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EXECUTIVE SUMMARY

This deliverable is a "Technology outlook" for the JERICO-Design Study (J-DS) Task 2.1 that has been developed in collaboration with the scientific vision created in WP1 and provides an overview of the current status of JERICO-RI infrastructures from a national perspective and guidance on the technology design for the future JERICO-RI. The Technology outlook will provide the basis for the gap analysis performed in T2.2 and finally the roadmap for the technical design of the future JERICO-RI in T2.3.

Section 2.2 in this Deliverable summarises information given by J-DS national representatives on the technical aspects (i.e., platforms/sensors) of the national JERICO infrastructures. Inputs from nations were received through a questionnaire, elaborated with relevant J-DS and JERICO-S3 (J-S3) work packages, and filled out by nation representatives over a 3-month period in 2022. The compilation of national inputs focus on the technical aspects of the infrastructure (systems/platforms/sensors), and on questions that deal with how the JERICO-RI infrastructure should look and function in the future (5-10 years).

Based on the information from the questionnaire, the underlying key scientific challenges (KSCs) and ongoing work within the WPs of JERICO-RI (both J-S3/J-DS), Section 4 provides a synthesis of the Technology outlook for the future operational JERICO-RI. This synthesis introduces a set of "core variables" considered to be essential to observe for the future operational JERICO-RI and the main platforms for (semi-)continuous sensors and observation that are involved. It also describes how the partners in JERICO-RI collaborate to provide high quality scientific coastal data and support coastal research and policy.

1. Introduction

JERICO-Design Study (J-DS) WP2, **Technical Design for an Operational JERICO-RI (physical part of the RI)** provides a plan, in the form of a roadmap, of how an RI for European coastal sea observations should be implemented technology-wise. In the initial phase of this process, it is necessary to investigate what the current technological state of the partners organising observations is, to find out what the different national and regional strategic further development plans are, and how a realistic vision of the future can be achieved.

J-DS Task 2.1 **Technical and technology outlook for coastal observatories (D2.1)** elaborates the outlook for the JERICO-RI, largely in collaboration with the scientific vision created in WP1 and provides insight on practical elements about how the technical aspects of the infrastructure should function in the future. As originally proposed, this outlook should have several key elements, including:

a) how the existing technologies could be enhanced and harmonised
b) which are the key new/future technologies
c) how to maintain and improve the excellence in system maintenance and operations
d) how to optimally exploit the observation capacity of platforms and sensors
e) how to improve the technical integration and coordination of observations
f) how to optimise observational synergies with other RIs.

This deliverable uses the background provided by previous phases of JERICO-RI as well as various needs of coastal observations, with national (J-DS WP1) and regional specificities (JERICO-S3 (J-S3)). In parallel with the development of D2.1 with JERICO-RI nation representatives, the Technical and technology outlook will also include input /feedback from various J-DS and J-S3 work packages (see below) to ensure that D2.1 will be realistic and fit-for-purpose so that it can best serve its purpose for the gap analysis to be performed in task 2.2 and the development for a roadmap for the technical design in task 2.3 (see Figure 1). Benchmarking with other European RI in different domains and international coastal observing systems has been carried out, to ensure connectivity and synergies.

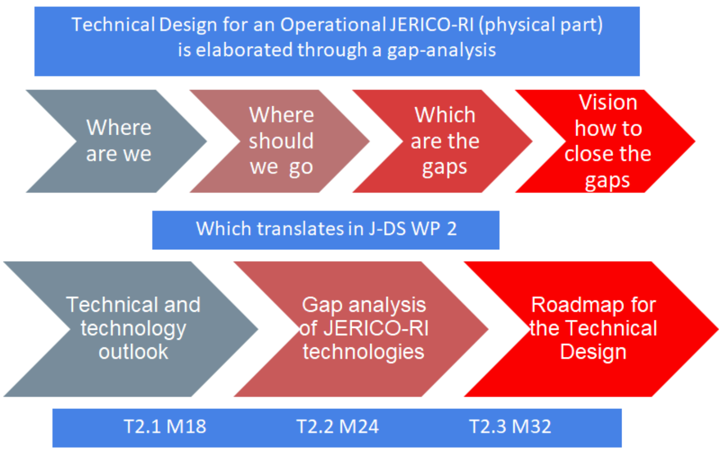

Figure 1. Process chart for technical design gap-analysis of JERICO-RI, translating into different tasks of WP2 in the JERICO Design Study (J-DS).

An effective technology design or outlook of any activity cannot be developed from a technology point-of-view only, in isolation from the other drivers and available resources of the activity. The choice of the optimal technologies is therefore a multi-criteria issue and the iteration towards an optimal solution also requires that the various elements that are not directly related to the technologies itself are considered. Thus, a realistic technology outlook for Europe's future coastal observations is not just a vision of how marine observation technology should evolve and be deployed, but must include practical elements, what is realistic over time, and strategic elements, including what the nation- and region-specific priorities are for technological development.

In order to build up the technology design for an operational JERICO-RI, we need to understand and consider the relevant boundary conditions and criteria. Some of these constraints are technology-specific (e.g., if technologies are mature, if they are costly, or if they are applicable only for specific sea regions), while others are related to capacities of making observations (e.g., does each study site have suitable human resources and knowledge, or is there adequate supporting infrastructures available) and strategic choices in making observations (e.g., is there a national and regional need and commitment for each type of observations, or if the required observations are already carried out by other communities). The same constraints need to be included in various steps of technology design; 1) in drafting a technology outlook - what are the key technological components of the operational JERICO-RI, 2) continuing with the technology gap analyses - analysing which elemental components are still missing, and 3) when formulating the technology roadmap - setting a way ahead to follow.

The technology design of JERICO-RI needs to fulfil sustainability requirements, enable scientific excellence and meet the needs of national stakeholders and funders. The process of technology design is likely iterative and has multiple perspectives to be balanced. There is no short-cut or template in making the technology design, but it requires that various stakeholders can have their say, their (sometimes conflicting) input is thoroughly analysed and final choices of the technology roadmap are based on common values. Throughout the whole process we need to keep the focus on making the end results achievable.

This document, **Technical and technology outlook for coastal observatories (D2.1)**, is a starting point of the JERICO-RI technical design. It takes into account various national, regional and European aspects when concluding on technology outlook. However, as technologies and strategic plans evolve, more stakeholders are providing their insight, and as we approach the more practical steps of gap analysis in forthcoming tasks, we likely need to revisit the outlook provided here various times in future. That said, we also look forward to receiving feedback from the readers of this document, as the JERICO-RI technology design will eventually, in its complexity, need to be a compromise in pleasing various partners, nations and stakeholders. Thus, we are all ears if you have something to say!

2. Main report

2.1 Methodology

There are various methods or frameworks to perform strategic planning, like the technology analysis here, with various steps of "outlook – gap analysis – roadmap". The framework facilitates the collection of appropriate information, helps to navigate through contrasting requirements and assists in balancing between various aspects when reaching to decisions.

Various methods were briefly screened during the onset of the Work package, like

- McKinsey 7Ss Framework
- Nadler-Tushman Congruence Framework
- SWOT Framework
- PESTEL Framework
- Fishbone Framework

Among the methods listed above, the McKinsey 7S Framework was considered the best suited for the topics and themes that are part of the JERICO-RI technology gap analysis (WP2 Task 2.2). This model (Figure 2) is suitable for organisational analysis, examination of how different organisational parts work together and to monitor changes in the organisation. The method originates from business consultants Waterman et al. (1980) and is related to facilitating organisational change and following its effectiveness. The key elements of McKinsey 7S Framework are that it recognises multiplicity of factors that influence the organisation, these factors are tightly interconnected, and progress in one area is not possible without progress in others, and that there is no hierarchy among the factors but through the time each of them could play a key role in changing the organisation.

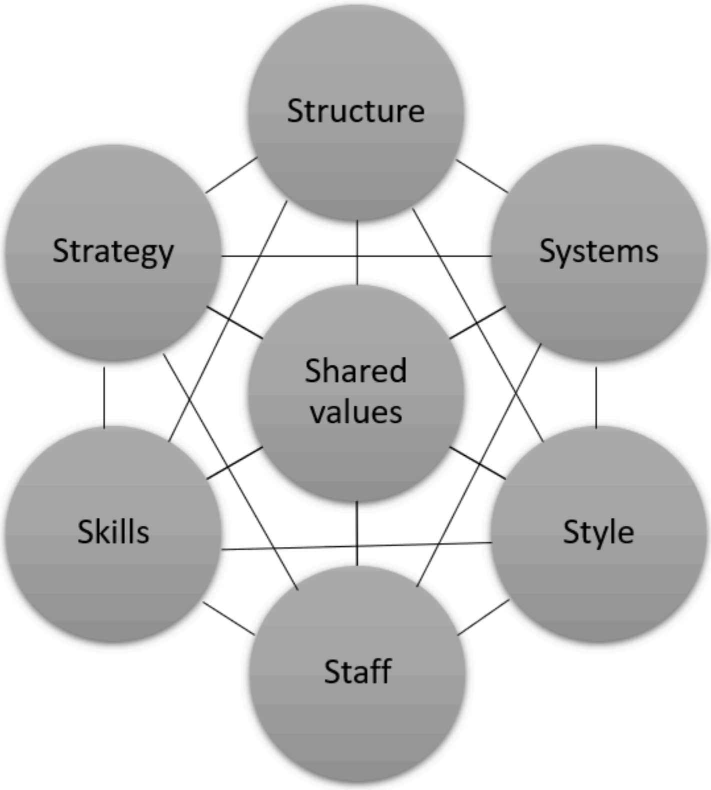

Figure 2. Graphical representation of McKinsey 7S Framework, with 7 elements of organisational framework, redrawn from Waterman et al. (1980).

The elements of the McKinsey model, 7S's, underline the complexity of organisations and interdependence of various factors. Originally the model was created to meet the management needs for commercial units, not for RIs, though many of the elements and principles are the same. This in mind, we also take the freedom to provide our interpretation of 7S's, more from RI perspectives, but following the original thematics.

In our JERICO-RI, ***Shared values*** are the key objectives agreed within JERICO partnership, so that JERICO-RI will be the future gateway for European coastal long-term observations and related services. All nuances of technology design need to agree and support these goals, which are explained more in detail in J-DS and J-S3 WP1 documents. As a summary for shared values, we may consider this is represented by the overall JERICO-RI science strategy.

The ***Strategy*** of JERICO-RI technology design needs to reflect and align with existing (or work-in-progress) national and regional strategies for developments in coastal observations. We need to build upon the existing coordination and integration of observations (technology-wise, in the context of this work), as well as take into account the needs and possible synergies for integration.

Systems refer to the current and desired use of technology and the key future technologies. This part of analysis checks the needs for multiplatform observations, mechanisms for transfer of knowledge and barriers for optimal use. Briefly, our aim is to analyse how the use of technology (platforms, sensors) is organised and implemented and if it meets the JERICO-RI science strategy.

Structure in our interpretation of McKinsey 7S stands for understanding what are the key scientific focus areas among different nations and regions, how different actors share the work and collaborate, and how all these are coordinated, and which might be the benefits from transnational and pan-European structures.

In our analysis we do not clearly separate ***Staff*** and ***Skills***, mainly because it may be hard at this phase of JERICO-RI technology planning to make an in-depth analysis of the actual technology-related personnel. With the two S's we refer here to overall availability of human resources for coastal observations, future needs in improving their competences, and needs for training, transnational support and specialisation.

Finally, the ***Style***, how leadership and organisation structures are designed and who they are affecting technology implementation of coastal observations is left out from the analysis as governance structures are dealt with in the other parts of J-DS. But of course we will interact with these other relevant tasks, bringing up the needs from technology implementation point-of-view, how JERICO-RI should be composed together and which governance structures are essential for technology implementation.

To collect information from J-DS nation representatives, we created a preliminary and wide range of questions for the "Technology outlook", reflecting the original key elements for Task 2.1 and the MacKinsey S's as outlined above. National representatives and WP participants evaluated the preliminary questions and their input was used to generate questions related to the technology outlook with relevance to "Key Scientific Challenges" (KSCs) outlined in WP1. This link between questions and KSCs ensured that the inputs from the national representatives were directly related to the scientific vision of the future JERICO-RI, and ensured compatibility with the technological developments through the outlook, gap analyses and ultimately the roadmap technology in J-DS WP2.

Using the input from J-DS nation representatives, the final questionnaire was distributed to and filled out by national representatives in J-DS over a 3 month period from January to March 2022. The intent was that the nation representatives would answer the questions with key input from others within their respective nations. We received responses from all 14 countries that were asked to complete the questionnaire using an online questionnaire form. The questions that were asked to the national representatives has been attached as an appendix to this report (Section 5 Annexes and References). The responses by individual nations were carefully assessed, with the aim of extracting the commonalities across all nations for the four McKinsey 7S criteria selected for the "Technology outlook" developments (Structure, Systems, Strategy, Staff/Skills, as described in Section 2.2). The questionnaire consisted of a combination of free-form answers and tables structured by Key Scientific Challenges (KSCs), where the national responses to the latter has been summarised into figures.

2.2 Summarised national inputs based on questionnaire

Background and introduction

The three first questions gave a general background for the national organisation of the JERICO-RI infrastructures, the number/types of platforms and institutions involved, the infrastructures foreseen as part of the future JERICO-RI, and which institutions were involved to complete the questionnaire. These questions serve as a background information on the national requirements and ambition for the rest of the questionnaire.

Input was gathered via J-DS national representatives for questions related to their respective countries. The national representatives provided information regarding who they contacted, and how information was collected. There were a number of different approaches applied by the different nations. For some nations, only the national representative provided information based on their knowledge of the national situation and participation in various national/European initiatives. For most nations the input is based on collated information and discussions with the national partners involved in JERICO-RI. Some nations conducted interviews/workshops with national institutions, environmental agencies and/or national infrastructure consortia.

Regarding the involvement of institutions in JERICO-RI, national representatives frequently mentioned that major research institutes focused on coastal observing and coastal ocean research topics/themes were generally involved in JERICO-RI. Academic institutions (e.g., national universities), on the other hand, were less involved in the national JERICO-RI infrastructures. As the JERICO-RI community mostly consists of those institutes practically involved in national coastal observations, there was also a general lack of input provided by national agencies or ministries and industrial partners. The academic, governmental, and industrial sectors could be important links between education, national policy making, technology development/innovation and coastal observing efforts for a future JERICO-RI, respectively and obviously their activities and requests need to be closely followed.

Current national JERICO-RI infrastructures

The national JERICO-RI infrastructures currently comprises various sensor-equipped observing platforms (see examples below), and many nations employ several types of platforms that support national coastal ocean observing efforts. The current JERICO-RI infrastructure is highly complex, with a large variation in types of observing platforms (with varying technological requirements), the extent of national observing capabilities and national organisation of JERICO-RI infrastructure (number/types of national partners).

The most widespread current national JERICO-RI infrastructures included (Table 1):

- Fixed platforms (platforms or buoys) - 13 countries
- HF radars - 6 countries
- Gliders - 6 countries
- FerryBox systems -6 countries
- Research vessels/manual sampling - 6 countries
- Tide gauge networks - 6 countries

Other platforms are listed by country as part of the current JERICO-RI infrastructure included: drifters (surface/profile), profilers (cable/buoy-based), various autonomous observation systems (ROV, AUV, drones), tide gauge networks, wave buoy network, weather buoy network, benthic landers, in addition to calibration and test facilities. Several nations also list more traditional manual sampling on research vessels or other ships as part of the JERICO-RI infrastructure, although some nations note that this is not included in the list of JERICO-RI infrastructures (see also below).

Table 1. Coastal ocean observing platforms that are currently part of national JERICO-RI infrastructures.

Present JERICO-RI infrastructure	**BE**	**HR**	**EE**	**FI**	**FR**	**DE**	**EL**	**IE**	**IT**	**NL**	**NO**	**PT**	**ES**	**SE**	**Tot**
Fixed plattform (moorings or buoys)	■	■	■	■	■	■	■	■	■	■		■	■	■	13
FerryBox systems			■	■		■	■			■	■			■	6
HF radars					■		■		■	■		■	■		6
Drifters (surface/profile)													■		1
Profilers (cable/buoy-based)			■		■								■		3
Gliders			■	■	■		■	■					■		6
ROV/AUV	■						■								2
Drones (various types)					■								■		2
Research vessel/manual sampling	■	■			■		■			■			■		6
Tide gauge networks					■		■	■		■		■	■		6
Wave buoy network							■	■		■		■			4
Weather buoy network							■	■							2
Benthic landers	■														1
Calibration and test facilities.				■	■		■					■			4

__Future national JERICO-RI infrastructures__

Regarding the outlook for coastal observing infrastructures, the types of platforms that are relevant to include in ~5-10 years time frame range widely (Table 2). Many responses include expanding on already existing platforms for national research infrastructures, but also suggestions for addition of new platforms/technologies. The platforms most frequently foreseen to be added to the national JERICO-RI infrastructures were:

- Fixed platforms (platforms or buoys) - 9 countries
- FerryBox systems- 6 countries
- HF radars - 7 countries
- Research vessels - 6 countries
- Tide gauge networks - 5 countries

There are also new types of observing infrastructures listed as relevant to include in the future JERICO-RI infrastructures, such as coastal/beach erosion sensors, river buoys, reflectance measurements, coastal weather services and mapping of noise and seabed (e.g., multibeam echosounder measurements). Several nations also include monitoring of new types of parameters such as eDNA, contaminants, health of aquaculture resources and fish-related parameters.

Several nations also include more low-frequency fixed station monitoring under the potential future national JERICO-RI infrastructures, operated or financed by national agencies. These types of monitoring programs are often designed to answer the national requirements to EU water quality directives (e.g., Water Framework Directive or Marine Strategy Framework Directive) and include manual sampling with often monthly resolution for physical-chemical and phytoplankton parameters. As noted above, some nations also include these types of measurements under the current national JERICO-RI infrastructure, indicating that there may be a need to clarify and assess the definitions of eligible JERICO-RI infrastructures, especially for the development of the future JERICO-RI.

Several nations also mention other current or planned nationally-organised coastal observing infrastructures, such as the research/monitoring program for the North Sea (MONS; Netherlands), FINMARI buoy network (Finland), CoastWatch (Norway) and MONIZEE (Portugal).

Table 2. Coastal ocean observing platforms that are envisioned to be part of the JERICO-RI infrastructure in the next ~5-10 years.

Future JERICO-RI infrastructure	BE	HR	EE	FI	FR	DE	EL	IE	IT	NL	NO	PT	ES	SE	Tot
Fixed plattform (moorings or buoys)	X	X		X	X		X		X	X			X	X	9
FerryBox systems			X	X	X		X			X		X			6
HF radars					X		X	X	X	X	X		X		7
Drifters (surface/profile)									X						1
Profilers (cable/buoy-based)														X	1
Gliders					X		X		X						3
ROV/AUV					X		X			X		X			4
Drones (various types)				X	X						X	X			4
Research vessel/manual sampling		X			X	X	X			X			X		6
Tide gauge networks				X	X		X				X		X		5
Wave buoy network					X			X	X						3
Weather buoy network			X		X			X							3
Benthic landers				X											1
Calibration and test facilities.					X		X								2
New instruments/methods															
Coastal/beach erosion	X				X		X								3
River buoys				X											1
Reflectance measurements				X			X			X					2
Mapping of noise and seabed				X	X		X			X					3
eDNA				X	X		X			X					3
Contaminants					X		X								2
Aquaculture and fisheries	X				X		X								4

Strategy

This section of the questionnaire deals with the national actions that are under implementation or planned, to make sure that the technical/technological aspects of the national JERICO-RI infrastructure are compatible with the JERICO science strategy.

National funding schemes

There are some countries where JERICO-RI infrastructures have received national funding as a part of research infrastructures included in the national RI-roadmap (Finland, France, Spain). Finland has a "Finnish Marine Research Infrastructure - FINMARI", that includes all national JERICO-RI activities with funding for new investments in the period 2021-2024 (operational costs of the infrastructure is funded by the institutions involved). France has the "French seashore and coastal research infrastructure - ILICO". The national funding was most often stated as being for four-year periods, with a combination of funding from national ministries and the individual research institutes. These countries state that the national JERICO-RI infrastructures are part of the national research infrastructure roadmaps.

Some nations state that part of the national JERICO-RI infrastructure has received national infrastructure funding such as Norway (National FerryBox infrastructure - NorSOOP) and Portugal (MONIZEE). While some nations operate JERICO-RI infrastructures that are partially or fully funded through national projects, initiatives or research institutions/centres (such as, Croatia, Estonia, Germany, Ireland, Sweden). The period of funding ranges from yearly funding to five-year periods. The funding sources include national research councils (infrastructure funding), national agencies and institutional funding.

Some nations had no explicit national funding for JERICO-RI infrastructure, but observations are included in other RIs or national/European initiatives funded for other purposes (Belgium, Netherlands). Some nations stated that the national funding has recently ended for the national JERICO-RI infrastructure (Greece, Italy).

Several nations have a mixture of funding for various parts of the JERICO-RI infrastructure, with funding coming from other RIs, institutions and/or national agencies (e.g., Ireland, Sweden).

Overall, there is a large variation in funding schemes for the national infrastructures, that range from fully funded national JERICO-RI infrastructures to no national funding.

<u>National and regional observing strategies</u>
Several nations state that the national JERICO-RI infrastructure is part of a national roadmap or strategy for coastal monitoring (6 countries). There are also several nations that have national strategies that include implementation of various regional conventions or EU directives (e.g., MSFD, WFD; 6 countries), and that have institutional collaboration or harmonisation including coastal infrastructures (4 countries). There are also some countries stating that there is no national roadmap including coastal infrastructures (4 countries).

All countries state that the national JERICO-RI partners are well positioned in the designing and/or implementation of national observing strategies for coastal waters.

<u>National technical coordination</u>
A few nations (Finland, France) have a funded national infrastructure including JERICO-RI activities, and these coordinate national technical and scientific activities. Most nations state that there is no formal national coordination of JERICO-RI activities (6 countries), however in many cases there is informal collaboration and harmonisation activities between national partners. Four countries state that there is no national coordination needed, as there is only one national partner involved in JERICO-RI activities.

Most nations (11 countries) indicate that there is a need to improve the technical coordination within the country, and that JERICO-RI would play an important role in facilitating this coordination both at a national and European level. The Key Scientific Challenges that will require the most technical coordination include KSC1: Land-Ocean Continuum, KSC2: Impacts of extreme/rare events, KSC2: Climate change impacts, KSC3: Anthropogenic disturbances, and KSC3: Long term datasets (Figure 3). The nations that state that no further technical coordination is needed either have a national committee and formal agreements for the national JERICO-RI infrastructure (Finland, FINMARI), or state that the efforts are coordinated through institutions involved with national monitoring programmes (Croatia, Estonia).

There were several different approaches to how this increased technical coordination could be achieved. Several countries state that there is especially a need to improve the coordination and harmonisation between physical, biogeochemical, biological and meteorological types of observations, especially to achieve integration between platforms and multi-platform activities. Many countries state that there is a need to improve coordination between different stakeholders at national and regional levels, and that there is a need for a national coordination committee or national strategy for coastal observations.

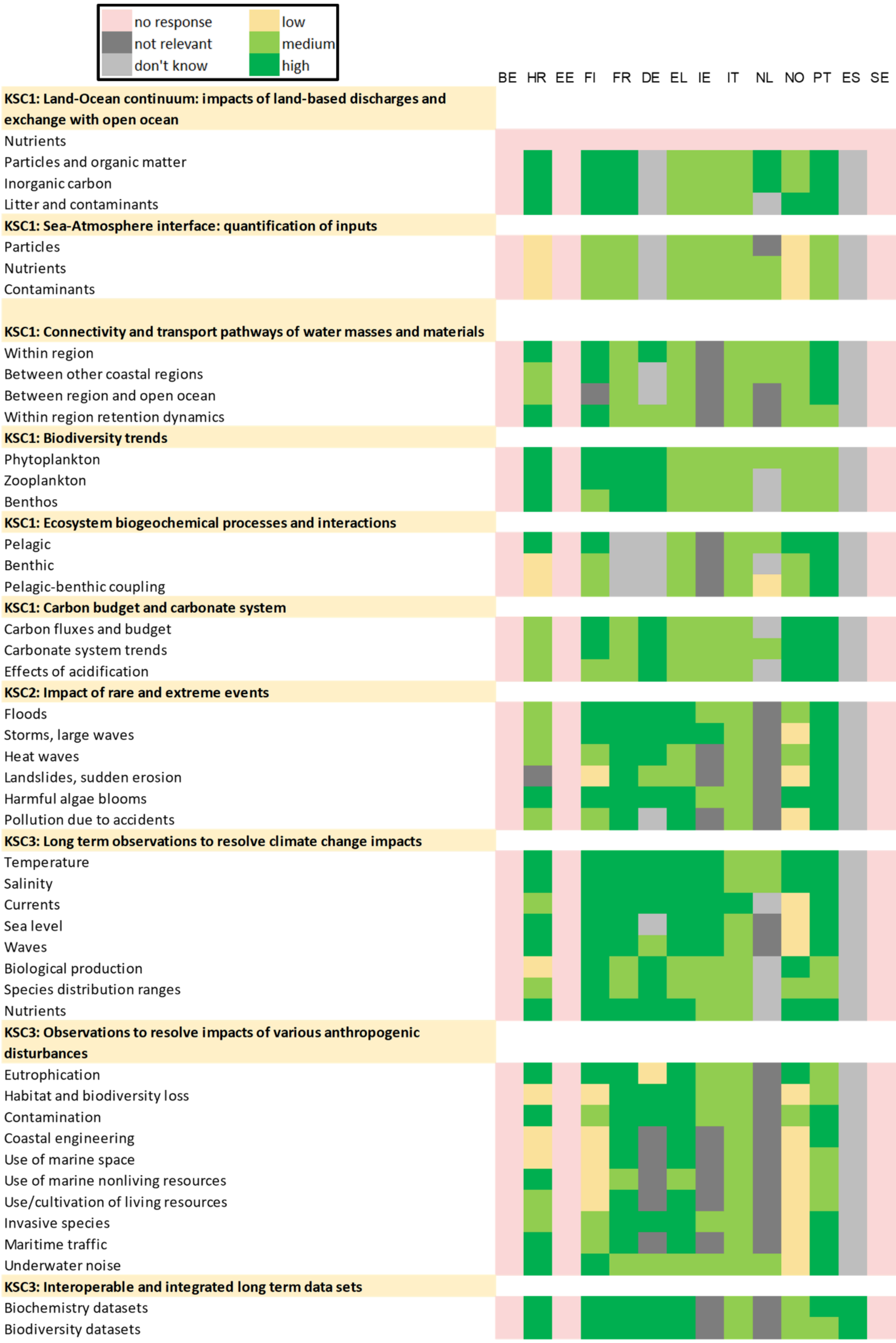

Figure 3. The degree of technical national coordination required for a future JERICO-RI (5-10 years), categorised by Key Scientific Challenges.

Regional technical coordination

Many nations highlight the need for improved technical coordination at the regional level, across neighbouring countries and across shared regional seas. This is especially to integrate measurements across platforms for different nations or facilitate the joint use of platforms between nations. Efforts on a regional scale include increased sharing and development of best practices and SOPs, shared monitoring guidelines, centralised actions for validations, QC routines and calibrations across nations/institutions. Suggestions to improve technical coordination at the regional level include working groups under regional conventions (e.g., HELCOM), MOUs, and collaboration through existing IRS/PSS in J-S3.

At the national level, several countries point to the need for formal agreements between institutions that contribute to coastal observations, either through a national JERICO-RI node or a national monitoring program. The importance of having a pan-European approach in guiding the regional technical coordination was noted.

Synergies with other European observing efforts (e.g. EuroGOOS, ERICs)

Most nations state that there is a high degree of potential synergies with ongoing European coastal observing efforts, either through various EuroGOOS groups or other existing ERICs/RIs in the country. Most national institutions are involved in various EuroGOOS working groups, task teams or regional groups (e.g., fixed platforms, NOOS/BOOS, etc). Several national JERICO-RI infrastructures are also actively collaborating with other ERICs/RIs, such as DANUBIUS-RI, ICOS, EMBRC, ARGO, EMSO, etc. However, most nations state that there is a need for increased coordination, both at the national and European level, to increase the synergies with other initiatives. The relative importance of improving synergies between JERICO-RI and other European initiatives within each KSC is indicated in results summarised in Figure 4.

The nations suggest a wide range of different strategies and examples. Many nations suggest closer integration between JERICO-RI and different EuroGOOS groups, and especially with the coordination efforts and technical discussions in task teams/working groups such as fixed platforms, gliders and FerryBoxes. Several nations also mention that the national JERICO-RI infrastructure should be represented in the various NOOS groups, and it is suggested that there could be a national group of experts to support national contact points from GOOS (e.g., through EOOS operational committee OC) to promote communication and collaboration.

In many countries, the synergies between the current and future JERICO-RI infrastructure and other national RIs (e.g. ICOS, DANUBIUS, eLTER, Euro-ARGO, EMSO, EMBRC) are evident and need to be coordinated. The need for coordination includes: defining operation boundaries between RIs, regular intercalibrations, joint products, workshops, common definitions, standards, reuse of common vocabularies for metadata, making software for DAQ and quality control open source, open hardware.

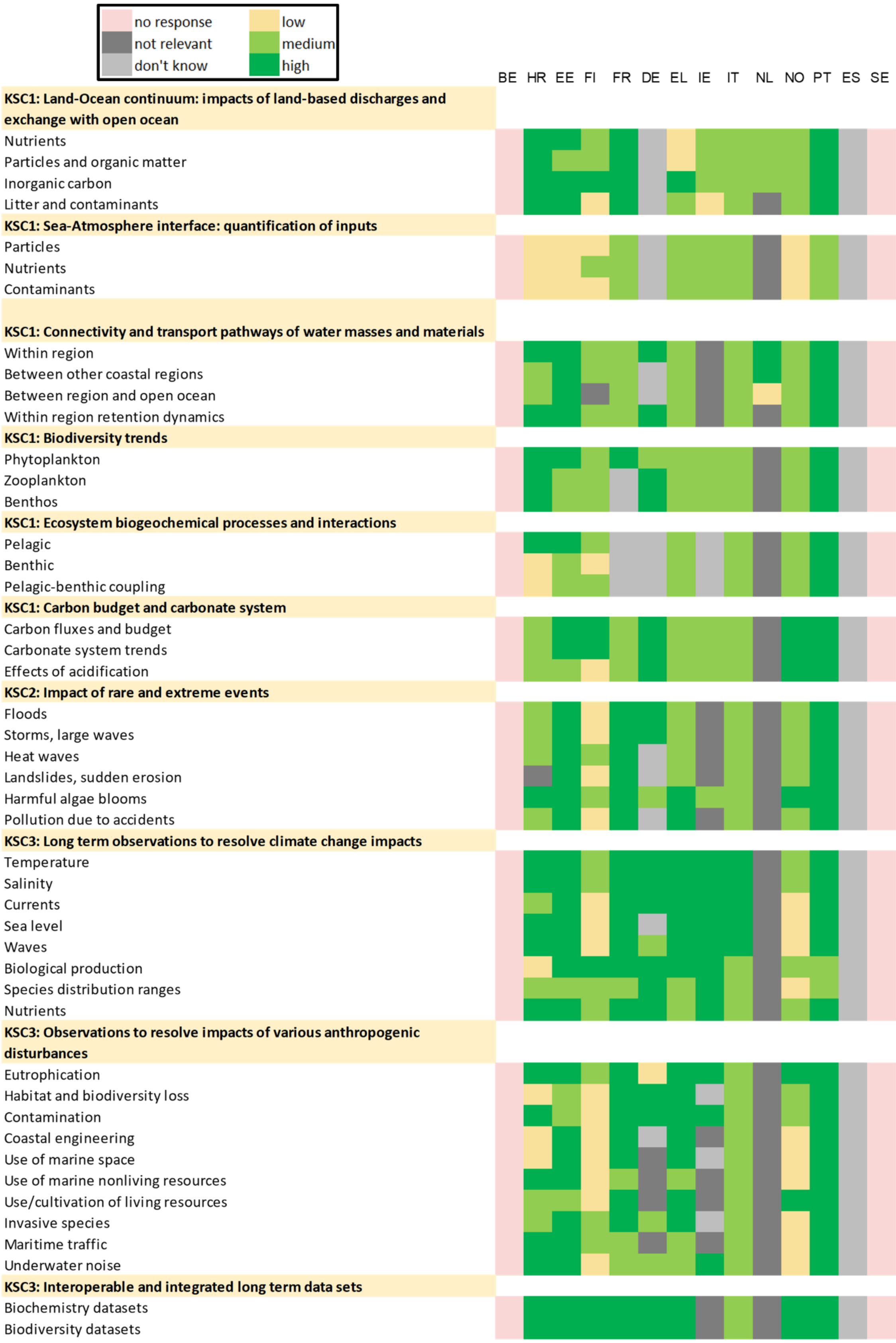

Figure 4. The need for improving synergies for the future JERICO-RI (5-10 years) in technical coordination of KSC's between JERICO-RI and other European ocean observing efforts such as EuroGOS and ocean/environment ERICs.

The national data flows from different infrastructures and RIs need to be streamlined with initiatives like Copernicus Marine Services and EMODnet. The need of adding JERICO-RI tags in metadata to the respective data is also highlighted. One nation also highlights the risks of overlap between ERICs and the need to have clear delineations, for example if nations fund the same sensors/services in the framework of different ERICs.

Use of JERICO infrastructures for modelling and remote sensing communities.
The remote sensing and modelling communities could represent important stakeholders and users for the JERICO-RI infrastructure, and through the questionnaire the nations were asked to what extent the current JERICO-RI infrastructure are able to meet the requirements from these communities, and what could be done to improve for the future.

Several nations highlight that the most important improvement is that the future JERICO-RI infrastructure is able to deliver quality controlled data in (near) real-time, with efficient data pipelines which adhere to the FAIR principles. Several nations already deliver data for the remote sensing and modelling communities, mostly physical and/or meteorological observations, while biogeochemical observations still are under development. Importance of delivering data through existing solutions (e.g., Copernicus Marine Services) is highlighted.

Systems

This section deals with how the technology (platforms, sensors) is organised and implemented to meet the JERICO science strategy. It examines which are the key long term (5-10 years) national goals for platform and sensor developments.

Sharing of technologies and their interoperability
In terms of sharing common technologies and being interoperable, the nations indicated the need for improved technical coordination at the national, regional, and EU levels across virtually all KSC topics and by all countries that provided responses (Figure 5, EU level). The majority of nations gave high importance to achieving this objective, for all scales (national, regional, EU). The nations state that achieving interoperability and sharing technologies was important to be able to deliver cost-efficient observations (shared servicing/maintenance/calibration costs) and to ensure that the joint JERICO observations are suitable for analyses at the regional and European scale by all JERICO users (e.g., marine scientists, national management, EU directives (e.g., WFD/MSFD)) or regional conventions (e.g., HELCOM, OSPAR) and modelling and satellite research communities. This is true for the technical part of the infrastructure to ensure that the recommended procedures and standards are used across national JERICO-RI infrastructures, but also needs to include the data management aspects, such as QA/QC routines, vocabulary and metadata structure used.

However, several nations also highlight that the regional specificities need to be taken into account, in terms of different methodological requirements in different regions, such as detection limits, ranges and accuracy. JERICO-RI may have an important role in coordinating how to distribute the knowledge which technologies are best suited in which coastal environmental conditions. JERICO-RI should also have room for development and use of new emerging technologies, which are not yet standardised.

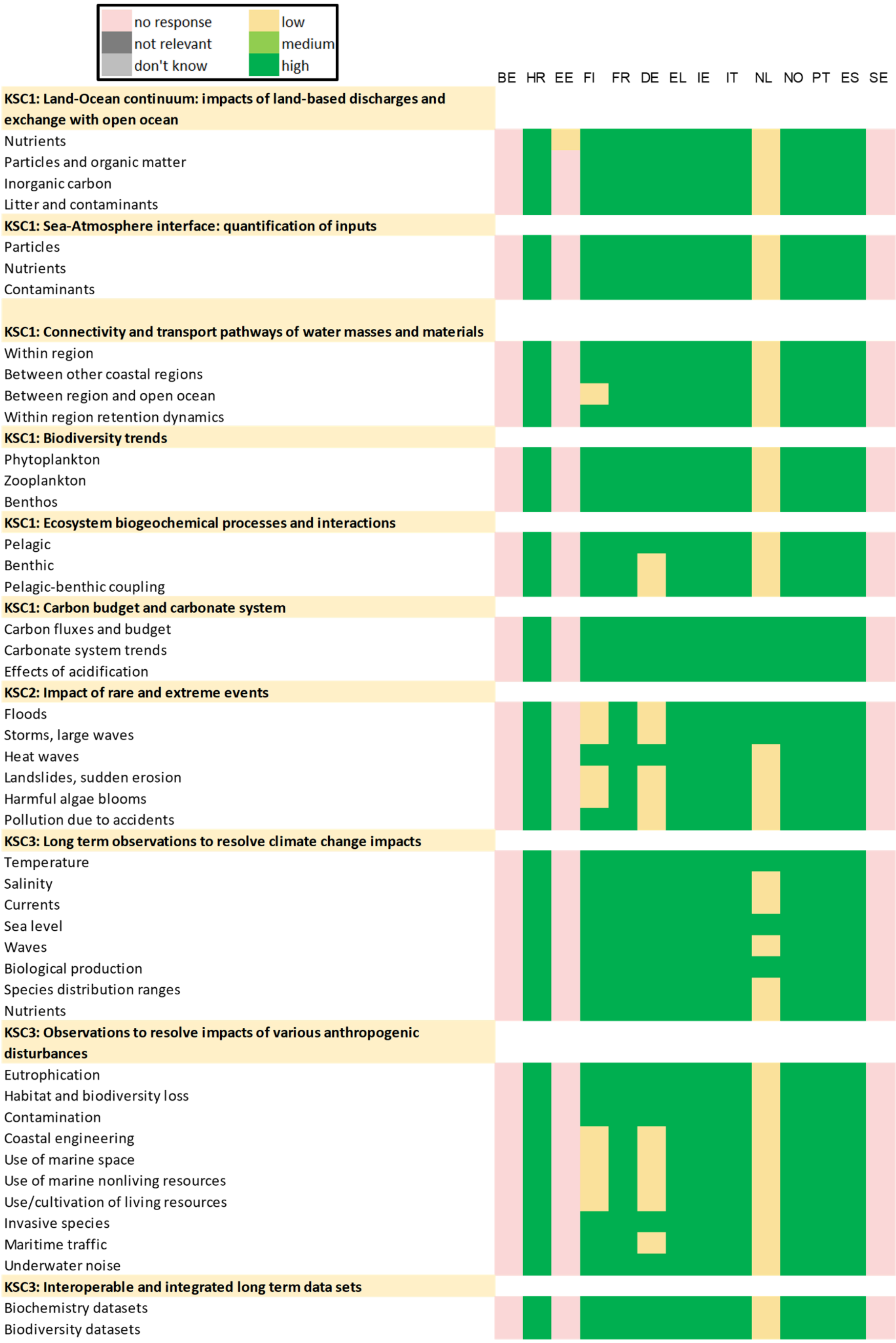

Figure 5. The need for improved technical coordination at the EU levels categorised by Key Scientific Challenges for a future JERICO-RI.

Long-term goals in system developments

Regarding the long-term goals (5-10 years) for the platform and sensor developments, several nations mention inclusion of biogeochemical/biological and carbon sensors on existing platforms. In addition, inclusion of new platforms (e.g., autonomous vehicles, benthic landers, see table 2), novel technologies (e.g., eDNA, imaging techniques), improvement of data availability (including near real-time quality control procedures) and provision of services are foreseen. A few countries state that they have submitted or are in the planning phase for larger national infrastructure projects, including JERICO observations (Netherlands, Portugal, Italy).

A transition from delayed mode research vessel based surveys towards operational real time observations was noted among answers. Need for improvements in observational capacities across land-sea, air-sea and pelagic-benthic interfases was highlighted. Overall needs to improve spatial and temporal range and resolution of observations was found important, to overcome issues of undersampling in some regions.

As specific variables to be observed more in detail in future, biodiversity (through eDNA and imaging), carbonate system and organic carbon fractions were mentioned. These foreseen developments include also using new technologies for taking discrete samples at observation platforms, to be delivered for further analyses in laboratories.

From a different perspective, some answers highlighted the future needs for evaluating the monitoring network performance guiding how to adapt to the changes in observing needs. Along the same thought, a need for an economic model for data production was noted. Some answers detailed long term objectives in development of new services for marine issues (related to data availability, supporting MSFD and WFD, modelling). Providing better support for a sustainable blue economy was identified as one potential long term goal.

Multiplatform observations

In terms of the technological outlook for the JERICO-RI multi-platform approach, several nations highlight the need for doing basin-wide and trans-national assessments, which requires harmonizations and intercomparisons between both platforms/sensors, across nations and potentially across different RIs. This is especially relevant for assessments connected to the EU frameworks such as WFD/MSFD (e.g., Chlorophyll a, nutrients) or for the GOOS Essential Ocean Variables (EOVs).

Specifically, it was noted that there are needs to improve multiplatform observations towards more transnational activities and improve harmonisation of methods, sharing platforms and data. Sharing RV activities need to be improved internationally and nationally, in supporting launching, recovering and maintaining autonomous systems and in providing reference measurements. Collaboration in specific new technologies is needed, as not all partners can invest in all new technologies at the required level; this may include creation of best practices and SOPs and calibration, validation and testing of sensors.

Variables that can be observed with satellites are especially suitable for multi-platform approaches, such as Chlorophyll a, total suspended matter (TSM) and sea surface temperature (SST). These are also key variables in determining impacts of anthropogenic disturbances, such as wind farms. Modelling needs to be included to interpret and interpolate observations.

Some answers highlighted that many of the GOOS EOVs require a multiplatform sampling strategy. The multiplatform approach will be specially relevant in the future for measurements of biogeochemical variables and biological components, like phytoplankton, higher trophic levels including zooplankton, jellyfish and fish. The need to improve the multiplatform approach for carbon cycle components was noted. Importantly, data standards for these activities need to be coordinated with JERICO-RI and other European partnerships.

Possibilities for improving studies of transport mechanisms and connectivity by combining multiparametric buoys, HF radars, tide gauges, autonomous vehicles was noted as one example for future multiplatform studies. Similar examples are also extreme events measured by wave and multiparametric buoys, tide gauges, HF radars, Climate Change and Long Term Variability measured by long time series of tide gauges, multiparametric buoys, wave buoys, HF radars and autonomous vehicles.

Structure

This section deals with the focus areas for national observations, and how the observations and supporting actions are shared, coordinated and implemented and if there are benefits from transnational and pan-European structures.

<u>Supporting actions</u>

The nations indicated the relative importance for a future JERICO-RI of intercalibrations, validations, best practices and audits for improving the excellence in system maintenance and operations for each KSC (Figure 6). There is a high degree of variation between nations, however many countries indicate a high degree of importance to using these harmonisation tools for assessing impacts of land-ocean processes (KSC1), rare and extreme events (KSC2) and climate change (KSC3).

Several nations explain that intercalibration efforts are more frequent for physical variables, and need to be expanded to biogeochemical/biological variables. Overall it was noted that for some variables (like nutrients) accreditation systems are available only for laboratory analyses, but not for sensors. There is a wide variability in how supporting activities (e.g. calibration and technical maintenance) is organised, but most answers indicated in-build structures within institutes (at least at some level.

There is a need to further develop common Standard Operating Procedures (SOPs) and best practice instructions across the JERICO-RI platforms and sensors. One answer highlighted a need to build a reliable and updated catalogue of existing observing platforms and related data and resources. A first version of this type of catalogue is underway in JericoCORE. The management and update of this catalogue is very much needed, and would be an essential component of the forthcoming JERICO-RI.

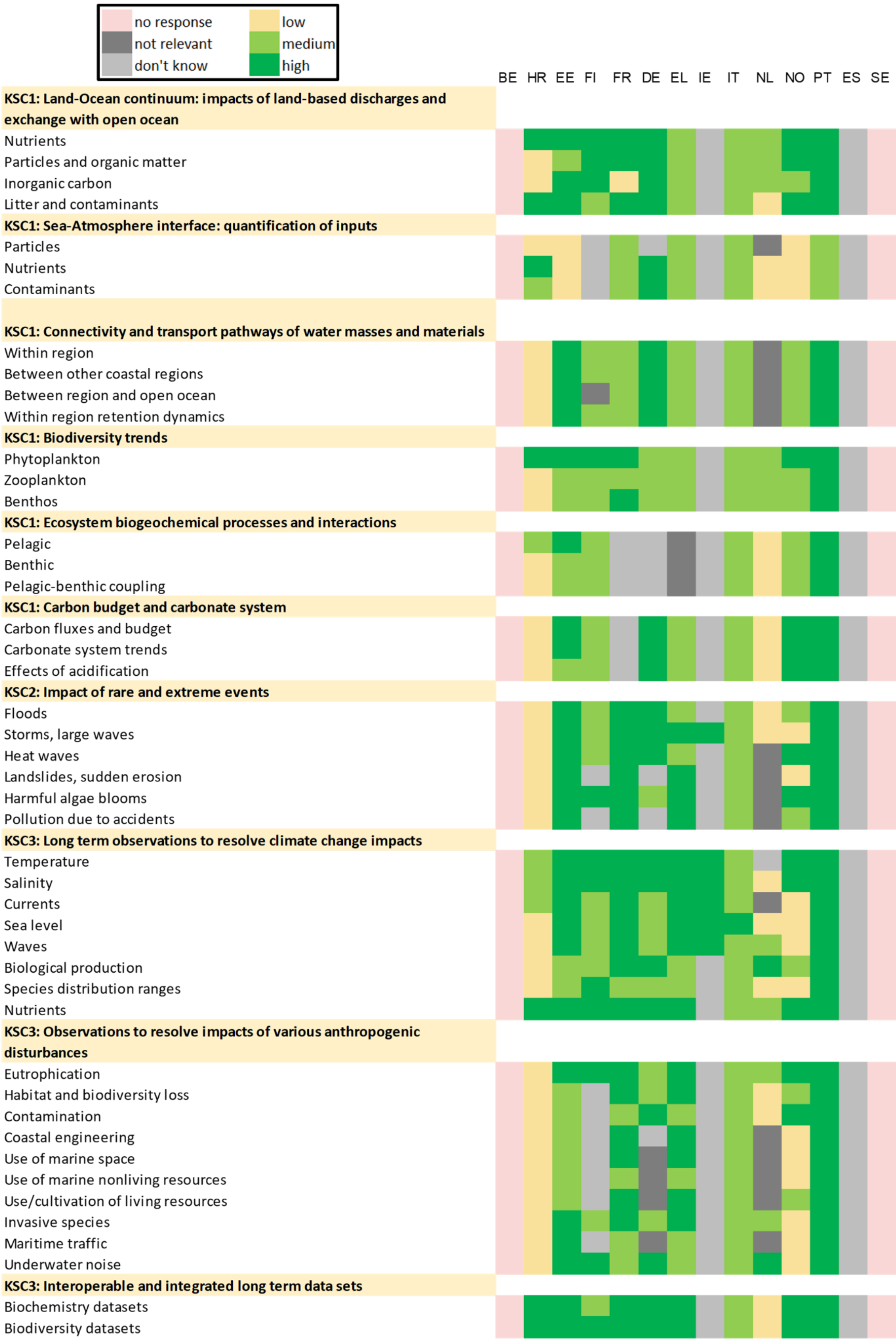
no response
not relevant
don't know
low
medium
high
BE HR EE FI FR DE EL IE IT NL NO PT ES SE
KSC1: Land-Ocean continuum: impacts of land-based discharges and exchange with open ocean
Nutrients
Particles and organic matter
Inorganic carbon
Litter and contaminants
KSC1: Sea-Atmosphere interface: quantification of inputs
Particles
Nutrients
Contaminants
KSC1: Connectivity and transport pathways of water masses and materials
Within region
Between other coastal regions
Between region and open ocean
Within region retention dynamics
KSC1: Biodiversity trends
Phytoplankton
Zooplankton
Benthos
KSC1: Ecosystem biogeochemical processes and interactions
Pelagic
Benthic
Pelagic-benthic coupling
KSC1: Carbon budget and carbonate system
Carbon fluxes and budget
Carbonate system trends
Effects of acidification
KSC2: Impact of rare and extreme events
Floods
Storms, large waves
Heat waves
Landslides, sudden erosion
Harmful algae blooms
Pollution due to accidents
KSC3: Long term observations to resolve climate change impacts
Temperature
Salinity
Currents
Sea level
Waves
Biological production
Species distribution ranges
Nutrients
KSC3: Observations to resolve impacts of various anthropogenic disturbances
Eutrophication
Habitat and biodiversity loss
Contamination
Coastal engineering
Use of marine space
Use of marine nonliving resources
Use/cultivation of living resources
Invasive species
Maritime traffic
Underwater noise
KSC3: Interoperable and integrated long term data sets
Biochemistry datasets
Biodiversity datasets

Figure 6. To what degree is it important for the future JERICO-RI (5-10 years) to use intercalibrations, validations, best practices and audits for improving the excellence in system maintenance and operations for each KSC.

Private sector involvement

Responses from countries varied, some having no involvement of companies in coastal observations, while some had collaboration with SMEs in platform development, supply of equipment and services, and others in providing maintenance services and in making additional observations.

One country (Norway) indicated a very high involvement of the private sector. They have cooperation with the research organisation through partnership in industrial clusters. They note it is crucial to define joint goals, strategy and action plan within the clusters, between private and research actors, instead of competing developments.

Portugal illustrated a couple of good examples for SME collaborations, in development of directional hydrophones for acoustical monitoring to operate in IH multiparametric buoys and in the fine tuning of a tsunami module from HF radars. Presently they are launching an initiative aimed at promoting a closer interaction with new technological SMEs and spin-offs involved in the development of marine observation technology, offering access to IH infrastructure and capacities to work together in solutions that can be incorporated in the future in MONIZEE infrastructure.

In addition, the support of Ferry companies in maintaining FerryBox operations was taken up. Some dedicated European-wide SMEs were noted, which contribute to data services

For future outlook some barriers were also observed when involving the private sector more in different parts of the coastal observing data value chain. These included high price of services, overall small market segment affecting how well companies can sustain high quality staff for very specific services and lack of appropriate sea going vessels by SMEs.

Future focus areas in making observations

It is important to have an understanding of the user needs for coastal observation systems, which KSCs are considered as most important and where the largest benefits of the JERICO-RI joint observation capacities will be. These requirements will have direct implications for how the JERICO-RI should be technically constructed, to be able to support future developments.

First, the countries were asked to select the three most important KSCs for their country, both at present and in the future. Several countries indicated that it was difficult to prioritise between the KSC, both due to lack of national priorities and due to the layout of the KSCs (some overlap, where e.g., nutrients/eutrophication is repeated across several topics). Many nations indicate that the following KSCs were important for their country:

- The land-sea continuum,
- Biodiversity trends
- Carbon budgets
- Long term observations to resolve climate change

- Observations to resolve impacts of various anthropogenic disturbances
- Impact of rare and extreme events

Secondly, countries were asked to identify which of the national and/or regional coastal observations are most important for the added-value of the pan-European JERICO-RI infrastructure. The listing was not very different from the one above, including:

- Biodiversity
- Biogeochemistry
- Integration of biological and physical observations
- Carbon budgets
- Extreme events
- Long term observations
- Harmful Algae blooms

Also a future pan-European JERICO-RI was considered to provide support for between system (e.g., land-sea) and between RI (e.g., observations-experiments) studies and an overall ecosystem approach. Importance of maintaining platform specific networks (e.g., HF radars, FerryBoxes) was noted.

As nicely summarised in one answer; all existing observing capacities respond to well defined needs at different scales (local, regional, global) and respond to science and society needs.

<u>Trans-institutional/national collaborations in technical support</u>

A European RI should provide benefits for national RIs in various levels and here we asked how JERICO-RI trans-institutional and transnational activities are foreseen to promote technical support. Basically all answers listed a variety of benefits, but answers vary a lot in the level of detail. Some answers were very specific and identified for example benefits for specific technologies (carbonate system, imaging) or platforms (FerryBox, fixed platforms). More generic answers indicate the possibilities in exchange of specific know-how within JERICO-RI, in sensor development and in data QA/QC.

One answer specified that human resources and more stable sensor technologies will benefit directly from trans-national collaborations, and that the most immediate impact would be expected for integrative data handling.

Staff/Skills

This section deals with the available human resources and competences for the observation infrastructure, and the countries were asked to what degree the technical competence of personnel would be sufficient to address each KSCs for the future JERICO-RI (5-10 years).

<u>Technical competence for making various observations</u>

Among the countries that responded, most gave high/medium confidence that there is technical competence of personnel to address all KSCs, and generally there was not a lot of variation in the responses within the different countries (Figure 7). This shows that the nations generally have good confidence in the ability to answer the observing needs for the various KSCs in the future, which was also reflected in the text responses given by nations.

However, some answers noted that there is a need to increase the amount of well-educated staff for observations and currently the work is distributed to too few persons. Many nations highlight that

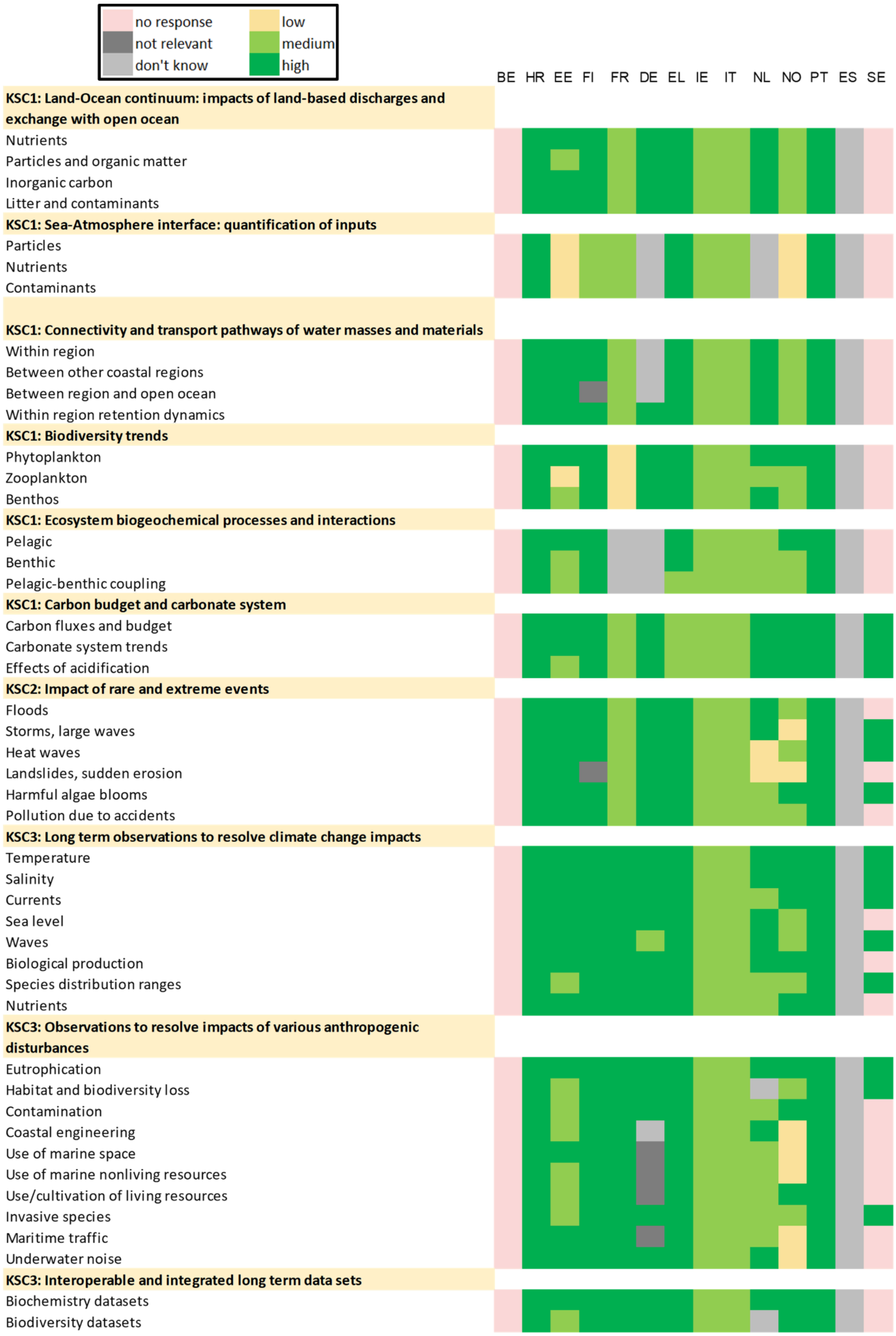

Figure 7. To what degree is the technical competence of personnel sufficient to address the KSCs for the future JERICO-RI (5-10 years).

there is a challenge in recruiting and educating personnel, especially technical personnel, which can also have good opportunities within the private sector. Issues with funding, especially when hiring technical persons was noted. As well, the marine research sector needs to compete on technicians and data persons with other sectors, sometimes providing higher salaries. It was also noted that there is a need for a well established training system for technicians and that a career roadmap is needed.

Need of shared technical services

The countries were asked if they had any preference for how technical services (e.g., calibrations, intercomparisons) could be shared between partners or provided by designated partners/technology centres for the future JERICO-RI infrastructure (5-10 yrs). Many countries do not explicitly choose between these two options, however state that sensor calibrations and intercomparisons (including biogeochemical/biological sensors) would be highly beneficial to the future JERICO-RI infrastructure. This also includes training of personnel and QA/QC workshops, provided either by technology centres or partners.

3. Outreach, dissemination and communication activities

The Technology and technological outlook was presented to the JERICO-RI community during the JERICO days in Lisbon on the 26-28 June 2022. It will also be sent to J-DS national representatives upon completion, and their feedback and comments will be taken into the further process in the technology design (T2.2 and T2.3).

4. Technology outlook synthesis

Based on the information from the questionnaire, the underlying key scientific challenges (KSCs) and ongoing work within the WPs of JERICO-RI (both J-S3/J-DS), this final chapter provides a synthesis of the technology outlook for the future operational JERICO-RI. The Technology outlook (J-DS T2.1) deals with the physical infrastructure for coastal observations in JERICO-RI, more specifically what are the key technological components and what needs to be observed and how. This information will then feed into the Technology gap analyses (T2.2) on which main technological elements are missing, and finally to create the Technology roadmap (T2.3).

It is important to note that parallel to the technology design of the future JERICO-RI there is also ongoing work on the JERICO e-infrastructure (JERICO CORE), which will provide the infrastructure for creating and sharing the information, data and services from the future operational JERICO-RI. The e-infrastructure is outside the scope of this report and is dealt with by WP3 in J-DS, however it is important to have good communication to make sure that the design of the physical infrastructure and the e-infrastructure are aligned. In addition, technology design links to J-DS WP5 Governance, especially on how the technical design affects operational structures of JERICO-RI (e.g., thematic centres) and how a JERICO label (being a flag for observation quality) will be developed and used.

This synthesis of the Technology outlook will introduce a set of “core variables” considered to be essential to observe for the future operational JERICO-RI and the main platforms for (semi)-continuous sensors and observation that are involved. It also describes how the partners in JERICO-RI collaborate to provide high quality scientific coastal data and support coastal research.

4.1 Core variables for JERICO-RI

In order to agree on a realistic and coherent arrangement of observations for the technology outlook, gap analysis and roadmap in WP2 of J-DS, we propose a set of variables that:

- Address the JERICO-RI Key Scientific Challenges (KSCs)
- Can be observed (semi)-continuously with sensors from platforms in (or near) the coastal ocean

This set of variables is considered as “core variables” and provides the basis for the observation network of the future operational JERICO-RI, based on the current KSCs and status of sensor development. If in the future new KSCs are defined, requiring observation of additional variables and if these variables can be observed with sensors, more variables can be added. Additional variables, not necessarily fulfilling all the criteria above, are not excluded from JERICO-RI, as long as they are interoperable with the core variables and contribute to addressing the KSCs.

We compiled the list of core variables which are required to observe the JERICO-RI's KSCs (Table 3). The list of variables is based on the GOOS list of Essential Ocean Variables (EOVs), extended to include variables needed to address the individual KSCs. The overview shows that the majority of variables are required for four or more KSCs (black in table). Some variables are required for two to three KSCs (water level, light, particles, nutrients in sediment, zooplankton biomass and benthic biomass - blue), while a few variables are only required for 1 specific KSC (wave height, sound and coastline integrity - white). Figure 8 shows a schematic illustration of the variables listed in Table 3, grouping them in physical, chemical, biological and benthic variables. It also shows the links between the coastal domain (main focus of JERICO-RI), and with the deep sea, atmosphere and land domains, which are included in KSC1 for JERICO-RI.

Table 3: Relevance of variables for the Jerico key scientific challenges. The column 'sum' indicates the number of KSCs that the variable is involved in. 1 KSC (light grey), 2 – 3 KSCs (blue) and more than 3 KSCs (black).

	KSC1						KSC2	KSC3				
Variable	land-ocean	air-sea	connectivity	biodiversity trends	biochemical processes	carbon budgets	extreme	Climate	disturbances	long term datasets		sum
water temperature			■		■	■	■	■		■		■
salinity	■		■		■			■	■	■		■
sea level							■	■				
wave height							■					
currents					■	■		■	■			■
Light					■	■			■			
Sound/ Noise									■			
oxygen					■	■			■	■		■
Carbon (DIC, pCO2, pH, alkalinity)					■	■			■	■		■
nutrients (N, P, Si) in water	■	■			■	■		■	■	■		■
nutrients (N, P, Si) in sediment					■				■	■		
particles / SPM	■	■			■	■			■	■		■
contaminants	■	■					■		■			■
phytoplankton biomass					■	■	■		■	■		■
phytoplankton diversity				■	■		■	■	■	■		■
primary production					■	■		■	■	■		■
zooplankton biomass					■					■		
zooplankton diversity				■	■			■	■	■		■
benthic biomass					■				■	■		
benthos composition				■	■			■	■	■		■
coastline							■					

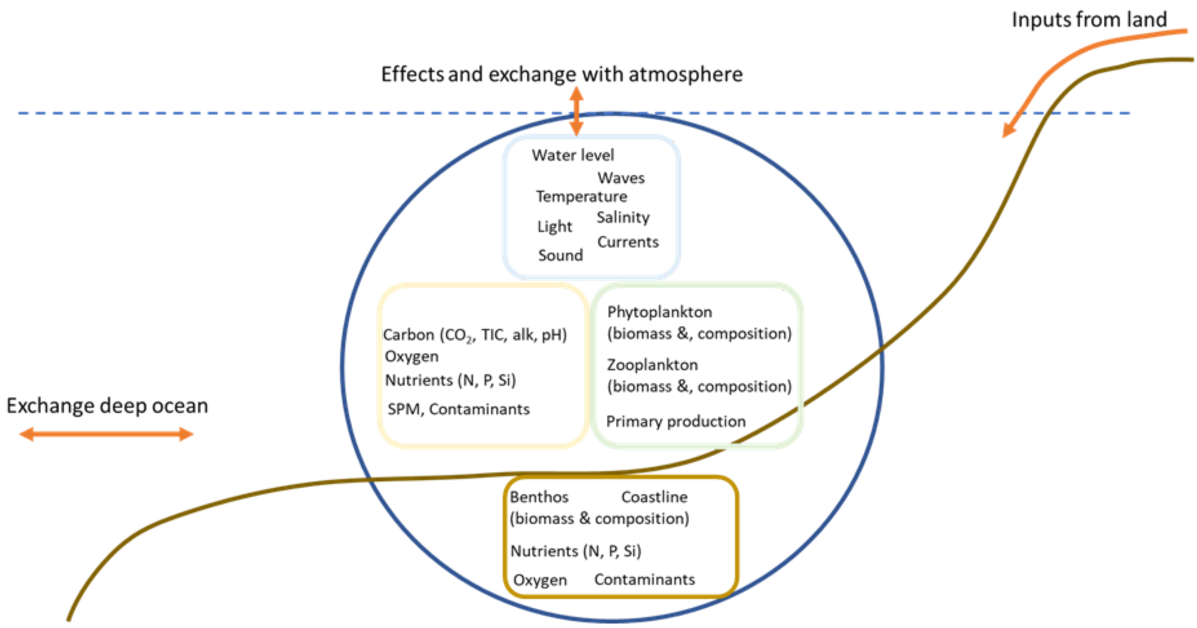

Figure 8. Overview of proposed variables to be included in the technology part of Jerico-RI (within the dark blue circle), the relevant interactions with other research areas (deep ocean, land and atmosphere) and the type of variables: physical (light blue box), chemical (yellow box), biological (green box) and benthic variables (brown box).

Figure 9 shows in more detail which extreme events under KSC2 affect which variables. Oxygen depletion is an additional type of extreme event that is not yet included in the current JERICO-RI KSCs, but is linked to eutrophication. Therefore, we propose to add it to the KSCs. It would not require an additional variable to be observed, but it would mean that oxygen observations are also made near the bottom in areas that are prone to oxygen depletion.

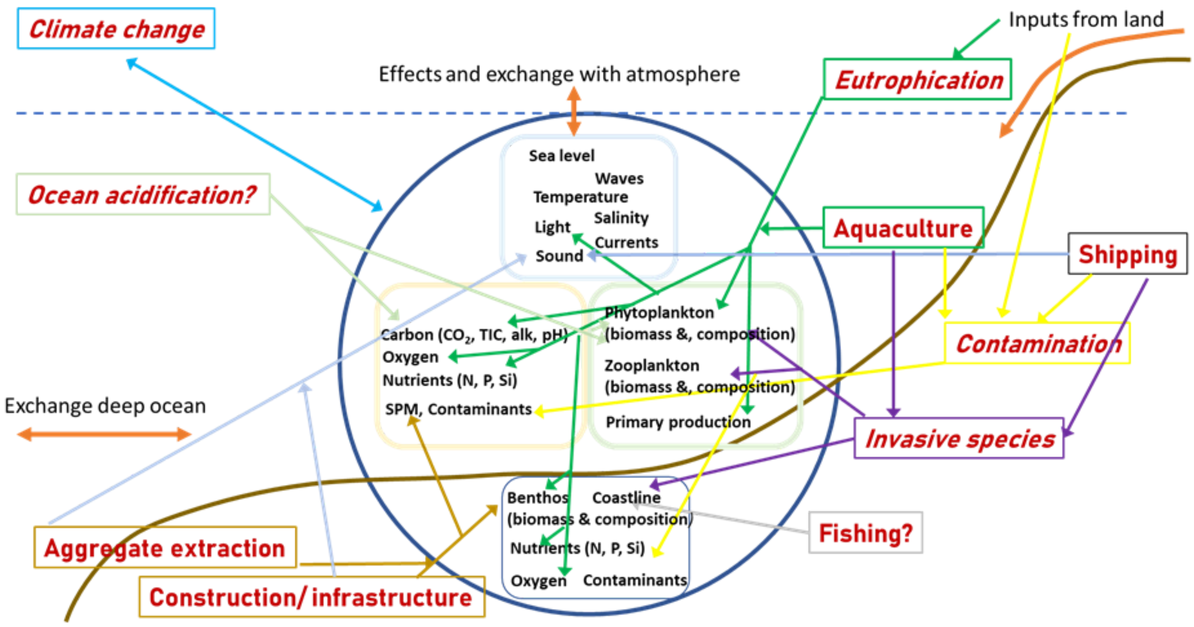

Figure 9: Schematization of variables in JERICO-RI, showing which variables are affected by which extreme events (in red) in KSC2.

Figure 10 shows in more detail which disturbances (human activities and resulting pressures) under KSC3 affect which JERICO variables. It shows that disturbances often affect several variables at the same time and that many variables are affected by multiple disturbances. Additional scientific challenges that were not yet included in the current JERICO-RI KSCs but that may be addressed with observations of the same variables are ocean acidification and effects of fishing pressure on benthic communities.

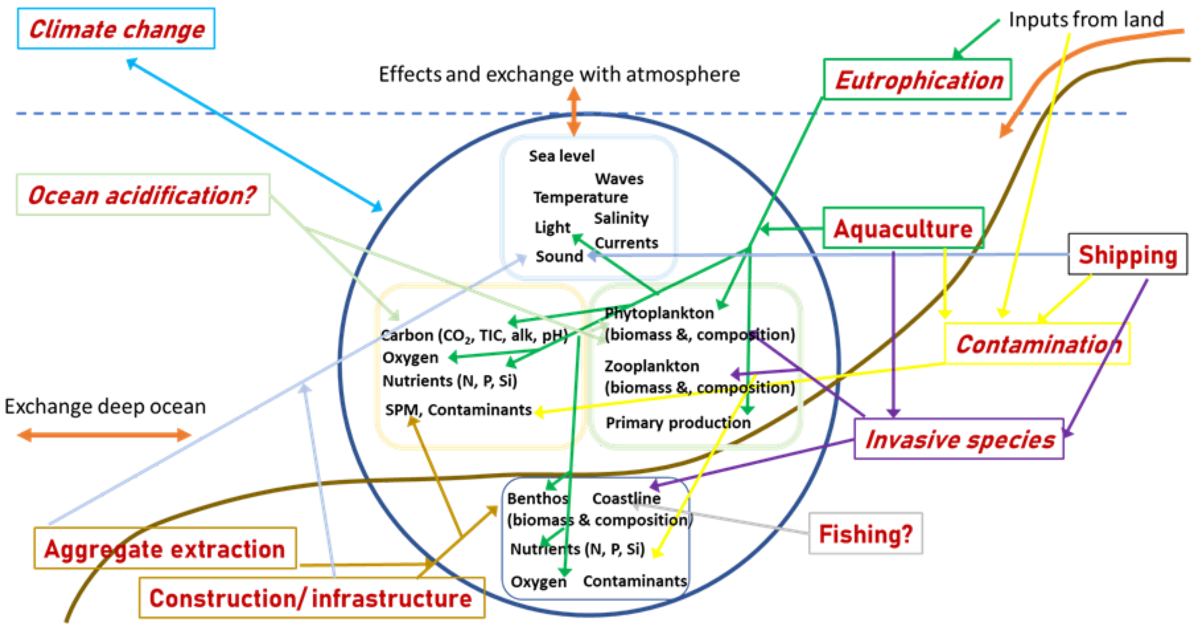

Figure 10: Schematic overview of human activities (in red) and resulting pressures (in red italics) included in KSC3 and the proposed Jerico variables involved.

4.2 JERICO platforms

Platform types

In the questionnaire national representatives have mentioned a wide range of observation platforms that are currently included in JERICO-RI (see Table 1) and foreseen to be included in the future JERICO-RI (5-10 years, see Table 2). The most frequently mentioned platforms were: fixed platforms at sea (such as buoys and moorings), HF radars, FerryBox systems and gliders. These form the core of JERICO-RI observation platforms and most of the harmonisation work done in JERICO projects has been targeting these platforms .

Many countries mentioned including in the future JERICO-RI platforms such as ROV/AUVs, drones (of various types), gliders and drifters/profilers. These additional platforms can also form part of JERICO-RI observation infrastructure, if required to address the KSCs. Tide gauge network is also mentioned frequently and whether it should be included in JERICO-RI platforms has been discussed in JERICO community. The decision should be made according to the need of tide gauge network data to tackle KSCs and the need for pan-European coordination in tide gauge operations.

The observation infrastructure of JERICO-RI has focused on automated observations from platforms and only little work is done to include more traditional manual water samping from research vessels or boats. This type of manual sampling often serves as routine monitoring by governments/agencies to fulfil the requirements of EU directives (WFD/MSFD) and other national commitments. Such classical monitoring data will be included in integrated information products through the JERICO e-infrastructure and/or used as an important element in calibrating/validating automated sampling on platforms, but is not as such part of the JERICO technology design that focuses on innovation in high-quality scientific coastal observations. However, at the time being not all of the variables listed in section 4.1 can be measured using sensors. In such specific cases, often related to sampling of biological specimens or discrete analyses of habitats like sediments, manual sampling (and follow-up laboratory or sensor-based analyses of samples) needs to be included as part of JERICO-RI. Often such sampling efforts are complemented by observations, like observing the physical state of the sea area.

Overall, JERICO-RI is targeting complex coastal ecosystems at nested spatiotemporal scales and to provide data answering various KSCs. Consequently, there is no need to be exclusive which measuring platforms are part of JERICO-RI and which are not, as long as the provided data is fit-for-purpose. Likely, new ways of making observations will arise and new platform-types become more popular within the JERICO-RI consortium. The key aspects, related to platforms, are that JERICO-RI should provide support for harmonising platform operations as needed by the community. The above-mentioned platform types most popular at present (fixed platforms, HF radars, FerryBox systems and gliders) are showing way in this process of harmonisation, for others to follow.

Multiplatform approach

The complexity of coastal ecosystems, the number of KSCs and associated variables to be observed makes two things especially important for coastal observing systems. First, there is no single platform that can be used to collect data optimally, but an integrated and coordinated multiplatform approach is needed for most KSCs. Second, data from almost any platform or variable can be used for various purposes, and therefore practically each platform deployed should be instrumented for multipurpose surveys as much as possible. This is nicely illustrated in Figures 9 and 10.

Going further along the same path, coupling of observational data with traditional monitoring data (with research vessel based manual sampling at low frequency and analysis of samples in laboratory) may be required for some KSCs, to combine spatiotemporal coverage obtained from observations with deep insight from laboratory analyses. Furthermore, coupling observations with experimental work, modelling or remote sensing may be needed to provide in-depth analysis of some KSCs.

The multiplatform approach and its connections to other ways of collecting information on functioning of coastal ecosystems require efficient coordination. This is in essence why JERICO-RI is needed, to coordinate pan-European multiplatform coastal observations and linking the observations (physical platforms, data and products) with other actors and users. This is required to make consistent multiplatform observations across European seas feasible and requires careful design and planning of the structure of regional platforms.

Another complication for multiplatform observing systems arises as there are hardly any national institutes, or even regions, that can perform such operations alone. Multiplatform operations that efficiently tackle KSCs would require transintitutional and transnational collaborations. The results from the questionnaire (Section 2.2) already provides information that some seeds for these cross-border operations exist, but they are often driven by bi-lateral interests, not by pan-European incentives.

The multi-platform approach will require further strengthening the collaboration within the regions (as is the aim in J-S3 WP3 and WP4), especially to improve the coordination and harmonisation between physical, biogeochemical, biological and meteorological types of observations (as also emphasised by national representatives in the questionnaire, Section 2.2). This requires efforts within the JERICO consortium (between partners/nations), but also with different stakeholders at national and regional levels.

Multi-platform approach for optimal spatial and temporal resolution

JERICO-RI aims to generate long (semi-) continuous time series that serve three purposes:

- To provide high resolution data for research on processes acting at several time scales, ranging from very small (seconds) to multiple years,
- To detect long term trends and,
- To provide (near) real-time data for various users and to allow detection and response to (extreme) events

This means that observations should be continued in the same way for many years in the same locations or trajectories to allow for detection of long term trends and analysis of causes of interannual variability, for example due to NAO oscillations or climate change impacts. A high temporal resolution is required to reduce biases due to undersampling, where observations are not representative of the range of variability in time. The choice of temporal resolution will depend on the variable, the research question and type of technology that is available for observing the variable. The use of coastal observations to detect and to respond to extreme events does not only pose challenges to the temporal resolution of observations but also to the timely availability of the data to the users.

JERICO-RI observations should allow the analysis of coastal processes at a European scale. To be representative at a European scale a sufficient number of JERICO-RI platforms, with appropriate capacities, should be available in each European Sea basin. Results from different (fixed and moving) platforms in the same area will be combined through JERICO-RI to get a good understanding of gradients and connections between sub-areas (PSS approach). For some KSCs it is also vital that observations are not only made at the surface, but also vertical profiles and/or observations near the bottom.

Often environmental RIs are designed to include a range of platforms with different observational capacities. Depending on the KSC and users of data, we may differentiate at least three levels of observations. Some data does not need to be measured at the highest quality level and/or adjacent to all other environmental data, and often the users are more local or regional. In J-S3 WP4 we named such observatories as “Standard observatories''. The second level, “Advanced observatory”, provides comprehensive and top-level measurements in specific scientific areas or services. They already may provide a good network of certain types of platforms or for certain KSC. On the third level, “Supersites” are highly instrumented sites with coordinated multiplatform capacity to address various KSC simultaneously, adapt to new challenges, and to connect with other RIs. More details of such structuration is given in J-S3 D4.1.

A network of JERICO-RI Supersites, Advanced sites and Standard sites, with clearly different levels of observation capacities and requirements for coordination, could provide a framework on how to structure the regional observations and how to connect to other observing communities. Whether the Supersite concept is feasible for coastal observations and how it needs to be developed, will be analysed after the report of JERICO-S3 Pilot Supersites is available in spring 2023, feeding to the later stages of JERICO-RI technical design (J-DS T2.2 and 2.3).

4.3 Quality of coastal observations and FAIR data

For all variables and platforms included in JERICO-RI, we aim to provide observing capabilities at a mature level in terms of Technology Readiness Levels (TRL; i.e., levels 7-9 in the nomenclature of the Global Ocean Observing System (GOOS)).

In JERICO-RI, methods for observation, calibration, quality control and data sharing should be harmonised between platforms, within regional sea basins and across Europe. This will ensure that all data from JERICO-RI are of high quality, coherent and interoperable so they can be used for ecosystem analysis at the scale of regional seas and Europe. Despite the need for harmonisation, JERICO-RI also needs to have innovative components, facilitating development of new technologies and methods.

JERICO-RI, with top-level observations, will be among leading actors in method development, in creation of best practices and in calibrations and validation of new and existing sensors. These will provide comprehensive FAIR datasets that enable analysis of interactions between different physical, chemical and biological variables, to meet scientific and societal needs. The JERICO-RI sites will also facilitate collaborations with industry and other RIs.

Preferably the platforms are also shared with other research consortia working on for example atmospheric observations, to optimise the integrated analysis of water-atmosphere interactions and climate change effects. Observations and methods/best practices should be shared across RIs and other stakeholders, so that observations are comparable between different environments and links between variables and the environment can be analysed.

Data from JERICO-RI observation platforms will be made available timely (to allow for early warning) and with the required metadata and quality assurance, through appropriate European data infrastructures, such as EMODnet. For novel sensor data this means that agreements need to be made for sharing the data in a suitable way.

4.5 Recommendations and next steps

Based on the results of the questionnaire and the outlook synthesis provided in the sections 4.1-4.3, we provide below some main conclusions for JERICO-RI technology outlook, structured along MacKinsey 7S model axis.

As a next step, the technology design will continue in analysing the technology design gaps (D2.2) and finally will draw a roadmap how JERICO-RI could reach well-coordinated and integrated technical design of coastal observations.

Strategy: The added value of having JERICO-RI as a pan-European coastal observation system, not just a network of observatories, needs to be crystallised and discussed in national RI forums. Once the need for pan-European coastal RI is foreseen nationally, countries need to be proactive, including also their preferences and plans for JERICO-RI from technology perspectives, in their national strategies and processes, if not already present. This needs to be also reflected in the national funding schemes.

JERICO-RI integrated coastal observing strategies using various technologies needs to be steered transnationally. At the same time, we need to guarantee there is flexibility for regionally and nationally steered observations within JERICO-RI platforms, using regionally appropriate technologies, to serve various local users and streamlined with national priorities. The observations not requiring transnational coordination at all, and of local interest only, should not be included in JERICO-RI.

Most countries indicated the need for improving technical coordination of coastal observations at various KSCs. As the coordination needs will vary within the nested spatial scales (national, regional, between regions, European), a method for a nested coordination solution needs to be found (no one-size-fit-for-all solution available). JERICO-RI needs to come up with proposals for such coordination.

There is a clear need for technological coordination between various marine RIs and other initiatives. The role of JERICO-RI in this technical coordination needs to be clarified and strengthened. It would help, if clear guidelines exist how observations are endorsed as JERICO-RI compatible (referring e.g. to observation quality requirements which may be defined as a part of JERICO label).

Systems: JERICO-RI requires an agreement about what national coastal observing components (platforms and variables) are presently included and what are the developments foreseen in the 5-10 years perspective. This selection must reflect the Key Scientific Challenges JERICO-RI is tackling, the key services and products JERICO-RI aims for, but also how various coastal observing components are governed by other RIs in some countries.

JERICO-RI should coordinate long-term coastal multiplatform observations using consistent technologies and provide technology support to secure cost-efficiency and interoperability. In addition, JERICO-RI needs to include novel types of observations as new coastal challenges will emerge and new technologies are developed. The ability to adopt new technologies should be reflected in the structure of the JERICO-RI organisation across the board.

According to the questionnaire, countries agree that there is a strong need for coordinated actions to share technologies and to create interoperable observations. This should not however compromise the need to provide regional services and products that might be based on region-specific requirements.

Dynamic service models and technology components need to be designed and implemented for JERICO-RI, allowing the dynamic adjustment of multiplatform observations to meet the needs of specific user communities, but without compromising the requirements of sustaining long-term data.

Structure: JERICO-RI needs to include supporting structures for technologies (for calibration, validation, best practices, test-beds, etc.) so that partners can collaboratively and cost-efficiently reach and maintain high quality coastal observations.

Well-established and strategically-planned collaborations and partnerships with the private sector and academia would improve the ability of JERICO-RI to participate in the development of marine observation technologies.

While making decisions on the technical structure of JERICO-RI, national priorities in KSCs and their evolution needs to be followed closely. The specific key areas where JERICO-RI could provide the highest added pan-European value need to be identified and technical observation structures must be specifically selected to support those topics.

Selected technologies need to be available and usable across partnership and mutually supported. Mechanisms for transnational technology support need to be in place in JERICO-RI.

Staff and skills: JERICO-RI needs to provide transnational training schemes for technical personnel to transfer the knowledge in the partnership, keep up the high competence of personnel and to improve the attractiveness of marine studies. An RI, despite being heavily invested in and equipped, can be rendered useless without trained personnel. Provision of technology training as a service to non-partners needs to be considered.

JERICO-RI needs to identify its gaps in technology competence, caused by lower technical capacities among some countries, regions or KSCs, and have specific mechanisms to help in solving these problems. Among potential solutions, sharing technical personnel and providing centralised actions may be considered.

1. Annexes and references

Questionnaire filled out by national representatives:

	Important information for filling out the questionnaire			
	This questionnaire is to fulfill the requirements laid out in **Task 2.1. Technical and technology outlook for coastal observatories**. The main deliverable of this task is a "Technical and technology outlook" (D2.1), which will provide perspectives on how the future fit-for-purpose JERICO-RI should look like from hardware and engineering point-of-view. This will feed into the gap analysis (T2.2) and the roadmap for the technical design of the JERICO RI (T2.3). NB! This questionnaire deals with the **technical and technological aspect of the JERICO infrastructure**, meaning the physical observation infrastructure (ie. platforms, ships, instruments and sensors)			
	This questionnaire is to be filled out by national representative, who should contact the relevant institutions/agencies within their country where needed. It has a combination of free-form answers and multiple-choice questions (structured by Key Scientific Questions - KSC). For questions on **current JERICO infrastructure**, answers should focus on the existing JERICO observation infrastructure and activities within the country/region. For questions regarding **future JERICO infrastructure** (e.g. in 5/10 yrs), answers should focus on the desired national coastal infrastructure as foreseen as part of a pan-european JERICO ERIC.			
Question ID		Type of answer	Info box content	Example answer that we are seeking
	GENERAL/INTRODUCTORY QUESTIONS			
1	Which institutions and infrastructures in your country are currently part of the JERICO infrastructure?	free form	List the most important platform types in the national JERICO infrastructure (do NOT give a full list of all platforms). If these are not clear in your country, explain it in your answer.	JERICO: FerryBoxes, Fixed platforms (xx institutions);
2	**Which key institutions and infrastructures in your country are not currently part of JERICO, but would be relevant**	free form	List the key national institutions and platforms that would be relevant to	non-JERICO: gliders, Argos, AUVs, cabled observatories (xx institutions.)

	to include in a future JERICO infrastructure (e.g. 5-10 yrs)?		include in the future JERICO ERIC	
3	Who was contacted for this questionnaire (institutions/entities) and/or list the documents that were used to collect relevant information?	free form	State the people interviewed and affiliations (e.g. research institutions, stakeholders, ministries, funding agencies) or the documents used as sources	XX and XX research institutions (part of JERICO), national research council, ministry of climate and environment. National strategy document for infrastructures
	STRATEGY: which national actions are under implementation, planned or needed, so that the technical/technological aspects of the national JERICO infrastructure are compatible with the JERICO science strategy			
4	**Is there an existing infrastructure funded by the country (e.g. research council/ministries) that is part of the current JERICO infrastructure? If so, what is the time scale of the current funding?**	free form	If relevant, describe the national infrastructures (planned or implemented), funding scheme and timescale of funding	There is a national infrastructure on FerryBoxes, funded by the national research council until 2025
5	Which national or regional strategic documents or initiatives (e.g. directives, national strategies, conventions, roadmaps, UN SDGs) are relevant for the technical part of the national JERICO infrastructure (both existing and currently under development)?	free form answer	List key national and regional strategic documents or initiatives, even if they are overlapping . Focus should be on the relevant national strategic documents- Please provide links if possible.	There is a national roadmap for research infrastructures, where the national node of JERICO is included (link). There is also a relevant white paper on ocean management and monitoring that includes a strategy for coastal infrastructures (link).
6	**Are JERICO partners involved in designing or implementing these national/regional strategies?**	free form answer	List national JERICO partners involved, or write none if not applicable	Yes, XX institution involved with national WFD-monitoring, while no relevant national strategy

7	Is there any form of existing coordination of the technical part of the national JERICO infrastructure? If so, please specify. (if no, move to Q8)	free form answer	Is there a national JERICO steering committee/coordination body or any form of agreement between national partners? If there are more than one JERICO partner in your country, describe how they are related, how their observation and monitoring activities are coordinated, and what is their role in current national monitoring strategy and operations.	Yes, there is a general assembly/MoU/agreement. No national coordination, everyone does as they please.
8	If there is national coordination of the technical part of the JERICO observation infrastructure, please indicate to what degree this applies to the individual KSCs	KSC answer table	For each individual KSC, indicate to which degree (low-high) the national observations are coordinated between partners/platforms	
9	Is there a need to improve technical integration and coordination of observations in your country for the future JERICO infrastructure (5/10 yrs) and how that could be best achieved?	free form answer	The answer should focus on technical aspects of the infrastructures (i.e. the physical infrastructures and hardware, including sensor/measurement operation and maintenance).	yes, there is a need to improve coordination on biological sensors (e.g. intercomparisons), while physical sensors are regularly intercalibrated between national institutions
10	Are there specific needs for technical coordination at the local, national or regional scale? Both at the present and for the future JERICO infrastructure?	free form answer	Define solutions for each scale using previous question as reference.	For example workshops/MOUs between different nations sharing regional sea etc
11	To what degree are there synergies between the national JERICO infrastructure and other European ocean observing efforts (e.g., EuroGOOS, ERICs, etc.) in your country?	KSC answer table and free form answer	Focus on the technical part of the infrastructure and answer for the infrastructure as a whole and on the individual KSC level. Describe synergies with other european observation efforts (EuroGOOS, NOOS) and/or ERICS: https://ec.europa.eu/info/research-and-innovation/strate	For my country there are inorganic carbon observations made both by the national JERICO infrastructure and ICOS-OTC

			gy/strategy-2020-2024/our-digital-future/european-research-infrastructures/eric/eric-landscape_en	
12	How could synergies between national JERICO infrastructure and other european observing efforts (e.g. EuroGOOS, ERICs) be further developed and optimised in your country, especially considering the future JERICO infrastructure?	free form answer	The answer should focus on technical aspects of the infrastructures (i.e. the physical infrastructures and hardware, including sensor/measurement operation and maintenance).	there could be regular inter-calibrations between overlapping inorganic carbon observations made by JERICO and ICOS. there could be a representative for the national JERICO infratsructure in the relevant NOOS.
13	To what extent is the current national JERICO observation infrastructure able to meet requirements of modelling (incl operational forecasting) and remote sensing? What can be done to improve on these individual aspects?	free form answer	Answer for the infrastructure as a whole and include aspects relevant for both modelling and remote sensing.	In my country, currently the national met office is assimilating near real-time observations of SST/SSS for the operational physical ocean forecasting model., in the future steps should be taken to include Chla observations as well. There are also regular observation of optical properties that could be used for satellite validation, but funding needs to be secured before it can be routinely used.
	SYSTEMS: how is the technology (platforms, sensors) organised and implemented to meet the JERICO science strategy			
14	How important is it for observing platforms and sensors to share common technologies and be interoperable with respect to KSCs? Indicate if it is important on EU level or only on national or regional level.	KSC answer table and free form	Interoperability and harmonization of observation platforms might be much more relevant for certain KSCs/variables than others, please include specifics.	A one-type-fits-all platform+sensor is good enough. Or, specific platforms and/or sensors are required in order to understand the system.

		answer.		
15	What are the key longterm (5-10 years) goals for platform and sensor developments in your country?	free form answer	Try to cover goals of all relevant organizations in your country. Indicate the status of the goals; is a goal so far only an intention or has it been included in concrete action plans? Imagine an optimal coastal observation system within 5-10 years while answering this.	no national JERICO infratsructure funded, or application sent by XX institutions to funding agency/ministries to secure funding for next xx years.
16	To what degree are currently available sensor technologies being optimally utilized by the national JERICO infrastructure? What can be done to improve?	free form answer	Try to estimate the technological readiness level (TRL) for key observations observations related to KSCs Essential Ocean Variables (cf: https://www.goosocean.org/index.php?option=com_content&view=article&layout=edit&id=283&Itemid=441).	for SST the underway observations are fairly advanced (TRL 8), while for underway measurements of nutrients we are at the technology development state (TRL 4)
17	Describe any potential ongoing joint national activities in maintaining and operating national JERICO observations, and what could be done to improve national coordination?	free form answer	Try to cover activities on all fronts. E.g. technical maintenance, data management, planning of improvements etc.	there are joint national JERICO meeting between the institutions involved, including arranging meeting with relevant ministries/agencies. Currently no regular intercalibrations between institutions
18	Do you have national (or transnational) mulltiplatform approaches for some variables? If yes, please list the measured variables and explain why these have been selected.	free form answer	Multiplatform is defined as making consistent observations with several different platforms, in a coordinated manner.	For example, measuring oxygen using profiling buoys and gliders, with comparable methods and co-planning the missions, data management and data use

19	In the coastal waters of your country, which variables should be measured using JERICO-RI multiplatform approach in the future? What types of transnational/transinstitutional collaborations could be used in these activities?	free form answer	Using the same definition as above, focus on the most important questions to be adressed by this approach in your country/region	For example: phytoplankton blooms studied by transnational fleet of FerryBox systems and buoys, sharing various parts of data value chain (e.g. calibration/validation/QC, data base/data use...)
20	Which are the key new technologies which are being used/under implementation in the national JERICO infrastructure, and what are or have been the main barriers for implementation?	free form answer	Are there any current/previous barriers (political/legal/etc) in implementing emerging technologies? Are the institutions responsible for national monitoring infrastructure ready to change their management and maintenance practices when shifting from national network to ERIC?	e.g. relevant technological compecence missing in research institutions, no coordination between national research institutions
21	How is the transfer and implementation of new technologies and methods between research institutions and environmental management organized in your country?	free form answer	in your country, who decides what technologies are implemented? is it only researchers, or does the policy bodies have certain requirements (e.g. remote sensing, microplastics etc)	e.g. only research institutions involved with technology implementation, strong national coordination etc
	STRUCTURE: what are the focus areas of national observations. How are the observations and the supporting actions technically coordinated and implemented			
22	To what degree are intercalibrations, validations, best practices and audits used to improve the excellence in system maintenance and operations within national JERICO infrastructure relative to each KSC?	KSC answer table and free form answer.	List relevant actions/processes on the whole infrastructure level, and on the individual KSC level	
23	**Describe the current national and regional technical support**	free form	Technical support structures include e.g.: calibration labs, repair/maintenance	

	structures and to what degree they are incorporated into the national JERICO infrastructure?	answer	facilities/groups, technical advice/know-how about platform/sensor deployments	
24	To what degree is the private sector (e.g. SME's) involved in technology development, implementation, and service? What are the barriers to improve involvement of the private sector in the future?	free form answer	focus on involvement of private sector (e.g. Small and Medium Enterprises (SMEs))	e.g. private company devleopping new sensor/observation technology included in relevant infrastructure development
25	What are the three most important KSCs for your country (or regional seas), both at present and in 10 years?	free form answer	List the most relevant KSC (see table for example) for your country or regional seas	e.g. my countries coastal waters the most improtant are: "Land-Ocean continuum", "Biodiversity trends", and "Long term observations to resolve climate change impacts"
26	Which of the national and/or regional coastal observations are most important for the added-value of the pan-european JERICO infrastructure?	free form answer	List those local observations which you think would bring the greatest added value for all JERICO users when they are integrated into JERICO-RI. You can use KSC categories to group observations.	e.g. in my national coastal waters we have exstensive observations of inorganic carbon, which will be of great importance in determining ocean acidification status and impacts in europe.
27	Which part of the national infrastructure would benefit most from trans-institutional/national collaborations in technical support?	free form answer	This question is about technical operations of observations/platforms.	e.g. sensor development of BGC/biological sensors
	STAFF/SKILLS: Human resources and competences available for the observation infrastructure			
28	To what degree is the technical competence of personnel sufficient to address JERICO observations of KSCs in your country?	KSC answer table and free form answer	This question is about technical operations of observations/platforms.	e.g. in my country we lack competence of HF radars and physical modelling that would be imprtant to increase knowledge on "Connectivity and transport pathways of water masses and materials"

29	Is there a difference between the current and the foreseen technical competence needs in 10 yrs, and what are the plans to fill this gap?	free form answer	Describe what is needed and actions taken to develop from the current national JERICO infrastructure to that that is foreseen as part of a pan-european JERICO ERIC.	e.g. there is a need to build competence in XX platforms and sensors
30	What is the best way to organize/fund training courses for scientists and what other organizations can contribute? E.g., JERICO-led, country-led, region-led?	free form answer	Describe what would be the optimal way to fund training activities	e.g. training courses in sensor calibrations/validations led to JERICO in cooperation with selected JERICO institues with excellence in this area
31	Describe the ongoing national coastal observation operations where staff and skills are supported by other countries.	free form answer	This question is about technical operations of observations/platforms.	e.g. part of national JERICO infrastructure where staff is supported by a regional initiative
32	For the future JERICO infrastructure (5-10 yrs), would your country prefer that some technical services (for ex calibrations, intercomparisons) were shared between JERICO partners or provided by designated partners/technology centers?	free form answer	Describe any preferences for technical services in the future JERICO infrastructure	e.g. my country lacks expertise in calibration of BGC sensors, and would prefer that there was a technology centre in the future JERICO infrastructure that could provide training/expertise
	ADDITIONAL INPUT NOT COVERED BY QUESTIONNAIRE			
	Here any additional relevant input can be collected (e.g., topics that are important that are not covered by KSCs, links to J-S3 PSS/IRS, etc.)			