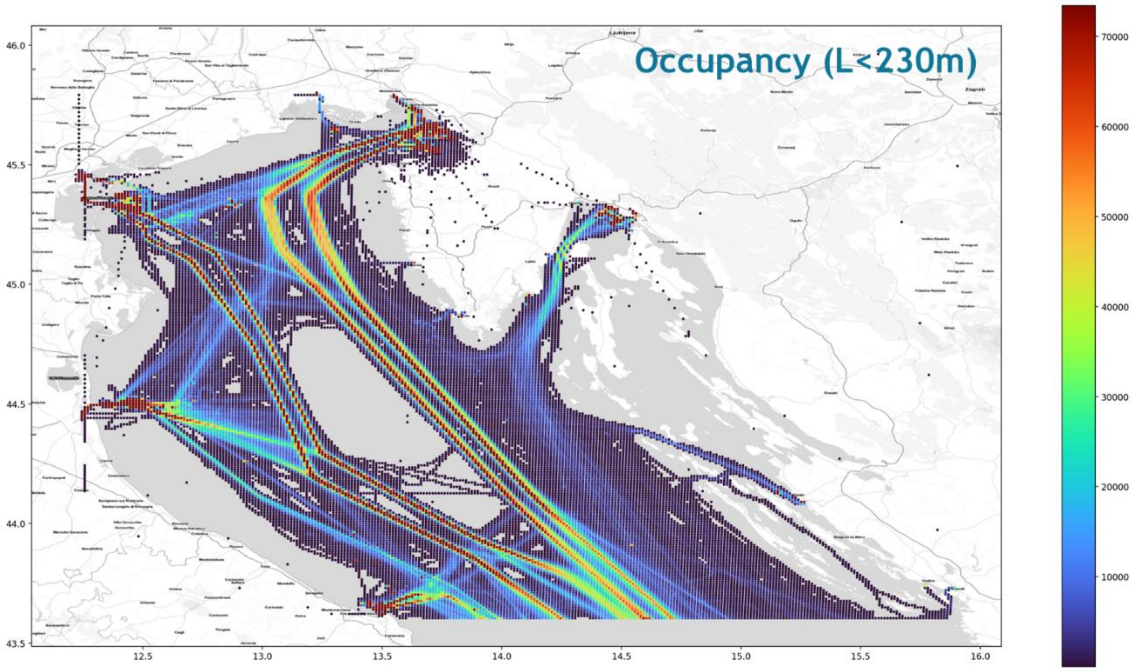


Figure 15: Temporal distribution (150<L<230m).

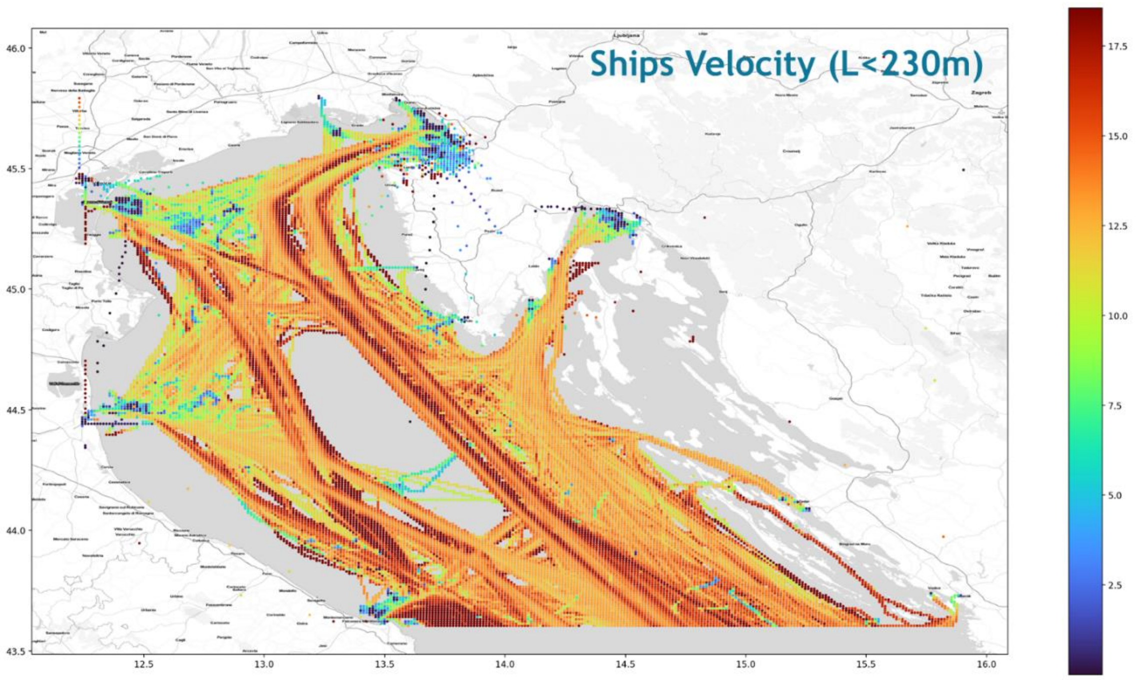


Figure 16: Ship velocity distribution (150<L<230m).

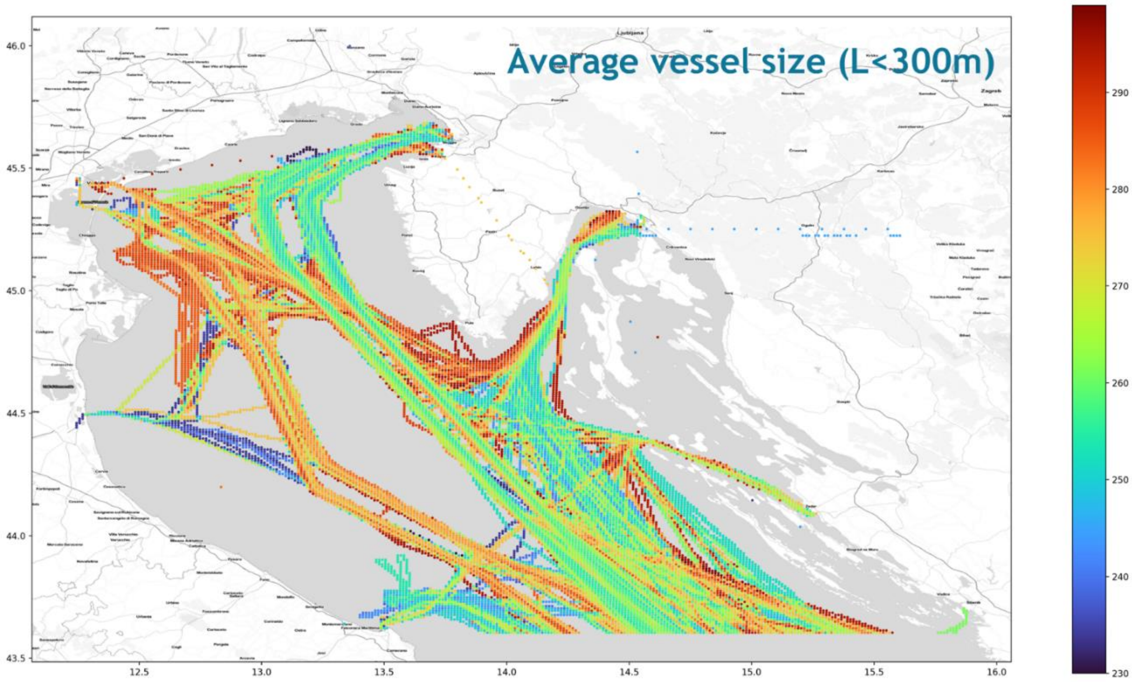


Figure 17: Average vessel size distribution (230<L<300m).

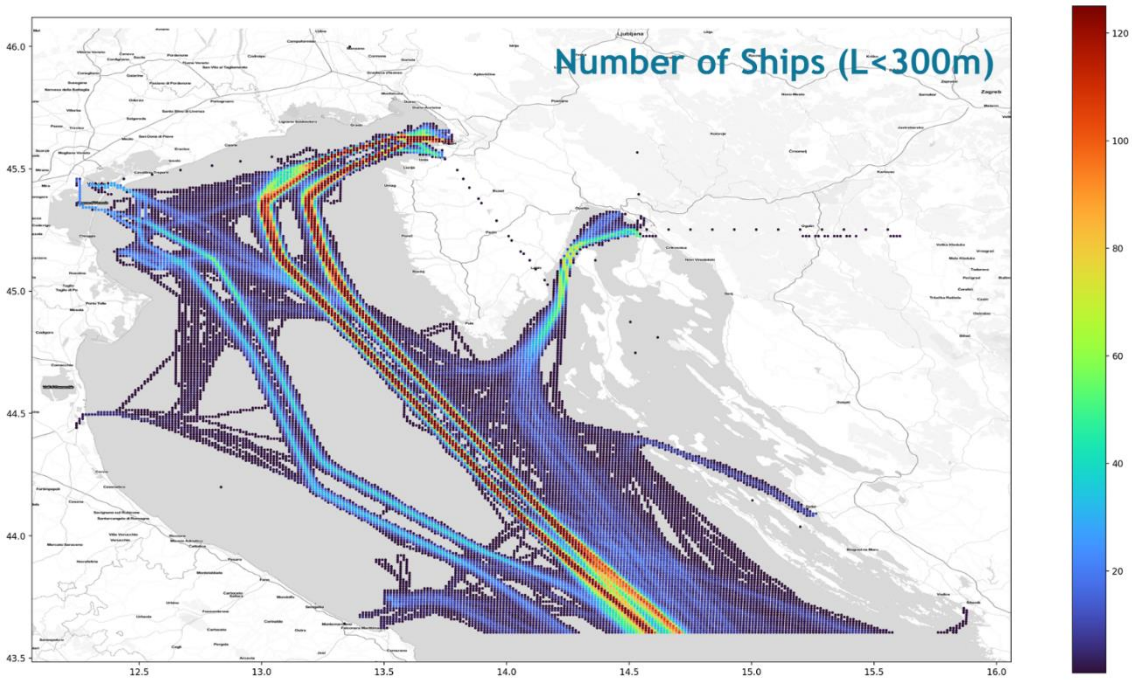


Figure 18: Ships position distribution (230<L<300m).

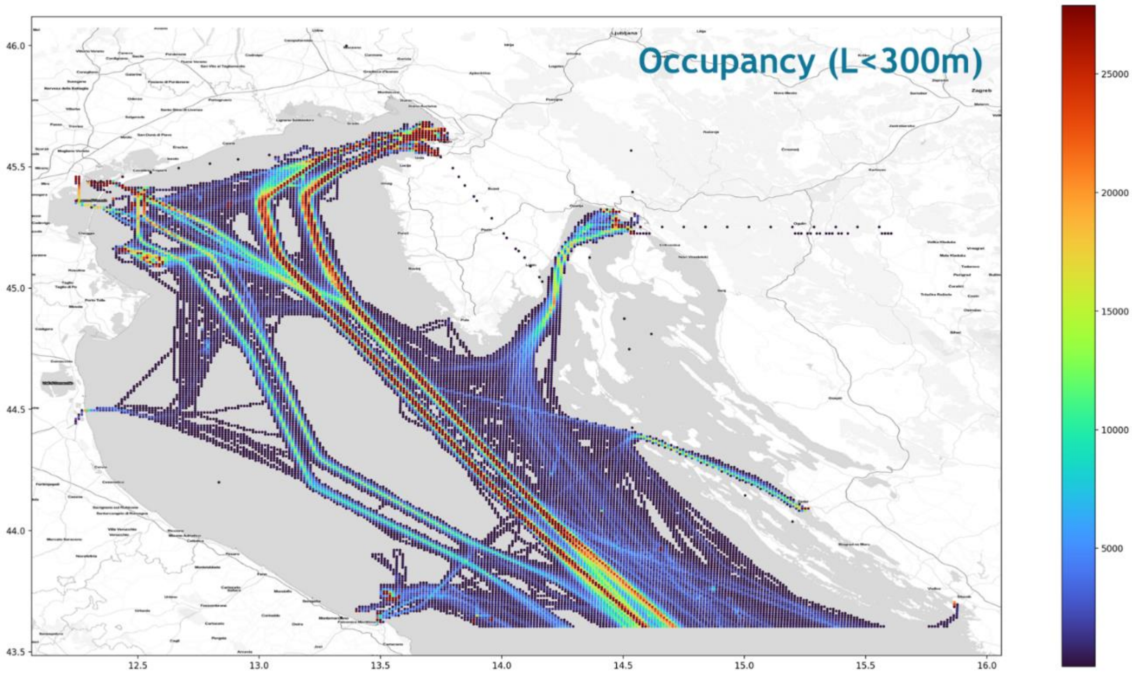


Figure 19: Temporal distribution (230<L<300m).

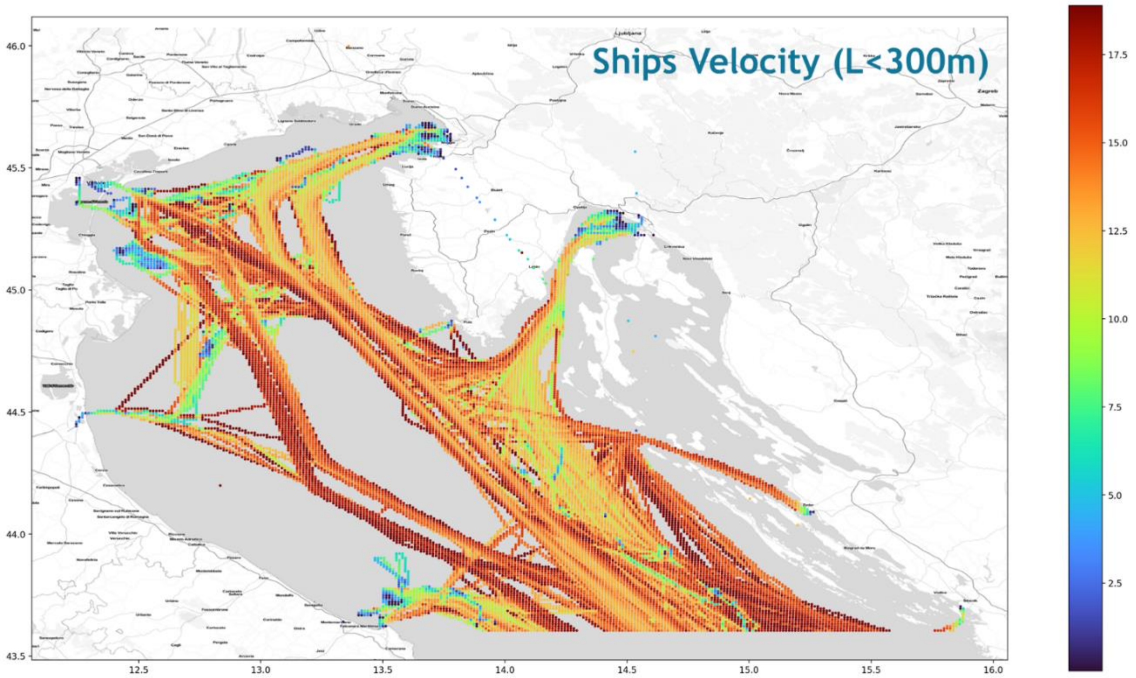


Figure 20: Ship velocity distribution (230<L<300m).

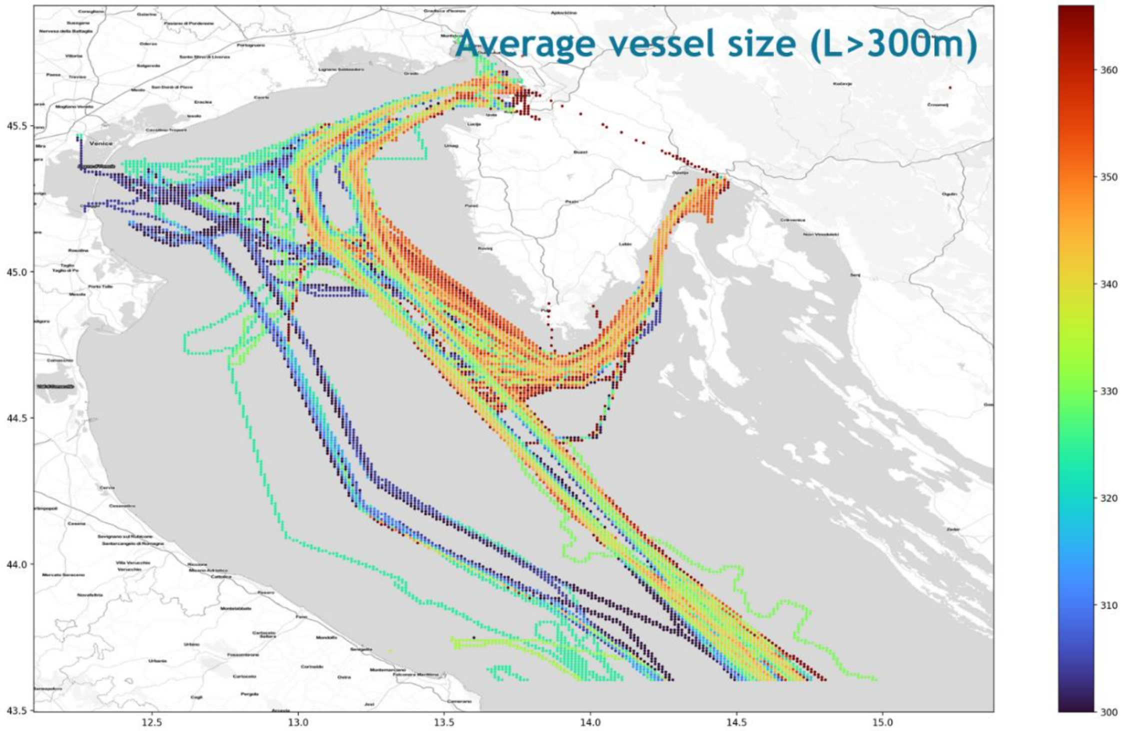


Figure 21: Average vessel size distribution (L>300m).

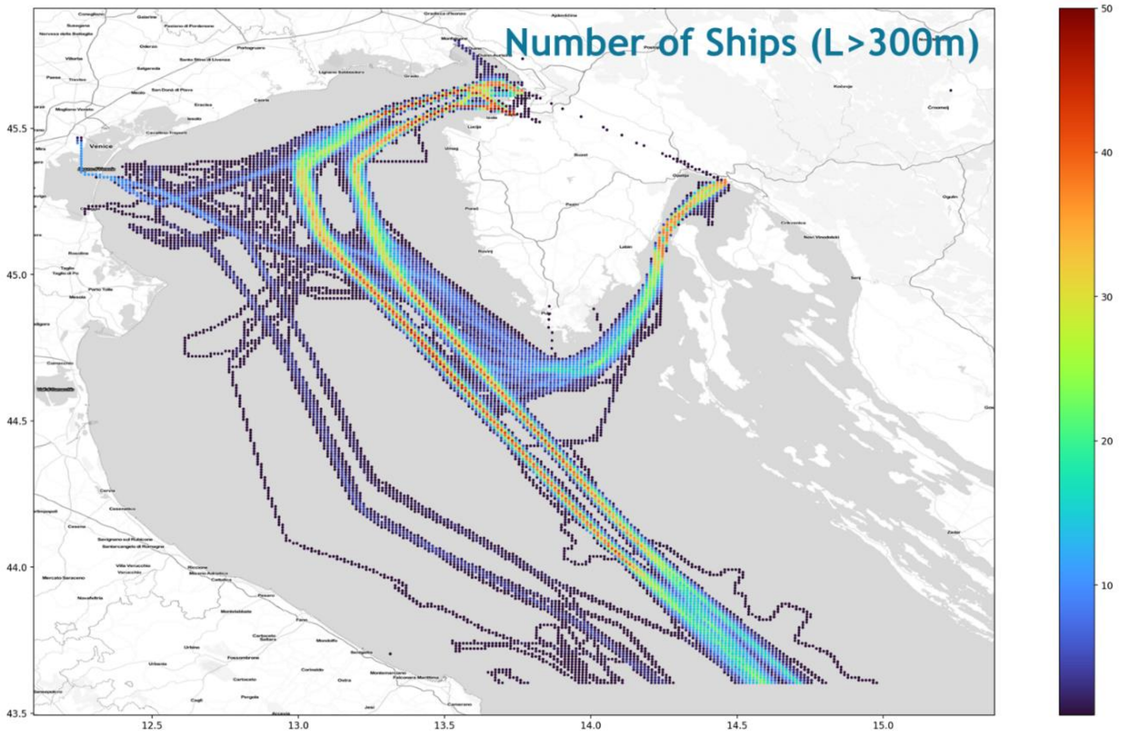


Figure 22: Ships position distribution (L>300m).

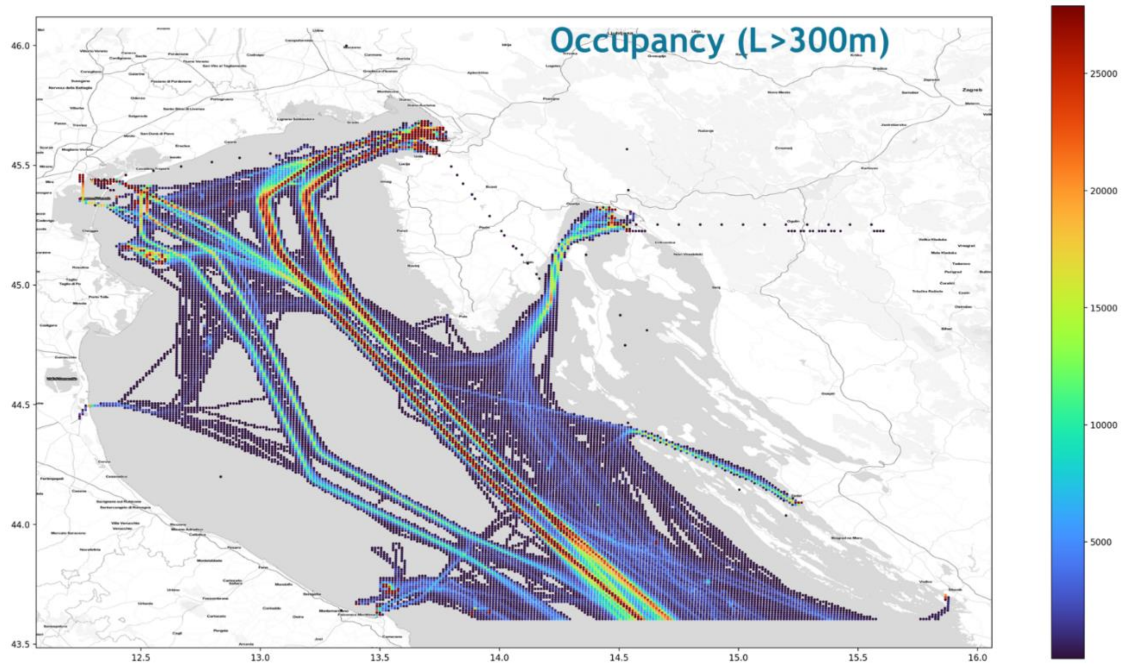


Figure 23: Temporal distribution (L>300m).

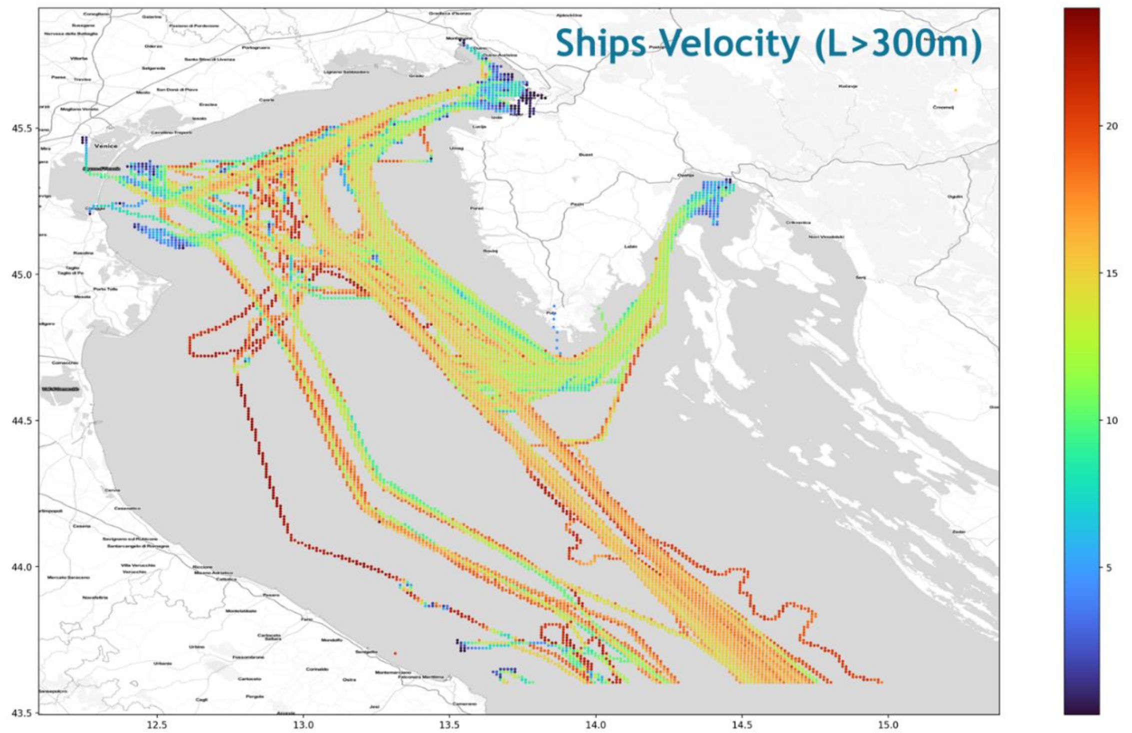
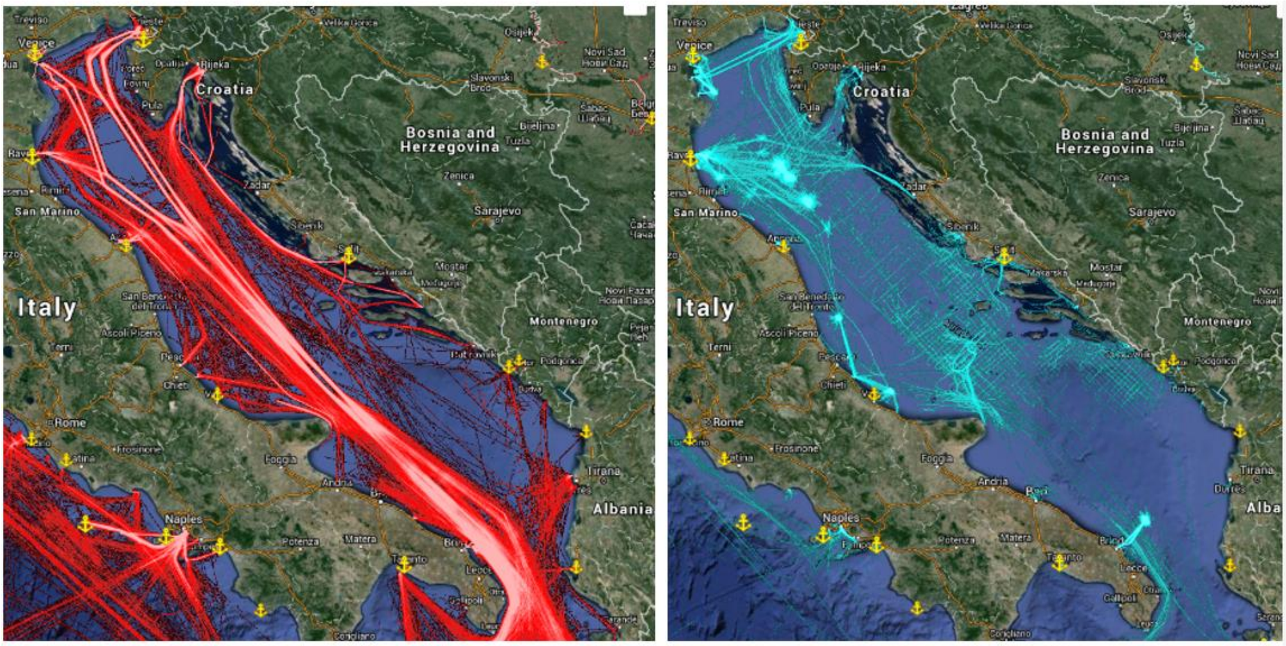


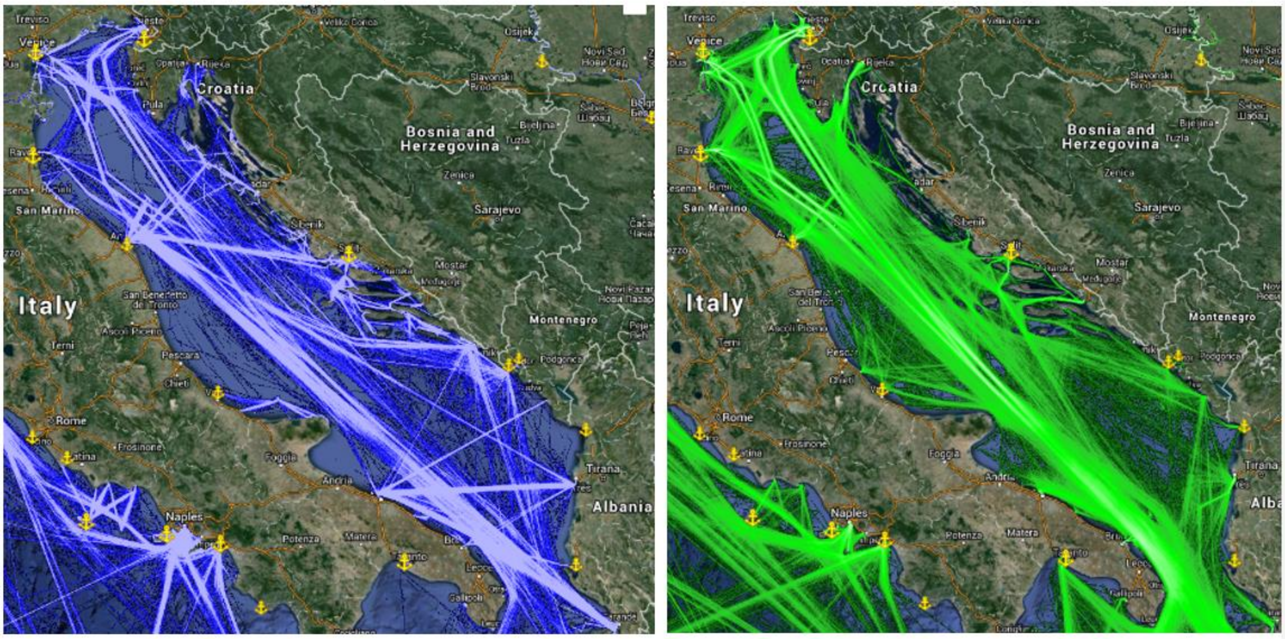
Figure 24: Ship velocity distribution (L>300m).

Figs. 25-26 shows the distribution of traffic as well as the density of ships, divided in four main categories: tankers, service vessels (well evident is a grid pattern of the trajectories of service vessels exploring for hydrocarbons under the seabed in Croatia), passenger ships (ferries and cruisers), and finally ro-ro ships, dry cargo ships such as container ships, general cargo ships, and bulk carriers. It can be seen that the vast majority of ships sail along the entire Adriatic Sea, irrespective of the type of ship.



a) Tankers *b) Service vessels*

Figure 25: Traffic density for Tankers and Service vessels.



c) Cruisers and Ferries d) Cargo vessel

Figure 26: Traffic density for Cruisers and dry cargo ships.

2.4 Incidents and accidents – some examples

The traffic survey shows that shipping in the region is moderate, that there is a wide variety of ships, and that although there is a traffic separation scheme, accidents can happen. Figs. 27-30 provide several examples of possible incidents in the area. Fig. 27 shows a realistic example of a possible collision within a Traffic Separation Scheme (TSS). A ship sailing inside the TSS, "Trident Hope", assumed it had the right of way, and 6 minutes before the collision it started an avoiding maneuver.

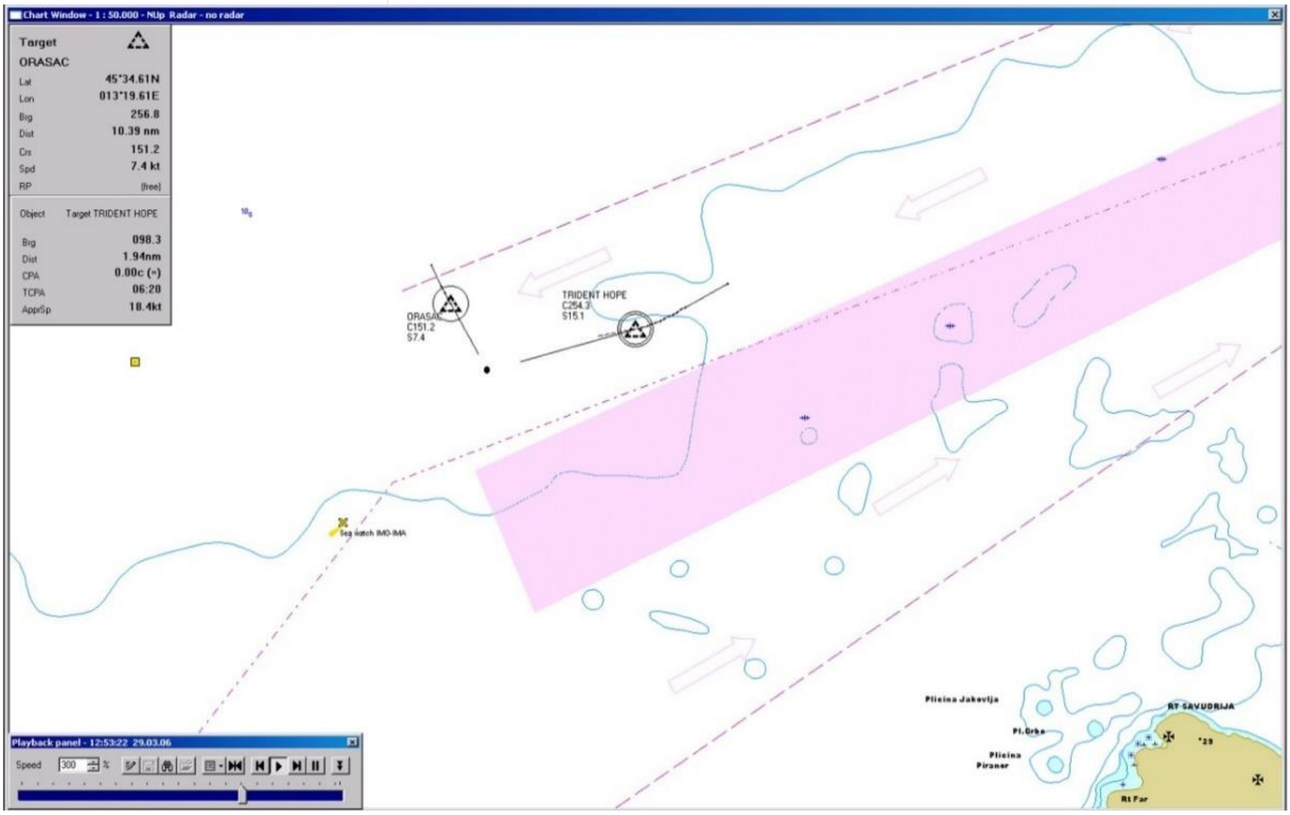


Figure 27: Close encounter at the exit of the TSS - "Trident Hope".

Fig. 28 shows a near miss when the ship "Anamcara" intersected the TSS incorrectly and at the same time made two wrong turns inside the TSS.

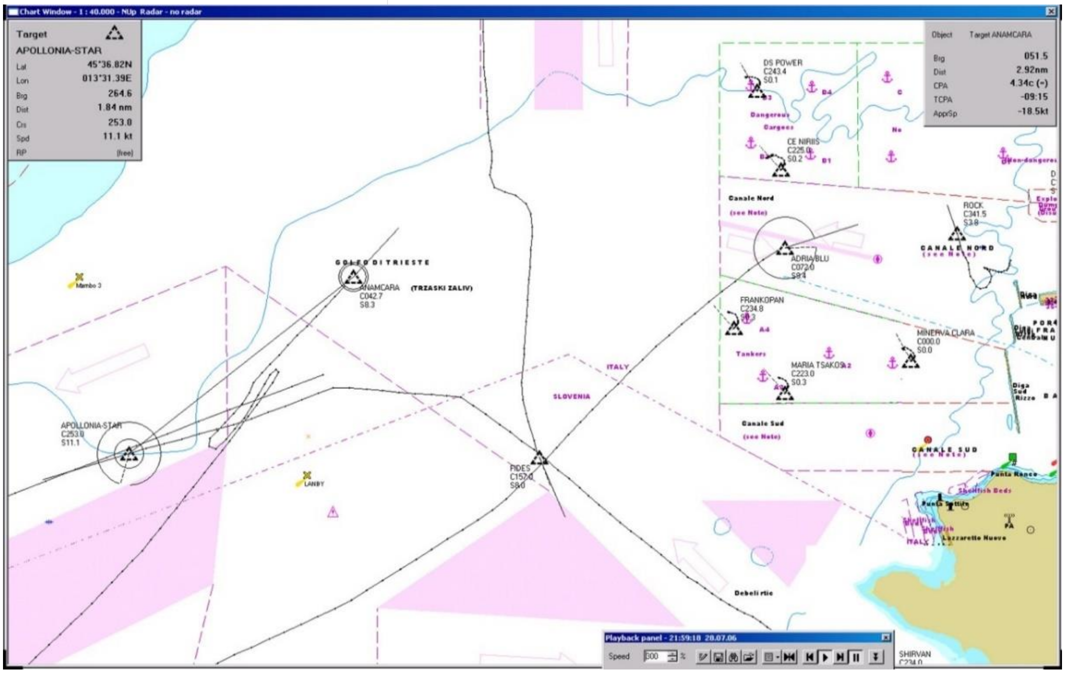


Figure 28: Near collision - "Anamcara".

Fig.29 shows a close encounter between the tanker "Seanostrum" and a ship improperly intersecting the TSS "Niyazi Gokalp".

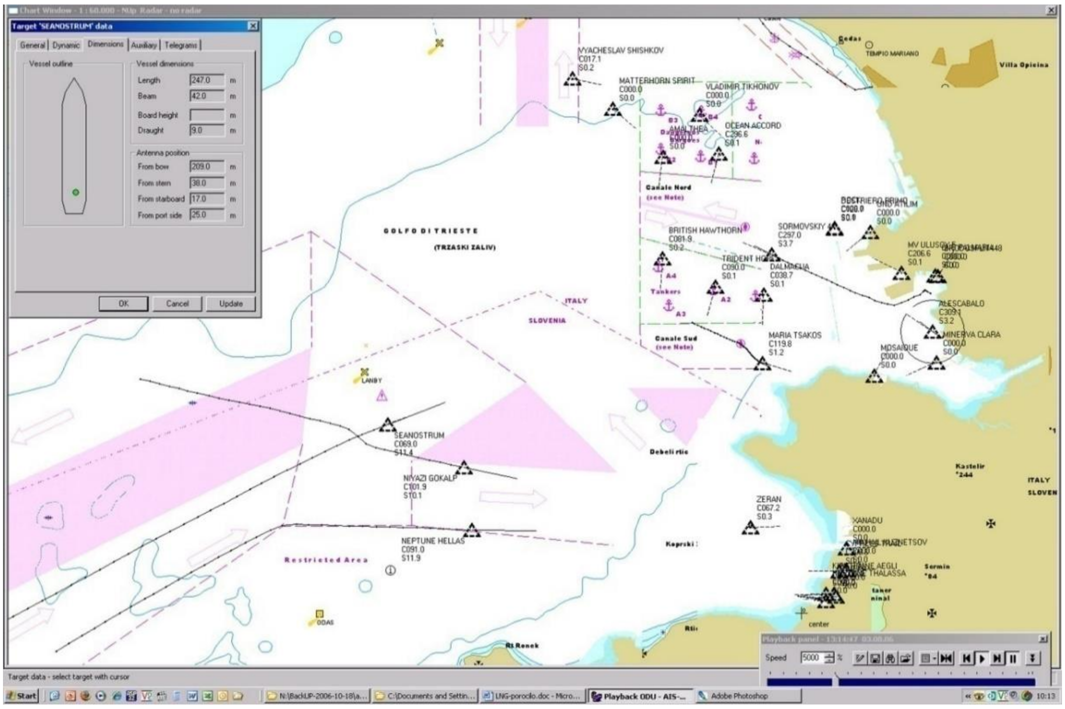


Figure 29: Close encounter of the "Niyazi Gokalp" with the tanker "Seanostrum".

The last example (Fig. 30) shows the large merchant ship "Und Atilm" (length 195 m - sister ship to the recently burnt "Und Adriyatik", it is noted that these ships generally violate traffic regulations and that they also discharge oily water into the sea - proof of which will follow below in the section on illegal discharges) passing through the anchorage at a high speed of 20.2 knots.

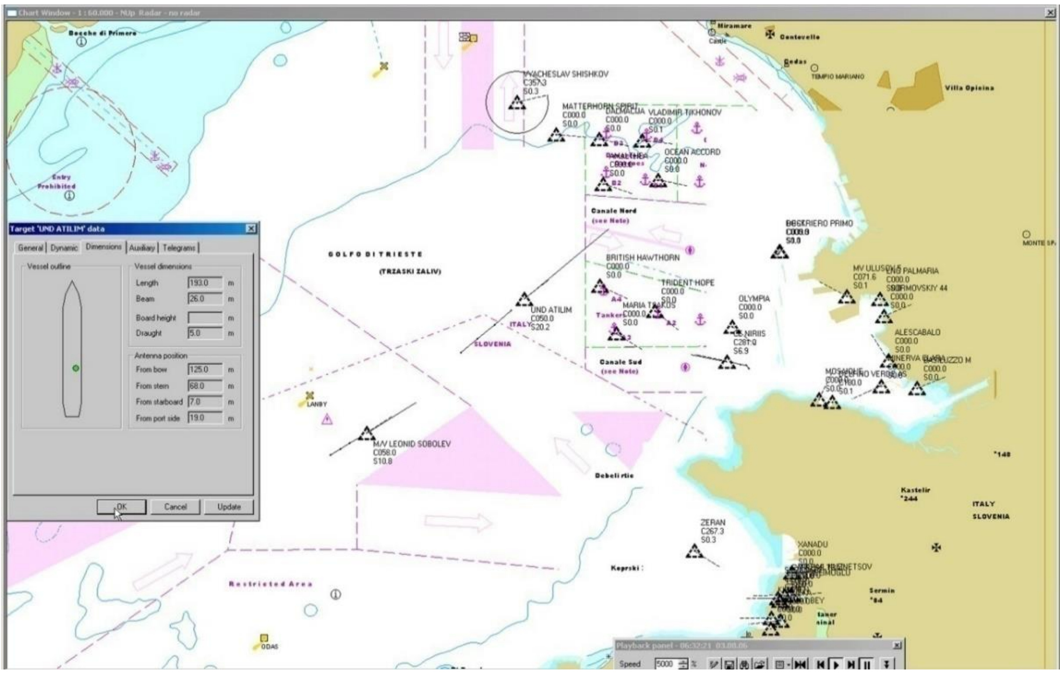


Figure 30: High speed crossing of an anchorage - "Und Atilm".

2.5 Ship collision risk assessment

Risk is assessed by first assigning a value to the probability of the event occurring and then to the severity of the consequences for shipping. Typically, two values are multiplied to form the risk matrix. Finally, the result is assigned to the risk matrix and classified as low, moderate, or high. The risk rating indicates the magnitude and acceptability of the risk and determines whether the task can be performed and when additional control measures are required to reduce the risk to ALARP (As Low As Reasonably Possible). The probability of collision and grounding for the Gulf of Trieste was first calculated in 2009 using a stochastic approach developed by Gucma et al. (2006), at a time when IWRAP was not available. The calculated unplanned event was significantly higher, mainly due to the 30% higher traffic volume, which was not as organized as it is now. Both approaches are presented here. A stochastic simulation model was used for the safety analysis of complex maritime traffic (Gucma et al., 2016). The modular structure of the model is shown in the figure below. This type of model can be used to analyse maritime traffic in different aspects: collision, grounding, collision with fixed objects, indirect collisions such as anchoring, and wave generation causing damage to the shore. The model can be extended and complemented with sub-models according to the research objectives. This modelling methodology is well established and has been applied in several case studies.

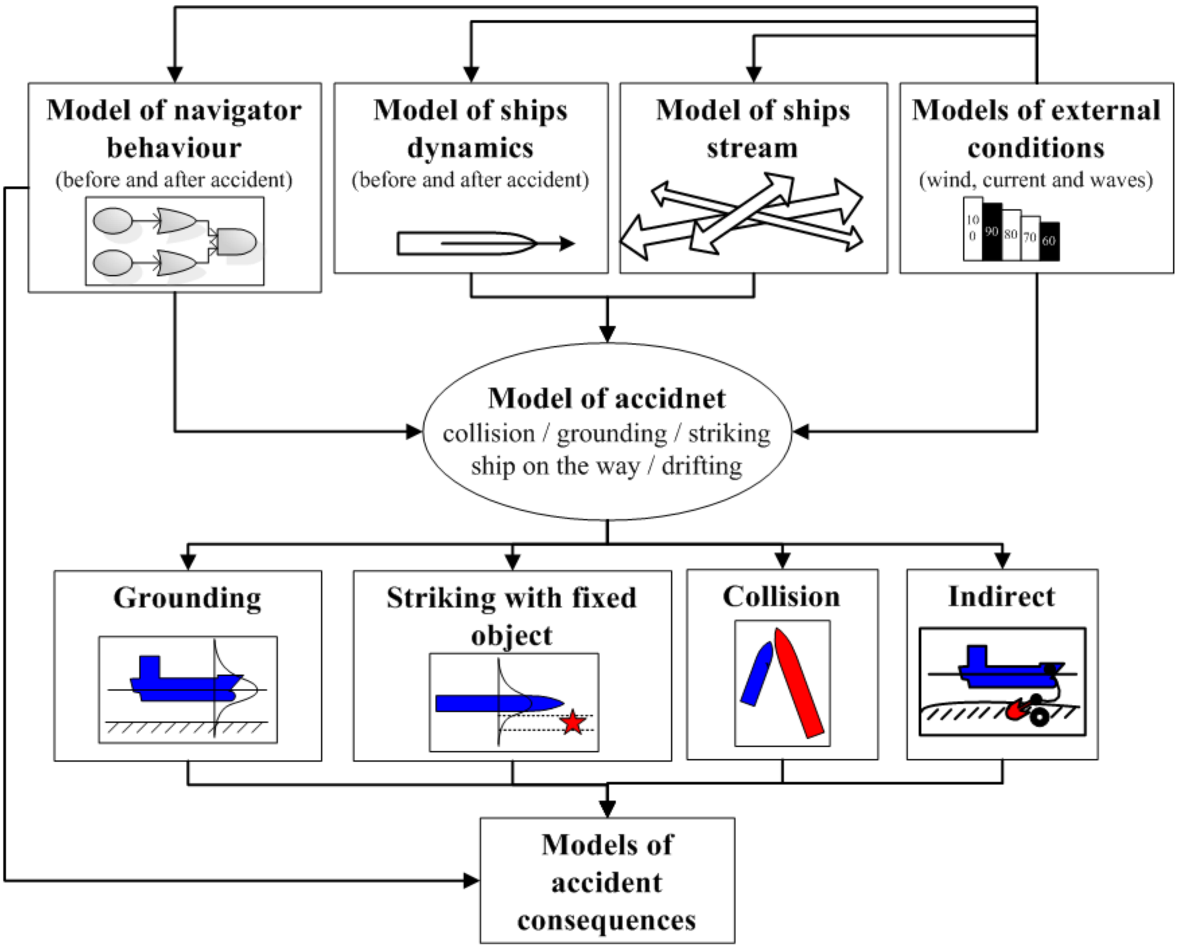


Figure 31: Diagram of the stochastic model for navigation safety assessment.

A simplified statistical model has been used to model the probability of a collision at sea. The model ignores a number of elements and their correlations/dependencies as it is simply based on statistical data obtained from observations of real shipping traffic. The biggest unknown parameter in this type of modelling is the exact number of close encounters. Some of them can be selected from the AIS archive, but it should be noted that these encounters are more numerous because the area off Koper is a crossing of shipping lanes, where there are often fishing boats and other vessels that are not included in the traffic archive. Therefore, the only way to determine the parameters for close encounters in such complex traffic regimes is to model traffic flows over longer periods of time. A simplification of the calculation is given by equating the collision probability over the whole area, which is also consistent with the available incident. The calculated collision probabilities for individual encounter states (head-on, crossing, and overtaking) are higher than $1*10^{-5}$, which is also the usual size class for the application of this type of safety analysis at sea. In the following, 30 typical waterways in the Gulf of Trieste are selected for input into the model, as shown in the following figures. First, the complexity of the traffic flows and trajectories is presented.

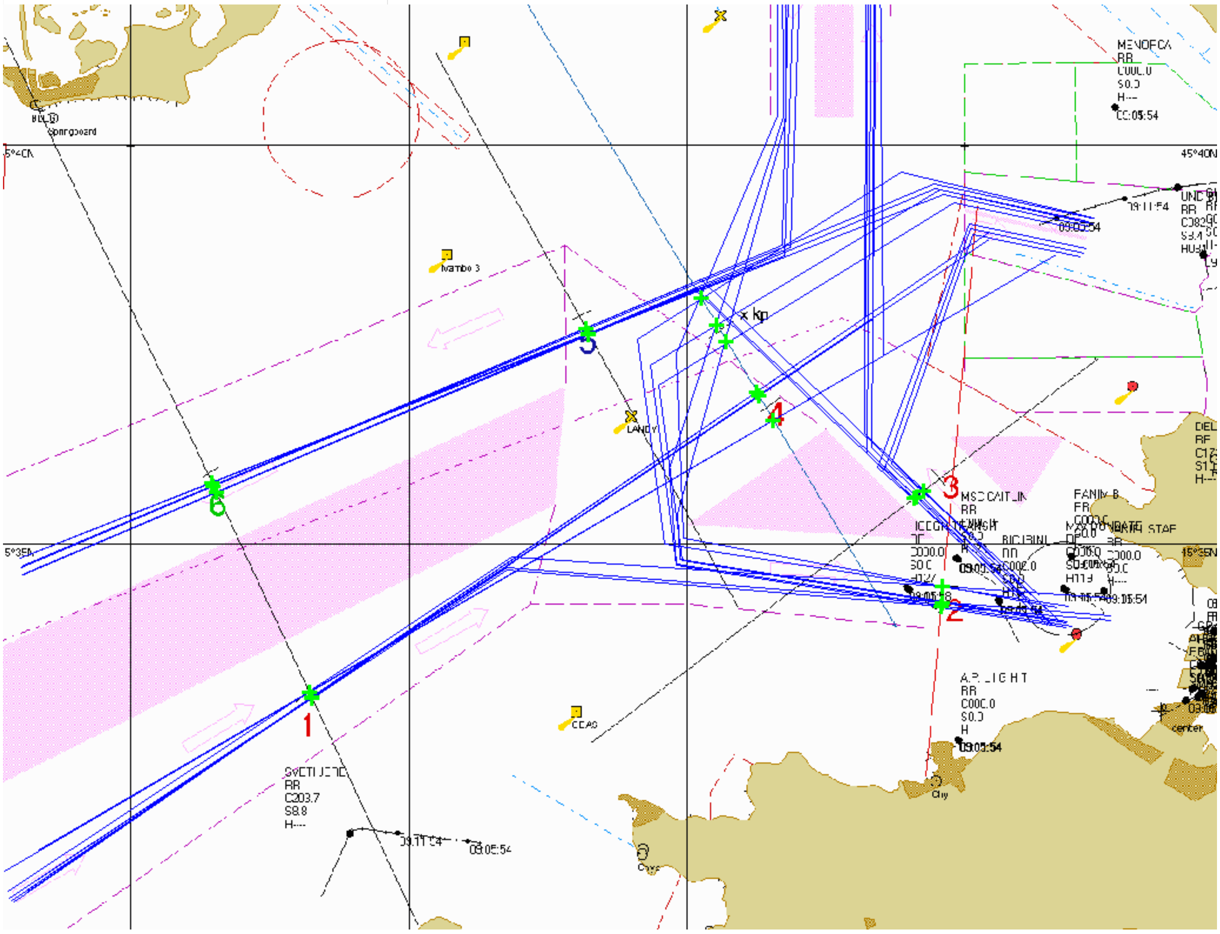


Figure 32: Selected fairways for modelling potential accidents in the Gulf of Trieste.

The traffic simulation is carried out in batches of 5 years. The increase in traffic over this period and the impact on safety can be analyzed relatively well. The results of the locations of potential incidents are presented in the next Figs. 33-34. The processed data show that vessels do not only sail in the regulatory areas, but also in the separation zones, in the lanes in the opposite direction, and in the local coastal traffic areas. Despite the separation scheme, inappropriate and dangerous *maneuvers* are sometimes made by vessels passing through the area *(Fig. 33)*. However, this does not mean that it is always ships that violate the rules, as their *maneuvers* may be the result of violations by other smaller vessels (mainly boats) that do not transmit AIS and are not detected by radars.

The model showed that the highest density of collisions in the area is located between the separation lines - the so-called 'precautionary zone' (Fig. 34). The probability of a major accident occurring during this period is estimated to be once every 120 years. The simulation showed that the time between collisions with just a 30% increase in traffic, an accident can be expected every 80 years.

Table 4 gives the detailed positions with encounter types and expected spillage depending on speed, ship size, and ship loading condition for the Gulf of Trieste.

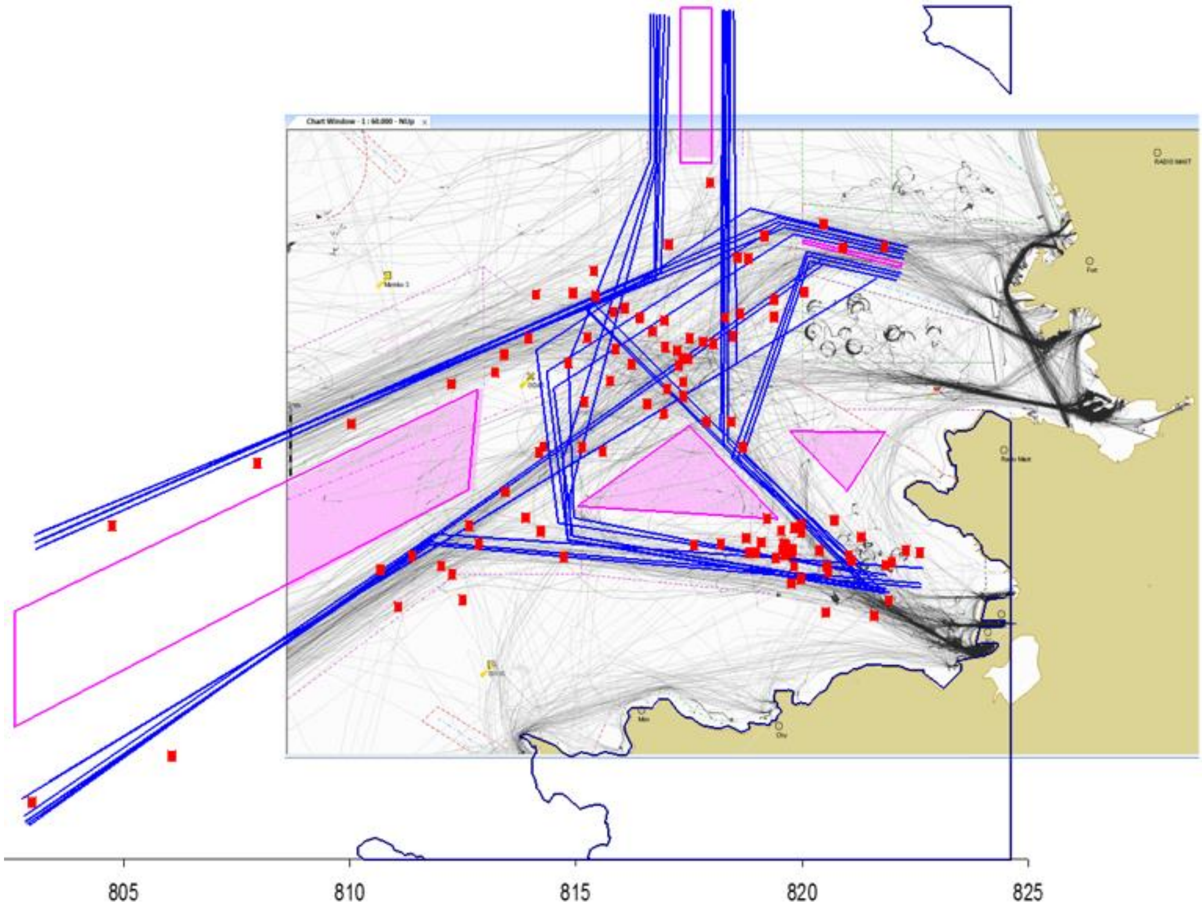


Figure 33: Analysis of the data relative to vessels sailing in the Gulf of Trieste.

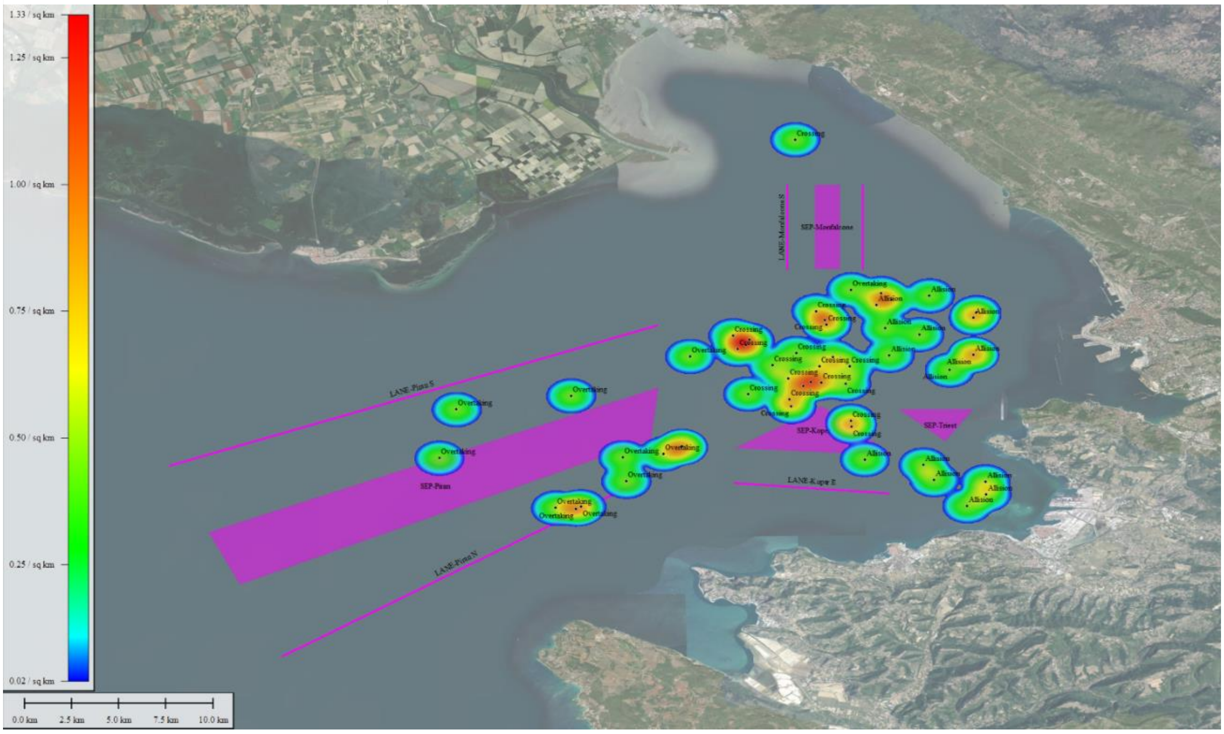


Figure 34: Simulation of possible collision locations.

Table 4: Potential accident locations in the Gulf of Trieste modelled stochastically, with indication of the type of accident, the type of oil product involved, and the estimated quantities of products released in the water.

LONGITUDE	LATITUDE	Type of accident	Bunker Oil (HFO_&_LSFO)	Crude Oil	Product (diesel)
13.69392222° E	45.55979235° N	Allision	1000		5000
13.70292459° E	45.56518537° N	Allision	1000		5000
13.70252715° E	45.57119571° N	Allision	1000		5000
13.67819703° E	45.57220059° N	Allision	1000		5000
13.67304983° E	45.57920814° N	Allision	1000		5000
13.64519026° E	45.58184783° N	Allision	1000		5000
13.68556035° E	45.62439027° N	Allision	1000	15000	5000
13.65690631° E	45.63141912° N	Allision	1000	15000	5000
13.69676223° E	45.63165696° N	Allision	1000	15000	5000
13.69676223° E	45.63165696° N	Allision	1000	15000	5000
13.67110737° E	45.64130274° N	Allision	1000	15000	5000
13.65506813° E	45.64424405° N	Allision	1000	15000	5000
13.69695240° E	45.64918949° N	Allision	1000	15000	5000
13.69822560° E	45.65170179° N	Allision	1000	15000	5000

13.65092488° E	45.65531408° N	Allision	1000	15000	5000
13.65795693° E	45.65778071° N	Allision	1000	15000	5000
13.67599200° E	45.65971947° N	Allision	1000	15000	5000
13.65295331° E	45.66089701° N	Allision	1000	15000	5000
13.63890604° E	45.59745103° N	Crossing	1500	30000	15000
13.63855922° E	45.60017275° N	Crossing	1500	30000	15000
13.61030592° E	45.60711050° N	Crossing	1500	30000	15000
13.60945121° E	45.61050520° N	Crossing	1500	30000	15000
13.58976625° E	45.61298687° N	Crossing	1500	30000	15000
13.61615616° E	45.61684767° N	Crossing	1500	30000	15000
13.63630284° E	45.61790272° N	Crossing	1500	30000	15000
13.62449205° E	45.61830636° N	Crossing	1500	30000	15000
13.61960735° E	45.61869464° N	Crossing	1500	30000	15000
13.60886889° E	45.62023407° N	Crossing	1500	30000	15000
13.62366451° E	45.62615882° N	Crossing	1500	30000	15000
13.63806024° E	45.62619455° N	Crossing	1500	30000	15000
13.60155729° E	45.62660554° N	Crossing	1500	30000	15000
13.63005648° E	45.63064472° N	Crossing	1500	30000	15000
13.61270392° E	45.63237405° N	Crossing	1500	30000	15000
13.58491862° E	45.63429868° N	Crossing	1500	30000	15000
13.58887546° E	45.63645763° N	Crossing	1500	30000	15000
13.59034623° E	45.63867045° N	Crossing	1500	30000	15000
13.58274019° E	45.64074606° N	Crossing	1500	30000	15000
13.62706152° E	45.64607300° N	Crossing	1500	30000	15000
13.62623297° E	45.64818178° N	Crossing	1500	30000	15000
13.62217252° E	45.65244776° N	Crossing	1500	30000	15000
13.61213715° E	45.73400742° N	Crossing	1500	30000	15000
13.50790922° E	45.55830098° N	Overtaking	500	5000	5000
13.49845857° E	45.55875748° N	Overtaking	500	5000	5000
13.51051232° E	45.55931577° N	Overtaking	500	5000	5000
13.53190853° E	45.57147604° N	Overtaking	500	5000	5000
13.44308846° E	45.58248147° N	Overtaking	500	5000	5000
13.53044396° E	45.58270515° N	Overtaking	500	5000	5000
13.54964278° E	45.58444207° N	Overtaking	500	5000	5000
13.55830186° E	45.58758087° N	Overtaking	500	5000	5000
13.55833543° E	45.58795816° N	Overtaking	500	5000	5000

13.45125168° E	45.60558592° N	Overtaking	500	5000	5000
13.50567977° E	45.61209393° N	Overtaking	500	5000	5000
13.56222224° E	45.63088427° N	Overtaking	500	5000	5000
13.63880156° E	45.66263050° N	Overtaking	500	5000	5000

The numerical results were then expertly processed and extrapolated from the Gulf of Trieste to the entire North Adriatic region. Fig. 35 shows the locations of potential encounters in the Northern Adriatic Sea, while Table 5 gives more detailed positions with encounter types and expected spillage depending on speed, ship size and ship loading condition. The most dangerous areas for incidents are anchorages and locations where waterways intersect.

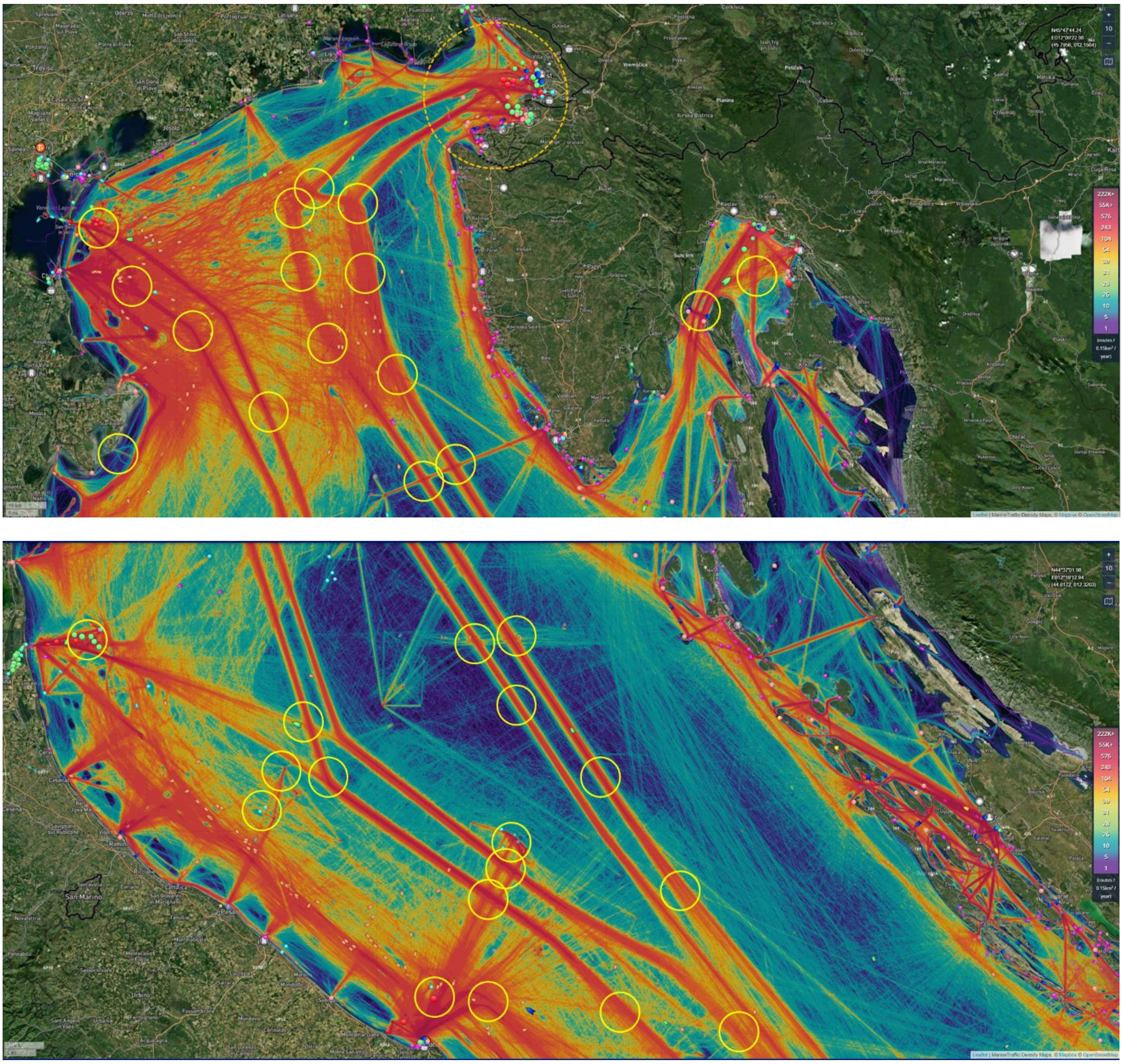


Figure 35: Probable accident locations in the Northern Adriatic Sea.

Table 5: Potential accident locations in the North Adriatic Sea - an extrapolated qualitative approach, with indication of the type of accident, the type of oil product involved, and the estimated quantities of products released in the water.

LONGITUDE	LATITUDE	Type of accident	Bunker Oil (HFO_&_LSFO)	Crude Oil	Product (diesel)
14.48815016° E	43.64815717° N	Crossing	1500	15000	15000
14.11154590° E	43.68319013° N	Crossing	1500	15000	15000
13.54751533° E	43.69720331° N	Allision	1000		5000
13.66837902° E	43.73573956° N	Crossing	1500		15000
13.69465374° E	43.94243399° N	Crossing	1500		15000
14.25868431° E	43.97571530° N	Overtaking	500	5000	5000
13.74720317° E	44.00199001° N	Crossing	1500		15000
13.78048448° E	44.06154604° N	Allision	1000		5000
13.04128914° E	44.10533723° N	Allision	1000	10000	5000
13.20944732° E	44.18591302° N	Crossing	1000		5000
13.06931550° E	44.22269763° N	Allision	1500		15000
14.02921846° E	44.22620092° N	Overtaking	500	5000	5000
13.14288471° E	44.31553496° N	Crossing	1000		5000
13.79800096° E	44.35407121° N	Overtaking	500		
13.77172624° E	44.50296126° N	Crossing	1500	30000	15000
13.65962079° E	44.50296126° N	Crossing	1500		15000
12.98873971° E	44.67111944° N	Overtaking	500		
13.41088681° E	44.77271501° N	Crossing	1500		15000
13.50372414° E	44.80424467° N	Crossing	1500	30000	15000
12.93969357° E	44.90233694° N	Overtaking	500	5000	5000
13.31980113° E	45.00743581° N	Crossing	1500	15000	15000
13.12711988° E	45.05473030° N	Crossing	1500		
12.70146948° E	45.08450831° N	Crossing	1500		
14.23941618° E	45.14231268° N	Crossing	1500	15000	15000
12.51754647° E	45.18435223° N	Crossing	1500		5000
13.03778584° E	45.19661376° N	Overtaking	500	5000	5000
13.23046709° E	45.20537200° N	Overtaking	500		
14.42333919° E	45.23865331° N	Crossing	1500	15000	5000
12.41419925° E	45.32798734° N	Allision	1000	10000	5000
12.99924959° E	45.35951700° N	Crossing	1500		

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13.19543414° E	45.37878513° N	Crossing	1500	30000	15000
13.05530232° E	45.40681149° N	Crossing	1500		
12.42470914° E	44.49945797°N	Allision	1500	5000	5000

2.6 Discussion

Shipping is perhaps the most international of the world's major industries - and potentially one of the most dangerous. It has always been recognized that the best way to improve safety at sea is to develop international rules that are followed by all shipping nations.

The traffic, density, and classification of maritime traffic in the North Adriatic have been presented in detail in this part of the study. A stochastic model has been applied to the extended area of the Gulf of Trieste, which is undoubtedly the riskiest area due to the numerous shipping lanes, the presence of a large number of hazardous substances, the shallow sea and the sensitive coastal zone. The results obtained are then extrapolated to the whole of the northern Adriatic using an experimental method. The predicted quantities of fuel and/or cargo discharged were also given. The probability of a major accident occurring during this period is estimated to be once every 120 years. A more accurate estimate would be obtained by IWRAP by analyzing a larger amount of AIS data, but the time and personnel cost for it exceeded NAMIRS funds and timetable. Thus, such an analysis is planned in the future.

3. Oil spill simulations and exposure estimation

3.1 Introduction

This section is devoted to the presentation of the oil spill simulations performed for the definition of the exposures (Task 2) of the area of interest, in the context of the Activity 2.1 – Environmental Risk Assessment of NAMIRS. The Lagrangian particle tracking model LTRANS-Zlev (Laurent et al., 2020) including the oil spill module OILTRANS was used to perform the oil spill simulations coupled with an MITgcm (Massachusetts Institute of Technology general circulation model, (Marshall et al., 1997) implementation for the Adriatic Sea (Querin et al., 2016), employing an evolution of the model (Silverstri et al. ,2020), and applied in other studies (Melaku Canu et al., 2015; Bruschi et al., 2021) and research projects (Bendoni et al., 2022, Canu et al., 2022).

3.2 Oil spill simulations set up

In section 2.5 three types of oil were identified as major potential threats for the area of interest: bunker oil, diesel oil, and crude oil. In order to obtain a statistical representation of the exposure, multiple oil spill simulations were performed from different release coordinates and repeated in time once a day every day for a one-year period (2018). Every oil spill simulation consisted in the release of 200 Lagrangian particles, advected by currents and wind drift using a Runge-Kutta scheme of 2nd order for a 10 day long time interval with an additional horizontal turbulent diffusivity of 10 m^2/s and stranding along the coast whenever the particles would approach at less than 10 meters from the border of the basin. The oil spill module OILTRANS computed the weathering processes to which the oil was subject, among them the initial spreading of the oil slick, the evaporation, the emulsification, and the vertical dispersion in the water column.

For every oil type (bunker, diesel, crude) the simulations were performed modeling oil spill releases according to the estimations made in section 2.5 of the position and volumes of oil susceptible to be released at the different coordinates. Two sets of oil spill simulations were performed, distinguished by the method obtained to define the oil spill release positions. In the first set of simulations 54 potential oil spill release sites were simulated, the coordinates and volume of the oil spills that were modeled are defined in Table 4: they were determined using the stochastic method described in section 2.5. The second set of simulations is made by 33 potential oil spill release sites, the coordinates and volume of those oil spills are defined in Table 5, they were obtained using an extrapolated qualitative approach based on expert knowledge.

At every potential incident site, among those 54+33 sites, the quantity of bunker, crude, and diesel oil susceptible to be released, as estimated in Tables 4-5, were used to define the quantity of oil to be released in the simulations. Every type of oil was modeled using a specific parameterization of the OILTRANS module, as described in Table 6: the specific oils to model were identified thanks to SIOT (Società Italiana per l'Oleodotto Transalpino S.p.A.), the main operator in the transportation of oil and oil products in the whole Mediterranean Sea, based in Trieste harbor, and providing a big portion of oil demand in Central Europe through the Transalpine Pipeline. After the stakeholders' workshop in Trieste, SIOT provided information on the most common oils travelling in the Northern Adriatic Sea and some of their characteristics, which were complemented from literature (see Table 6). SIOT's help was much appreciated and instrumental for obtaining good results for NAMIRS.

Table 6: Model parameterization of the different oil types. These parameters are those of the specific oils "Bunker C Fuel Oil 171", "Diesel Fuel Oil (1994) 242 & 254" and crude oil "Arabian light 46" taken from the Canadian catalogue of Crude Oil and Oil Product Properties (Jokuty et Al., 1999, revised 2022). The Fingas evaporation equation of type 1 is $\%Evap = (A + B \times T_w) \times ln(t) \times (1 - W_c)$ while type 2 is $\%Evap = (A + B \times T_w) \times sqrt(t) \times (1 - W_c)$ where T_w is the water temperature, t is time and W_c is the water content.

	bunker	diesel	crude
API	11.4	37.2	19.66
Dynamic viscosity at 15°C	8.706	4.5	0.014
SARA asphaltenes content	11%	0%	3%
SARA resin content	17%	2%	6%
SARA saturated compounds	25%	76%	51%
Evaporation Fingas A parameter	0.31	0.31	2.52
Evaporation Fingas B parameter	0.045	0.018	0.037
Evaporation Fingas equation type	1	2	1

The total number of oil spill simulations that were run varies according to the type of oil, as not all oil types were identified as threats on every release site. The number of oil spill simulations that were run are 19440 for the stochastic bunker oil, 19440 for the stochastic diesel oil, 17280 for the stochastic crude oil, 11880 for the expert bunker oil, 9360 for the expert diesel oil and 5400 for the expert crude oil. For every set of simulations and every oil type the results were aggregated by summing the oil quantities in every cell of the domain, taking as initial time the instant of the release of every oil spill.

3.3 Oil spill simulations results

The results of the oil spill simulations allow to assess, for every oil type and every set of simulations, as presented in Fig. 36, the average volume of oil remaining on the surface, stranding on surface, dispersed in the water column, and stranded at depth, within the water column. One can see that bunker and diesel oil behave in similar ways, with a relatively slow dispersion in the water column resulting in a quantity of stranded oil more important on the surface respect to the quantity of oil stranded at depth. Crude oil tends instead to disperse faster in the water column resulting in almost identical quantities of oil stranded on the surface respect to the oil stranded at depth.

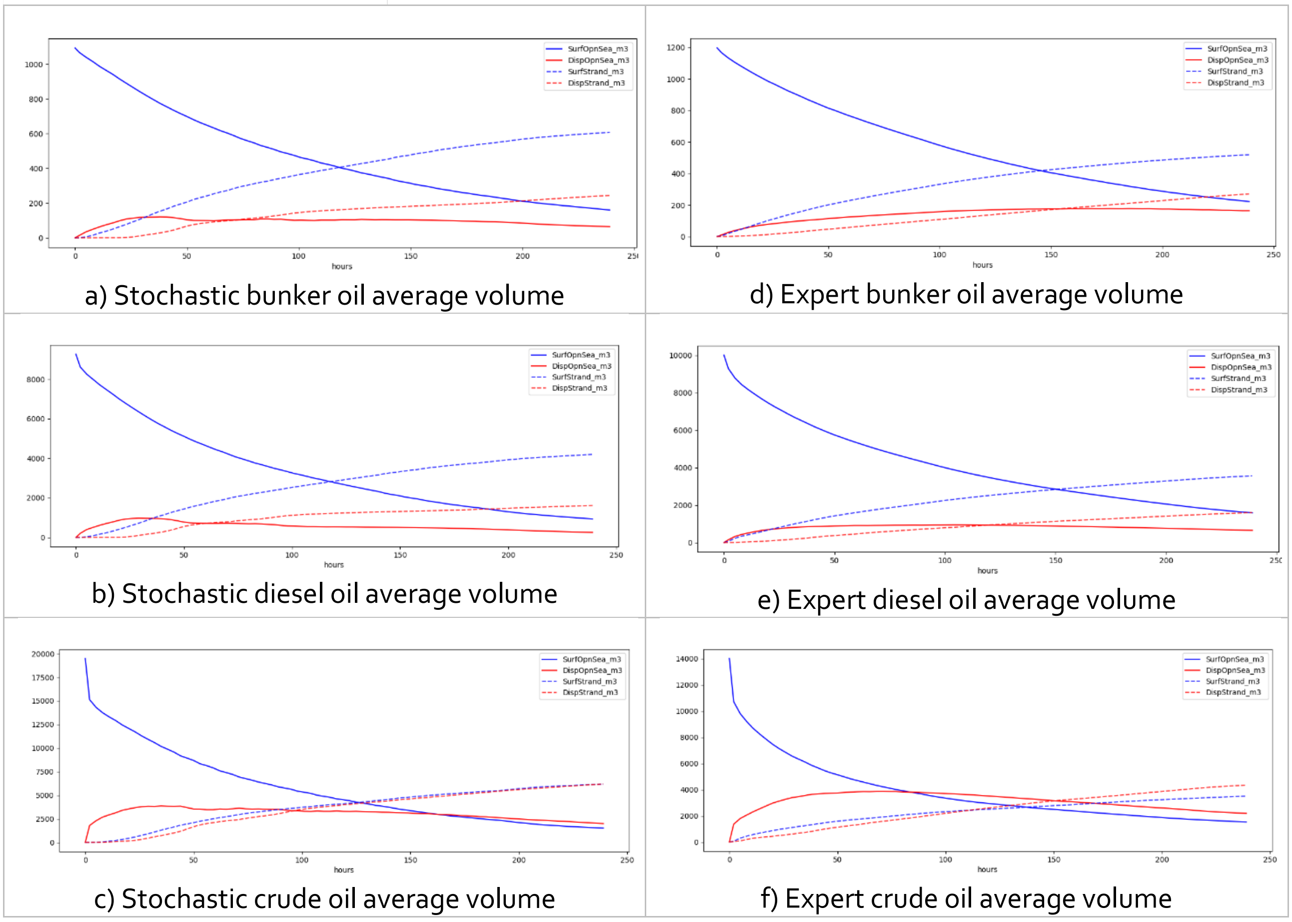

Figure 36: Average volumes of oil remaining on the surface (continuous blue line), stranding on surface (dashed blue line), dispersed in the water column (continuous red line) and stranded in the water column (dashed red line), for every set of simulations (Stochastic and Expert) and every oil type (bunker, diesel and crude).

The oil spill simulations allowed to produce maps of oil density every 3 hours after the release. In order to give an overview of the results, we chose to present in this report in Figs. 37-38 (respectively for the Stochastic and Expert sets of simulations) only the bunker oil maps at two time-instants: 11 hours and 23 hours after the release of the oil spills. These maps allow to identify which open sea areas and which coastal areas are more susceptible to be impacted by the oil spills, according to the threat defined by the release sites and oil volumes defined in Tables 4-5.

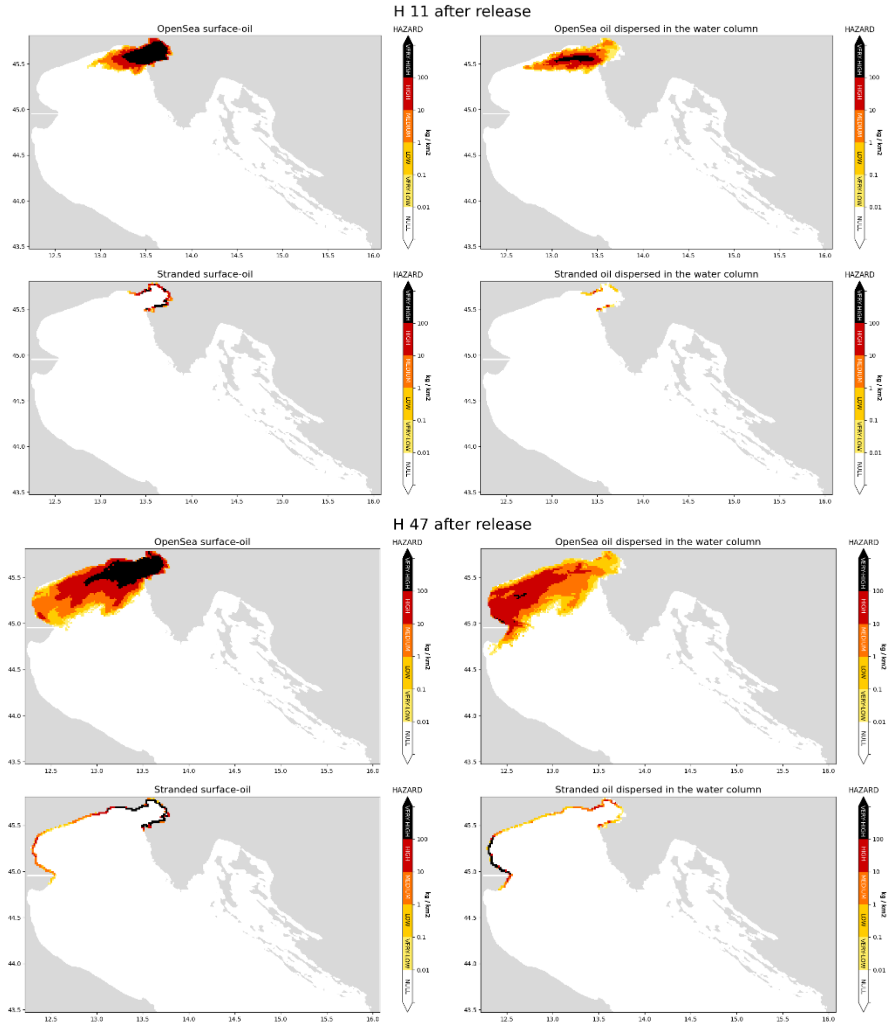

Figure 37: Stochastic set of simulations for the bunker oil type at 11 hours (top) and 47 hours(bottom) after the release of the oil spills.

The figure 37 highlights that potential bunker oil slicks in the Gulf of Trieste (Stochastic set of release sites) represents a threat limited to the Gulf of Trieste itself for the first 11 hours after a potential incident, with oil stranding mainly on the surface respect to the oil stranded at depth. Instead, after 2 days of transport the threat extends along the Italian coasts up to the Po River delta. Regarding the surface stranded oil, the major exposure remains along the coasts of the Gulf of Trieste, while at depth larger quantities of oil stranded along the coastal areas between Venice and the Po River delta.

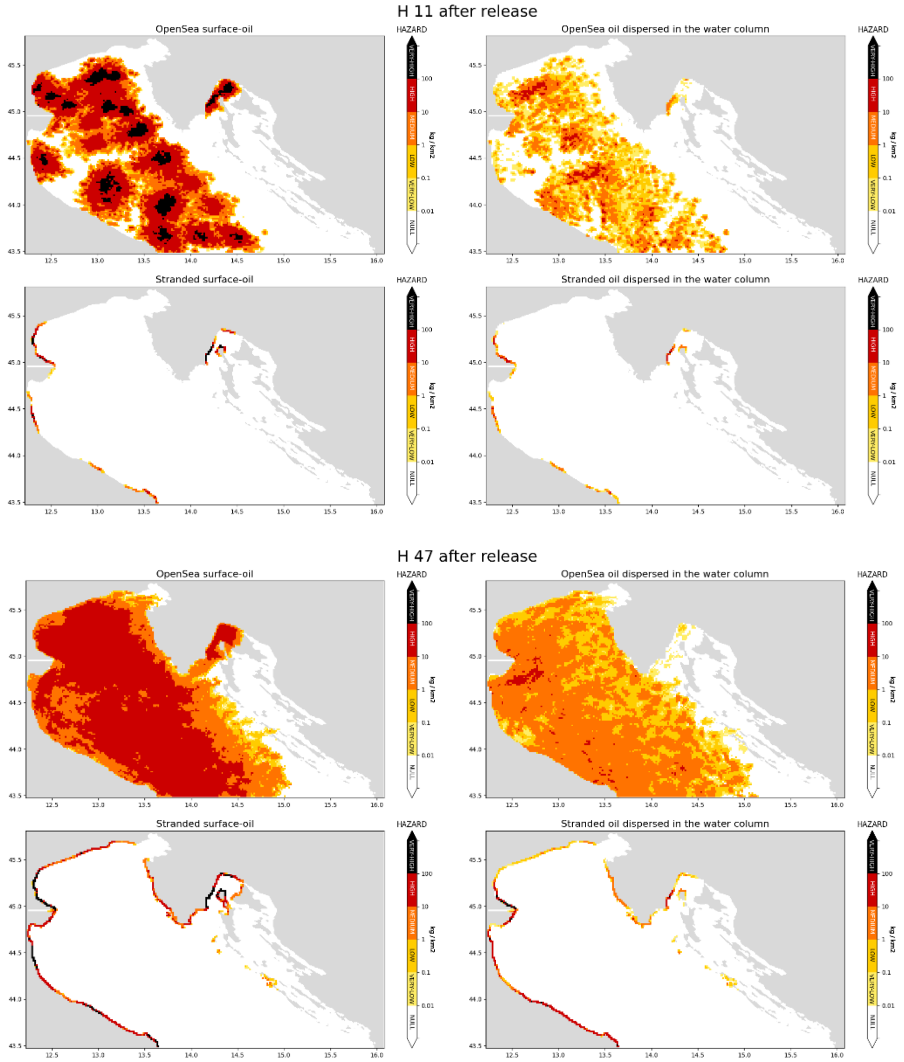

Figure 38: Expert set of simulations for the bunker oil type at 11 hours (top) and 47 hours(bottom) after the release of the oil spills.

Fig. 38 shows that potential bunker oil slicks released along the main traffic routes of the northern Adriatic (Expert set of release sites) represent a threat (both on surface and at depth) at short time interval (11 hours) for local costal segments, namely between Venice and the Po River, close to the Italian cities of Ravenna and Ancona, and on the northern part of the Croatian Island of Cres and the continental area closer to it next to Rijeka. Two days after the release, instead, most of the northern Italian coasts are concerned by stranded oil (except for the Gulf of Trieste) and in Croatia the threat extends along all the Istrian peninsula from Rijeka to Savudrija.

4. Stakeholders' involvement

4.1 Introduction

One of the main goals of NAMIRS 2.1 was the assessment of the vulnerability of coastal areas of the Northern Adriatic Sea. This can be done in a purely objective manner by conducting scientific research on which types of coasts are the most sensitive to oil spills (e.g., ESI, see Petersen et al., 2019). However, such approach would neglect the subjective value represented by the coast for the different stakeholders, i.e., for those who have a direct, tangible or intangible interest in the areas to remain unaffected by the consequences of oil spills. The stakeholders can have an interest because they engage in economic activities in the coastal areas (maritime transportation, harbour activities, tourism, mariculture, fishery, etc.), because they value the pristine state of the area (i.e., consider its social, cultural, landscape values), or because they are engaged in activities related to environmental protection or cleaning, either as part of NGOs, public bodies (research institutes, local government), or of private enterprises in this sector.

Thus, the partners of NAMIRS choose an inclusive, participative, holistic approach to the assessment of the coastal areas' vulnerability in the Northern Adriatic Sea, by combining expert knowledge with the stakeholders' involvement. In particular, a specific Coastal Vulnerability Assessment (CVA) method was developed in the form of a questionnaire to be compiled by stakeholders during purposedly organized workshops. The CVA was developed according to the guidelines of the Delphi method, applied in the IALA PAWSA risk assessment method (IALA, 2022). Since the goals of the risk assessment in NAMIRS is different than the one addressed in the PAWSA methos, the CVA procedures were adapted to the specific needs of this project.

The outcomes of the workshops were processed and joined with expert knowledge from literature in order to permit to classify the coastal areas based on their vulnerability to oil spills. GIS maps of vulnerability indexes related to the different considered vulnerability factors were also produced. Coastal vulnerability estimations will help in establishing priority areas for intervention in case of oil spills.

4.2 NAMIRS vulnerability factors

The first step in the CVA procedure was the identification of the vulnerability factors. Three different factors of vulnerability were identified:

- Geomorphological factoros
- Environmental factors
- Socioeconomic factors

Geomorphological factors are related to the typology of the coast. Different stakeholders can give a different value to a coastal stretch, depending on the possible use there are making of them: e.g., some may value the coast for its recreational potential, outside of established beach resorts, others as place for an economic activity (hotel, camping, restaurant). Thus, if a coast is low or high, easily reachable or inaccessible, sandy or rocky, natural or artificial, it all plays a role in the value assigned to it by a potential stakeholder.

Environmental factors are related to important environmental features such as protected areas, important habitats, presence of protected or important species. Also in this case we expect that the value assigned by different categories of stakeholders, based on their interest and knowledge, may be different. For instance, people form the research sector or working in environmentalist organizations will have a different consideration for the protected areas and for their different level of protection. An interesting outcome will be also the valuation for coastal areas without any type of legislative protection.

Socioeconomic factors are those most dependent on the subjective perception of the stakeholders. For a mariculturist any possible disruption of mariculture activities would be seen as much more impacting then the pollution of a beach. On the other hand, the owner of a beach resort might value much more the protection of the beach, than of the mussel or fish farms in front of it. Even more complex is the evaluation of factors that are not measured in monetary terms: the aesthetic value of a pristine, natural coastline, or the cultural and historical value associated to the seafront of an old seaside town, might not be easily transformed in monetary value. Fig. 39 shows a schematic representation of the three groups of vulnerability factors considered for NAMIRS CVA process.

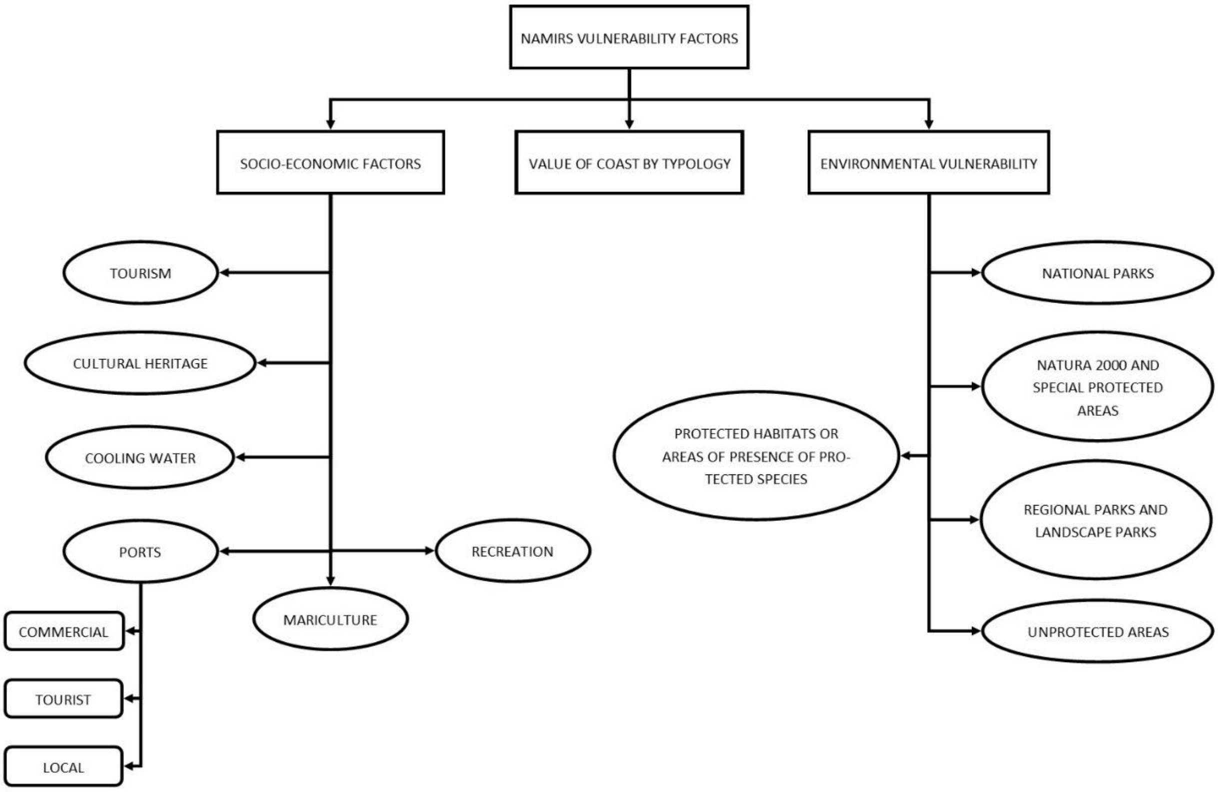

Figure 36: Schematic representation of the vulnerability factors considered in NAMIRS CVA.

4.3 CVA questionnaire structure

4.3.1 CVA Step 1

Step 1 of the CVA asked participants to indicate their role in the assessment process, their role in oil spill cleaning activities in general, and their level of familiarity with vulnerability factors. This resulted in a numerical value for the participant's level of knowledge for each of the available factors.

Roles were divided into the following categories:

- environmental association and NGO;
- business sector employer (fishermen, shipping, touristic facilities etc.);
- scientist, professor, or teacher;
- civil servant/elected official;
- citizen.

Then, the participants had to state how would they participate in oil spill clean-up operations, should an oil spill occur, by selecting one of the following options:

- would be in action per his/her duty;
- would step in action only if requested;
- would only actively monitor the cleaning procedures and offer suggestions or proposals to an appropriate service;
- would monitor the event as a citizen;
- would not be interested.

Level of familiarity with each factor was determined by asking the participants to answer the following questions with scores from 1 to 9, the former presenting the lowest level of familiarity, while latter presents the highest:

- To what extent are you, in this moment, familiar with the problem of oil spills as a whole?
- To what extent are you, in this moment, familiar with the geomorphological state of our coast (relating to different coast type cleaning difficulty)?
- To what extent are you, in this moment, familiar with environmental protection (areas with different protection status levels)?
- To what extent are you, in this moment, familiar with oil spill cleaning and intervention technology?
- To what extent are you familiar with the socio-economic value of the various stretches of coastline dedicated either to tourism, recreation, mariculture, cultural heritage, economy, etc.?

The goal of Step 1 questions was to allow the research team to possibly take into account the expertise and familiarity of each of the respondent. Obviously, the opinion of a persona professionally involved in oil spill management outweighs the opinion expressed by a person with a lower level of involvement or knowledge in the issue.

After completing the self-assessment step, the participants were shown a navigational chart with 12 areas, where an oil spill is most likely to occur due to high traffic density and the presence of either drilling platforms, LNG terminals, etc. They were asked to choose three areas where they believed an oil spill is most likely to occur.

Participants could choose between the following 12 areas:

- 1 Trieste anchorage
- 2 Crude oil terminal SIOT - Trieste
- 3 Koper anchorage
- 4 Rijeka anchorage as well as JANAF and INA terminals
- 5 Venice anchorage
- 6 Vela Vrata
- 7 LNG terminal Rovigo
- 8 Southern entrance/exit to/from separation scheme
- 9 Northern entrance/exit to/from separation scheme
- 10 Separation triangle in the Gulf of Trieste
- 11 Platforms in North Adriatic near to the coast
- 12 Platforms in North Adriatic between separation zones
- 13 Other (please mark on the chart)

Please note that while Croatian workshops took place, the 4th option was solely represented by Rijeka anchorage without INA and JANAF terminals. After one of the participants of Croatian workshop added INA terminal under the optional 13th answer, the research team decided to add those two terminals to the 4th answer. The decision to join them with Rijeka anchorage is due to their close proximity to each other.

4.3.2 CVA Step 2

In Step 2 of the CVA participants were asked to rate the values assigned to each vulnerability factor using scores from 1 to 9, where 1 represents the lowest level of vulnerability, and 9 the highest level of vulnerability.

Firstly, the participants were asked to assess the vulnerability of the socioeconomic factors (see Fig. 39) that may be affected by an oil spill, which include tourism, cultural heritage, cooling water stations, ports, recreational areas (man-made structures built along the coast for sports and other recreational activities), and maricultures (without distinction for fish farms, shellfish farms, or other types of mariculture). Ports were further divided into commercial (e.g., Trieste, Koper, Rijeka), tourist (marinas), and local ports (i.e., small harbours typically found in old seaside towns, which are used by local fishermen or local owners of pleasure boats).

Secondly, the participants were asked to assess the values of different types of coasts. The following coast types were identified in the Northern Adriatic Sea based on information from the EMODnet portal (see Section 5):

- Erodible rock with sediments at the base
- Extended beaches (> 1 km)
- Small beaches (< 1 km)
- Artificial coastline
- Muddy coastline
- Non-erodible rock without sediments at the base

- Harbour area

Finally, the participants were asked to evaluate the vulnerability of environmental factors, i.e., considering the protection status of the coastal areas in the Northern Adriatic Sea. The following categories of protections status have been identified for NAMIRS goals, considering the different terminology and protections levels in use in the three North Adriatic countries:

- National Parks and Marine Protected Areas
- Natura 2000 and special protection areas
- Unprotected areas
- Regional parks and Landscape parks
- Protected habitats or areas of presence of protected species

In order not to influence the evaluation of the participants, the different categories of protection were not ordered according to an increasing or decreasing level of legislative protection.

4.3.3 CVA Step 3

Step 3 asked participants to state their comparative importance rating of each group of vulnerability factors with scores from 1 to 9, which were then converted to percentage ratios.

4.4 Stakeholders' workshops

Three stakeholders' workshops were organized, each one in a different partner country, in order to involve as much as possible, the local stakeholders into the process of risk management.

The workshops were organised by three project partners: UL FPP from Slovenia, OGS from Italy, and ATRAC from Croatia, with the goal to obtain subjective estimations of coastal vulnerability on the shores of the Northern Adriatic Sea. The participants met at each of the organised workshops either live in-situ, or online via a provided link to the digital version of the CVA questionnaire. The workshops proceeded in a completely anonymous way but with known participants.

4.4.1 Workshop in Croatia

The workshop for the Croatian stakeholders was organized by ATRAC on September 29th, 2022, at the ATRAC premises in Rijeka.

The stakeholder mapping for the Croatian workshop was done by compiling all the previous contacts ATRAC has collected during its work in the relevant sector. It included all governmental and non-governmental entities, public and private sectors that are engaged in environmental protection activities and oil spill prevention and clean-up. That list was then reduced to stakeholders that could benefit from the NAMIRS project or their input was important to the project's goals. The invitation for the workshop was sent by e-mail.

Among the governmental stakeholders, the following were invited to participate:

- Ministry of Maritime Affairs, Transport and Infrastructure

- Ministry of Environmental Protection and Energy
- Ministry of the Interior
- Istra County
- Primorje – Gorski kotar county
- Lika – Senj County
- Zadar county
- Croatian Hydrocarbon Agency
- Croatian Coast Guard
- State Audit Office
- Šibenik – Knin County
- Port Authorities
- Civil protection

Among non-governmental stakeholders, the following were invited:

- Private companies for oil spill prevention and clean-up
- Oil companies
- Touristic offices
- Faculty of Maritime Studies of the University of Rijeka
- Municipalities
- National parks
- Nature parks

The workshop started with a presentation from ATRAC's director, Vedran Martinić, who at the beginning shortly presented ATRAC and its activities. He then proceeded with explaining the ESI index, different types of the coast, and specificities of the Croatian coastline. He gave a few examples of case studies that happened during the years in which the coastline was heavily polluted, and of the techniques that were used for cleaning the specific coast. Then, Valter Suban (UL-FPP) explained the questionnaire as well as its purpose and led the compilation by the participants. The workshop ended with a discussion from the participants which opened some interesting questions about our capabilities in case of a major oil spill.

Figure 40: Two photographs from the Croatian stakeholders' workshop in Rijeka at ATRAC premises, on September 29th, 2022.

4.4.2 Workshop in Slovenia

The workshop for the Slovenian stakeholders was organized by UL-FPP on October 6th, 2022, at the UL-FPP premises in Portorož.

Stakeholder mapping for Slovenian Coastal Vulnerability workshop was undertaken by means of identifying all governmental and non-governmental, public and private services and societies that either engage in environmental protection activities, run a business with a social or economic value, or otherwise deal with oil spill prevention and clean-up. The research team first identified four important classes of tasks related to oil spill detection and clean-up, i.e., prevention, preparedness and monitoring activities (PPM); detection and alerting tasks (DA); cleaning and cleaning-related activities (CCRA); post cleaning operations (PCO). Any service which engages in any of the tasks falling in either of the four classes, was suitable for participation in the Coastal Vulnerability Assessment Workshop.

Since UL-FPP is familiar with all official services who engage abovementioned activities, most of the governmental stakeholders were contacted by a telephone call or were sent an official invitation by e-mail. Most of the non-governmental stakeholders, however, were contacted and invited via e-mail only. All contact addresses were found online on each of the stakeholder's web pages.

Among the governmental stakeholders, the following were invited to participate:

- Ministry of Infrastructure (Slovenian Maritime Administration)
- Ministry of Defense (Administration for Civil Protection and Disaster Relief)
- Ministry of Agriculture, Forestry and Fisheries (Fishery Inspection)
- Ministry of Environment and Spatial Planning (Slovenian Environmental Agency (ARSO), VGP Drava, Institute for Water of the Republic of Slovenia, Slovenian Water Agency)
- Ministry of the Interior (Police)
- Ministry of Health (National Institute for Public Health)
- Ministry of Finances (Financial Administration)

Among research and educational stakeholders, the following were invited to participate:

- National Institute for Biology
- Coastal municipalities
- Gymnasium, electro and nautical school Piran
- Turistica (University of the Littoral - Faculty of Tourism Studies)
- FHŠ (University of the Littoral - Faculty of humanistic studies)
- University of the Littoral - Biotechnical faculty
- Maritime museum Piran
- Managers of coastal and marine protected areas

Among the economic operators, the following were invited to participate:

- Petrol (Fuel company)
- Luka Koper INPO
- TGZ Portorož (Tourism)
- Adria Tow company
- Piloti Koper (harbour pilots)

Among the non-governmental stakeholders, the following were invited:

- Morigenos (NGO for marine mammal monitoring and protection)
- DOPPS (NGO for birds monitoring and protection)
- PINA
- Trinity

Figure 41: Two photographs from the Slovenian stakeholders' workshop in Portorož at UL-FPP premises, on October 6th, 2022.

The workshop was organised live on the premises of UL-FPP and online via a prearranged link to a Zoom meeting. All the important stakeholders (first team responders, environmental protection agencies, etc.) were present, with only a couple of stakeholders who engage in touristic activates being absent. The workshop started with the presentations from Valter Suban (UL-FPP), Vinko Bandelj (OGS), and Vedran Martinić (ATRAC) relating to coastal clean-up, to the oil spill problem in general, and to the importance of vulnerability mapping. Before participants started filling out the questionnaire for coastal vulnerability evaluation, Valter Suban gave them a quick presentation on the structure of the questionnaire and the meaning behind its questions.

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4.4.3 Workshop in Italy

The workshop for the Italian stakeholders was organized by OGS on October 13th, 2022, at the OGS premises in Via Beirut 2 in Trieste.

The stakeholder mapping for the Italian workshop was done starting from different lists of stakeholders that OGS already compiled in several past projects: HarmoNIA (Harmonization and Networking for Contaminant Assessment in the Ionian and Adriatic, Seas, EU ADRION, 2018-2019), ADRIREEF (Innovative exploitation of Adriatic Reefs in order to strengthen blue economy, EU Interreg Italy – Croatia, 2018-2021), FAIRSEA (Fisheries in the Adriatic region - a Shared Ecosystem Approach, EU Interreg Italy - Croatia, 2019-2021), SHAREMED (Sharing and Enhancing Capabilities to Address Environmental Threats in Mediterranean Sea, EU Interreg-MED, 2019-2022). Since each one of these projects had a different objective and goals, and thus possibly a different set of interested stakeholders, the lists were pruned of all the stakeholders that might not be relevant for NAMIRS and complemented with other stakeholders in order to satisfy NAMIRS goals.

The area of interest for the Italian stakeholders' mapping was the entire Northern Adriatic coast of Italy, from region Marche to region Friuli-Venezia Giulia. Four categories of stakeholders were deemed interesting for NAMIRS purposes: Public authorities, Research and environmental services, Protected areas managers and NGOs, and Economy sector. All four categories can be involved in the management of the oil spill, of the cleaning and restoration measures that need to take place after an oil spill or can represent stakeholders impacted by the consequences of an oil spill. The four categories reflect the "roles" that the participants had to assign themselves to in CVA Step 1. For all stakeholders cited below the roles and contact information of the contact persons were searched online on publicly accessible websites of the stakeholders or extracted from the existing lists of stakeholders of the projects cited above. When appropriate, more than one email address was contacted for each stakeholder.

In the category Public authorities, we listed local (coastal municipalities) and regional (four regions: Marche, Emilia Romagna, Veneto, Friuli-Venezia Giulia) territorial public authorities: they are those whose officials are elected by citizens and are the direct responsible for the local and regional policies, including environmental issues and economic sector. Thus, we included here also the environmental protection agencies (ARPA) that are in Italy organized on a regional level, civil protection, and public authorities promoting economy (e.g., FLAC and GAC), which are usually promoted either by regional government or by the most important municipalities. In the Public authorities category also other authorities were included, such as the port authorities of the major ports in the area, the firefighters, the Coast Guard (also one of the partners in NAMIRS), and the Italian Court of Auditors. Furthermore, the CEI – Central European Initiative, an intergovernmental organization promoting collaboration in the wider central European area was also invited as stakeholder: while CEI is also the LP of NAMIRS, it is not actively involved in the activities of 2.1 (as it is not the Italian Coast Guard), thus no conflict of interest was detected. The total number of stakeholders in this category was 34, but for many of them several different possible contacts were identified. In some cases, the contacts were of front offices or public relation offices, in other cases we tried to identify the administrative structure of the public authority that might be most interested into NAMIRS goals (e.g., environmental, tourism or economic regional directorates, or relevant city councilors).

The stakeholders for the category Research and environmental services were the easiest to be identified because of the many interactions that OGS has with similar institutions. Thus, the possible stakeholders to invite were identified based on personal relationships of members of the OGS NAMIRS workgroup with other researchers and scientists, on past participations in common projects with similar goals and objectives, and on the existing lists of stakeholders of the projects cited above. We included in this category public research institutions such as universities and research institutes, but also private research institutes, cooperative for environmental services, as well as companies for environmental services. Cooperatives for environmental services often employ scientist who are great experts for local environmental features and can provide consultancy services to local authorities in dealing with environmental problems, participate in monitoring programs and in scientific projects. Companies for environmental services are economic players and should be put in the category of Economy sector, but they also provide services in case of oil spill, such as consultancy and cleaning service, and sell specific equipment for intervention in case of oil spill. A rather crude way of explaining the rationale for the inclusion of the environmental companies in the category Research and environmental services is that these companies have a positive impact from an oil spill (because this is their core business), while the companies included in the category Economy sector are those that are generally negatively impacted by an oil spill (i.e., tourism, productive activities, mariculture and fishery operators). The total number of stakeholders identified in this category was 27, but for many of them several different persons were contacted. This was the case, e.g., for the University of Trieste (6 employees contacted) and the CNR-ISMAR institute of Venice (8 employees contacted).

In the category Protected areas managers and NGOs we included stakeholders that are involved in the management of protected areas, in environmental protection, or in environmental education. Many of these are organizations with national and local offices, and where possible both were contacted: this was the case, e.g., of WWF, Marevivo, LIPU. Some of them are generalist environmental organizations, others more specifically dealing with the protection of marine ecosystems, and possibly also involved in monitoring or citizen science projects, such as DelTa, Dolphin Biology and Conservation, Fondazione Cetacea. We included in this category also nautical societies, sport fishing associations, and scuba diving clubs (including the association of the Italian scientific scuba divers AIOSS). All these stakeholders may be strongly impacted by the consequences of an oil spill but can also be seen as sentinels distributed along the coastline that have a day-to-day knowledge of the state of the sea, and their members may be counted on as possible volunteers to join operations after an oil spill. The total number of stakeholders in this category was 42 and also in this case, more than one email address was contacted when needed.

The last category, Economy sector, was devoted to economy operators in the field of tourism, nautical sector, and fishery and aquaculture. All these activities are in general negatively impacted by an oil spill. Among the nautical sector stakeholders there were very big players, such as Fincantieri, the biggest Italian ship building company, Ocean s.r.l, provider of marine services on a local and regional level, as well as the regional Maritime Technology Cluster FVG, and the nautical engineering company MICAD. In the touristic sector we contacted several associations of touristic operators (hotels, camping facilities) in the coastal areas of the Northern Adriatic Sea, including beach resorts and marinas. Fishery and aquaculture operators were the most abundant stakeholders represented in this category, due to the small size and huge number of these operators in the area, and also due to many contacts that OGS has already established with this sector in past projects. One of the most important stakeholders in this group was undoubtedly SIOT (Società Italiana per l'Oleodotto Transalpino S.p.A.), who is the main operator in the transportation of oil and oil products in the whole Mediterranean Sea, based in Trieste harbor, providing a big portion of oil demand in Central Europe through the Transalpine Pipeline. The total number of stakeholders in this category was 36.

The total number of contacted Italian stakeholders across all four categories was 139. An email inviting them to attend the NAMIRS Italian workshop, explaining the goals of the project and the structure and goal of the workshop, was sent to 209 email addresses. Some of the addresses turned out inactive or unreachable, thus additional research was performed in order to find a valid email for these stakeholders, but not for all was this successful.

At the workshop 17 people participated in presence representing 12 different stakeholders, while 9 people, representing 7 other stakeholders, participated online. Table 7 shows the breakdown per category of the participants and stakeholders contacted and present at the NAMIRS workshop for the Italian stakeholders. At the workshop were also present members of the OGS NAMIRS workgroup, and representatives of partners in the project UL-FPP, ATRAC, CEI and of the Italian Coast Guard. Tables 8-11 cite all contacted stakeholders for each stakeholder category.

Table 7: Breakdown of the Italian stakeholders contacted and present at the workshop in Trieste per category of stakeholder.

	Public authorities	**Research and environmental services**	**Protected areas managers and NGOs**	**Economy sector**	**TOTAL**
Contacted stakeholders	34	27	42	36	139
Contacted emails	65	57	49	38	209
Participating stakeholder	5	4	7	3	19
Participating people	5	10	8	3	26

The workshop opened with a welcome from the director of the Oceanography section of OGS, Cosimo Solidoro, who also briefly introduced the institute and in particular its Oceanography Section. Anna Marconato (CEI), project leader of NAMIRS, presented the project, its goals and mission. Followed a talk by Vinko Bandelj presenting the work being done in NAMIRS 2.1 activity Environmental Risk Assessment. Valter Suban presented the partner UL-FPP and its institutional activities, while Vedran Martinić presented the partner ATRAC and its main activities in the field of oil spill cleaning. After a coffee break, Fabrizio Gianni and Serena Zunino (both OGS) led the compilation of CVA questionnaires, by presenting the questions and illustrating them with figures and photographs for better understanding. The workshop ended with talks by Dario Giaiotti (ARPA-FVG), illustrating FIRESPILL (a project with many overlapping with NAMIRS), Riccardo Scottu (DESMI Ro-Clean A/S), presenting his company and its services for oil spill prevention and cleaning, and Donata Canu (OGS), presenting the ECHO group of OGS and its main scientific expertise.

Table 8: Stakeholders invited to the Italian workshop in the category of Public authorities.

PUBLIC AUTHORITIES				
N	**NAME**	**ROLE**	**CONTACTS**	**PARTICIPATED**
1	Regione FVG	Regional authority	4	
2	Regione Veneto	Regional authority	3	
3	Regione Emilia-Romagna	Regional authority	3	
4	Regione Marche	Regional authority	3	
5	ARPA FVG	Regional environmental agency	4	YES
6	ARPA Veneto	Regional environmental agency	2	
7	ARPA ER	Regional environmental agency	2	
8	ARPA Marche	Regional environmental agency	1	
9	Protezione civile	Civil protection of 4 regions	4	
10	Corte dei Conti	Court of Auditors	1	
11	Guardia Costiera - Capitanerie di Porto	Coast guard	4	YES
12	Autorità di sistema portuale del Mare Adriatico Orientale	Port authority	1	
13	Autorità di sistema portuale del Nord Adriatico	Port authority	1	
14	Autorità di sistema portuale del Mare Adriatico centro-settentrionale	Port authority	1	
15	Autorità di sistema portuale del Mare Adriatico centrale	Port authority	2	
16	Comune Cesenatico	Local authority	1	
17	Comune Rimini	Local authority	1	
18	Comune Chioggia	Local authority	3	
19	Comune San Michele al Tagliamento	Local authority	2	
20	Comune Lignano Sabbiadoro	Local authority	2	

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21	Comune Grado	Local authority	2	
22	Comune Monfalcone	Local authority	1	
23	Comune Duino-Aurisina – Občina Devin-Nabrežina	Local authority	2	
24	Comune Trieste	Local authority	4	
25	Vigili del Fuoco	Firefighters	2	YES
26	Comune di Staranzano	Local authority	1	YES
27	Aries - Azienda speciale della Camera di Commercio di Trieste	Public authority promoting economy	1	
28	FLAG GAC Friuli - Venezia Giulia	Public authority promoting economy	1	
29	Vegal Venezia Orientale	Public authority promoting economy	1	
30	FLAG GAC Chioggia e Delta del Po	Public authority promoting economy	1	
31	Delta 2000 - Gruppo di Azione Locale Emilia-Romagna	Public authority promoting economy	1	
32	G.A.C. Marche Nord	Public authority promoting economy	1	
33	FLAG GAC Marche Centro	Public authority promoting economy	1	
34	CEI – Central European Initiative	Intergovernamental organization	1	YES

Table 9: Stakeholders invited to the Italian workshop in the category of Research and environmental services.

RESEARCH AND ENVIRONMENTAL SERVICES				
N	**NAME**	**ROLE**	**CONTACTS**	**PARTICIPATED**
1	OGS	Public research institute	3	YES
2	CNR-ISMAR Trieste	Public research institute	2	YES
3	CNR-ISMAR Venezia	Public research institute	8	
4	ISPRA - Chioggia	Public research institute	5	
5	Università di Trieste	Public university	7	YES
6	Università di Venezia - Ca' Foscari	Public university	3	
7	Università di Padova	Public university	2	
8	Università di Bologna	Public university	2	
9	Politecnico Marche	Public university	2	
10	Rete LTER-Italia	Monitoring network	1	
11	CORILA	Research consortium	1	
12	Thetis S.p.A.	Environmental services company	1	
13	SELC Società Cooperativa	Environmental services cooperative	2	
14	Shoreline - Soc. Coop. servizi per la qualità dell'ambiente marino	Environmental services cooperative	1	
15	Cestha	Environmental services cooperative	1	
16	Esplora s.r.l.	Environmental services cooperative	1	
17	GRUPPO C.S.A. S.P.A.	Environmental services company	1	
18	GreenSea	Environmental services company	1	

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19	Cooperativa Sestante di Venezia	Environmental education cooperative	1	
20	Hyla Società Cooperativa	Environmental education cooperative	1	
21	Consorzio mediterraneo s.c.a.r.l.	Research consortium	1	
22	Fondazione ENI Enrico Mattei	Foundation	2	
23	DESMI	Environmental services company	1	YES
24	LaFornitrice	Environmental services company	1	
25	Istituto Delta – Ecologia applicata	Environmental services company	1	
26	Garbage Service Srl	Environmental services company	2	
27	t-ELIKA	Environmental services company	1	

Table 10: Stakeholders invited to the Italian workshop in the category of Protected areas managers and NGOs.

PROTECTED AREAS MANAGERS AND NGOs				
N	**NAME**	**ROLE**	**CONTACTS**	**PARTICIPATED**
1	AMP Miramare	Protected area	1	YES
2	Riserva naturale regionale delle Falesie di Duino	Protected area	1	
3	Riserva naturale Foce Isonzo – Isola della Cona	Protected area	1	
4	Associazione per la Laguna di Caorle e Bibione	Protected area	1	
5	Parco del Sile	Protected area	1	
6	Parco Lagunare	Protected area	1	
7	Associazione Naturalistica Cavallino	Protected area	1	
8	Tegnùe di Caorle P.to Falconera	Protected area	1	

9	Associazione tegnue di Chioggia	Protected area	1	
10	Delta Po Veneto Parco regionale	Protected area	1	
11	Ente Parco Delta del Po Emilia-Romagna	Protected area	3	
12	Ente Parco Naturale Regionale del Conero	Protected area	1	
13	Associazione Paguro	Protected area	1	
14	Adriapan - Adriatic Protected Areas Network	Protected area	2	
15	Amici della Terra	Environmental NGO	1	
16	Legambiente	Environmental NGO	1	
17	Greenpeace	Environmental NGO	1	
18	Italia Nostra	Environmental NGO	1	
19	Mareamico	Environmental NGO	1	
20	Marevivo	Environmental NGO	2	
21	FAI	Environmental NGO	1	
22	LIPU	Environmental NGO	2	
23	WWF Italia	Environmental NGO	3	
24	Oceanomare Delphis	Environmental NGO	1	
25	Fondazione Cetacea	Environmental NGO	1	
26	DelTa (Delfini e Tartarughe dell'alto Adriatico)	Environmental NGO	1	YES
27	Dolphin Biology and Conservation	Environmental NGO	1	
28	Associazione "Comitato per la casa dei pesci"	Environmental NGO	1	

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29	AIOSS - Associazione italiana operatori scientifici subacquei	Scientific scuba divers association	1	YES
30	FIPSAS - Federazione Italiana Pesca sportiva ed Attività Subacquee	Sport fishing association, recognized as environmental protection association by the Ministry	1	YES
31	Lega Navale Italiana	Nautical association	1	YES
32	Assonautica	Nautical association	1	
33	ARCI PESCA FISA	Sport fishing association	1	
34	Barcolana	Nautical association	1	
35	SVBG	Nautical association	1	
36	Sirena	Nautical association	1	
37	Čupa	Nautical association	1	
38	Murena diving club	Scuba divers association	1	YES
39	Acquamission diving club	Scuba divers association	1	
40	Circolo sommozzatori trieste	Scuba divers association	1	
41	Scuba tortuga	Scuba divers association	1	
42	Club del gommone	Nautical association	1	YES

Table 11: Stakeholders invited to the Italian workshop in the category of Economy sector.

ECONOMY SECTOR				
N	**NAME**	**ROLE**	**CONTACTS**	**PARTICIPATED**
1	Associazione Riviera del Conero e Colli dell'Infinito	Tourism	1	
2	MARITIME TECHNOLOGY CLUSTER FVG s.c.a.r.l.	Nautical sector	1	
3	Fincantieri	Nautical sector	1	

4	Samer Seaports & Terminals	Nautical sector	1	
5	SIOT - Trieste Italian Society for the Transalpine Pipeline	Oil transport company	1	YES
6	Ocean s.r.l.	Nautical sector	1	
7	Cooperativa spiagge Ravenna	Tourism	1	
8	Destinazione Turistica Romagna	Tourism	1	
9	Porto turistico di Jesolo	Tourism	1	
10	Portopiccolo	Tourism	1	
11	Pro Loco Marina di Ravenna	Tourism	1	
12	Ravenna Incoming	Tourism	1	
13	Società Gestione Campeggi	Tourism	1	
14	AGCI FVG	Fishery & aquaculture	1	
15	AMA - Associazione Mediterranea Acquacoltori	Fishery & aquaculture	1	
16	API (Associazione Piscicoltori Italiani)	Fishery & aquaculture	1	
17	CO.VE.P.A. - Consorzio Veneto Pesca Artigianale	Fishery & aquaculture	1	
18	Co.Ge.Mo. Monfalcone - Consorzio gestione pesca compartimento di Monfalcone	Fishery & aquaculture	1	
19	COGIUMAR - Consorzio giuliano maricoltori	Fishery & aquaculture	1	
20	Federcoopesca	Fishery & aquaculture	1	
21	Federpesca	Fishery & aquaculture	1	
22	LegaCoopFVG	Fishery & aquaculture	1	
23	Legapesca	Fishery & aquaculture	1	

24	Organizzazione di Produttori della Pesca di fasolari dell'Alto Adriatico	Fishery & aquaculture	1	
25	Unci pesca (Unione Nazionale Cooperative Italiane della Pesca e Acquacoltura)	Fishery & aquaculture	1	
26	CO.GE.MO	Fishery & aquaculture	1	
27	CO.GE.VO Chioggia	Fishery & aquaculture	1	
28	CO.GE.VO. Venezia	Fishery & aquaculture	1	
29	Organizzazione di Produttori Bivalvia Veneto S.C.	Fishery & aquaculture	1	
30	Cooperativa Casa del Pescatore	Fishery & aquaculture	1	
31	Cooperativa Adriatica	Tourism	1	
32	Coop Copego	Fishery & aquaculture	2	
33	Anapi pesca (Associazione Nazionale Autonoma Piccoli Imprenditori della pesca)	Fishery & aquaculture	2	
34	FINALMAR	Fishery & aquaculture	2	
35	MICAD	Nautical sector	1	YES
36	Master Blue Growth	Tourism	1	YES

Figure 42: Two photographs from the Italian stakeholders' workshop in Trieste at OGS premises, on October 13th, 2022.

4.5 Workshops results and analysis of outcomes

This Section contains the results obtained from the three organised workshops in Rijeka, Portorož and Trieste, where in total 104 people participated either in-situ or online via provided links to the digital versions of the questionnaire. The research team processed the obtained results to gather raw statistical information from each of the workshops, which will be subjected to further processing in the following phases of NAMIRS.

For easier understanding of the question list in the column on the left of the following tables, please refer to the following legend:

- Q4a – Socio-economic factors/mariculture
- Q4b – Socio-economic factors/tourism
- Q4c – Socio-economic factors/recreation
- Q4d – Socio-economic factors/cultural heritage
- Q4e – Socio-economic factors/cooling water stations
- Q4f – Socio-economic factors/commercial ports
- Q4g – Socio-economic factors/tourist ports
- Q4h – Socio-economic factors/local ports
- Q5a – Geomorphology/erodible rock with sediments at the base
- Q5b – Geomorphology/extended beaches (> 1 km)
- Q5c – Geomorphology/small beaches (< 1 km)
- Q5d – Geomorphology/artificial coastline
- Q5e – Geomorphology/muddy coastline
- Q5f – Geomorphology/non-erodible rock without sediments at the base
- Q5g – Geomorphology/harbour area
- Q6a – Environment/national parks and marine protected areas
- Q6b – Environment/Natura 2000 and special protected areas
- Q6c – Environment/unprotected areas
- Q6d – Environment/regional parks and landscape parks
- Q6e – Environment/protected habitats or areas of presence of protected species
- Q7a – Comparison/socioeconomic factors
- Q7b – Comparison/environmental factors
- Q7c – Comparison/geomorphological factors
- Q7d – Comparison/socioeconomic factors to %
- Q7e – Comparison/environmental factors to %
- Q7f – Comparison/geomorphological factors to %

The raw statistical data showcased in the tables are coloured in shades of green, yellow and red. Numbers marked in green represent the lowest level of vulnerability, yellow ones represent a medium level of vulnerability, and red ones a high level.

The self-assessment of the 104 participants gave as a result 7 representatives of environmental organisations and other NGOs, 13 members of business sector, 30 scientists, professors, or teachers, 48 civil servants or elected officials, 5 citizens, while one participant did not answer to this question. This is shown in Fig. 43, with numbers related to answers through the following legend:

- 1 = environmental association and NGO;
- 2 = business sector employees (fishermen, shipping, touristic facilities etc.);
- 3 = scientist, professor, or teacher;
- 4 = civil servant/elected official;
- 5 = citizen.

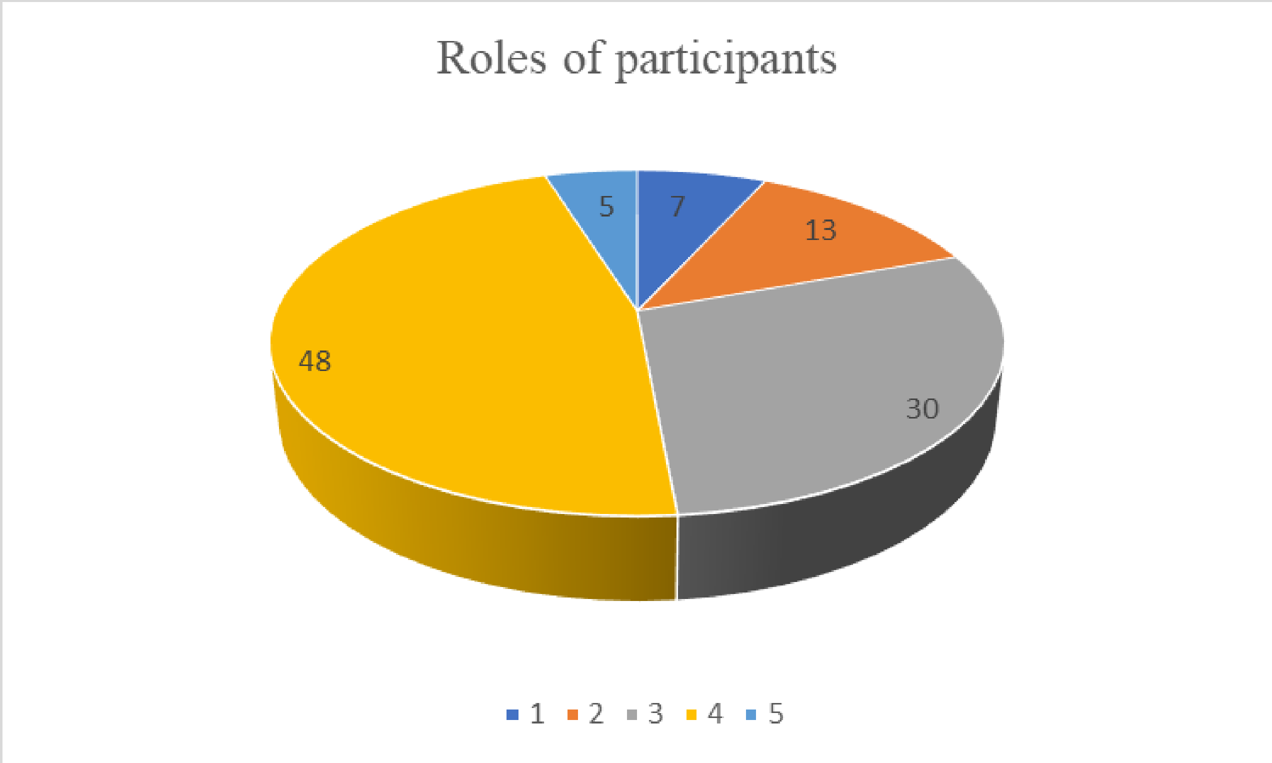

Figure 373: Breakdown of the self-assessed role of the participants to all three workshops.

The participants were asked to state their task in the case of an oil spill event. The chart in Fig. 44 shows a distribution of participants by their stated tasks, based on the following legend:

- 1 = would be in action per his/her duty;
- 2 = would step in action only if requested;
- 3 = would only actively monitor the cleaning procedures and offer suggestions or proposals to an appropriate service;
- 4 = would monitor the event as a citizen;
- 5 = would not be interested.

From a total of 104 participants, there were 35 people who would be in action per their duty, 23 people who would step in action if requested, 24 people who would actively monitor the situation and offer suggestions to appropriate services, 21 people who would monitor the event as a citizen, and no persons who would not be interested.

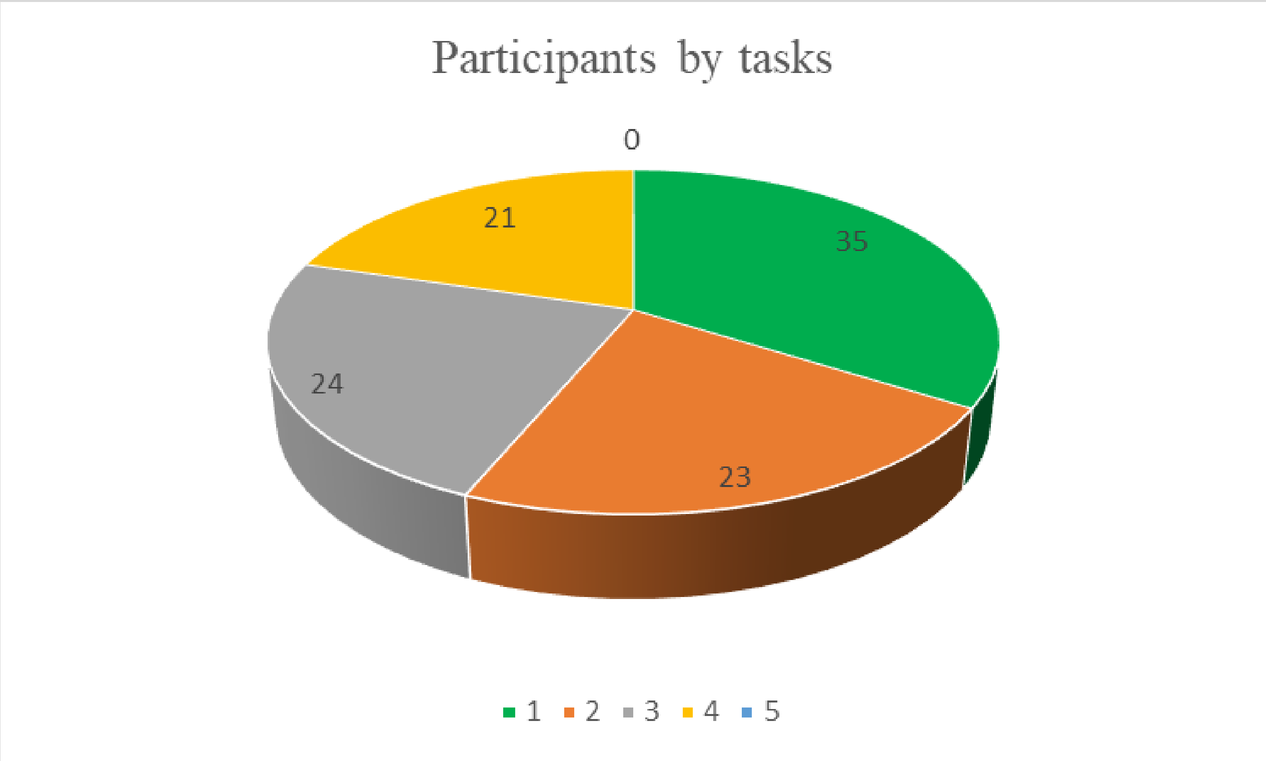

Figure 44: Breakdown of the self-assessed task in case of oil spill of the participants to all three workshops.

4.5.1 Slovenian results

A total of 54 people participated in the Slovenian CVA workshop, 14 of them live and 40 online. The self-assessment of the roles of the participants gave the following results: 29 civil servants or elected officials, 3 members of business sector, 16 scientists, professors, or teachers, 3 members of environmental organisations or other NGOs, and 3 citizens.

Live

In total, 14 people participated to the workshop in-situ. Of them 9 identified themselves as civil servants or elected officials, 1 as member of business sector, and 4 as scientists, professors, or teachers. Table 12 showcases the main statistics of vulnerability scores provided by participants for each vulnerability factor, indicated in the left column.

Table 12: Main statistics for vulnerability scores provided by participants to the live Slovenian workshop for each vulnerability factor: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

Question	Average	Mode	Median	Standard deviation
Q4a	6,8	9	8	2,5
Q4b	7,1	9	7	2,1
Q4c	5,6	5	6	1,7
Q4d	6,4	7	7	1,5
Q4e	4,9	3	5	2,4
Q4f	6,1	6	6	2,0
Q4g	6,4	8	7	2,0
Q4h	6,6	7	7	1,5
Q5a	7,1	9	8	2,5
Q5b	6,3	8	8	2,7
Q5c	6,8	9	8	2,3
Q5d	5,0	6	6	2,4
Q5e	6,0	7	7	2,3
Q5f	6,8	8	8	2,2
Q5g	5,9	6	6	2,2
Q6a	7,8	9	8	1,6
Q6b	7,8	9	8	1,6
Q6c	6,7	7	7	1,7
Q6d	7,6	9	8	1,5
Q6e	7,9	9	9	1,6
Q7a	7,4	7	8	1,5
Q7b	8,0	9	9	1,6
Q7c	6,9	8	7	1,6
Q7d	33%	29%	33%	/
Q7e	36%	38%	37%	/

Co-funded by the European Union

Q7f	31%	33%	30%	/

On average, the participants of the live workshop gave the highest priority to various protected areas in the environmental vulnerability factors group, while lesser importance was given to geomorphological and socio-economic factors, although there were no major differences between them. However, it must be mentioned that the scores were very dispersed as it is indicated by the standard deviation.

The results for the question on the areas of highest oil spill probability at the live Slovenian workshop are shown on the chart in Fig. 45. To interpret the chart correctly, please refer to the areas list in Section 4.3.1 of this report.

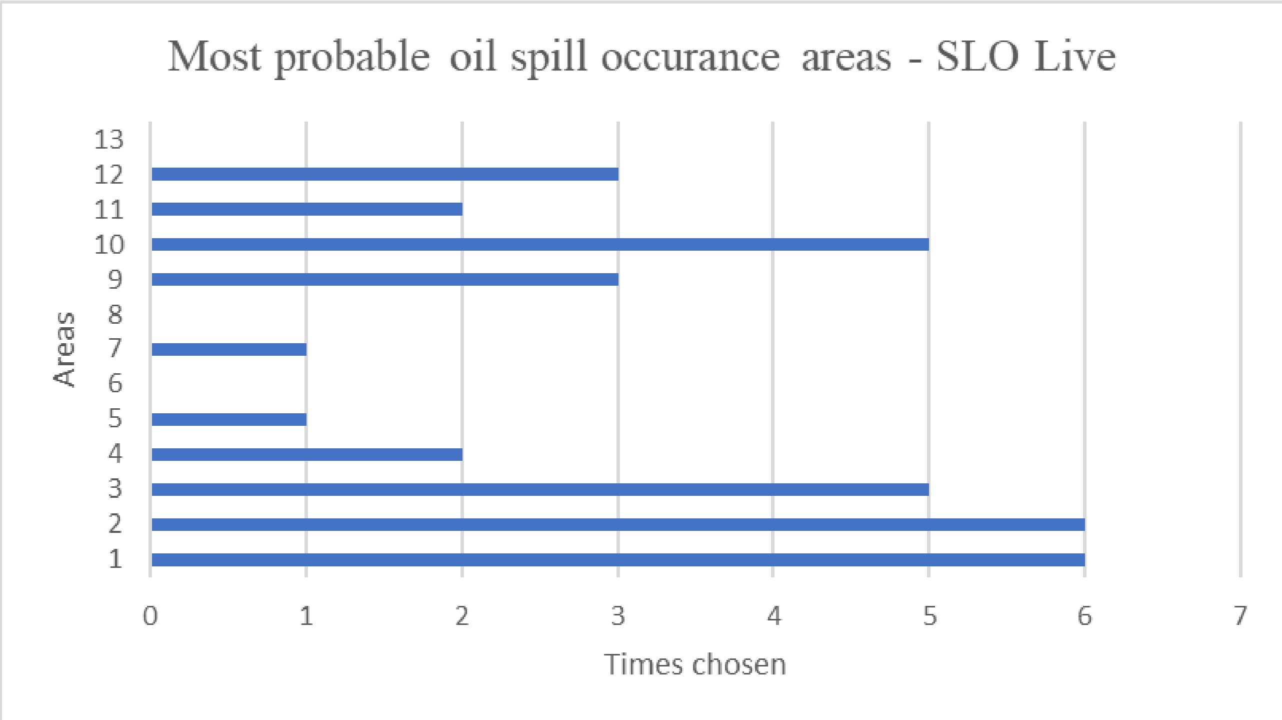

Figure 38: Most probable oil spill locations as selected by the participants to the live Slovenian workshop.

Online

A total of 40 people participated in the online workshop. Among them 20 identified themselves as civil servants or elected officials, 2 as members of business sector, 12 as scientists, professors, or teachers, 3 as members of environmental organisations or other NGOs, and 3 as citizens. Table 13 showcases the main statistics of vulnerability scores provided by participants for each vulnerability factor, indicated in the left column.

Table 13: Main statistics for vulnerability scores provided by participants to the online Slovenian workshop for each vulnerability factor: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

Question	Average	Mode	Median	Standard deviation
Q4a	7,2	8	8	2,0
Q4b	7,0	7	7	1,7
Q4c	5,9	6	6	2,0
Q4d	6,0	7	6	2,0
Q4e	5,6	5	6	1,6
Q4f	5,7	6	6	2,2
Q4g	5,9	6	6	2,0
Q4h	5,8	6	6	2,0
Q5a	8,1	9	9	1,3
Q5b	7,6	9	8	1,8
Q5c	6,1	7	7	2,4
Q5d	5,1	5	5	2,2
Q5e	6,6	7	7	1,9
Q5f	7,0	9	7	2,2
Q5g	4,8	3	5	2,3
Q6a	7,8	9	8	1,7
Q6b	7,7	9	8	1,6
Q6c	6,9	7	7	1,6
Q6d	7,3	7	7	1,7
Q6e	7,7	9	8	1,6
Q7a	6,9	7	7	1,5
Q7b	8,0	9	9	1,3
Q7c	7,3	8	8	1,7
Q7d	31%	29%	29%	/
Q7e	36%	38%	38%	/

Q7f	33%	33%	33%	/

The results of the online workshop very closely resemble those of the live workshop, the only difference being in geomorphology which was preferred over socio-economic factors. As it is indicated by the standard deviation, the scores were very dispersed.

The results for the question on the areas of highest oil spill probability at the online Slovenian workshop are shown on the chart in Fig. 46. To interpret the chart correctly, please refer to the areas list in the Section 4.3.1 of this report.

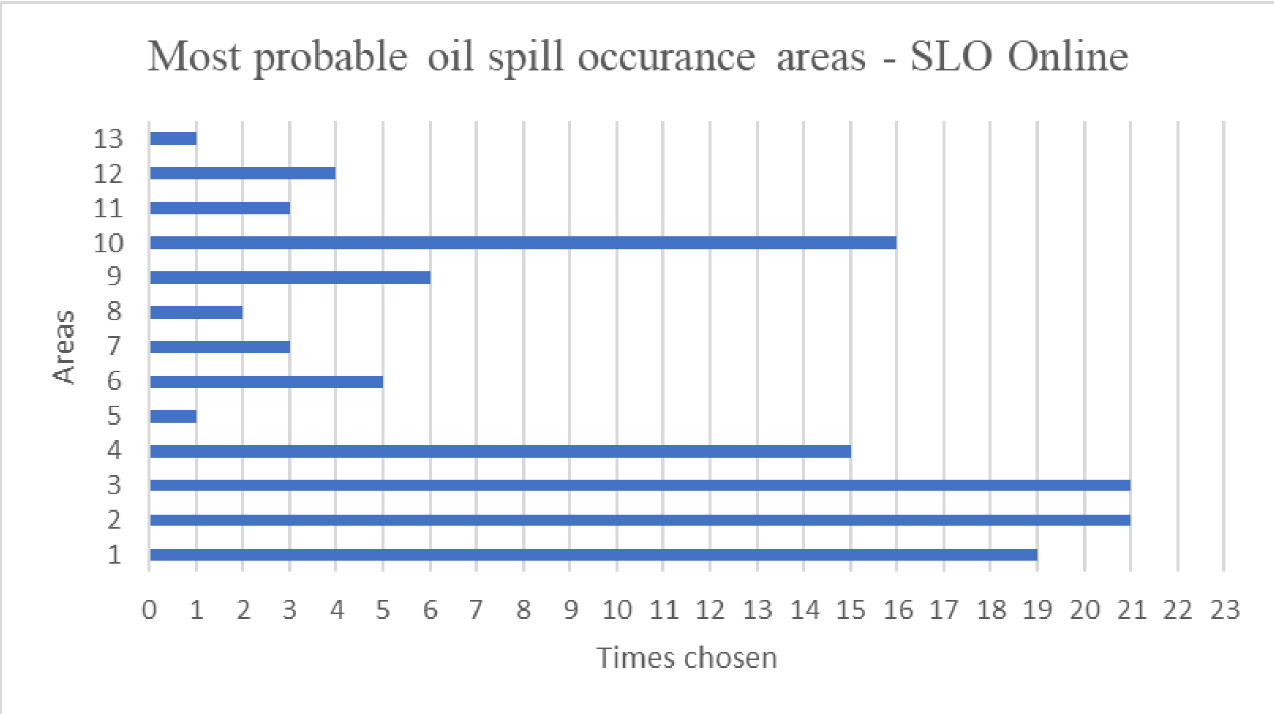

Figure 46: Most probable oil spill locations as selected by the participants to the online Slovenian workshop.

4.5.2 Croatian results

A total of 24 people participated in the Croatian CVA workshop, which was held only live in Rijeka.

Among those who participated 16 identified themselves as civil servants or elected officials, 2 as scientists, professors, or teachers, and 6 as members of the business sector. Table 14 showcases the main statistics of vulnerability scores provided by the participants for each vulnerability factor, indicated in the left column. Last three lines, however, slightly differ from the Slovenian and Italian ones. This is because the first version of the CVA questionnaire did not ask participants to compare the three factors with scores from 1 to 9, but solely with a percentage ratio. While the results between all three workshops are comparable, because the scores can be transformed to percentage ratios, the Croatian ones did not provide the participants' general assessment of importance (e. g., if a participant would give scores 3, 3, 3, to three vulnerability factors, and another scores 9, 9, 9, the percentage scores would be in the same ratio of 33%, 33% and 33%, but it is clear that the second participant deems all three factors to be much more important than the first one).

Table 14: Main statistics for vulnerability scores provided by participants to the Croatian workshop for each vulnerability factor: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

Question	Average	Mode	Median	Standard deviation
Q4a	8,6	9	9	0,7
Q4b	8,3	9	9	0,8
Q4c	7,4	9	8	1,5
Q4d	6,9	9	7	1,7
Q4e	6,1	6	6	1,6
Q4f	6,8	7	7	1,9
Q4g	7,5	9	8	1,8
Q4h	6,6	7	7	2,2
Q5a	7,0	8	8	1,0
Q5b	8,0	9	9	1,4
Q5c	7,4	8	8	1,5
Q5d	5,3	5	5	2,0
Q5e	6,3	6	6	2,1
Q5f	4,7	5	5	1,9
Q5g	5,5	7	6	2,4
Q6a	8,8	9	9	0,6
Q6b	8,3	9	8	0,7
Q6c	7,5	9	8	1,3
Q6d	7,8	8	8	1,2
Q6e	8,5	9	9	1,0
Q7d	32%	30%	30%	/

Q7e	39%	40%	40%	/
Q7f	29%	20%	30%	/

The results of the Croatian workshop show the highest assessed importance being given to environmental and socioeconomic factors, while geomorphological factors were not estimated to be as important. As was the case with Slovenian workshop results, the Croatian ones show high dispersion too.

The results for the question on the areas of highest oil spill probability at the Croatian workshop are shown on the chart in Fig. 47. To interpret the chart correctly, please refer to the areas list in the Section 4.3.1 of this report.

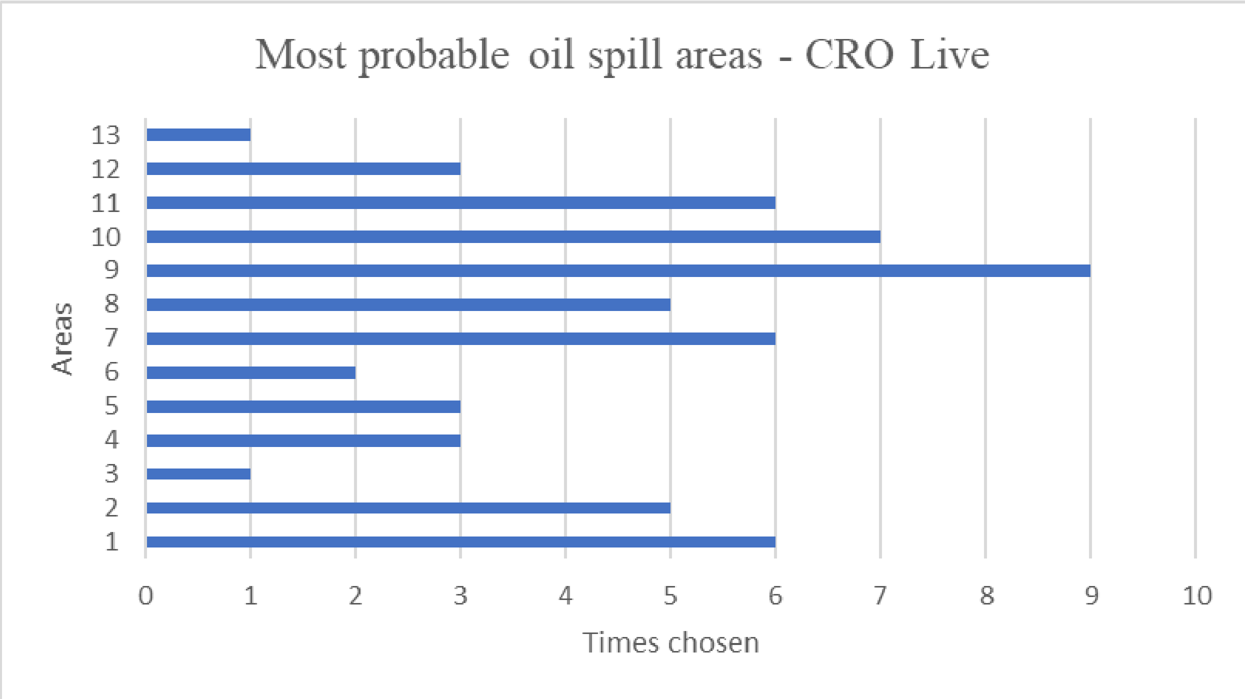

Figure 397: Most probable oil spill locations as selected by the participants to the Croatian workshop.

4.5.3 Italian results

A total of 26 people participated in the Italian CVA workshop, 10 of them online and 16 live. Among them, 12 identified themselves as scientists, professors, or teachers, 4 as members of business sector, 3 as civil servants or elected officials, 4 as members of environmental organisations or other NGOs, 2 as citizens, and one participant did not answer to this question.

Live

The workshop was conducted at the same time live as well as online. Of a total of 26 participants, 16 people participated live. Among them 7 identified themselves as scientists, professors, or teachers, 2 as members of business sector, 1 as civil servant or elected official, 1 as citizen, and 1 did not answer this question. Table 15 showcases the main statistics for each vulnerability factor, indicated in the left column.

Table 15: Main statistics for vulnerability scores provided by participants to the live Italian workshop for each vulnerability factor: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

Question	Average	Mode	Median	Standard deviation
Q4a	8,3	9	9	1,3
Q4b	8,1	9	9	1,0
Q4c	7,6	9	8	1,6
Q4d	7,3	7	7	1,3
Q4e	5,5	6	6	2,0
Q4f	6,6	9	7	2,4
Q4g	7,4	9	8	1,4
Q4h	6,9	9	7	1,8
Q5a	7,3	8	8	1,8
Q5b	8,1	9	8	1,3
Q5c	7,8	7	8	1,2
Q5d	5,8	6	6	1,9
Q5e	7,7	9	9	1,9
Q5f	6,6	6	7	2,1
Q5g	5,6	9	6	3,0
Q6a	8,5	9	9	0,8
Q6b	8,3	9	9	1,4
Q6c	6,9	7	7	1,2
Q6d	8,3	9	9	1,0
Q6e	8,4	9	9	1,3
Q7a	7,5	7	8	1,1

Q7b	8,7	9	9	0,5
Q7c	7,4	7	7	1,4
Q7d	32%	30%	32%	/
Q7e	37%	39%	38%	/
Q7f	31%	30%	30%	/

The participants gave the highest priority to environmental factors, while socio-economic and geomorphological factors were estimated to be almost equally important. Once again standard deviation highlights high score dispersion.

The results for the question on the areas of highest oil spill probability at the live Italian workshop are shown on the chart in Fig. 48. To interpret the chart correctly, please refer to the areas list in the Section 4.3.1 of this report.

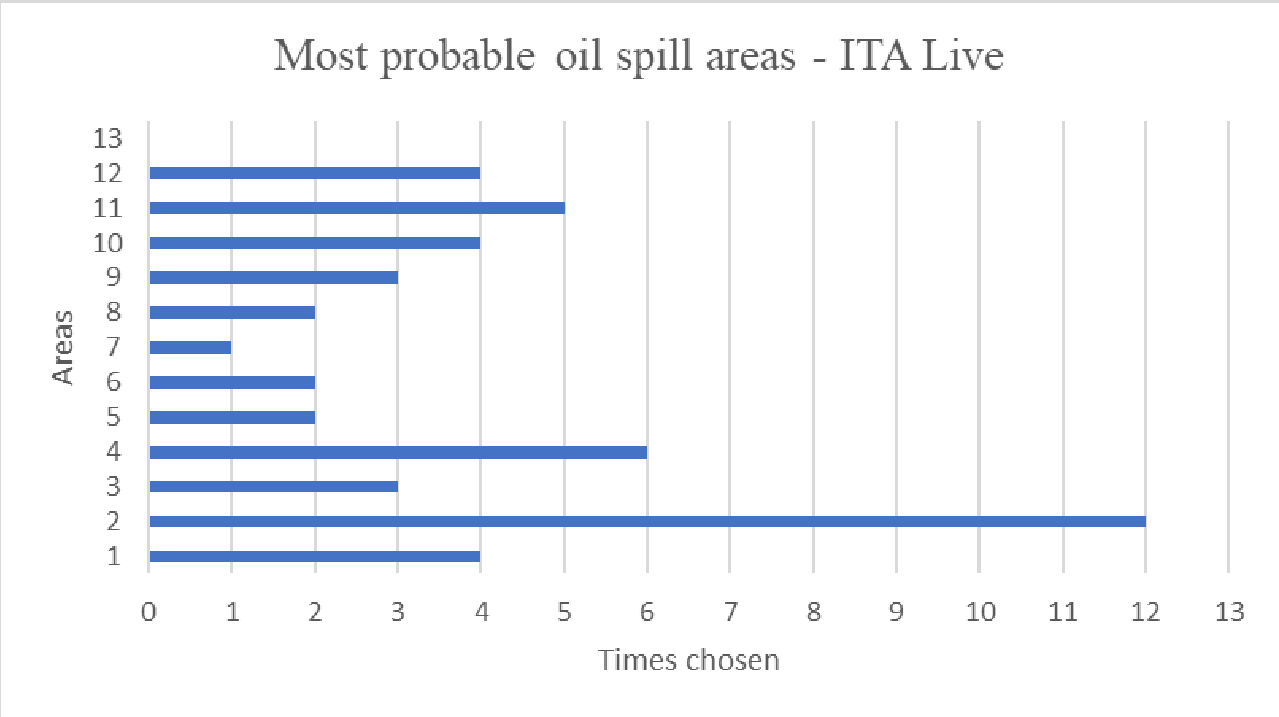

Figure 408: Most probable oil spill locations as selected by the participants to the live Italian workshop.

Online

From the total of 26 participants, 10 participated online. Among them were 5 scientists, professors, or teachers, 1 civilian, 2 members of business sector and 2 civil servants or elected officials. As was the case in the tables showcased above, the one below provides the same information.

Table 16: Main statistics for vulnerability scores provided by participants to the online Italian workshop for each vulnerability factor: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

Question	Average	Mode	Median	Standard deviation
Q4a	8,3	9	9	0,8
Q4b	7,4	8	8	1,1
Q4c	6,9	8	8	1,6
Q4d	7,2	7	7	1,0
Q4e	6,4	7	7	1,3
Q4f	5,3	6	6	1,8
Q4g	6,3	7	7	1,9
Q4h	6,0	6	6	2,0
Q5a	6,7	8	7	1,9
Q5b	7,3	9	8	1,6
Q5c	7,8	7	8	0,8
Q5d	4,3	6	4	1,9
Q5e	7,0	8	8	1,4
Q5f	6,9	8	8	1,9
Q5g	4,1	2	4	2,3
Q6a	8,4	9	9	0,8
Q6b	7,9	9	9	1,4
Q6c	7,3	7	7	1,4
Q6d	8,3	9	9	1,0
Q6e	8,8	9	9	0,4

Co-funded by the European Union

Q7a	7,8	8	8	1,1
Q7b	8,5	9	9	1,3
Q7c	7,0	7	7	1,3
Q7d	33%	33%	33%	/
Q7e	36%	38%	38%	/
Q7f	30%	29%	29%	/

Unlike in the previous workshops, the participants of the online Italian workshop gave a higher priority to socio-economic factors then to geomorphology, while environmental factors were assessed in the same manner as before and given the top priority. However, the scores were highly dispersed as it is shown by standard deviation values.

The results for the question on the areas of highest oil spill probability for those participating online to the Italian workshop are shown on the chart in Fig. 49. To interpret the chart correctly, please refer to the areas list in the Section 4.3.1 of this report.

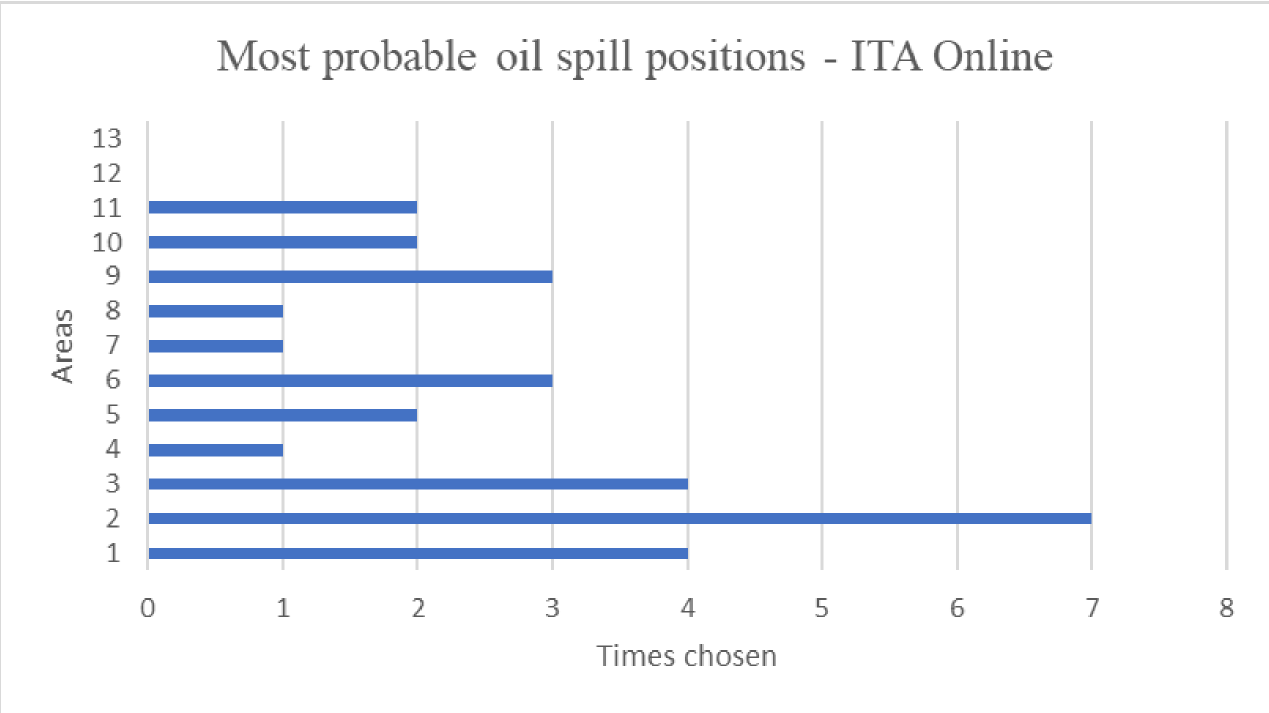

Figure 419: Most probable oil spill locations as selected by the participants to the online Italian workshop.

4.5.4 Joint workshop results

Table 17 shows the joint results of the three organised stakeholders' workshops.

Table 17: Main statistics for vulnerability scores provided by participants to all three stakeholders' workshops for each vulnerability factor: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

Question	Average	Mode	Median	Standard deviation
Q4a	7,8	9	8,8	1,8
Q4b	7,6	9	8	1,5
Q4c	6,7	7	8	1,9
Q4d	6,8	7	7	1,7
Q4e	5,7	5	6	1,8
Q4f	6,1	6	7	2,1
Q4g	6,7	8	7	1,9
Q4h	6,4	7	7	2,0
Q5a	7,2	9	8	1,8
Q5b	7,5	9	8	1,8
Q5c	7,2	7	8	2,0
Q5d	5,1	6	5	2,1
Q5e	6,7	9	7	2,0
Q5f	6,4	7	7	2,2
Q5g	5,2	5	6	2,5
Q6a	8,2	9	9	1,3
Q6b	8,0	9	8	1,4
Q6c	7,1	7	7	1,4
Q6d	7,8	9	8,5	1,5
Q6e	8,3	9	9	1,4
Q7a	7,4	7	8	1,4

Q7b	8,3	9	9	1,2
Q7c	7,1	8	7	1,5
Q7d	32%	29%	32%	/
Q7e	36%	38%	38%	/
Q7f	31%	33%	30%	/

The joint results highlight that the highest priority was given to the environmental factors, while socio-economic and geomorphological factors were given similar levels of priority with the slight advantage of the former.

The research team also separately calculated measures of central tendency and standard deviation for each of the self-assessed categories of stakeholders. In this way, possible differences in the answers due to the different background of the participants can be assessed.

Table 18 shows joint results of answers provided by members belonging to either environmental organisations or other NGOs.

Table 18: Main statistics for vulnerability scores of each vulnerability factor provided by participants that self-assessed as members of Environmental organizations of NGOs in all three stakeholders' workshops: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

	Environmental organisation or NGO			
	Average	Mode	Median	Standard deviation
Q4a	7,4	9	9	2,8
Q4b	7,6	9	9	2,2
Q4c	7,3	9	9	2,6
Q4d	7,0	9	8	2,6
Q4e	4,6	6	5	1,6
Q4f	4,7	5	5	2,1
Q4g	6,4	6	6	2,3
Q4h	6,3	6	6	2,2
Q5a	7,3	9	8	2,3
Q5b	5,9	8	7	2,9

Co-funded by the European Union

Q5c	6,7	9	8	3,1
Q5d	4,7	2	5	2,4
Q5e	8,6	9	9	0,8
Q5f	6,9	9	7	2,5
Q5g	2,3	1	2	1,6
Q6a	7,7	9	9	2,6
Q6b	8,0	9	9	2,6
Q6c	7,4	9	8	1,9
Q6d	7,6	9	9	2,6
Q6e	7,7	9	9	2,6
Q7a	7,1	7	7	1,6
Q7b	8,7	9	9	0,7
Q7c	6,9	8	8	1,9
Q7d	31%	29%	29%	/
Q7e	38%	38%	38%	/
Q7f	30%	33%	33%	/

Table 19 shows joint results of answers provided by employees of the maritime business sector.

Table 19: Main statistics for vulnerability scores of each vulnerability factor provided by participants that self-assessed as members of the Business sector in all three stakeholders' workshops: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

	Business sector			
	Average	Mode	Median	Standard deviation
Q4a	8,2	9	9	1,2
Q4b	7,9	9	9	1,5
Q4c	6,7	9	7	2,0
Q4d	6,9	7	7	1,5

Co-funded by the European Union

Q4e	5,5	3	6	2,1
Q4f	7,4	9	8	2,1
Q4g	7,0	9	8	2,1
Q4h	6,8	9	7	2,2
Q5a	7,3	8	8	1,4
Q5b	7,8	9	9	1,6
Q5c	7,2	9	8	1,9
Q5d	5,0	3	5	2,5
Q5e	6,3	5	6	1,7
Q5f	5,8	8	6	2,4
Q5g	5,3	7	6	2,6
Q6a	8,2	9	9	1,2
Q6b	7,7	8	8	1,4
Q6c	6,9	5	7	1,5
Q6d	7,7	9	8	1,4
Q6e	8,5	9	9	0,9
Q7a	7,1	9	7	1,8
Q7b	8,3	9	9	1,1
Q7c	8,0	9	8	1,1
Q7d	30%	33%	29%	/
Q7e	35%	33%	38%	/
Q7f	34%	33%	33%	/

Table 20 shows joint results of answers provided by those that in the three workshops identified themselves as scientists, professors or teachers.

Co-funded by the European Union

Table 20: Main statistics for vulnerability scores of each vulnerability factor provided by participants that self-assessed as Scientist, professor or teacher in all three stakeholders' workshops: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

	Scientist, professor or teacher			
	Average	Mode	Median	Standard deviation
Q4a	7,8	9	8	1,7
Q4b	7,2	7	7	1,5
Q4c	6,2	7	7	2,0
Q4d	6,2	7	7	1,8
Q4e	5,9	5	6	1,4
Q4f	5,6	6	6	2,4
Q4g	6,3	6	7	1,9
Q4h	6,0	6	6	2,0
Q5a	7,8	9	8	1,6
Q5b	7,4	8	8	1,9
Q5c	6,6	7	7	1,8
Q5d	4,8	6	5	2,2
Q5e	6,8	9	7	2,0
Q5f	6,8	7	7	2,2
Q5g	5,0	3	5	2,5
Q6a	7,9	9	8	1,3
Q6b	7,8	9	8	1,3
Q6c	6,8	7	7	1,2
Q6d	7,3	8	8	1,4
Q6e	8,0	9	9	1,4
Q7a	6,8	7	7	1,5
Q7b	8,0	9	9	1,3
Q7c	7,0	7	7	1,8

Q7d	31%	30%	31%	/
Q7e	37%	39%	38%	/
Q7f	32%	30%	31%	/

Table 21 shows joint results of answers provided by participants to all three workshop who self-assessed as civil servants or elected officials.

Table 21: Main statistics for vulnerability scores of each vulnerability factor provided by participants that self-assessed as Civil servant, elected official in all three stakeholders' workshops: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

	Civil servant, elected official			
	Average	Mode	Median	Standard deviation
Q4a	7,6	9	8	1,9
Q4b	7,6	9	8	1,6
Q4c	6,6	8	7	1,8
Q4d	6,6	5	7	1,7
Q4e	5,8	5	6	1,9
Q4f	6,1	6	6	1,8
Q4g	6,7	8	7	2,0
Q4h	6,2	7	7	2,0
Q5a	7,4	9	8	1,9
Q5b	7,7	9	8	1,6
Q5c	7,1	8	8	2,0
Q5d	5,5	5	5	1,9
Q5e	6,3	7	7	2,1
Q5f	6,1	9	6	2,2
Q5g	5,5	7	6	2,2
Q6a	8,3	9	9	1,2

Q6b	8,0	9	8	1,2
Q6c	7,1	7	7	1,5
Q6d	7,8	9	8	1,4
Q6e	8,2	9	9	1,3
Q7a	7,5	8	8	1,2
Q7b	8,2	9	9	1,3
Q7c	7,3	8	8	1,4
Q7d	33%	32%	32%	/
Q7e	36%	36%	36%	/
Q7f	32%	32%	32%	/

Table 22 shows the joint results of answers provided by participants to all three workshop who self-assessed as citizens.

Table 22: Main statistics for vulnerability scores of each vulnerability factor provided by participants that self-assessed as Citizen in all three stakeholders' workshops: Average, Mode, Median, Standard deviation. In the leftmost column the corresponding question of the CVA, see legend in Section 4.5.

	Citizen			
	Average	Mode	Median	Standard deviation
Q4a	8,0	8	8	0,7
Q4b	7,2	7	7	1,1
Q4c	6,8	7	7	0,8
Q4d	7,0	7	7	0,7
Q4e	5,4	7	6	2,1
Q4f	7,2	7	7	0,9
Q4g	7,0	7	7	1,2
Q4h	6,6	7	7	1,1
Q5a	6,6	9	8	2,9

Q5b	8,4	9	9	0,9
Q5c	7,2	7	7	2,0
Q5d	5,2	4	4	2,8
Q5e	7,0	8	8	2,0
Q5f	7,2	9	8	2,0
Q5g	6,2	5	5	2,7
Q6a	8,8	9	9	0,4
Q6b	8,8	9	9	0,4
Q6c	7,6	7	7	1,3
Q6d	8,6	9	9	0,9
Q6e	8,6	9	9	0,9
Q7a	7,4	8	8	1,5
Q7b	8,2	9	9	1,3
Q7c	7,2	7	7	0,4
Q7d	32%	33%	33%	/
Q7e	36%	38%	38%	/
Q7f	32%	29%	29%	/

In Figs. 50-69 the participants' rankings of the different vulnerability factors are shown as graph charts.

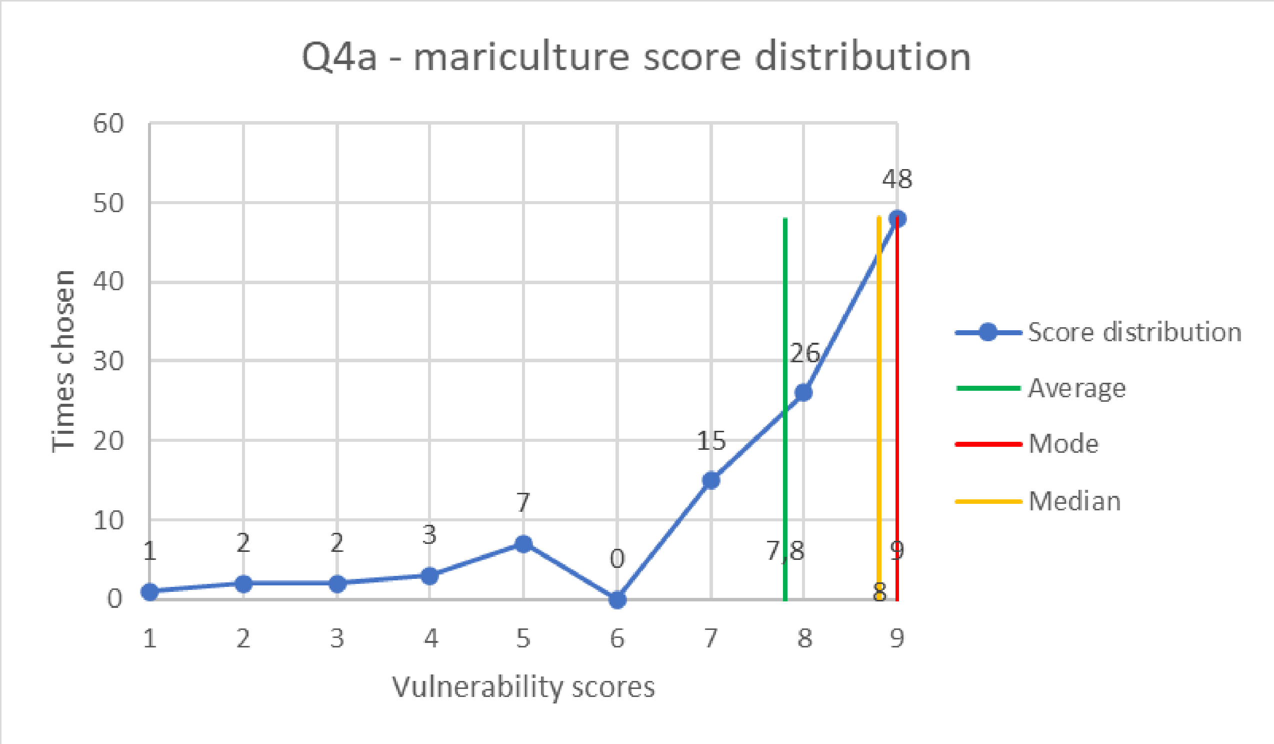

Figure 50: Graph chart of the rankings assigned to Q4a vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

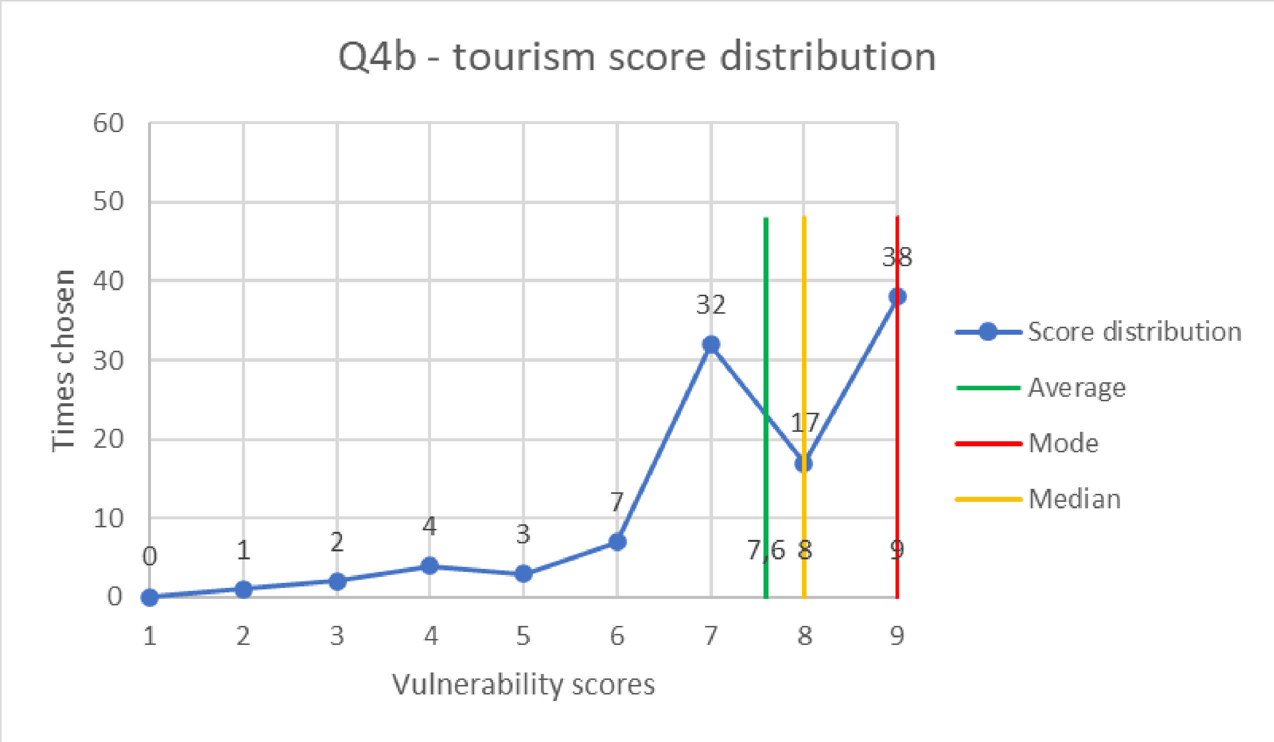

Figure 51: Graph chart of the rankings assigned to Q4b vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

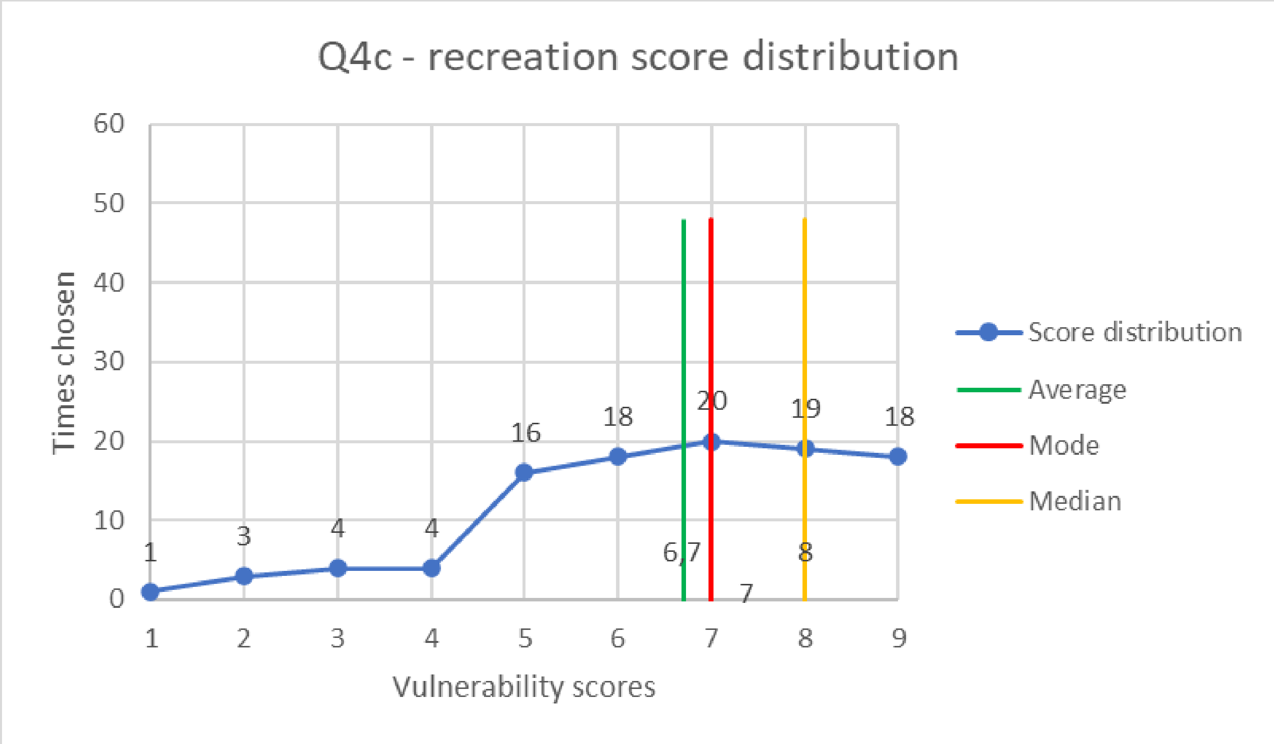

Figure 52: Graph chart of the rankings assigned to Q4c vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

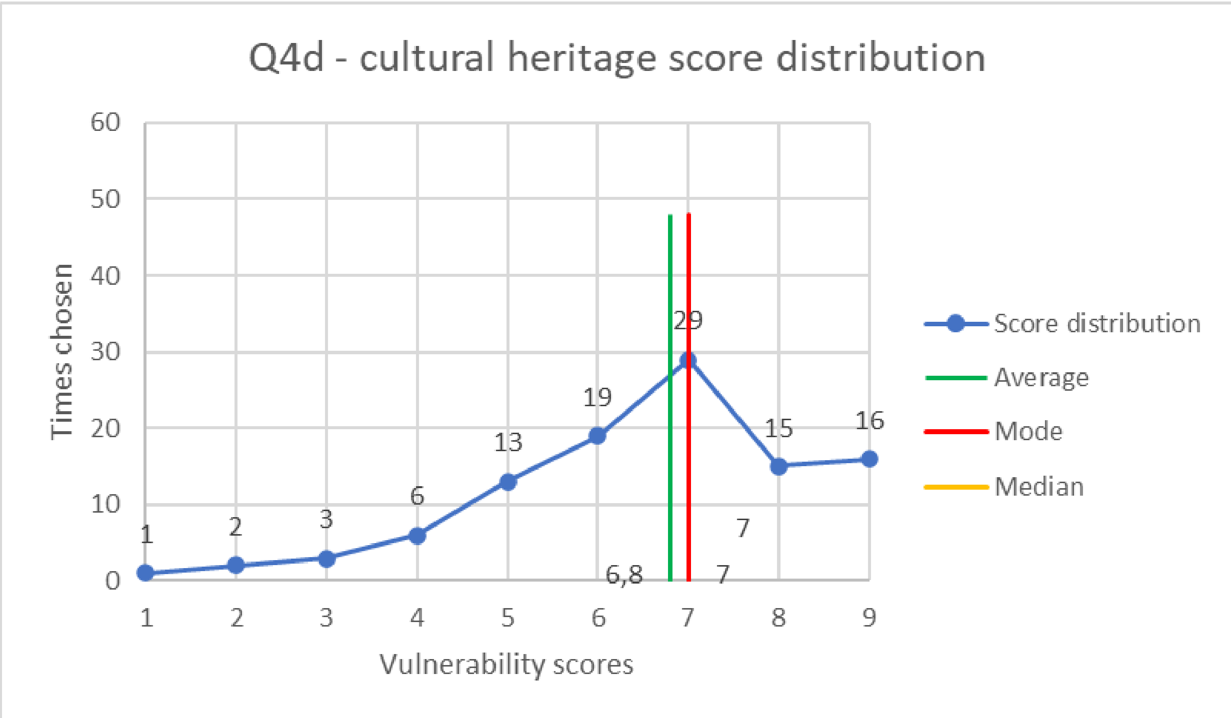

Figure 53: Graph chart of the rankings assigned to Q4d vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

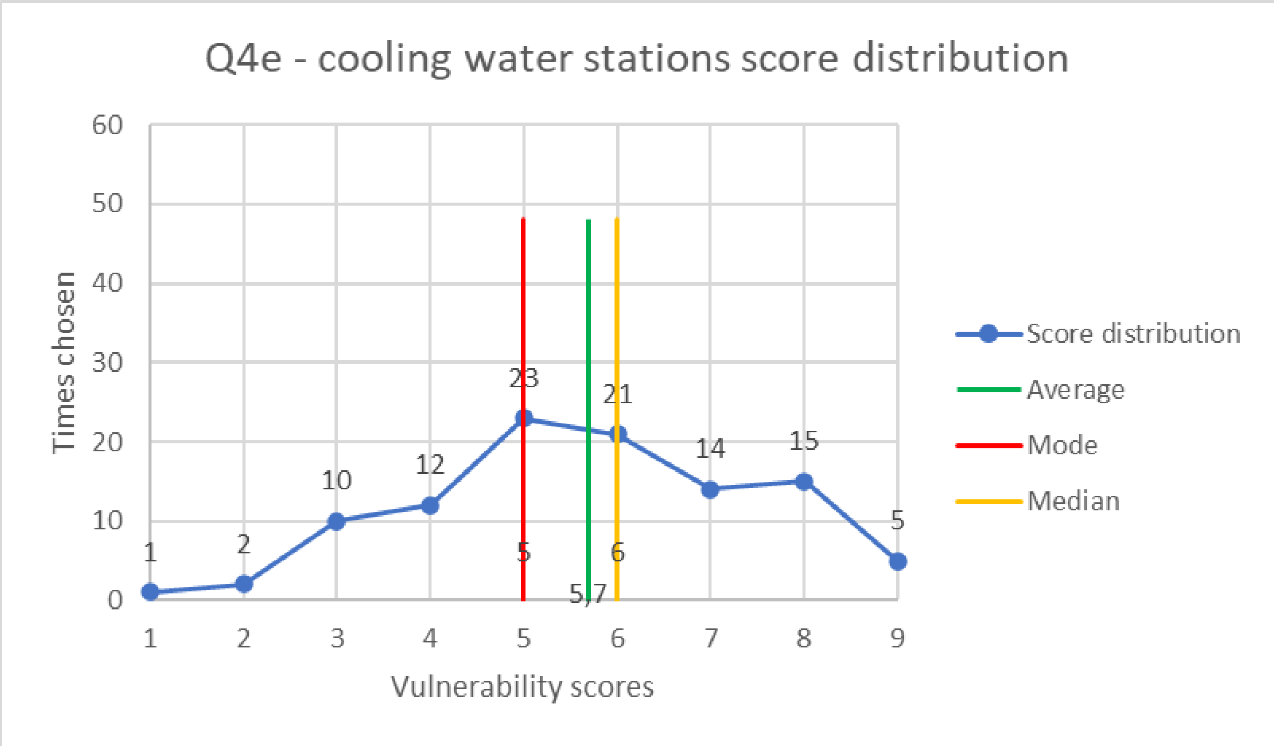

Figure 54: Graph chart of the rankings assigned to Q4e vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

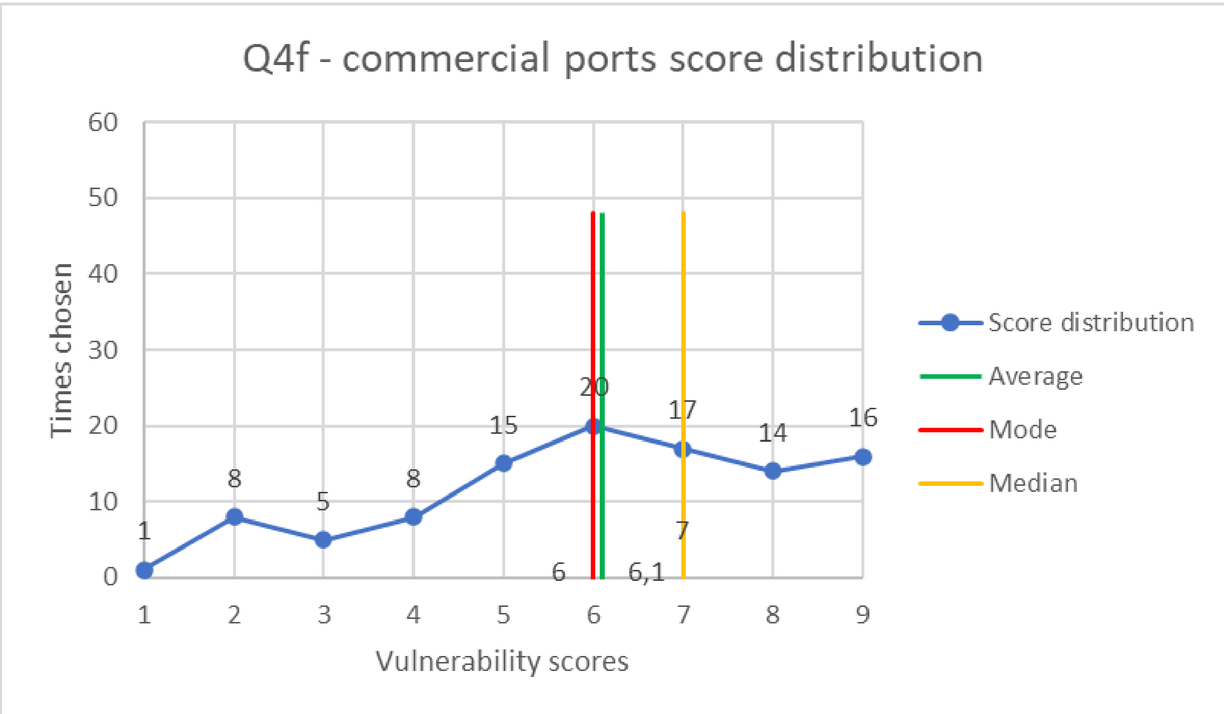

Figure 55: Graph chart of the rankings assigned to Q4f vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

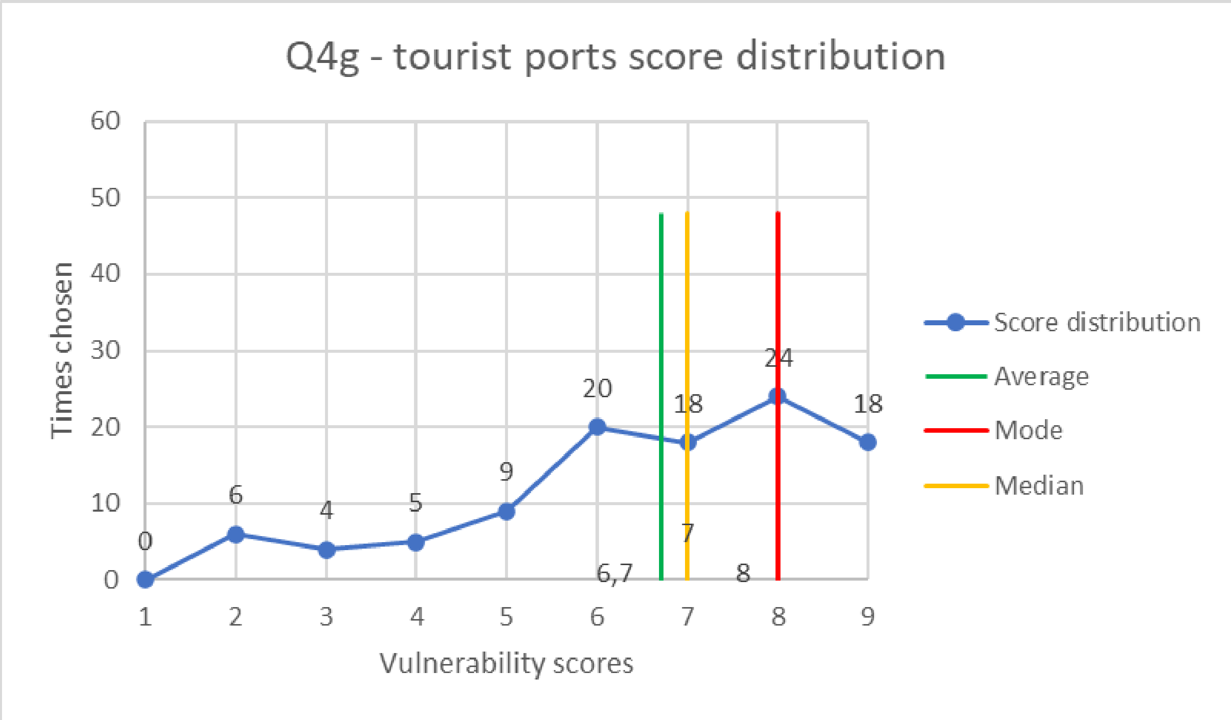

Figure 56: Graph chart of the rankings assigned to Q4g vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

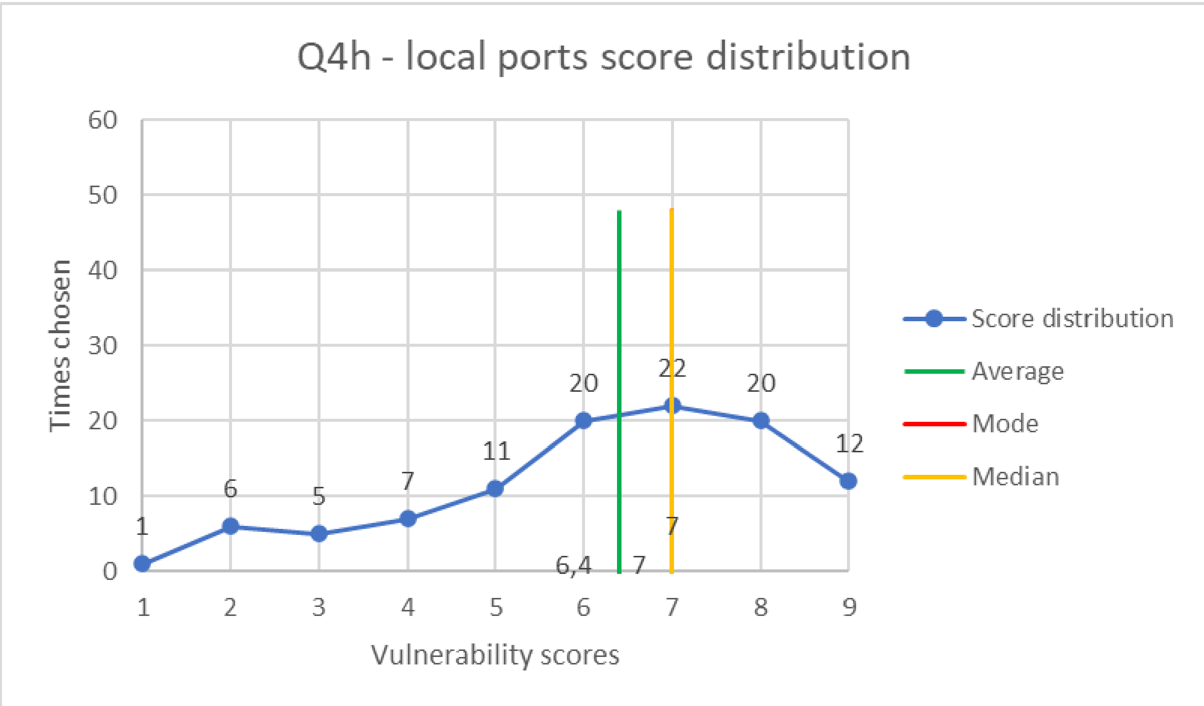

Figure 57: Graph chart of the rankings assigned to Q4h vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

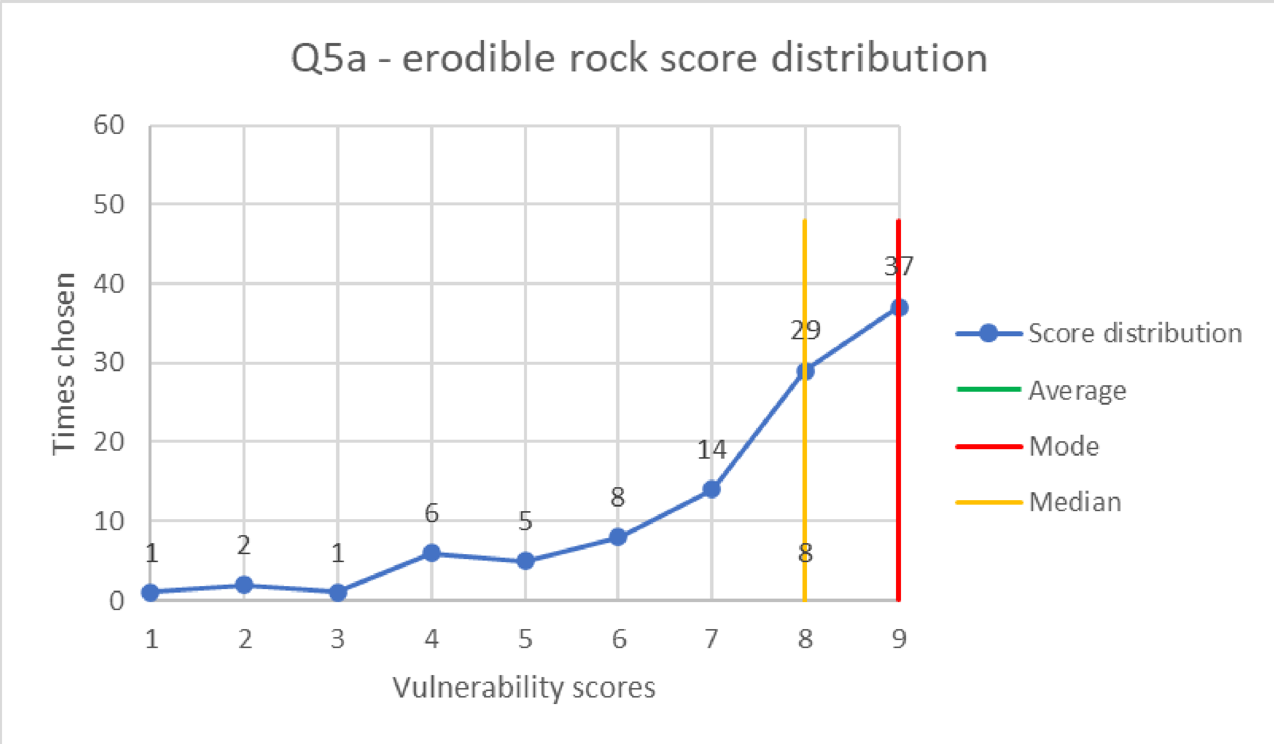

Figure 58: Graph chart of the rankings assigned to Q5a vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

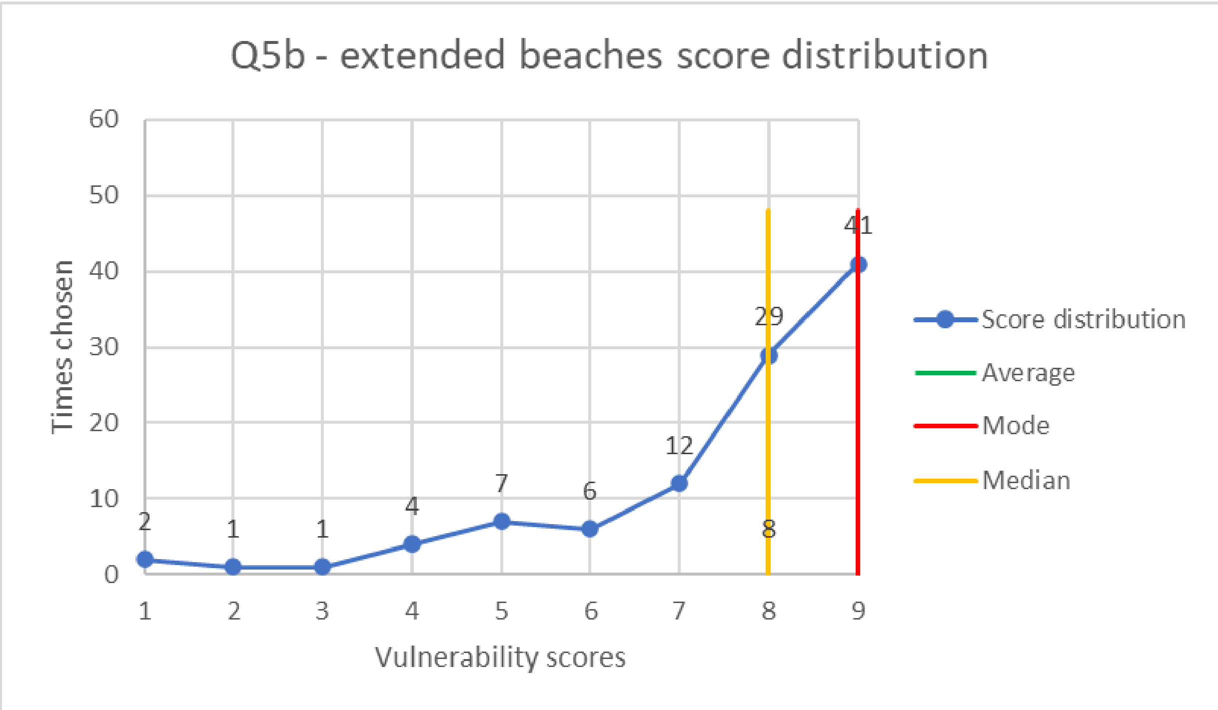

Figure 59: Graph chart of the rankings assigned to Q5b vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

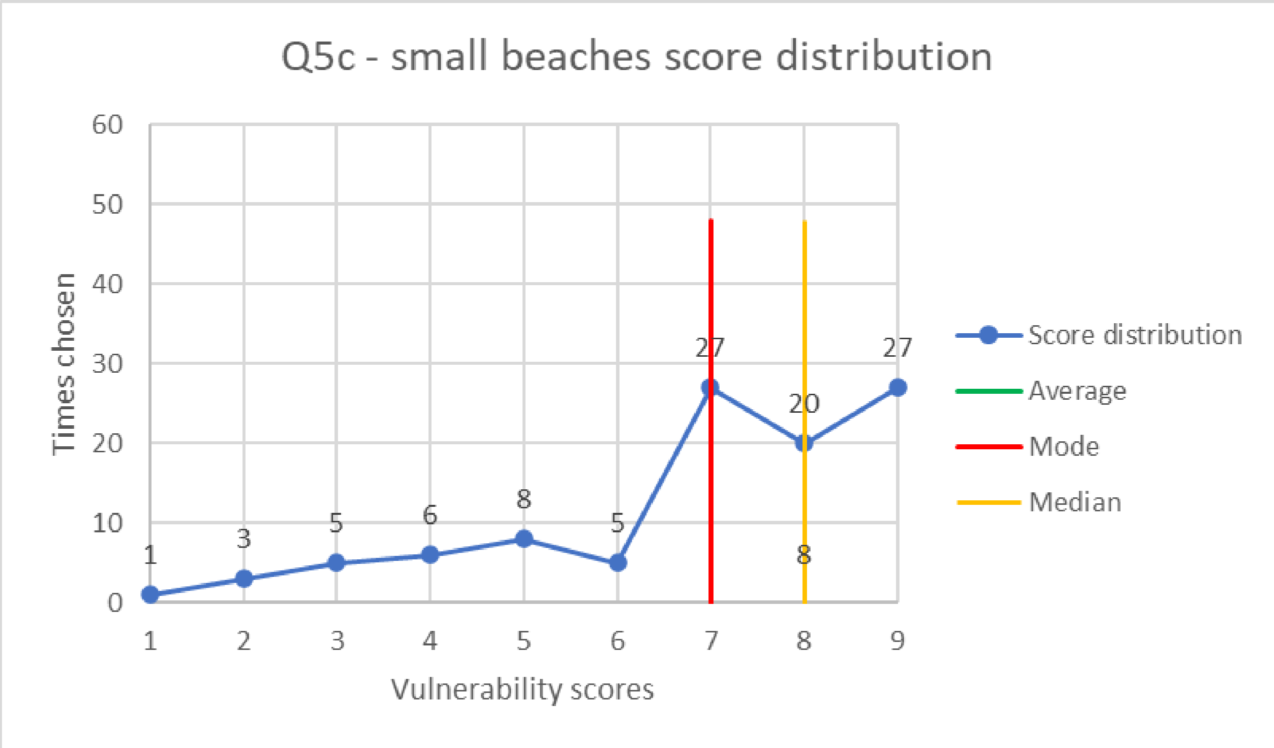

Figure 60: Graph chart of the rankings assigned to Q5c vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

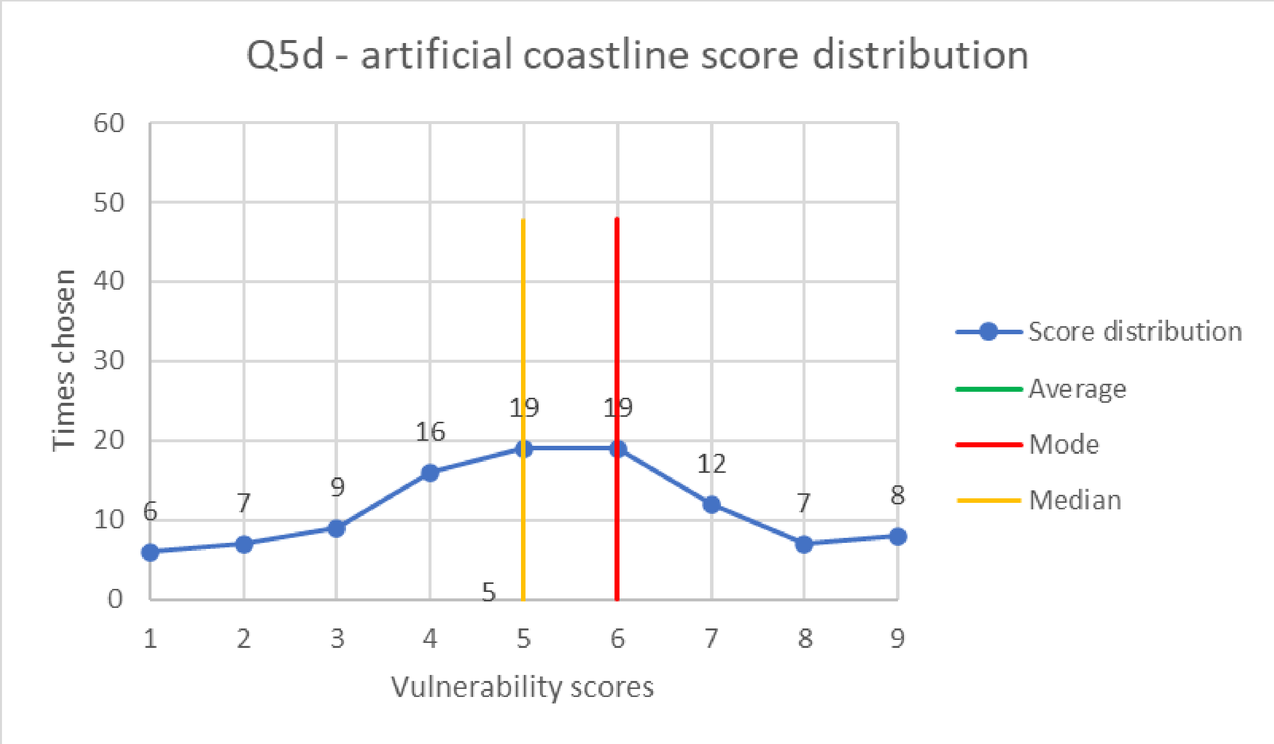

Figure 61: Graph chart of the rankings assigned to Q52 vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

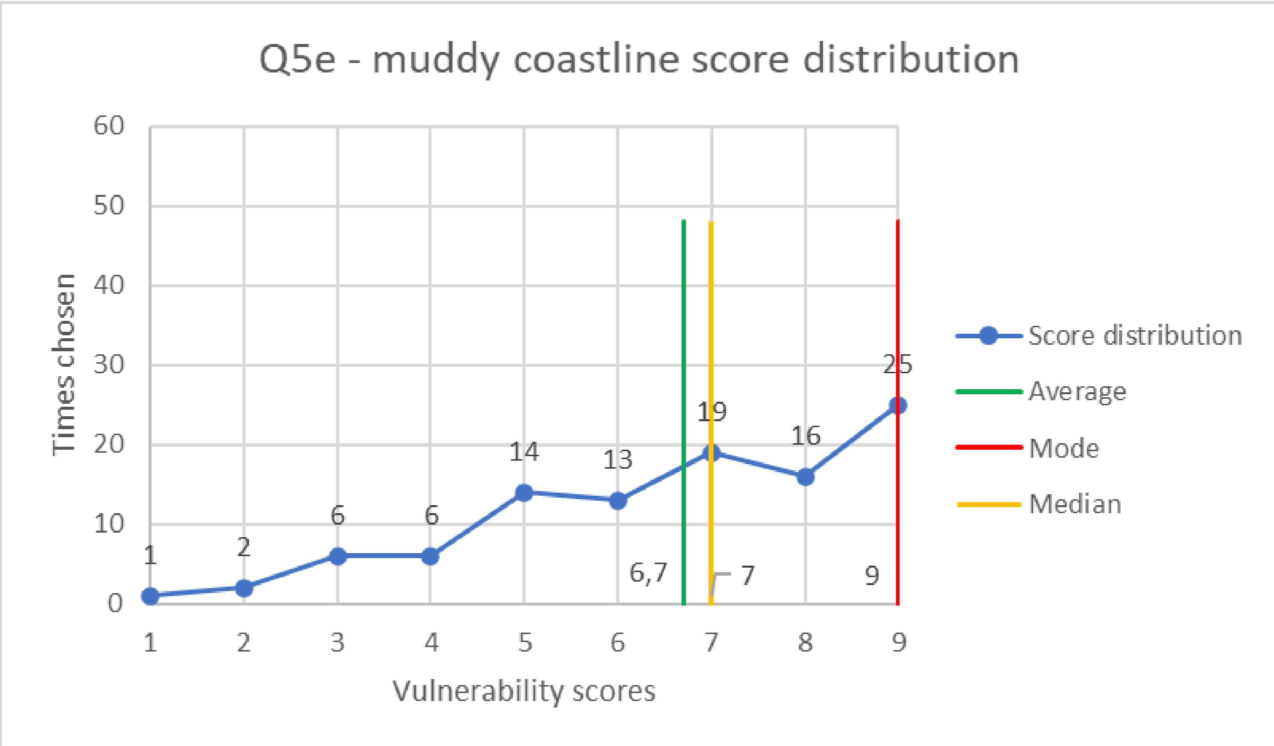

Figure 62: Graph chart of the rankings assigned to Q5e vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

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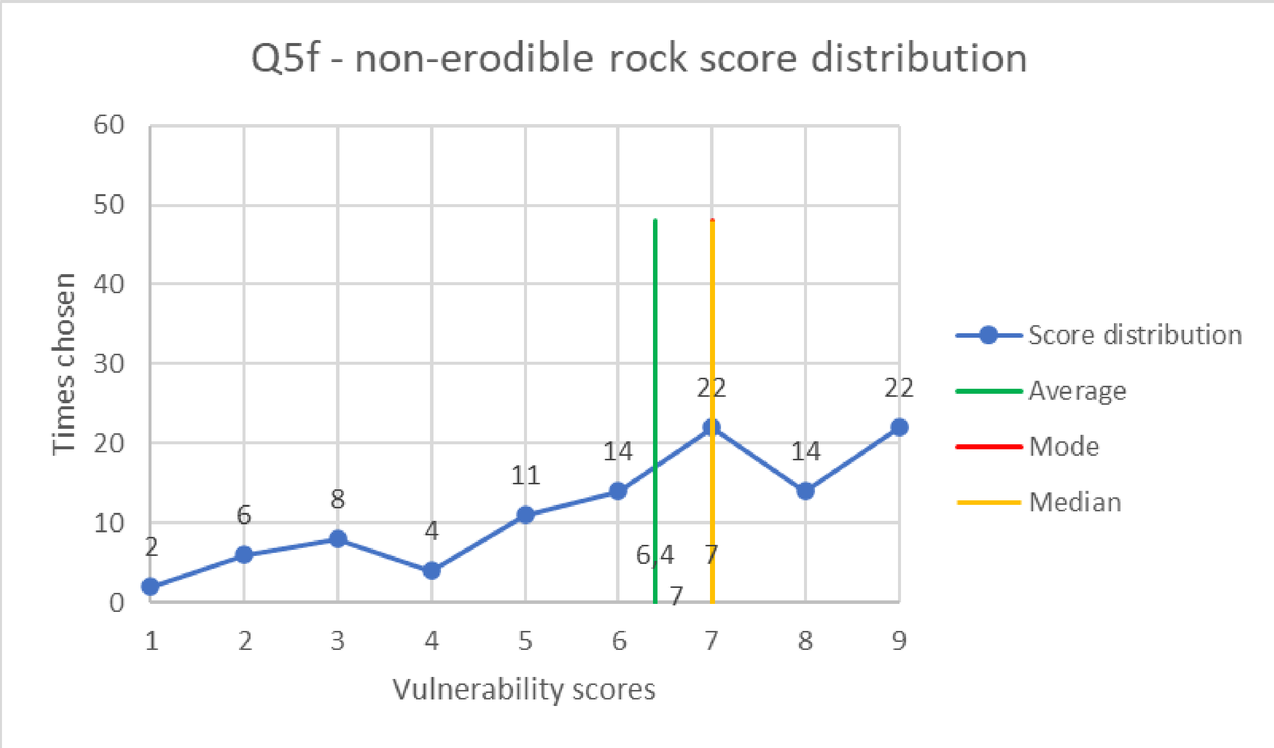

Figure 63: Graph chart of the rankings assigned to Q5f vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

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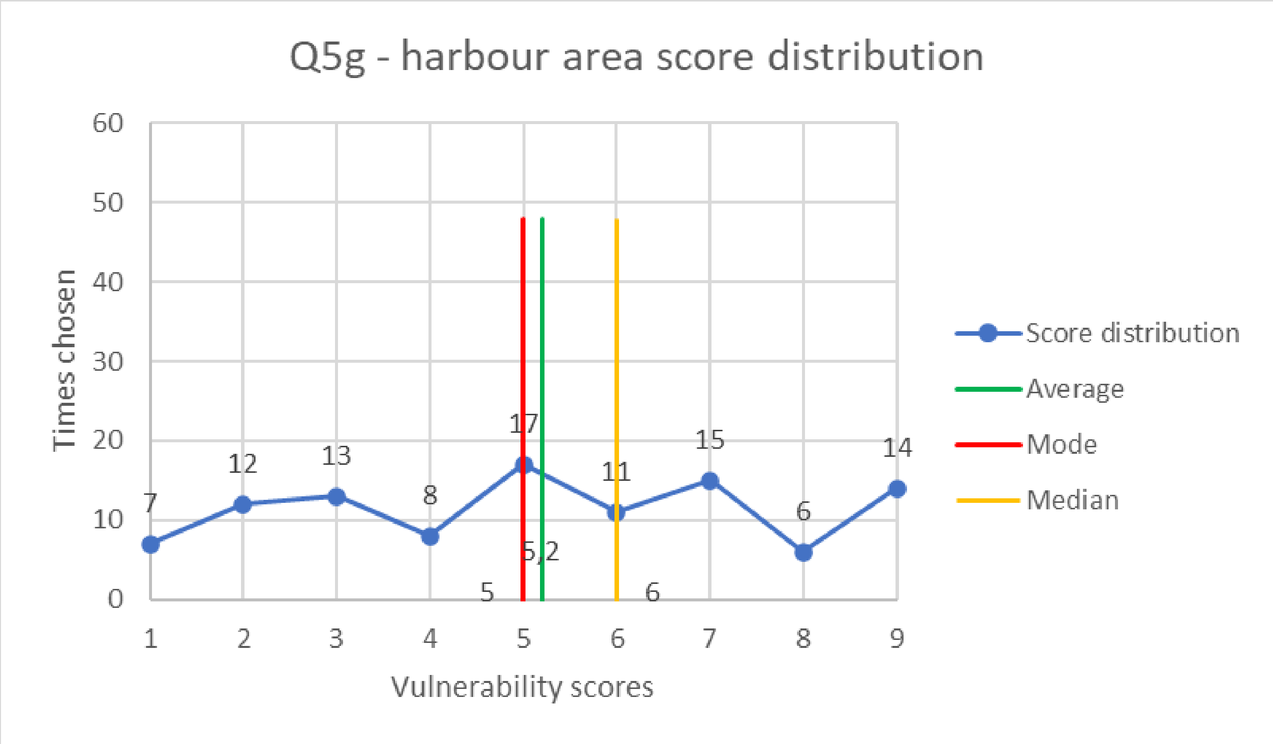

Figure 64: Graph chart of the rankings assigned to Q5g vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

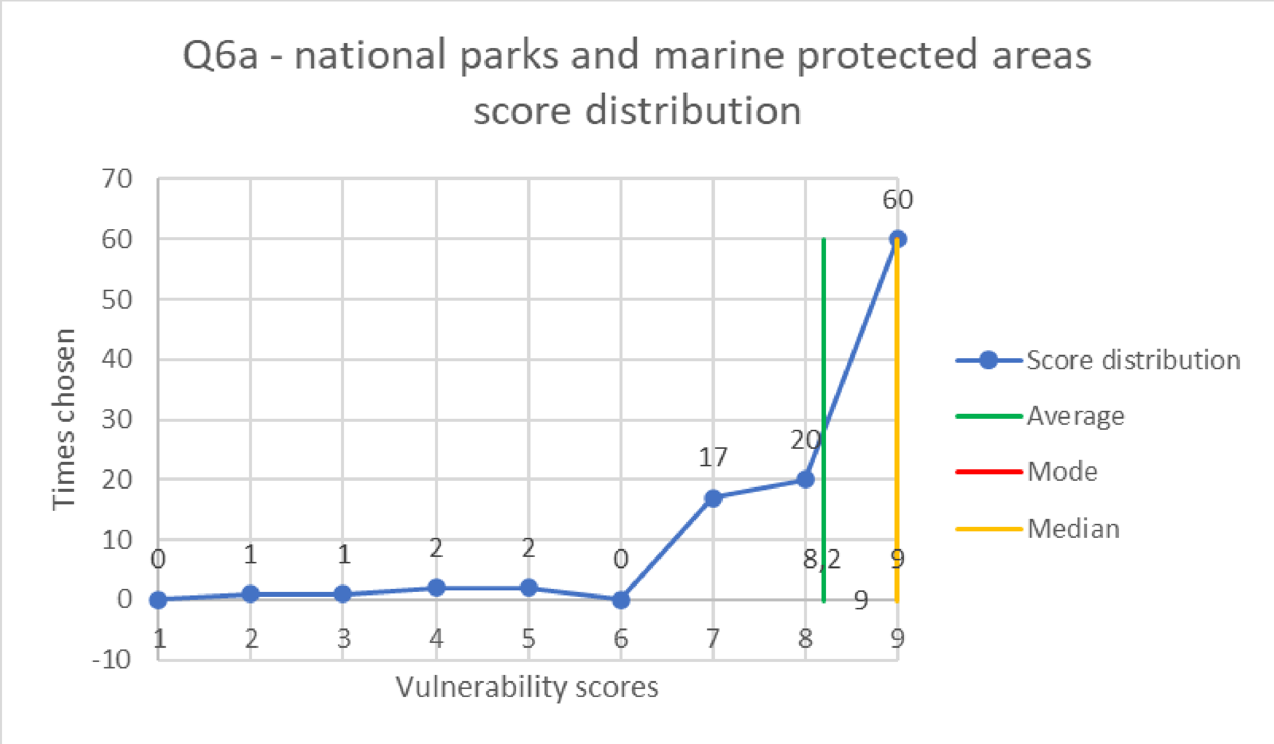

Figure 65: Graph chart of the rankings assigned to Q6a vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

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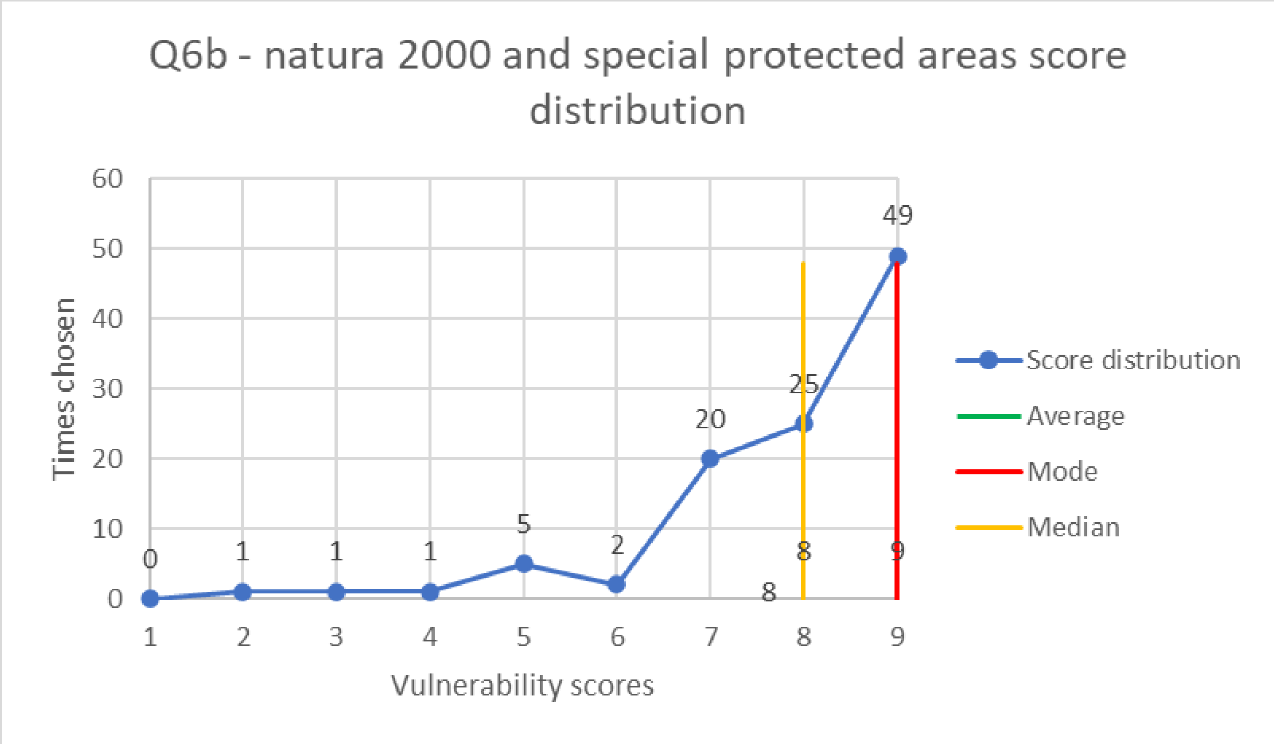

Figure 66: Graph chart of the rankings assigned to Q6b vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

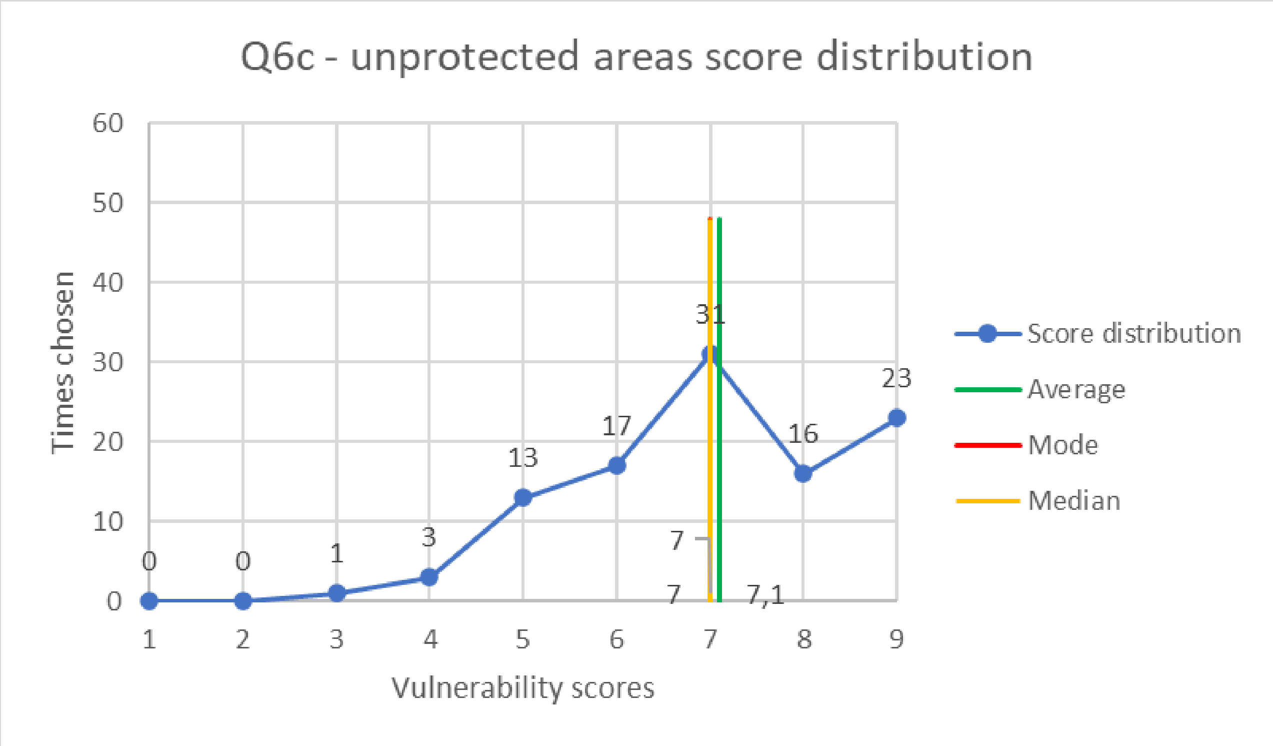

Figure 67: Graph chart of the rankings assigned to Q6c vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

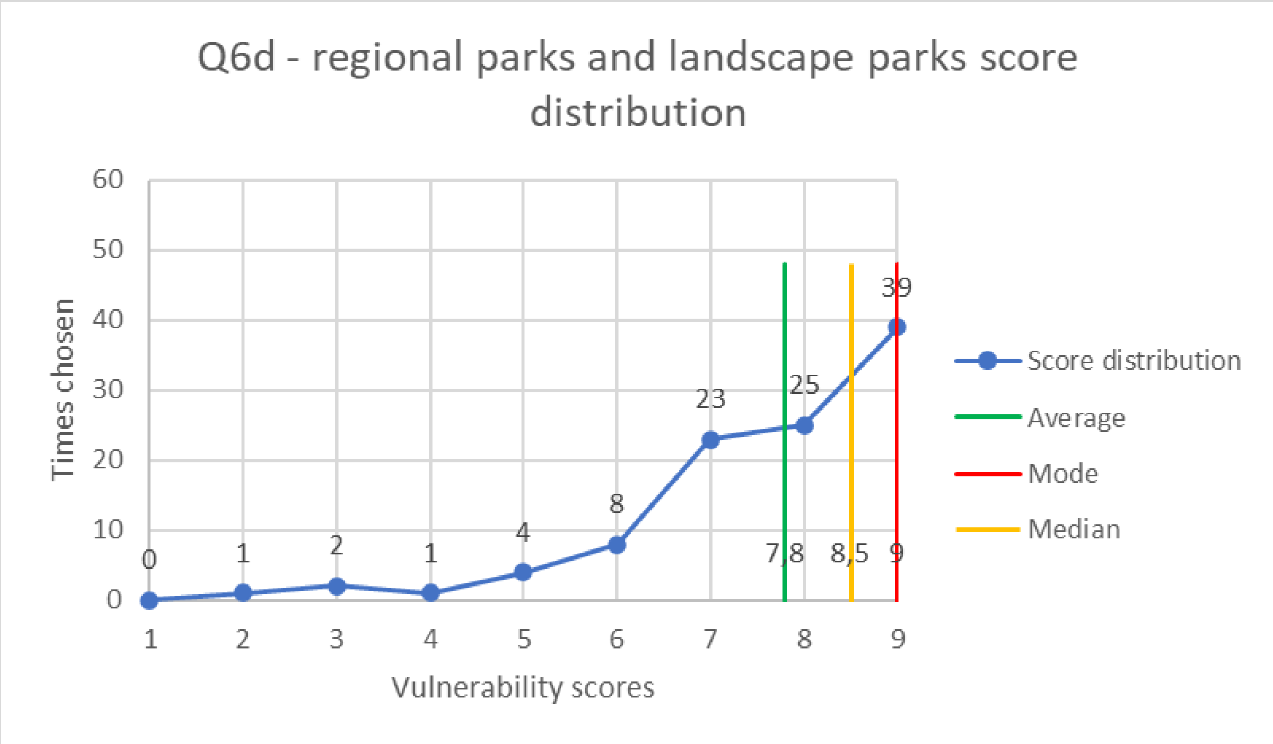

Figure 68: Graph chart of the rankings assigned to Q6d vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

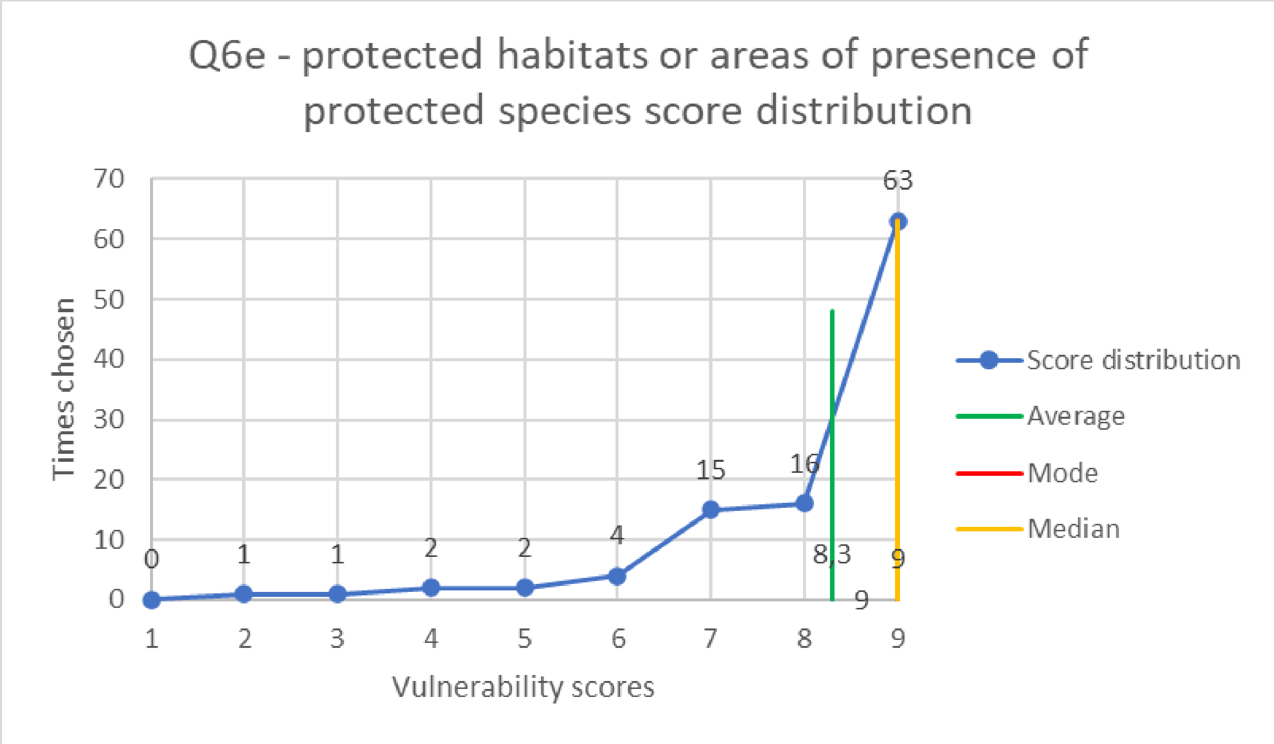

Figure 69: Graph chart of the rankings assigned to Q6e vulnerability factor by participants to all three workshops. Blue = score distribution, Green = average score value, Red = mode of score values, Yellow = median score value.

The graphs show that most participants refrained from using the lowest available scores, most likely due to not having a complete perspective over the importance of some of the vulnerability factor groups, which led to overestimation of the vulnerability for some factors. This is also highlighted by the overall standard deviation values which show high dispersion. In general, it can be observed that the highest rankings are those most favoured for all vulnerability factors.

In Fig. 70 the results on the most probable position of oil spill incidents in the Northern Adriatic Sea according to all the participants to the three workshops are shown.

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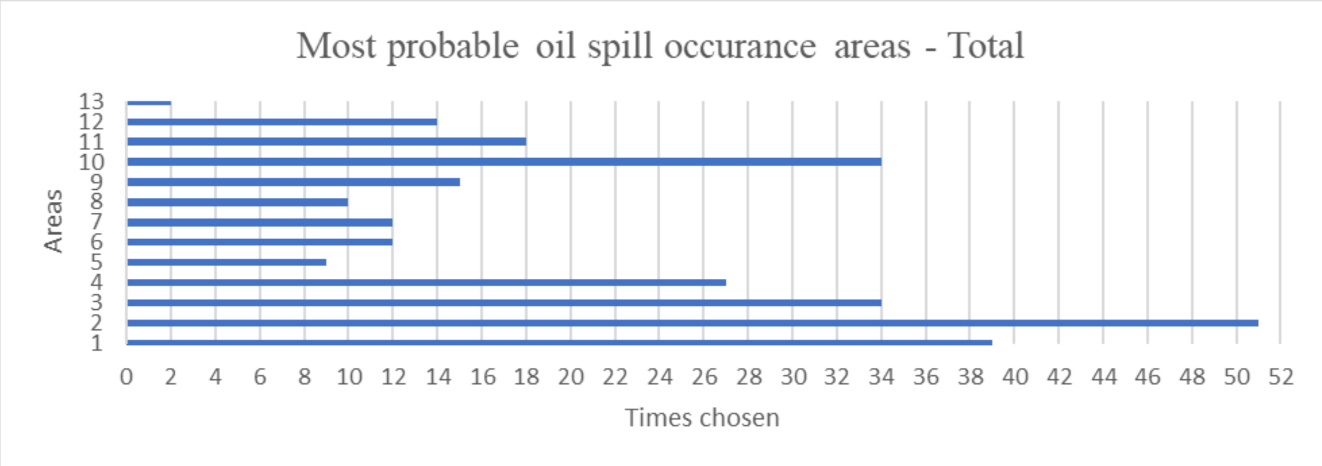

Figure 70: Most probable oil spill locations as selected by the participants to all three stakeholders' workshops.

It can be seen that the participants perceived as the most dangerous areas the SIOT terminal in Trieste, the Trieste anchorage, the separation triangle, and the Koper anchorage. Two participants indicated additional positions for incidents involving oil spills. The first participant indicated the INA terminal in front of Rijeka (see 4.3.1: this choice was later included into the 4th option, so this area was chosen 28 times in total), while the other did not suggest any alternative position.

In general, the results to this question were as expected, with two exceptions, first being the high number of times the SIOT terminal was selected, the second being the low number of times the Venice anchorage was selected. In fact, SIOT terminal was the people's first choice by a large margin, probably also because of the memories of the terrorist attack in 1972. On the other hand, the latter was chosen fewer times than expected, most likely because there were not many participants from that region, but predominantly from Slovenia, Croatia, and the FVG region in Italy.

4.6 Discussion

The cumulative score distribution graphs of each vulnerability factor highlight how most participants refrained from using the whole available spectre of scores ranging from the lowest to the highest, but mostly used scores of the upper half, which can be interpreted in two ways.

The first assumption based on the results would be that participants simply deem all the vulnerability factors to be very important and consequentially would not neglect any of them should an oil spill occur. Another hypothesis is that workshop participants lacked proper knowledge on some of the vulnerability factors, which resulted in overestimation. A better explanation from the organizers on the vulnerability factors might have enlarged the range of values used by the participants. Nevertheless, all participants belonged to a group of experts, and we can consider that in any case they had sufficient knowledge for an informed compilation of the questionnaires.

The joint results highlighted that the participant stakeholders assigned the highest priority, with a share of 36%, to the environmental factors, while socio-economic and geomorphological factors were given similar levels of priority topping 32% and 31% respectively. Thus, all three groups of vulnerability factors were

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valued in a similar way from the stakeholders. More detailed analysis might bring in the spotlight possible different rankings assigned by the different categories of stakeholders.

The result on the group of environmental vulnerability factors were in part surprising. All categories of protection were assigned high vulnerability values by the stakeholders. This might have been the result of a conscious choice by the stakeholders. Nowadays the environmental conscience is very high and perhaps the stakeholders perceived that no area, protected or unprotected, should be degraded by the consequences of an oil spill. On the other hand, perhaps the communication from the organizers as to what are the unprotected areas was not sufficient. In fact, it seems as if the stakeholders did assign a high vulnerability to unprotected areas precisely because they are not protected. With the same logic, a protected area, being already protected, was considered less vulnerable to oil spills. This might have been addressed better by the organizers, since a pollution from and oil spill would degrade the protected and the unprotected areas in the same way. Nevertheless, inherent in the system of nature protection and conservation is the idea that areas need different protection according to their importance. Thus, areas more deserving protection, get higher levels of protection (i.e., at the level of MPAs or National Parks), while areas less deserving protection, get lower forms of protection (e.g., Natura2000 or protected habitats according to one of the EU directives). The results of the stakeholders' workshops might have been different if we chose to ask about the "value" or "importance" of the environmental factors, rather than about the "vulnerability".

In any case, the results for the group of environmental factors were too much compressed on the high end of the ranking: the lowest average value 7,1 was assigned to the category of unprotected areas, the highest 8,3 to protected habitats or areas of presence of protected species. To MPAs and National Parks, the highest levels of protection in Italy and Croatia respectively, the average value of vulnerability assigned by the participants was 8,2. If we used these values for the vulnerability index and vulnerability mapping, simply all areas of the Northern Adriatic coastline would require very high priority in case of oil spills... This is not practical from the point of view of intervention in case of oil spill and it is thus not useful in the frame of NAMIRS scope and goals. Thus, the research team decided not to use the results of the stakeholders' workshops regarding the vulnerability of environmental factors for vulnerability indexes and mapping derivation. Instead, we opted to use an expert knowledge approach and to assign vulnerability rankings to environmental factors proportionally to the level of legislative protection granted to each protected area. Thus, the MPAs and National Parks were rated highest, the unprotected areas lowest, on a ranking from 1 to 9 (more on this in Section 5).

For the group of geomorphological vulnerability factors, in the workshops we did not ask for "vulnerability" of the different types of coastlines, but for the "value" assigned to them by the stakeholders. This was done because the environmental vulnerability of the coastline is not a matter of subjective judgment, but of objective factors related to the substrate type (grain size, permeability, trafficability, mobility), slope of the shoreline, and its exposure to waves and tides. All these factors affect the fate of the oil particles that might reach the shore, as well as the cleaning methods to apply and their efficiency. Thus, in the vulnerability indexes and mapping, the stakeholders' evaluation of geomorphological factors was merged with the socioeconomic factors, since both express the perceived, subjective value of the stakeholders. On the other hand, in the computation of the geomorphological vulnerability index, we used a modified version of the NOAA ESI (Petersen et al., 2019) instead. The ESI index is an objective evaluation of the difficulty of cleaning each cost type, originally developed for US coasts, but here adapted to the Northern Adriatic Sea coast typologies (see the next Section).

The results of the stakeholders' workshops thus provided the necessary information in order to proceed with the computation of the vulnerability indexes and the production of vulnerability maps for the Northern Adriatic Sea. Based on these, suggestions for the prioritization of protection and cleaning of different coastal areas can be included in contingency planning for emergencies in the Northern Adriatic Sea. A possible future improvement would be to apply the Delphi method of priority selection. In the question on the "familiarity" with the topics of the questionnaire, the participants had to self-assess their level of knowledge on each of the vulnerability factors. The scores of those who expressed higher familiarity level, would have greater importance than the scores of participants with a lesser level of familiarity. In the Delphi method the participants are divided into three levels of knowledge, and the input of each of them is then adjusted to match the corresponding knowledge level. In this way, the answers can be weighted by the expertise of the stakeholders and more weight is given to those that have higher expertise in a certain field.

The involvement of the stakeholders already sparked some interesting developments. First of all, as already described in Section 3, the oil spill simulations set up was possible also thanks to the information on the most common oils travelling in the Northern Adriatic Sea and their characteristics provided by one of the stakeholders, namely SIOT: operating in the Trieste port this is Europe's largest crude oil terminal in the Mediterranean. SIOT's help was much appreciated and instrumental for obtaining good results for NAMIRS. Another stakeholder that participated in the Italian workshop, the Marine Protected Area of Miramare (the first MPA declared in Italy in 1986) asked OGS to help in the preparation of a specific contingency plan in case of oil spill for the area under protection. Thus, NAMIRS is already outgrowing its scope.

Besides obtaining valuable information for the goals of NAMIRS, and besides the abovementioned developments, and while not being the main goal of the workshops, there were other benefits associated to the organization of the three stakeholders' workshop. One of them was the strengthening of the collaboration between NAMIRS partners, with frequent meetings and coordination between the organizers from the three involved partners (UL-FPP, OGS, ATRAC). Another is the outreach of the project and its goals to a wider public of persons, institution and companies, interested in the exploitation of the sea and of the coastal areas.

5. Vulnerability mapping and assessment

5.1 Maps of vulnerability factors

Rapid interventions of the Coast Guard and Response Teams and decisions on priority areas to protect in case of an oil spill event, require detailed information and maps on coastal vulnerability that decision makers can easily and quickly consult.

To provide high-resolution maps of different vulnerability factors (VFs) and the total coastal vulnerability in the Northern Adriatic Sea, georeferenced data on the presence of the selected VFs in NAMIRS (Socioeconomic VFs, Environmental VFs, and Geomorphological VFs; see Section 4), was obtained by previous projects we carried out in the area, by searching on online databases and asking to colleagues that could store such data. A list of the maps of the VFs for each VF group is reported in Table 23 with information on the source, the file format, and a brief description.

Because most kinds of oil are less dense than water, most spilled oil floats on the water surface and it expects to affect mainly upper-sublittoral and surface organisms and structures. Thus, only VFs on the coastline and up to 5 meters depth were retained for the final coastal vulnerability assessment. The bathymetry chart of the Northern Adriatic Sea, used to clip all the maps, was derived from EMODnet – Bathymetry. In addition, a buffer of 3 nautical miles radius was drafted around the coastline to include only the VFs that are closer to the coast, being more prone to be affected by oil spill. Since the study area of the NAMIRS project includes only the marine portion of the Northern Adriatic Sea, coastal lagoons (i.e., the Venice lagoon and the Grado-Marano lagoon) were not considered in the analysis.

Finally, to create the maps of the VFs and of the total coastal vulnerability a score was assigned to each VF based on the mean scores given by the participants to the three workshops or according to our expertise. All operations and analyses on the maps and visualization were performed using the free and open source QGIS software with the WGS84 coordinate reference system (EPSG:4326).

Socioeconomic VFs - The selected socioeconomic VFs included 'Mariculture', 'Cultural heritage sites', 'Harbour areas', 'Recreational-touristic traits of coast', and the 'Value of coast by typology' (Table 23). The 'Mariculture' VF map was downloaded by the Adriplan data portal (http://data.tools4msp.eu/) and include location of shellfish and fish farms (Fig. 71). The map of 'Cultural heritage sites' VF was created by merging information from maps of archaeological and paleontological sites available on EMODnet – Geology (www.emodnet-geology.eu/), EMODnet Human Activities (www.emodnet-humanactivities.eu/), and on the Bioportal of Croatia (bioportal.hr). A 100 m radius buffer was created around each cultural heritage point with the aim to cover as much as possible the total extension of the sites (Fig. 72). To have a more realistic representation of the 'Harbour areas' VF, the original map of points identifying the ports in the Northern Adriatic Sea, downloaded by the Adriplan data portal, was modified by adding additional ports after comparison with the Google Satellite map. Then, a 100 m, 250 m and 750 m radius buffer were drawn around local ports, marinas and commercial ports, respectively, and an intersection with the Northern Adriatic Sea coastline was performed to obtain a polyline shape file representing harbour areas (categorized in local ports, marinas, commercial ports) (Fig. 73). Since no maps reporting the recreational and touristic sites were available, a joined map of the 'Recreational-touristic traits of coast' VF was generated by intersection between the Northern Adriatic Sea coastline and a 100 m radius buffer drawn around the bathing water sites downloaded from EMODnet - Human Activities (Fig. 74). Although the number of traits of coast with recreational-touristic activities may be underestimated using the information on bathing water sites, this was the only available information that we could use as a proxy for deriving such VF. The 'Value of coast by typology' VF represents different geomorphological types of coasts, that expect to have a different value to the person who uses them for either environmental or socio-economic activities. The map of 'Value of coast by typology' was created by modifying a map of coastal typology in the Northern Adriatic Sea, download from EMODnet – Geology. Nevertheless, different classifications were used by the countries in their entries on the coast typology in the Northern Adriatic Sea. In fact, some categories were present only in Italy, others only in Slovenia, still others only in Croatia. In many cases these categories across different countries were related to the same coast typology. Thus, the original coastal geomorphologies reported in this map were merged in seven categories for simplicity: erodible rock with sediments at the base, extended beaches (> 1 km), small beaches (< 1 km), artificial coastline, muddy coastline, non-erodible rock without sediments at the base, and harbour area (Fig. 75). A value was then assigned to each of these coastal typologies according to the results of the questionnaires (see paragraph 4 and below). Although the 'Cooling water stations' VF was considered in the questionnaire provided to the participants of the workshops, no information on the location of this VF in the Northern Adriatic Sea was found, thus the cooling water stations were not included in the final coastal vulnerability map.

Table 23. List of the vulnerability factors used for the coastal vulnerability assessment.

VF	Type	Source	Description	VF group
Mariculture	Shape (polygons)	Adriplan data portal	Shellfish and fish farms	Socio-economic
Cultural heritage sites	Shape (points)	EMODnet geology and human activities; Bioportal Croatia	Archaeological-Paleontological sites	Socio-economic
Harbour areas	Shape (polylines)	Created in QGIS using the coastline of Northern Adriatic Sea, and a layer of ports downloaded from Adriplan data portal	Commercial-industrial ports, local ports, marinas. Further harbour areas were added to the original file after comparison with Google Satellite	Socio-economic
Value of coast by typology	Shape (polylines)	Modified in QGIS from a layer of coastal typology downloaded from EMODnet geology	The coastline of Northern Adriatic Sea is divided in polylines and classified according to the different coastal typologies (e.g., muddy coastline, erosion-resistant coast, harbour area). A value is then assigned to each	Socio-economic

			typology according to the results of the questionnaires	
Recreational-touristic traits of coast	Shape (polylines)	Created in QGIS using the coastline of Northern Adriatic Sea, and the bathing water sites downloaded from EMODnet - Human Activities	The layer reports the traits of coast characterized by touristic and/or recreational activities	Socio-economic
National parks and Marine Protected Areas of National legislation	Shape (polygons)	Mapamed		Environmental
Regional parks and Landscape parks	Shape (polygons)	Mapamed		Environmental
Natura 2000 and special protection areas	Shape (polygons)	Mapamed		Environmental
Protected habitats and areas of presence of protected species	Shape (polygons, points)	EMODnet Biology (www.emodnet-biology.eu/)	Distribution of coralligenous and maerl	Environmental
	Shape (points)	EMODnet Biology; updated by Emmanuelle Descourvieres	Distribution of *Fucus virsoides*	
	Shape (points)	EMODnet Biology	Distribution of *Cystoseira* spp.	
	Shape (polygons, points)	Miramare MPA; EMODnet Biology	Distribution of *Pinna nobilis*	
	Shape (points)	EMODnet Biology	Distribution of habitat-forming invertebrates	
	Shape (points)	Bioportal of Croatia	Distribution of biocenoses	
	Shape (polygons, points)	Prof. Annalisa Falace, National Institute of Biology of Slovenia, EMODnet Biology	Distribution of seagrasses	

	Shape (points)	EMODnet Biology	Distribution of *Cladocora caespitosa*	
	Shape (points)	Falace et al 2015; Fortibuoni et al 2020; Gordini and Ciriaco 2020; Ponti 2020; Prof. Annalisa Falace; Adriblu data portal	Distribution of rocky outcrops ('*trezze*')	
Unprotected areas	Shape (polygons)	Created in QGIS by difference between the map of Northern Adriatic Sea marine region and the joined map of protected areas and species	Areas without the presence of any kinds of protected site or protected species and habitat	Environmental
Coast cleaning difficulty	Shape (polylines)	Created in QGIS using as a base the layer of coastal typology downloaded from EMODnet - Geology and the ESI ranking of NOAA (Petersen et al., 2019)	The coastline of Northern Adriatic Sea is divided in polylines and classified according to the different coastal typologies (e.g., muddy coastline, erosion-resistant coast, harbour area) and ESI ranking of NOAA.	Geomorphological

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Figure 71. Map of the mariculture in the Northern Adriatic Sea.

Figure 72. Map of the cultural heritage sites in the Northern Adriatic Sea.

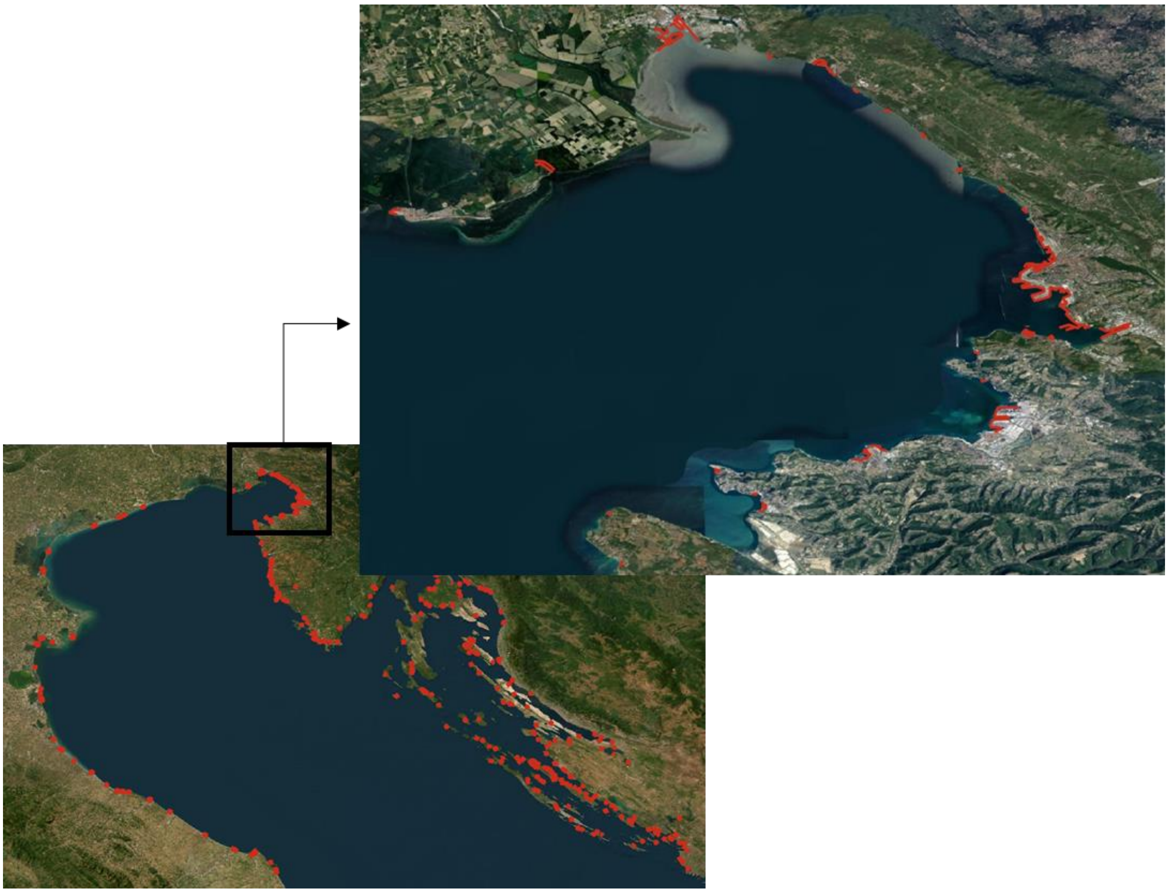


Figure 73. Map of the harbour areas in the Northern Adriatic Sea with details of the Gulf of Trieste.

Figure 74. Map of the recreational-touristic traits of coast in the Northern Adriatic Sea.

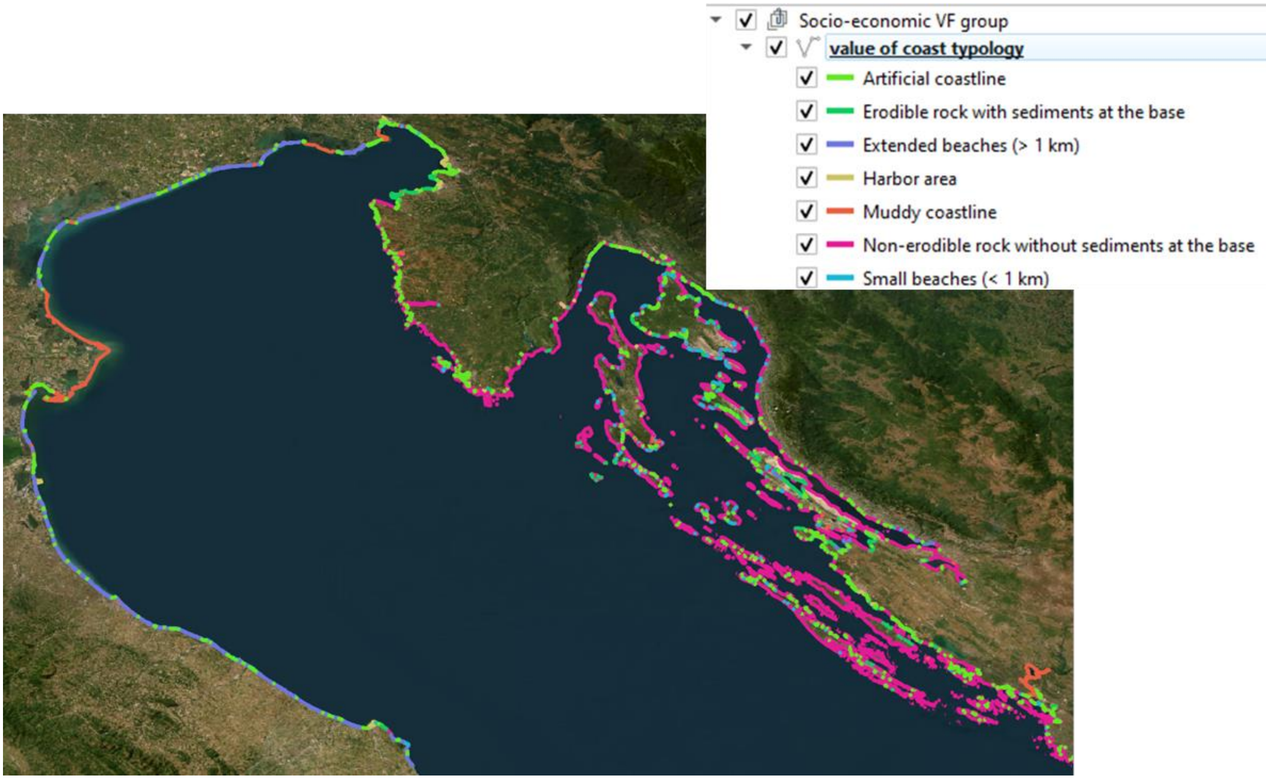


Figure 75. Map of the coastal typologies in the Northern Adriatic Sea. A value is then assigned to each typology according to the results of the questionnaires (not shown in the map).

To each socioeconomic VF the corresponding mean score as given by the participants to the three workshops was assigned. They ranged between 5.1 and 7.8 (Table 24). 'Mariculture' got the highest score, while the lowest value was assigned to the 'artificial coastline' category of the 'Value of coast by typology' VF.

Table 24. Score assigned to each socioeconomic VF.

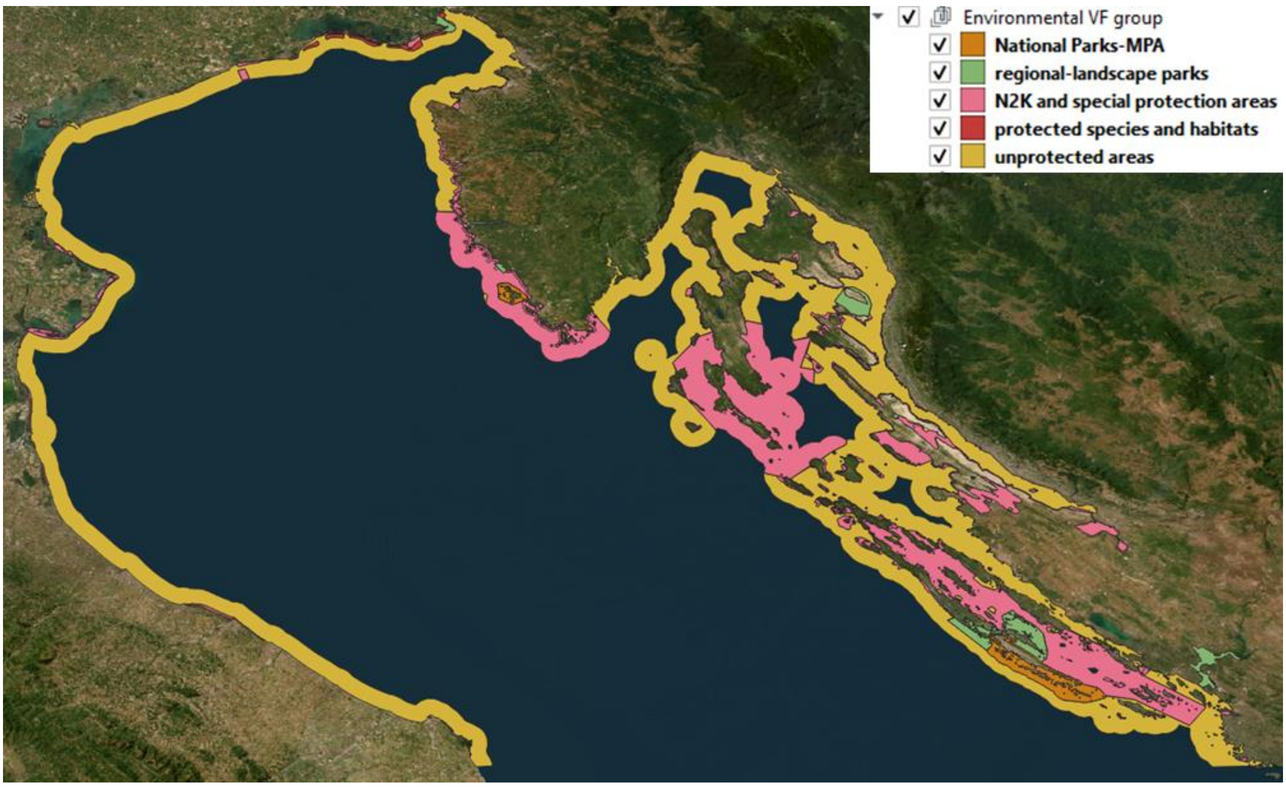
Socioeconomic VF	Category of the socioeconomic VF	Score
Mariculture		7.8
Cultural heritage sites		6.8
Recreational-touristic traits of coast		7.15
Harbour areas	Local ports	6.4
	Marinas	6.7
	Commercial ports	6.1
Value of coast by typology	Erodible rock with sediments at the base	7.2
	Extended beaches (> 1 km)	7.5
	Small beaches (< 1 km)	7.2
	Artificial coastline	5.1
	Muddy coastline	6.7
	Non-erodible rock without sediments at the base	6.4
	Harbour area	5.2

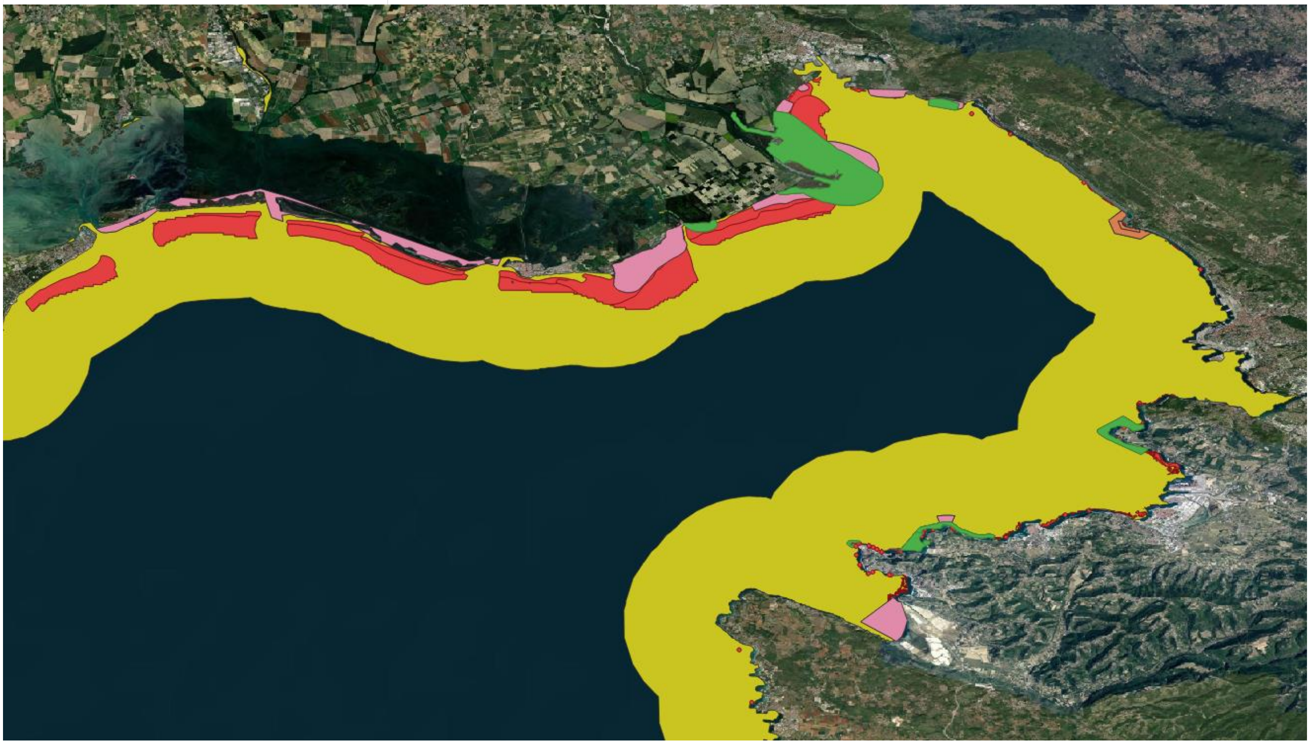
Environmental VFs - The environmental VF group included 'National Parks and Marine Protected Areas (MPAs)', 'Regional and Landscape parks', 'Natura 2000 sites and special protection areas', 'Protected habitats or areas of presence of protected species', and 'Unprotected areas' (Table 25). The maps of the protected areas in the Northern Adriatic Sea were downloaded from MAPAMED (www.mapamed.org), a database of marine protected areas in the Mediterranean Sea. Nature reserves, Natural monuments, National special reserves, and Landscape parks were included in the 'Regional and Landscape parks' VF. All parks designed under an international legislation (e.g., Ramsar sites, SPAMI) were considered 'special protection areas' and included in a VF with Natura 2000 sites. The maps with the distribution of protected species and habitats in the Northern Adriatic Sea were obtained from literature, Adriblu data portal and colleagues (Tab. 23). A 100 m radius buffer was created around the occurrence points of species and habitat as a better proxy of their presence. The 'Unprotected areas' VF was obtained by subtracting the surface area of the joined map of protected areas and protected species and habitats to the map of the whole Northern Adriatic Sea marine region (Fig. 76).

Participants to the workshops assigned a mean score of 8.3 to protected species and habitats; 8.2 to national parks and MPAs; 8 to Natura 2000 and special protection areas; 7.8 to regional and landscape parks and 7.1 to unprotected areas. Since these scores would give a misleading result, increasing the importance of protected species and habitats respect to the Natura 2000 sites and regional parks, we decided to assign an arbitrary score (from 1 to 9) to the environmental VFs based on the level of formal protection granted to the different categories of protected areas (Tab. 25).

Table 25: Vulnerability scores assigned to each environmental VF.

Environmental VF	Score
National parks and MPAs	9
Regional and landscape parks	7
Natura 2000 and special protection areas	5
Protected species and habitats	3
Unprotected areas	1





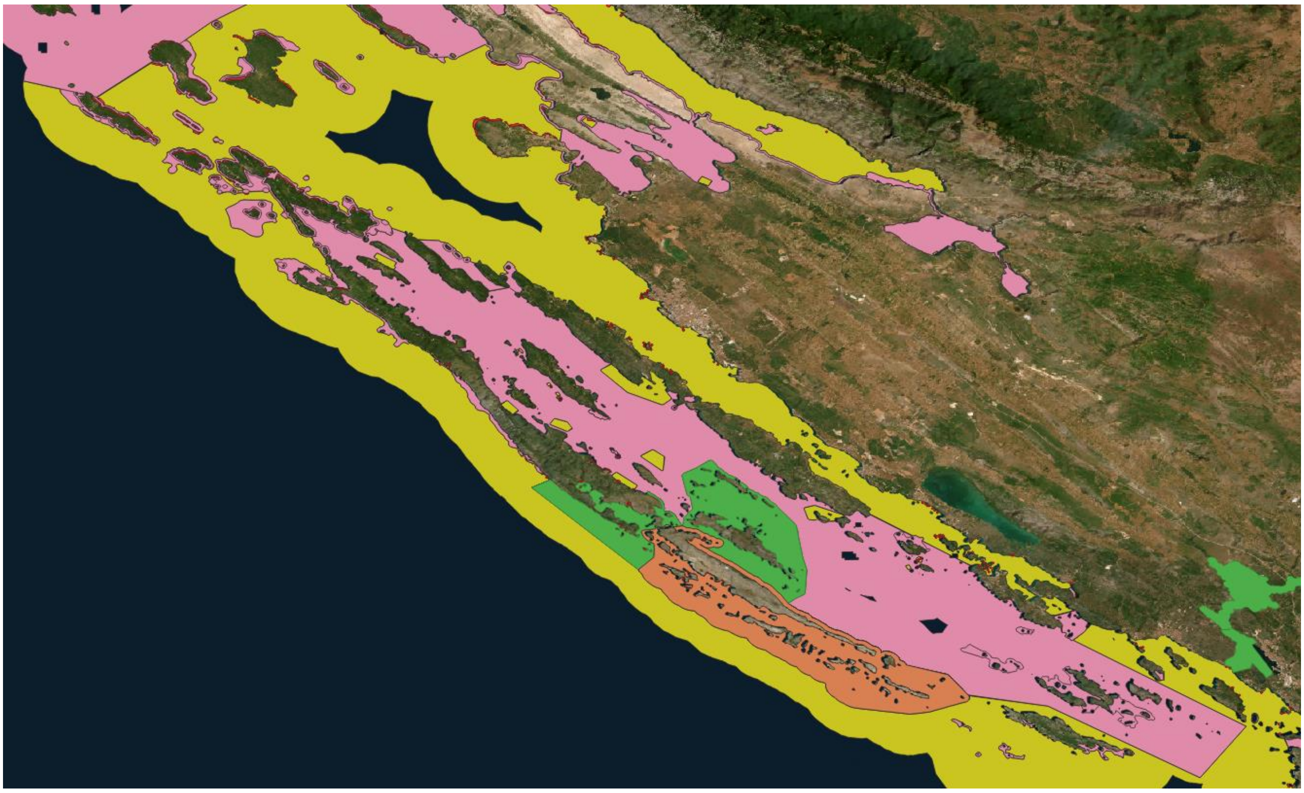


Figure 76. Map of the environmental VFs in the Northern Adriatic Sea. Details of the Gulf of Trieste and the coastline of the Kornati archipelago are also shown.

Geomorphological VFs - Since every beach or coastline is composed of different materials, which respond to oil in different ways, geomorphology must be taken into account as well.

To create a map with the information on the coast cleaning difficulty, coastal geomorphologies in the Northern Adriatic Sea, were downloaded from EMODnet – Geology. Nevertheless, different classifications were used by the countries in their entries on the coast typology in the Northern Adriatic Sea. In fact, some categories were present only in Italy, others only in Slovenia, still others only in Croatia. In many cases these categories across different countries were related to the same coast typology. These categories were compared and matched, as much as possible, Environmental Sensitivity Index (ESI) that assess the coastal sensitivity to oil spill (https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/shoreline-sensitivity-rankings-list, Petersen et al., 2019) (Table 26, Fig. 77). For instance, the categories 'Harbor area' and 'Coastal embarkment with construction' were unified and matched with the NOAA category 'Exposed solid man-made structures', while all the categories that identify small and pocket beaches were unified and matched with the NOAA category 'Mixed sand and gravel beaches' (see Table 26 for a complete correspondence between our categories and those identified by NOAA). To each identified category, a score was assigned according to the ESI ranking. This ranking ranges from 1 to 10: higher values indicate greater sensitivity to oil spill, thus, in our case, a value of 10 indicates a higher coast cleaning difficulty. The lowest scores are assigned to the coastal typology categories that are easier to clean such as 'Exposed rocky shores' and 'Exposed man-made structures' (score 1) and 'Fine to medium-grained sand beaches' (score 3). Intermediate scores are assigned to 'Mixed sand and gravel beaches' (score 5), and to 'Gravel beaches' and 'Riprap' (score 6). A high score (8) is assigned to 'Sheltered rocky rubble shores'. Since NOAA ESI attributes a rank from 7 to 10 to categories identifying estuaries and muddy coastlines (i.e., 'Exposed tidal flats', 'Sheltered tidal flats', 'Vegetated low banks', 'Salt- and brackish-water marshes'), we assigned a rank of 9 to these coastal typologies in the Northern Adriatic Sea. The ESI ranks 2, 4, and 10 were not assigned in the NAMIRS ranking since the categories of coastal geomorphology identified in the NOAA index with this score are not present in the Northern Adriatic Sea (e.g., 'Coarse-grained sand beaches' - score 4, and 'Inundated low-lying tundra' - score 10). Since the NOAA ranking scale goes from 1 to 10, while the rank scale proposed in the questionnaires presented to the participants ranged between 1 and 9, we rescaled the assigned ranks according to this range. The new ranking is reported in Table 26.

Table 26. Coastal typologies classified by sensitivity to oil via Environmental Sensitivity Index (ESI) values, defined by the NOAA, the modified ESI as applied in this project, and the new rank assigned to the coastal typologies for the coast cleaning difficulty map after being rescaled from 1 to 9.

Coastal typology (EMODnet - Geology)	NOAA categories	NOAA rank	NAMIRS assigned rank	Rescaled NAMIRS rank
Erosion-resistant rock and/or cliff, without loose eroded material in the fronting sea	Exposed rocky shores	1	1	1
Harbor area	Exposed, solid man-made structures	1	1	1
Coastal embankment with construction	Exposed, solid man-made structures	1	1	1
Sand beach fronting upland (> 1 Km long)	Fine to medium-grained sand beaches	3	3	2.78
Pocket beaches (< 200 m long)	Mixed sand and gravel beaches	5	5	4.56
Small beaches	Mixed sand and gravel beaches	5	5	4.56
Small beaches (200 to 1000 m long) separated by rocky capes (< 200 m long)	Mixed sand and gravel beaches	5	5	4.56
Small beaches (200 to 1000 m long) separated by channels or harbours	Mixed sand and gravel beaches	5	5	4.56
Gravel beach fronting upland (> 1 km long)	Gravel beaches	6	6	5.49
Heterogeneous beach	riprap	6	6	5.49
Artificial beach	riprap	6	6	5.49
Artificial shoreline (walk, dike, quay) without beach	riprap	6	6	5.49
Erodible rock and/or cliff, with rock waste and sediments (sand or pebbles) at its base	Sheltered rocky rubble shores	8	8	7.22
Beach, unspecified	Exposed tidal flats; Sheltered tidal flats; Vegetated l	7-10	9	8.11
Beach that is part of extensive non-cohesive sedimentary systems (barrier, spit, tombolo)	Exposed tidal flats; Sheltered tidal flats; Vegetated l	7-10	9	8.11
Muddy coastline laguna	Exposed tidal flats; Sheltered tidal flats; Vegetated l	7-10	9	8.11
Muddy coastline Po	Exposed tidal flats; Sheltered tidal flats; Vegetated l	7-10	9	8.11
Muddy coastline, including tidal flat, salt marsh	Exposed tidal flats; Sheltered tidal flats; Vegetated l	7-10	9	8.11
Estuary	Exposed tidal flats; Sheltered tidal flats; Vegetated l	7-10	9	8.11

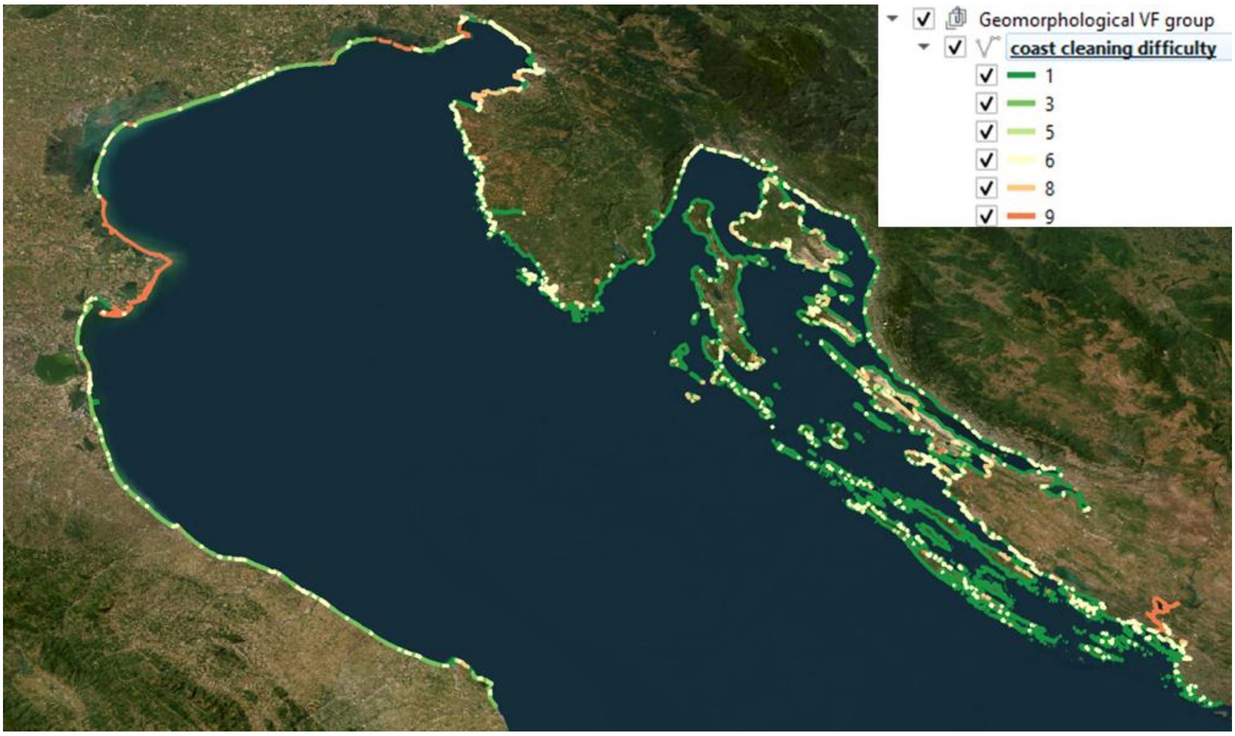


Figure 77. Map of the geomorphological typologies of coast in the Northern Adriatic Sea ranked according to the modified ESI. Higher rank values indicate greater difficulty in coastal clean-up.

5.2 Mapping the coastal vulnerability

All maps of the VFs were transformed from vector to raster format with a 100x100m cell size, to calculate the coastal vulnerability index. Before raster conversion, a 50 m radius buffer was drawn around the polyline shape files (i.e., 'Value of coast by typology', 'Recreational-touristic traits of coast', 'Harbour areas', 'Coast cleaning difficulty') to embrace the whole trait of coast.

Separate vulnerability maps for each VF group were generated by overlapping all VF rasters and extracting the maximum value in each raster pixel (Figs. 78-80). Finally, a map of total coastal vulnerability was obtained with the same method (Fig. 81). Although this method presents some limitation as only one VF is considered in each pixel, it guarantees adequate decisions on the priority areas requiring intervention in case of oil spill, because the most vulnerable VFs are selected to create the vulnerability maps. Vulnerability scores of the maps were then categorized in four classes and visualized in GIS with different colours: very low vulnerability (1-2, green), low vulnerability (3-5, yellow), medium vulnerability (6-7, orange), high vulnerability (8-9, red).


Socio-economic VF group
socioeconomic VFs
Band 1: Height
1-2
3-5
6-7
8-9

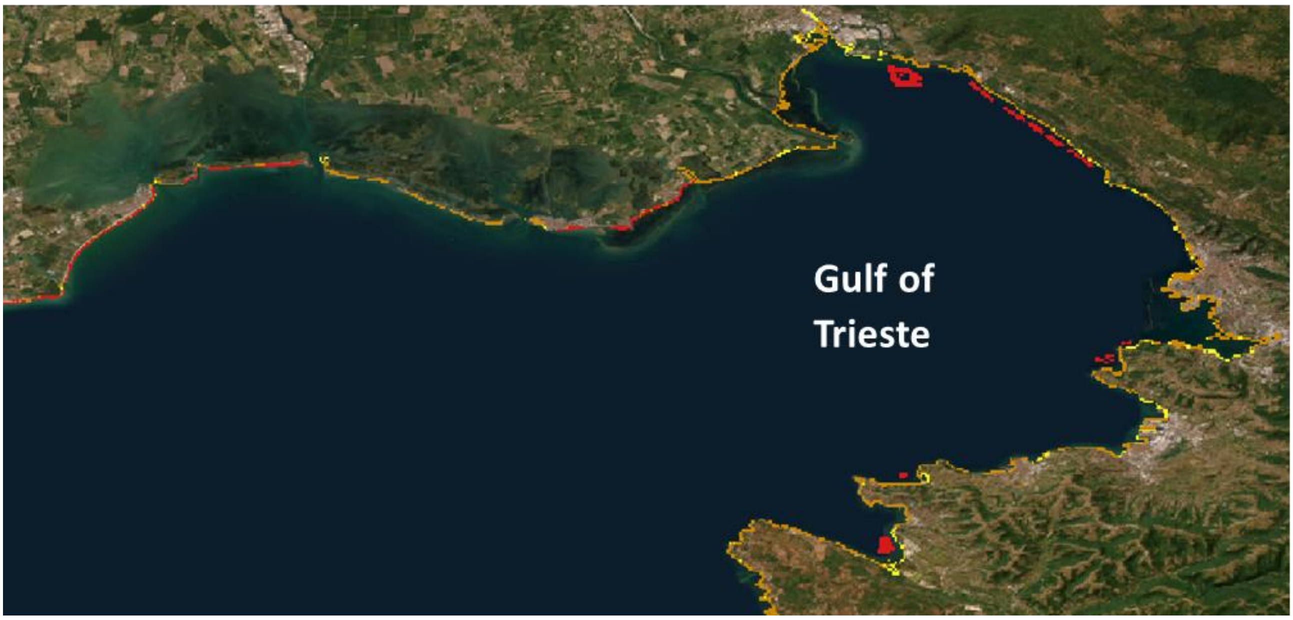

Gulf of
Trieste

Figure 78. Maps of the coastal vulnerability for the socioeconomic VF group with details of the Gulf of Trieste and the coastline near Rijeka. The red color indicates higher coastal vulnerability.

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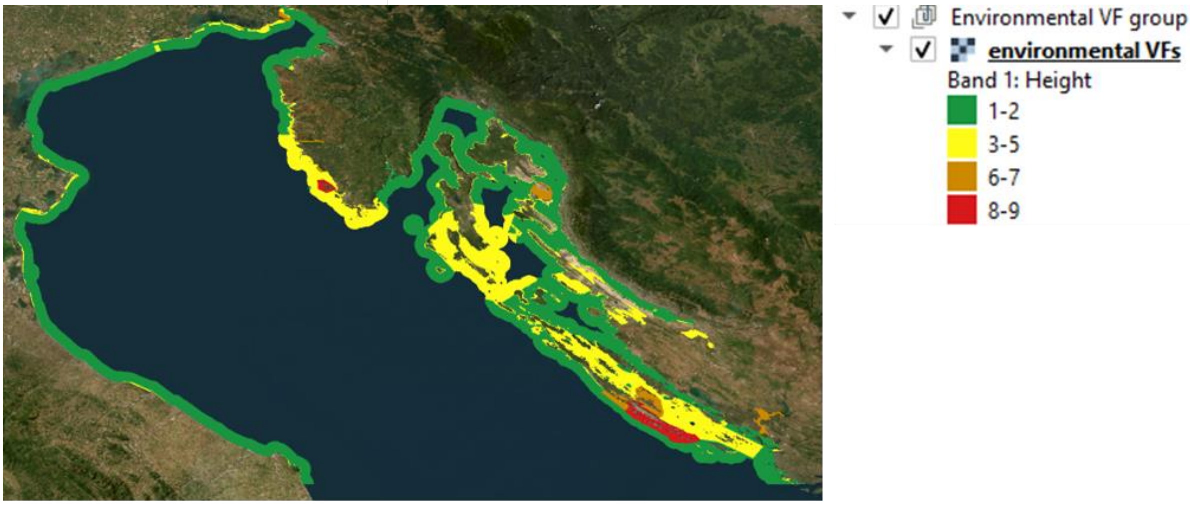

Environmental VF group
environmental VFs
Band 1: Height
1-2
3-5
6-7
8-9


Gulf of
Trieste

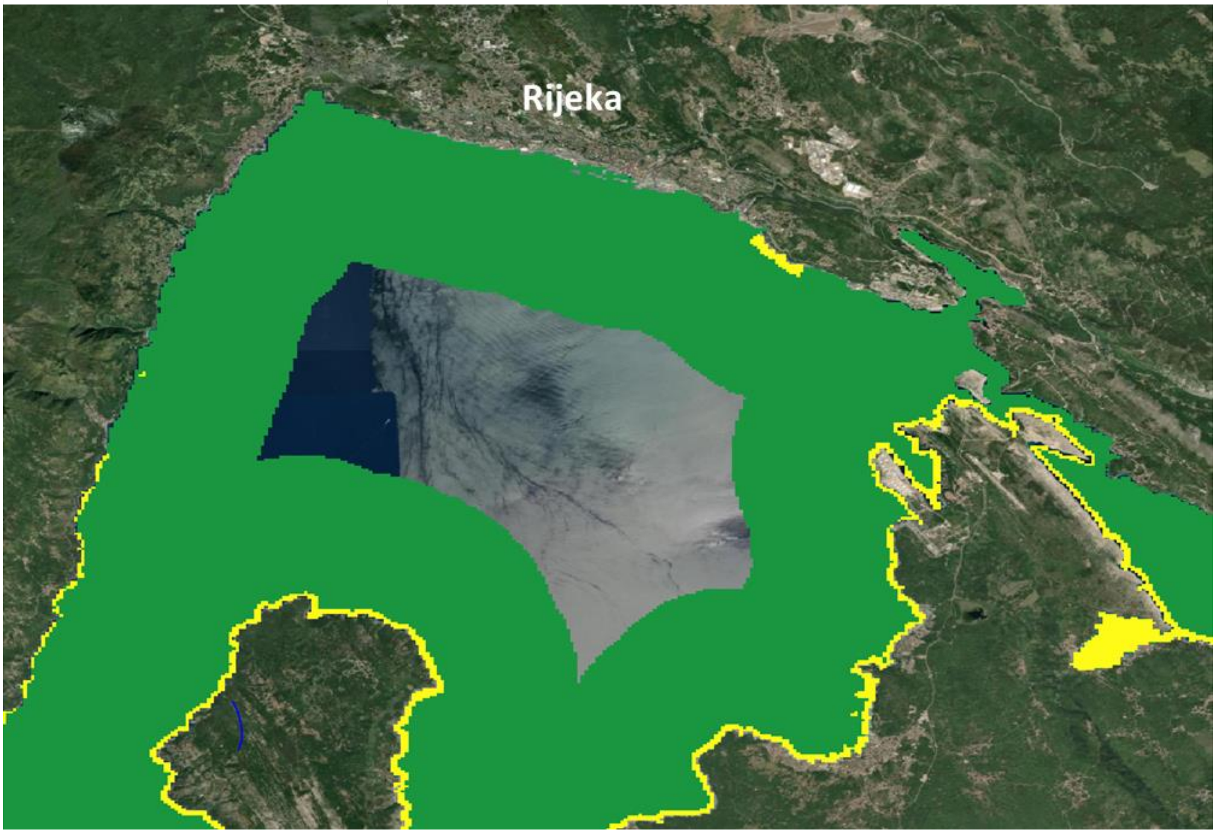
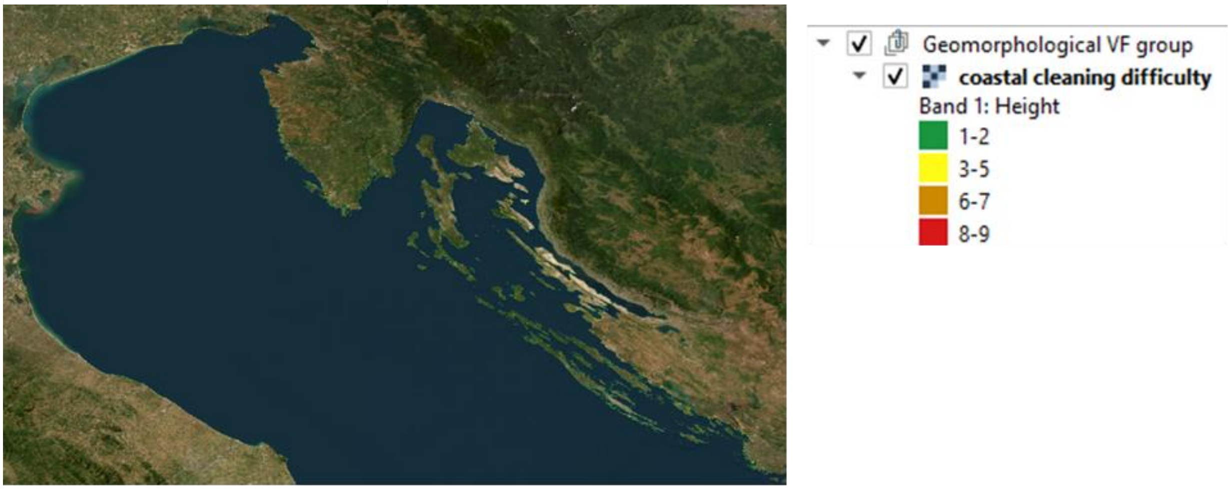
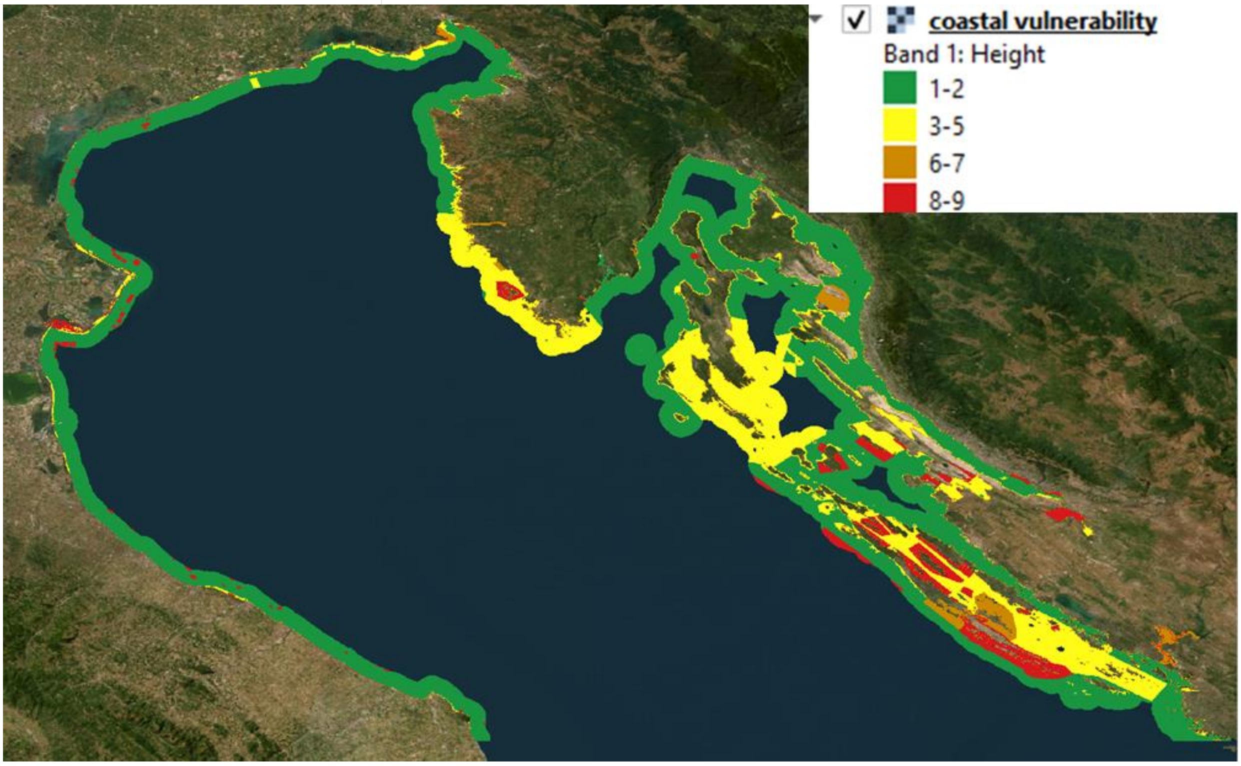


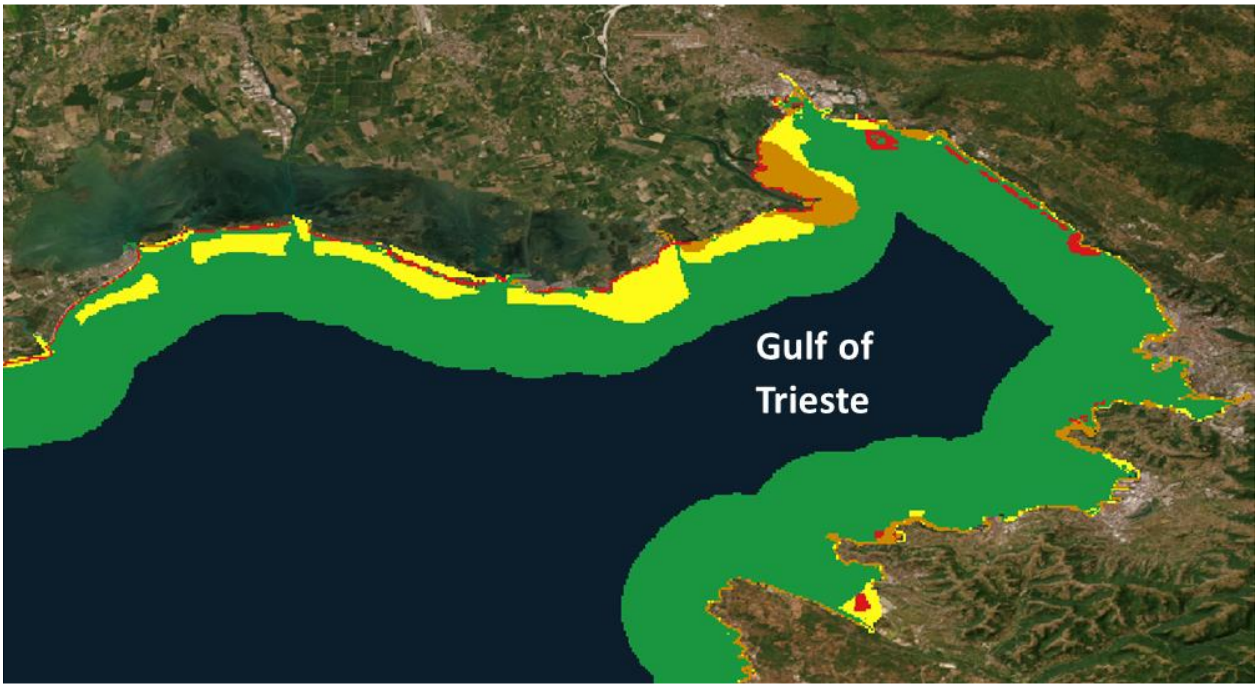
Figure 79. Maps of the coastal vulnerability for the environmental VF group with details of the Gulf of Trieste and the coastline near Rijeka. The red colour indicates higher coastal vulnerability.


Geomorphological VF group
coastal cleaning difficulty
Band 1: Height
1-2
3-5
6-7
8-9


Gulf of
Trieste

Figure 80. Maps of the coastal vulnerability based on the coast cleaning difficulty with details of the Gulf of Trieste and the coastline near Rijeka. The red color indicates higher coast cleaning difficulty.


coastal vulnerability
Band 1: Height
1-2
3-5
6-7
8-9


Gulf of
Trieste

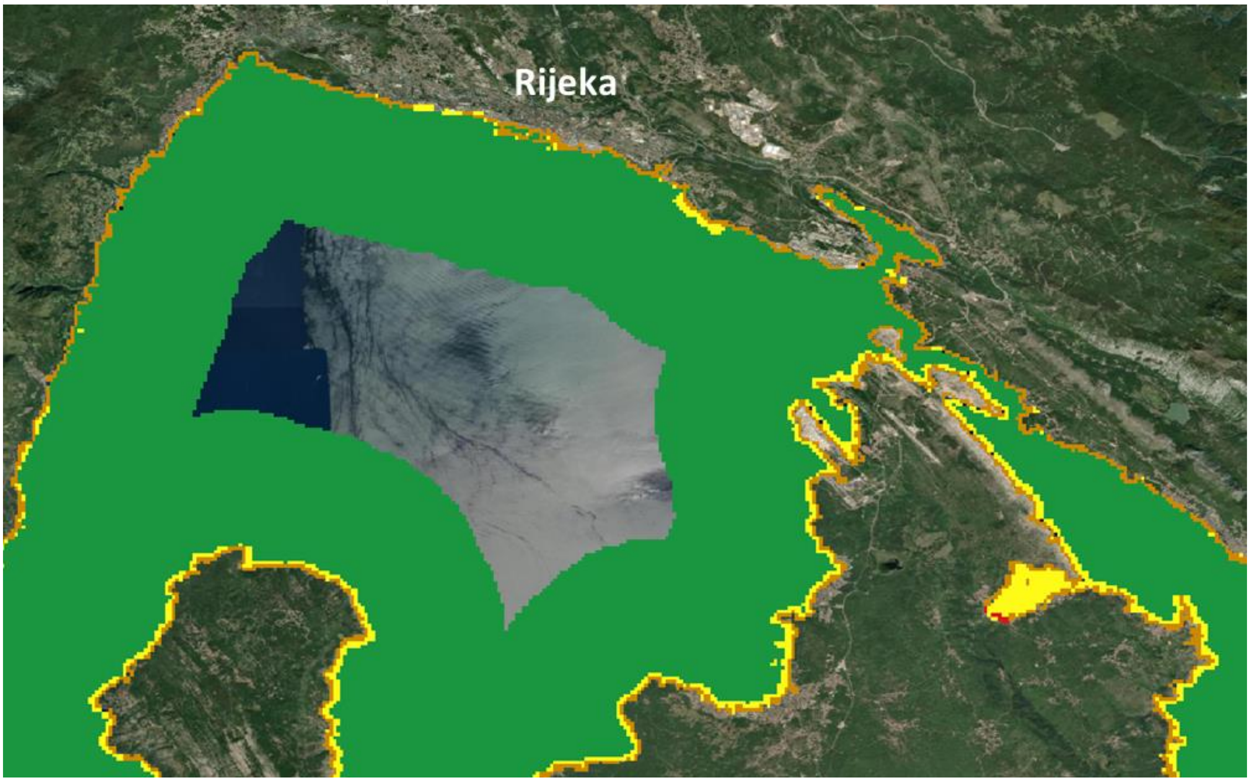


Figure 81. Maps of the total coastal vulnerability obtained by using information from all the selected VF groups. Details of the Gulf of Trieste and the coastline near Rijeka are also shown. The red color indicates higher coastal vulnerability.

5.3 GIS project and map visualization

All maps were included in a geopackage file for QGIS (Fig. 82). The GeoPackage open format is a container that allows to store GIS data (layers) in a single file. A single GeoPackage file can contain various data (both vector and raster data) in different coordinate reference systems, as well as tables without spatial information; all these features allow to share data easily and avoid file duplication.

In the geopackage file created for the NAMIRS project, and named 'NAMIRS CVA.gpkg', vector and raster maps of all VFs were included, together with the vulnerability maps (both the total coastal vulnerability map and the vulnerability maps of the single VF groups). In the geopackage file, a QGIS project, named 'NAMIRS project' was also uploaded (Fig. 82). Once the project is opened in the QGIS layer panel, the vulnerability maps can be visualized divided by VF group and with different colours according to the four classes of the vulnerability scores (Fig. 83).

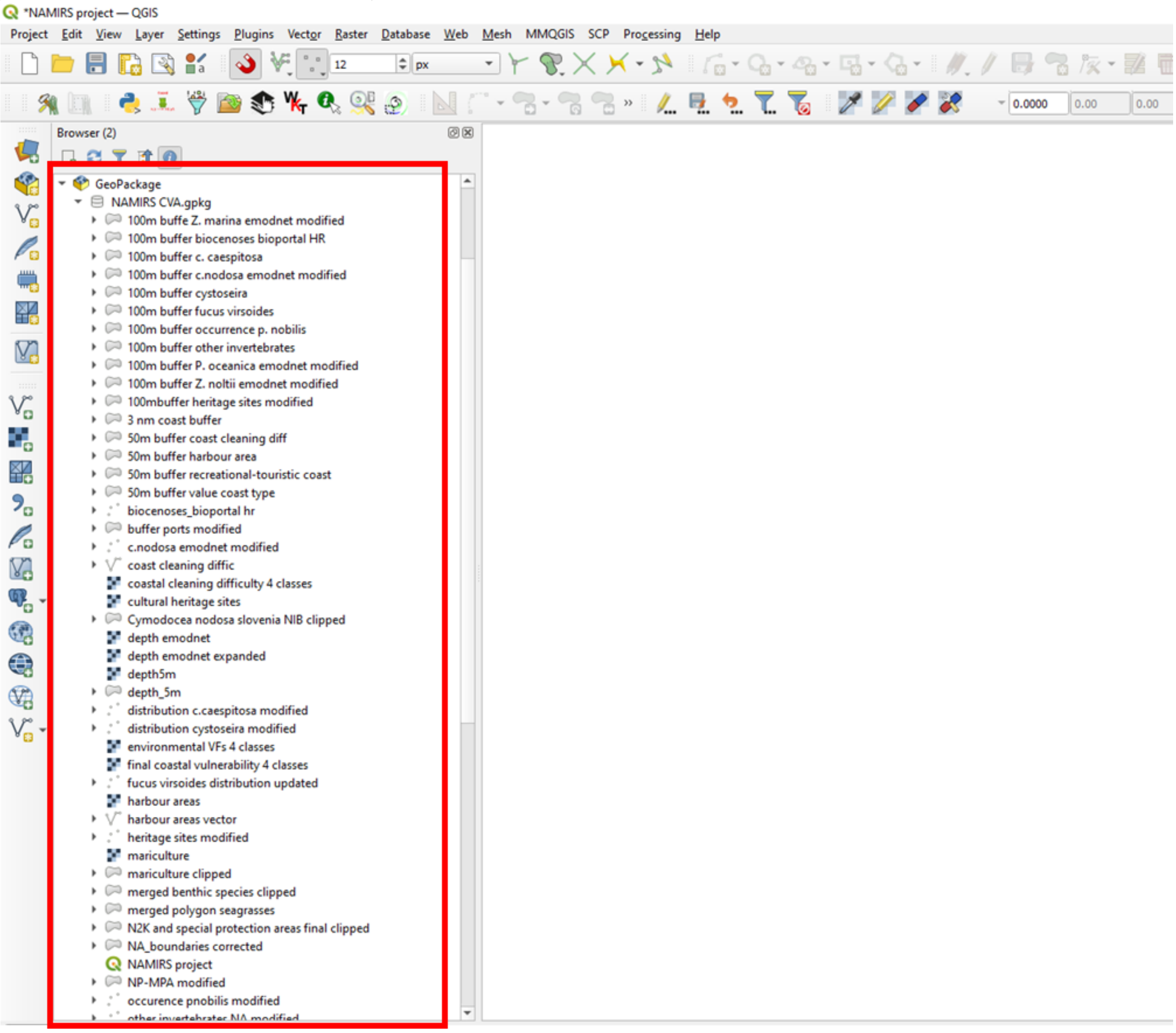


Figure 82. A screenshot of the geopackage file uploaded in QGIS with all the layers and the NAMIRS project (red box).

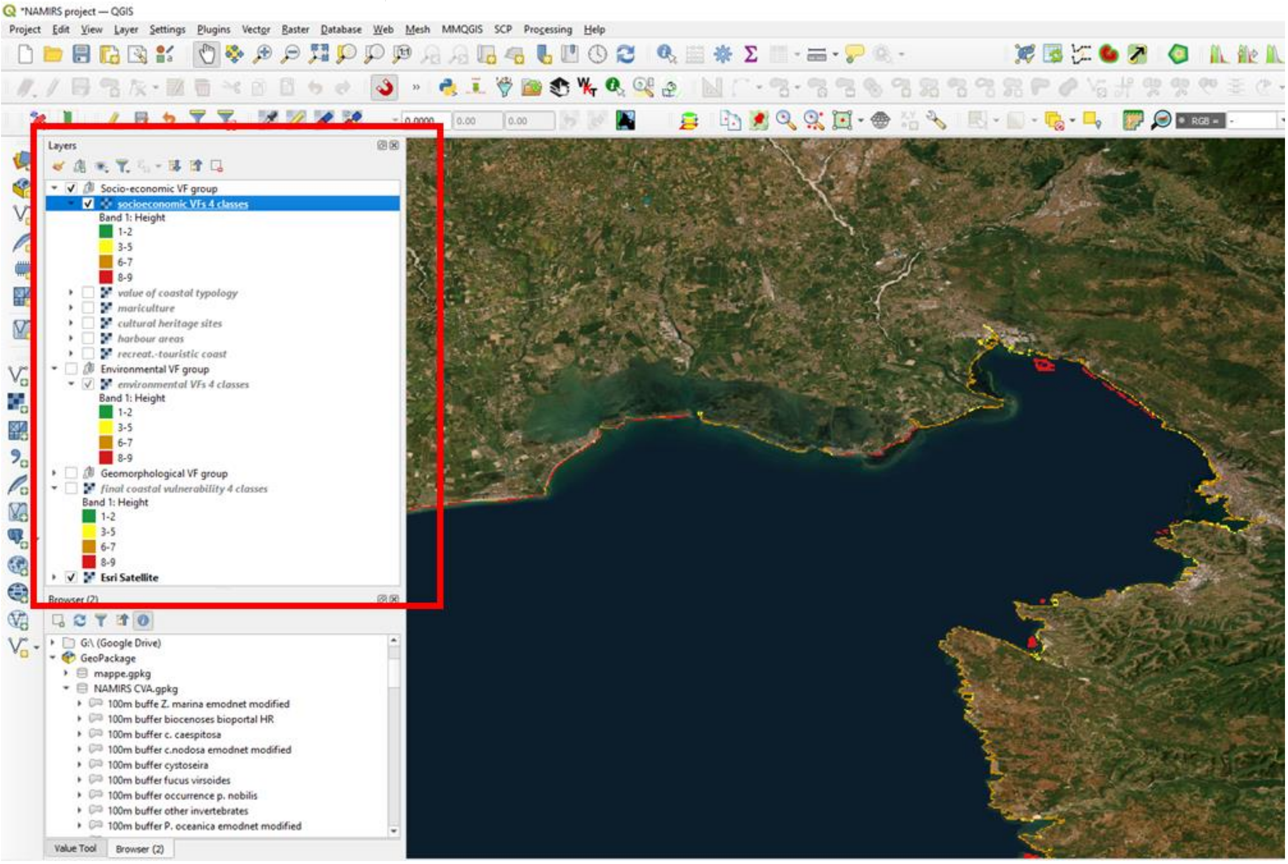


Figure 83. A screenshot of the NAMIRS project opened in the QGIS layer panel (red box). The symbology of the VF group maps is categorized in four classes representing the different levels of coastal vulnerability.

6. Cumulative oil spill risk index

6.1 Introduction

The term risk refers to the expected loss as a function of hazard, exposure and vulnerability (UNDRO, 1979; Cardona, 2005). Hazard is defined as a potentially damaging event which may cause the loss of biological organisms, environmental degradation, damages and degradation of structures with social and economic importance, and is strictly characterized by its location, intensity, frequency and probability (UNISDR, 2005). Exposure expresses how likely the receptors can be exposed to the abovementioned hazards. Thus, it depends on the type of hazard, on the mechanisms by which receptors can be impacted, and by their location. Vulnerability to a specific hazard is the propensity of the receptors (individuals, groups of people, species, habitats, ecosystems, but also social and economic systems, infrastructure, etc.) to be damaged if they are exposed to that hazard (Menoni et al. 2012).

In literature there exist different conceptual frameworks for the identification and quantification of the mutually interdependent concepts of Hazard-Exposure-Vulnerability-Risk (Landis 2004, Birkmann, 2007; Halpern et al., 2008). In this work, we followed the approaches developed in Menoni et al. (2012), Melaku Canu et al. (2015), Depellegrin et al. (2017), Menegon et al. (2018), Furlan et al. (2018), and in the projects HarmoNIA (Harmonization and Networking for Contaminant Assessment in the Ionian and Adriatic, Seas, EU ADRION, 2018-2019) and SHAREMED (Sharing and Enhancing Capabilities to Address Environmental Threats in Mediterranean Sea, EU Interreg-MED, 2019-2022), adapting them to the specificities of NAMIRS.

In particular, Task 1 (see Section 2) provided an estimate of the hazard related to oil spill in the Northern Adriatic Sea. The estimate was based on the analysis of the traffic in the area, considering routes, traffic density, type of vessels and their characteristics (length, speed, velocity, cargo). From the analysis we derived the information on the most probable location of incidents, the type of incidents (collision, allision, grounding), the type of vessels involved, and the type and quantities of possible oil spills.

In Task 2 (see Section 3) the information on the oil spill hazard was used to derive the information on the exposure of the coastal environment to oil spills in Northern Adriatic Sea. This was done by simulating oil transformation, advection, dispersal, and stranding with an oil spill model based on a Lagrangian particle tracking model on top of a specific North Adriatic 3D hydrodynamic model with real-world forcings (meteorological conditions, river inflows). The quantities of simulated oil particles that reach the coast over different periods of time provide the exposure of coastal receptors.

In Task 3 (see Sections 4-5) we identified the coastal receptors that can be impacted by an oil spill and assessed their vulnerability assigning weights through a combination of literature information, expert knowledge, and stakeholders' involvement.

The last step, described in this Section, is the integration of the exposure maps with the vulnerability maps in order to obtain the final risk assessment of coastal areas for oil spill in the Northern Adriatic Sea. These results will be then useful for contingency planning, which is one of the main expected results of NAMIRS.

6.2 Cumulative oil spill risk index

To calculate the risk index in NAMIRS, the maps of exposure related to the possible events of oil spill in the Northern Adriatic Sea (see Section 3) were multiplied to the maps of each vulnerability factor (environmental, geomorphological and socioeconomic) and the map of the total coastal vulnerability derived in Section 5.

Prior to conducting the analysis, we summed up the values of the exposure maps generated using expert and stochastic methods for each oil type (bunker oil, crude oil, and diesel oil) and each time step after the simulated oil spill. This allowed us to encompass all potential sites of oil spill release in the Northern Adriatic Sea. Furthermore, we summed the values of the maps representing the average volume of oil remaining on the surface, stranding on surface, dispersed in the water column, and stranded at depth, in order to have a unique map for each oil type and time step after the release. The maps of dispersed oil in the water column were first clipped to 5 meters deep since we considered vulnerability factors from the surface up to this depth.

For each type of oil, we then calculated the time it took for 30% and 50% of the oil released in each simulation to become stranded (at surface and in water column). To do that we divided the average volume of stranded oil (in m^3/km^2) in each time step by the total amount of oil released in each oil type simulation (Tables 27-29). The average volume of stranded oil in m^3/km^2 was obtained by summing the volume of oil in the map cells, multiplied by the area in km^2 of the cells and divided by the number of releases. For the bunker oil, 30% of oil stranded in 68 hours after the release and 50% stranded in 131 hours after the release. For the crude oil, 30% and 50% of stranded oil was reached after 83 and 173 hours, respectively, while for the diesel oil, 30% of oil stranded in 83 hours and 50% in 185 hours from the release.

Since the maps of the vulnerability factors range between 1 and 9 (see Section 5), to calculate the risk index the maps representing the 30% and 50% of stranded oil, for each oil type, were scaled at the same range of values. The minimum and maximum of the range (1 and 9) were matched with the minimum and maximum of the maps of 50% of stranded oil. After multiplying the hazard maps with the vulnerability factor maps and with the total coastal vulnerability map, a square root transformation was applied to convert the maps to the 1-9 range.

To be in accordance with the vulnerability factor maps, risk maps were created up to 5 meters of bottom depth and up to 3 nautical miles from the coast (see Section 5). For the same reason only the marine portion of the Northern Adriatic Sea was considered while coastal lagoons (i.e., the Venice lagoon and the Grado-Marano lagoon) were kept out of the analysis.

All operations and analyses on the maps and visualization were performed using the free and open source QGIS software with the WGS84 coordinate reference system (EPSG:4326).

Table 27. Computation of the percentage of bunker oil stranded after each hourly time step from the release. Time steps at which 30% and 50% of the released volume of oil is stranded on the coast are highlighted.

		EXPERT				STOCHASTIC					
days	hours	SurfOpnSea_m3	DispOpnSea_m3	SurfStrand_m3	DispStrand_m3	SurfOpnSea_m3	DispOpnSea_m3	SurfStrand_m3	DispStrand_m3	Sum oil released	%STRANDED
0.0	0	1196.97	0.00	0.00	0.00	1092.59	0.00	0.00	0.00	2289.56	
0.1	2	1166.25	9.98	4.88	0.04	1066.35	14.52	0.16	0.00		0.22
0.2	5	1133.26	26.29	19.61	0.36	1038.83	34.98	5.69	0.18		1.13
0.3	8	1104.74	38.25	33.42	2.31	1014.02	49.59	15.04	0.26		2.23
0.5	11	1078.89	48.38	47.03	3.91	986.69	63.31	27.99	0.44		3.47
0.6	14	1054.07	57.70	60.65	5.43	963.33	75.54	38.65	0.52		4.60
0.7	17	1029.71	65.93	74.82	7.15	940.07	86.31	50.74	0.61		5.82
0.8	20	1006.89	72.46	88.31	9.74	913.54	98.61	64.52	0.81		7.14
1.0	23	984.25	77.80	102.01	13.23	889.22	108.41	77.90	1.74		8.51
1.1	26	964.79	82.30	113.43	16.62	865.10	113.54	92.76	5.72		9.98
1.2	29	943.95	87.08	126.01	20.00	841.15	117.86	107.08	10.89		11.53
1.3	32	923.23	92.26	138.20	23.31	818.20	118.95	122.37	17.34		13.16
1.5	35	905.10	96.10	149.06	26.66	795.88	119.58	138.95	22.38		14.72
1.6	38	886.43	100.00	159.76	30.64	773.92	120.77	153.38	28.66		16.27
1.7	41	866.99	103.88	170.82	35.05	754.34	120.11	166.45	35.73		17.82
1.8	44	849.54	106.36	181.41	39.35	734.53	116.22	181.49	44.37		19.51
2.0	47	831.60	110.35	191.60	43.07	715.93	110.77	194.00	55.88		21.16
2.1	50	814.20	114.32	201.22	46.83	698.42	104.06	206.12	67.94		22.80
2.2	53	799.58	117.07	209.56	50.29	679.94	99.96	220.42	76.22		24.31
2.3	56	783.51	120.55	218.46	53.93	662.87	99.66	231.62	82.39		25.61
2.5	59	767.75	123.89	227.01	57.75	647.83	99.44	241.85	87.38		26.82
2.6	62	753.38	126.04	235.29	61.63	632.42	98.76	253.72	91.59		28.05
2.7	65	738.31	128.80	243.41	65.75	616.64	100.23	263.89	95.73		29.21
2.8	68	723.44	131.92	251.41	69.46	603.46	102.52	272.38	98.07		30.19
3.0	71	709.53	134.26	259.42	72.96	588.24	103.02	284.10	101.07		31.34
3.1	74	695.28	137.10	267.09	76.67	571.85	104.07	294.75	105.77		32.51
3.2	77	681.19	139.66	274.94	80.31	558.93	104.97	302.53	109.96		33.53
3.3	80	667.71	141.80	282.61	83.96	546.45	104.73	311.43	113.74		34.58
3.5	83	654.10	144.36	289.90	87.70	531.48	108.19	319.91	116.77		35.56
3.6	86	640.74	146.88	297.02	91.36	520.61	108.58	326.18	120.92		36.49
3.7	89	627.64	148.81	304.25	95.27	508.57	106.49	335.05	126.18		37.59
3.8	92	614.44	151.21	311.36	98.94	494.90	107.12	343.14	131.12		38.63
4.0	95	600.80	153.97	318.85	102.30	485.19	103.84	350.12	137.10		39.67
4.1	98	587.15	156.06	326.62	106.06	474.24	100.76	358.67	142.58		40.79
4.2	101	574.33	158.39	333.55	109.61	461.61	101.66	366.48	146.50		41.76
4.3	104	561.53	160.95	340.48	112.91	453.33	100.40	372.52	149.97		42.62
4.5	107	549.53	162.69	347.06	116.59	443.22	99.57	380.21	153.19		43.55
4.6	110	537.90	163.73	353.51	120.68	430.77	102.13	387.69	155.62		44.44
4.7	113	525.95	165.14	359.93	124.78	422.64	102.05	393.58	157.91		45.26
4.8	116	515.04	166.25	365.74	128.76	413.19	102.04	400.72	160.23		46.10
5.0	119	504.14	167.10	371.76	132.75	401.73	104.53	407.59	162.33		46.93
5.1	122	492.94	168.73	377.48	136.57	393.73	104.48	413.62	164.35		47.70
5.2	125	482.97	169.67	382.81	140.28	384.40	104.26	421.03	166.50		48.51
5.3	128	472.92	170.45	388.28	144.03	373.95	106.09	427.61	168.55		49.29
5.5	131	461.97	172.35	393.86	147.48	366.63	105.21	433.50	170.83		50.04
5.6	134	452.60	172.91	398.89	151.27	358.06	104.37	440.83	172.92		50.84

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Table 28. Computation of the percentage of crude oil stranded after each hourly time step from the release. Time steps at which 30% and 50% of the released volume of oil is stranded on the coast are highlighted.

		EXPERT				STOCHASTIC					
days	hours	SurfOpnSea_m3	DispOpnSea_m3	SurfStrand_m3	DispStrand_m3	SurfOpnSea_m3	DispOpnSea_m3	SurfStrand_m3	DispStrand_m3	Sum oil released	%STRANDED
0.0	0	14000.00	0.00	0.00	0.00	19479.17	0.00	0.00	0.00	33479.17	
0.1	2	10702.48	1355.27	56.52	34.08	15118.83	1791.73	0.01	0.46		0.27
0.2	5	9794.63	1790.34	293.32	81.99	14306.03	2297.14	11.14	8.42		1.18
0.3	8	9189.00	2050.94	441.86	195.96	13737.40	2680.15	50.44	16.15		2.10
0.5	11	8667.80	2306.27	567.76	281.71	13300.76	2919.35	126.66	45.12		3.05
0.6	14	8235.75	2528.37	674.69	342.96	12912.19	3133.76	197.92	77.31		3.86
0.7	17	7837.69	2749.81	775.35	383.91	12451.11	3392.66	309.05	111.09		4.72
0.8	20	7452.85	2962.43	866.47	434.58	12078.17	3546.80	432.08	157.75		5.65
1.0	23	7124.65	3116.30	957.64	490.65	11710.57	3677.09	574.13	210.78		6.67
1.1	26	6834.44	3258.82	1029.10	542.25	11283.90	3786.44	748.35	316.24		7.87
1.2	29	6549.18	3385.08	1106.82	602.74	10917.12	3823.43	912.79	448.92		9.17
1.3	32	6320.89	3457.28	1178.68	671.51	10564.18	3809.06	1104.11	598.18		10.61
1.5	35	6098.34	3543.50	1244.18	730.01	10171.26	3858.82	1302.46	721.27		11.94
1.6	38	5849.60	3633.35	1316.73	806.21	9867.88	3827.44	1472.94	866.18		13.33
1.7	41	5647.98	3659.86	1389.52	900.10	9558.04	3817.81	1637.38	1004.06		14.73
1.8	44	5441.72	3707.36	1459.90	980.84	9163.87	3835.62	1819.30	1184.39		16.26
2.0	47	5268.06	3725.02	1528.26	1061.92	8927.82	3684.34	1957.63	1419.54		17.82
2.1	50	5125.99	3739.42	1584.20	1127.79	8678.17	3537.12	2094.16	1667.54		19.34
2.2	53	4974.23	3773.15	1635.18	1189.76	8326.29	3532.69	2252.46	1855.68		20.71
2.3	56	4820.83	3806.51	1685.45	1254.76	8131.88	3462.37	2365.85	1997.67		21.82
2.5	59	4688.89	3831.73	1729.42	1313.68	7895.35	3462.81	2495.90	2095.45		22.80
2.6	62	4564.86	3845.58	1770.77	1379.12	7585.49	3542.96	2621.18	2193.10		23.79
2.7	65	4440.85	3840.86	1816.69	1458.69	7399.81	3520.18	2724.48	2291.44		24.77
2.8	68	4318.42	3855.10	1861.87	1518.90	7200.64	3559.30	2828.45	2340.98		25.54
3.0	71	4210.12	3856.65	1907.63	1577.28	6925.60	3624.62	2955.76	2417.83		26.46
3.1	74	4105.44	3851.39	1955.54	1637.34	6755.02	3555.82	3065.96	2542.27		27.48
3.2	77	4001.33	3850.24	1999.96	1696.24	6588.56	3534.06	3151.84	2639.94		28.34
3.3	80	3916.18	3824.22	2047.68	1757.93	6392.15	3545.64	3233.64	2738.62		29.21
3.5	83	3824.72	3804.71	2097.48	1817.84	6238.60	3522.87	3319.44	2824.97		30.05
3.6	86	3738.80	3793.08	2135.39	1876.23	6087.37	3512.04	3393.52	2909.16		30.81
3.7	89	3654.30	3765.35	2177.22	1945.48	5887.98	3507.63	3471.82	3031.59		31.74
3.8	92	3556.89	3750.39	2222.65	2011.28	5762.24	3426.83	3540.49	3165.91		32.68
4.0	95	3468.63	3740.02	2257.17	2074.74	5627.07	3358.13	3601.08	3305.83		33.57
4.1	98	3392.55	3711.99	2291.34	2143.80	5420.37	3360.63	3673.82	3434.92		34.48
4.2	101	3318.29	3683.45	2326.76	2210.68	5314.59	3293.81	3740.96	3537.76		35.29
4.3	104	3247.61	3664.60	2352.63	2273.58	5196.19	3274.82	3798.57	3615.06		35.96
4.5	107	3180.10	3637.69	2384.71	2335.45	4999.33	3320.12	3867.99	3695.19		36.69
4.6	110	3114.15	3614.24	2413.16	2396.07	4884.07	3287.71	3936.61	3772.19		37.39
4.7	113	3053.91	3583.14	2439.19	2460.81	4770.38	3286.96	3992.07	3829.19		38.00
4.8	116	2998.39	3548.52	2469.17	2520.68	4607.71	3325.12	4043.36	3900.93		38.63
5.0	119	2951.58	3513.73	2495.45	2575.63	4520.58	3283.58	4093.86	3977.41		39.26
5.1	122	2902.98	3482.48	2517.42	2633.00	4415.24	3276.16	4146.98	4035.63		39.82
5.2	125	2855.81	3447.18	2541.88	2690.91	4267.08	3289.47	4214.49	4101.83		40.47
5.3	128	2804.51	3416.04	2569.01	2746.11	4165.40	3260.34	4280.95	4164.84		41.10
5.5	131	2762.64	3379.52	2593.80	2799.50	4051.35	3245.23	4349.96	4223.85		41.72
5.6	134	2716.52	3340.84	2622.48	2855.47	3923.06	3234.55	4424.61	4287.92		42.39
5.7	137	2661.01	3306.88	2653.55	2914.17	3834.14	3200.05	4492.73	4342.40		43.02
5.8	140	2607.97	3278.32	2682.97	2966.17	3728.67	3186.80	4557.23	4395.67		43.62
6.0	143	2566.37	3236.88	2711.06	3021.49	3600.07	3143.03	4647.31	4477.36		44.38
6.1	146	2529.73	3197.97	2736.73	3071.49	3485.46	3130.77	4720.11	4531.48		44.98
6.2	149	2495.50	3160.03	2761.49	3118.67	3398.01	3118.25	4774.26	4576.88		45.49
6.3	152	2458.27	3123.27	2788.50	3165.89	3290.29	3077.72	4843.83	4655.31		46.16
6.5	155	2417.37	3093.77	2816.06	3208.57	3202.72	3050.43	4907.02	4707.17		46.71
6.6	158	2380.18	3065.93	2841.84	3247.61	3101.48	3046.37	4963.05	4756.11		47.22
6.7	161	2345.54	3035.02	2868.81	3285.94	3015.65	2994.43	5024.71	4831.77		47.82
6.8	164	2302.31	3001.32	2904.06	3327.53	2941.84	2953.08	5079.49	4892.06		48.40
7.0	167	2259.49	2971.06	2934.79	3369.97	2849.02	2948.69	5127.27	4941.31		48.91
7.1	170	2225.72	2936.92	2960.17	3412.44	2774.62	2898.29	5179.15	5014.02		49.48
7.2	173	2184.91	2902.00	2991.63	3456.79	2720.01	2840.77	5224.60	5080.72		50.04
7.3	176	2149.15	2868.56	3018.09	3499.43	2650.43	2821.95	5264.68	5128.94		50.51
7.5	179	2112.15	2835.53	3048.36	3539.35	2578.93	2778.63	5321.99	5186.53		51.07

Table 29. Computation of the percentage of diesel oil stranded after each hourly step from the release. Time steps at which 30% and 50% of the released volume of oil is stranded on the coast are highlighted.

		EXPERT				STOCHASTIC					
days	hours	SurfOpnSea_m3	DispOpnSea_m3	SurfStrand_m3	DispStrand_m3	SurfOpnSea_m3	DispOpnSea_m3	SurfStrand_m3	DispStrand_m3	Sum oil released	%STRANDED
0.0	0	10000.00	0.00	0.00	0.00	9259.26	0.00	0.00	0.00	19259.26	
0.1	2	9283.30	146.14	62.31	0.72	8614.33	203.54	0.82	0.04		0.33
0.2	5	8777.04	322.65	228.10	4.56	8249.54	396.52	30.83	2.29		1.38
0.3	8	8428.43	429.70	335.19	19.79	7982.16	506.76	82.43	3.09		2.29
0.5	11	8157.75	509.93	413.74	33.44	7711.18	611.44	160.21	4.93		3.18
0.6	14	7911.58	579.66	491.04	48.08	7477.57	700.23	228.95	5.82		4.02
0.7	17	7672.72	642.34	577.90	62.44	7245.14	779.29	314.42	6.90		4.99
0.8	20	7449.74	688.36	665.64	83.92	6999.06	865.40	411.11	9.02		6.07
1.0	23	7241.35	725.84	750.86	107.79	6777.10	928.38	505.74	17.73		7.18
1.1	26	7052.68	757.38	829.05	129.39	6560.65	954.65	610.87	51.39		8.42
1.2	29	6859.20	784.18	916.20	155.72	6350.29	968.87	714.43	95.55		9.77
1.3	32	6675.43	811.36	996.09	182.68	6144.75	962.07	827.90	149.37		11.19
1.5	35	6510.39	829.88	1068.69	209.43	5945.91	958.21	949.31	189.13		12.55
1.6	38	6344.65	843.80	1143.41	242.14	5756.85	951.72	1056.16	238.11		13.91
1.7	41	6177.10	852.56	1221.20	281.01	5585.97	934.28	1150.56	294.36		15.30
1.8	44	6027.29	857.15	1291.26	315.43	5411.98	893.93	1258.90	365.12		16.77
2.0	47	5880.33	867.23	1358.65	346.69	5254.00	837.37	1348.70	456.14		18.23
2.1	50	5740.12	882.24	1421.29	372.72	5107.39	771.06	1432.45	553.12		19.62
2.2	53	5616.78	891.48	1476.13	396.59	4951.40	733.54	1531.95	616.70		20.88
2.3	56	5489.10	899.06	1534.80	423.96	4812.67	718.22	1610.39	662.95		21.97
2.5	59	5370.10	908.23	1586.39	449.74	4685.88	710.33	1682.50	697.54		22.93
2.6	62	5254.98	908.30	1639.72	479.76	4552.98	703.37	1766.31	726.71		23.95
2.7	65	5139.69	906.76	1692.19	513.92	4426.07	702.70	1839.02	755.53		24.93
2.8	68	5028.96	911.80	1742.15	540.61	4316.77	711.51	1898.72	771.13		25.72
3.0	71	4923.35	914.02	1793.28	564.61	4188.48	712.16	1981.33	792.02		26.64
3.1	74	4820.85	918.03	1838.93	590.29	4064.52	702.67	2056.08	827.64		27.59
3.2	77	4719.22	923.16	1886.52	612.71	3966.32	693.58	2107.24	861.02		28.39
3.3	80	4622.84	923.81	1933.39	635.70	3862.77	686.31	2168.04	889.23		29.21
3.5	83	4524.87	925.83	1979.83	660.40	3755.55	690.87	2228.29	910.58		30.01
3.6	86	4428.77	927.70	2026.79	683.73	3671.49	680.18	2271.19	941.52		30.76
3.7	89	4336.76	925.70	2073.02	708.15	3577.31	657.50	2328.91	980.87		31.63
3.8	92	4242.04	928.10	2119.09	731.59	3482.96	639.15	2384.34	1018.66		32.47
4.0	95	4148.38	933.13	2166.58	750.94	3406.09	605.53	2430.25	1063.83		33.29
4.1	98	4054.28	933.35	2217.01	772.91	3318.67	578.08	2490.43	1100.16		34.17
4.2	101	3965.09	937.10	2260.90	793.90	3230.28	569.37	2546.13	1123.90		34.92
4.3	104	3879.39	941.64	2303.23	812.65	3160.05	557.49	2589.36	1144.82		35.57
4.5	107	3799.13	939.83	2343.24	835.01	3081.36	545.65	2642.92	1164.37		36.27
4.6	110	3719.51	937.46	2382.80	858.52	2998.24	545.15	2695.61	1178.81		36.95
4.7	113	3637.28	934.85	2425.77	881.94	2933.23	541.15	2735.37	1191.33		37.56
4.8	116	3565.60	929.06	2461.01	905.99	2859.30	534.90	2786.38	1204.58		38.20
5.0	119	3491.50	925.36	2498.54	928.92	2783.05	537.01	2834.59	1215.46		38.83
5.1	122	3419.65	925.33	2533.83	948.52	2717.01	535.35	2876.74	1225.44		39.38
5.2	125	3352.24	922.04	2567.65	968.83	2643.94	529.75	2929.39	1236.64		39.99
5.3	128	3286.59	918.56	2600.50	989.01	2574.20	529.33	2974.97	1247.17		40.56
5.5	131	3218.56	918.15	2635.80	1006.48	2509.38	523.27	3019.46	1258.93		41.13
5.6	134	3157.20	912.79	2667.16	1026.49	2441.24	516.46	3069.84	1269.56		41.71
5.7	137	3095.42	906.35	2700.18	1047.10	2378.05	514.05	3114.02	1277.44		42.26
5.8	140	3033.46	901.20	2733.02	1066.98	2316.32	511.09	3157.06	1285.19		42.80
6.0	143	2974.77	894.36	2764.41	1086.73	2231.88	507.58	3223.02	1294.11		43.45
6.1	146	2917.74	888.29	2795.78	1104.80	2168.73	506.05	3269.14	1300.36		43.98
6.2	149	2862.42	881.76	2825.02	1124.03	2118.45	503.50	3302.52	1306.88		44.44
6.3	152	2811.88	873.61	2851.46	1143.03	2047.38	497.91	3356.74	1317.36		45.01
6.5	155	2760.80	865.30	2879.74	1161.33	1992.34	493.92	3397.10	1324.76		45.50
6.6	158	2710.05	859.81	2906.92	1177.60	1943.76	489.21	3431.59	1331.91		45.94
6.7	161	2661.09	854.85	2933.41	1192.33	1877.85	485.00	3482.86	1339.57		46.46
6.8	164	2610.90	848.80	2961.96	1208.01	1820.47	480.86	3527.39	1346.04		46.96
7.0	167	2558.95	842.73	2991.63	1224.44	1776.31	475.87	3559.11	1352.78		47.40
7.1	170	2512.56	834.90	3016.78	1241.55	1723.11	470.22	3599.46	1361.20		47.87
7.2	173	2463.55	828.06	3045.31	1257.68	1672.61	462.57	3638.36	1370.75		48.35
7.3	176	2414.50	822.19	3073.08	1273.60	1635.51	455.66	3664.31	1379.28		48.76
7.5	179	2368.19	813.74	3099.51	1290.83	1587.49	450.22	3699.87	1387.91		49.21
7.6	182	2322.37	806.16	3125.84	1307.19	1543.71	440.37	3732.71	1399.84		49.67
7.7	185	2275.13	799.93	3152.70	1323.02	1510.86	431.17	3755.05	1410.61		50.06
7.8	188	2228.61	791.88	3180.12	1339.48	1468.60	424.99	3785.62	1419.84		50.50

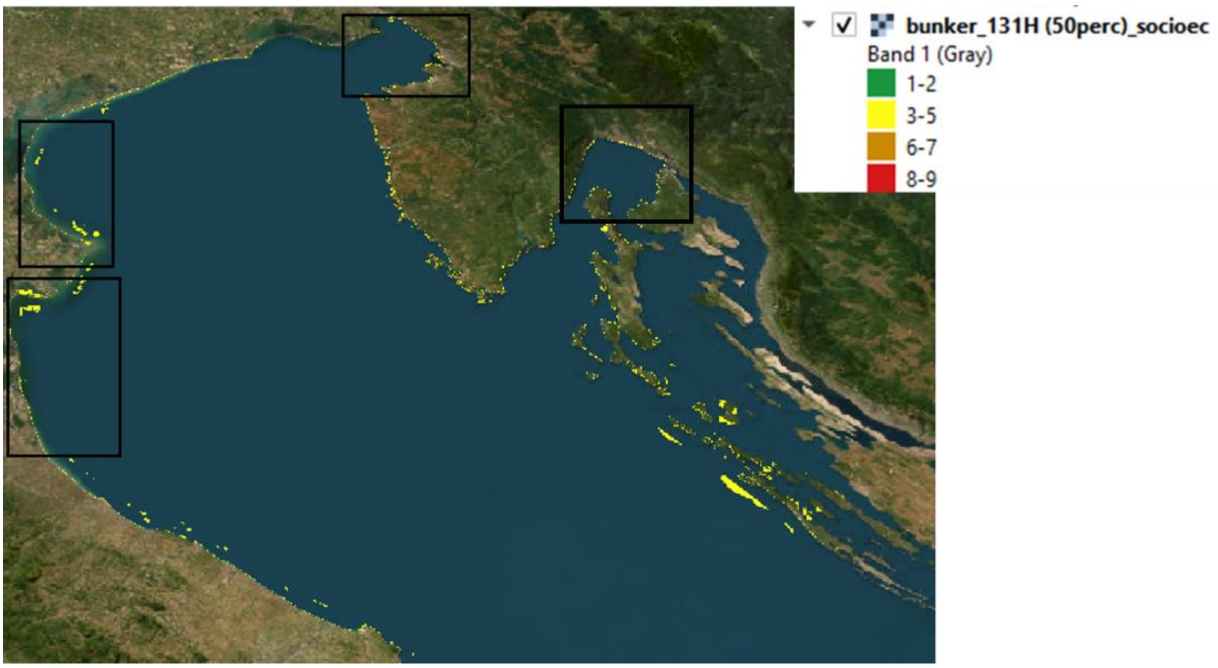
6.3 Maps of risk index for oil spill in Northern Adriatic Sea

The risk index calculated for the Northern Adriatic Sea showed that the areas with the highest risk are in the proximity of the Isonzo river mouth and Grado town, Trieste-Miramare coastline, Strunjan Landscape park and Debeli rtič in Slovenia and from Chioggia town to the Po Delta river. These areas are reached by the highest quantity of oil in case of incident and are particularly sensitive due to the presence of numerous recreational-touristic activities, protected species, such as *Cymodocea nodosa,* forming dense meadows at very shallow waters, protected areas (e.g., Miramare MPA, Strunjan Landscape park), aquaculture and muddy coastline that is very difficult to clean (see Section 5). Although the coastline of Veneto and Emilia-

Romagna Regions had high values of vulnerability for the socioeconomic factors due to the presence of extended beaches (> 1 km) with several recreational and touristic activities, these areas did not get a high-risk value because the amount of oil calculated to strand on these coasts was minor compared to the volume that reached the gulf of Trieste and the Po Delta. The same consideration can be extended to the areas of Kornati and Brijuni National parks in Croatia.

The areas with the highest risk level are the same for each type of oil considered. The highest risk values were recorded for crude oil and diesel oil, particularly in the 50% stranded oil scenario, but after a longer time after release compared to bunker oil. Risk assessment based on 30% and 50% of stranded oil indicated, as expected, an increase in risk with the amount of stranded oil, yet the identification of areas most at risk remained similar between the two scenarios.

To give an overview of the results, some examples of the risk maps created with the single vulnerability factors are shown (Figs. 84-85). Figs. 86-91 present the final risk maps based on the 30% and 50% stranded oil, for the three oil types (bunker, crude, diesel), considering the total coastal vulnerability. As for the maps of the vulnerability factors (Section 5), risk scores were categorized in four classes and visualized in GIS with different colours: very low risk (1-2, green), low risk (3-5, yellow), medium risk (6-7, orange), high risk (8-9, red). Some areas have no risk values due to the presence of no data in the vulnerability factor maps or in the hazard maps. All maps were included in the geopackage file for QGIS already created for the vulnerability factor maps (see Section 5).



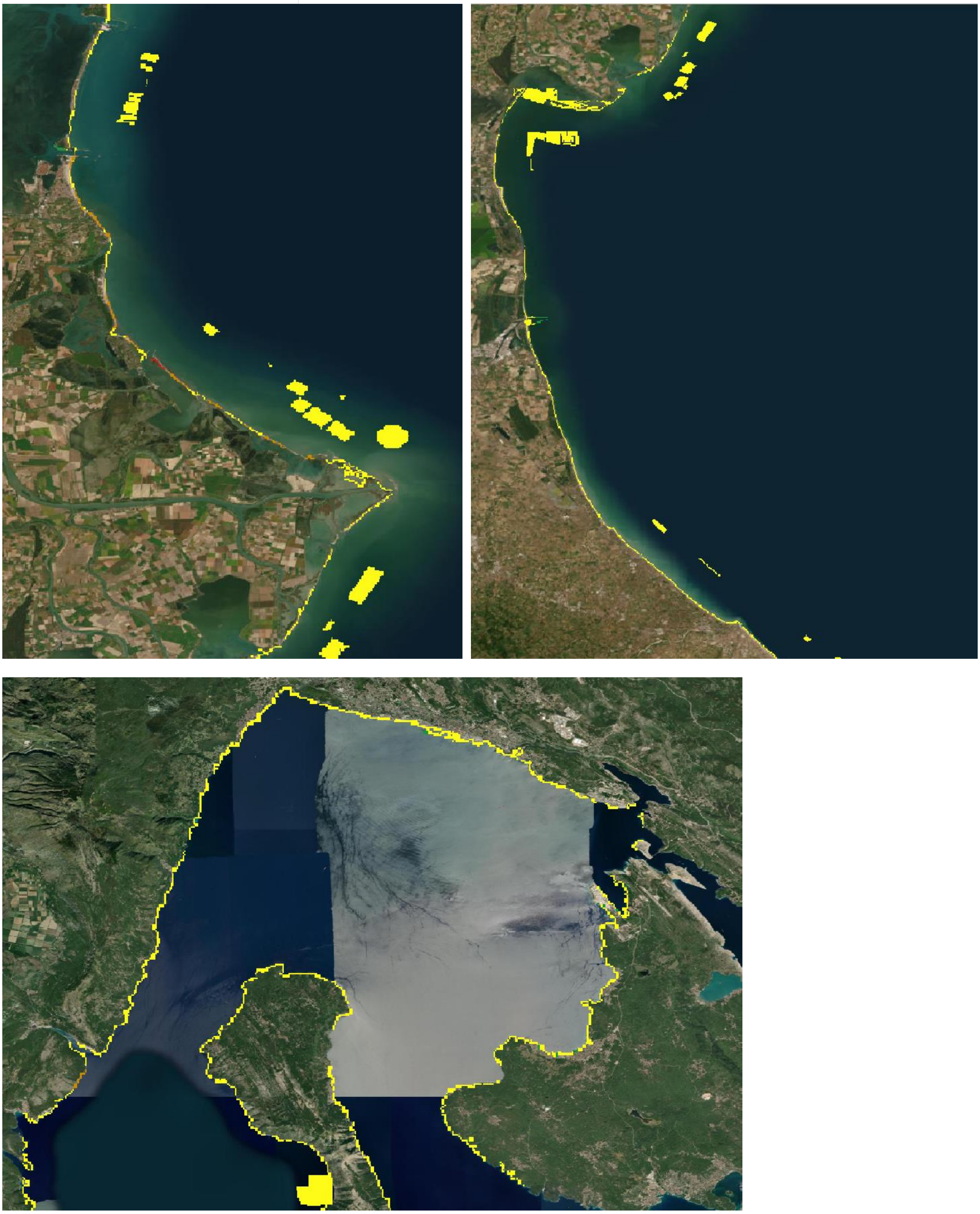


Figure 84. Close up of the Gulf of Trieste, the Po delta, the Emilia-Romagna coastline, and the Kvarner Gulf, with the risk values calculated with the 50% stranded bunker oil and the socioeconomic vulnerability factors.

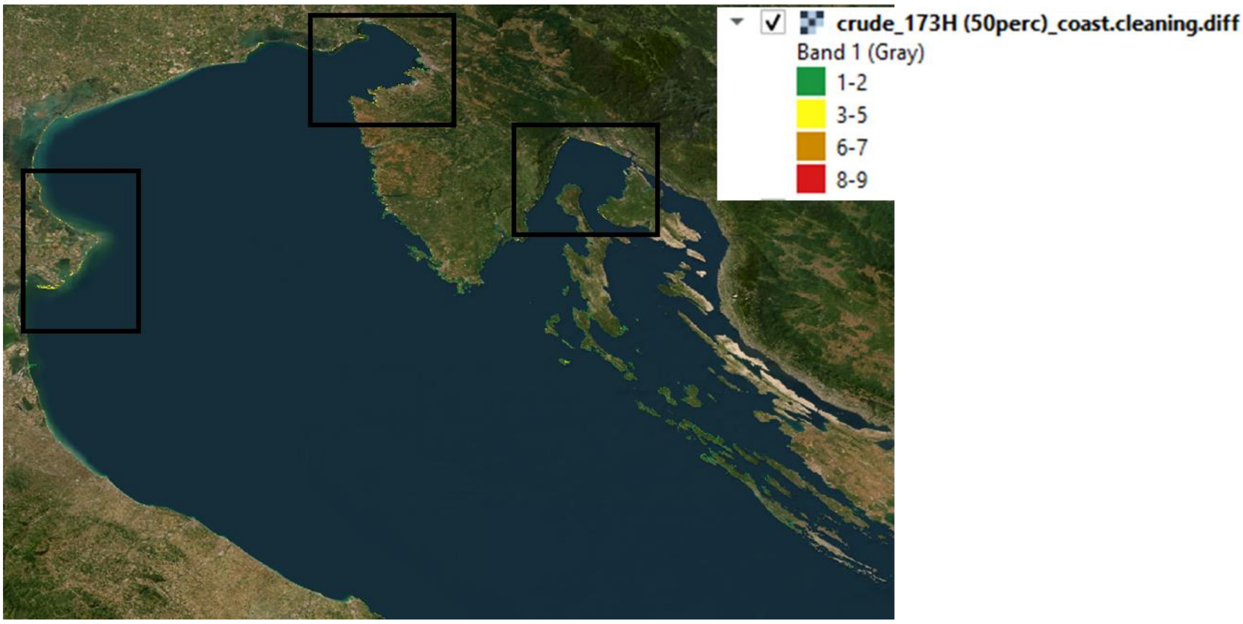

crude_173H (50perc)_coast.cleaning.diff
Band 1 (Gray)
1-2
3-5
6-7
8-9

Figure 85. Close up of the Gulf of Trieste, the Po delta, and the Kvarner Gulf, with the risk values calculated with the 50% stranded crude oil and the geomorphological vulnerability factors (coast cleaning difficulty).

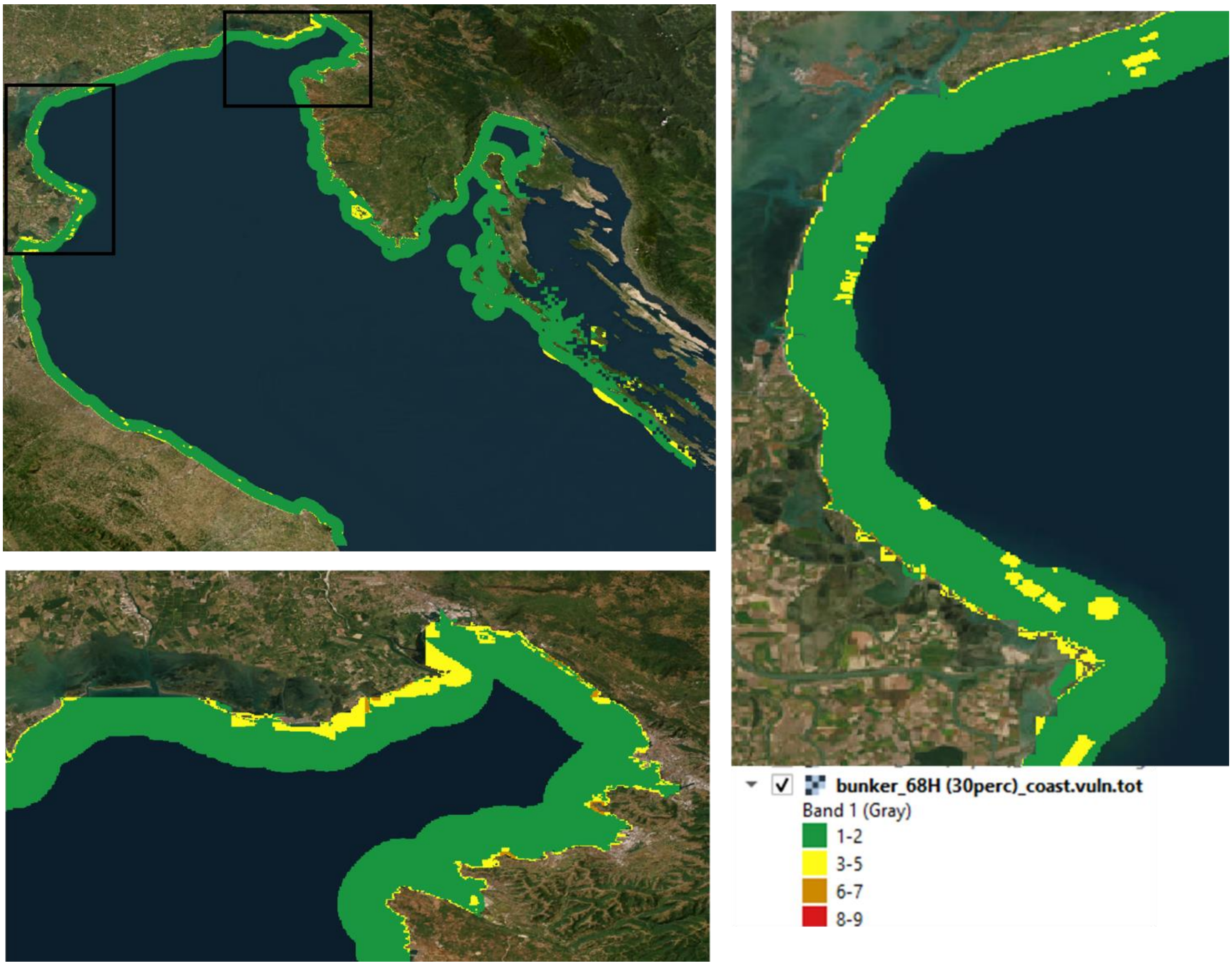


Figure 86. Maps of the risk index based on the 30% stranded bunker oil (68 hours after release) and the total coastal vulnerability with a zoom on the Gulf of Trieste and the Po delta.

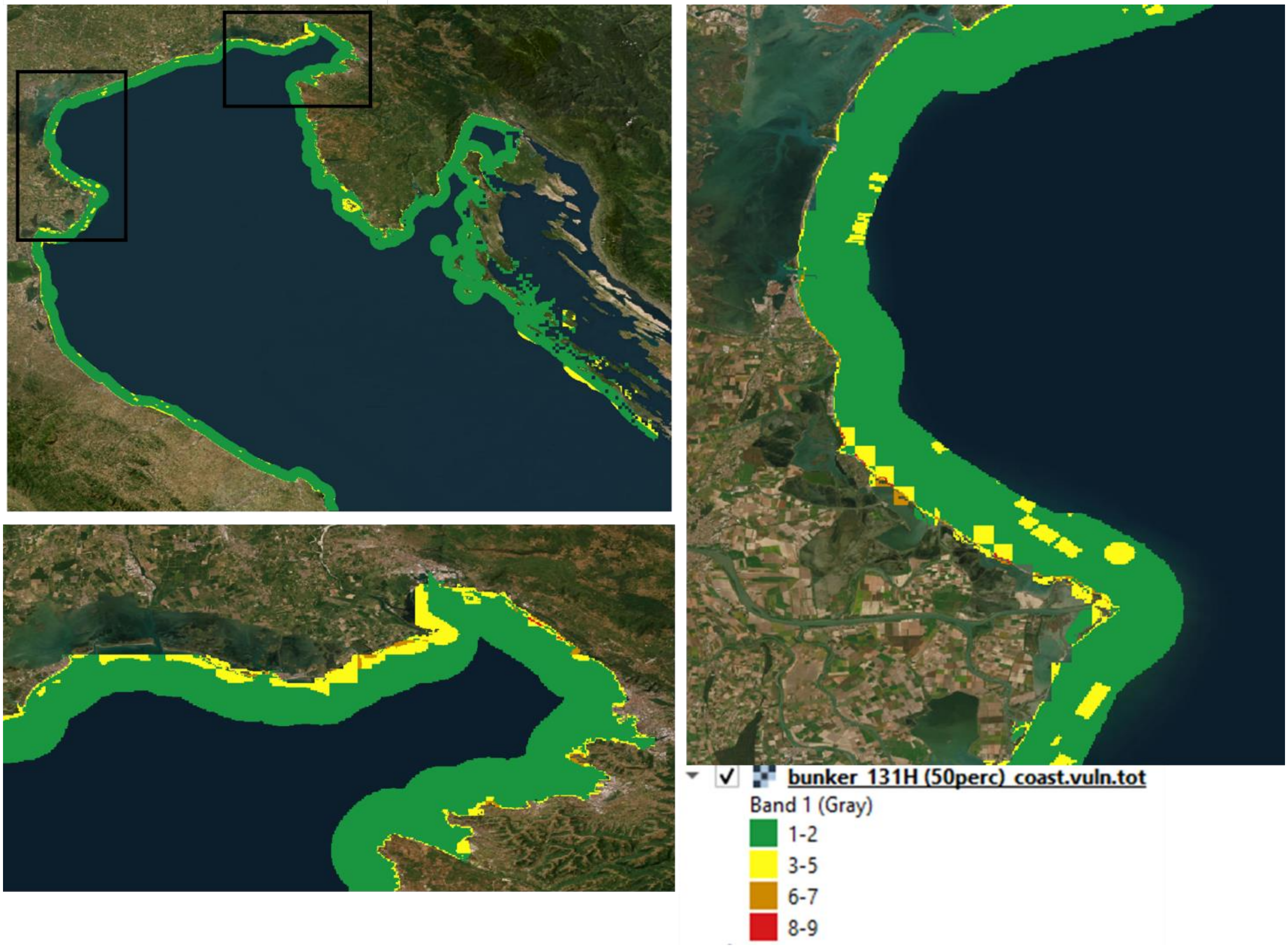


Figure 87. Maps of the risk index based on the 50% stranded bunker oil (131 hours after release) and the total coastal vulnerability with a zoom on the Gulf of Trieste and the Po delta.

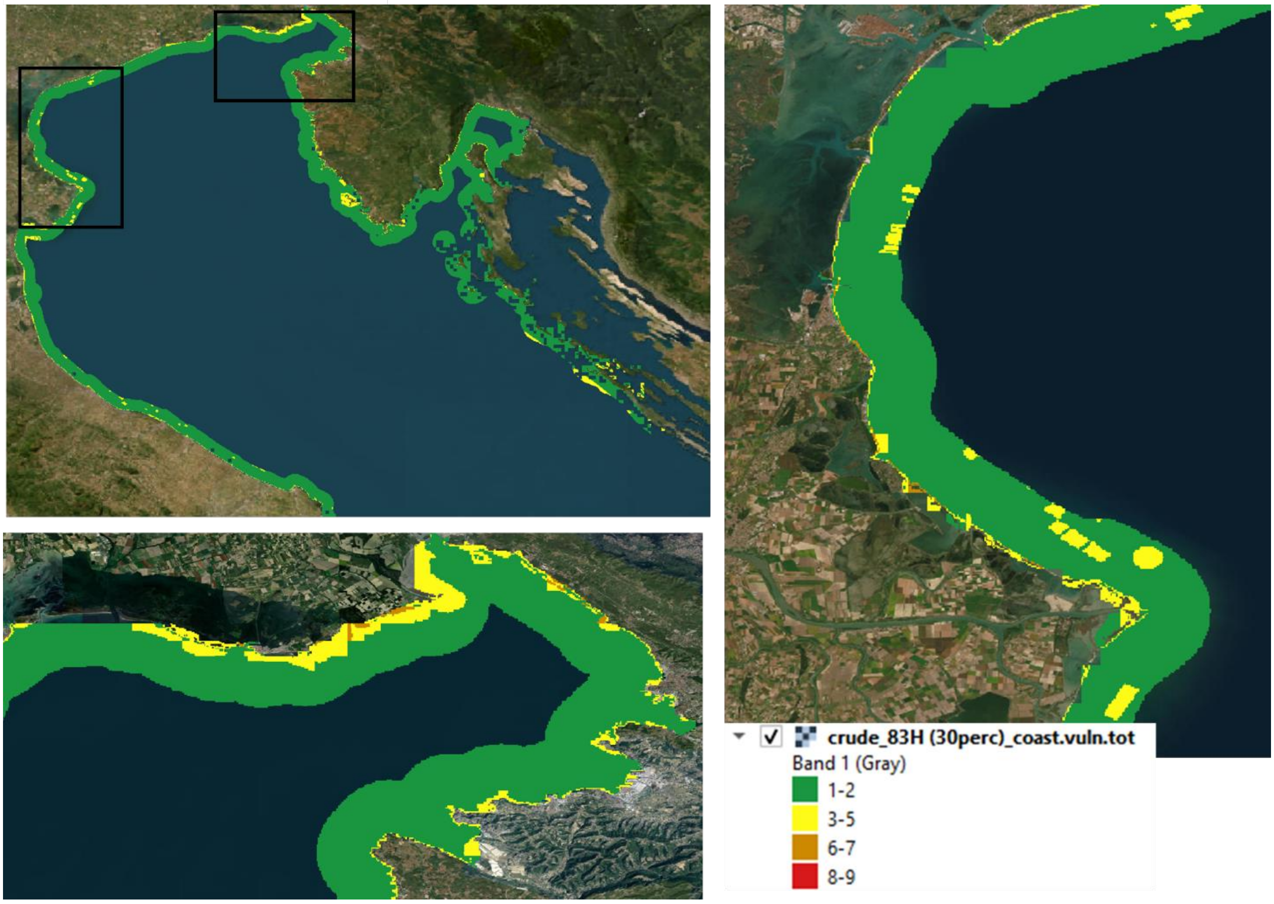


Figure 88. Maps of the risk index based on the 30% stranded crude oil (83 hours after release) and the total coastal vulnerability with a zoom on the Gulf of Trieste and the Po delta.

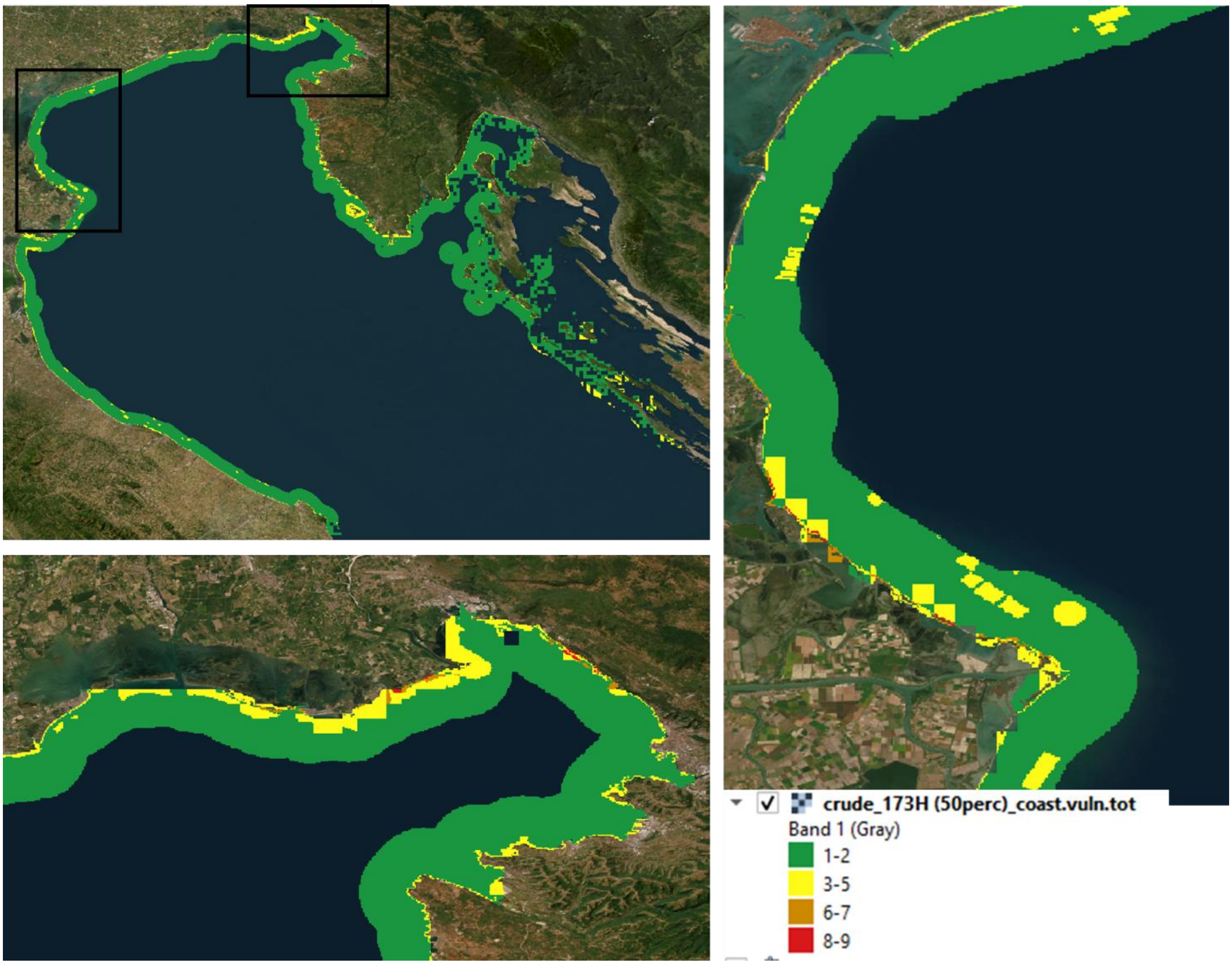


Figure 89. Maps of the risk index based on the 50% stranded crude oil (173 hours after release) and the total coastal vulnerability with a zoom on the Gulf of Trieste and the Po delta.

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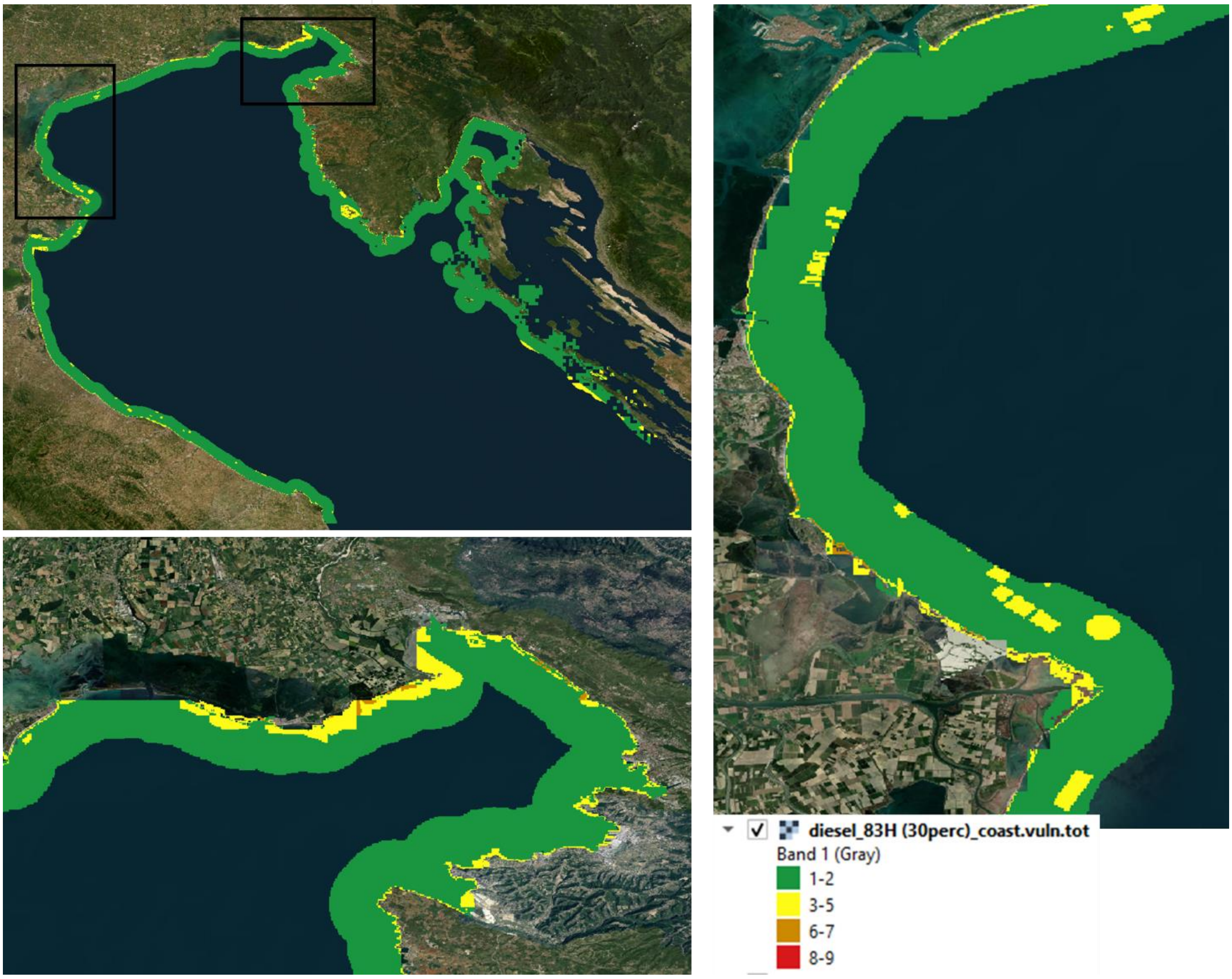

Figure 90: Maps of the risk index based on the 30% stranded diesel oil (83 hours after release) and the total coastal vulnerability with a zoom on the Gulf of Trieste and the Po delta.

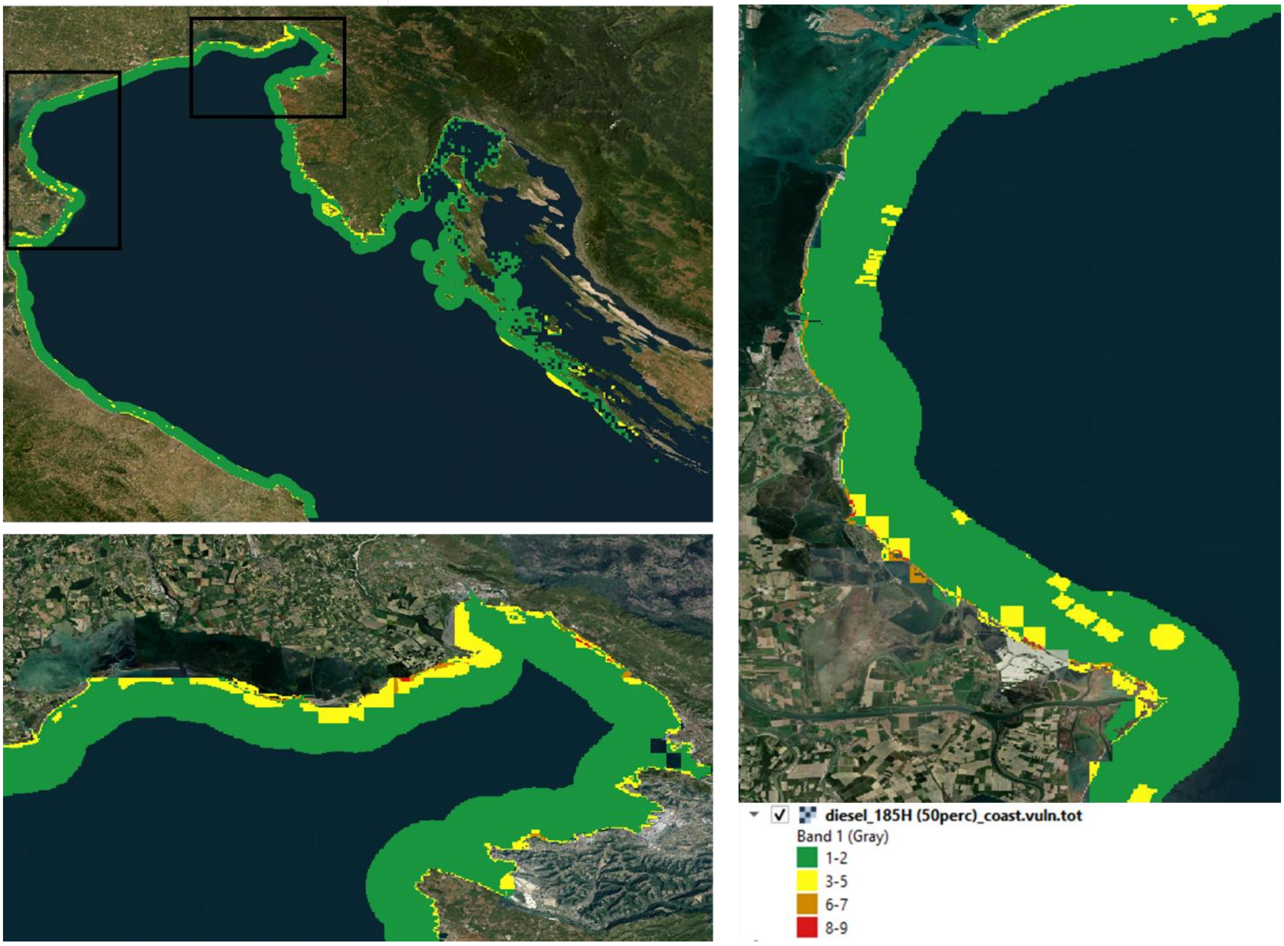

Figure 91. Maps of the risk index based on the 50% stranded diesel oil (185 hours after release) and the total coastal vulnerability with a zoom on the Gulf of Trieste and the Po delta.

7. Conclusions

The Risk Assessment is a fundamental step in each contingency planning since it allows to identify the type of risk to which different areas are exposed, and to plan for possible mitigation measures, or for intervention measures in case of need. The results of NAMIRS Activity 2.1 will thus be useful in particular for NAMIRS Activity 2.3, but more in general they will contribute to the overall goals of the whole project.

The Risk Assessment in NAMIRS was performed applying a multidisciplinary, holistic, and participative methodology, integrating results of marine traffic analysis, oil spill simulations, marine spatial planning, stakeholders' involvement, literature information, and expert knowledge. While relying on established procedure in the scientific community, the methodology was adapted to the specific needs of the NAMIRS project. The results fulfilled the goals of Activity 2.1, but were also limited by the time, spatial, and financial constraints of NAMIRS. Thus, we list here some possible developments that might be explored in future projects.

Marine traffic analyses are the basis for hazard estimation in case of oil spills. Nevertheless, they are time and resource consuming. Thus, for NAMIRS we were able to perform these analyses limiting the rigorous statistical approach to the Gulf of Trieste (anyway the busiest area in the Northern Adriatic Sea), extrapolating the results to the rest of the study area. More significant results might be obtained by performing the analyses on a longer dataset of sea currents and including a larger study area.

The oil spill simulations were planned to give us a statistically significant estimation of the exposure of coastal areas to oil spills. Also in this case, extending the simulations to a longer timeframe would have increased the robustness of the results. Other possible developments include analysis per different meteorological scenarios (e.g., during extreme weather, considering different wind regimes), and the inclusion of additional type of oils. While we considered the most abundant oils being transported in the Northern Adriatic Sea, each oil has its own characteristics that make it more or less impacting in case of a spill, thus including more types of oil would strengthen the confidence in the results.

For the mapping of the receptors potentially impacted by an oil spill we relied mostly on publicly available databases of sea and coast use. While these databases are maintained by EU infrastructures (e.g., EMODnet), not always is the information in them accurate nor updated. There are also differences in how the information is provided by different countries, thus it was not straightforward to use this information for the purposes of marine spatial planning. Among the vulnerability factor groups, the one most lacking in information is also the one that might be considered the most immediately impacting on the life of people, i.e., the socioeconomic group. Among the databases that we accessed there were almost no information on areas devoted to different type of activities, e.g., touristic activities, industrial activities, recreation, etc. This is a major drawback for a proper assessment of the risk. The information gathered might be complemented assessing other, more specific databases (e.g., local regulatory plans), which are also less easily accessible. In some cases, the use of aerial photography or remote sensing (satellite) monitoring, through appropriate analysis approaches, might also improve the receptors identification and their vulnerability assessment.

The most obvious and ambitious development would be to enlarge the area of application of the risk assessment to the whole Adriatic Sea and possibly beyond. Disasters have no borders, and this is true in particular for disasters on sea, where the currents and winds can easily disperse the agent causing impact (e.g., pollutants, oil), thus reducing its impact, but can also spread it over huge areas, across different administrative and political entities, habitats, and human and non-human populations, effectively amplifying its impact. Thus, further cross-border cooperation in this field is of the utmost importance.

The result of the Environmental Risk Assessment of Activity 2.1 is a statistically based definition of the oil spill risk of coastal areas. Nevertheless, no statistical approach can be of much help during an emergency, when the field operators need to take fast and informed decisions in order to respond efficiently. Only an operative system, forced by real-time meteorological conditions, providing short-term forecasts of the fate of an oil spill can give useful information during an emergency. While the elements of such system are the same as those applied here (e.g., a high-resolution, 3D hydrodynamic model with a Lagrangian particle-tracking module able to simulate the fate of oils with different chemical and physical characteristics), the operational set-up of it exceeded the constraints of NAMIRS. Future projects should consider the possibility to build and implement a specific, real-time, possibly open and free, oil spill simulator, and to integrate it into the Standard Operating Procedures in case of incidents at sea.

One of the most interesting and useful activities in Activity 2.1 was the involvement of the stakeholders. With the workshops we collected useful information that allowed us to include not only our own, necessarily limited, knowledge and expertise, in the risk assessment procedure, but also the opinion of a much higher number of persons, institutions, and companies, directly involved in the exploitation of the sea and of the coastal areas. A possible refinement of the results obtained through the stakeholders' workshops would be to apply the Delphi method of priority selection, in order to weight stakeholders' answers by their respective expertise and increasing the confidence in the results. Furthermore, the NAMIRS partners plan later to open up the participation to the questionnaires to a general public (possibly online or during outreach activities). In this way, the opinion of selected experts collected during the workshops will be complemented by the opinions of a wider, non-professional public.

NAMIRS stakeholders' workshops already sparked some interesting developments. The oil spill simulations set up was possible also thanks to the information on the most common oils travelling in the Northern Adriatic Sea and their characteristics provided by SIOT, a stakeholder that participated in the Italian workshop. Furthermore, another stakeholder, the Marine Protected Area of Miramare, requested OGS help for the preparation of a specific contingency plan in case of oil spill for the area under protection. Our conclusion is that any future project in this field should foresee appropriate ways of stakeholders' involvement.

The workshops were also a good occasion for the outreach of the selected stakeholders on NAMIRS and its goals. The partners involved in Activity 2.1 plan further outreach activities, such as participations to international conferences and publication of scientific articles in international journals.

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