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D1.3.1 Report on Marine Traffic and Environmental Risk Assessment

Author: Vinko Bandelj, Fabrizio Gianni, Andrea Petronio, Célia Laurent, Stefano Querin, Stefano Piani, Donata Canu (OGS); Marko Perkovič, Peter Vidmar, Valter Suban, Urban Pegan, Danijela Tuljak-Suban (UL-FPP)

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OGS Expert Group: Vinko Bandelj, Donata Canu, Stefano Querin, Fabrizio Gianni, Andrea Petronio, Stefano Piani, Célia Laurent, Davide Agnetta, Giorgio Bolzon, Valeria Di Biagio, Laura Feudale, Anna Teruzzi

UL-FPP Expert Group: Marko Perkovič, Peter Vidmar, Valter Suban, Danijela Tuljak-Suban, Urban Pegan, Bor Petrovčič, Migel Mehlmauer, Matjaž Felicjan

Author: Vinko Bandelj, Fabrizio Gianni, Andrea Petronio, Célia Laurent, Stefano Querin, Stefano Piani, Donata Canu (OGS); Marko Perkovič, Peter Vidmar, Valter Suban, Urban Pegan, Danijela Tuljak-Suban (UL-FPP)

PPs involved: OGS, UL-FPP

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ABBREVIATIONS

AF	Application Form
AIS	Automatic Identification System
AP	Associated partner
ASAP	Adriatic Sensitive Areas Protection – mechanism
CM	Communication Manager
EU	European Union
JS	Joint Secretariat
LP	Lead partner
PCP	Permanent Coordination Platform
PM	Project Manager
PP	Project partner
WP	Work package
WPL	Work package leader

1. SCOPE OF THE WP

1.1 MAPPING AND MODELLING

1.1.1 BACKGROUND

The procedures of the WP1 of ASAP build on the NAMIRS project (North Adriatic Maritime Incident Response System), funded by the European Commission Directorate-General for European Civil Protection and Humanitarian Aid Operations – (DG ECHO), which ran from March 1st, 2022, to February 28th, 2024. NAMIRS contributed to laying ground for the development of a prompt intervention mechanism at sea in the Northern Adriatic, at a time when the area was not covered by a sub-regional contingency plan. The project resulted in increased preparedness, thanks to training classes involving first responders and emergency managers from all three countries (Italy, Slovenia, Croatia) and to a full-scale exercise at sea. It also produced a map of risk assessment of coastal areas of the Northern Adriatic Sea, to be used to prioritize areas of intervention during an emergency (tactical mitigation measure) and for the long-term planning of operators (strategic mitigation measure), an inventory of available resources in region, and Standard Operating Procedures to be used in case of transnational oil spill response.

The Adriatic is a semi-enclosed sea, characterized by unique environmental and cultural heritage, but also by important economic activities. It is also waterway access to the heart of Europe, thus affected by heavy maritime traffic. Despite high international standards of navigation, the risk of maritime accidents leading to oil spills or to other forms of pollution still persists. In marine environments, pollution does not know any border: mutual support and transnational coordinated response at sea are crucial to save the environment, to protect the citizens and to uphold local and national economy from the effects of pollution.

Based on the experience acquired in NAMIRS, ASAP project aims at transferring knowledge and best practices from that area to the whole Adriatic basin in order to strengthen maritime protection from the effects of the spill-over of pollutants, especially in case of big-scale accidents at sea that cannot be managed by a single Country and need to be faced at joint transnational level.

1.1.2 DESCRIPTION OF WP1

The first Work Package was dedicated to mapping and modelling activities, with the final aim to identify a common strategic approach for protecting and safeguarding the most sensitive areas in the

Adriatic basin, from the effects of maritime accidental pollution deriving from oil-spill. In particular the activities entailed:

- consultation of key stakeholders, contributing to the evaluation of the sensitiveness of the Adriatic Sea and shores;
- marine traffic analysis and incident risk assessment;
- mapping of Sensitive Areas in the whole Adriatic basin;
- simulating relevant scenarios of oil spill;
- environmental risk assessment;
- identification of anti-pollution resources available in the area and mode of deployment;
- elaboration of a transnational strategy for protecting and safe-guarding sensitive areas in case of accident. More specifically, in the framework of WP1 three stakeholders' focus groups were organized, one in each South Adriatic country (i.e., Albania, Bosnia and Herzegovina, Montenegro), in order to involve a broader public opinion in the process of Risk Assessment to oil spill. The goal of the focus groups was also to raise awareness of the local stakeholders, increasing knowledge and influencing behavior of local /national/regional authorities (e.g., public authorities responsible for first response in case of accidental marine pollution), civil protection organisations and NGOs. Web and press campaigns were also set up by PP2 and all partners, in order to inform the general public.

2. ACTIVITIES, TIME-PLAN AND PARTNERS' RESPONSABILITIES

2.1 ACTIVITY 1.3 – RESEARCH ACTIVITITES AND MODELLING

Start period: Period 1, Months 1 - 6

End period: Period 4, Months 19 – 24

Description

This Activity is coordinated by WP leader – PP2, and further divided in Tasks, each with one PP in charge.

Task 1.3.1 Marine traffic analysis and risk of accidents

An analysis on the marine traffic data in the Adriatic Sea is performed in order to identify the areas with a higher risk of marine accidents, and to estimate the type of incidents (collision, allision, grounding), the type of vessels involved, and the type and quantity of oil potentially spilled. Responsible for this Task is PP3 with the support of PP2.

Task 1.3.2 Oil spill scenarios simulations

Relevant scenarios are simulated to assess the exposure of coastal areas to oil spills in the Adriatic Sea. Possible case studies are identified for areas with a higher risk of accidents, along the main shipping routes, under specific meteo-marine conditions, or in areas with greater vulnerability. Responsible for this Task is PP2 with the support of PP3.

Task 1.3.3 Mapping of sensitive areas and oil spill risk assessment

Sensitive areas in the whole Adriatic are mapped, based on the information collected during focus group workshops, on publicly available data sources (e.g., EMODNET portal, Copernicus), and on the results of the NAMIRS project. A vulnerability assessment will be carried out for the different areas, taking account of the outcomes of the focus groups. A risk assessment index is calculated and mapped for the whole Adriatic area. Responsible for this Task is PP2 with the support of PP3.

2.2 TIME-PLAN

The originally planned schedule of WP1 and Activity 1.3 is outlined below.

Activity 1.1 Joint Methodology for the Implementation of the WP - RP1, months 1-2

- D1.1.1 Joint Methodology for WP1 - due in month 2
- D1.1.2 Technical Coordination Meetings - report (SC/virtual meetings) – due in month 15

Activity 1.2 Stakeholders' Consultation – RP1 and RP2, months 2-10

- D1.2.1 Report on the Focus Group organised in Montenegro – due in month 9
- D1.2.2 Report on the Focus Group organised in Bosnia-Herzegovina – due in month 4
- D1.2.3 Report on the Focus Group organised in Albania – due in month 8

Activity 1.3 Research Activities and Modelling – RP1, RP2, RP3, months 3-15

- D1.3.1 Report on Marine Traffic and Environmental Risk Assessment – due in month 13
- D1.3.2 Presentation of the results of the WP – due in month 14
- Output 1.1 Strategy for protecting and safeguarding Adriatic Sensitive Areas – due in month 15

Activity 1.4 Mapping Technical Resources – RP1, RP2, RP3, months 3-15

- D1.4.1 Map of the response capacity in the Adriatic Sea – due in month 13

Activity 1.5 HNS Spill Simulation – RP1, months 3-6

- D1.5.1 Upgrade of the Simulator centre in Portorož – due in month 6

2.3 OVERVIEW OF ACTIVITY 1.3

Task 1.3.1 was completed in RP2 by PP3. An analysis of maritime traffic data in the Adriatic was performed and a list of locations where marine incidents are more likely to occur was identified, taking into account the estimated type of oil or oil products involved and the estimated quantity released. The list was then transferred to Task 1.3.2.

In Task 1.3.2, PP2 ran a hydrodynamic model of the Adriatic Sea, and the resulting current fields were used in a particle tracking model with releases in the locations identified in 1.3.1. The hydrodynamic model for the whole Adriatic Sea was built based on models developed by OGS within the MER project (Marine Ecosystem Restoration - an Italian NRRP project led by ISRPA). It represents a substantial improvement in resolution, initialization and forcing compared to the models used in NAMIRS. Due to computational requirements, the model was run on Leonardo, the leading Italian public supercomputer. The current fields were then used in the Lagrangian particle tracking model in order to simulate dispersal in case of oil spills. Because of the complexity of the modelling work and of unforeseen delays due to technical problems with the computational resource used to run the hydrodynamic and the dispersal model, these activities were delayed and caused a delay also in Task 1.3.3 and of the public presentation of WP1 results. Anyway, all activities in this Task were completed in RP3.

In Task 1.3.3, the vulnerability maps of NAMIRS were integrated with information from the Middle and Southern Adriatic. This first part of the work was completed in RP2. The final risk assessment index to oil spill for the entire Adriatic was calculated after the completion of the oil spill simulations. All activities of the Task were completed in RP3.

Because of the abovementioned delays in Task 1.3.2, the end of the whole Activity was delayed and so was the public presentation of WP1 results, that was organized in Trieste at the LP premises on February 4th, 2026. On that occasion, the specific outcomes of Activity 1.3 represented a substantial part of the presentation.

2.4 ORGANIZATION OF THE DELIVERABLE

The following Section 3 is dedicated to Task 1.3.1 - Marine Traffic Analysis and Risk of Accidents. Section 4 to the modelling performed in Task 1.3.2 - Oil spill scenarios simulations, in particular Section 4.2 details the hydrodynamic model developed specifically for ASAP purposes, and Section 4.3 the Lagrangian oil spill simulation model used. Section 5 is dedicated to Task 1.3.3 - Mapping of sensitive areas and oil spill risk assessment. In particular, Section 5.2 reports the results of stakeholders' involvement, including the results of three stakeholders' workshops held during NAMIRS project; Section 5.3 details the vulnerability mapping and assessment; and Section 5.4 reports on the final risk index mapping for the Adriatic Sea. All references are listed in the Reference section. Figures and tables are numbered sequentially throughout the whole document.

3. TASK 1.3.1 MARINE TRAFFIC ANALYSIS AND RISK OF ACCIDENTS

3.1 INTRODUCTION

A comprehensive navigational risk assessment was previously conducted in the Northern Adriatic Sea within the NAMIRS project, establishing a structured methodological framework for maritime traffic analysis and oil-spill hazard estimation in a semi-enclosed, environmentally sensitive basin. The ASAP project represents a logical methodological and geographical extension of that work. It expands the assessment to the entire Adriatic Sea and further enhances the analytical approach through refined modelling procedures, broader AIS traffic datasets, and more detailed environmental consequence scenarios.

Within the ASAP framework (Activity 1.3), maritime traffic analysis and oil-spill hazard estimation were conducted for the entire Adriatic region, covering all Adriatic coastal states under a harmonised analytical approach. The objective of this section is to provide **a basin-wide overview of traffic density patterns** and to **identify navigational hotspots as locations where accidents with pollution potential may occur**. These locations subsequently serve as spatial inputs for oil spill simulations; therefore, they must be characterised not only by their geometry and traffic structure, but also by the likely accident type, accident probability, and the expected type and quantity of potential releases. The resulting parameters are then used in subsequent steps to derive vulnerability and risk indicators consistently across the basin. The regulatory landscape governing maritime safety and environmental protection in the Adriatic region is shaped by international conventions, European Union legislation, and national implementation frameworks that vary in operational practice. No single prescriptive regional methodology exists for probabilistic maritime accident risk assessment. Consequently, the approach adopted in this study follows internationally recognised principles by integrating quantitative modelling, AIS-based traffic analysis, historical casualty information, and structured expert judgement. This integrated methodology supports a balanced evaluation of accident likelihood and potential consequences, particularly in areas where historical spill statistics are limited or where cargo transparency is constrained.

3. 2 METHODOLOGICAL FRAMEWORK

The methodological framework applied in this study follows a progressive analytical sequence beginning with a detailed traffic density assessment and culminating in probabilistic collision modelling and spill scenario definition. First, vessel traffic patterns are analysed using AIS-based density charts and processed AIS datasets, including the MarineTraffic enterprise-level archives, which provide detailed vessel classification by ship type and size class. Traffic intensity is evaluated spatially and temporally in order to identify principal shipping corridors, convergence zones, route intersections, and port approach funnels across the Adriatic basin.

Following this quantitative screening, candidate hotspot areas are identified through a structured expert assessment. Expert judgement is a recognised component of maritime risk studies in complex navigational environments, particularly where local knowledge of encounter dynamics, operational constraints, and traffic behaviour is essential. Experienced masters, pilots, and VTS operators contribute to the identification and validation of locations where encounter complexity, route geometry, restricted manoeuvring space, or operational patterns may increase the probability of collision or allision. These hotspots are then examined in more detail with respect to vessel type composition, ship size distribution, and representative operational conditions, including typical loading patterns that influence both manoeuvring behaviour and spill consequences.

The basin-wide methodology builds upon the previously developed Northern Adriatic assessment framework and extends it consistently to the central and southern Adriatic, ensuring continuity and comparability of results while allowing the refined AIS dataset and modelling configuration to be applied uniformly across the entire region. AIS-derived trajectories are subsequently structured for probabilistic modelling within the IWRAP (IALA Waterway Risk Assessment Programme) environment, where traffic intensity, route geometry, vessel-class distributions, and prevailing speed profiles define exposure and encounter conditions. Encounter types are differentiated into crossing, head-on, and overtaking situations consistent with the IWRAP framework. To avoid overestimating accident frequencies due to low-speed or stationary interactions associated with anchorage, harbour manoeuvring or local port operations, the encounter screening is restricted to dynamically evolving situations. Specifically, only encounters in which at least one vessel maintains a minimum operational speed (expert-defined at 9 knots) are considered candidates for collision modelling. This criterion is introduced to ensure that analysed encounters represent navigationally significant kinetic scenarios rather than low-energy contact situations and to improve the interpretability of IWRAP outputs at the basin scale.

The outcome of this stage is a spatially explicit identification of encounter hotspots across the Adriatic basin, differentiated by encounter type and vessel-class interaction. These dynamically filtered encounter datasets form the probabilistic basis for subsequent accident frequency estimation and spill scenario definition presented in the following subsections.

3.2.1 PROBABILISTIC MODELLING FRAMEWORK (IWRAP THEORY)

The probabilistic assessment of navigational accident likelihood in the present study is based on the IWRAP (IALA Waterway Risk Assessment Programme) model, an internationally recognised framework for estimating collision and grounding frequencies in confined and open-water navigation areas. IWRAP is grounded in encounter theory and traffic conflict modelling. The fundamental principle of the model is that collision frequency can be expressed as the product of two principal components: the geometrical encounter frequency and the causation probability. In simplified form, the annual collision frequency F_c may be expressed as:

$$F_c = N_e \cdot P_c$$

where, N_e represents the number of geometrically possible ship encounters per year and P_c represents the causation probability, i.e., the conditional probability that a geometrically defined encounter results in an actual collision due to human, technical, or organisational failure. The encounter frequency component N_e is determined from traffic flow characteristics derived from AIS data, including vessel intensity, route geometry, speed distribution, and crossing angles. Encounters are categorised into three principal types: crossing, head-on, and overtaking situations. Geometrical modelling assumes defined traffic lanes or route segments and evaluates the probability of ships occupying intersecting positions within a specified time window. The causation probability P_c represents the likelihood that an encounter will develop into a collision given the failure of collision avoidance mechanisms. This parameter incorporates implicit assumptions regarding human performance, situational awareness, technical reliability, and compliance with the Convention on the International Regulations for Preventing Collisions at Sea (COLREG). Default causation factors provided in IWRAP are derived from empirical accident statistics and have been widely applied in international waterway risk studies. In the present assessment, causation factors were reviewed in relation to regional traffic characteristics but not fundamentally modified, ensuring comparability with previous Northern Adriatic studies. Grounding frequency estimation follows a similar conceptual structure, in which accident frequency is expressed as the product of traffic exposure and the conditional failure probability, accounting for fairway width, vessel domain, and navigational constraints. To ensure that modelled encounters represent kinetically meaningful navigational

situations, the present study introduces an additional dynamic filtering criterion. Only encounters involving at least one vessel maintaining a minimum operational speed of 9 knots are included in the collision modelling dataset. This expert-defined threshold excludes low-energy interactions associated with anchorage manoeuvring, harbour operations, or drifting conditions, thereby preventing artificial inflation of calculated accident frequencies.

The integration of high-resolution AIS-derived trajectories into the IWRAP framework enables spatially explicit estimation of collision frequencies across the entire Adriatic basin. The model output consists of encounter-based accident frequency distributions differentiated by encounter type and vessel class interaction, forming the probabilistic basis for subsequent spill scenario definition and environmental risk modelling.

3.3 DATA

The traffic analysis conducted within the ASAP framework is based on an integrated AIS data environment combining processed AIS archives, live AIS streams and historical datasets, complemented by the information collected by the Mandatory Ship Reporting System in the Adriatic Sea (ADRIREP). This integrated data environment enables both high temporal resolution in traffic characterisation and basin-wide continuity in trajectory reconstruction.

3.3.1 AIS DATA INFRASTRUCTURE AND PROCESSING

Shore-based AIS stations provide high-resolution kinematic data within coastal waters and port approach areas, ensuring reliable spatial and temporal coverage of the most traffic-intensive sectors. These data are complemented by the MAREΣ regional exchange network, which aggregates AIS streams from multiple Mediterranean coastal states. The integration of national and regional AIS feeds enables basin-wide trajectory reconstruction across the Adriatic Sea and reduces the risk of coverage discontinuities, particularly in offshore areas or at sector boundaries. Satellite AIS and long-range AIS systems are available in principle, but they are not required for this study because their temporal resolution is lower and the Adriatic Sea is effectively covered by the favourable placement and elevation of shore-based AIS stations. In the Northern Adriatic, elevated sites such as Slavnik (Slovenia) and Učka (Croatia), together with coastal and island stations along Italy, Croatia, Montenegro and Albania, provide near-complete AIS reception coverage across the basin. AIS operates in the VHF band on two dedicated channels (AIS 1: 161.975 MHz; AIS 2: 162.025 MHz), and transmission intervals vary from seconds to minutes depending on vessel class, speed, navigational

status, and manoeuvring behaviour. Detailed transmission intervals for Class A and Class B transponders are provided in Table 1.

All raw AIS messages are stored in MS SQL databases using Wartsila *TranDB* software. Due to the extremely high data volume in the Adriatic (several hundred million AIS messages per month, reaching up to approximately 500 million in peak periods), data are partitioned by message type, date, and time interval. Dedicated offline mirrored servers were established at UL FPP to enable large-scale export without interfering with operational AIS recording. Data extraction was performed using Python (*pymssql*), and the monthly CSV datasets were exported for further processing.

Robust pre-processing and quality control procedures were implemented prior to analysis. AIS datasets were geographically filtered to the Adriatic domain and temporally structured into manageable processing intervals. Because AIS reporting rates vary with vessel behaviour, trajectories were resampled to a uniform temporal resolution (10 seconds) using linear interpolation. Extended signal gaps were handled cautiously to avoid artificial trajectory distortion and to preserve the integrity of encounter identification. Quality control included removal of corrupted records, filtering unrealistic speed or position jumps, verification of MMSI consistency and vessel-type classification based on AIS static messages supplemented by external vessel databases, where required. Particular care was taken to distinguish between genuinely dynamic navigation and low-speed manoeuvring or stationary conditions, as this distinction directly affects subsequent encounter statistics and probabilistic modelling.

The theoretical AIS communication range depends on antenna height and can be approximated by:

$$d = 2.5(\sqrt{h_{TX}} + \sqrt{h_{RX}})$$

where distance is expressed in nautical miles and antenna heights are expressed in metres. Elevated shore stations, therefore, significantly extend reception range under favourable propagation conditions, supporting basin-wide AIS coverage.

Table 1: AIS Transmission Intervals for Class A and Class B Transponders

AIS Tran. Class	Ships Dynamic Condition	Dual Channel Interval	Single Channel Interval
Class A	Ship at anchor or moored	3 min	6 min
	SOG 0–14 knots	10 sec	20 sec
	SOG 0–14 knots and changing course	3.3 sec	6.6 sec

AIS Tran. Class	Ships Dynamic Condition	Dual Channel Interval	Single Channel Interval
	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
Class B	SOG <2 knots	3 min	6 min
	SOG >2 knots	30 sec	1 min
	Ship static information	6 min	12 min

3.3.2 ADRIREP

In addition to standard AIS dynamic and static messages, the ADRIREP mandatory ship reporting system constitutes an important supplementary source of structured maritime information within the Adriatic basin. While AIS provides high-frequency kinematic and identification data, ADRIREP provides voyage- and cargo-related, as well as declarative information that is not systematically available through AIS transmissions. The system was originally adopted under SOLAS regulation V/11 as the mandatory ship reporting system "In the Adriatic Sea" (MSC.139(76)) and applies to defined categories of vessels presenting elevated navigational or environmental risk, including oil tankers of 150 GT and above, ships of 10,000 GT and above, and all vessels carrying dangerous or polluting goods, irrespective of size (International Maritime Organization - IMO, 2002). From a risk assessment perspective, ADRIREP reports provide structured information, including vessel identity, voyage details, draught, destination, and, most importantly, cargo classification under the IMDG, IBC, IGC, IMSBC Codes, and MARPOL Annex I. Where applicable, reports also contain information on quantities and general categories of hazardous or polluting substances on board. This is particularly relevant for tanker traffic and vessels transporting hazardous and noxious substances (HNS), as it enables partial identification of cargo types and approximate onboard quantities. Such information significantly improves the plausibility assessment of spill scenarios and supports hazard characterization in environmental consequence modelling. The operational area of ADRIREP covers the entire Adriatic Sea north of latitude 40°25'.00 N and involves coordinated participation of the Adriatic coastal states through designated competent shore-based authorities (NCSR, 2023).

The original system architecture, adopted in 2003, was based primarily on VHF voice reporting at defined reporting lines. At the time of its introduction, AIS coverage was limited, and coastal radar surveillance was not yet fully developed. Consequently, ADRIREP functioned as a sector-based reporting mechanism, relying on manual communication and inter-sector message redistribution procedures between maritime authorities. Over time, several operational limitations of this legacy structure became apparent. The redistribution of reports between adjacent monitoring sectors depended on established communication protocols that did not always guarantee seamless data continuity. Previous technical assessments identified occasional reporting gaps and inconsistencies, particularly when reports were not systematically forwarded across sector boundaries. As a result, historical ADRIREP datasets cannot be considered fully exhaustive cargo databases and require careful validation when used for quantitative analysis. Recognising these limitations, a comprehensive modernisation process has been initiated at the regional level, with support from the European Maritime Safety Agency (EMSA). The modernised ADRIREP framework is based on an integrated digital information solution enabling automated electronic reporting through the SafeSeaNet platform, in accordance with Directive 2002/59/EC. The modernisation aims to reduce administrative burdens on ships, eliminate redundant reporting, and ensure automatic distribution of structured report data among all participating coastal states. The technical assistance project for the modernisation of ADRIREP emphasises interoperability, data reuse, and enhanced situational awareness through integration with national maritime single-window systems and AIS infrastructures (EMSA, 2023). The integrated information solution described in the ADRIREP modernisation documentation provides a platform for real-time data exchange, enabling competent shore-based authorities to access harmonised voyage and cargo data. By shifting from predominantly VHF-based communication to structured electronic submission via SafeSeaNet, the system increases reliability, traceability, and reporting consistency. In operational terms, electronic reporting allows ships to reuse previously submitted information and reduces the risk of transcription errors or incomplete transmission. From a modelling perspective, the digitalisation of ADRIREP substantially improves the potential usability of reported cargo and voyage information for environmental risk analysis. Despite these improvements, the ADRIREP data in the present study are treated as a supporting validation layer rather than a comprehensive cargo inventory. Quantitative traffic modelling, encounter frequency estimation, and probabilistic collision assessment remain grounded primarily in AIS-derived vessel movement data, which provide continuous, high-resolution trajectory information across the entire Adriatic basin. ADRIREP information is therefore used to enhance interpretative accuracy, particularly in hotspot areas involving tanker traffic and vessels transporting hazardous substances.

The role of ADRIREP becomes especially significant in the context of Hazardous and Noxious Substances (HNS) risk analysis. Existing publicly accessible records remain highly incomplete regarding the number of HNS-carrying vessels and the actual quantities transported, particularly for chemical tankers. It is often difficult to distinguish between crude oil tankers, product tankers, and chemical tankers solely on the basis of AIS ship type codes. The most demanding analytical challenge concerns vessels transiting the Adriatic without calling at regional ports, as cargo details for such vessels are rarely available in national port databases. ADRIREP reporting, therefore, represents one of the few structured mechanisms for capturing and analysing cargo-related information for ships in transit. Sample ADRIREP report formats are provided in the subsequent table for illustration of message structure and reporting designators. These structured report examples demonstrate the scope of cargo, draught, and voyage-related information that may be available for integration into risk modelling workflows. ADRIREP data will be particularly important for refining HNS-related risk scenarios, as current datasets remain fragmented and incomplete.

The ADRIREP mandatory ship reporting system was not established as a primary input source for the present navigational risk assessment; nevertheless, the subsequent methodological screening of the reporting archive demonstrated that ADRIREP contains operationally valuable hazard descriptors. In particular, ADRIREP messages can provide (i) structured reporting lifecycle information (FR/PR/ER), (ii) destination and routing intelligence supporting sector-based traffic interpretation, and (iii) declared cargo and bunker fuel inventories relevant for consequence-based pollution scenarios. Given the practical limitations of cargo transparency within AIS static messages, ADRIREP may therefore be considered a meaningful complementary layer for Hazardous and Noxious Substances (HNS) exposure assessments, especially when chemical tanker traffic and cargo composition are of interest. For the purpose of this methodological evaluation, 1,966 ADRIREP PDF reports were processed (Italian Coast Guard centres only). The parsed dataset provides full temporal coverage within the extracted archive and allows systematic extraction of report type, timestamps, ports of departure and destination, vessel identity, cargo declaration fields, and bunker inventories. A key methodological decision concerned the interpretation of cargo quantities. ADRIREP cargo fields can contain multiple hazardous goods classes and quantities, and the same message may include both parcel-type IMDG declarations and bulk tanker declarations. To avoid systematic bias, cargo was reported in a dual format, fully in tonnes:

- IMDG parcel DG (t): quantities explicitly declared in *kg* and tied to an IMO class (typical for packaged dangerous goods).

- Bulk cargo (t): quantities declared through TOT Quantity in *mt* (typical for tanker/bulk movements).

During the observation period, the system generated an average of 64 reports per day. The daily frequency ranged between approximately 45 and 84 reports, without pronounced spikes or operational interruptions. This relatively stable daily frequency indicates continuous transit activity within the Adriatic basin, stable functionality of the reporting system, and absence of major reporting disruptions. For comparative purposes, the diurnal distribution of reporting activity was defined as the interval 06:00–18:00 UTC, and the night as 18:00–06:00 UTC, ensuring equal 12-hour periods. The difference between day and night reporting is approximately 3.4% (51.7% for day activities and 48.3% for night activities), indicating an almost perfectly balanced 24-hour distribution. From a navigational risk perspective, this confirms that maritime transit through the Adriatic Sea is operationally continuous, with no significant administrative or procedural asymmetry between day and night. Consequently, exposure to potential collision or grounding incidents may reasonably be modelled using a uniform 24-hour exposure framework, as further implemented in the IWRAP probabilistic analysis. To ensure comparability between weekdays, the number of reports was normalised by the actual number of occurrences of each weekday in the analysed period. The distribution indicates relatively uniform weekly traffic intensity, with slightly elevated activity. However, variations remain within approximately ±10% of the overall daily average (~64 reports/day). The analysed Italian Coast Guard transmissions comprise 732 FR (First Report), 560 PR (Position Reports), and 674 ER (End Reports), enabling reconstruction of vessel transit trajectories across reporting sectors. Cargo declarations within ADRIREP messages include structured references to IMO hazard classes and quantities. The aggregated declared quantities by hazard class are summarised in the following table. Table 2 presents the voyage-based mass balance of declared dangerous goods within the ADRIREP system, separated into Parcel IMDG cargo (primarily containerised or general cargo) and Bulk cargo (mainly tanker cargo) declared in metric tonnes. The total declared dangerous goods clearly show that Adriatic hazardous cargo exposure is dominated by bulk tanker traffic, which accounts for more than 98% of the total mass transported. Class 3 overwhelmingly dominates the bulk segment. This corresponds to crude oil, refined petroleum products, fuel oils, naphtha, and similar hydrocarbons. The spatial distribution confirms that this flow is strongly associated with Trieste's major crude oil terminal, likely also traffic towards Omišalj (Krk Island, totalling 266 kt), and product movements in the Northern Adriatic. Bulk flows classified under IMO Class 2.1 (flammable gases) are primarily associated with LNG import operations at the Rovigo offshore terminal and the Krk LNG terminal in Omišalj. The voyage-based analysis indicates that Rovigo accounts for approximately 160 kt of LNG during the analysed period, while Omišalj records a higher throughput, in the order of 300 kt, corresponding to FSRU-based LNG import operations. Bulk chemical shipments, primarily classified

under IMO Class 8 (corrosive substances) and to a lesser extent Class 9, are geographically concentrated in industrial ports such as Ravenna, Rijeka, and Bakar.

Table 2: Declared Dangerous Goods (IMO Classes)

IMO Class	Parcel IMDG (t)	Bulk (t)
2.1	4,477.3	653,531.7
2.2	1,812.6	700.0
2.3	158.5	0.0
3	18,805.7	4,143,766.2
4.1	408.6	0.0
4.2	22.6	0.0
4.3	2,186.5	0.0
5.1	11,449.9	0.0
5.2	293.7	0.0
6.1	2,510.2	0.0
6.2	0.9	0.0
8	14,048.2	32,895.9
9	31,131.3	87,365.5
Unclassified	889.9	6,120.0
Total	**88,196.0**	**4,924,379.3**

The twenty most *frequent* destination ports are led by Trieste, followed by Venice and Ravenna. The dominance of Northern Adriatic ports underscores the region's strategic role as a primary maritime gateway. Trieste alone accounts for 134 calls, substantially exceeding those of other destinations, highlighting its role as a central hub within the reporting network.

Table 3: Ranking of Ports by Dangerous Goods Throughput

Destination	Destination name	Calls	IMDG parcel (t)	Bulk (t)	Bunker (t)
ITTRS	Trieste (IT)	134	14,860.8	2,317,102.1	92,246
ITVCE	Venice (IT)	98	9,844.9	1,201,653.4	52,559

HROMI	Omišalj (HR)	7	0	406,404.3	10,684
SIKOP	Koper (SI)	59	38,466.9	302,927.1	49,362
ITRAN	Ravenna (IT)	83	13,101.6	299,640.6	25,412
ITPMA	Palermo (IT)	35	1,185.6	172,654.4	18,402
GRIGO	Igoumenitsa (GR)	22	2,193.9	168,096.9	18,758
ITFAL	Falconer (IT)	9	0	164,010.7	5,520
ITRVO	Rovigo (IT)	3	0	161,213.0	7,161
HRPLE	Ploče (HR)	9	59.9	146,608.5	3,504
HRRJK	Rijeka (HR)	15	3,443.9	124,864.7	13,563
ITPVT	Porto Levante (IT)	7	0	122,059.0	4,274
ITAUG	Augusta (IT)	26	4.2	101,942.1	16,992
ITBDS	Brindisi (IT)	47	612.6	97,084.2	20,931
ITALY	*(IT)	1	0	94,394.3	195
ITMLZ	Milazzo (IT)	17	0	91,886.3	9,271
HRSPU	Split (HR)	2	0	59,426.6	30,140
FRFOS	Fos-Sur-Mer (FR)	3	0	51,325.0	408
ALROM	Romano (AL)	7	0	47,713.5	1,617
ITOTN	Ortona (IT)	3	0	36,376.0	730

When analysing ADRIREP sector activities, Brindisi emerges as the most active reporting sector in the analysed period, reflecting its geographic position within the southern Adriatic traffic flow (Brindisi: 713 reports; Ancona: 410; Trieste: 379; Venezia: 209; and Ravenna: 136). The dominant vessel categories in the reporting sample are Tankers (504) and Cargo Ships (427). The significant share of tankers confirms the relevance of petroleum and chemical cargo streams, while the predominance of cargo vessels indicates diversified commercial traffic. The total bunker inventory within the analysed reporting set is 600 kt. From an environmental risk standpoint, this figure is of major importance, as bunker fuel may be a dominant pollution source in collision or grounding scenarios, including when vessels are in ballast condition. Of the processed reports, 99.7% contain a non-empty cargo field, and 28.8% explicitly declare ballast condition. The concentration of hazardous cargo flows toward Northern Adriatic ports reinforces the region's elevated environmental exposure profile.

Table 4: Bunker Fuel Types and Quantities Carried by Vessels

Vessel group	Unique calls	IMDG (t)	BULK (t)	HFO (t)	MDO (t)	MGO (t)	Bunker total (t)
Cargo ship	427	70,318.9	0.0	195,218.0	52,625.0	18,321.0	266,164.0
Tanker	504	2,737.1	4,924,379.3	154,083.0	129,397.0	33,012.0	316,492.0
Other	83	15,140.0	0.0	26,382.0	11,027.0	4,311.0	41,720.0
Total	**1,014**	**88,196.0**	**4,924,379.3**	**375,683.0**	**193,049.0**	**55,644.0**	**624,376.0**

3.4 AIS-BASED TRAFFIC CHARACTERISATION

To establish a representative traffic baseline, AIS-derived data were analysed using the Marine Traffic platform. For this, the last year at disposal in Marine Traffic at the time of the analysis was used, i.e., the year 2023. All other computations described below in Section 3.5 were based on MAREΣ and ADRIREP data for 2024.

Unlike the standard AIS classification scheme, which often groups vessels into broad categories (e.g., “cargo ships,” encompassing container vessels, general cargo ships, and Ro-Ro vessels), Marine Traffic uses a more granular classification structure derived from multiple data sources, including registry databases and vessel particulars. This enhanced categorisation enables more precise differentiation of vessel subgroups relevant to navigational risk assessment. The refined vessel classes were subsequently aligned with the IWRAP modelling framework, enabling differentiated weighting of encounter probabilities by ship type. In particular, oil tankers, product/chemical tankers, bulk carriers, container vessels, Ro-Ro ships, and passenger vessels were treated as distinct traffic categories, reflecting differences in operational profiles, manoeuvrability, and potential environmental consequences.

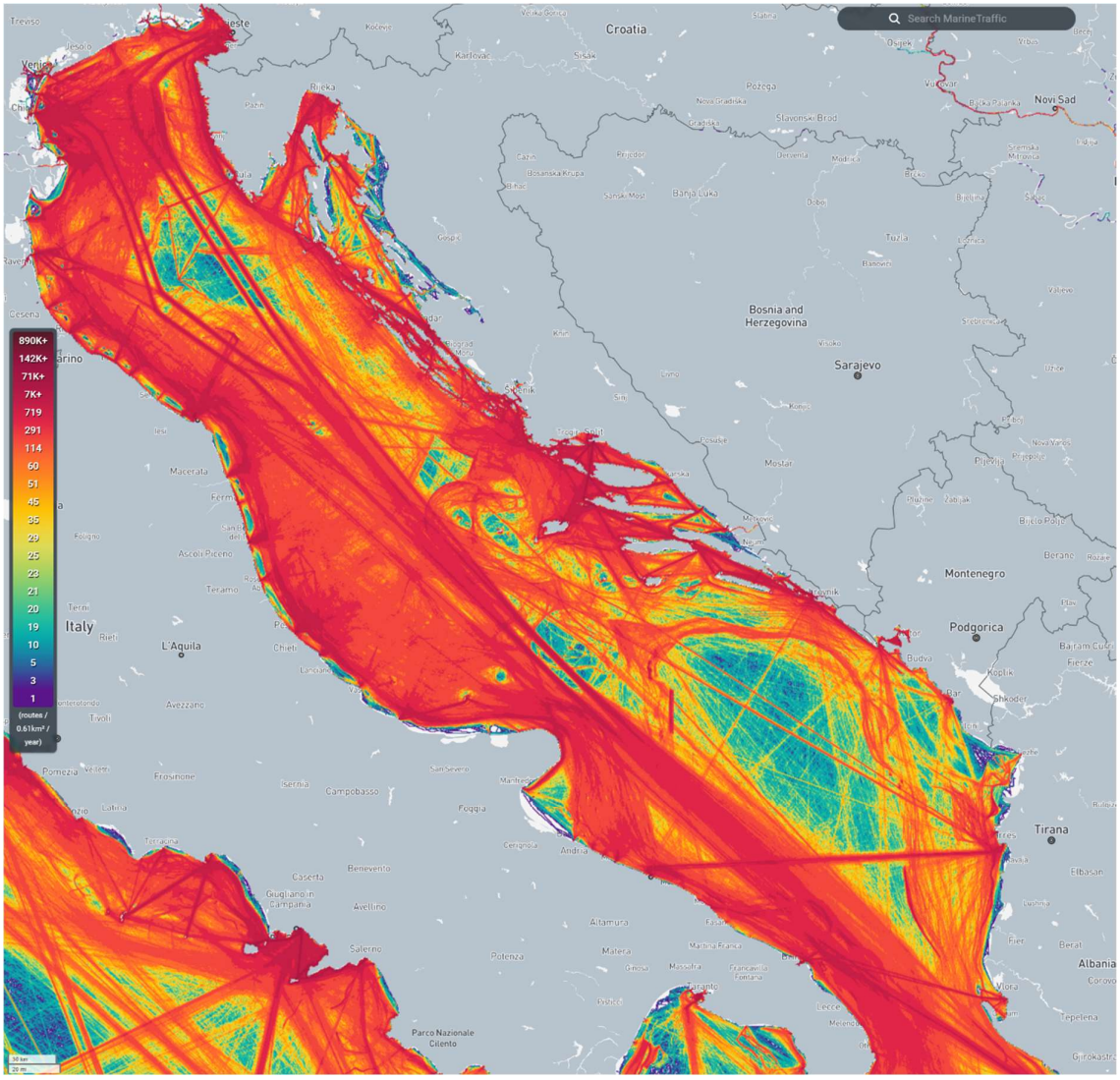


Figure 1. Annual AIS route density for 2023 (0.61 km^2 grid), including all vessel categories (commercial, tanker, passenger, fishing, and pleasure craft), illustrating dominant longitudinal shipping corridors, high-intensity port approach sectors, and cross-Adriatic ferry routes across the Adriatic Sea.

The 2024 dataset was used to quantify annual traffic density, route structure, and speed distributions across the Adriatic basin. Spatial analysis confirmed the concentration of traffic in port approach areas in the northern Adriatic, while the central and southern sectors are characterised by longitudinal transit flows along established international corridors. These basin-wide patterns support the adoption of a regional modelling approach rather than a purely port-centred assessment. Speed distributions extracted from AIS data were used to distinguish dynamic transit traffic from

manoeuvring or stationary operations, ensuring that only navigationally relevant interactions were incorporated into subsequent encounter analysis. The resulting traffic characterisation provided the empirical basis for route definition, vessel class distribution matrices, and encounter modelling within the IWRAP environment.

Fig. 1 presents the annual traffic density of all vessel categories derived from AIS route aggregation for the reference year 2023. The spatial distribution clearly highlights the dominant longitudinal shipping corridor extending along the Adriatic axis toward the Northern Adriatic ports. The highest concentration of traffic converges on the Gulf of Trieste, the Venetian Lagoon, Ravenna, and Ancona, reflecting their role as the basin's principal commercial nodes. The map also reveals clearly structured transverse ferry corridors across the Adriatic, particularly between Albania and Italy and between Croatia and Italy, forming distinct cross-basin traffic flows. In contrast, markedly lower traffic intensity is observed in the deepest central Adriatic sector and in the vicinity of the major offshore gas field west of Istria, where navigation is operationally constrained. Island archipelagos and shallow coastal zones display minimal or no AIS route density, consistent with navigational restrictions and hydrographic limitations. The map legend expresses AIS route density as the number of recorded vessel transits per spatial grid cell of 0.61 km^2, approximately equal to 781 m × 781 m. The highest-density class exceeds 890,000 recorded passages per grid cell per year, indicating highly concentrated, repeatedly used navigation tracks aligned with established shipping lanes.

Among all vessel categories operating in the Adriatic, passenger vessels and tankers represent the two groups associated with the highest potential risk exposure, albeit for fundamentally different reasons. Passenger vessels concentrate large numbers of people on board, placing primary emphasis on life safety, while tankers carry substantial quantities of oil or hazardous liquid cargo, posing significant environmental and pollution risks in the event of an accident. Fig. 2 (left) presents AIS-derived trajectories of all tanker categories operating in the Adriatic during 2023, including Handysize, Handymax/Panamax, Medium Range (MR), Long Range (LR1/LR2), and Aframax class vessels, covering crude oil, petroleum products, chemical, and gas tankers. The spatial distribution reveals a dominant longitudinal transit corridor aligned with the Adriatic axis, with the highest traffic concentration converging toward the Gulf of Trieste. This pattern is strongly influenced by the SIOT terminal in Trieste, one of the most significant crude oil entry points in the Mediterranean, handling approximately 50 million tonnes of cargo annually and receiving over 400 large crude tankers. In addition to Trieste, multiple Adriatic ports accommodate terminals for diesel, gasoline, jet fuel and chemical products, further contributing to sustained tanker traffic across the basin. The maximum recorded tanker route density exceeds 140,000 annual transits per 0.61 km^2 grid cell, indicating highly concentrated and repeatedly used tanker lanes. Fig. 2 (right) illustrates the annual trajectories of

passenger vessels, including ferries and cruise ships. The spatial pattern similarly reflects a pronounced longitudinal structure, complemented by dense cross-Adriatic ferry connections. Major passenger traffic hubs include Venice and Ancona on the Italian side, Split and Zadar along the Croatian coast, and ports in southern Italy and Albania that support intensive ferry operations. The highest passenger route density class reaches approximately 300,000 annual transits per grid cell, highlighting the operational intensity of short-sea and regional passenger services. While the longitudinal corridor remains dominant, passenger traffic shows stronger transversal connectivity than tanker routes, reflecting the network structure of ferry services across the basin.

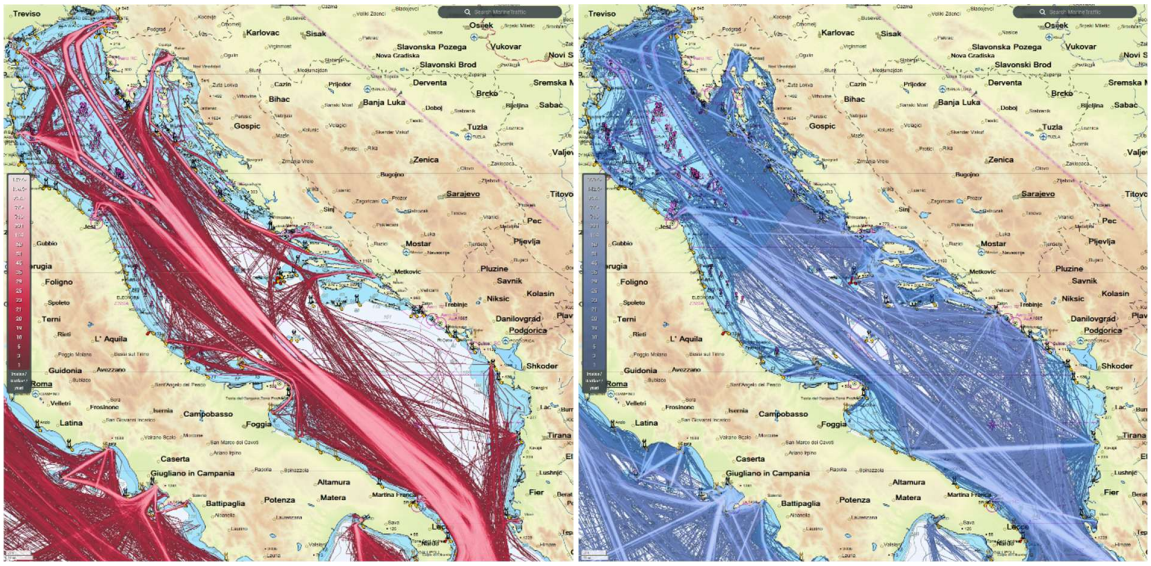


Figure 2. Annual AIS trajectories (2023) of tanker vessels (left) and passenger vessels (right), illustrating dominant longitudinal Adriatic corridors and major port connectivity patterns.

The contrast between tanker and passenger vessel traffic highlights two fundamentally different risk dimensions within the Adriatic basin. Tanker traffic, although numerically lower in density than some passenger corridors, dominates the environmental risk profile due to the large quantities of oil and hazardous liquid cargo it transports. Passenger vessels, on the other hand, represent elevated life-safety exposure because of the high number of people on board, particularly during peak seasonal operations. However, AIS-derived density maps must be interpreted with caution when assessing risk. High route-density values for passenger vessels do not necessarily correspond to elevated collision probability. In coastal and port areas, numerous smaller passenger vessels, ferries may remain within a limited spatial grid cell for extended periods while moored or at anchor. Such a stationary or low-speed presence increases recorded AIS density but does not inherently represent dynamic navigational

risk. The distinction between traffic intensity and operational encounter risk is therefore critical, especially in zones where vessels are stationary or operating under controlled manoeuvring conditions, and particularly when vessels are berthed without passengers on board. For this reason, subsequent encounter analysis focuses exclusively on dynamically evolving interactions between vessels under navigation, ensuring that probabilistic modelling reflects genuine collision exposure rather than static traffic concentration.

Although LNG and LPG carriers do not pose the same large-scale marine pollution hazard as crude oil or product tankers, their operational profiles, vessel dimensions, and onboard fuel quantities make them a significant vector in any comprehensive navigational risk assessment. Modern LNG and LPG carriers are typically large, highly specialised vessels with substantial displacement and kinetic energy during transit. In the event of a collision or allision, the primary concern may not be environmental contamination from cargo, but rather structural damage, fire/explosion risk, and navigational obstruction in constrained waterways. For this reason, gas carriers are further analysed separately and presented in Fig. 3, distinguishing between LNG carriers (right) and LPG carriers (left). LPG traffic follows a predominantly longitudinal pattern along the Adriatic axis, with activity concentrated around terminals in the vicinity of Rovigo and Venice in the northern Adriatic, Rijeka on the eastern coast, and the industrial port area north of Durres (Porto Romano/MBM) in Albania, forming operational links toward southern Italian ports including Brindisi.

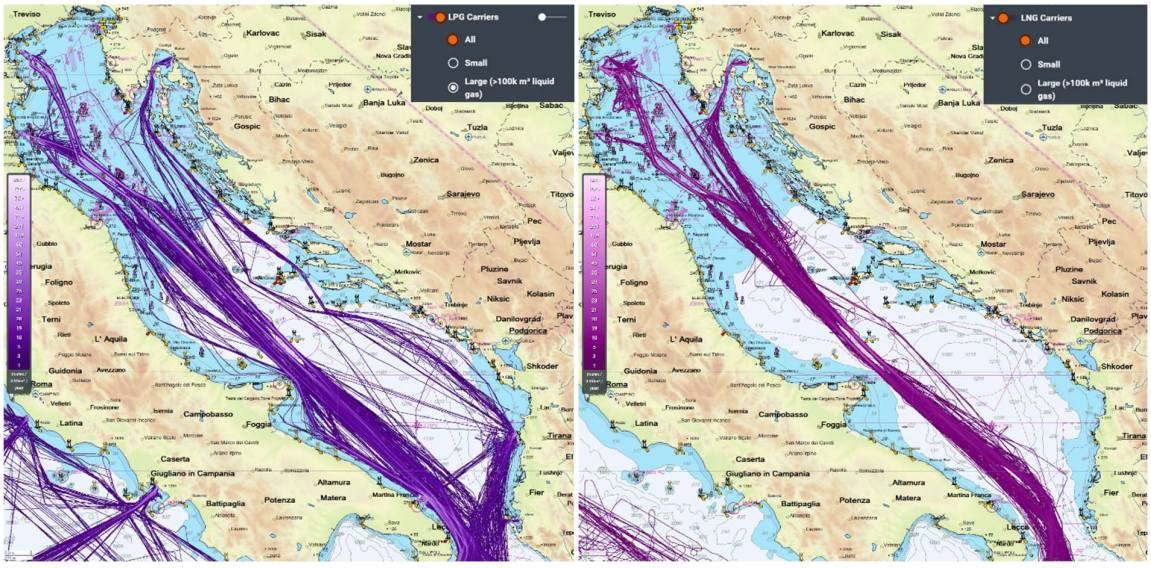


Figure 3. Annual AIS trajectories (2023) of gas carriers in the Adriatic Sea: LPG carriers (left) and LNG carriers (right), illustrating predominantly longitudinal transit patterns and terminal-focused operations at Rovigo, Venice, Rijeka, the island of Krk, Ravenna, and Porto Romano (Albania).

LNG traffic, by contrast, exhibits a more structured offshore-oriented pattern. The dominant nodes include the offshore LNG terminal near Rovigo, the LNG terminal at Krk, and limited infrastructure activity in the Ravenna area. The trajectories are primarily longitudinal and terminal-focused, reflecting point-to-point supply operations rather than distributed basin-wide trading patterns. While the environmental consequence profile of LNG and LPG differs from that of crude oil tankers, their presence in the same navigation corridors increases encounter complexity and must therefore be incorporated into probabilistic collision modelling.

The broader cargo vessel class, comprising general cargo ships, bulk carriers, and Ro-Ro vessels (including PCC car carriers), represents a structurally important component of Adriatic commercial traffic (Fig. 4 – left). In the Marine Traffic classification, this group excludes container vessels, which are treated separately (Fig. 4 – right). The spatial distribution of cargo vessel trajectories reveals a pronounced longitudinal corridor extending along the full Adriatic axis, confirming the basin's role as a north–south transit route connecting the Mediterranean deep-sea and the far east with Central European hinterlands. Traffic intensity is particularly concentrated in the northern Adriatic, where major bulk and PCC/PCTIC terminals are located. The PCC terminal in Koper represents one of the strongest gateways in the region, while large bulk carriers, including Capesize-class vessels with drafts up to approximately 17.2 m, regularly call at Koper. Additional major cargo ports reinforcing the longitudinal corridor include Trieste, Monfalcone, Venice, Chioggia, Ravenna, Rijeka, Split, Ploče, Porto Romano (Durres), Ancona, Ortona, Bari, and Brindisi. Container vessels, analysed separately, exhibit a similarly structured longitudinal traffic pattern. Northern Adriatic container hubs, Rijeka, Koper, and Trieste, receive larger container ships and support feeder services, resulting in dense northbound and southbound liner traffic aligned with established Mediterranean trade routes.

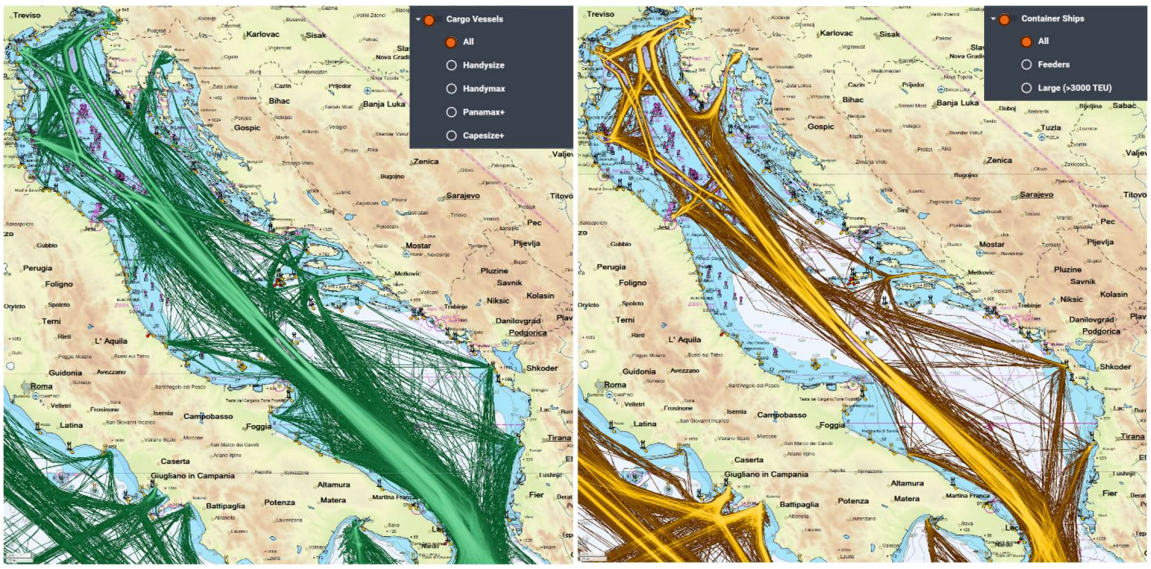


Figure 4. Annual AIS trajectories (2023) of (left) cargo vessels (general cargo, bulk carriers and Ro-Ro/PCC vessels) and (right) container ships, illustrating dominant longitudinal Adriatic transit corridors and concentration toward major northern Adriatic terminals.

Service and support vessels constitute an additional operational layer within the Adriatic traffic system. The left panel of Fig. 5 illustrates AIS trajectories of tugs and special craft, including offshore support vessels, supply boats, and other auxiliary units. While a portion of this traffic follows the dominant longitudinal corridor, a significant share consists of transversal movements, particularly in the northern Adriatic, where extensive offshore gas exploitation fields are located in both Italian and Croatian sectors. Offshore-related operations generate repeated short-range crossings between production platforms, coastal bases, and supply ports. Similar industrial support patterns are also observed along the Italian coastline further south, where offshore infrastructure remains active. The right panel presents the density of pleasure craft movements.

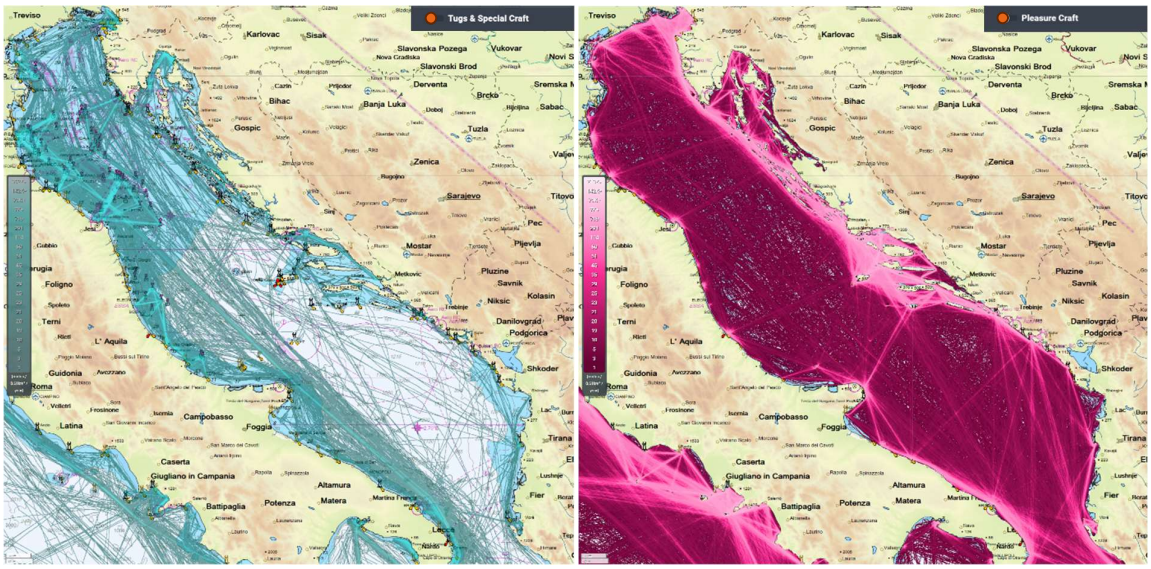


Figure 5. Annual AIS trajectories (2023) of (left) tugs and special craft, including offshore support vessels associated with Adriatic gas fields, and (right) pleasure craft density, illustrating strong seasonal recreational activity and widespread coastal distribution across the Adriatic Sea.

Recreational traffic exhibits a markedly different spatial structure compared to commercial shipping. Density is especially pronounced during the summer season, when one of the world's largest charter fleets operates simultaneously along the Croatian coast, complemented by a substantial privately owned Italian recreational fleet distributed throughout the Adriatic basin. The resulting spatial footprint is extensive, covering coastal zones, island archipelagos, and open-sea transit corridors. Although pleasure craft generally operate at lower displacement and speed (sailing boats) compared to commercial vessels, their high seasonal concentration and frequent route variability can contribute to navigational complexity. In congested areas or near major shipping corridors, interactions between recreational vessels and merchant traffic may increase the risk of collisions.

Fisheries represent a historically and economically significant maritime activity in the Adriatic Sea and constitute a distinct operational layer within the overall traffic system. The left panel of Fig. 6 illustrates all recorded AIS trajectories of fishing vessels during the reference year. The spatial footprint demonstrates widespread activity across both coastal and offshore areas, with particularly intensive operations in the northern Adriatic and in productive fishing grounds along the Italian and Croatian continental shelves. Unlike merchant shipping, fishing vessel movements are characterised by irregular patterns, frequent course alterations, and reduced transit speeds associated with active fishing operations. These behavioural characteristics increase navigational unpredictability and may generate localised encounter complexity, particularly where fishing grounds overlap with major

longitudinal shipping corridors. Fishing vessels are frequently present within or in proximity to Traffic Separation Schemes (TSS) and established transit lanes, occasionally acting as dynamic obstacles to through-traffic. The right panel presents calculated fishing pressure, incorporating not only spatial trajectory density but also the temporal component of vessel presence. This representation reflects cumulative occupation intensity rather than simple route frequency, highlighting areas of prolonged fishing activity. The temporal distribution of fishing operations shows observable variability, with reduced activity on weekends and a marked seasonal decline in August, when a substantial portion of the Italian fishing fleet traditionally suspends operations.

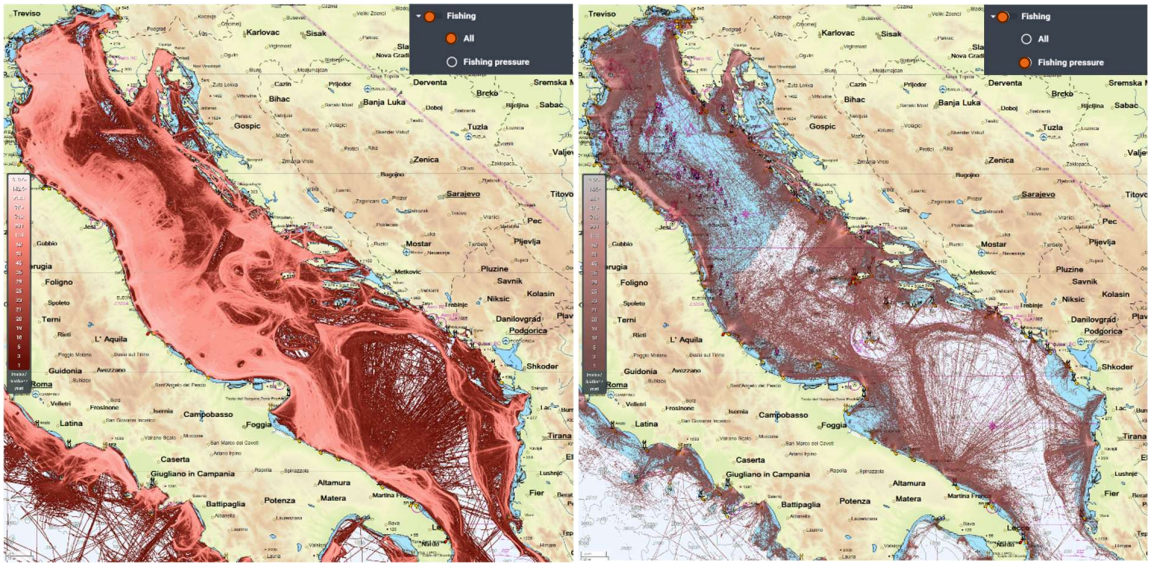


Figure 6. Annual AIS trajectories (2023) of fishing vessels (left) and calculated fishing pressure incorporating temporal vessel presence (right), illustrating spatial intensity and cumulative operational occupation across the Adriatic Sea.

From a risk perspective, fishing vessels typically do not carry hazardous cargo; however, their high spatial concentration, manoeuvring variability, and frequent operation at low speeds contribute to encounter complexity with commercial vessels.

To provide a clearer representation of potential interaction zones, tanker trajectories are overlaid onto the aggregated traffic layer of all vessel categories. This composite visualization allows direct identification of spatial coincidence between high-risk cargo carriers and dense multi-class traffic flows. The left panel of Fig. 7 presents the northern and central Adriatic, while the right panel focuses on the southern Adriatic basin. The overlay shows that tanker routes largely follow the dominant longitudinal corridor; however, several segments are close to coastal belts and port approach areas. In certain stretches, tankers are observed navigating at or near service speed within relatively confined

coastal corridors. Such operating conditions imply that potential accident locations may occur close to shore, where environmental sensitivity is typically higher. Moreover, higher transit speeds increase kinetic energy and may contribute to more severe structural damage in the event of collision or allision, potentially resulting in larger oil outflow volumes. The spatial superposition highlights not only encounter probability zones but also areas where the combination of vessel type, speed profile, and coastal proximity may amplify environmental consequences.

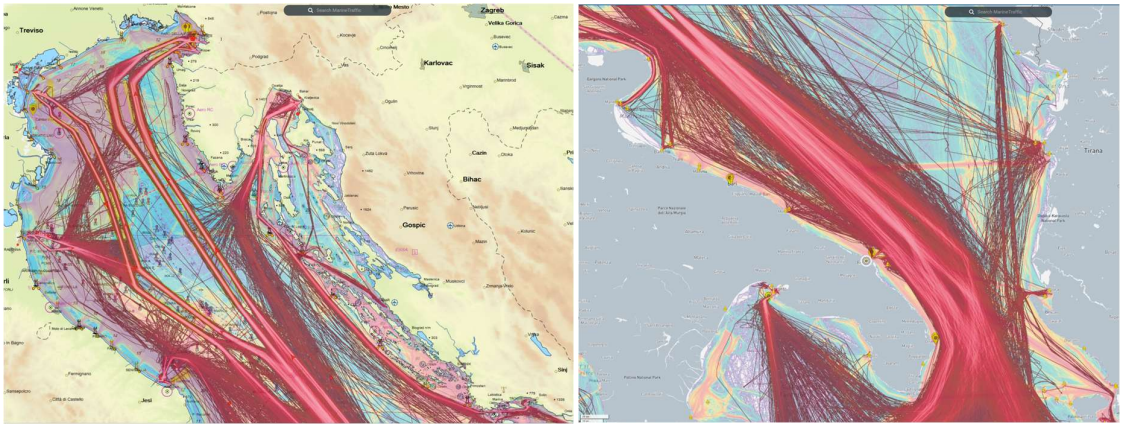


Figure 7. Overlay of tanker trajectories onto aggregated AIS traffic density (2023): northern and central Adriatic (left) and southern Adriatic (right), illustrating spatial interaction zones and coastal proximity of high-capacity tanker routes.

3.5 TRAFFIC RISK ANALYSIS

For the probabilistic assessment of collision and grounding frequencies, a dedicated IWRAP (IALA Waterway Risk Assessment Program) model was developed for the entire Adriatic Sea. In contrast to the generalized density grids used in Marine Traffic visualisations, a refined traffic network was constructed, incorporating a higher-resolution fairway structure and explicitly defined route segments reflecting the dominant longitudinal corridors and port approach channels. The model was populated with full-year AIS traffic data for 2024 from the national Slovenian AIS system, complemented by data from MAREΣ. Based on the preceding traffic screening and preliminary IWRAP encounter analysis, potential high-risk locations were first identified through expert judgement. This approach follows the methodology previously applied in the NAMIRS project, where the most complex segment, the extended area of the Gulf of Trieste, was modelled stochastically, while other sections were defined through structured expert assessment. Given the spatial scale of the entire Adriatic basin and the complexity of modelling release scenarios at each potential interaction point, the expert group

reduced the candidate collision and grounding locations to a representative set of critical nodes. These locations correspond to zones of high tanker traffic intensity, encounter convergence, or proximity to environmentally sensitive coastal areas. Fig. 8 presents tanker trajectory density overlaid with the selected incident locations. The selected nodes represent scenarios that may lead to the release of bunker fuel (HFO/LSFO), cargo diesel (refined products) and crude oil cargo. Where multiple release types are plausible for a single vessel at a given location, the scenario is represented by three concentric circles. The smallest circle corresponds to bunker fuel volume, the intermediate ring to diesel cargo, and the outermost ring to crude oil cargo, reflecting increasing release quantities. The radii are calculated based on predefined spill volumes and uniform surface-film thickness assumptions (0.1mm), ensuring consistent spatial comparability across scenarios. The associated table provides the geographical coordinates, accident type (collision, crossing, overtaking, allision), release type, and corresponding estimated volumes for each selected location.

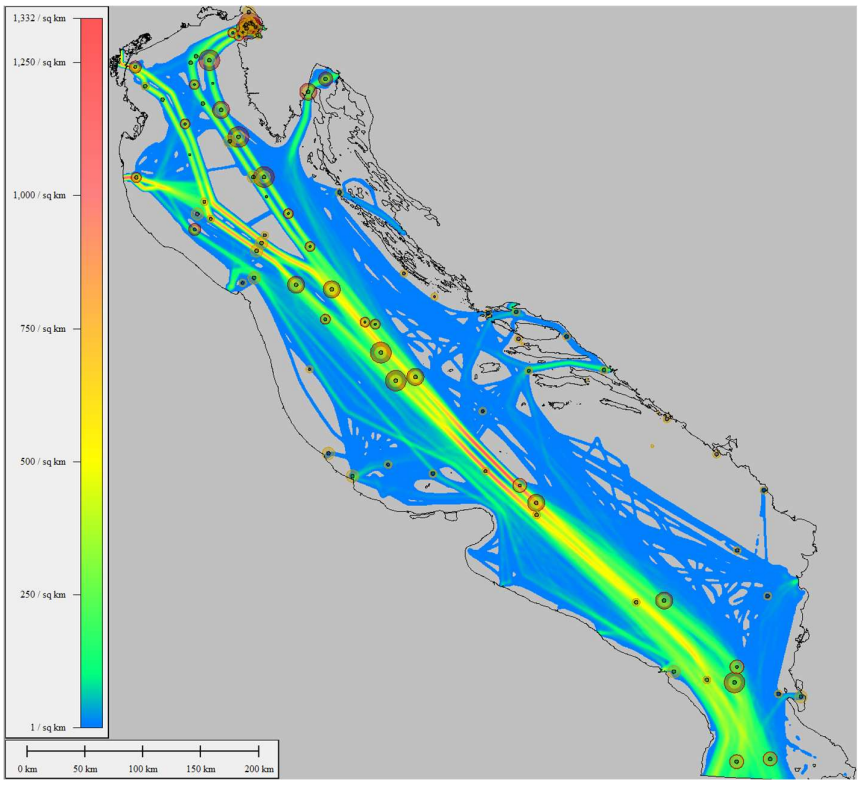


Figure 8. Tanker traffic density (2024) with selected representative collision and grounding locations used in the IWRAP-based risk assessment. Concentric circles indicate potential release scenarios: inner ring – bunker fuel (HFO/LSFO), middle ring – diesel cargo, outer ring – crude oil cargo, proportional to predefined release volumes.

The subsequent figure presents trajectories of large crude oil tankers overlaid with dynamically identified near-encounter situations derived from AIS data. The analysis includes interaction events in which the Closest Point of Approach (CPA) between two vessels initially fell below 800 m and subsequently decreased to 400 m during the encounter sequence. To ensure that only genuinely navigationally relevant situations were considered, at least one of the interacting vessels was required to maintain a speed of 9 knots or greater, thereby excluding static or low-speed manoeuvring conditions. This dynamic filtering ensures that the identified events represent operational transit scenarios rather than anchorage proximity, port manoeuvring, or stationary traffic accumulation. The spatial distribution of such reduced-CPA encounters closely follows the main longitudinal crude oil tanker corridor but also highlights convergence zones near port approaches and selected cross-Adriatic routes. The figure additionally overlays the previously expert-selected representative accident locations. The spatial coincidence between dynamically observed near-miss clusters and predefined scenario nodes confirms the methodological consistency between AIS-based encounter screening and expert-based scenario reduction. This integrated approach enhances the robustness of subsequent probabilistic modelling and spill-consequence assessment.

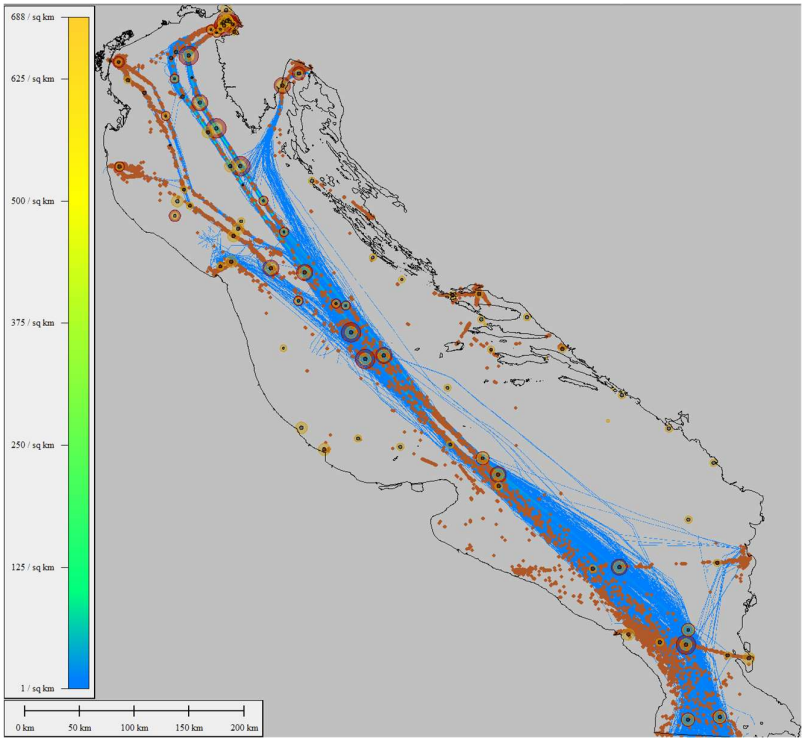


Figure 9. Trajectories of large crude oil tankers (2024) with dynamically identified near-encounter events (CPA 800–400 m; ≥ 9 knots for at least one vessel), overlaid with expert-selected representative accident locations used for probabilistic modelling.

It should be emphasized that not every dynamically identified close-encounter event necessarily results in structural damage or cargo release. The subsequent analysis, therefore, applies a simplified collision severity model that incorporates encounter geometry (overtaking, crossing, head-on), vessel speeds, and representative vessel size classes with their respective draughts. Based on these parameters, relative impact energy indices were calculated for each encounter. The resulting values, ranging from 1,000 to 3,000 in normalized units, represent comparative penetration potential rather than absolute structural response. A reference threshold value of 1000 corresponds to the minimum estimated energy required to cause hull penetration leading to potential outflow, while higher index values indicate progressively greater structural loading and increased likelihood of breach. This approach allows differentiation between low-severity navigational proximity events and physically plausible spill-generating collisions within a basin-wide probabilistic framework. The probabilistic modelling results indicate a somewhat higher collision exposure in the Otranto Strait than previously estimated through expert-based assessment. This divergence does not invalidate the earlier approach; rather, it suggests that the dynamic evolution of traffic patterns in the Otranto entry corridor may not have been fully captured in the original qualitative screening.

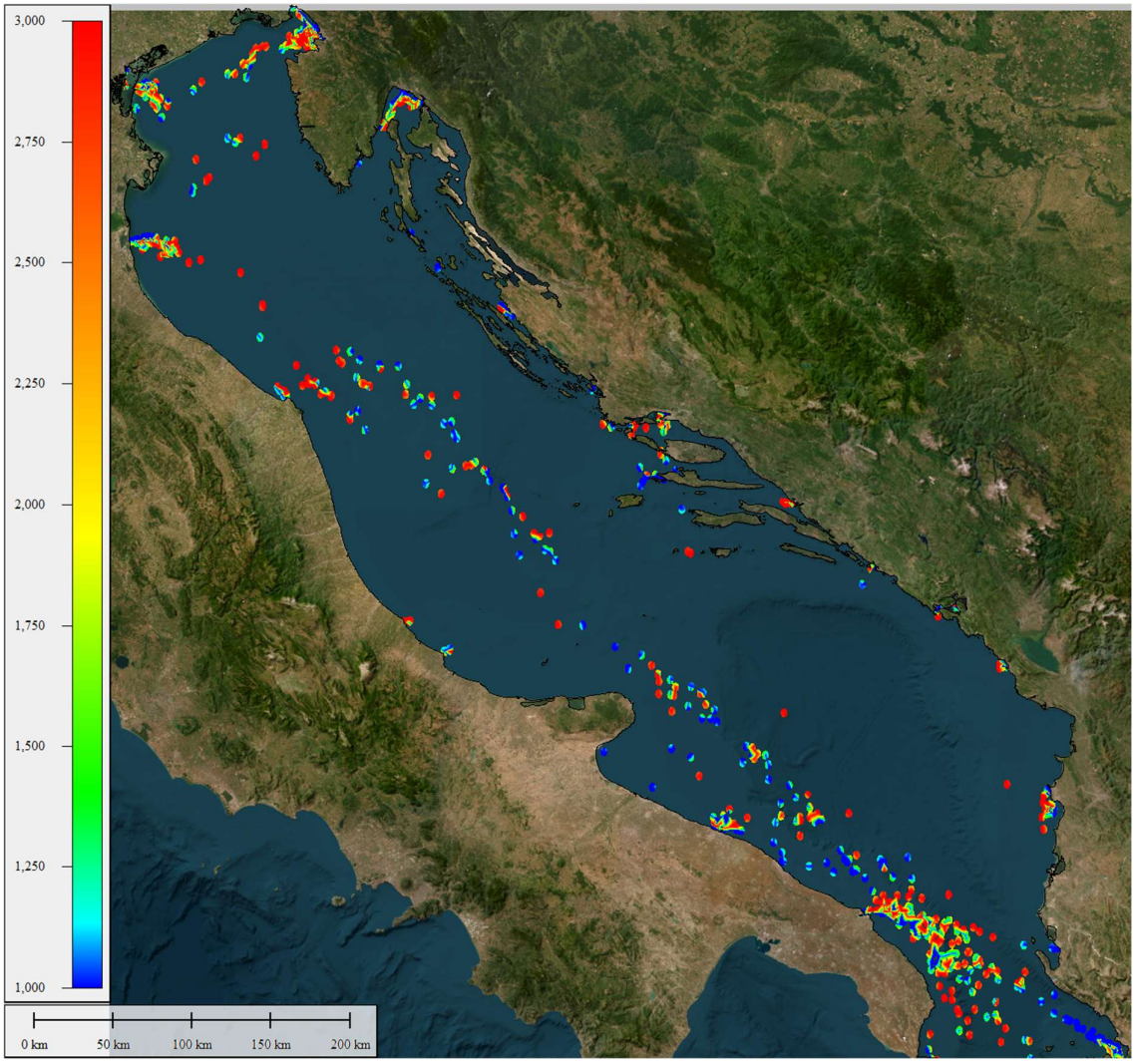


Figure 10. Relative collision energy index for dynamically filtered encounter events (CPA 800–400 m; ≥ 9 knots). Values (1,000–3,000) represent normalized impact energy derived from vessel speed, size, and encounter geometry.

The increased traffic intensity and interaction complexity observed in the AIS-based modelling highlight the need for a more detailed examination of vessel flows at the Adriatic–Ionian transition. For this reason, a focused traffic review was conducted along the Otranto crossing line (Fig. 11), representing the principal maritime gateway between the Adriatic Sea and the Mediterranean basin. The following figures provide a structured breakdown of traffic characteristics across this control line.

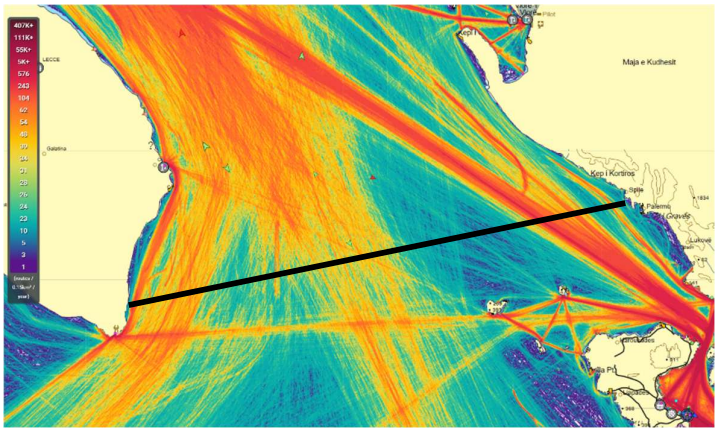


Figure 11. Crossing line statistics

Fig. 12 presents the number of all vessels crossing the Otranto line during the period May–August 2024, categorized by the next port of call for both northbound and southbound traffic. Only the most significant destinations are shown, representing the dominant traffic flows toward the Northern Adriatic industrial cluster. The data are derived from AIS static voyage messages, specifically the "next port of call" field transmitted by vessels. It should be noted that this information is manually entered by the vessel's crew and may therefore be subject to inconsistencies, typographical variations, or incomplete updates. As a result, minor deviations in absolute values are possible, and the analysis should be interpreted as indicative of dominant routing patterns rather than as exact port-throughput statistics. The consolidated results clearly confirm the structural concentration of northbound traffic toward the Northern Adriatic energy and industrial hubs, with Trieste and Ravenna representing the primary destinations, followed by Koper. Southern Adriatic ports such as Brindisi and Ancona form a secondary traffic tier, while Venice and Durres account for comparatively smaller northbound flows within the analysed period. The consolidated southbound crossings of the Otranto line confirm a pronounced routing concentration toward the Greek Ionian gateway of Igoumenitsa, which significantly exceeds all other individual destinations. Piraeus is the second major hub, serving onward distribution to the Eastern Mediterranean and global liner networks. A secondary traffic tier includes Augusta, Corfu, Patras, and Gioia Tauro, indicating diversified distribution between Southern Italy and Western Greece. The presence of ports such as Mersin further illustrates the role of the Otranto Strait as a transit corridor extending beyond the Adriatic–Ionian interface toward the Levant and Eastern Mediterranean basin.

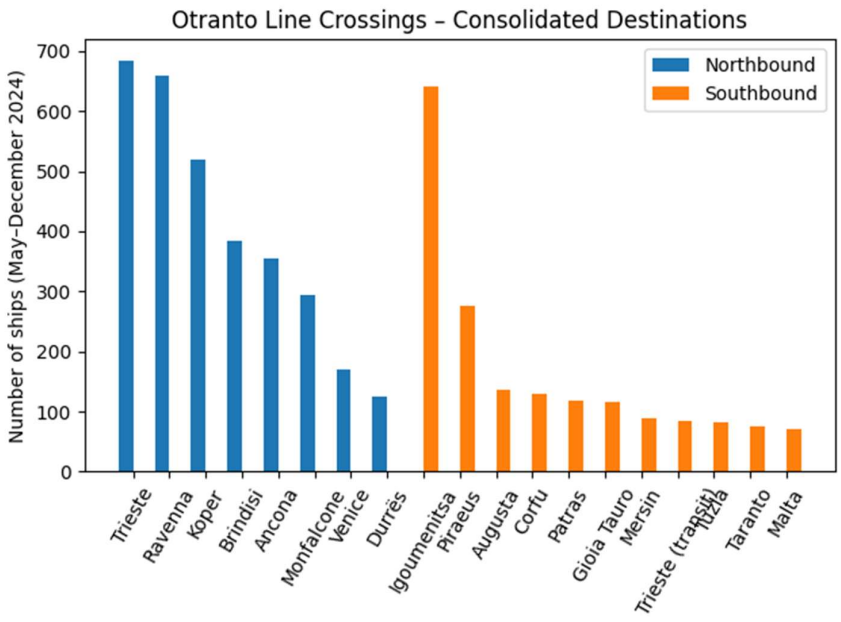


Figure 12. Consolidated northbound and southbound vessel crossings of the Otranto control line (May–August 2024), aggregated by next port of call and harmonized to eliminate duplicated AIS destination codes. The figure illustrates the dominant routing structure between the Northern Adriatic industrial cluster and the Ionian–Eastern Mediterranean gateways. Note: The data are derived from AIS static voyage reports ("next port of call"), manually entered by ship crews. While dominant routing patterns are reliably captured, minor inconsistencies or coding variations may introduce marginal deviations in absolute counts.

Fig. 13 illustrates the vessel length (LOA) distribution for both northbound and southbound traffic during the same period. Both directions show a broadly similar size distribution:

- The dominant class lies between approximately 120 m and 220 m LOA, corresponding primarily to medium-sized cargo vessels, product tankers, and feeder container ships.
- A significant number of vessels fall within the 80–150 m range, representing smaller general cargo and regional tankers.
- A smaller but operationally relevant fraction exceeds 250 m LOA, including large crude oil tankers and larger container vessels.

The symmetry between northbound and southbound distributions confirms that the Strait handles balanced bidirectional flows of comparable vessel dimensions, increasing encounter probability under opposing traffic conditions.

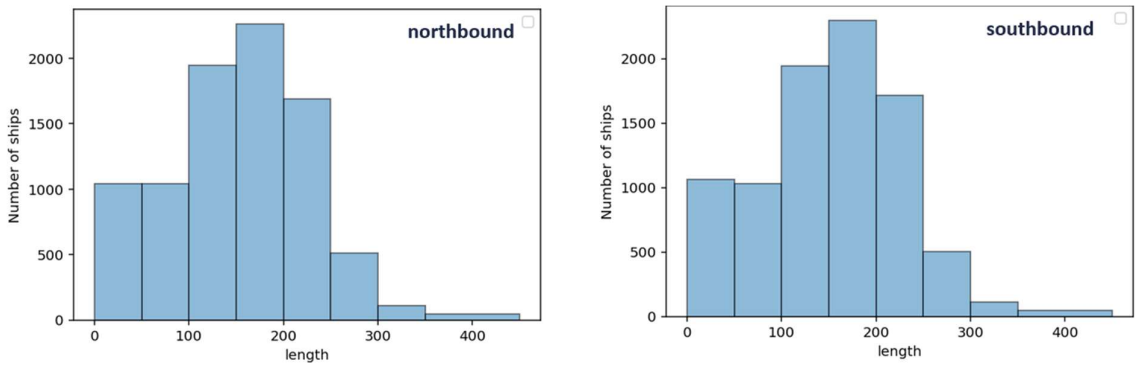


Figure 13. Distribution of vessel length overall (LOA) for northbound and southbound crossings of the Otranto line (May–August 2024).

Fig. 14 presents monthly traffic counts (May–August 2024) categorized by vessel type and dangerous goods (DG) involvement. Key observations include:

- Total crossings range approximately between 1,200 and 1,650 vessels per month per direction.
- Cargo vessels constitute the dominant category in both directions.
- Tankers represent a stable and non-negligible fraction (approximately 140–170 per month).
- DG-classified vessels consistently account for a measurable subset of traffic, reflecting the transport of petroleum products and other hazardous cargo.

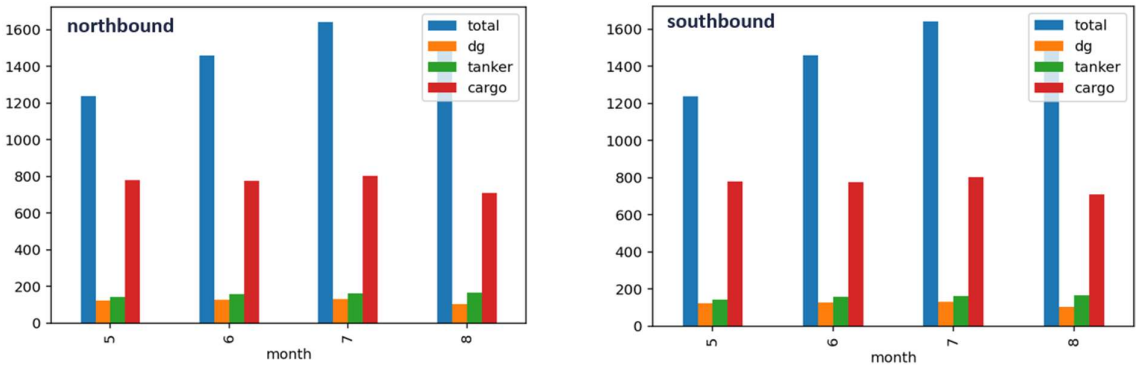


Figure 14. Monthly number of vessels crossing the Otranto line (May–August 2024), categorized by vessel type and dangerous goods (DG) classification for both traffic directions.

The monthly increase toward July indicates seasonal amplification of traffic intensity, particularly relevant for probabilistic collision exposure modelling.

Using the IWRAP application and AIS-derived kinematic data, a high-resolution spatial distribution of both average and maximum vessel speeds across the entire Adriatic Sea was generated. The results reveal a strongly structured speed field: longitudinal transit corridors are characterized by stable operational speeds of commercial vessels, whereas localized maximum values are particularly pronounced within archipelago regions. These elevated maxima are primarily associated with high-speed recreational craft (motor yachts and planning vessels), which are seasonally concentrated in coastal waters. Distinct high-speed bands are also observed along regular ferry routes, reflecting scheduled operations and optimized transit profiles. From a risk perspective, vessel speed is a critical determinant of encounter severity and potential impact energy. The spatial variability of both average and peak speeds, therefore, represents an essential input for subsequent probabilistic modelling.

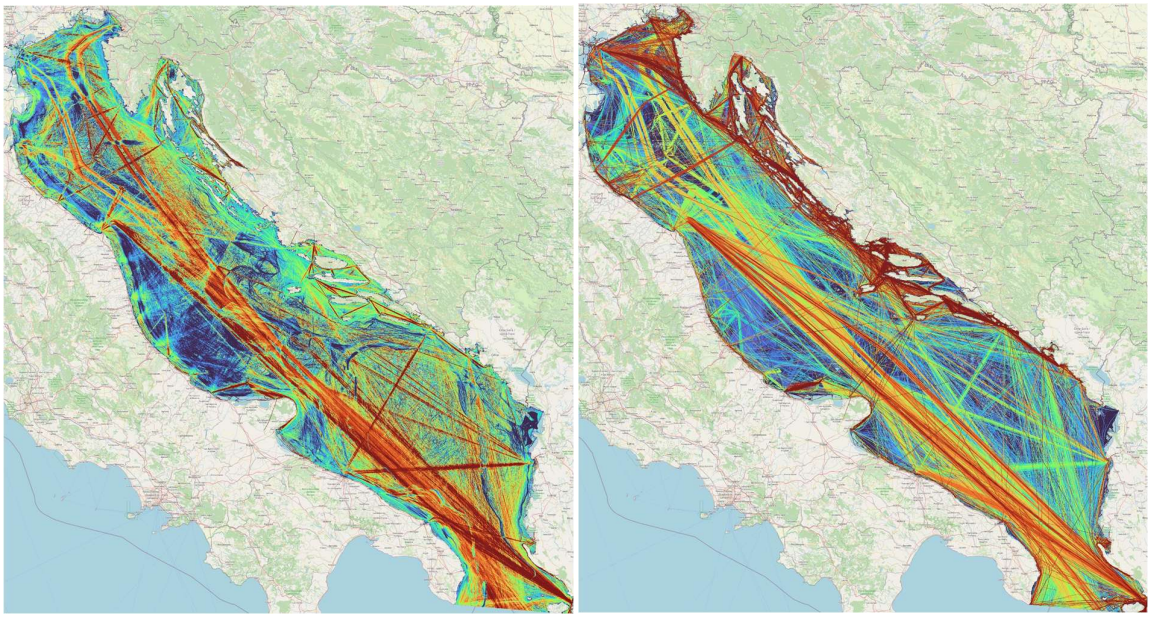


Figure 15. High-resolution spatial distribution of average and maximum vessel speeds in the Adriatic Sea derived from AIS data within the IWRAP modelling framework. Elevated maximum speeds are observed in archipelago regions due to high-speed recreational craft and along established ferry corridors.

3.5.1 PROBABILISTIC SHIP COLLISION AND GROUNDING ASSESSMENT (IWRAP)

Risk within the present study is defined as a function of event frequency and consequence severity. In line with established maritime risk assessment practice, the probabilistic occurrence of navigational accidents (collision, allision, and grounding) is first quantified, after which representative consequence scenarios are applied in subsequent chapters. The resulting risk levels are interpreted within the ALARP (As Low As Reasonably Practicable) framework. While earlier assessments in the

Northern Adriatic (NAMIRS project) applied stochastic simulation methodologies based on the approach of Gucma et al. (2006, 2016), the present basin-wide analysis employs the IWRAP (IALA Waterway Risk Assessment Programme) model as the primary probabilistic tool. IWRAP provides a structured and internationally recognized framework for estimating accident frequencies based on geometric encounter theory and traffic distribution characteristics. The model integrates:

- vessel traffic intensity and directional flow structure,
- vessel type composition and size classes,
- fairway geometry and traffic separation schemes,
- encounter configurations (crossing, overtaking, head-on),
- and grounding exposure along navigational corridors.

Unlike dynamic consequence models, IWRAP primarily evaluates the frequency of potential accident events, rather than structural damage or spill magnitude. Collision and grounding probabilities are derived from encounter rates, traffic density distributions, and causation factors calibrated according to established maritime safety literature. For the Adriatic-wide assessment, AIS-derived traffic data for the full year 2024 were processed and structured into a high-resolution spatial grid, enabling detailed representation of longitudinal transit corridors, port-approach convergence zones, and cross-basin ferry routes. Based on these inputs, IWRAP simulations were performed to identify statistically significant encounter clusters and spatially concentrated accident probabilities. The resulting probabilistic outputs formed the quantitative foundation for defining representative incident locations.

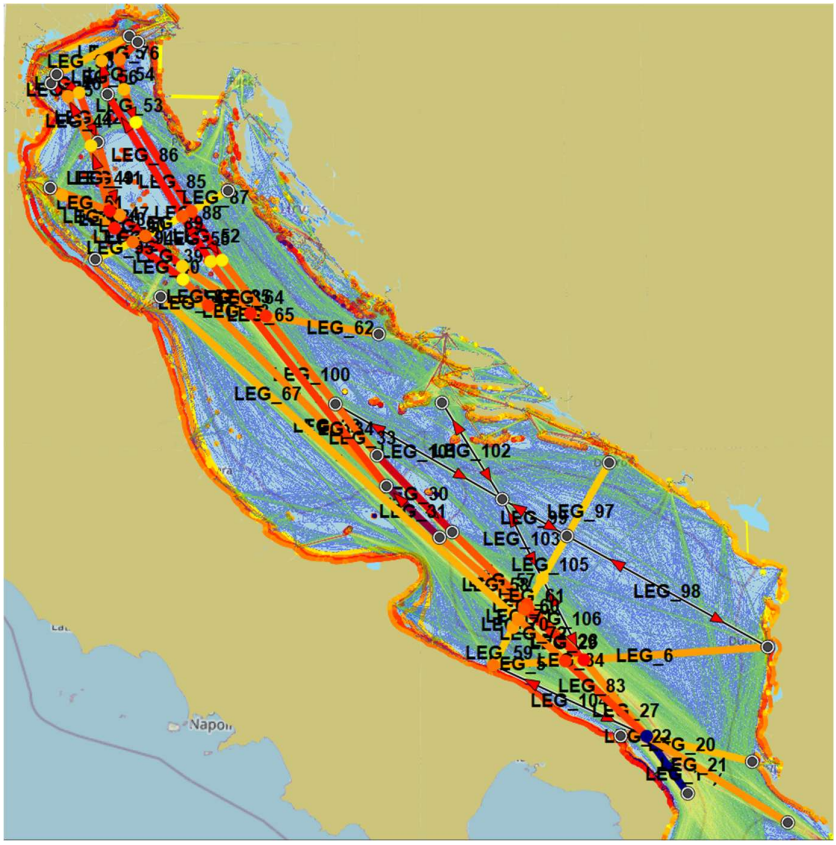


Figure 16. Quantified risk for sailing legs, waypoints, and shallow bathymetry segments

These locations were subsequently refined through expert evaluation, ensuring consistency with operational practices, vessel maneuvering characteristics, hydrometeorological exposure, and known navigational constraints. In particular, dynamically filtered close-encounter situations (CPA thresholds combined with minimum speed criteria) were cross-checked against modelled collision frequencies to ensure physical plausibility. It is important to emphasize that the probabilistic modelling step determines where accidents are most likely to occur, whereas the subsequent spill assessment determines the consequences of such accidents. The assumed release quantities of bunker fuel (HFO/LSFO), crude oil, and refined petroleum products were therefore derived from a combination of traffic composition analysis, representative vessel classes, and operational expertise, rather than directly from IWRAP outputs. Fig. 16 presents the spatial distribution of risk levels using colour gradients for individual waypoints, sailing legs, and shallow/coastal areas. Darker colours indicate higher risk levels. The IWRAP model identified particularly elevated risk along the southern Adriatic coast at the entrance to the Adriatic Sea, as well as in parts of the central Adriatic. Increased

risk levels are also observed in the area between Istria and the ports of Ravenna and Ancona. The highest risk values are recorded in the Gulf of Trieste, which has already been analysed in detail within the NAMIRS project. The identified high-risk areas are illustrated in greater detail in Fig. 18.

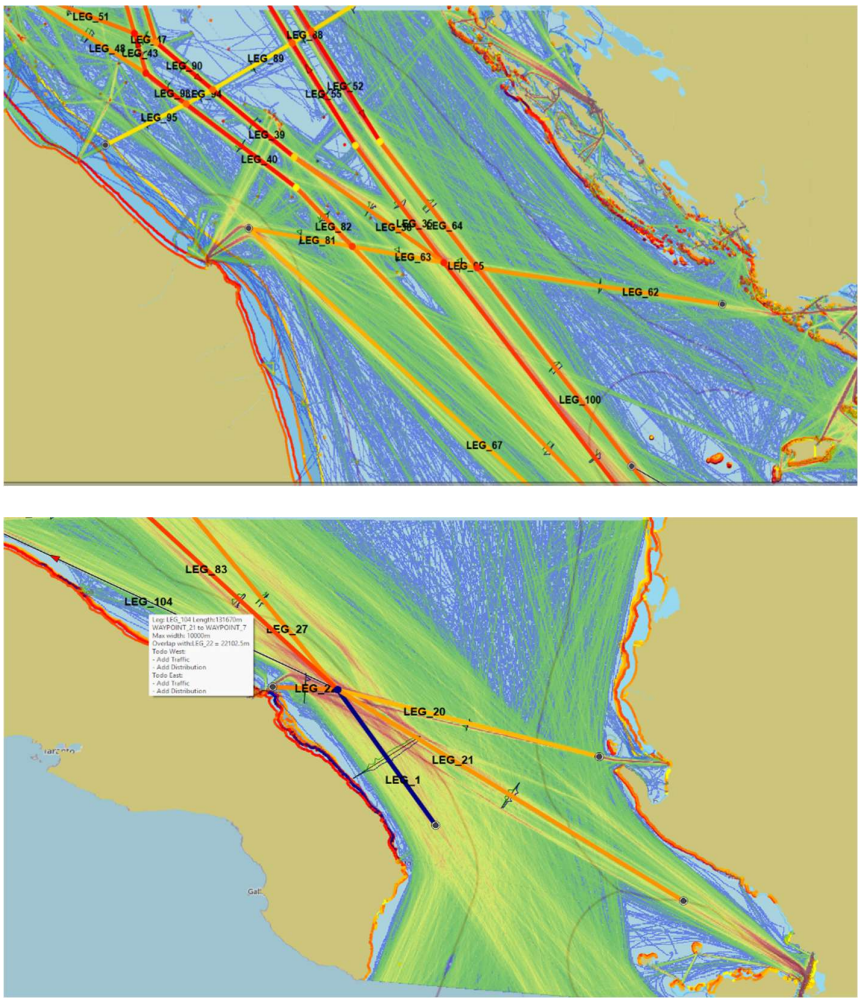


Figure 17. Detailed view of high collision and grounding risk areas derived from IWRAP analysis

The presented probabilities in Table 5 are derived from IWRAP probabilistic modelling. The calculations exclude anchorage areas and port approach/harbour manoeuvring zones, focusing exclusively on navigational risk along defined traffic legs and open-sea routes. Therefore, the results represent basin-wide navigational risk under through-traffic conditions and do not account for confined port-area operational risks. The results indicate that grounding represents the dominant navigational risk category in the Adriatic Sea under the analysed traffic conditions. The total grounding

frequency corresponds to an annual probability of approximately 0.113 events per year, meaning that statistically, one grounding event may be expected roughly every 9 years within the modelled area. Notably, drifting groundings contribute significantly more to the total grounding risk than powered groundings, suggesting that loss-of-control scenarios (e.g., propulsion or steering failure) represent critical vulnerability. In contrast, allisions exhibit substantially lower frequencies, with a total annual probability of approximately 0.0042 (one event every ~238 years). This is expected, given that fixed-object interactions are limited in open-sea traffic legs and primarily occur near coastal or port structures, which were excluded from this model. Regarding ship collisions, the total collision frequency corresponds to an annual probability of approximately 0.0207 (one collision every ~48 years). Among collision types, overtaking and merging scenarios contribute more than head-on and crossing encounters. This reflects the structured traffic flow and longitudinal traffic alignment typical of Adriatic shipping routes. Bend-related collisions are very rare, indicating that geometric route curvature alone does not significantly elevate risk at the basin scale.

Table 5. Detailed view of high collision and grounding risk derived from IWRAP analysis

Incident Type	Years Between Incidents	Annual Probability (1/year)
Powered Grounding	70.4	0.0142
Drifting Grounding	10.11	0.09891
Total Groundings	**8.8**	**0.11315**
Powered Allision	598.1	0.00167
Drifting Allision	395.2	0.00253
Total Allisions	**238.0**	**0.0042**
Overtaking Collision	97.4	0.01027
Head-On Collision	267.0	0.00375
Crossing Collision	988.3	0.00101
Merging Collision	191.1	0.00523
Bend Collision	2278.0	0.00044
Total Collisions	**48.3**	**0.02069**

Table 6 presents the distribution of annual grounding probability (λ) across vessel length classes and ship categories for the Adriatic Sea. The estimated grounding frequency is 0.11315 events per year, corresponding to an expected return period of approximately 8.8 years. The results indicate that grounding risk is not uniformly distributed across vessel types or size categories. The highest

contributions come from cargo vessels, particularly in the 125–225 m range, and from tankers in the 175–275 m range. Importantly, the presented values represent only open-sea and defined traffic leg risk, as anchorage areas and port approach/manoeuvring zones were excluded from the probabilistic modelling framework.

Table 6. Annual probability of total grounding events classified by vessel length and type

Length	Crude oil	Oil products	Chemical	Gas	Container	General cargo	Bulk	Ro-Ro cargo	Passenger	Fast ferry	Support	Fishing	Pleasure	Other	Sum
0-25															
25-50						0.000116737			2.68493e-05	5.00346e-06	0.00146857				0.00161716
50-75		5.30141e-06				0.000586792			8.1304e-06	1.34217e-05	0.000181824			0.000138504	0.000933974
75-100		0.000308415				0.00718409					7.3783e-05			0.000356066	0.00792235
100-125		0.00432108				0.0108847			0.0020638		1.30588e-05			0.000138457	0.0155636
125-150		0.00331205				0.0103571			0.00330333		1.36119e-05			0.000145405	0.0171315
150-175		0.00089023				0.00784592			0.000831889					0.000454091	0.0100221
175-200		0.0073847				***0.0155314***			0.000653045					0.000542302	0.0241114
200-225						0.0124504			0.00125697						0.0137074
225-250		0.00445986				0.00662792			0.000113406						0.0112012
250-275		0.00579587				5.12651e-05			0.000516236						0.00636338
275-300		0.000784536			3.57679e-05	0.000585418			0.000403195						0.00180892
300-325		0.000507677				0.000416861			5.02144e-05						0.000974753
325-350		4.35223e-05							0.000113565						0.000157088
350-375						0.0016356									0.0016356
375-400															
400-															
Sum		0.0278132			3.57679e-05	0.0742741			0.00748321	1.84252e-05	0.00175084			0.00177483	0.11315

Table 7 presents the annual collision probability (λ) structured as a striking–stuck interaction matrix between vessel categories operating in the Adriatic Sea. The total basin-wide collision frequency amounts to 0.0207 events per year, corresponding to an expected return period of approximately 48 years. The results indicate that collision exposure is strongly concentrated in interactions involving General cargo vessels, which represent the dominant contributor to total collision probability 0.0133). Oil product tankers contribute significantly through interactions with cargo and passenger vessels.

Table 7. Annual probability of total collision events classified by vessel type

Striking/Struck	Crude oil	Oil products	Chemical	Gas	Container	General cargo	Bulk	Ro-Ro cargo	Passenger	Fast ferry	Support	Fishing	Pleasure	Other	Sum
Crude oil															
Oil products		0.00075858			6.67777e-06	0.0038917			0.000353443	6.82205e-07	2.47416e-05			0.000141669	0.00517749
Chemical															
Gas															
Container		5.08051e-07			1.26528e-10	1.20993e-06			1.62021e-07	8.7898e-10	1.37444e-08			1.73909e-08	1.91214e-06
General cargo		0.002888			1.2773e-05	***0.0089279***			0.00108164	1.39399e-06	7.76418e-05			0.000353366	0.0133427
Bulk															
Ro-Ro cargo															
Passenger		0.00027564			3.85596e-07	0.000914739			0.000139511	1.1038e-07	1.17156e-05			1.79281e-05	0.00136003
Fast ferry		1.50426e-07			4.4778e-11	5.11004e-07			1.13219e-07	1.20801e-11	6.08438e-09			9.74421e-09	7.90534e-07
Support		0.000124297			2.09705e-07	0.000315931			4.71895e-05	2.52458e-08	2.00372e-06			7.20622e-06	0.000496863
Fishing															
Pleasure															
Other		7.36334e-05			1.81115e-07	0.000206565			2.4711e-05	2.34064e-08	1.49196e-06			5.19492e-06	0.000311801
Sum		0.00412081			2.02273e-05	0.0142586			0.00164677	2.23612e-06	0.000117615			0.000525391	0.0206916

3.6 INTEGRATED RISK SYNTHESIS

Shipping remains one of the most international and strategically important industries in the world, yet it also represents a domain in which navigational safety and environmental protection depend fundamentally on harmonised international regulation and consistent operational practice. The development and implementation of common safety standards under the framework of international maritime conventions have historically proven to be the most effective mechanism for reducing risk at sea. Nevertheless, the semi-enclosed character of the Adriatic Sea, combined with high traffic density and significant volumes of hazardous cargo, requires basin-specific analytical approaches that integrate traffic modelling, probabilistic assessment and cargo exposure analysis. Within the ASAP project, maritime risk assessment was conducted through a multi-layered analytical framework. First, basin-wide traffic density and vessel classification were evaluated using high-resolution AIS data (including Marine Traffic enterprise datasets), enabling detailed spatial representation of vessel types, speeds, encounter geometry and route convergence zones. This was complemented by probabilistic collision modelling performed in the IWRAP (IALA Waterway Risk Assessment Programme) environment, where encounter frequencies and accident probabilities were derived using dynamically filtered AIS trajectories. Only operationally relevant encounters were considered, thereby excluding low-energy manoeuvring or stationary interactions that would artificially inflate risk estimates. In parallel with traffic modelling, ADRIREP ship reporting messages were reviewed to assess declared dangerous goods, bunker quantities, and bulk cargo exposure. The review of ADRIREP data revealed substantial inconsistencies in reporting practice, particularly regarding:

- mixed use of units (kg vs. metric tonnes),
- inconsistent declaration of total quantities (TOT Quantity),
- incomplete association between IMO class and mass,
- repeated reporting of identical cargo across FR and PR messages,
- and limited transparency for bulk chemical cargo transported under multi-parcel declarations.

These inconsistencies introduce significant uncertainty into quantitative exposure estimates, especially for chemical tankers and vessels carrying multiple IMDG classes simultaneously. Despite these limitations, the combination of expert judgement, vessel-type classification and cross-validation with AIS-derived voyage data enabled the identification of the most plausible cargo exposure scenarios. Based on integrated traffic analysis, probabilistic encounter modelling, and

cargo exposure review, the most likely accident locations were determined along major shipping corridors, traffic convergence zones, and port approach areas. For each identified hotspot, the most probable incident type (collision or allision) was assigned using IWRAP-derived encounter statistics.

Grounding scenarios were fully modelled within the IWRAP probabilistic framework, incorporating detailed bathymetric data and depth profiles, including shallow areas surrounding numerous islands and archipelagos across the Adriatic basin. However, potential spill release locations resulting from grounding events were not further developed in the subsequent spill simulation phase. This decision was based on the fact that grounding-induced releases would, by definition, imply immediate interaction between the pollutant and the coastline, thereby shifting the analytical focus from offshore spill propagation and response modelling to shoreline contamination and clean-up scenarios, which were beyond the scope of the present project phase. Shoreline impact assessment and coastal clean-up scenario development remain feasible extensions for future work.

For each identified accident location, estimated release quantities were defined for:

- bunker fuel (HFO/LSFO),
- refined petroleum products (diesel),
- crude oil (where relevant for tanker exposure).

These quantities represent scenario-based release assumptions derived from vessel type, declared cargo data, and typical tanker sizes. Detailed coordinates, accident type, and release assumptions are presented in Table 8. The graphical representations accompanying this section illustrate the initial spatial extent of the assumed spill volumes. Each concentric circle represents the surface area corresponding to the estimated release quantity, distributed as a uniform 0.1 mm oil layer. The inner circle corresponds to bunker fuel, the intermediate ring to refined product (diesel), and the outer ring, where applicable, to crude oil exposure. These graphical representations do not include hydrodynamic transport, meteorological forcing, or weathering processes; they serve solely as initial-condition visualisations for subsequent spill-propagation modelling. The stochastic model previously applied to the extended Gulf of Trieste, recognised as the highest-risk area in the Northern Adriatic due to dense traffic, hazardous cargo, shallow bathymetry, and an environmentally sensitive coastline, was extrapolated to the broader Adriatic basin using a harmonised methodological framework. The predicted quantities of fuel and/or cargo potentially discharged were integrated with probabilistic encounter frequencies to estimate accident likelihood. The probability of a major navigational accident within the analysed traffic regime is estimated at approximately once every 8

years (including collisions and groundings), subject to traffic growth trends and evolving operational conditions.

Table 8. Identified high-probability accident locations in the Northern Adriatic with corresponding accident type and scenario-based release quantities of bunker fuel (HFO/LSFO), crude oil and refined petroleum products (diesel). Release quantities represent initial spill assumptions for subsequent hydrodynamic dispersion modelling

LONGITUDE	LATITUDE	Type of Accident	Bunker Oil (HFO_&_LSFO)	Crude Oil	Product (diesel)
13.70292	45.56519	Allision	1000	0	5000
13.68556	45.62439	Allision	1000	15000	5000
13.65507	45.64424	Allision	1000	15000	5000
13.58977	45.61299	Crossing	1500	30000	15000
13.58274	45.64075	Crossing	1500	0	15000
13.62217	45.65245	Crossing	1500	30000	15000
13.61214	45.73401	Crossing	1500	0	15000
13.50791	45.55830	Overtaking	500	5000	5000
13.44309	45.58248	Overtaking	500	5000	5000
13.54964	45.58444	Overtaking	500	5000	5000
13.56222	45.63088	Overtaking	500	5000	5000
13.63880	45.66263	Overtaking	500	5000	5000
13.05530	45.40681	Crossing	1500	0	0
13.19543	45.37879	Crossing	1500	30000	15000
12.99925	45.35952	Crossing	1500	0	0
12.41420	45.32799	Allision	1000	10000	5000
14.42334	45.23865	Crossing	1500	15000	5000
13.23047	45.20537	Overtaking	500	0	0
13.03779	45.19661	Overtaking	500	5000	5000
12.51755	45.18435	Crossing	1500	0	5000
14.23942	45.14231	Crossing	1500	15000	15000
12.70147	45.08451	Crossing	1500	0	0
13.12712	45.05473	Crossing	1500	0	0
13.31980	45.00744	Crossing	1500	15000	15000
12.93969	44.90234	Overtaking	500	5000	5000
13.50372	44.80424	Crossing	1500	30000	15000
13.41089	44.77272	Crossing	1500	0	15000
12.98874	44.67112	Overtaking	500	0	0
13.77173	44.50296	Crossing	1500	30000	15000

13.65962	44.50296	Crossing	1500	0	15000
12.42471	44.49946	Allision	1500	5000	5000
13.79800	44.35407	Overtaking	500	0	0
13.14288	44.31553	Crossing	1000	0	5000
14.02922	44.22620	Overtaking	500	5000	5000
13.06932	44.22270	Allision	1500	0	15000
13.20945	44.18591	Crossing	1000	0	5000
13.04129	44.10534	Allision	1000	10000	5000
13.78048	44.06155	Allision	1000	0	5000
13.74720	44.00199	Crossing	1500	0	15000
14.25868	43.97572	Overtaking	500	5000	5000
13.69465	43.94243	Crossing	1500	0	15000
13.66838	43.73574	Crossing	1500	0	15000
13.54752	43.69720	Allision	1000	0	5000
14.11155	43.68319	Crossing	1500	15000	15000
14.48815	43.64816	Crossing	1500	15000	15000
14.56925	44.38620	Crossing	1500	0	5000
15.24834	43.76961	Overtaking	1000	0	5000
15.57175	43.59134	Overtaking	500	0	5000
16.43418	43.47485	Crossing	1500	0	5000
16.13823	43.46389	Crossing	1500	0	5000
14.41957	43.41802	Crossing	1000	5000	5000
14.83842	43.39607	Overtaking	500	5000	5000
14.94691	43.38011	Overtaking	500	5000	5000
16.96701	43.28471	Crossing	1500	0	5000
16.45890	43.26821	Crossing	1500	0	5000
16.50216	43.22720	Crossing	0	0	1000
15.00596	43.16112	Allision	1500	30000	15000
14.25203	43.03176	Overtaking	500	0	5000
17.36183	43.02574	Crossing	1500	0	5000
16.56739	43.02072	Crossing	1000	0	5000
15.37125	42.97251	Crossing	1500	15000	15000
17.18262	42.94989	Crossing	0	0	1000
15.16389	42.94336	Allision	1500	30000	15000
16.08124	42.70667	Crossing	1000	0	5000
17.93175	42.69556	Crossing	0	0	1000
18.02582	42.64709	Crossing	1500	0	5000

17.87064	42.43461	Crossing	0	0	1000
14.45252	42.37732	Crossing	1500	0	15000
18.54973	42.37123	Crossing	1500	0	5000
15.08287	42.28951	Crossing	1000	0	5000
16.11147	42.23868	Overtaking	1000	0	5000
15.55527	42.21988	Crossing	1500	0	5000
14.70658	42.19851	Crossing	1500	0	15000
16.47264	42.12573	Overtaking	1000	5000	15000
19.04892	42.08752	Allision	1500	0	5000
16.64567	41.98910	Crossing	1500	15000	15000
16.65116	41.89410	Crossing	1500	0	5000
18.76740	41.61339	Crossing	1500	0	5000
19.08875	41.25097	Crossing	1500	0	5000
17.99699	41.21483	Crossing	1500	15000	15000
17.70173	41.20139	Crossing	1500		5000
18.76465	40.68377	Overtaking	1000	5000	15000
18.09929	40.64626	Allision	1500	0	15000
18.44743	40.57955	Crossing	1500	0	5000
18.73994	40.55869	Allision	1500	30000	15000
19.20479	40.46680	Crossing	1500	0	5000
19.44031	40.44329	Allision	1500	0	15000
19.11622	39.94029	Overtaking	1500	5000	15000
18.76191	39.91817	Overtaking	1500	5000	15000

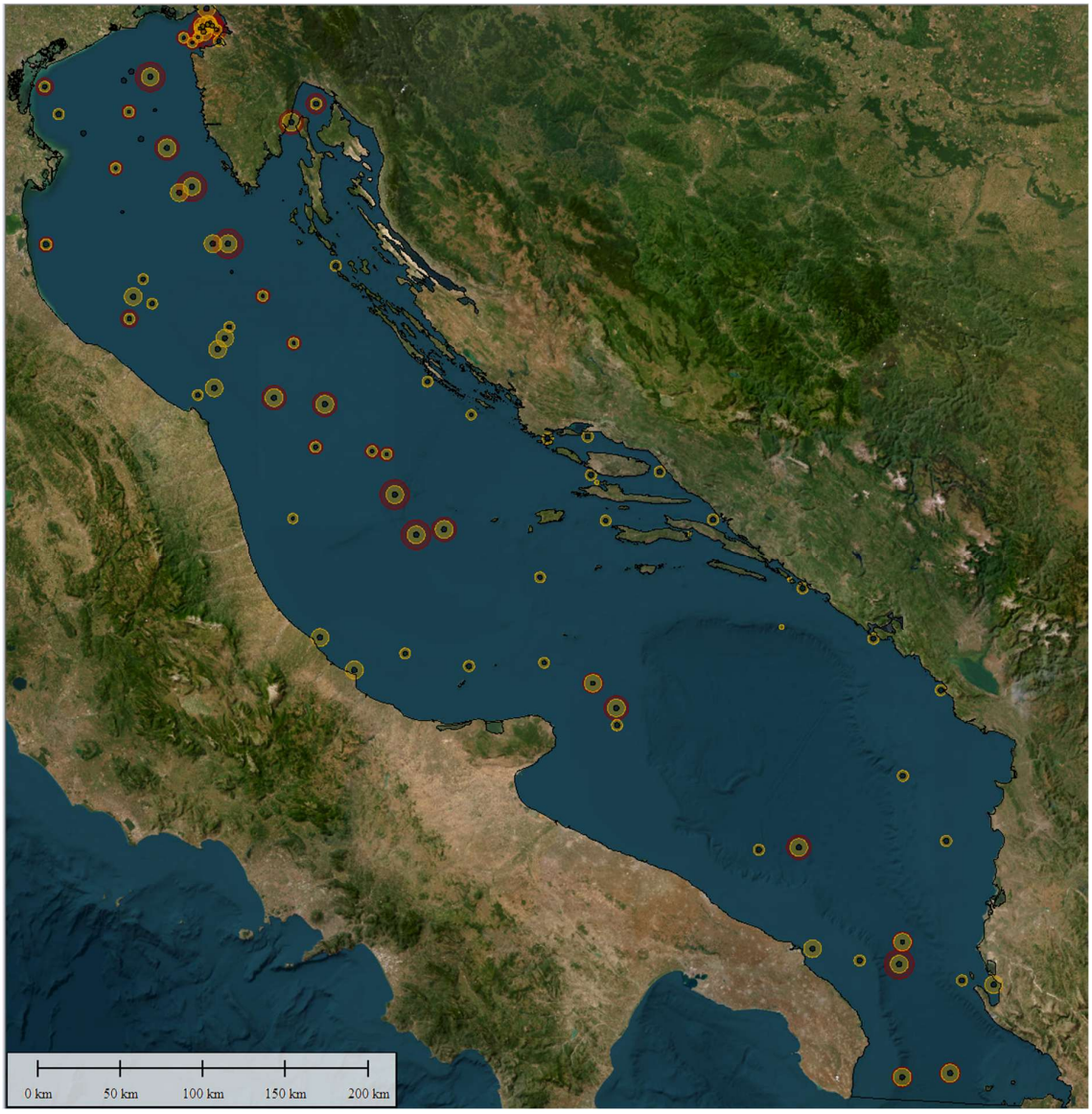


Figure 18. Final expert-defined accident locations identified through integrated AIS traffic analysis, probabilistic IWRAP modelling and expert evaluation, as summarised in Table 8. These locations represent the selected hotspots for subsequent spill scenario simulations.

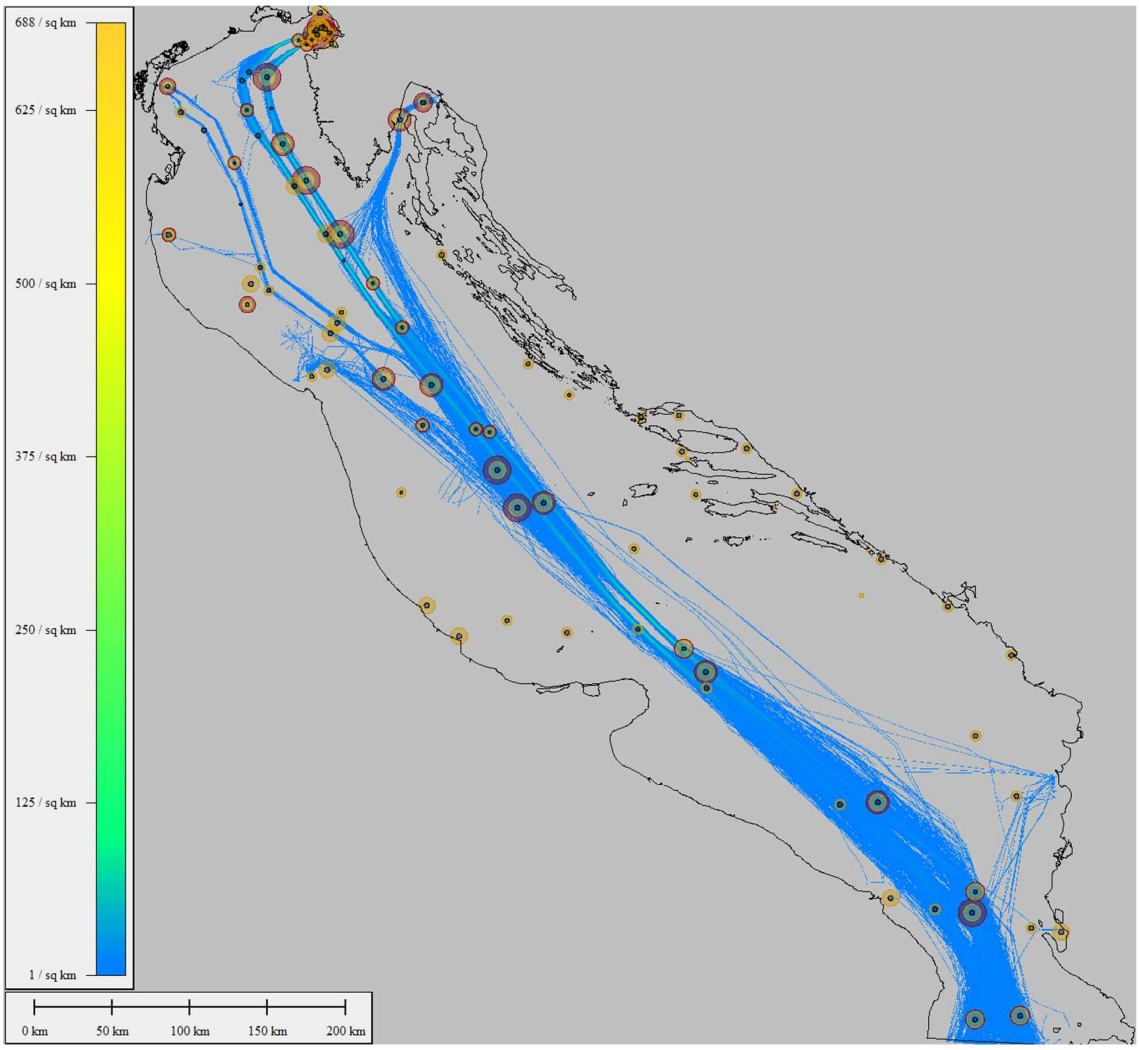


Figure 19. Spatial representation of the selected accident hotspots (Table 8) overlaid with the main crude oil tanker traffic corridors, highlighting the relationship between high-exposure navigation routes and scenario-based spill modelling locations.

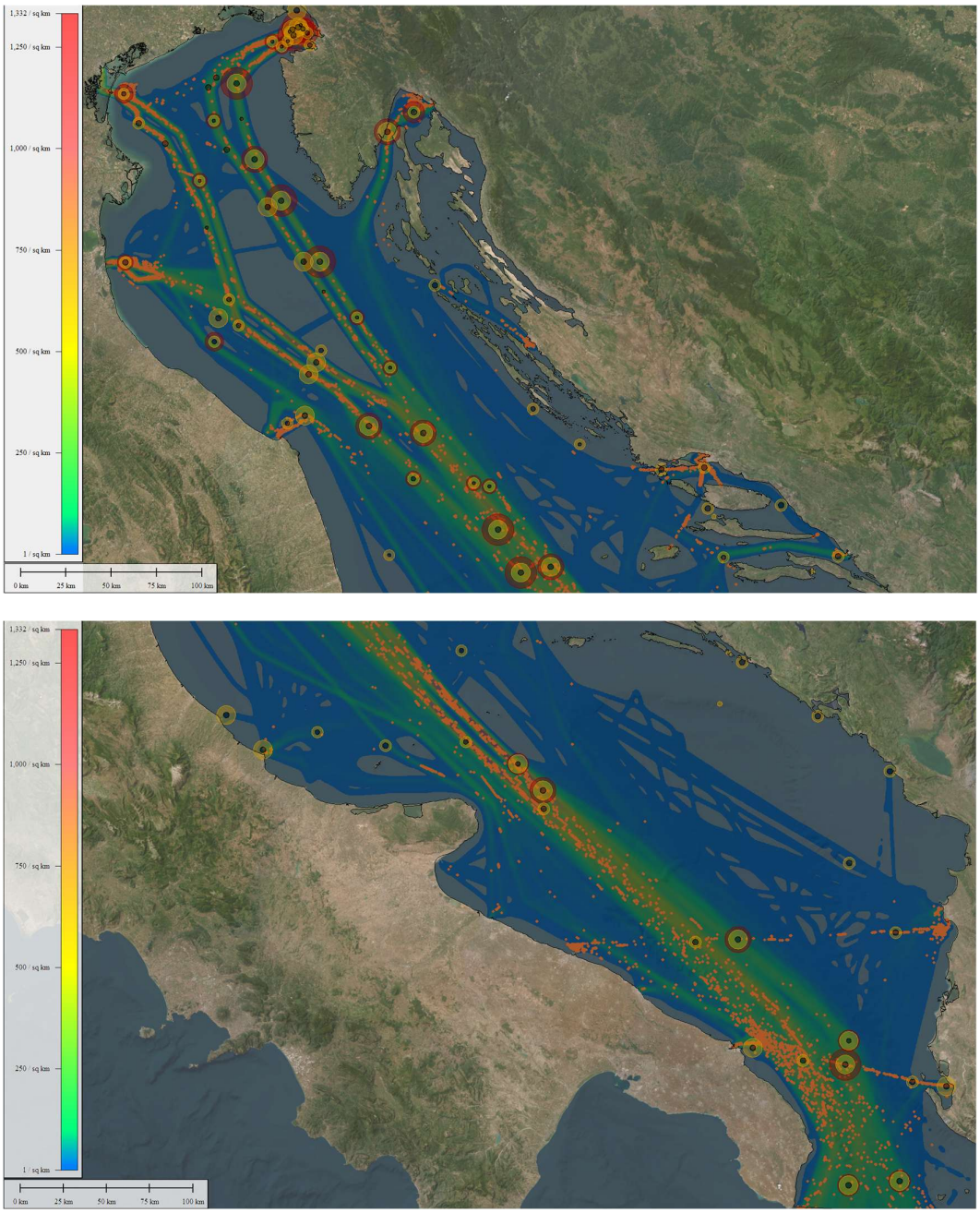


Figure 20. Detailed view of the previously identified accident modelling locations, including IWRAP-derived close-encounter zones and corresponding high-density traffic corridors. The figure illustrates the spatial correlation between probabilistically calculated near-miss concentrations, traffic intensity patterns, and the final expert-selected spill modelling hotspots.

4. TASK 1.3.2 OIL SPILL SCENARIOS SIMULATIONS

4.1 MODELLING APPROACH

Oil spill simulations rely on a coupled modelling framework combining a Lagrangian transport model, used to simulate the trajectories of oil particles, and environmental forcing fields. These typically include ocean currents and temperature provided by a hydrodynamic ocean model, as well as wind fields supplied by an atmospheric model. The accuracy of oil spill trajectory predictions therefore strongly depends on the quality and resolution of the environmental fields used to force the Lagrangian particles.

4.2 HYDRODYNAMIC MODEL FOR THE ADRIATIC SEA

4.2.1 CHARACTERISTICS OF THE HYDRODYNAMIC MODEL

In the Adriatic Sea, previous hydrodynamic modelling configurations at 1/32° resolution were developed by Querin et al (2016) using the MITgcm (Massachusetts Institute of Technology general circulation model), a three-dimensional ocean circulation model solving the primitive equations of fluid dynamics on a finite-volume grid and designed to simulate ocean dynamics across a wide range of spatial scales, making it particularly suitable for semi-enclosed basins such as the Adriatic Sea.

Building on these previous modelling efforts, the present work develops a new high-resolution configuration aimed at improving the representation of the area of interest. For the purposes of this project, a new configuration of the MITgcm model for the Adriatic Sea has been developed. In particular, a novel very high–resolution grid at 1/192° has been implemented, enabling a significantly improved representation of the area of interest and of the relevant coastal and mesoscale processes. This upgrade concerns not only the horizontal and vertical grid resolution, but it also entails a substantial increase in the accuracy of bathymetry, coastline and river input representation.

The resulting simulations cover the whole 2024 year, from January 1st to January 1st of 2025, for the entire Adriatic Sea (see Fig. 22 below for the bathymetry of the model). Model domain spans from latitude of 39.91°N to 45.84°N and from longitude 12.11°E and 20.1°E. The choice for the southern boundary was made in order to prevent numerical issues such as recirculation patterns or flow instabilities across the open boundary of the domain. The maximum depth of 1250 m is reached in the southern Adriatic Pit.

The new 1/192° (both in longitude and latitude) domain discretization ensures a uniform horizontal resolution of about 500 m, while 72 vertical layers are adopted for an accurate representation of vertical dynamics (e.g., mixing and thermohaline stratification). These layers are stretched from surface to sea bottom: the first layer is centered at 0.53 m below the sea surface; the second one is at 1.65 m, while the 10th is at 15.88 m. The vertical thickness of each subsequent layer increases up to 56.8 m for the lowest. The total cell count is about 18 million (17.797593). Half a million of them are used to resolve just the surface layer (551.610).

The process of domain definition, grid generation, and the set-up of the initial and boundary conditions are automatized by a pre-processing tool developed by the OGS ocean modeling group.

The boundary conditions at the southern side as well as the initial conditions of the model are provided by the "Mediterranean Sea Physics Analysis and Forecast" product of the Copernicus Marine DataStore, at daily frequency, (see Mediterranean Sea Physics Analysis and Forecast | Copernicus Marine Service). In case of missing files or records, boundary values are linearly interpolated from the previous and the next available values.

Meteorological data from the COSMO 2i model (https://www.cosmo-model.org/content/default.htm) are used to derive the atmospheric forcing conditions at the free surface. All required quantities are interpolated from the meteo data, every hour, with an interpolation procedure to fill between two available values. The forcing at the surface are: temperature, precipitation, atmospheric pressure, wind, long and short-wave radiation. An example of the data used to feed the MITgcm model is given in Fig. 21, for the temperature (Kelvin) at the sea surface over the Italian region.

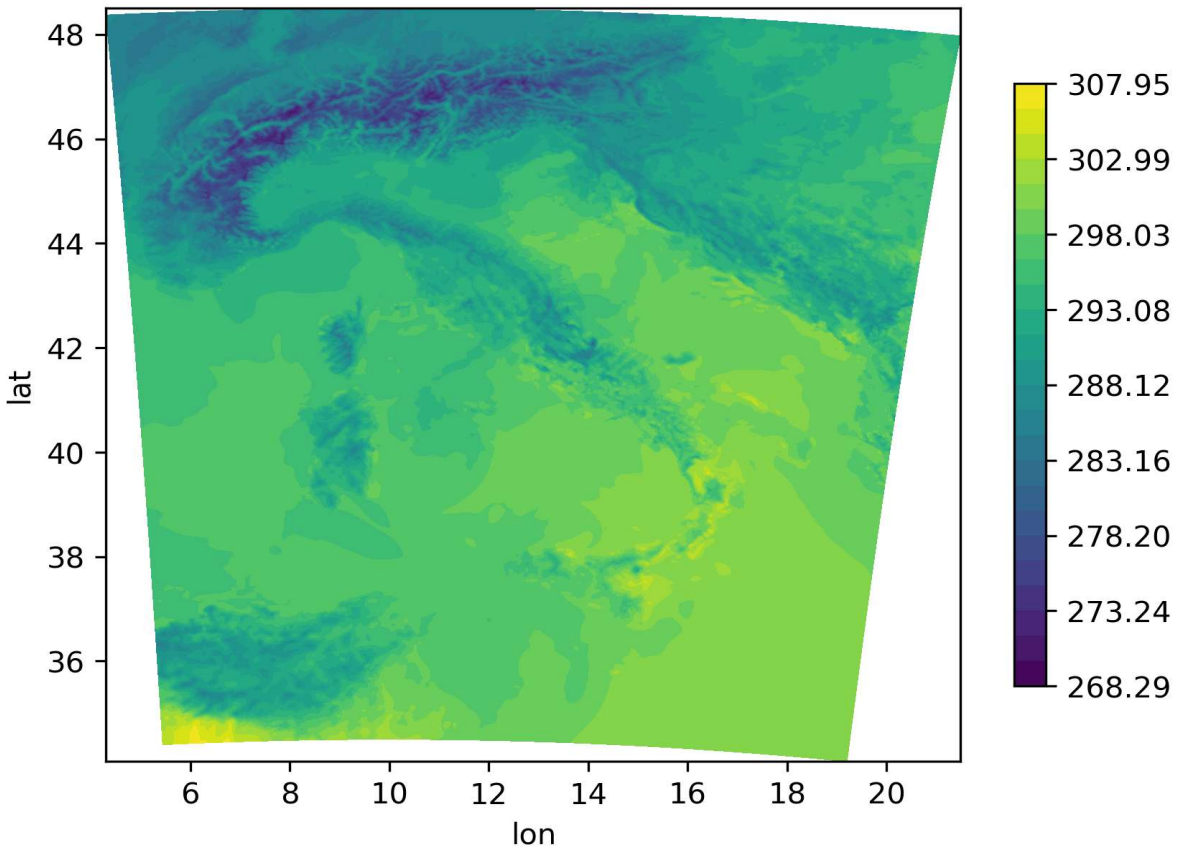


Figure 21. Temperature snapshot (K) extracted from the meteo dataset COSMO 2i used in the hydrodynamic simulations.

River discharges were taken from the "European Flood Awareness System" (EFAS) service of Copernicus EMS considering the 50 main rivers flowing into the Adriatic Sea. We retained all the rivers (22) with a yearly mean discharge of at least 20 m^3/s.

Model equations, which include the Coriolis and the buoyancy body forces, are integrated with a fixed time-step of 50 seconds and provide average outputs at daily and 3-hour frequency for all variables.

More specifically, the model dumps output files containing the following variables: potential temperature, practical salinity, currents (vertical, zonal and meridional components), mixed layer depth, turbulent diffusivity and sea surface height anomaly.

The computational cost of the hydrodynamic simulation is relevant: the run required about 130.000 core-hours, on the Leonardo HPC facility, the second Italian HPC system (10^{th} worldwide), located at the CINECA Tecnopolo in Bologna. Leonardo has 1.824.768 cores (consuming 8.000 kW) and can perform 240 million billion mathematical operations per second. It is a cluster with two partitions, the

DCGP partition with traditional architecture useful for scientific computations, and the BOOST partition with accelerators useful for advanced AI applications.

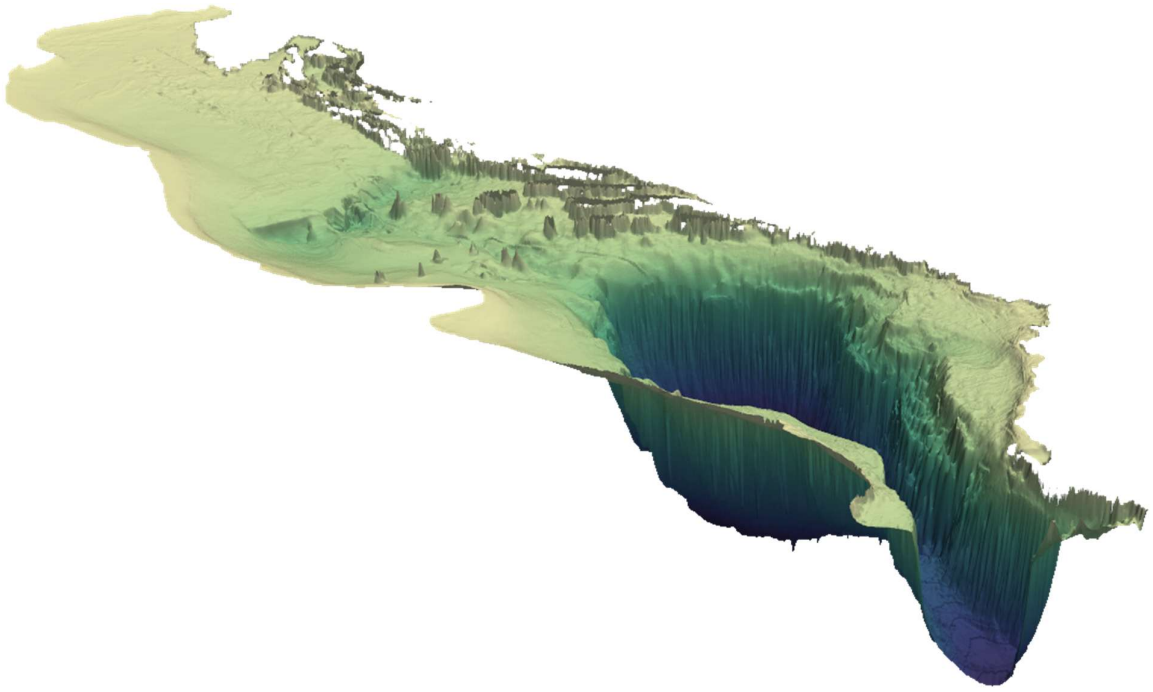


Figure 22. Model bathymetry of the Adriatic Sea, the colours show the depth: from light green, for shallow regions, to dark blue for deeper areas.

4.2.2 FLOW FIELDS

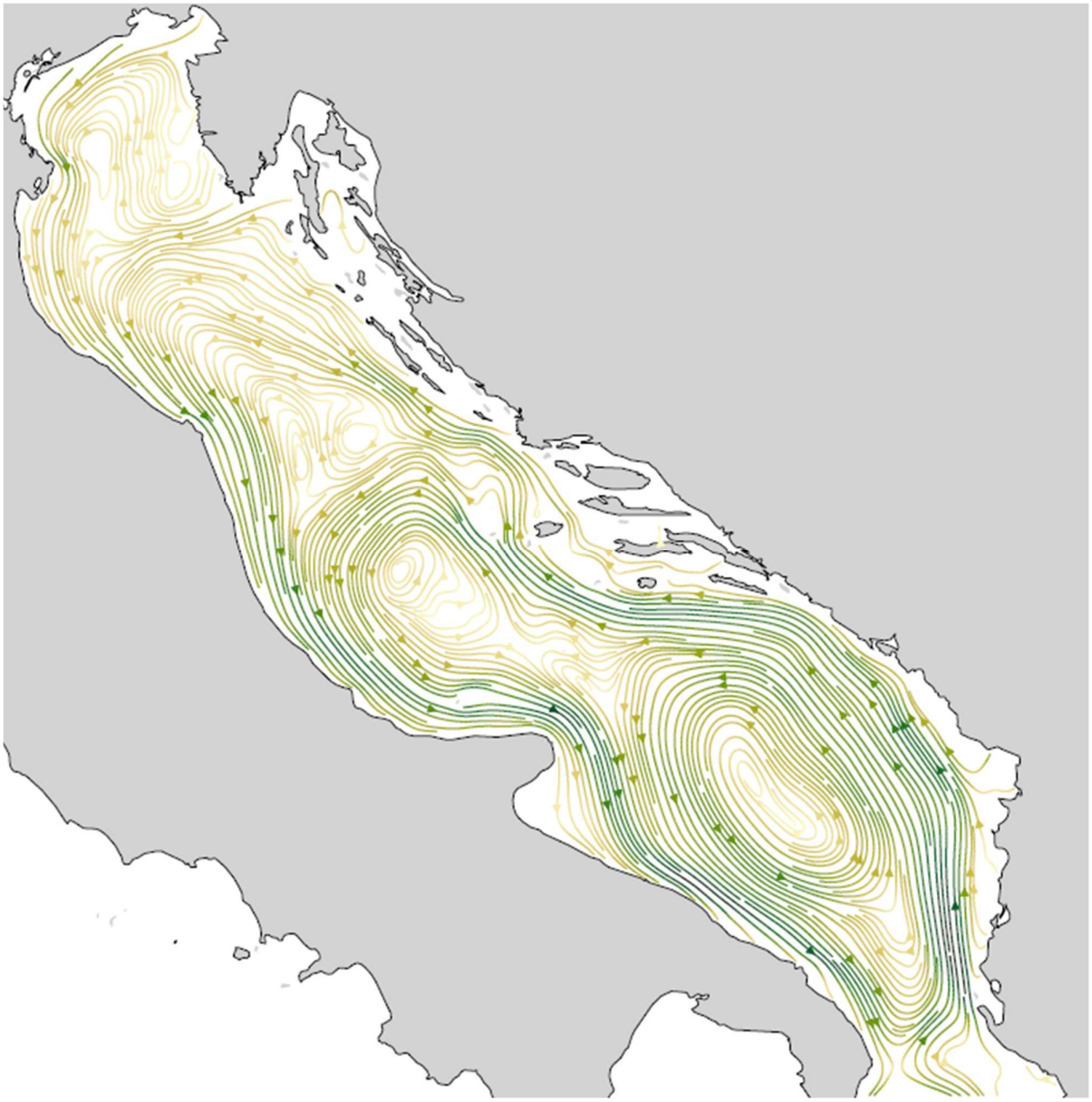
The numerical results of marine circulation in 2024 show the typical patterns of the Adriatic Sea, with the seasonal and daily variability realistically reproduced by the model.

Fig. 23 shows the surface streamlines of the yearly averaged velocity field, from which we can identify the main characteristics of the flow. As expected, the basin-scale circulation of the Adriatic Sea largely maintained its typical cyclonic structure, with northward surface flow along the eastern coast and southward return flow along the western margin.

The inflow from the Ionian Sea through the Strait of Otranto brings in more saline waters feeding the circulation along the eastern margin of the basin. On the other hand, coastal waters along the western Adriatic are strongly influenced by riverine inputs, particularly from the Po River, resulting in relatively fresher and more stratified water masses. However, circulation and stratification were significantly

modulated by anomalously warm atmospheric conditions, as 2024 was among the warmest years on record in the Mediterranean basin. High sea surface temperatures enhanced upper-layer stratification, particularly in the northern Adriatic, reducing vertical mixing during summer.

The dominant winds, Bora and Scirocco, play a key role in modulating short-term circulation patterns and variability, affecting both current intensity and vertical mixing processes. In the shallow northern Adriatic basin, circulation is more strongly controlled by atmospheric forcing, which enhances seasonal variability.



1 Figure 23: Average surface currents in the Adriatic Sea for the 2024 simulation. Low current velocities are shown in yellow, high current velocities are shown in blue.

4.3 OIL SPILL SIMULATIONS

This chapter presents the oil spill modelling framework developed within the ASAP project for the Adriatic Sea. The framework is based on the open-source LTRANS-Zlev Lagrangian particle tracking model (Laurent et al 2020, North et al. 2006) coupled with the OILTRANS oil weathering module (Berry et al., 2012), enabling the simulation of oil spill transport and transformation under realistic marine conditions. The system explicitly accounts for hydrodynamic and atmospheric forcing, as well as oil-specific physical and chemical processes governing the evolution of surface oil slicks.

The modelling framework is designed to predict the spatial and temporal distribution of oil slicks originating from predefined release locations identified in previous project tasks. By simulating oil slicks released continuously over time from source points representative of major incident risk, the model supports the production of statistically based probability maps describing the hazard and exposure of surface waters to oil contamination.

4.3.1 SET-UP OF THE SIMULATIONS

The coupled LTRANS-Zlev–OILTRANS model is forced by high-resolution hydrodynamic fields—specifically current velocities and temperature—generated by the Adriatic Sea simulations performed with the MITgcm, as described in Chapter 4. The oil spill simulations consistently employ the same atmospheric wind forcing used in the hydrodynamic model. This integrated configuration ensures physical consistency between circulation dynamics and oil spill fate processes, enabling a robust assessment of oil slick transport and persistence at sea. Simulations were designed to represent spatial variability, oil-type dependency, and short-term fate of spills under realistic oceanographic conditions. The oil spill scenario setup includes daily releases from 89 distinct locations encompassing the whole Adriatic Sea. Each spill event is represented in the model by 2000 Lagrangian particles, simultaneously released every 24 hours for the entire 2024, and then tracked for 10 days. This time span is usually enough for the oil to get stranded to the shore or to be dispersed in the water column. The simulation is advanced with a time step of 100s, both for the computation of the new particles' positions and the chemical-physical transformations, namely the weathering process. The oil spill scenario as already described is repeated for three different oil kinds: Diesel, Crude oil, Bunker fuel. In the following a brief description of the main characteristics of each oil is provided.

DIESEL

Diesel is a refined, light fuel mainly transported in smaller quantities for fueling ships or offshore platforms. It has low-viscosity, spreads quickly if spilled, and evaporates relatively fast.

Spill risk: leaks are often acute but short-lived; they can contaminate surface waters and shorelines rapidly. In the simulations, the diesel oil slicks were setup with the following parameters, corresponding to "Diesel Fuel Oil (1994)" from Jokuty et al. 1999 – rev 2022:

- API=37.2
- Dynamic viscosity: 4 mPas at 15°C
- Percentages of Asphaltenes, Resin and Saturated compounds: 0%,2%,76%
- Evaporation set with:
    - F_B=0.31 and F_T=0.018
    - type-2 Fingas formulation: $F_B + F_T \times \left(T - T_{ref}\right) \times \sqrt{time} \times (1 - Wat_{content})$

CRUDE

Crude Oil is an unrefined petroleum shipped from production sites to refineries around the world. Its composition varies from light to heavy, so it can either spread quickly or form persistent slicks.

Spill risk: accidental releases can create large, long-lasting pollution, affecting marine life and coasts over long distances. In the simulations, the crude oil slicks were setup with the following parameters, corresponding to "Arabian Light" crude oil from Jokuty et al. 1999 – rev 2022, known to be one of the crude oils transiting in the Adriatic Sea:

- API=19.66
- Dynamic viscosity: 14 mPas at 15°C
- Percentages of Asphaltenes, Resin and Saturated compounds: 3%,6%,51%
- Evaporation set with:
    - F_B=2.52 and F_T=0.037
    - type-1 Fingas formulation: $F_B + F_T \times \left(T - T_{ref}\right) \times \log(time) \times (1 - Wat_{content})$

BUNKER OIL

Bunker Oil (Heavy Fuel Oil) is a thick residual oil used mainly to power large ships. Transported as fuel for vessels, it is viscous, dense, and slow to evaporate.

Spill risk: spills are hard to clean, persist in the environment, and tend to sink or coat marine surfaces, causing long-term contamination. In the simulations, the diesel oil slicks were setup with the following parameters, corresponding to "Bunker C Fuel Oil (Alaska)" oil from Jokuty et al. 1999 – rev 2022:

- API=37.2
- Dynamic viscosity: 8706 mPas at 15°C
- Percentages of Asphaltenes, Resin and Saturated compounds: 0%,2%,76%
- Evaporation set with:
    - F_B=0.31 and F_T=0.045
    - type-2 Fingas formulation: $F_B + F_T \times \left(T - T_{ref}\right) \times \log(time) \times (1 - Wat_{content})$

4.3.2.1 TRANSPORT PROCESSES

The oil spill simulation model represents the main physical processes that impact the fate of oil at sea from the initial spill up to several days. Such processes are the gravity-viscous driven diffusion of the oil slick, acting in the first hours after the event, the advection by ocean currents derived from the hydrodynamic simulations, the drift induced by the wind stress at sea surface, the diffusion driven by the turbulent eddies of the sea current. Such an effect is parametrized by a stochastic displacement method. Eventually the oil reaching the shore undergoes stranding and interacts with the coastline.

As already mentioned, the surface motion of the oil slick is modelled as the combined effect of advection by surface currents, wind-induced drift, and turbulent diffusion. The advective transport velocity of the slick is expressed as:

$$U_{oil} = U_{currents} + 0.035 \times U_{Deflected\,Wind}$$

where the wind-induced drift component corresponds to 3.5% of the wind speed measured at 10m above sea level, accounting for unresolved near-surface processes. In addition, a Coriolis-induced

deflection of 5° to the right (in the northern emisphere) is applied to the wind-driven drift, in accordance with values reported in the literature.

4.3.2.1 WEATHERING PROCESSES

The OILTRANS module simulates the main oil weathering mechanisms affecting spill evolution, estimating variations of oil density and viscosity due to temperature variations, emulsification, and evaporation. The evaporation process accounts for the removal of oil from the water surface due to the combined effect of temperature and wind speed. The model includes a representation of the initial gravity–viscous spreading phase happening in the very first hours after the occurrence of the spill and considers a representation of the vertical dispersion to account for the removal of oil from the water surface due to the entrainment of oil droplets in the water column by breaking waves.

MECHANICAL SPREADING

Models the initial gravity–viscous spreading phase adopting the Fay-type formulations (Fay, 1971), in which a terminal slick thickness is defined, beyond which mechanical spreading ceases.

EVAPORATION

Evaporation is the primary removal process at the sea surface, and in the model is represented by Fingas (2013) empirical formulations that reliably predict evaporation rates across a wide range of oil types, with a parametrization that considers oil composition, temperature, wind speed, and slick area.

EMULSIFICATION

Emulsification is the process of incorporating water into the oil slick affecting oil density.

Such effect is predicted using the Fingas empirical method (Fingas and Fieldhouse (2004), Fingas (2011).

VERTICAL DISPERSION

The effect of entrainment of oil droplets in the water column by breaking waves is modelled based on the Delvigne and Sweeney (1988) formulation, considering that small droplets become permanently dispersed in the water column.

4.3.2 RESULTS OF THE SIMULATIONS

Hereafter, the analysis of the transport of three kinds of simulated oils, namely bunker, crude oil and diesel, is briefly reported. Each release slick has its own release point, and its release volume as indicated by the previous Expert analysis. For sake of clarity, even though the simulation data are saved at specific snapshots of every 3 hours, the maps are provided at 3, 6, 12 hours after the release, and then after 1, 2, 3 days. The results are the average of the corresponding snapshot of each release time (365 daily releases) of all the release points.

4.3.2.1. BUNKER OIL HAZARD ESTIMATIONS

The bunker oil is released at 85 over 89 release points across the Adriatic Sea, for a total volume of 103000 tons, each day for the year 2024.

In Fig. 24 the time evolution of the fate of Bunker oil at sea is depicted. The plot represents the oil mass in tons evolving in time, showing the values at sea surface (in blue line), the values of the oil at surface that got stranded (in dashed blue line), while the oil fraction that is dispersed in dispersed in the water column is represented in green line, while the stranded dispersed oil is showed in dashed green line.

At release time, all the oil mass is localized around the release point, at the surface, and the weathering process starts: the evaporation is more effective in the first hours after the release and starts to reduce the oil mass along with the dispersion process. As expected, the oil at surface has a steep decrease in the first hour after the release, and then continues to decrease but a slower rate, due principally to the dispersion and strandings processes. The dispersion process starts right after the release at a steep rate and reaches a final value after about 100h.

The distance of the release points from the coastline and the local wind and current conditions determine the rate of the stranding processes of both the surface and stranded oil. In this case the stranding of the surface oil starts growing fast after the release reducing slowly the rate after 100h, but even after the 10 days is still evident a growing trend of stranding of surface oil. A similar behavior holds also for the dispersed stranding oil, with the major difference at the release time, where a very slow growth (negative concavity) persists for the first 2 days, and after which it shows a steady quasi-linear rate.

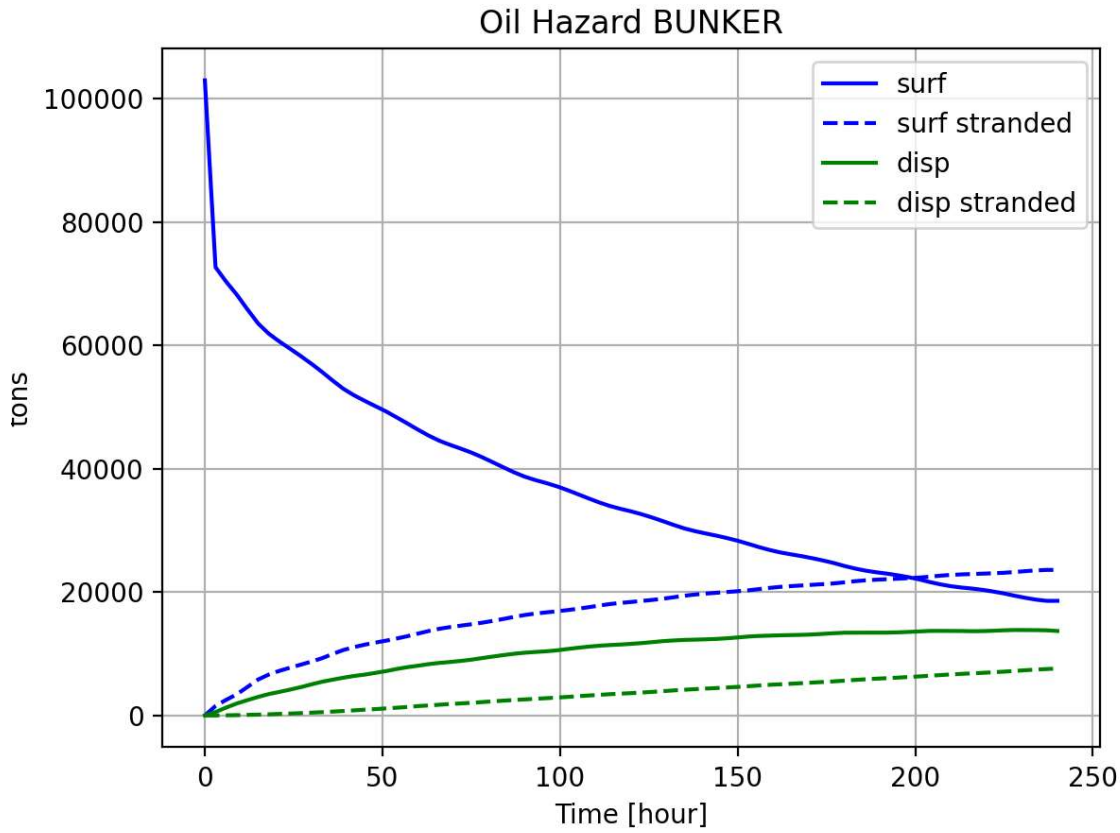


Figure 24. Time evolution of the fate of Bunker oil at sea: oil tons at sea surface (blue line), surface stranded oil (dashed blue line), dispersed oil in the water column (green line), stranded dispersed oil (dashed green line).

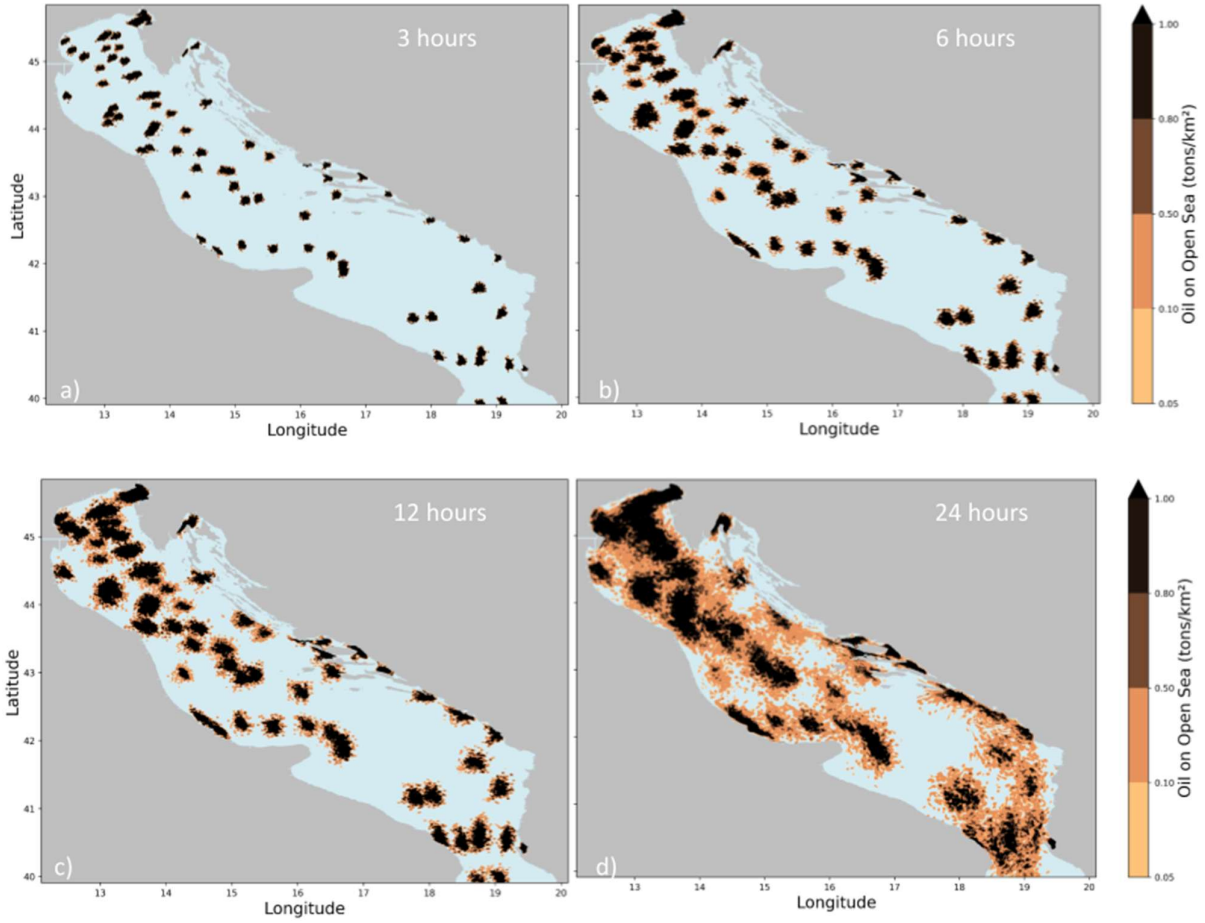
In Fig. 25 spatial evolution of oil slicks are reported for 6 different times, for the bunker oil: at 3 hours after the release, in panel a), 6 hours in panel b), at 12 hours in panel c), and in panels d),e) and f) after 1, 2 and 3 days after the event. The contour plot shows the concentration of oil in terms of tons per square kilometer. For the sake of clarity, the values below a threshold of 0.1 tons/km^2 are blanked, while the colors are saturated above a suitable value.

The same settings are applied in the figures of the other two oil kinds, crude and diesel, in the corresponding sections.

The first 3 and 6 hours contour plots show a uniform spreading around the release points, for the slick in open sea, while the ones closer to the shore already appear elongated along the coastline. After 12 and 24 hours the oil starts to cover larger areas, with overlapping more slicks. The oil reaches the north Adriatic region costs, both on the western and eastern sides, up to Ancona. The coastlines

between Pescara and Vasto are quite impacted from the two nearby release points, as well as the southern part of the Dalmatian coast and the shores around the Otranto Strait.

After 2 and 3 days more oil coming from open sea slicks start to get stranded on top of the one already present at the coastline.



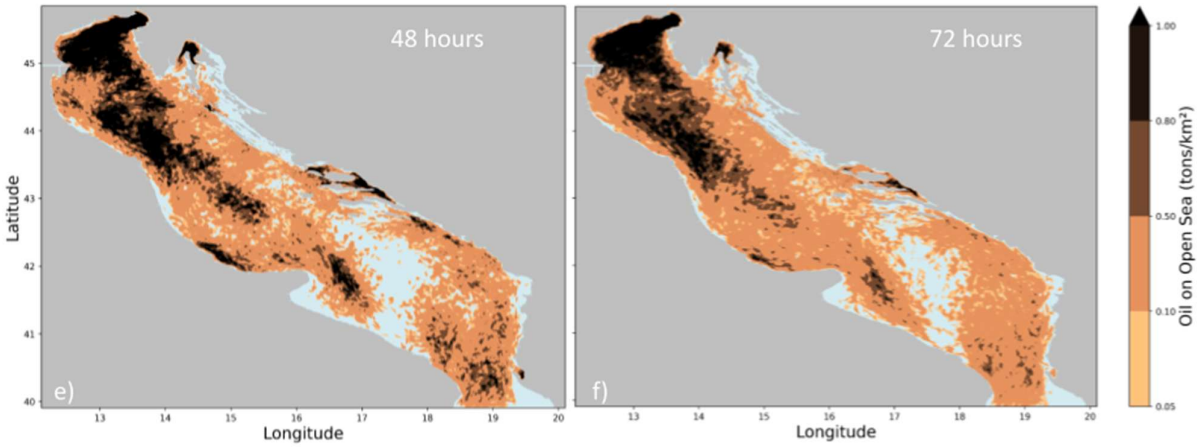


Figure 25. Bunker oil surface oil distribution in time of the average density (tons form squared kilometer). In panel a) concentration 3 hours after the spill, in panel b) 6 hours after the spill, c) and d) after 12 and 24 hours respectively. In e) and f) after 2 and 3 days.

4.3.2.1. CRUDE OIL HAZARD ESTIMATIONS

Crude oil is released at 39 over 89 release points across the Adriatic Sea, for a total volume of 550000 tons, each day.

In Fig. 26 evolution of crude oil is shown. As for the bunker oil, the oil at the surface, right after the release time, rapidly drops due to the combined effect of evaporation weathering process and the droplets dispersion in the water column. After ten days the presence at the surface remains negligible. The dispersion process starts abruptly, reaching a peak around 100 hours before slowly decreasing. Such a decrease is mostly related to the stranding of the dispersed phase, that begins after around 30 hours and then continues with a growing trend. Conversely, the stranding of the surface oil starts just after the release time, growing in time.

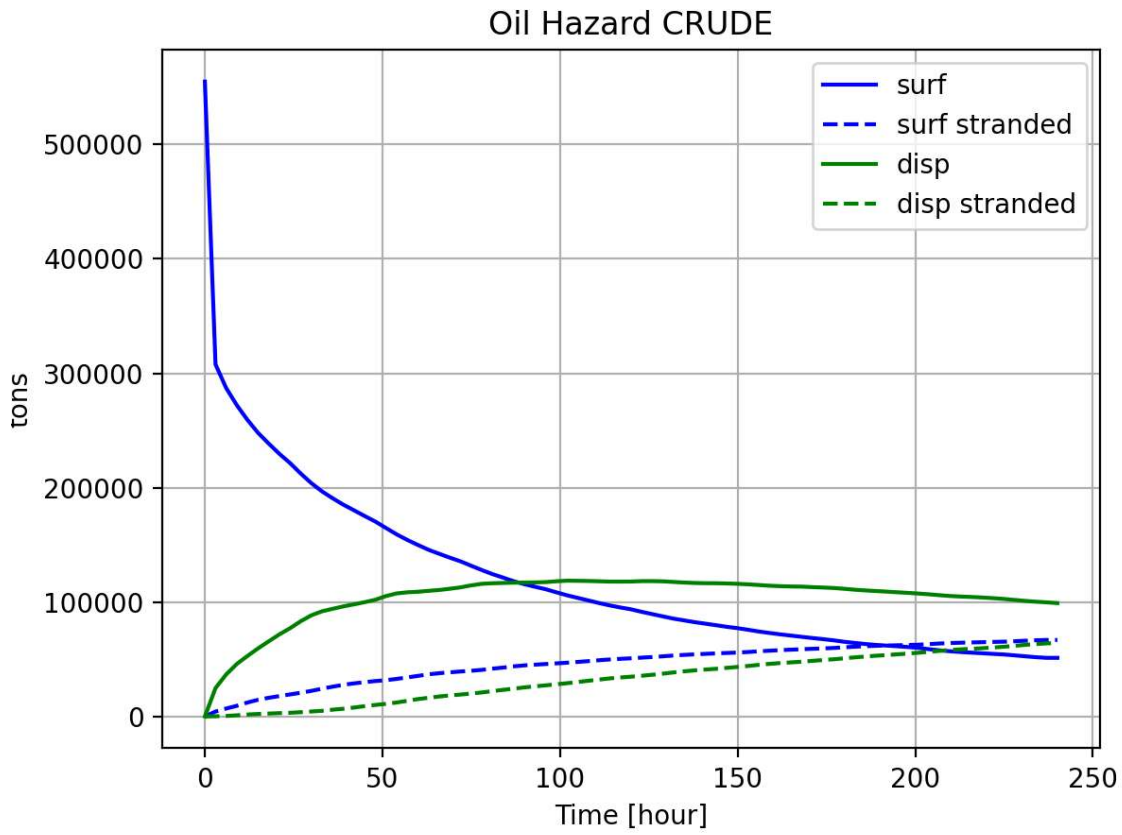


Figure 26. Time evolution of the fate of cruder oil at sea: oil tons at sea surface (blue line), surface stranded oil (dashed blue line), dispersed oil in the water column (green line), stranded dispersed oil (dashed green line).

In Fig. 27 spatial evolution of the average oil slicks in time is also shown.

Crude oil has less release points with respect to the other two kinds here considered, and they are mostly in the north Adriatic, with fewer in the southern part of the Adriatic. Among them, only the ones in Trieste and Rijeka gulfs are very close to the coastlines, while no release points are present in the Dalmatian region.

Such distribution is the key factor of the delay in the stranding of oil respect to the bunker case, along with the intense dispersion process. As can be seen in the contour plots even after 3 days, a large part of the oil is still far from the shores, except for the northern Adriatic region.

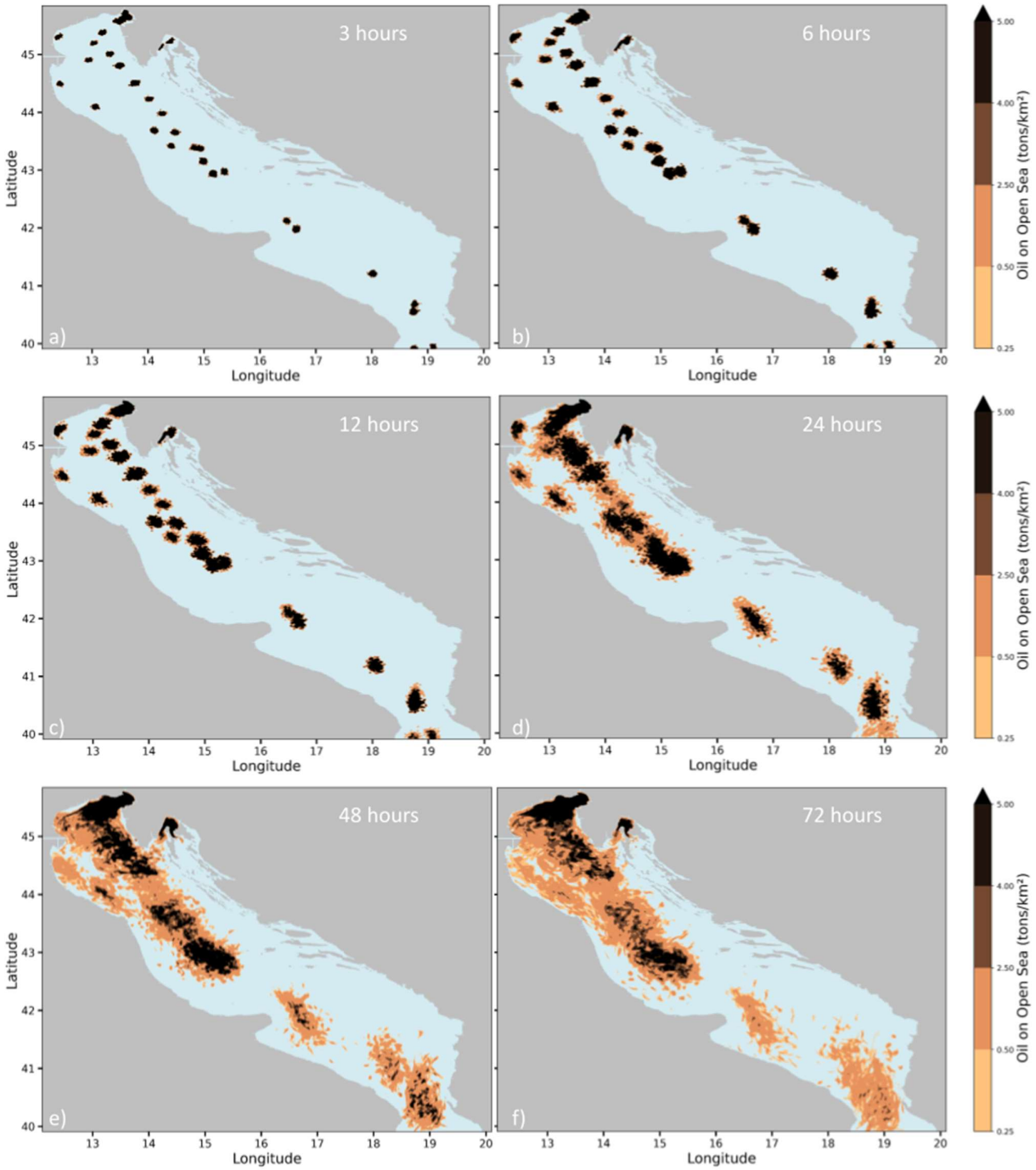


Figure 27. Crude oil surface oil distribution in time of the average density (tons form squared kilometers). In panel a) concentration 3 hours after the spill, in panel b) 6 hours after the spill, c) and d) after 12 and 24 hours respectively. In e) and f) after 2 and 3 days.

4.3.2.1. DIESEL HAZARD ESTIMATIONS

Diesel is released at 82 over 89 release points across the Adriatic Sea, for a total volume of 704000 tons, each day.

Diesel evolution in time resembles the behavior already discussed for the crude oil, with the peak of dispersed surface oil around 100 hours. Such a peak is much larger than the previous case, reaching almost 180.000 tons. The evolution in time is shown in Fig. 28.

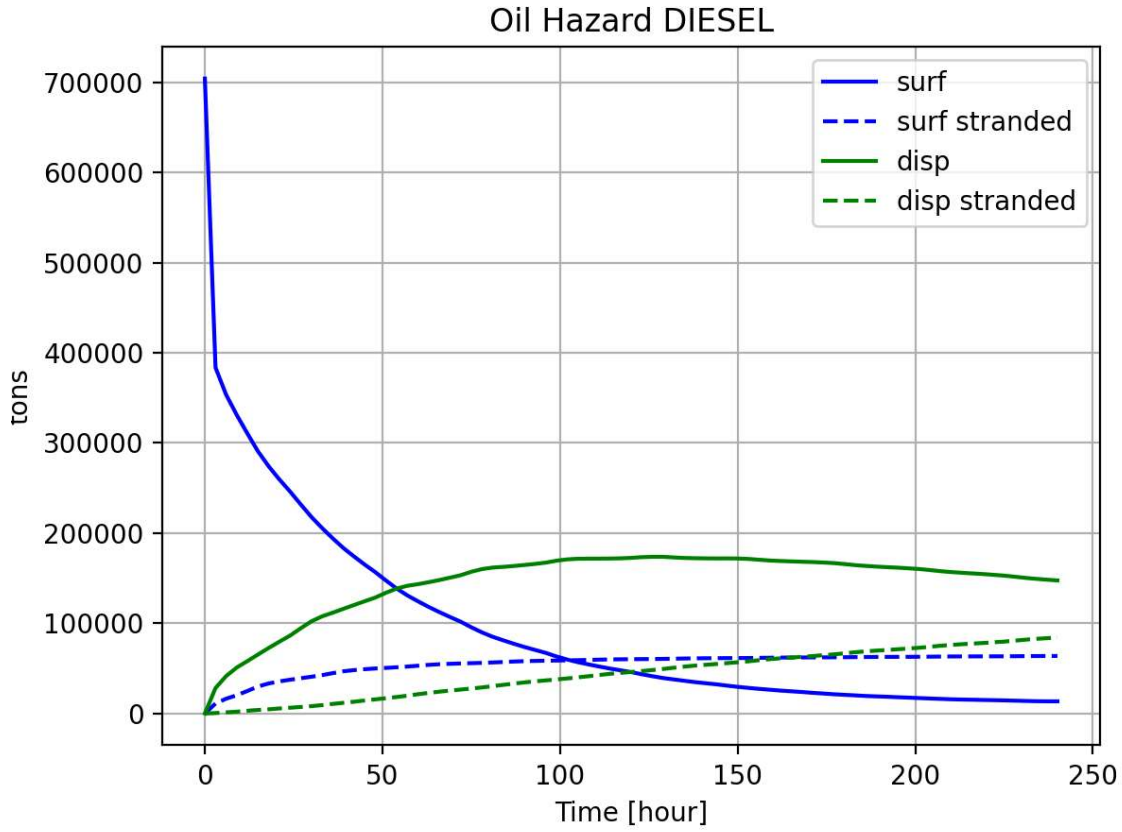


Figure 28. Time evolution of the fate of diesel at sea: oil tons at sea surface (blue line), surface stranded oil (dashed blue line), dispersed oil in the water column (green line), stranded dispersed oil (dashed green line).

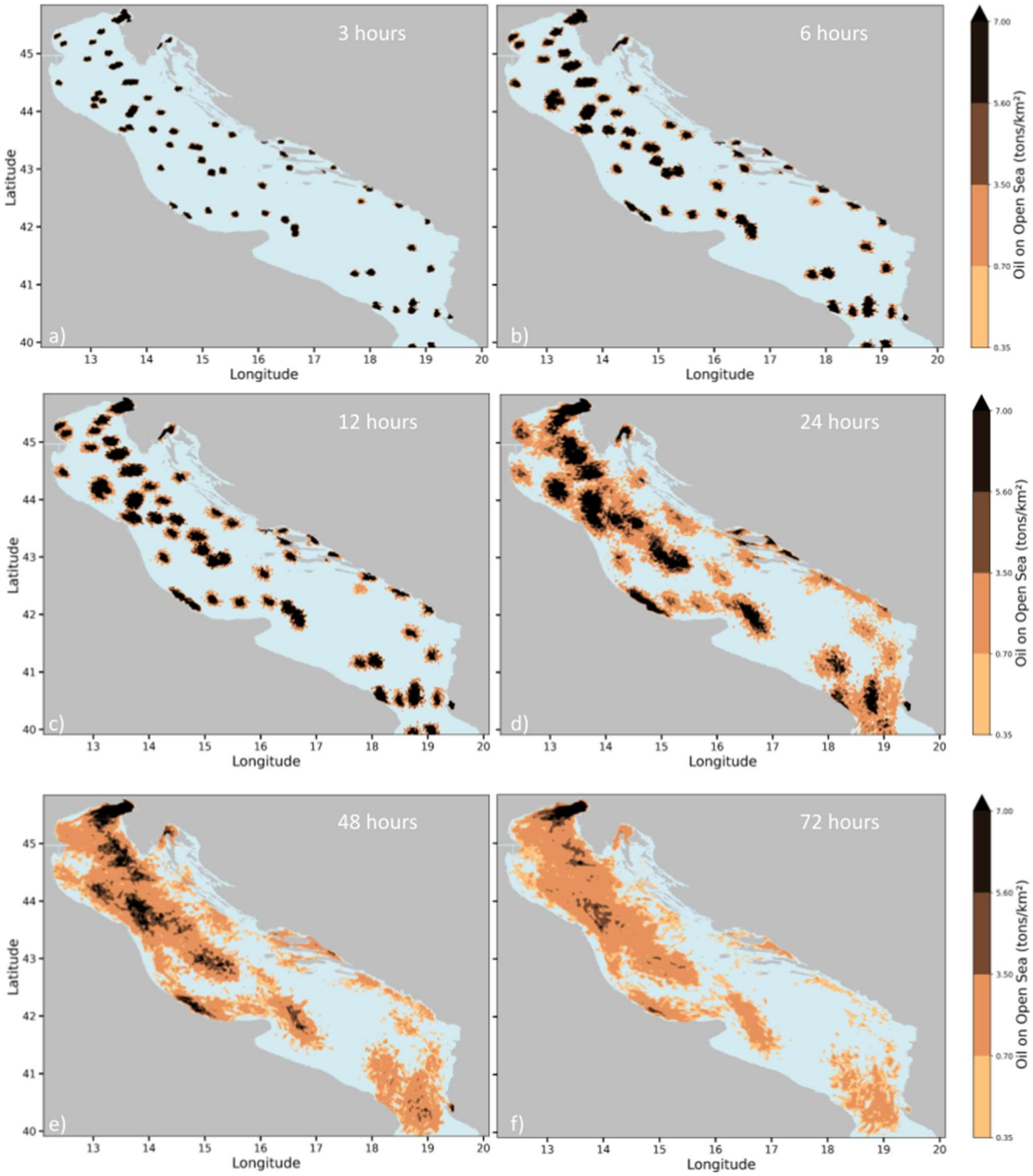


Figure 29. Diesel distribution in time of the average density (tons form squared kilometers). In panel a) concentration 3 hours after the spill, in panel b) 6 hours after the spill, c) and d) after 12 and 24 hours respectively. In e) and f) after 2 and 3 days.

Spatial evolution of diesel in time is presented in Fig. 29. The behaviour is quite similar to the case of the crude oil considering the release points in the northern Adriatic, while differs in the southern region. The release points in the Dalmatian region, the coastline between Pescara and Vasto, and in Otranto Strait are responsible of stranding of oil as for the bunker case even though with less impact due to the different weathering parameters that permits a large evaporation

Finally, it is worth noting the difference of the overall dynamics among the three oils dispersion, that are driven by the total oil amount released, the different physical-chemical properties. Considering the cases of bunker (b), crude (c) and diesel (d) we notice that the surface oil decreases more rapidly from (b) to (d) reaching a value after ten days of 20%, 10% and less than 5% respectively. Stranded surface oil is greater than all other quantities only for case (b), after ten days. Dispersed oil quantity becomes greater than the surface quantities in cases (c) and (d) after around 80 and 55 hours respectively, and after 200 and 125 hours both stranded contributions become larger than the surface oil presence.

5. TASK 1.3.3 MAPPING OF SENSITIVE AREAS AND OIL SPILL RISK ASSESSMENT

5.1 METHODOLOGICAL APPROACH

For the mapping of sensitive areas of the Adriatic to oil spills, their vulnerability assessment and the oil spill risk assessment the same methodologies were followed as in the NAMIRS project.

For the vulnerability assessment, two elements are required: the mapping of all factors that can be negatively affected by an oil spill, and a score indicating how much each factor can be affected. For socio-economic factors, these scores were obtained involving stakeholder focus groups, held in each of the three Southern Adriatic countries (Bosnia & Herzegovina, Albania, Montenegro). Similarly, in NAMIRS, three stakeholders' workshops were conducted in the three Northern Adriatic countries (Italy, Slovenia, Croatia). The results of the three ASAP focus groups and of the three NAMIRS stakeholders' workshops were then combined in ASAP to evaluate vulnerability to oil spill along the entire Adriatic coastline.

For risk assessment, the vulnerability map needs to be combined with the hazard estimated through oil spill simulations. In this way, we can define the risk as the product of hazard (oil particles advected over a certain area in a certain time as a consequence of an oil spill), exposure (vulnerability factors present along the coastline), and vulnerability scores for each factor.

Section 5.2 presents the outcomes of the focus groups, reporting also those of the NAMIRS project. Section 5.3 describes the mapping of the vulnerability factors along the Adriatic coasts, the derivation of the vulnerability scores for factors other than the socio-economic ones, and the integration of all this information in a single vulnerability assessment. Section 5.4 details the derivation of the risk index for the entire Adriatic Sea coastline by combining oil spill simulation results with the vulnerability index.

5.2 STAKEHOLDERS' FOCUS GROUPS

The same methodology applied in the North Adriatic basin for stakeholder workshops in NAMIRS was also used for the ASAP focus groups. In particular, a questionnaire developed in NAMIRS was adapted for the ASAP countries and used during focus group meetings. Stakeholders' participation in the focus groups was possible either in person or online. The results of stakeholder consultations in all six countries were merged, contributing to spill modelling and risk assessment activities.

Through scientific analysis of geomorphological coastline types, their distribution, and associated socio-economic activities, including legally protected natural areas, it is possible to objectively assess sensitivity to oil spills (e.g., ESI; see Petersen et al., 2019).

This objective approach does not fully capture the social value of the coastline for local communities and the various stakeholders involved in maritime and coastal activities. Stakeholders are defined as individuals or organizations with a direct, tangible, or intangible interest in ensuring that these areas are not affected by the consequences of oil spills. Their interests may stem from economic activities such as maritime transport, port operations, tourism, mariculture, and fisheries. Others may value the coastline for its pristine condition, appreciating its social, cultural, and scenic significance. Additionally, some stakeholders are involved in environmental protection or cleanup activities, including NGOs, public institutions (such as research centres and local authorities), and private companies operating in the environmental sector.

To address this gap, the partners of the ASAP project adopted an inclusive, participatory, holistic approach to assessing the sensitivity of coastal areas in the Adriatic Sea. The approach combined expert knowledge with active stakeholder involvement. Specifically, a tailored Coastal Vulnerability Assessment (CVA) method was developed in the form of a questionnaire, designed to be completed by stakeholders during dedicated workshops. The CVA was structured following the principles of the Delphi method, as applied in the IALA PAWSA risk assessment framework (IALA, 2022). However, since the objectives of the ASAP risk assessment differ from those of the PAWSA method, the CVA procedures were adapted to meet the specific needs of the project.

The outcomes of the workshops were analysed and combined with expert insights from the literature to classify coastal areas according to their sensitivity to oil spills. These coastal sensitivity assessments are intended to guide the identification of priority areas for intervention in the event of an oil spill.

5.2.1 SENSITIVITY FACTORS

The first step in the procedure was the identification of sensitivity factors. Three groups of sensitivity factors were identified: geomorphological, environmental, and socio-economic factors.

Geomorphological factors in the CVA relate to the physical characteristics and typology of the coastline. The perceived value of a coastal stretch can vary significantly among stakeholders, depending on how they use or intend to use the area. For instance, some may prioritize its recreational potential beyond established beach resorts, while others may consider its suitability for economic activities such as hotels, campsites, or restaurants. Consequently, attributes such as elevation (low or high), accessibility, substrate type (sandy or rocky), and whether the coast is natural or artificial all influence how different stakeholders assess its value.

Environmental factors include legally protected areas such as national parks, critical habitats, and the presence of protected or ecologically significant species. As with other factors, the value assigned to these elements can vary among stakeholder groups, depending on their interests and level of expertise. For example, individuals from the research community or environmental organizations may place greater importance on protected areas and better understand distinctions in their levels of legal protection. A particularly relevant outcome regards how stakeholders evaluate coastal areas that are not covered by any formal legislative protection.

Socio-economic factors are often the most influenced by stakeholders' subjective perceptions. For example, a mariculturist may consider any disruption to mariculture activities far more impactful than pollution affecting a nearby beach. Conversely, a beach resort owner may prioritize the protection of the beach over offshore mussel farms or fishery operations. The evaluation becomes even more complex when considering non-monetary values, such as the aesthetic appeal of an unspoiled natural coastline or the cultural and historical significance of a historic seaside town, which are difficult to quantify in purely economic terms.

Fig. 30 shows a schematic representation of the three groups of sensitivity factors and their corresponding criteria considered in the ASAP CVA process.

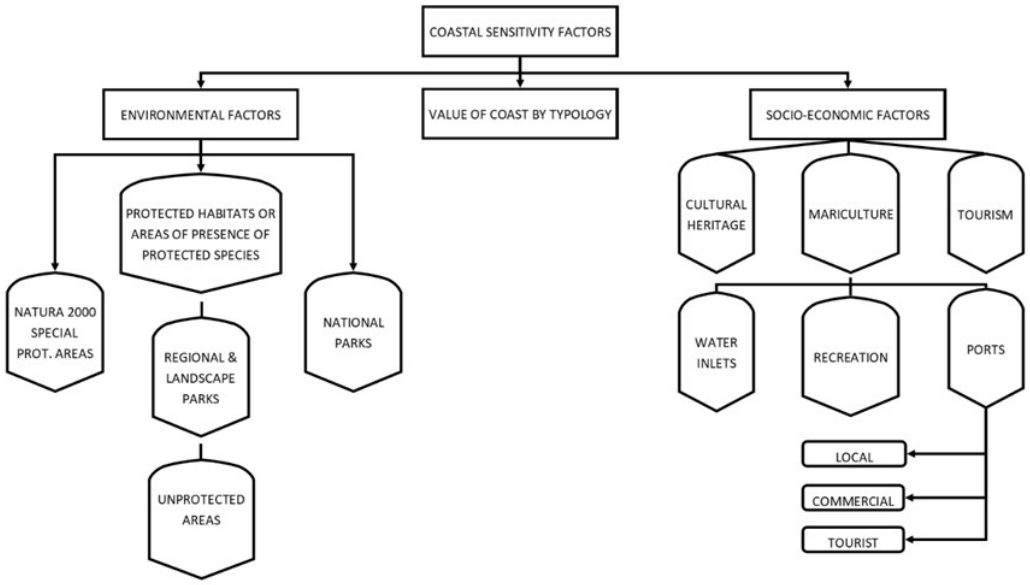


Figure 30: Schematic representation of the sensitivity factors considered in ASAP CVA.

By compiling the selected criteria into factor groups and deciding on a rating scale, a coastal sensitivity questionnaire was formed, ready for the invited stakeholders to fill out and give an opinion on the value of sensitivity for each criterion.

5.2.1.1 CVA STEP 1

The first step of the CVA required participants to state their role in the assessment process, the actions they would be expected to take in oil spill cleaning activities in general, and their level of familiarity with sensitivity factors, with emphasis on how spilled oil would affect each of them. The numerical values obtained were used as indices of each participant's level of knowledge of the available assessment criteria.

Stakeholder roles were classified into the following categories:

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

- citizen.

Participants were asked to indicate what actions they would be required to take in oil spill clean-up operations by selecting one of the available options:

- would be in action as per their duty,
- would step into action only if requested,
- would only actively monitor the cleaning procedures and provide suggestions or proposals to an appropriate service,
- would monitor the event as a citizen, or
- would not be interested.

At the end of the first step, participants' level of familiarity with each factor was defined by asking them to answer the following questions with scores from 1 to 9, where 1 represented the lowest level of familiarity, and 9 the highest:

- To what extent are you, at this moment, familiar with the problem of oil spills as a whole?
- To what extent are you, at this moment, familiar with the geomorphological state of our coastline (relating to different coast type cleaning difficulties)?
- To what extent are you, at this moment, familiar with environmental protection (areas with different protection status levels)?
- To what extent are you, at 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 values obtained allowed the research team to consider the expertise and familiarity level of each respondent. In this way, the opinions of professionals involved in oil spill management were given greater weight than those of individuals with lower levels of involvement or knowledge of the issue.

5.2.1.2 CVA STEP 2

The second step of the assessment process was dedicated to rating all identified sensitivity factors. Participants were asked to rate each factor using a scale from 1 to 9, where 1 represented the lowest level of sensitivity, and 9 the highest.

The initial set of criteria evaluated comprised socioeconomic factors (Fig. 30). These included tourism, cultural heritage, cooling water station inlets, ports, recreational zones (such as coastal structures designed for sports and leisure), and mariculture areas in general (without distinguishing between specific types like fish farms, shellfish farms, or other forms of mariculture). Ports were further categorized into commercial ports (e.g., Trieste, Koper, Rijeka), tourist ports (marinas), and local ports, which are typically small harbours in historic coastal towns used by local fishermen or private boat owners.

Then, participants were asked to evaluate the importance of different coastal types. The categories of coastline, identified in the Adriatic Sea, were identified using data from the EMODnet portal:

- Erodible rocky shores with sediment accumulation at the base
- Long beaches (over 1 km in length)
- Short beaches (less than 1 km)
- Man-made coastlines
- Muddy shores
- Hard, non-erodible rocky coasts without sediment at the base
- Port or harbour zones

Finally, participants assessed the sensitivity of environmental factors, taking the protection status of coastal areas in the Adriatic Sea into account. Based on the project's goals, the following protection status categories were defined, reflecting the varying terminology and levels of protection used in partner countries:

- National Parks, Marine Protected Areas, Protected Areas of National Interest (only Slovenia)
- Natura 2000 and Special Protection Areas
- Unprotected areas
- Regional parks and Landscape parks
- Protected habitats or areas of presence of protected species

To avoid influencing participants' evaluations, the protection categories were presented without any hierarchical ordering based on legislative strength.

5.2.1.3 CVA STEP 1

In Step 3, participants were asked to assign a relative importance score to each group of sensitivity factors, using a scale from 1 to 9. These scores were subsequently converted into percentage values.

5.2.2 IDENTIFICATION OF STAKEHOLDERS

Stakeholders mapping was undertaken by identifying all governmental and non-governmental, public and private entities that are either engaged in environmental protection activities, or run a business with a social or economic value, or are involved in oil spill prevention and clean-up. First, four key tasks related to oil spill detection and clean-up were defined: prevention, preparedness and monitoring activities (PPM); detection and alerting tasks (DA); cleaning and cleaning-related activities (CCRA); and post cleaning operations (PCO). Any entity involved in at least one these tasks was considered suitable for participation in the Coastal Sensitivity Assessment Workshop. Within ASAP, local partners PP7, PP8, PP9 with the help of PP2, PP3, LP and of the associated partners GMD-AL and MSPMA, identified and invited the relevant stakeholders to join the stakeholders' focus groups.

5.2.3 STAKEHOLDERS' FOCUS GROUPS RESULTS

This Section contains the results obtained from the six organised workshops in Rijeka, Portorož, Trieste (within the NAMIRS project), and Kotor, Durres, and Sarajevo (within the ASAP project), where in total 203 people participated either in situ or online via provided links to the digital versions of the questionnaire. The research team processed the collected data to obtain raw statistical information from each workshop, which will be further processed in the following phases of ASAP. For easier understanding of the question list in the column on the left of the following tables, 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 shown in the tables are colour-coded in shades of green, yellow, and red. Values in green represent the lowest level of sensitivity, yellow indicates a medium level of sensitivity, and red ones represent a high level of sensitivity.

The self-assessment of the 203 participants resulted in 22 representatives of environmental organisations and other NGOs, 20 members of the business sector, 48 scientists, professors, or teachers, 83 civil servants or elected officials, and 30 citizens. This is shown in Fig. 31, with numbers related to answers through the following legend:

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

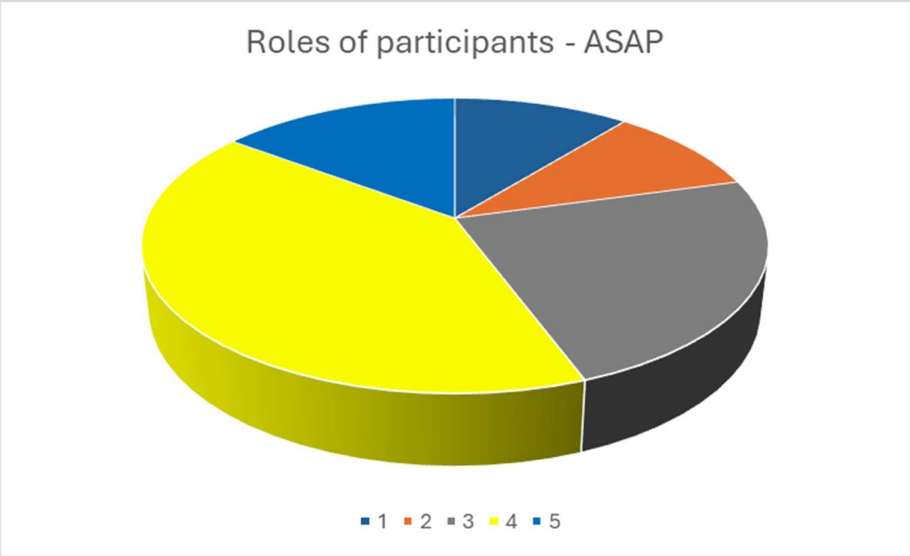


Figure 31 Breakdown of the self-assessed role of the participants to all three workshops.

Participants were asked to indicate their role in the event of an oil spill. The chart in Fig. 32 shows the 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.

Out of a total of 203 participants, 76 indicated they would be in action as part of their duty, 37 would step into action if requested, 43 would actively monitor the situation and offer suggestions to relevant services, 40 would monitor the event as a citizen, and 7 would not be interested. The results of the self-assessment are shown in Fig. 33.

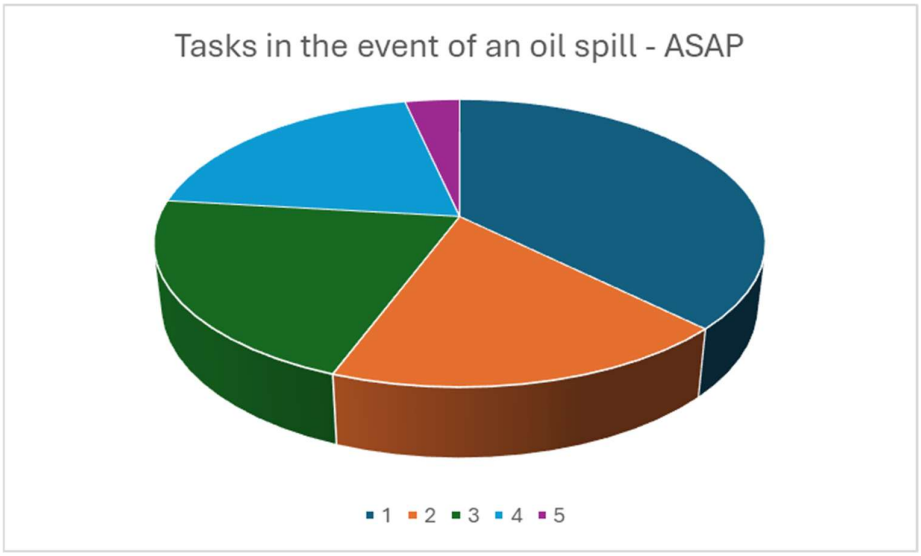


Figure 33: Breakdown of the self-assessed task in case of oil spill of the participants to all three workshops.

5.2.4 RESULTS OF THE NAMIRS STAKEHOLDERS' WORKSHOP IN CROATIA

A total of 24 people participated in the Croatian CVA workshop, which was held in person only in Rijeka on September 29th, 2022.

Among the participants, 16 identified themselves as civil servants or elected officials, 2 as scientists, professors, or teachers, and 6 as members of the business sector. Table 9 shows the main statistics of the sensitivity scores provided by participants for each sensitivity factor, indicated in the left column.

The 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 instead with a percentage ratio. While the results between all three workshops are comparable, as the scores can be converted into percentage ratios, the Croatian data do not explicit the participants' general assessment of importance (e. g., if a participant would assigned scores of 3, 3, and 3, to three sensitivity factors, and another one 9, 9, and 9, both would result in the identical shares of 33%, 33% and 33%, but it is clear that the second participant considers all three factors to be much more important than the first one).

Table 9: Results of the NAMIRS stakeholders' workshop in Rijeka (Croatia). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
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	1.8
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	1.9
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
Q5h	8.3	9	9	0.9
Q6a	8.8	9	9	0.6
Q6b	8.3	9	8	0.8
Q6c	7.5	9	8	1.3
Q6d	7.8	8	8	1.3
Q6e	8.5	9	9	1.0
Q7a	0	0	0	/
Q7b	0	0	0	/
Q7c	0	0	0	/
Q7d	32%	30%	30%	/
Q7e	39%	40%	40%	/
Q7f	29%	20%	30%	/

The results of the Rijeka workshop indicate that the highest assessed importance was assigned to environmental and socio-economic factors, while geomorphological factors were considered less important.

5.2.5 RESULTS OF THE NAMIRS STAKEHOLDERS' WORKSHOP IN SLOVENIA

A total of 54 people participated in the Slovenian CVA workshop, 14 of them in person in Portorož on October 6th, 2022, and 40 online. The self-assessment of the roles of the participants produced the following results: 29 civil servants or elected officials, 3 members of the business sector, 16 scientists, professors, or teachers, 3 members of environmental organisations or other NGOs, and 3 citizens.

IN-PERSON RESULTS

Of the 14 in-person participants, 9 identified themselves as civil servants or elected officials, 1 as a member of the business sector, and 4 as scientists, professors, or teachers. Table 10 shows the main statistics of sensitivity scores provided by participants for each sensitivity factor, indicated in the left column.

Table 10 shows the main statistics for sensitivity scores provided by participants to the in-person Slovenian workshop for each sensitivity factor, including: Average, Mode, Median, and Standard deviation. The leftmost column reports the corresponding question of the CVA, see legend at the beginning of this chapter.

Table 10: Live results of the NAMIRS stakeholders' workshop in Portorož (Slovenia). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
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	1.6
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	2.3
Q5h	7.1	7	7	1.4
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	1.6
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%	/
Q7f	31%	33%	30%	/

On average, participants of the in-person workshop assigned the highest priority to protected areas in the environmental sensitivity factors group, while lower importance was given to geomorphological and socio-economic factors, although the differences between them were not substantial.

ONLINE RESULTS

Of the online participants, 20 identified themselves as civil servants or elected officials, 2 as members of the business sector, 12 as scientists, professors, or teachers, 3 as members of environmental organisations or other NGOs, and 3 as citizens. Table 11 shows the main statistics of sensitivity scores provided by participants for each sensitivity factor, indicated in the left column.

Table 11: Online results of the NAMIRS stakeholders' workshop in Portorož (Slovenia). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
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	2.0
Q5f	7.0	9	7	2.2
Q5g	4.8	3	5	2.3
Q5h	7.1	9	8	2.1
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.

COMBINED RESULTS FOR NAMIRS STAKEHOLDERS' WORKSHOP IN SLOVENIA

Table 12 shows the combined (in-person + online) results of the Slovenian stakeholders' workshop organized during NAMIRS.

Table 12: Combined results of the NAMIRS stakeholders' workshop in Portorož (Slovenia). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	7.1	9	8	2.12
Q4b	7.0	7	7	1.80
Q4c	5.9	6	6	1.88

Q4d	6.1	7	7	1.86
Q4e	5.4	5	5	1.82
Q4f	5.8	6	6	2.10
Q4g	6.1	8	6	1.98
Q4h	6.0	6	6	1.91
Q5a	7.9	9	9	1.72
Q5b	7.3	9	8	2.11
Q5c	6.2	9	7	2.35
Q5d	5.1	5	5	2.25
Q5e	6.5	7	7	2.03
Q5f	6.9	9	7	2.14
Q5g	5.1	3	5	2.34
Q5h	7.1	9	7	1.86
Q6a	7.8	9	8	1.62
Q6b	7.7	9	8	1.55
Q6c	6.9	7	7	1.58
Q6d	7.4	7	8	1.66
Q6e	7.8	9	8	1.59
Q7a	7.0	7	7	1.52
Q7b	8.0	9	9	1.33
Q7c	7.2	8	8	1.63
Q7d	32%	29%	29%	/
Q7e	36%	38%	38%	/
Q7f	32%	33%	33%	/

5.2.6 RESULTS OF THE NAMIRS STAKEHOLDERS' WORKSHOP IN ITALY

A total of 26 people participated in the Italian CVA workshop, of whom16 attended in person in Trieste on October 13th, 2022, and 10 online. Among them, 12 identified themselves as scientists, professors, or teachers, 4 as members of the 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 this question.

IN-PERSON RESULTS

The workshop was conducted simultaneously in person and online. Of a total of 26 participants, 16 people participated in person. Among them, 7 identified themselves as scientists, professors, or teachers, 2 as members of the business sector, 1 as a civil servant or elected official, 1 as a citizen,

and 1 did not answer this question. Table 13 shows the main statistics for each sensitivity factor, indicated in the left column.

Table 13: Live results of the NAMIRS stakeholders' workshop in Trieste (Italy). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
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	2.0
Q5f	6.6	6	7	2.1
Q5g	5.6	9	6	3.0
Q5h	7.9	9	8	1.5
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%	/

Participants assigned 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.

ONLINE RESULTS

Out of the 26 participants, 10 participated online. Among them were 5 scientists, professors, or teachers, 1 civilian, 2 members of the business sector, and 2 civil servants or elected officials (Table 14).

Table 6 shows the main statistics for sensitivity scores provided by participants to the online Italian workshop for each sensitivity factor: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Table 14: Online results of the NAMIRS stakeholders' workshop in Trieste (Italy). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
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
Q5h	7.6	8	8	1.8
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	1.1
Q6e	8.8	9	9	0.4
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, participants of the online Italian workshop assigned higher priority to socio-economic factors than to geomorphology, while environmental factors were assessed in the same manner as before and given top priority. However, the scores showed a high level of dispersion, as indicated by the standard deviation values.

COMBINED RESULTS OF THE NAMIRS STAKEHOLDERS' WORKSHOP FOR ITALY

The combined (in-person + online) results of the NAMIRS stakeholders' workshop in Trieste are presented in Table 15.

Table 15: Combined results of the NAMIRS stakeholders' workshop in Trieste (Italy). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	8.3	9	9	1.13
Q4b	7.8	9	8	1.06
Q4c	7.3	9	8	1.59
Q4d	7.3	7	7	1.16
Q4e	5.8	6	6	1.77
Q4f	6.1	9	6	2.20
Q4g	7.0	6	7	1.63
Q4h	6.6	6	7	1.88
Q5a	7.0	8	8	1.79
Q5b	7.8	9	8	1.40
Q5c	7.8	7	8	1.00
Q5d	5.2	6	6	2.00
Q5e	7.4	9	8	1.74

Q5f	6.7	8	7	1.94
Q5g	5.0	9	5	2.77
Q5h	7.8	9	8	1.58
Q6a	8.5	9	9	0.80
Q6b	8.2	9	9	1.38
Q6c	7.1	7	7	1.24
Q6d	8.2	9	9	0.97
Q6e	8.6	9	9	1.04
Q7a	7.6	8	8	1.08
Q7b	8.6	9	9	0.84
Q7c	7.2	7	7	1.31
Q7d	32%	33%	33%	/
Q7e	37%	38%	38%	/
Q7f	31%	29%	29%	/

5.2.7 RESULTS OF THE ASAP STAKEHOLDERS' FOCUS GROUP IN BOSNIA & HERZEGOVINA

A total of 36 people participated in the Bosnia & Herzegovina focus group in Sarajevo, on October 10th, 2024. 21 of them were present at the venue in Sarajevo, 15 participated online. Among them, 10 identified themselves as scientists, professors, or teachers, 4 as civil servants or elected officials, 3 as members of environmental organisations or other NGOs, and 19 as citizens.

IN-PERSON RESULTS

The workshop was conducted at the same time in person as well as online. Of a total of 36 participants, 21 people attended in person. Among them, 10 identified themselves as scientists, professors, or teachers, 2 as civil servants or elected officials, 6 as citizens, and 3 people as members of environmental organisations or other NGOs. Table 16 shows the main statistics for each sensitivity factor, indicated in the left column.

Table 16: Live results of the ASAP focus group in Sarajevo (Bosnia & Herzegovina). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	8.5	9	9	0.8
Q4b	7.9	9	8	1.1

Q4c	7.8	9	8	1.1
Q4d	7.3	9	7	1.6
Q4e	6.8	9	7	2.0
Q4f	6.2	6	6	1.7
Q4g	7.0	8	7	1.4
Q4h	6.5	7	7	1.4
Q5a	7.4	9	8	1.8
Q5b	8.2	9	8	1.0
Q5c	7.6	9	8	1.7
Q5d	6.0	7	7	1.8
Q5e	6.1	8	7	2.4
Q5f	6.7	7	7	1.9
Q5g	7.3	7	8	1.6
Q5h	/	/	/	/
Q6a	8.7	9	9	0.5
Q6b	8.4	9	9	0.8
Q6c	7.9	9	8	1.3
Q6d	7.5	7	8	1.8
Q6e	8.5	9	9	0.9
Q7a	7.5	8	8	1.2
Q7b	8.4	9	9	1.0
Q7c	7.3	7	7	0.9
Q7d	32%	33%	33%	/
Q7e	36%	38%	38%	/
Q7f	31%	29%	29%	/

As was the case in the outcomes of workshops executed in other partner countries, the Bosnia & Herzegovina stakeholders also assigned the highest priority to environmental factors, while geomorphological and socio-economic criteria were given approximately the same level of importance. However, some of the criteria were inconsistently assessed, showcasing disagreement between participants.

ONLINE RESULTS

15 people participated in the online execution of the workshop. Among them were 13 citizens and 2 civil servants or elected officials. As was the case in the tables showcased above, the one below

provides the same information. Table 17 shows the results of the online Bosnia & Herzegovina focus group.

Table 17: Online results of the ASAP focus group in Sarajevo (Bosnia & Herzegovina). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Tableon	μ	Mode	Median	S
Q4a	6.2	7	7	2.4
Q4b	6.7	9	7	2.1
results				
Q4e	7.0	8	8	2.0
Q4f	6.1	8	7	2.5
Q4g	6.9	9	8	2.5
Q4h	7.1	8	8	2.1
Q5a	6.7	7	7	1.7
Q5b	6.3	6	6	1.5
Q5c	6.9	5	7	1.8
Q5d	5.4	5	5	1.5
Q5e	6.8	5	7	1.6
Q5f	6.4	5	6	1.4
Q5g	6.9	8	8	2.2
Q5h	/	/	/	/
Q6a	7.2	9	8	2.5
Q6b	7.1	9	8	2.6
Q6c	6.7	7	7	2.2
Q6d	6.6	6	7	2.2
Q6e	7.5	9	9	2.4
Q7a	6.6	8	8	2.9
Q7b	7.0	9	8	3.0
Q7c	7.1	9	8	3.0
Q7d	32%	31%	33%	/
Q7e	34%	35%	33%	/
Q7f	34%	35%	33%	/

Online participants assigned equal importance to environmental and geomorphological factors, while socio-economic factors were assessed as less important, albeit by a small margin. However, a very high standard deviation indicates inconsistency in stakeholders' assessment.

COMBINED RESULTS OF THE BOSNIA & HERZEGOVINA FOCUS GROUP

The combined (in-person + online) results of the Bosnia & Herzegovina focus group are displayed in Table 18.

Table 18: Combined results of the ASAP focus group in Sarajevo (Bosnia & Herzegovina). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	7.6	9	8	1.96
Q4b	7.4	9	8	1.67
Q4c	7.5	8	8	1.40
Q4d	7.3	9	8	1.74
Q4e	6.9	8	8	1.95
Q4f	6.2	8	6	2.03
Q4g	7.0	8	8	1.85
Q4h	6.8	7	7	1.72
Q5a	7.1	9	8	1.77
Q5b	7.4	9	8	1.50
Q5c	7.3	9	8	1.73
Q5d	5.8	5	6	1.72
Q5e	6.4	8	7	2.10
Q5f	6.6	7	7	1.72
Q5g	7.1	8	8	1.87
Q5h	/	/	/	/
Q6a	8.1	9	9	1.77
Q6b	7.8	9	9	1.88
Q6c	7.4	9	8	1.77
Q6d	7.1	8	8	1.99
Q6e	8.1	9	9	1.74
Q7a	7.1	8	8	2.06
Q7b	7.8	9	9	2.15

Q7c	7.2	8	8	2.02
Q7d	32%	32%	32%	/
Q7e	35%	36%	36%	/
Q7f	33%	32%	32%	/

5.2.8 RESULTS OF THE ASAP STAKEHOLDERS' FOCUS GROUP IN ALBANIA

In total, 44 people participated in the ASAP stakeholders's focus group in Durres on February 19th, 2025, either in person or online via the provided digital versions of the questionnaire. Among participants, there were 7 members of environmental organisations or other NGOs, 5 members of the marine business sector, 2 scientists, professors, or teachers, 27 civil servants or elected officials, and 3 citizens.

IN-PERSON RESULTS

20 people participated in person: 5 of them identified themselves as environmental organisation or other NGO members, 2 as members of marine businesses, 2 as scientists, professors or teachers, 9 as civil servants or elected officials, and 2 as citizens.

Table 19 highlights the average, mode, median, and standard deviations of grades dedicated to each sensitivity criterion by the participants on live workshops.

Table 19: Live results of the ASAP focus group in Durres (Albania). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	6.8	9	7	2.2
Q4b	6.4	5	7	2.0
Q4c	6.5	6	6	1.9
Q4d	6.0	6	6	2.2
Q4e	5.5	5	5	2.3
Q4f	6.4	6	6	1.9
Q4g	6.9	6	7	2.0
Q4h	7.0	6	7	1.6
Q5a	7.0	9	8	2.5
Q5b	8.0	9	9	2.1
Q5c	7.2	9	8	2.5
Q5d	5.1	5	5	2.4

Q5e	5.1	9	5	2.8
Q5f	5.6	8	6	2.8
Q5g	6.5	8	8	2.9
Q5h	/	/	/	/
Q6a	6.6	9	7	2.6
Q6b	6.8	8	8	2.4
Q6c	7.2	7	7	1.6
Q6d	7.4	8	8	2.0
Q6e	7.5	9	8	2.0
Q7a	7.3	9	8	2.1
Q7b	8.1	9	9	1.9
Q7c	7.5	7	8	1.6
Q7d	32%	36%	32%	/
Q7e	35%	36%	36%	/
Q7f	33%	28%	32%	/

Live participants estimated the priorities of factor groups in the same manner as online participants, giving all of them almost the same level, the highest of which was the one given to the environmental group.

ONLINE RESULTS

The remaining 24 people participated online, namely 2 members of environmental organisations or other NGOs, 3 members of the marine business sector, 18 civil servants or elected officials, and 1 citizen.

Table 20 highlights the results of the online participants to the focus group in Albania.

Table 20: Online results of the ASAP focus group in Durres (Albania). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	6.2	9	6	2.4
Q4b	6.5	8	7	2.1
Q4c	6.3	7	7	2.0
Q4d	5.9	5	6	2.1
Q4e	4.7	6	5	2.5
Q4f	6.6	8	7	2.3

Q4g	6.7	7	7	1.7
Q4h	6.3	5	7	2.0
Q5a	6.5	9	6	2.2
Q5b	7.3	9	8	1.9
Q5c	7.3	9	9	2.3
Q5d	4.4	2	4	2.5
Q5e	5.3	5	5	2.4
Q5f	6.3	9	7	2.1
Q5g	6.4	9	7	2.3
Q5h	/	/	/	/
Q6a	7.1	9	8	2.2
Q6b	7.0	8	8	2.0
Q6c	7.5	9	8	1.7
Q6d	7.0	9	8	2.0
Q6e	7.0	9	8	2.0
Q7a	7.4	7	8	1.3
Q7b	8.2	9	9	1.7
Q7c	7.6	9	8	1.3
Q7d	32%	28%	31%	/
Q7e	35%	36%	37%	/
Q7f	33%	36%	33%	/

COMBINED RESULTS OF THE FOCUS GROUP IN ALBANIA

Table 21 below highlights the combined results from the online and in-person Albanian focus groups.

Table 21: Combined results of the ASAP focus group in Durres (Albania). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	6.4	9	7	2.24
Q4b	6.4	7	7	1.98
Q4c	6.4	6	6	1.91
Q4d	5.9	5	6	2.08
Q4e	5.0	5	5	2.38

Q4f	6.5	6	7	2.05
Q4g	6.8	7	7	1.81
Q4h	6.6	9	7	1.84
Q5a	6.7	9	8	2.29
Q5b	7.6	9	8	1.98
Q5c	7.3	9	8	2.36
Q5d	4.7	5	5	2.42
Q5e	5.2	5	5	2.56
Q5f	5.9	8	6	2.41
Q5g	6.4	9	7	2.52
Q5h				0.00
Q6a	6.9	9	8	2.34
Q6b	6.9	8	8	2.15
Q6c	7.3	9	8	1.64
Q6d	7.1	9	8	2.00
Q6e	7.3	9	8	1.94
Q7a	7.3	9	8	1.66
Q7b	8.1	9	9	1.76
Q7c	7.5	9	8	1.44
Q7d	32%	33%	32%	/
Q7e	35%	33%	36%	/
Q7f	33%	33%	32%	/

5.2.9. RESULTS OF THE ASAP STAKEHOLDERS' FOCUS GROUP IN MONTENEGRO

19 people participated in the Montenegrin stakeholders' focus group in Kotor on June 25th, 2025, 11 of them online and 8 in-person. Among them, 6 identified themselves as scientists, professors, or teachers, 1 as a member of the marine business sector, 4 as civil servants or elected officials, 5 as members of environmental organisations or other NGOs, and 3 as citizens.

IN-PERSON RESULTS

8 people participated in the online execution of the workshop. Among them, 2 were members of environmental organisations or other NGOs, 4 civil servants or elected officials, and 3 scientists, professors, or teachers. As was the case in the tables showcased above, Table 22 shows the mean, mode, median and standard deviation values of obtained sensitivity grades from experts who participated live.

Table 22: Live results of the ASAP focus group in Kotor (Montenegro). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	7.5	7	7	0.7
Q4b	6.9	9	8	2.3
Q4c	7.1	9	8	2.0
Q4d	7.4	9	8	2.1
Q4e	5.5	7	7	2.9
Q4f	7.5	7	8	0.9
Q4g	7.6	8	8	1.3
Q4h	7.6	8	8	0.9
Q5a	6.9	8	8	1.7
Q5b	7.8	9	9	2.0
Q5c	7.8	9	9	2.2
Q5d	4.0	7	4	2.3
Q5e	5.6	5	6	2.5
Q5f	5.6	8	6	2.7
Q5g	5.1	8	6	2.6
Q5h	7.1	8	8	2.1
Q6a	8.4	9	9	1.0
Q6b	7.7	8	8	1.7
Q6c	8.3	8	8	0.7

Q6d	7.4	8	8	2.1
Q6e	8.3	9	9	1.5
Q7a	7.3	9	7	1.6
Q7b	8.6	9	9	0.7
Q7c	7.8	8	8	0.7
Q7d	31%	35%	29%	/
Q7e	37%	35%	38%	/
Q7f	33%	31%	33%	/

As was the trend in other workshops, the participants in live Montenegrin workshops also assigned the highest priority to environmental factors and placed geomorphological factors before socio-economic, albeit not by much.

ONLINE RESULTS

In total, 11 people participated in the online execution of coastal sensitivity assessment workshops in Montenegro. 3 participants identified themselves as members of environmental organisations or other NGOs, 1 participant declared themself a member of the marine business sector, 4 participants were civil servants or elected officials, and the last 3 participants were citizens. Table 23 highlights the results of sensitivity factors grading by online participants.

Table 23: Online results of the ASAP focus group in Kotor (Montenegro). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	8.5	9	9	0.8
Q4b	7.4	7	7	1.1
Q4c	7.0	7	7	1.5
Q4d	7.3	8	8	1.6
Q4e	5.8	1	7	3.2
Q4f	6.4	9	6	2.3
Q4g	7.4	8	8	1.5
Q4h	6.8	7	7	2.2
Q5a	6.8	9	7	1.8
Q5b	5.7	3	6	2.5
Q5c	8.3	9	9	1.1
Q5d	5.0	1	7	3.7

Q5e	7.9	9	8	1.3
Q5f	6.4	9	8	3.2
Q5g	4.5	1	5	3.3
Q5h	/	/	/	/
Q6a	8.2	9	9	1.3
Q6b	8.1	9	9	1.6
Q6c	7.4	9	9	3.2
Q6d	7.7	9	9	1.7
Q6e	8.6	9	9	0.9
Q7a	6.1	7	7	2.5
Q7b	8.1	9	9	1.7
Q7c	7.9	9	9	1.6
Q7d	28%	28%	28%	/
Q7e	37%	36%	36%	/
Q7f	36%	36%	36%	/

Online participants assigned the highest importance to the environmental and geomorphological factors, while socio-economic factors were given the lowest level. High standard deviation on some of the criteria suggests inconsistency in stakeholders' assessment.

COMBINED RESULTS OF THE FOCUS GROUP IN MONTENEGRO

The combined (in-person + online) results of the Montenegrin focus groups are highlighted in Table 24.

Table 24: Combined results of the ASAP focus group in Kotor (Montenegro). For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	8.1	9	8	0.91
Q4b	7.2	7	7	1.63
Q4c	7.1	9	7	1.64
Q4d	7.3	8	8	1.72
Q4e	5.7	7	7	2.95
Q4f	6.8	9	7	1.84
Q4g	7.5	8	8	1.35
Q4h	7.2	8	8	1.72

Q5a	6.8	8	7	1.66
Q5b	6.6	9	7	2.41
Q5c	8.1	9	9	1.57
Q5d	4.6	1	4	3.08
Q5e	6.9	9	7	2.11
Q5f	6.1	9	7	2.87
Q5g	4.7	8	5	2.90
Q5h	7.1	8	8	1.96
Q6a	8.3	9	9	1.10
Q6b	7.9	9	9	1.54
Q6c	7.7	9	9	2.45
Q6d	7.6	9	8	1.74
Q6e	8.5	9	9	1.14
Q7a	6.6	9	7	2.11
Q7b	8.3	9	9	1.34
Q7c	7.8	9	8	1.23
Q7d	29%	33%	29%	/
Q7e	37%	33%	38%	/
Q7f	34%	33%	33%	/

5.2.10. COMBINED RESULTS OF THE NAMIRS AND ASAP STAKEHOLDERS' WORKSHOPS

Lastly the results from all focus groups were compiled into a joint database. Table 25 highlights mean, mode, median and standard deviation values for each sensitivity criterion.

Table 25: Combined results for all (NAMIRS + ASAP) stakeholders' consultations. For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	7.4	9	8	1.95
Q4b	7.2	9	7	1.74
Q4c	6.7	9	7	1.83
Q4d	6.6	7	7	1.89
Q4e	5.8	5	6	2.16
Q4f	6.3	6	6	2.07

Q4g	6.8	8	7	1.87
Q4h	6.5	7	7	1.90
Q5a	7.2	9	8	1.93
Q5b	7.4	9	8	1.89
Q5c	7.1	9	8	2.06
Q5d	5.1	5	5	2.28
Q5e	6.4	9	7	2.26
Q5f	6.3	7	7	2.29
Q5g	5.7	9	6	2.57
Q5h	/	/	/	/
Q6a	7.9	9	9	1.75
Q6b	7.7	9	8	1.74
Q6c	7.2	9	7	1.68
Q6d	7.5	9	8	1.74
Q6e	8.0	9	9	1.62
Q7a	7.2	7	7	1.67
Q7b	8.1	9	9	1.58
Q7c	7.2	7	8	1.65
Q7d	32%	30%	29%	/
Q7e	36%	39%	38%	/
Q7f	32%	30%	33%	/

The joint results highlight that the highest priority was assigned to the environmental factors, while socio-economic and geomorphological factors were given equal levels of priority.

The research team also 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 backgrounds of the participants can be assessed.

Table 21 shows the main statistics for sensitivity scores of each sensitivity factor provided by participants who self-assessed as members of environmental organizations and NGOs in all (NAMIRS +ASAP) stakeholders' consultations.

Table 26: Combined results for members of environmental organizations and NGOs for all (NAMIRS + ASAP) stakeholders' consultations. For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	8.0	9	9	1.79
Q4b	7.2	9	7	1.76
Q4c	7.1	9	8	2.02
Q4d	6.9	9	7	1.93
Q4e	5.8	6	6	2.14
Q4f	5.8	6	6	1.97
Q4g	6.9	6	7	1.66
Q4h	6.7	6	7	1.70
Q5a	7.1	9	8	1.93
Q5b	7.0	8	8	2.29
Q5c	7.5	9	9	2.28
Q5d	4.8	7	5	2.32
Q5e	7.2	9	8	1.82
Q5f	7.2	9	8	1.90
Q5g	4.8	1	5	2.94
Q5h	/	/	/	/
Q6a	8.0	9	9	2.08
Q6b	8.1	9	9	1.81
Q6c	8.0	9	8	1.29
Q6d	7.5	9	8	2.02
Q6e	8.0	9	9	1.75
Q7a	7.0	8	7	1.65
Q7b	8.8	9	9	0.75
Q7c	7.5	8	8	1.57
Q7d	30%	32%	29%	
Q7e	38%	36%	38%	
Q7f	32%	32%	33%	

Table 27 shows the main statistics for sensitivity scores of each sensitivity factor provided by participants who self-assessed as members of the Business sector in all (NAMIRS + ASAP) stakeholders' workshops.

Table 27: Combined results for participants from the business sector for all (NAMIRS + ASAP) stakeholders' consultations. For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	7.2	9	8	2.53
Q4b	6.9	9	8	2.56
Q4c	6.4	9	7	2.43
Q4d	6.4	7	7	2.50
Q4e	4.4	3	4	2.34
Q4f	6.7	9	8	2.52
Q4g	6.4	9	7	2.46
Q4h	6.3	9	7	2.33
Q5a	6.4	8	6	2.17
Q5b	7.7	9	8	1.59
Q5c	7.1	9	7	1.93
Q5d	4.2	6	3	2.41
Q5e	5.8	5	5	2.07
Q5f	5.2	3	6	2.43
Q5g	5.4	7	6	2.65
Q5h	/	/	/	/
Q6a	7.0	9	9	2.87
Q6b	6.9	9	8	2.66
Q6c	6.7	8	7	1.97
Q6d	6.7	9	8	2.56
Q6e	7.5	9	9	2.44
Q7a	7.0	7	7	1.56
Q7b	8.1	9	9	1.20
Q7c	7.5	9	8	1.78
Q7d	31%	28%	29%	
Q7e	36%	36%	38%	
Q7f	33%	36%	33%	

Table 28 shows the main statistics for sensitivity scores of each sensitivity factor provided by participants who self-assessed as Scientist, professor, or teacher in all stakeholders' workshops.

Table 28: Combined results for participants profiles as Scientist, professor, or teacher for all (NAMIRS + ASAP) stakeholders' consultations. For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	7.9	9	9	1.54
Q4b	7.2	7	7	1.59
Q4c	6.6	7	7	1.90
Q4d	6.4	7	7	1.92
Q4e	5.8	5	6	1.99
Q4f	5.8	6	6	2.19
Q4g	6.5	8	7	1.76
Q4h	6.1	6	6	1.89
Q5a	7.6	8	8	1.60
Q5b	7.5	8	8	1.95
Q5c	7.1	7	7	1.75
Q5d	4.9	6	5	2.32
Q5e	6.5	9	7	2.32
Q5f	6.5	7	7	2.31
Q5g	5.4	7	6	2.63
Q5h	/	/	/	/
Q6a	8.0	9	8	1.26
Q6b	7.7	9	8	1.43
Q6c	6.9	7	7	1.77
Q6d	7.3	7	8	1.64
Q6e	8.1	9	9	1.32
Q7a	7.0	7	7	1.79
Q7b	8.2	9	9	1.21
Q7c	7.1	7	7	1.53
Q7d	31%	30%	30%	
Q7e	37%	39%	39%	
Q7f	32%	30%	30%	

Table 29 shows the combined results of answers provided by participants to all three workshops who self-assessed as civil servants or elected officials. Main statistics for sensitivity scores of each sensitivity factor provided by participants who self-assessed as Civil servant, elected official in all stakeholders' consultations.

Table 29: Combined results for participants profiles as Civil servants or elected officials for all (NAMIRS + ASAP) stakeholders' consultations. For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	7.1	9	8	2.00
Q4b	7.4	9	8	1.65
Q4c	6.7	8	7	1.75
Q4d	6.6	5	7	1.78
Q4e	5.8	5	6	2.23
Q4f	6.5	6	7	1.98
Q4g	6.9	8	7	1.91
Q4h	6.6	8	7	1.98
Q5a	7.3	9	8	2.01
Q5b	7.6	9	8	1.93
Q5c	7.1	9	8	2.32
Q5d	5.3	5	5	2.32
Q5e	6.1	7	7	2.35
Q5f	6.0	7	6	2.34
Q5g	5.8	9	6	2.52
Q5h	/	/	/	/
Q6a	8.0	9	9	1.46
Q6b	7.8	9	8	1.39
Q6c	7.4	9	8	1.48
Q6d	7.7	9	8	1.38
Q6e	8.0	9	9	1.45
Q7a	7.5	7	8	1.37
Q7b	8.2	9	9	1.60
Q7c	7.2	8	8	1.50
Q7d	33%	29%	32%	
Q7e	36%	38%	36%	
Q7f	32%	33%	32%	

Table 30 shows the combined results of answers provided by participants to all workshops who self-assessed as citizens.

Table 30: Combined results for participants profiles as Citizens for all (NAMIRS + ASAP) stakeholders' consultations. For each sensitivity factor the main statistics are shown: Average, Mode, Median, and Standard deviation. In the leftmost column, the corresponding question of the CVA, see legend at the beginning of this chapter.

Question	μ	Mode	Median	S
Q4a	7.3	9	8	2.06
Q4b	7.0	7	7	1.66
Q4c	7.1	8	7	1.37
Q4d	7.1	7	7	1.69
Q4e	6.4	7	7	1.83
Q4f	6.4	8	7	1.83
Q4g	7.0	8	7	1.69
Q4h	7.0	7	7	1.50
Q5a	6.8	9	7	2.00
Q5b	7.2	9	7	1.60
Q5c	7.0	7	7	1.84
Q5d	5.5	5	5	1.94
Q5e	6.6	9	7	2.18
Q5f	6.6	9	7	2.06
Q5g	7.1	8	8	1.89
Q5h	/	/	/	/
Q6a	7.9	9	9	2.00
Q6b	7.7	9	9	2.15
Q6c	7.5	9	8	1.91
Q6d	7.4	9	8	1.89
Q6e	8.0	9	9	1.89
Q7a	6.9	8	8	2.26
Q7b	7.5	9	8	2.40
Q7c	7.2	7	8	2.22
Q7d	32%	33%	33%	
Q7e	35%	38%	35%	
Q7f	33%	29%	33%	

5.2.11 DISCUSSION OF STAKEHOLDER SENSITIVITY EVALUATIONS

The high standard deviation values observed across sensitivity factors suggest that most participants did not utilize the full range of available scores. Instead, they predominantly selected values from the upper half of the scale. This pattern can be interpreted in two ways. One possibility is that participants genuinely considered all sensitivity factors to be highly important and would therefore not overlook any of them in the event of an oil spill. Alternatively, the limited use of lower scores may reflect a lack of familiarity with certain factors, leading to overestimation. Improved guidance from the organizers might have encouraged a broader distribution of scores. Nevertheless, since all participants were experts in their fields, it is reasonable to assume they possessed sufficient knowledge to complete the questionnaires in an informed manner.

The aggregated results show that stakeholders assigned the highest priority (36%) to environmental factors, while socio-economic and geomorphological factors followed closely, each receiving 32%. This indicates a relatively balanced valuation across all three categories. A more detailed analysis could reveal variations in prioritization among different stakeholder groups.

The results for environmental sensitivity factors were somewhat unexpected. All categories of environmental protection received high sensitivity scores. This may reflect a deliberate choice by stakeholders, driven by heightened environmental awareness and the belief that no area—protected or unprotected—should suffer the consequences of an oil spill. However, it is also possible that the distinction between protected and unprotected areas was not clearly communicated. Some stakeholders may have rated unprotected areas as highly sensitive precisely because they lack formal protection, while assuming that protected areas are inherently more resilient. This misinterpretation could have been mitigated with clearer explanations, as both types of areas are equally vulnerable to oil pollution.

It is important to note that the concept of nature conservation inherently involves assigning different levels of protection based on ecological importance. Areas deemed more valuable receive higher protection (e.g., MPAs or National Parks), while others receive lower levels (e.g., Natura 2000 sites or habitats protected under EU directives). The results might have differed had the questionnaire focused on the “value” or “importance” of environmental factors rather than their “sensitivity.”

The environmental sensitivity scores were heavily skewed toward the high end of the scale. The lowest average score was assigned to unprotected areas, while the highest went to protected habitats or areas with protected species. MPAs and National Parks received an average score. If these values were used directly in sensitivity mapping, nearly the entire Adriatic coastline would be

classified as high priority for oil spill response—an impractical outcome for emergency planning. Therefore, the research team chose not to use these stakeholder-derived scores for environmental sensitivity mapping.

The stakeholder workshops provided essential input for computing sensitivity indices and producing sensitivity maps for the Adriatic Sea. These outputs support contingency planning by identifying priority areas for protection and cleanup. A potential future enhancement would be to apply the Delphi method, which weights responses based on participants' self-assessed familiarity with each sensitivity factor. This method categorizes participants into three expertise levels and adjusts their input, accordingly, giving more weight to those with higher expertise.

Beyond the core objectives of ASAP, the workshops yielded further benefits, including strengthened collaboration and knowledge exchange among stakeholders. One of them was the strengthening of the collaboration between ASAP partners, with frequent meetings and coordination between the organizers of the involved partners. Another key aspect is the project's outreach, aiming to engage a broader audience, including individuals, institutions, and companies, with an interest in the sustainable use of marine and coastal resources.

5.3 ADRIATIC COASTLINE VULNERABILITY

5.3.1 DATA COLLECTION

Coastal vulnerability was assessed considering three groups of vulnerability factors (VFs): geomorphological, environmental and socioeconomic factors.

To provide high-resolution maps of the single groups of VFs and the total coastal vulnerability in the Adriatic Sea, georeferenced data on the presence of the selected VFs in ASAP were obtained by previous projects we carried out in the area (including NAMIRS), by searching in online databases, and from colleagues and project partners. A list of the layers for each VF group is reported in Table 31 with information on the source, the file format, and a brief description.

Because most kinds of oil are less dense than water, most spilled oils float on the water surface and it is expected that it affects mainly upper-sublittoral and surface organisms and structures. Thus, only VFs on the coastline and up to 5 meters depth were retained for the coastal vulnerability assessment. The bathymetry chart of the Adriatic Sea, used to clip all the maps, was derived from GEBCO (https://download.gebco.net/). 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 ASAP project includes only the marine portion of the Adriatic Sea, coastal lagoons (i.e., the Venice lagoon) were not considered in the analysis.

Finally, to create the maps of the single 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 ASAP project workshops or according to expert opinion (see next paragraphs). Layers were then overlapped and in every pixel of the maps the maximum score was extracted. All operations and analyses on the maps and visualization were performed using the free and open source QGIS software version 3.40 (2024), with the WGS84 coordinate reference system (EPSG:4326).

Table 31. List of the vulnerability factors used for coastal vulnerability assessment and sources for them.

VF	Type	Source	Description	VF group
Mariculture	Shape (polygons)	Adriplan data portal, ASIG Albania, Urh et al 2018, Giovanardi and Pioli 2018, Mandić et al 2021, Giansante 2023, Pagano et al 2023, Petrosillo et al 2023, Milosevic et al 2024, Portale dati aperti	Shellfish and fish farms. Further mariculture plants were added to the original file after comparison with Google Satellite	Socio-economic

		PA Italia, www.regione.marche.it		
Cultural heritage sites	Shape (points)	ASIG Albania, EMODnet geology and human activities, Bioportal of Croatia, The Oxford Roman Economy Project, MSP Knowledge Catalogue, raptor.cultura.gov.it, octopusfoundation.org, Register of cultural heritage in Slovenia, ADRIAS project, Siti archeologici d'Italia	Archaeological-Paleontological sites	Socio-economic
Ports	Shape (polylines)	Created in QGIS using the coastline of Adriatic Sea, and a layer of ports downloaded from Adriplan data portal	Commercial-industrial ports, local ports, marinas. Further ports 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 coast typology downloaded from EMODnet geology and a layer of CORINE land cover2000 for Albania downloaded from the European Environmental Agency, Google Satellite for Bosnia and Herzegovina	The coastline of Adriatic Sea is divided in polylines and classified according to the different coast typologies (e.g., muddy coastline, erosion-resistant coast, harbour area).	Socio-economic
Recreational - tourist stretches of coast	Shape (polylines)	Created in QGIS by intersection between the coastline of Adriatic Sea and the bathing water sites downloaded from EMODnet - Human Activities and from MSP Knowledge Catalogue, the tourist ports from the layer 'Harbour areas', tourist stretches of coast from MSP Knowledge Catalogue and the ASAP project partner NGO 'Our Action' in Montenegro, and the stretches of coast representing beaches in the	The layer reports the stretches of coast characterized by tourist and/or recreational activities	Socio-economic

		layer 'Value of coast by typology'		
Cooling water stations	Shape (points)	SEADRION 2014-2020 project report	Points of presence of cooling water station inlets	Socio-economic
National parks and Marine Protected Areas (MPAs) of National legislation	Shape (polygons)	Mapamed.org, protectedplanet.net, the ASAP project partner NGO 'Our action' for Montenegro, the Italian Ministry of Environment, the European Environmental Agency ASIG Albania		Environmental
Regional parks and Landscape parks	Shape (polygons)	Mapamed.org, protectedplanet.net, the ASAP project partner NGO 'Our action' for Montenegro, the Italian Ministry of Environment, the European Environmental Agency ASIG Albania		Environmental
Natura 2000 (N2K) and special protection areas	Shape (polygons)	Mapamed.org, protectedplanet.net, the ASAP project partner NGO 'Our action' for Montenegro, the Italian Ministry of Environment, the European Environmental Agency ASIG Albania		Environmental
Protected habitats and areas of presence of protected species	Shape (points)	EMODnet Biology, OBIS, GBIF, reefcheck.med.org, Bioportal of Croatia, the ASAP project partner NGO 'Our action' for Montenegro, Mediseh project, Baldan et al 2024, Descourvieres et al 2024, Gianni et al 2025	Points with occurrence of protected species and habitats	Environmental
Unprotected areas	Shape (polygons)	Created in QGIS by difference between the map of 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 habitats	Environmental
Coastal cleaning difficulty	Shape (polylines)	Created in QGIS using as a base the layer of coast typology downloaded from EMODnet - Geology and the	The coastline of Adriatic Sea is divided in polylines and classified according to	Geomorphological

		ESI ranking of NOAA (Petersen et al., 2019)	the different coast typologies (e.g., muddy coastline, erosion-resistant coast, harbour area) and ESI ranking of NOAA.	

5.3.2 SOCIO-ECONOMIC VULNERABILITY FACTORS

The selected socioeconomic VFs included 'Mariculture', 'Cultural heritage sites', 'Ports', 'Cooling water stations', 'Recreational - tourist stretches of coast', and the 'Value of coast by typology'.

For 'Mariculture', a layer with their presence in the Adriatic Sea was obtained from the Adriplan project website and was successively updated and modified with information available in peer-reviewed articles and grey literature, from online databases, and by double-checking the presence of the plants on Google Satellite (Fig. 34, Table 31).

The map of 'Cultural heritage sites' VF was created by merging information from layers of archaeological and paleontological sites available on different online databases (e.g., EMODnet – Geology and -Human Activities, the Register of cultural heritage in Slovenia, the Bioportal of Croatia, etc.), and from ADRIAS project (see Table 31 for a detailed list of the sources). Since the cultural heritage sites for Slovenia were available as polygon geometries, the centroids of these polygons were extracted, and joined with the point-based sites from the other countries. Sites deeper than 5m and inland were removed. 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. 35).

To have a more realistic representation of the 'Ports' VF, the original map of points identifying the ports in the 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, 150 m and 200 m radius buffer were drawn around local ports, marinas and commercial ports, respectively, and an intersection with the Adriatic Sea coastline was performed to obtain a polyline shape file representing harbour areas (categorized in local ports, marinas, commercial ports) (Fig. 36).

Locations of the 'Cooling water stations' were taken from the SEADRION project report and manually digitized in QGIS. However, the exact location of the seawater intake/outlet was not specified, so some positional inaccuracies may be present. Installations for which the discharge pipe is reported to be deep (>5 m) were not considered. A 100 m buffer was created around each point with the aim to cover as much as possible the total extension of the sites (Fig. 37).

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 coast typology in the Adriatic Sea, download from EMODnet – Geology. Coastal geomorphologies for Bosnia and Herzegovina were added manually using Google Satellite as reference map since were not present in the EMODnet layer. The same was done for Albania, on the base of the CORINE Land Cover 2000 map downloaded from the European Environmental Agency website. Nevertheless, different classifications were used by the countries in their entries on the coast typology in the Adriatic Sea. In many cases these categories in 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. 38).

Since no maps reporting the recreational and tourist sites were available, a joined map of the 'Recreational - tourist stretches of coast' VF was generated by intersection between the Adriatic Sea coastline and a 200 m radius buffer drawn around the bathing water sites downloaded from EMODnet - Human Activities and MSP Knowledge Catalogue (Fig. 39). The categories representing beaches in the 'Value of coast by typology' VF, where tourist facilities are present, were also included in the final layer of 'Recreational - tourist stretches of coast'. Other areas dedicated to tourism for Montenegro were obtained from the ASAP project partner NGO 'Our Action', and from online databases (Table 31). Although the number of stretches of coast with recreational - tourist 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.



Figure 34: Map of the maricultures in the Adriatic Sea.



Figure 35. Map of the cultural heritage sites in the Adriatic Sea.

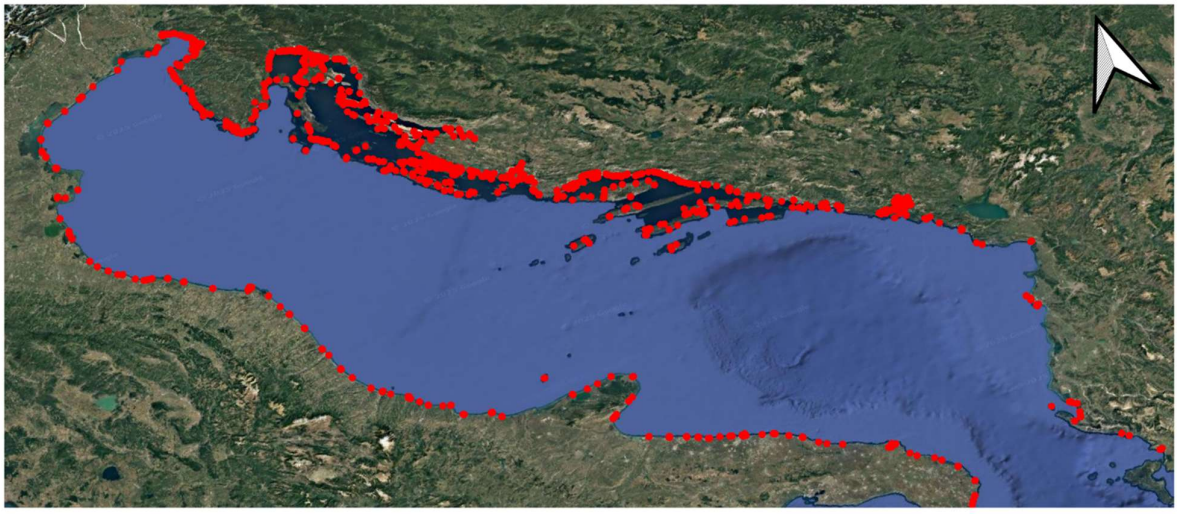


Figure 36. Map of the ports in the Adriatic Sea.



Figure 37. Map of the cooling water stations in the Adriatic Sea.

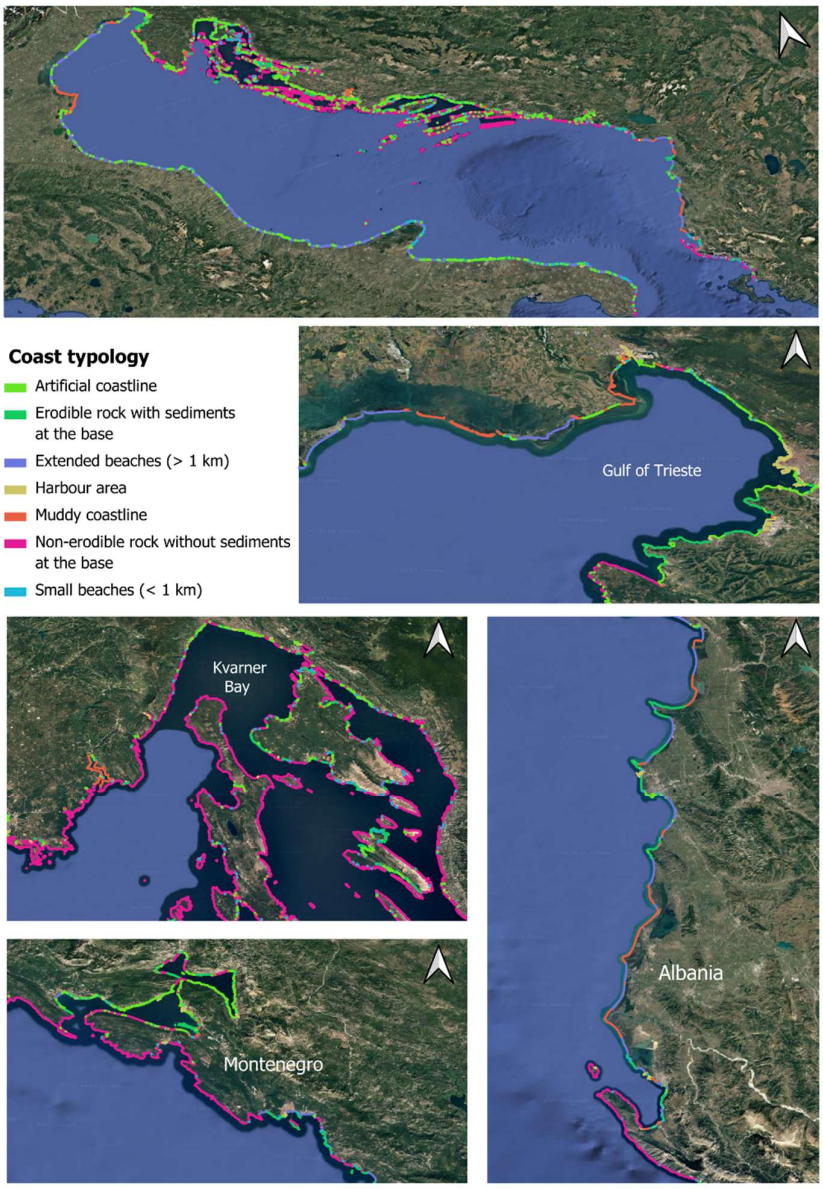


Figure 38. Map of the coast typologies in the Adriatic Sea with a zoom to some areas as an example.

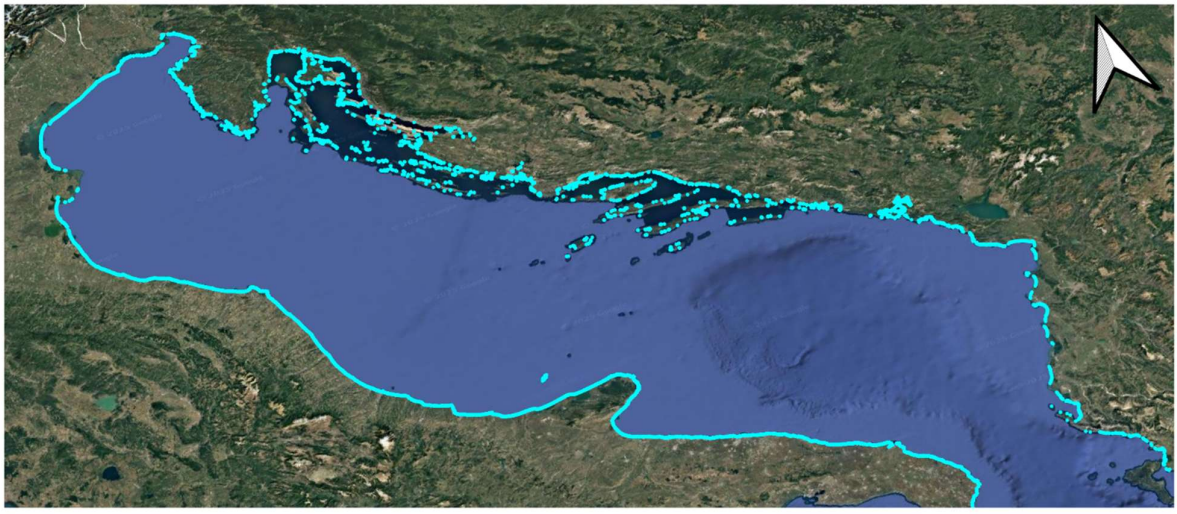


Figure 39. Map of the recreational - tourist stretches of coast in the Adriatic Sea.

To each socioeconomic VF the corresponding mean scores as given by the participants to the workshops was assigned. The score given to the 'Recreational - tourist stretches of coast' VF was averaged between the values obtained for the questions on tourist and recreational sites in the questionnaires. Overall, the VF scores ranged between 5.1 and 7.4 (Table 32). 'Mariculture' and the category 'Extended beaches' of the 'Value of coast by typology' VF got the highest score (7.4), while the lowest value was assigned to the 'artificial coastline' category of the 'Value of coast by typology' VF.

Table 32. Score assigned to each socioeconomic VF.

Socioeconomic VF	Category of the socioeconomic VF	Score
Mariculture		7.4
Cultural heritage sites		6.6
Recreational - tourist stretches of coast		7.0
Cooling water stations		5.8
Ports	Small port	6.5
	Tourist port	6.8
	Commercial port	6.3
Value of coast by typology	Erodible rock with sediments at the base	7.2
	Extended beaches (> 1 km)	7.4
	Small beaches (< 1 km)	7.1
	Artificial coastline	5.1

	Muddy coastline	6.4
	Non-erodible rock without sediments at the base	6.3
	Harbour area	5.7

5.3.4 ENVIRONMENTAL VULNERABILITY FACTORS

The environmental VF group included marine and coastal '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'. Layers of protected areas in the Adriatic Sea were downloaded from different websites (MAPAMED, protectedplanet.net, European Environmental Agency, and the Italian Ministry of Environment), while for Montenegro they were obtained from the ASAP project partner NGO 'Our Action' (see Table 31 for a detailed list of the sources). In the category 'National parks-MPAs', MPAs of national statute and National Parks with coastal and/or marine environments were considered. Nature reserves, Natural monuments, National special reserves, and Landscape parks were included in the 'Regional and Landscape parks' VF. However, two Landscape parks (Strunjan and Sečovlje Salina) and two Natural Monuments (Cape Madona and Debeli Rtič) in Slovenia were included in the 'National parks-MPAs' category since they were elevated to protected areas of national relevance from the Slovenian law. 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 coastal portion of the protected areas was considered up to 50m inland (Fig. 40).

Protected species and habitats were firstly selected based on Bern Convention (1979), Bonn Convention (1979), Barcelona Convention (1976), Habitat Directive (92/43 EEC), CITES, and IUCN Red List for the Mediterranean (considering the 'Critically Endangered', 'Endangered', 'Vulnerable', and 'Near Threatened' categories (last access Dec. 2024)). Taxonomic identification of species was double-checked on WoRMS. We considered species occurrences between 2000 and 2024. Marine protected species occurrences recorded in OBIS and GBIF databases (GBIF.org (09 December 2024)) were downloaded, after quality checking, using the packages 'robis' (Provoost and Bosch, 2022), 'rgbif' (Chamberlain and Boettiger, 2017; Chamberlain et al., 2025), and 'finch' (Chamberlain, 2020) in R (R Core Team 2024). Duplicated data and records with coordinates on land were removed. Other occurrences of the species and habitats in the Adriatic Sea were obtained from scientific literature, EMODnet-Biology, Reef Check Mediterranean, Bioportal of Croatia, and the ASAP project partner NGO 'Our Action' for Montenegro (see Table 31 for a detailed list of the sources). A 100 m radius

buffer was created around the occurrence points of species and habitats as a better proxy of their presence (Fig. 40).

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 Adriatic Sea marine region (Fig. 40).

An arbitrary score (from 1 to 9) was assigned to the environmental VFs based on the level of formal protection of the different categories of protected areas (Table 33).

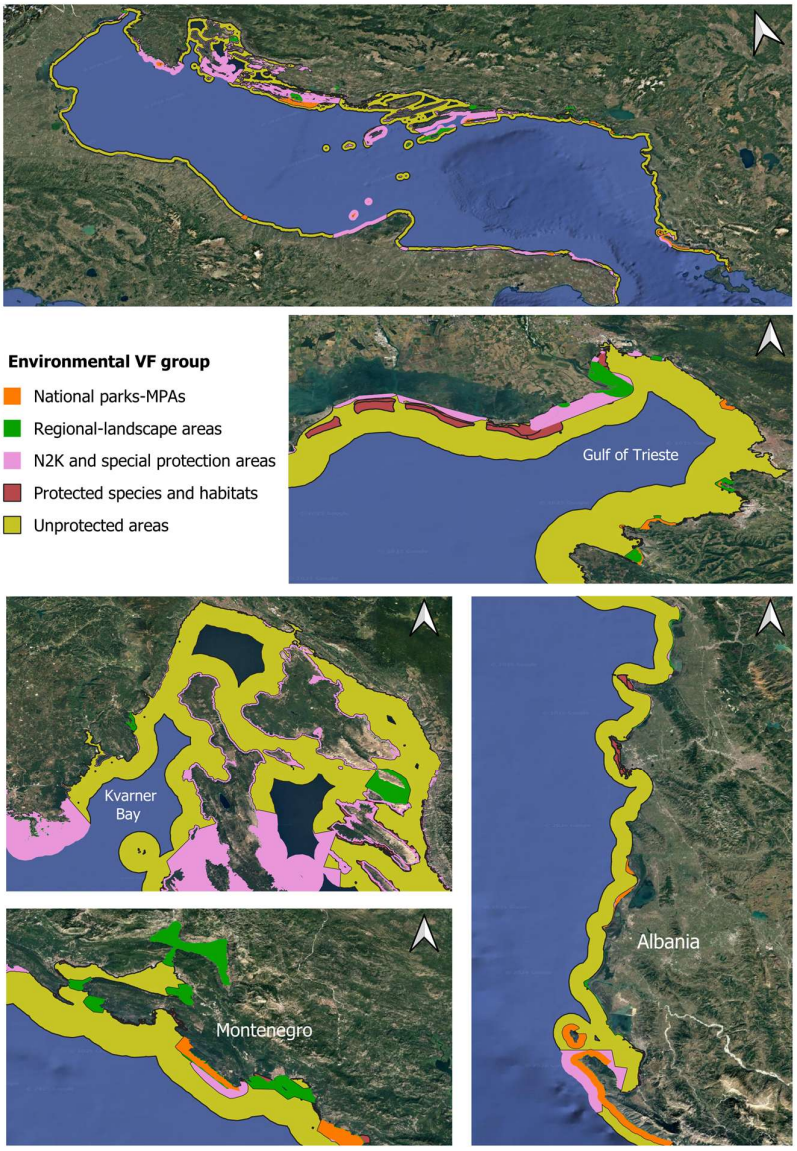


Figure 40. Map of the environmental VFs in the Adriatic Sea with a zoom to some areas as an example.

Table 33: Vulnerability scores assigned to each environmental VF based on it legal protection status.

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

5.3.4 GEOMORPHOLOGICAL VULNERABILITY FACTORS

Since every beach or coastline is composed of different materials, which respond to oil in different ways, to create a map with the information on the coastal cleaning difficulty, geomorphology must be considered as well.

A layer of coastal geomorphologies in the Adriatic Sea was downloaded from EMODnet – Geology. Since no data was available for Albania and Bosnia and Herzegovina in this layer, coastal geomorphologies for these two countries were assigned manually based on Google Satellite maps, the categories used in EMODnet and in the stakeholder's workshops. All geomorphological categories were then compared and matched, as much as possible, to the Environmental Sensitivity Index (ESI) that assesses 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 34, Fig. 41). For instance, the categories 'Harbour 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 34 for a complete correspondence between the assigned categories in ASAP 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 coastal cleaning difficulty. The lowest scores are assigned to the coast 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 coast typologies in the Adriatic Sea. The ESI ranks 2, 4, and 10 were not assigned in the ASAP ranking since the categories of coastal geomorphology identified in the NOAA index with this score are not present in the available layer of coastal geomorphologies of the 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 34.

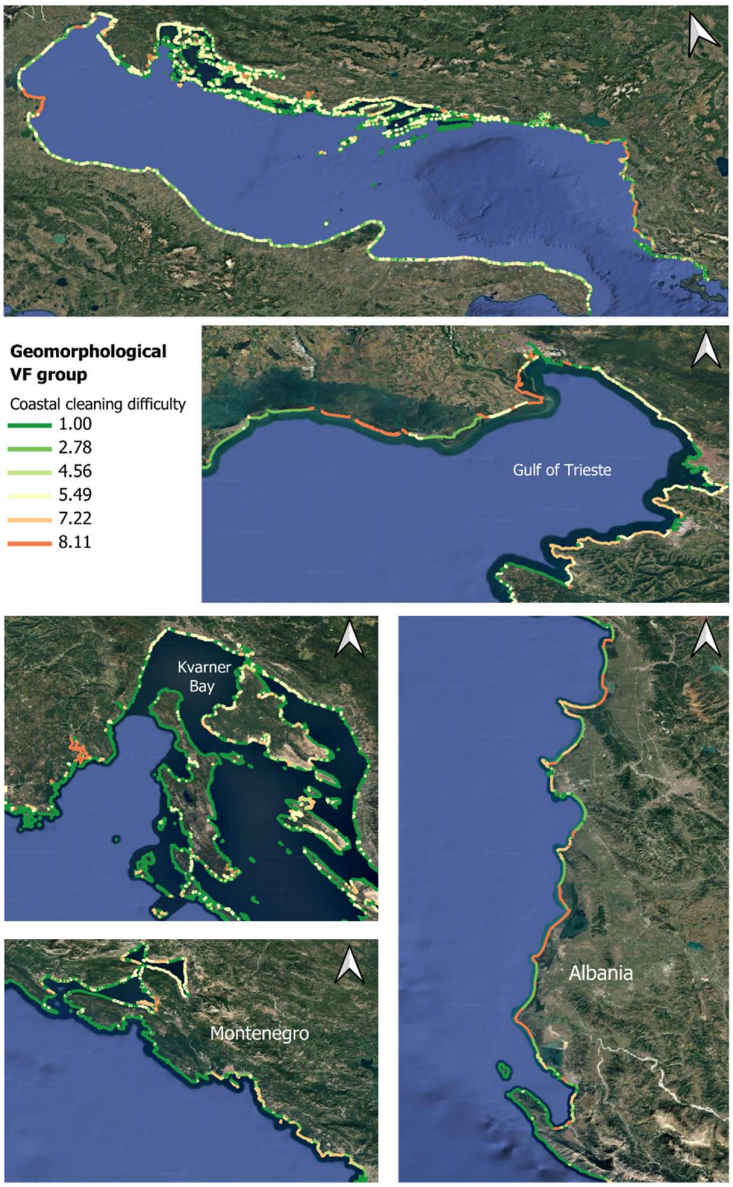


Figure 41. Map of the geomorphological typologies of coast in the Adriatic Sea ranked according to the modified ESI and scaled from 1 to 9. Higher rank values indicate greater difficulty in coastal clean-ups. As an example, zooms to some coastal areas are provided.

Table 34. The table shows the coast typologies classified by sensitivity to oil via the Environmental Sensitivity Index (ESI) values defined by the NOAA, the matched EMODnet categories, the modified ESI value as applied in this project, and the new rank assigned to the coast typologies after being rescaled from 1 to 9.

Coastal typology (EMODnet - Geology)	NOAA categories	NOAA rank	ASAP assigned rank	Rescaled ASAP 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
Beach made of mine-waste	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
Muddy coastline laguna	Exposed tidal flats; Sheltered tidal flats; Vegetated low banks;Salt- and brac	7-10	9	8.11
Muddy coastline Po	Exposed tidal flats; Sheltered tidal flats; Vegetated low banks;Salt- and brac	7-10	9	8.11
Muddy coastline, including tidal flat, salt marsh	Exposed tidal flats; Sheltered tidal flats; Vegetated low banks;Salt- and brac	7-10	9	8.11
Estuary	Exposed tidal flats; Sheltered tidal flats; Vegetated low banks;Salt- and brac	7-10	9	8.11

5.3.5 COASTAL VULNERABILITY ASSESSMENT

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 shapefiles (i.e., 'Value of coast by typology', 'Recreational - tourist stretches of coast', 'Ports', 'Coastal cleaning difficulty') to embrace the whole stretch 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. 42-44). Finally, a map of total coastal vulnerability was obtained with the same method (Fig. 45). 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).

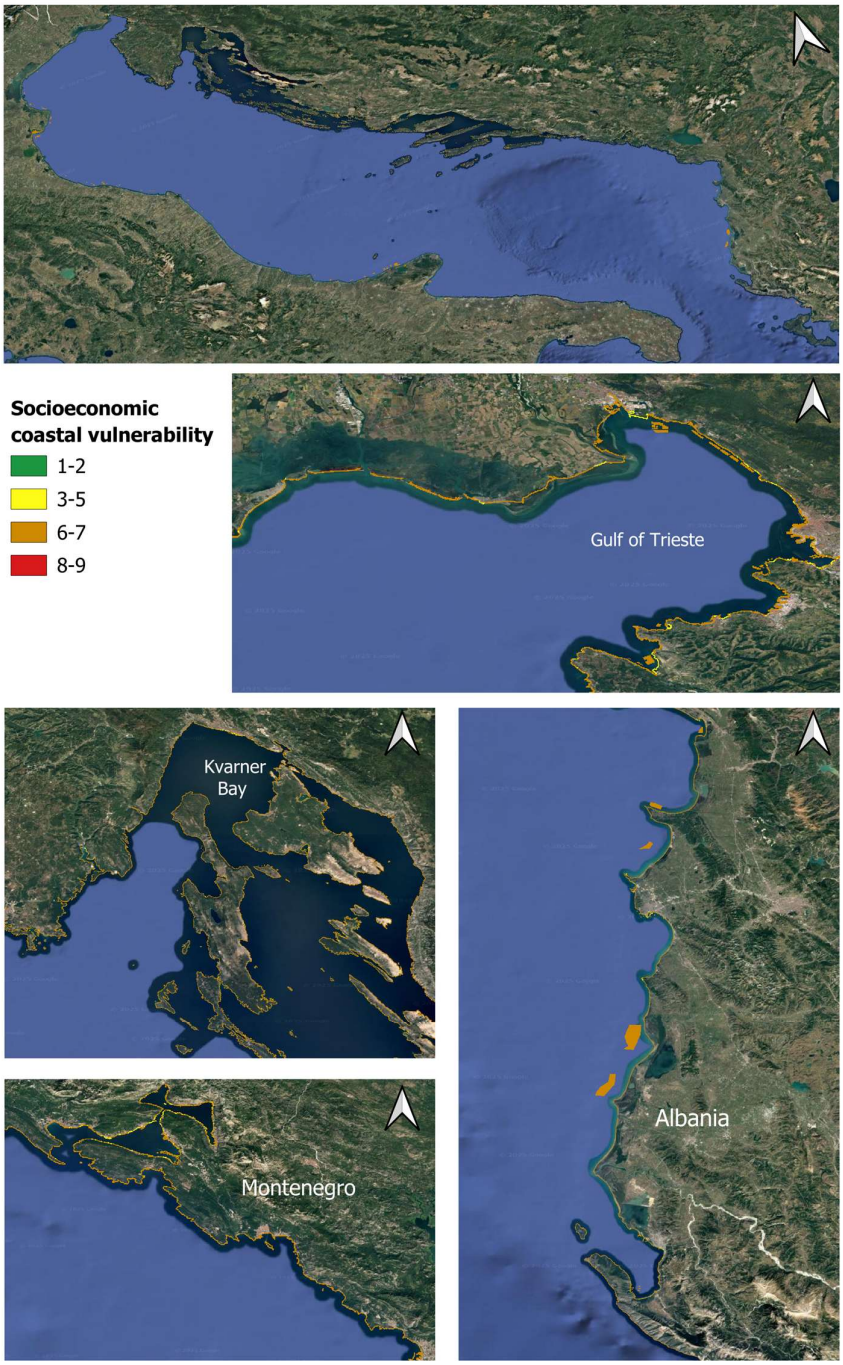


Figure 42. Maps of the coastal vulnerability for the socioeconomic VF group for the Adriatic Sea with a zoom to some areas as an example. The red color indicates higher coastal vulnerability.

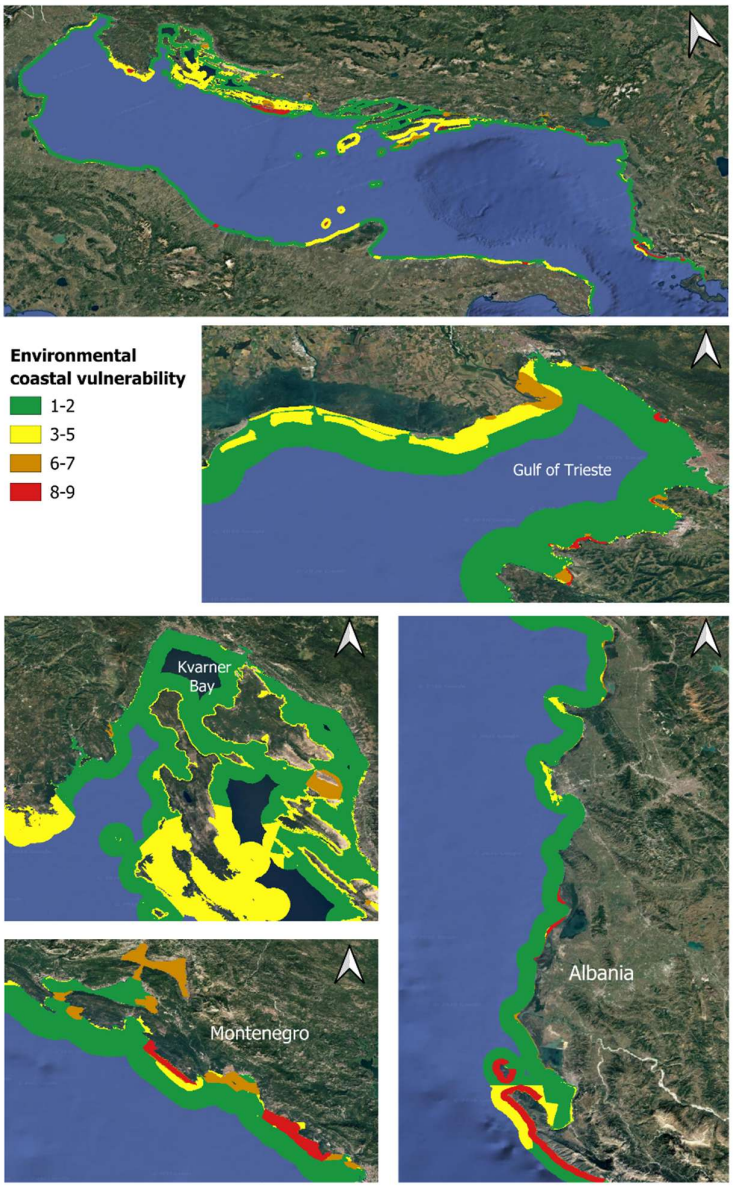


Figure 43. Maps of the coastal vulnerability for the environmental VF group for the Adriatic Sea with a zoom to some areas as an example. The red color indicates higher coastal vulnerability.

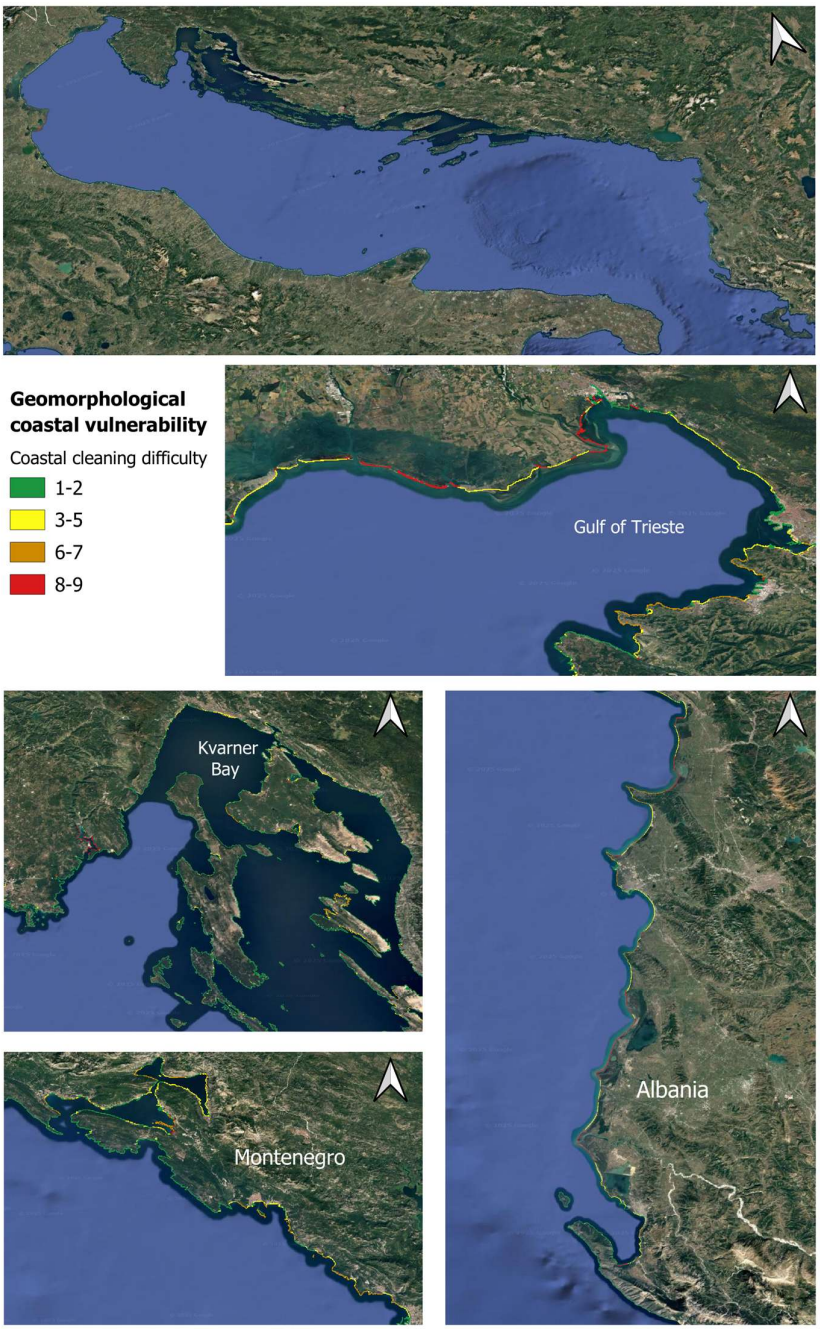


Figure 44. Maps of the coastal vulnerability based on the geomorphological VF (coastal cleaning difficulty) for the Adriatic Sea with a zoom to some areas as an example. The red color indicates higher coastal cleaning difficulty.

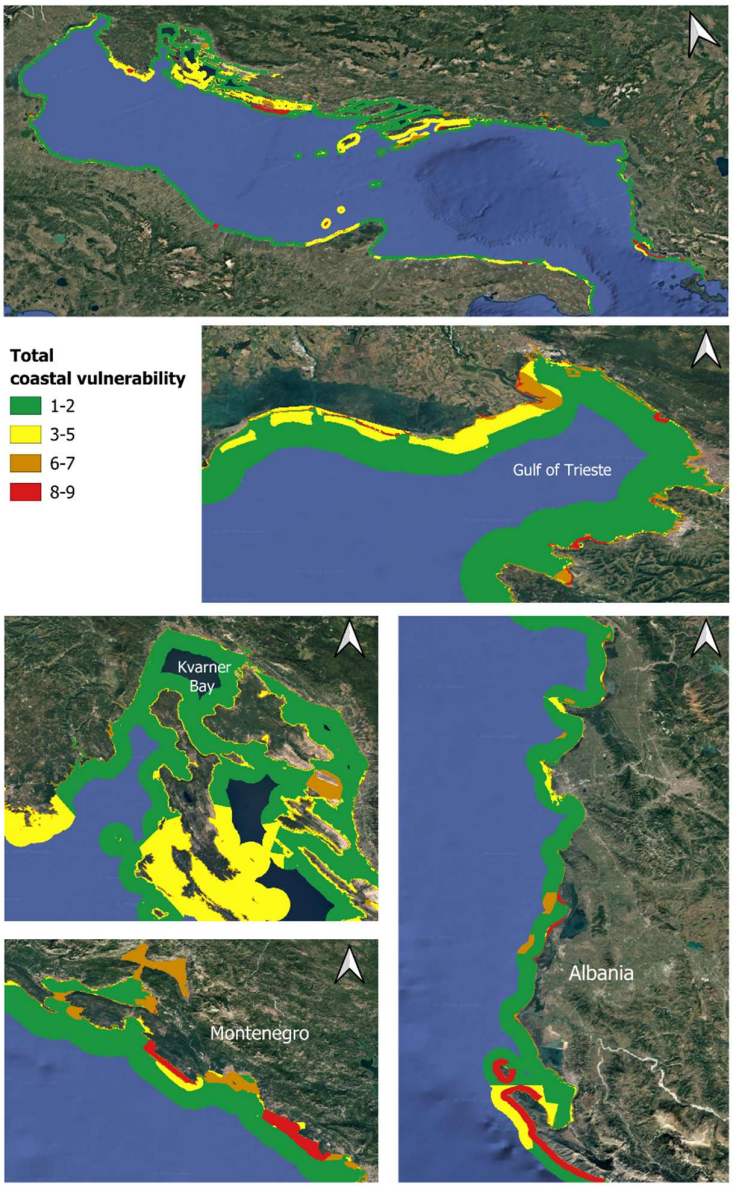


Figure 45. Maps of the total coastal vulnerability obtained by using information from all the selected VF groups, for the Adriatic Sea with a zoom to some areas as an example. The red color indicates higher coastal vulnerability.

Considering each individual vulnerability factor, the environmental coastal vulnerability map shows that most of the coastaline is protected (83%) and falls within the 3–9 vulnerability score range (Fig. 43). Among the protected areas, Natura 2000 (N2K) sites prevail (53.5%), followed by regional parks (15%), while Marine Protected Areas (MPAs) established under national legislation account for 9.7% of the coastal area. The area between the coastline and 3 nm offshore generally exhibits low vulnerability, as it is mostly unprotected. However large protected areas extend in the Croatian archipelago, the Istrian peninsula, and the Apulia region, which are characterized by several large N2K sites, as well as areas in the Gulf of Trieste, Montenegro, and Albania, where protected areas designated under different legislative frameworks and species protection measures are present (Fig. 43).

Regarding the socio-economic vulnerability factor, most of the coastal area, including mariculture sites, falls within the medium–high vulnerability score range (6–7) (97%) (Fig. 42). This reflects the high values assigned by stakeholders during the workshops to socio-economic factors such as coastal type value, ports, tourist and recreational areas, and cultural sites.

In contrast, most of the coastal area classified under the geomorphological vulnerability factor, based on the modified Environmental Sensitivity Index (ESI), falls within low to medium–low vulnerability score ranges (1–2 and 3–5), accounting for 88% of the coastline (Fig. 44). Exceptions include coastal areas of high tourist relevance and muddy coastlines, such as the Po River delta and the Grado–Marano Lagoon (in the FVG Region in Italy), which exhibit higher vulnerability scores. The proportion of coastline classified with the highest vulnerability scores is approximately 5%.

Once all individual vulnerability factors are combined to generate the total coastal vulnerability map, the resulting pattern shows that the coastline exhibits higher vulnerability scores compared to the adjacent offshore areas up to 3 nautical miles (nm) (Fig. 45, 46). In most cases (97%), coastal stretches are characterized by high, medium–high vulnerability values (6–9) (Fig. 46). This pattern is mainly driven by the medium–high scores assigned by stakeholders to socio-economic factors (see previous paragraphs), as well as by the presence of coastal protected areas and geomorphological features that make oil removal difficult (e.g., muddy coastline of the Po river delta). However, the marine area adjacent to the coastline (up to 3 nm) also reaches medium–high vulnerability values in some cases, particularly in the Croatian archipelago, due to the presence of numerous protected areas (Fig. 45, 46).

The same difference between coastal and offshore areas is observed in terms of vulnerability percentages across the three Adriatic subregions (Northern, Central, and Southern Adriatic) and countries. When examining the percentages of high, medium–high vulnerability values (6-9) within each subregion, the Central and Southern Adriatic show slightly higher percentages than the Northern Adriatic, both along coastal areas and offshore up to 3 nm (Fig. 47). Considering the Adriatic countries, it is noteworthy that Albania (AL), Slovenia (SLO) and Montenegro (MNE), although characterized by smaller coastal areas compared to Croatia and Italy, display some of the highest percentages of highly vulnerable coastal stretches within their borders (Fig. 48). This is mainly due to the presence of nationally protected areas and/or muddy coastlines that are difficult to clean. Bosnia and Herzegovina (BIH) show high percentages of coastal stretches with medium–high vulnerability scores (6–7) (86%), while stretches with high scores (8–9) are not present (Fig. 48). When considering only the offshore

marine area, AL and MNE still show a notable proportion of highly vulnerable areas (8% and 7%, respectively).

Overall, environmental vulnerability factors contributed most to the scores assigned in the total coastal vulnerability map (95%). In contrast, when considering only the coastal area, socio-economic vulnerability factors accounted for the largest contribution (72%), while the geomorphological factors contributed 13%.

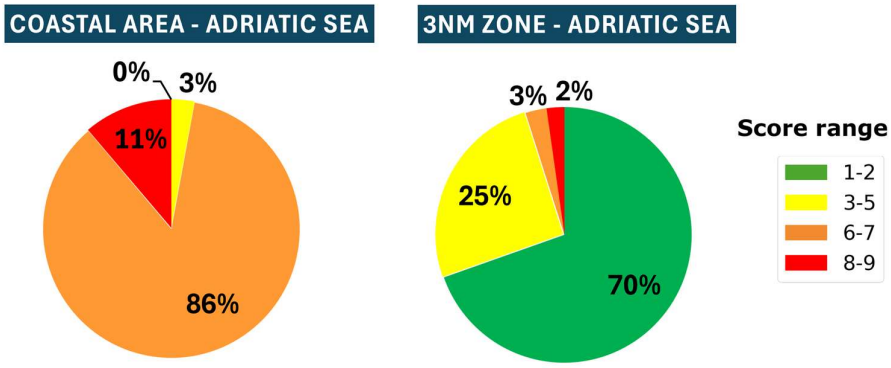


Figure 46. Percentage distribution of the four vulnerability score classes in the total coastal vulnerability map for the coastal area (left) and the offshore area up to 3 nm (right).

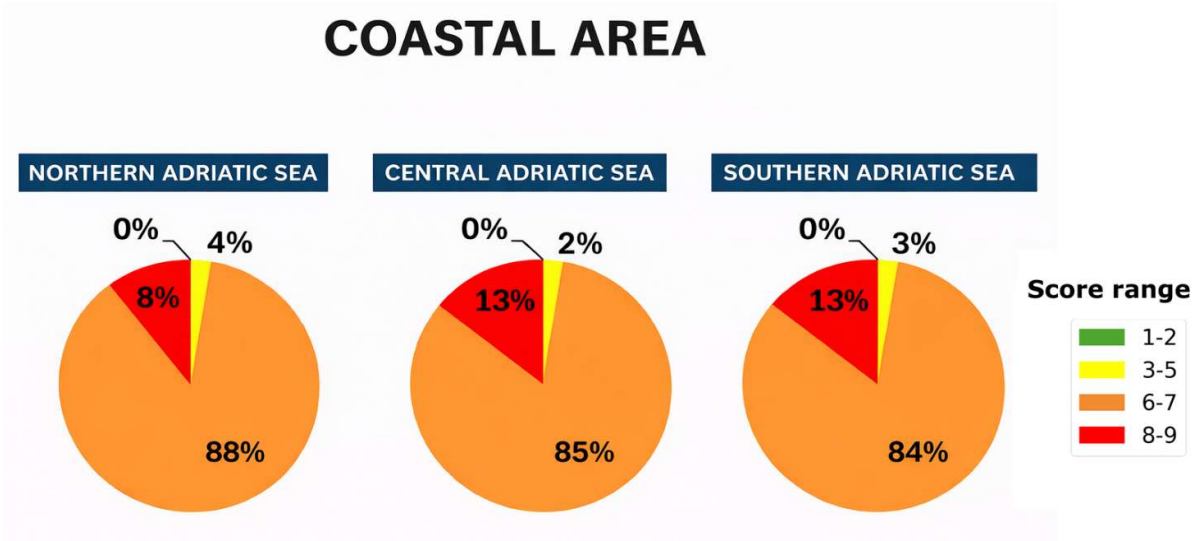


Figure 47. Percentage distribution of the four vulnerability score classes for total coastal vulnerability across the coastal areas of the three Adriatic Sea subregions.

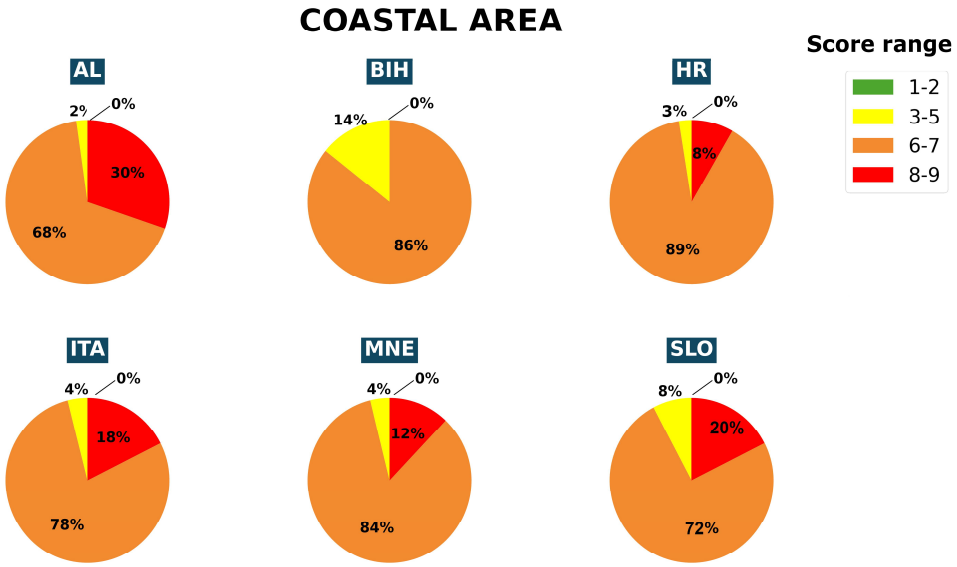


Figure 48. Percentage distribution of the four vulnerability score classes for total coastal vulnerability across the coastal areas of the Adriatic countries.

5.3.6 GIS PROJECT AND MAP VISUALIZATION

All maps were included in a geopackage file for QGIS (Fig. 49). 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 ASAP project, and named 'ASAP CVA.gpkg', 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 'ASAP project' was also uploaded (Fig. 50). 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. 50).

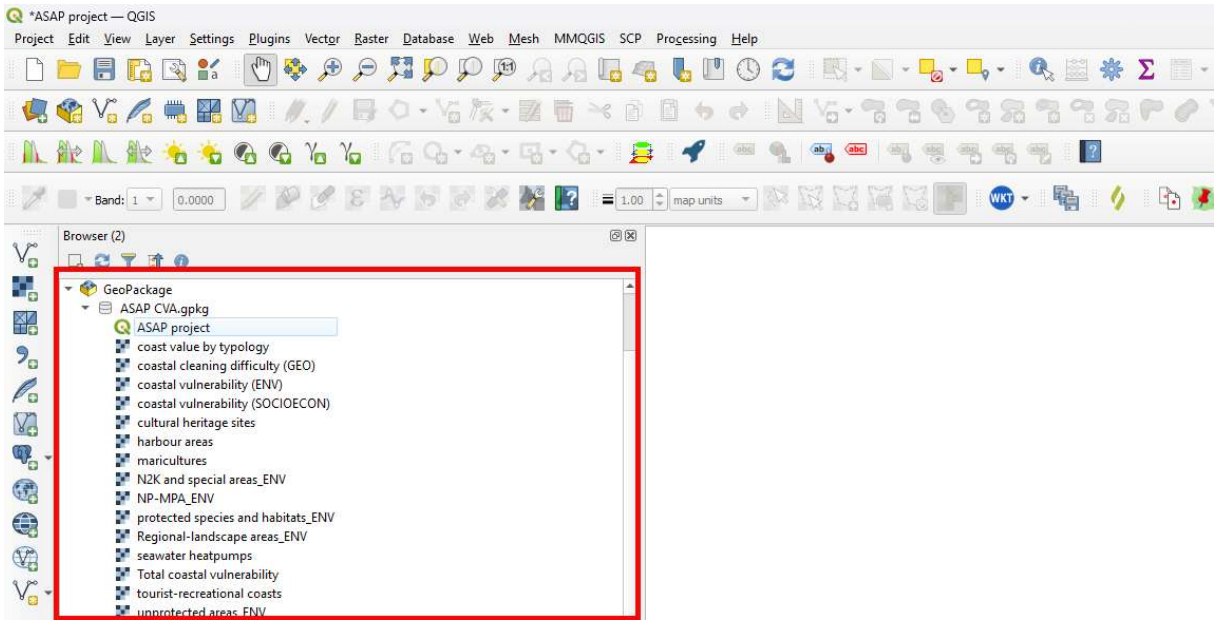


Figure 49. A screenshot of the geopackage file uploaded in QGIS with all the layers and the ASAP project (red box).

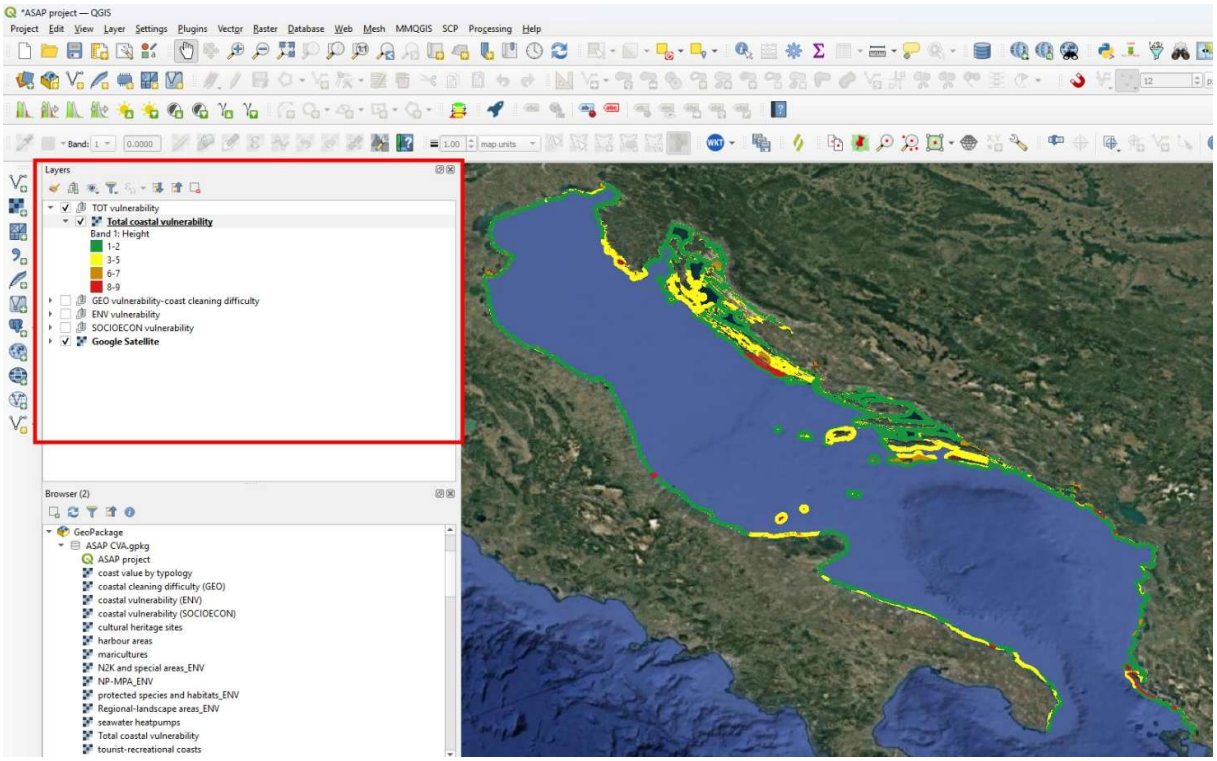


Figure 50. A screenshot of the ASAP project opened in the QGIS layer panel (red box). The symbology of the VF group maps is categorized into four classes representing the different levels of coastal vulnerability.

5.3.7 DIFFERENCES BETWEEN COASTAL VULNERABILITY IN ASAP AND NAMIRS

5.3.7.1 GEOMORPHOLOGICAL VULNERABILITY FACTORS

99.6% of coastal stretches remain unchanged, while only 0.39% show a different score. Nearly all coastal stretches exhibiting a score change (0.37%) display a negative difference between ASAP and NAMIRS. This result is due to the fact that these coastal stretches received a lower score in ASAP than in NAMIRS, as they were reassigned to a different geomorphological category associated with a lower score. Reclassification of these coastal stretches was necessary to correct erroneous categorizations reported in the NAMIRS and EMODNET datasets. However, these few score changes do not affect the subdivision of coastal stretches into the four vulnerability score classes visualized in QGIS; therefore, no significant visual changes are evident in the map.

5.3.7.2 SOCIO-ECONOMIC VULNERABILITY FACTORS

94.12% of the stretches of coast have a different score in ASAP respect to NAMIRS. Almost all of the values that changed (89%) are negative. Therefore, in ASAP the changes mainly reflect a decrease in the importance assigned to some NAMIRS coastal stretches, as indicated by the fact that the difference was calculated as ASAP − NAMIRS. However, almost all differing values between ASAP and NAMIRS (83%) show only minor changes, with differences ranging between −0.5 and −0.05, and 61% exhibiting a change of only −0.1.

In the four vulnerability score classes visualized in QGIS, no significant changes are observed, except for mariculture plants across the entire northern Adriatic area and for the coast typology 'Extended beaches' in Italy. In NAMIRS, these factors fall within the highest vulnerability class (red), whereas in ASAP they are classified as medium–high vulnerability (orange). These differences are due to slightly different scores assigned by stakeholders (Table 35) and to the fact that many mariculture sites identified in NAMIRS in Croatia are no longer present.

In general, changes between ASAP and NAMIRS in socioeconomic factors are due to:

- Correction of erroneous categorization of the geomorphology of some stretches of coast reported in NAMIRS and EMODNET.
- Addition of some missing stretches of coast.
- Differences in scores assigned by stakeholders.
- Updated presence of mariculture plants, in particular in Croatia.
- Updated layer of bathing waters useful for identifying the recreational - tourist stretches of coast

5.3.7.3 ENVIRONMENTAL VULNERABILITY FACTORS

97.76% of the areas remain unchanged, while only 2.25% show a different score. Nearly all areas exhibiting a score change (2.19%) display a positive difference between ASAP and NAMIRS. This result is due to the update of layers of protected habitats and species and areas. However, these few score changes do not affect the subdivision of the areas into the four vulnerability score classes visualized in QGIS; therefore, no significant visual changes are evident in the map.

In general, changes between ASAP and NAMIRS in environmental factors are due to: Updated presence of protected species and habitats. Updated presence of any typology of protected areas.

5.3.8 TOTAL COASTAL VULNERABILITY

89.47% of coastal stretches and areas remain unchanged, while only 10.53% show a different score. 7.33% of the coastal stretches and areas exhibiting a score change display a negative difference between ASAP and NAMIRS, while 3.20% of them display a positive difference. However, these few score changes do not affect the subdivision of coastal stretches and areas into the four vulnerability score classes visualized in QGIS except for mariculture sites across the entire northern Adriatic area, the coast typology 'Extended beaches' in Italy and some protected areas.

Table 35. Comparison of results obtained in in the NAMIRS workshops and in the ASAP focus groups.

	μ ASAP	μ NAMIRS
Mariculture	7.4	7.8
Tourist sites	7.2	7.6
Recreational sites	6.7	6.7
Cultural heritage sites	6.6	6.8
Cooling water stations	5.8	5.7
Commercial port	6.3	6.1
Tourist port	6.8	6.7
Small port	6.5	6.4
Erodible rock	7.2	7.2
Extended beaches (> 1 km)	7.4	7.5
Small beaches (< 1 km)	7.1	7.2
Artificial coastline	5.1	5.1
Muddy coastline	6.4	6.7
Non-erodible rock	6.3	6.4
Harbour area	5.7	5.2
National Parks and MPAs	7.9	8.2
N2K and special protection areas	7.7	8.0
Unprotected areas	7.2	7.1
Regional-landscape parks	7.5	7.8
Protected species and habitats	8.0	8.3

5.4. ADRIATIC RISK INDEX FOR OIL SPILLS

5.4.1 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, damage 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 3) provided an estimate of the hazard related to oil spill in the 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 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 4), the information on the oil spill hazard was used to derive information on the exposure of the coastal environment to oil spills in the 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 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 Section 5.3) 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 total coastal vulnerability map in order to obtain the final risk assessment of coastal areas for oil spill in the Adriatic Sea. These results will be then useful for contingency planning, which is one of the main expected results of ASAP.

5.4.2 CUMULATIVE OIL SPILL RISK INDEX

To calculate the risk index in ASAP, the maps of exposure related to the possible events of oil spill in the Adriatic Sea (see Section 4) were multiplied to the map of the total coastal vulnerability derived in Section 5.

As first step, 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, were summed up in order to have a unique map for each oil type after 10 days from the release (the maximum time step used in the simulations). The resulting maps were then clipped at 3nm from the coast as the vulnerability maps. Data were log(1+x) transformed since their distribution was highly right skewed.

Since the map of the total coastal vulnerability ranges between 1 and 9 (see Section 5.3), to calculate the risk index, the exposure maps for each oil type ten days after the release 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 exposure maps. After multiplying the exposure maps 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 map, risk maps were created up to 5 meters of bottom depth and up to 3 nautical miles from the coast. For the same reason only the marine portion of the Adriatic Sea was considered while coastal lagoons (i.e., the Venice lagoon and the Grado-Marano lagoon) were kept out of the analysis.

Finally, to know the percentage of stranded oil at each time step, the amount of oil released in each simulation to become stranded (at surface and in water column) was calculated for each time step and oil type. To do that, we divided the average volume of stranded oil (in ton/km2) each time step by the total amount of oil released in each oil type simulation. The average volume of stranded oil in ton/km2 was obtained by summing the volume of oil in the map cells, multiplied by the area in km2 of the cells, and divided by the number of releases. Ten days after the release of the particles, the percentage of stranded oil is 30% for the bunker oil, 24% for the crude oil, and 21% for the diesel oil.

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).

5.4.2 MAPS OF RISK INDEX IN THE ADRIATIC SEA

As for the maps of vulnerability, 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 missing data in the vulnerability factor maps or because the langrangian model did not cover and estimate oil spill in that area in the exposure maps. All maps were included in the geopackage file for QGIS already created for the vulnerability factor maps (see Section 5.3).

To give an overview of the results, some examples of the risk maps are shown (Figs. 51-53).

The spatial distribution of the high-risk areas is generally consistent across all oil types considered, and overall risk levels are comparable. Nevertheless, bunker oil shows a higher proportion of stranded oil earlier than crude and diesel oils due to the fact that bunker oil is released much closer to the coast, and the release points are more evenly distributed across the three Adriatic sub-basins. On the contrary, in the central and southern Adriatic, the crude oil release points are generally located far from the coastline.

The risk index calculated for the Adriatic Sea shows that most areas are classified as having low–medium oil spill risk (Fig. 55). This pattern is mainly due to the fact that the surface area between the coastline and the offshore zone up to 3 nm has a low risk because, within 10 days of release, most of the oil becomes stranded along the coastline, where the majority of vulnerability factors are concentrated. However, where marine protected areas are present in the offshore zone, medium–high risk levels can occur.

Considering the coastline, the highest-risk areas are located in the Gulf of Trieste and the Po Delta. These areas are exposed to the largest quantities of oil in the event of a spill and are particularly sensitive due to the presence of numerous recreational and tourist activities, protected species, such as *Cymodocea nodosa*, which forms dense meadows in very shallow waters, protected areas, and muddy coastlines that are difficult to clean (see Section 5.3). A significant portion of the Adriatic coastline also falls within the medium–high risk class (17–29%) (Fig. 55).

When results are divided by Adriatic subregions, the highest risk scores are mainly found in the Northern Adriatic Sea coastline, while the Southern Adriatic coastlines show the highest proportion of medium–high risk values (up to 50%) in the event of an oil spill. Considering country-level patterns,

the Slovenian and Italian coastlines show the highest proportions of areas classified as high (6-12%) and medium–high risk (>60%). Coastlines of Albania and Montenegro appear to be much more exposed to bunker and diesel oil spill risk respect to that of crude oil with high percentages of coastline with medium-high risk (20-48%) (Fig. 56-59).

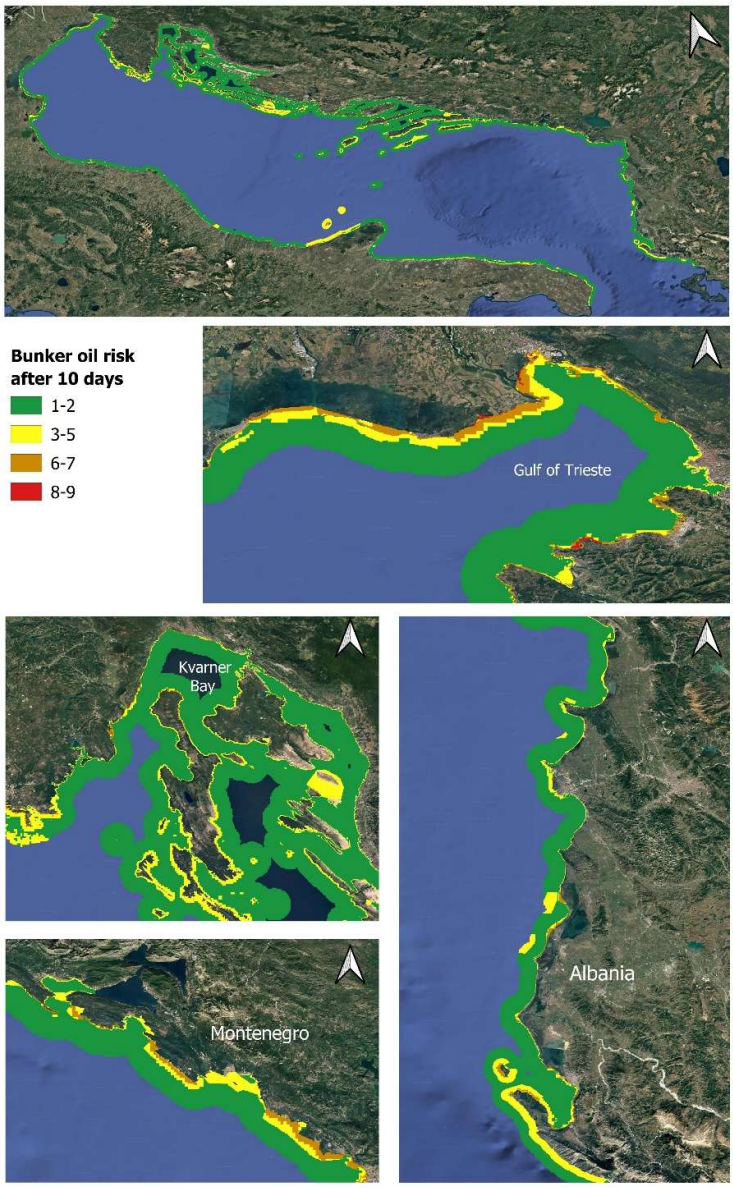


Figure 51. Maps of the risk index for the bunker oil, 10 days after release with a zoom on some of the most exposed areas.

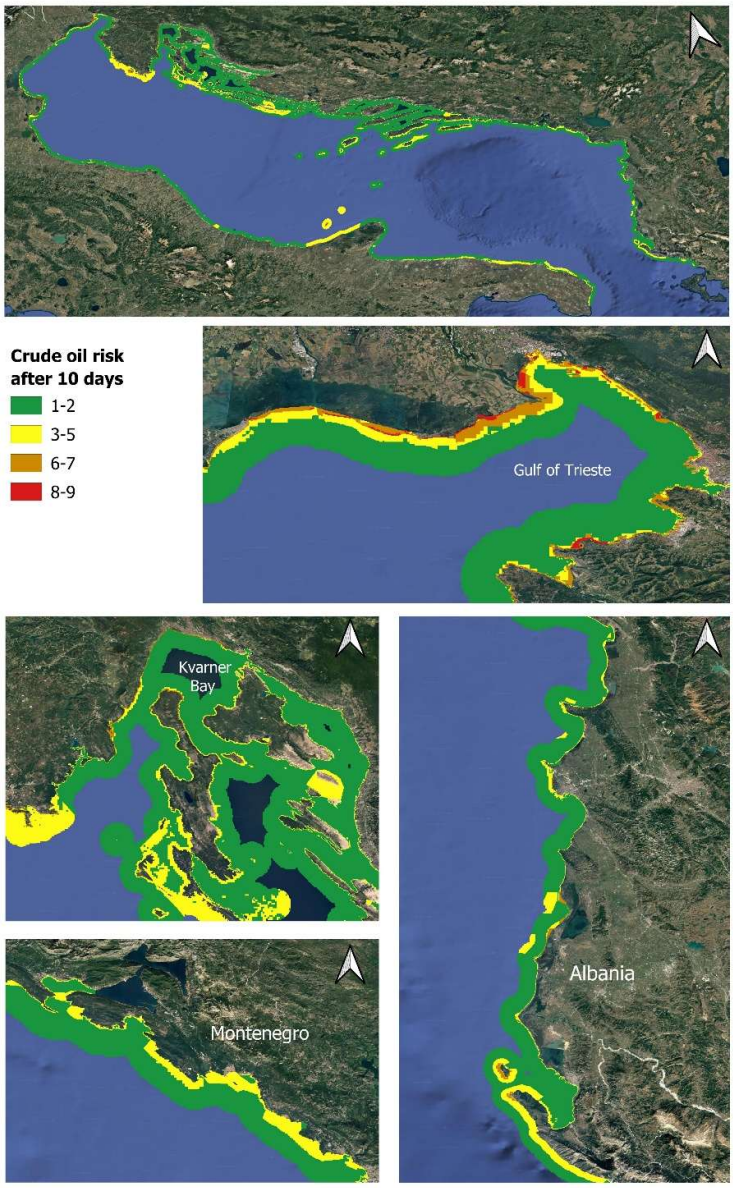


Figure 52. Maps of the risk index for the crude oil, 10 days after release with a zoom on some of the most exposed areas.

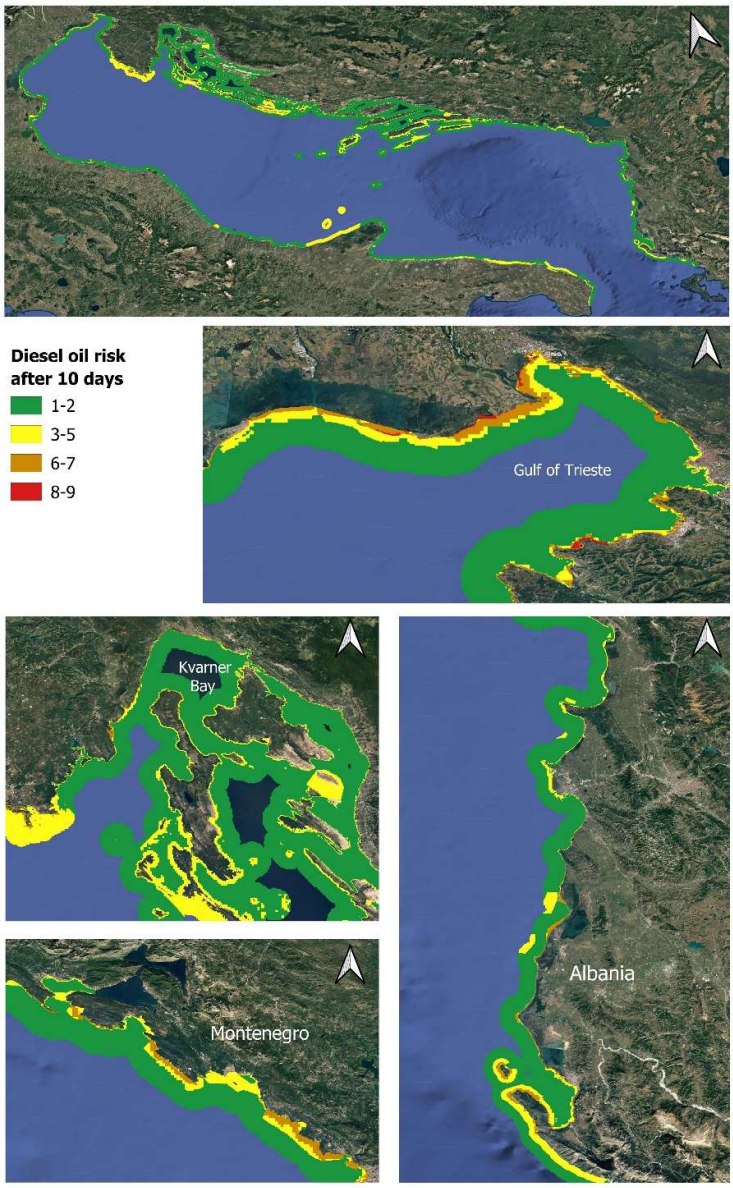


Figure 53. Maps of the risk index for the diesel oil, 10 days after release with a zoom on some of the most exposed areas.

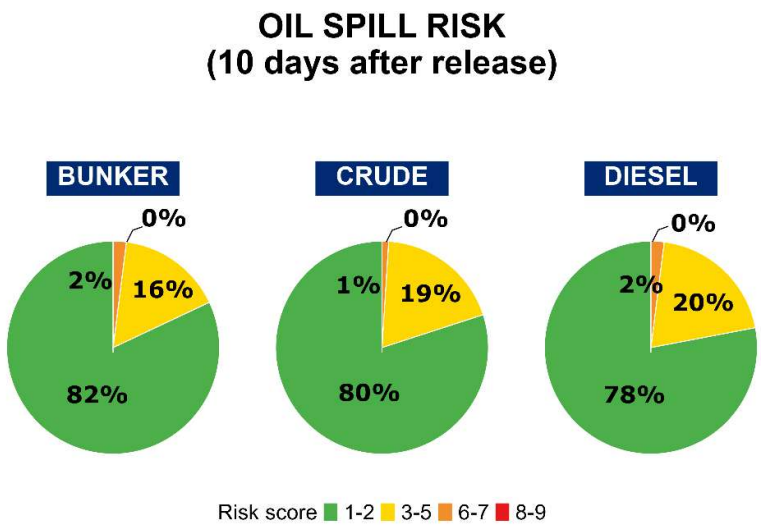


Figure 54. Percentage distribution of the four vulnerability score classes for the three different oils in the oil spill risk maps of the Adriatic Sea.

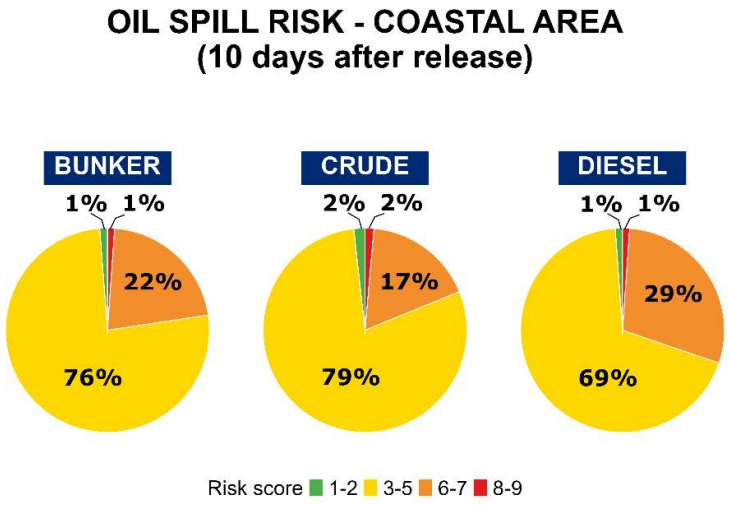


Figure 55. Percentage distribution of the four vulnerability score classes for the three different oils in the Adriatic coastal area of the oil spill risk maps.

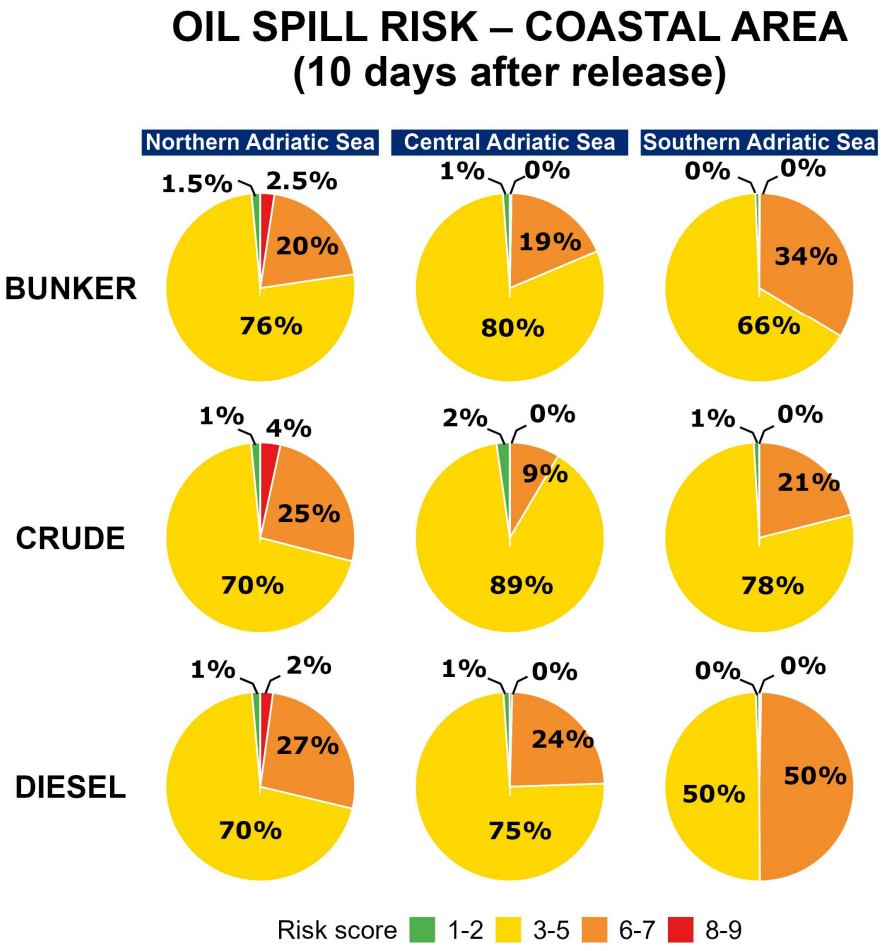


Figure 56. Percentage distribution of the four vulnerability score classes for the three different oils, divided by Adriatic subregions, in the coastal area of the oil spill risk maps.

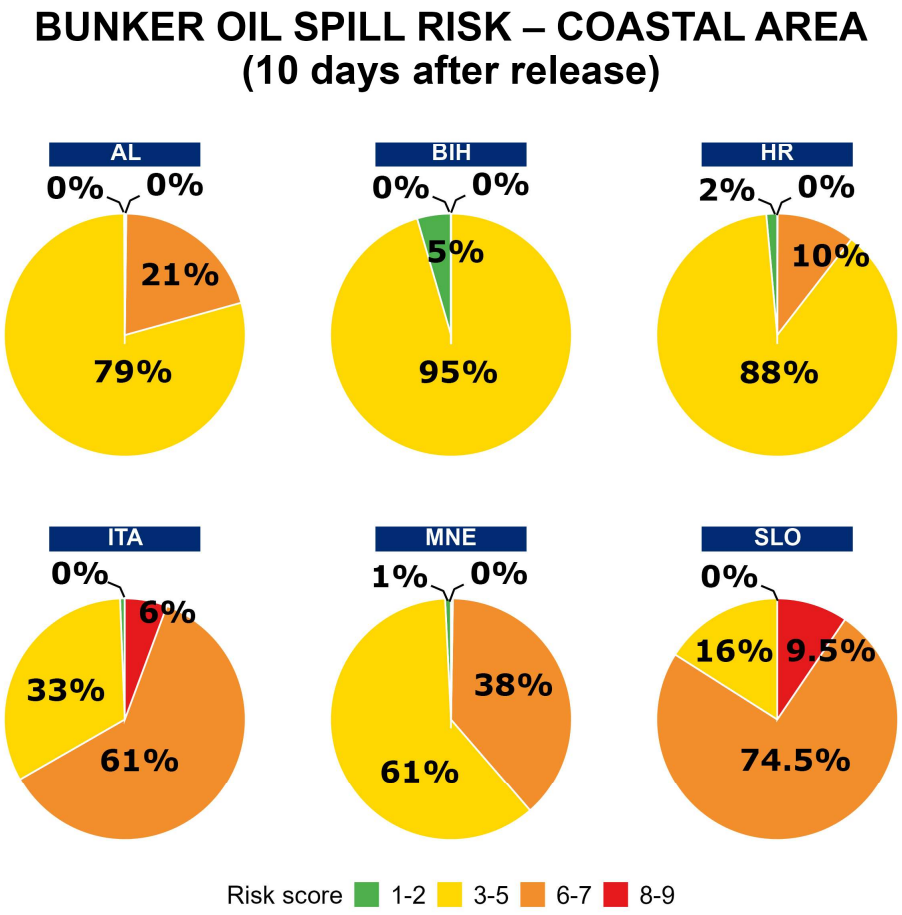


Figure 57. Percentage distribution of the four vulnerability score classes for bunker oil, divided by Adriatic countries, in the coastal area of the oil spill risk maps.

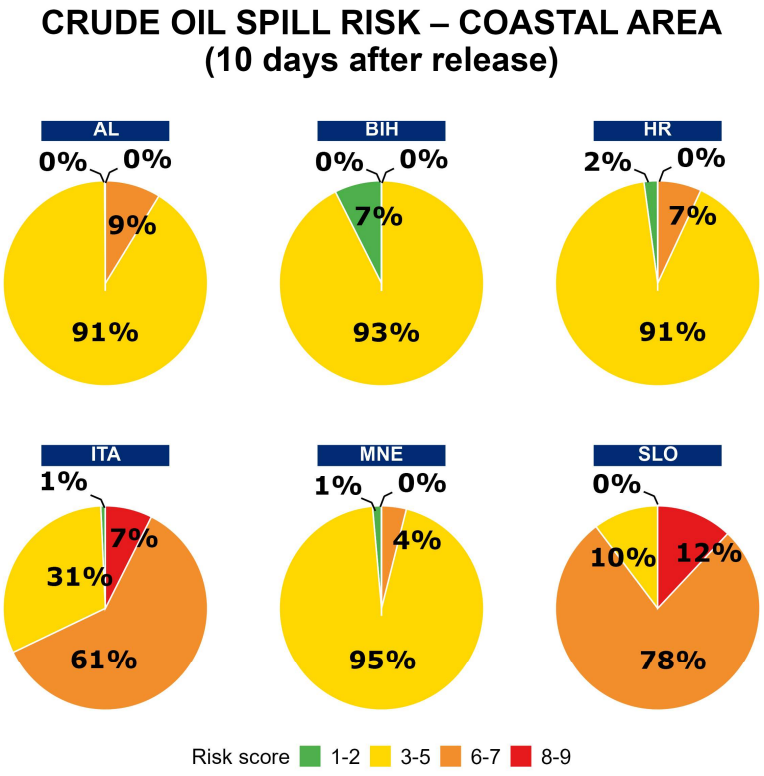


Figure 58. Percentage distribution of the four vulnerability score classes for crude oil, divided by Adriatic countries, in the coastal area of the oil spill risk maps.

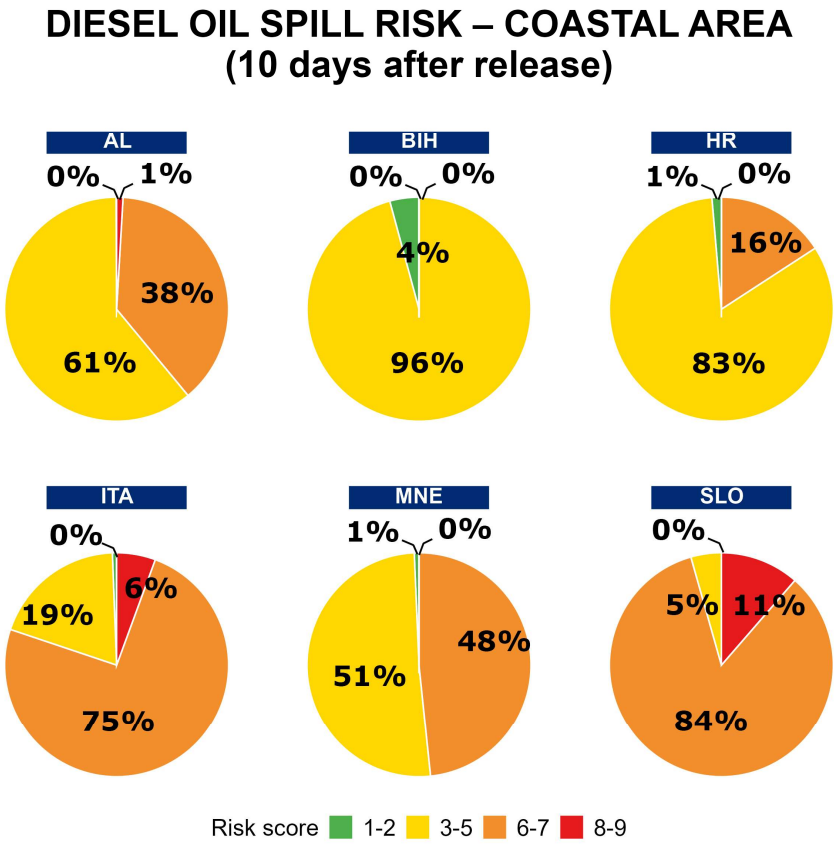


Figure 59. Percentage distribution of the four vulnerability score classes for diesel oil, divided by Adriatic countries, in the coastal area of the oil spill risk maps.

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