TECHERA

"A new technology era in the Adriatic Sea – Big data sharing and analytics for a circular sea economy"

D3.2.3 Flagship paper on data-driven solutions for sea economy

30/06/2023

Deliverable Number D.3.2.3
Final version

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Project Acronym	TECHERA
Project ID Number	10417714
Project Title	A new technology era in the Adriatic Sea – Big data sharing and analytics for a circular sea economy
Priority Axis	Blue innovation
Specific objective	1.1 - Enhance the framework conditions for innovation in the relevant sectors of the blue economy within the cooperation area
Work Package Number	3
Work Package Title	Clustering thematic activities
Activity Number	3.2
Activity Title	Contributions to the next programming period
Partner in Charge	LP-UNIBO
Partners involved	Luca De Marchi, Alessia Cariani, Luca Mulazzani, Alice Ferrari, Alberto Ceccacci (UNIBO) Igor Celic, Simone Libralato (OGS) All PPs
Status	Final
Distribution	Public

Partnership:

Executive summary

This deliverable contains a paper to be published in an international journal about data-driven and technological solutions used to tackle issues within the main sectors of the blue economy, focusing on circular economy and low carbon emissions and in connection with EUSAIR flagship.
The paper is developed and prepared for the submission to an international scientific Journal.

TECHERA Flagship paper: A new technology era in the Adriatic Sea – Big data sharing and analytics for a circular sea economy

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KEY-WORDS: blue economy; data-driven solutions; ICT tools; technology; fisheries; aquaculture.

ABSTRACT

Modern livelihoods related to fishery and aquaculture sectors (Blue Sectors) are deeply rooted in the Adriatic coastal communities, the latter representing silent sentries cherishing traditional practices and knowledge. However, current environmental and socio-economic scenarios are often not compliant with an effective, real-time management of the marine resources, especially considering all the stochastically- and human-induced factors influencing the distribution and abundance of marine species.

Despite National governments and International organisations' effort in implementing important regulatory measures, many stocks are not recovering as expected, thus requiring the maximisation of regional cooperation among Adriatic countries to mitigate the emerging threats insisting on shared renewable resources and the value chains of seafood products across the Basin.

This effort implies the complete integration of two main components, the Hydrosphere and the Infosphere, resulting in the data-sharing among a widespread stage of policy makers, scientists, and the communities themselves according to simple and ready-to-use information.

Furthermore, knowing the cross-border obstacles that need to be solved and the available innovative technologies for tackling such challenges will help to identify gaps and most functional solutions that will improve the understanding and management of Blue Sectors.

Introduction

The blue sectors of fisheries and aquaculture in the Adriatic Sea are of great relevance for the coastal communities of the basin. However, the state of fisheries and aquaculture in the Adriatic Sea reflects a complex interplay of environmental factors, economic interests, and regulatory measures.

Rising sea temperatures, altered ocean currents, and increased ocean acidification are all factors that can influence the distribution and abundance of marine species in the future (Hidalgo et al., 2018). Yet, these changes are already influencing marine communities by facilitating invasion by new invasive species that can change structure and functioning of the Adriatic Sea ecosystem. These changes can disrupt traditional fishing patterns and affect the productivity of aquaculture operations.

In response to these challenges, both National governments and International organisations have implemented various regulatory measures. These include setting catch limits, establishing marine protected areas, and promoting sustainable fishing practices. The European Union plays a significant role in regulating fisheries in the Adriatic through the Common Fisheries Policy (CFP; European Commission 2016), which seeks to ensure the sustainable management of fish stocks. However, although in the last years an improving trend is identifiable from stock assessments (FAO, 2022) still many stocks are not recovering.

While challenges persist in the wild fisheries sector, aquaculture has been growing steadily in the Adriatic region. Aquaculture offers the potential to mitigate pressure on wild fish stocks and provide a sustainable source of seafood. Commonly farmed species in the region include seabream (*Sparus aurata* L.), seabass (*Dicentrarchus labrax* L.), mussels (*Mytilus galloprovincialis* Lamarck, 1819), Japanese carpet shell (*Ruditapes philippinarum* A. Adams & Reeve, 1850), European flat oyster (*Ostrea edulis* L.) and Pacific cupped oyster (*Magallana gigas* Thunberg, 1793). Innovations in aquaculture technology, such as offshore farming and recirculating aquaculture systems, are however, necessary to further develop this industry and compete with other countries' production. Thus, while challenges like overfishing and pollution persist, there is also potential for sustainable growth in the aquaculture sector and for increasing economic efficiency of fisheries. While in general, efforts to promote responsible fishing practices, protect critical habitats, and adapt to a changing climate are essential to ensure the long-term health and productivity of the Adriatic Sea's marine ecosystems, these might take advantage of data driven solutions and new technologies.

Regional cooperation and collaboration among Adriatic countries are crucial for addressing common challenges in these sectors because of i) the shared nature of renewable resources within the basin and ii) the interplay of the seafood value chains in the countries bordering the basin. Initiatives like the Adriatic-Ionian Macroregion and various scientific research projects aim to foster cooperation, share data, and develop sustainable management strategies for the sea's resources.

This work, therefore, aims at synthesising data-driven solutions for the sea economy, especially focusing on the aquaculture and fishery sectors. The approach starts with the identification of cross-border obstacles to be solved and the potential new tools for tackling such challenges. Identifying gaps and most functional solutions, is here used to set the priorities for the next programming period.

Key aspects for a green and digital transition in the Adriatic Sea

All policy frameworks of the EU see green and digital transition as key aspects for a sustainable and competitive development of the continent. The same approach is identified for the Adriatic region. In particular, the Italy-Croatia Interreg program 2021-2027 will consider two cross-cutting issues that are seen as aspects of great relevance by the EU: circular economy and digitalization. This is in compliance with new 2021-2027 EU priorities on green and digital transition. Both innovation patterns (circular economy and digitalization) are based on, and need of, large amounts of data. In turn, these approaches will allow to achieve thematic objectives such as sustainable fisheries, healthy marine ecosystems and, finally, will open the doors to new possibilities for blue careers.

In order to maintain these expectations, a synergy between *Hydrosphere* and *Infosphere* is required. Hydrosphere still represents a non-well known environment of dynamic interactions between natural and human components. Infosphere is needed to fill these gaps, but information is still not adequately collected and stored. Even when collected, information is not easily available and usable. Sources of information and results should be planned to be interoperable. It is needed that tools such as web apps and shared platforms be able to interact using shared data mutually.

Figure 1: A visual representation of the interplay between infosphere and hydrosphere for improving understanding and management of Blue Sectors.

A good example of this has been obtained in TECHERA project when, in the area of Trieste, the drone developed by Sushi Drop project collected data on a marine relict, platform used by Fair Sea project stored data, and the tools developed by Adrireef permitted to display the results.

Ideally, as recently reported by the Joint Research Center of the European Union, the green and digital transitions reinforce each other. Digital Twins, in particular, are virtual counterparts of the real world, which could model, among others, sea traffic or fishing activities, in order to optimise them, reduce emissions, balance the trade-offs and guarantee sustainable economies. However, sometimes the two transitions can also clash, since digitalisation uses electricity, and many digital technologies are resource-intensive. Both also have costs that are necessary to attribute either to the collectivity, since new management tools provide benefits to the citizens, or to the private agents that are considered in charge of a more efficient and responsible use of resources. A reflection on property rights should be necessary.

To make the most out of the twin transition, proactive and integrative management will be needed. Theoretically, the digital transition will be spearheaded mainly by the private sector due to its huge economic potential. However small firms (e.g., artisanal fleets) can experience difficulties to understand, accept and finally pay for innovation. Digital divide is one of the main reasons for slow diffusion of technological innovations. Conservative behaviours are normally found among old and less educated entrepreneurs. On the other hand, to harness the benefits of innovation for greening and to limit its harmful effects, state and civil society engagement is necessary. Actually, in the management of common resources, as is the case of fish stocks, environmental, social and economic objectives should coincide. However, the optimal solutions of each of these objectives do not coincide and are not synchronised. In order to obtain long-run benefits for both the environment and the fishers, fishers have to sacrifice some of their short-run income. Time preferences of agents should be considered even in the case the biological system of the sea would be perfectly known and forecasting models would be perfect to foresee the future flow of catches and revenues. Unfortunately, we are far from this ideal situation. Forecasting tools, in the case of fisheries, are far from being perfect and fishers normally do not trust them. More data and more analyses are necessary to understand the role of factors that are not currently considered in prediction models, such as the role of water temperatures, the interactions with alien species and the supply of nutrients from rivers.

This is particularly true for the Adriatic Sea. Current models have gaps to explain why, after years of fishing effort reduction, fish stocks have not yet recovered. Without a clear understanding of this, which necessitates the collaboration of all countries around the sea basins, it would be difficult to gain the trust of fishers.

A quantitative approach based on analysis of issue/solutions

Inspired by several published reviews and synthesis (Drakopulos et al., 2022; Gladju et al., 2022) we identified first a series of issues in fisheries and aquaculture (Table 1 and Table 2) and crossed them with a series of possible solutions (Table 3) that could be used to search into different informative datasets. Discussion among experts allowed detailing issues and solutions as key-areas for investigating current gaps, well-developed areas of investigation and possible new avenues for future research and projects.

Relevant issues within the fisheries sector were identified within seven main areas of intervention such as 1) improving stock sustainability, 2) optimization of fishing, 3) reduction of Environmental and habitat impacts, 4) improve carbon footprint, 5) improve selectivity, 6) increase the value of products and 7) reducing costs of production (Table 1). Within these areas specific objectives that might require intervention for improving the sustainability of fisheries were identified. A total of 37 possible objectives of intervention were identified for fisheries (O1-O36).

For aquaculture five main areas were identified as 1) optimization of management, 2) optimization of production, 3) monitor and control production, 4) valuing products, 5) reducing costs (Table 2). The inspection of these areas permitted to identify a total of 23 objectives of intervention (O37-O59) that might be considered useful objectives for improving the sustainability of the aquaculture sector. It is worth noting that the post-harvesting objectives are common between fisheries (O30-O37) and aquaculture (O52-O59) sectors, although were considered separated.

Additionally, a series of data-driven approaches that might be used as possible solutions were identified (S1-S15). These solutions aim at a) collecting more data for improving knowledge; b) processing the data for better results and management solutions; c) informing systems to share, communicate or distribute the results obtained (see Table 3).

For each objective (O1-O59) and each solution (S1-S15) were defined a set of searching keywords (Supplementary materials) to be used for seeking comprehensive sources in order to provide an organised roadmap for synthesis and reviews.

Table 1. Specific objectives tackled to solve issues within different sub-sectors of the fisheries sector.

Sector	subsector	Issue	Objective	
Fisheries applications	***Management***	*Stock sustainability*	accurate assessment of fish diversity	**O1**
			accurate assessment of fish abundance	**O2**
			accurate assessment of fish distribution	**O3**
			estimation of age	**O4**
			estimation of size	**O5**
			estimation of growth	**O6**
			estimation of recruitment	**O7**
			estimation of other biological aspects	**O8**
	Inputs and services for production	*Optimization of fishing*	identifying fishing zones*	**O9**
			enforcement of fishing regulations	**O10**
			Monitoring fishing vessel movement	**O11**
			Monitoring fishing gear use	**O12**
			Monitoring fishing catch	**O13**
			best fishing grounds*	**O14**
		Environmental and habitat impacts	Monitoring of primary production	**O15**
			Risks of harmful alfal blooms	**O16**
			pollution risks	**O17**
			environmental monitoring	**O18**
			reducing gear impact on sea bottom	**O19**
	Production	*Improve carbon footprint*	improve lightening systems	**O20**
			improve catchability	**O21**
			increasing energetic efficiency and sustainability of marine operations	**O22**
			ICT systems applied to navigation and fishing	**O23**
			reduction costs	**O24**
		Improve selectivity	deterrents or escaping devices	**O25**
			auxiliary tools for fishing	**O26**
			mode of use of fishing gear	**O27**
			improving selectivity	**O28**
			systems for improving quality onboard	**O29**
	Transformation of product	*Valuing products*	tools for transformation of seafood	**O30**
			packaging and conservation	**O31**
			development new products	**O32**
			certifications and labelling	**O33**

			systems for improving quality on land	**O34**
	Distribution and consumption	*Reducing costs*	transport, logistic and cold chain	**O35**
			ICT systems applied to transformation and marketing	**O36**
			Circularity	**O37**

Table 2. Specific objectives tackled to solve issues within different sub-sectors of aquaculture sector.

Sector	**subsector**	**Issue**	**Objective**	
Aquaculture applications	***Management***	optimization of management	farm activity production planning	**O38**
			farm optimal placing	**O39**
	Inputs and services for production	optimization of production	farm activity tracking	**O40**
			automatic fish processing	**O41**
			forecast disease outbreak	**O42**
			anomaly detection in water quality	**O43**
			real time monitoring and remote control	**O44**
			automated operation and maintenance of cages	**O45**
	Production	*monitor and control production*	monitor and control feeding rate	**O46**
			monitor and control water quality	**O47**
			monitor fish growth	**O48**
			monitor fish biomass	**O49**
			monitor fish behavior	**O50**
			control of input water and tratment	**O51**
	Transformation of product	*Valuing products*	tools for transformation of seafood	**O52**
			packaging and conservation	**O53**
			development new products	**O54**
			certifications and labelling	**O55**
			systems for improving quality on land	**O56**
	Distribution and consumption	*Reducing costs*	transport, logistic and cold chain	**O57**
			ICT systems applied to transformation and marketing	**O58**
			Circularity	**O59**

Table 3. Specific data-driven and technological solutions, approaches and data to be used to solve issues.

Areas of intervention	**Solutions**	
data collections	satellites	s1
	information centres	s2
	portable devices	s3
	environmental buoys	s4
	sensor networks	s5
	internet of things	s6
	underwater drones and camera	s7
	data on catches	s8
	automatic vessel identification system	s9
	genetic data	s10
	market data	s11
	collecting web data (e.g., on consumers)	s12
data processing	data processing	s13
Informing systems	web/mobile applications	s14
	databases and platforms	s15

Results

The search strings for objectives of search for issues for the aquaculture sector (O38-O59) were crossed with the search strings for the solutions foreseen (S1-S15) and the resulting searching strings were used to search reiteratively in the Pubmed database. Results of the multiple searches are synthetically reported in Figure 2 in which are highlighted the elements that are completely absent from the literature (NA values), or only considered in a very few works (red graded cells) as well as areas where there is abundant literature (blue graded cells).

For instance, satellites are used quite extensively in aquaculture analyses for a very broad scope of issues and are especially used in works related to optimal placing of fish farming and planning (column S1 Table 1, more than 4000 published works each).

Other areas where there seems to be very mature research because of very large number of scientific works (>4000) are the use of data on catches to control the feeding rate, the water quality and the quality on land (column S8 crossing rows O46, O47 and O56), as well as general data processing tools for monitoring fish growth and circularity (column S13 crossing O48 and O59 in Figure 2).

Conversely, information centres, genetic data and market data (S2, S10 and S11, respectively) as tools or solutions were showing a low number of scientific works across all sectors and objectives, highlighting large space for improvement and use of such technologies and facilities in the aquaculture sector. Similarly, web and mobile apps (S14) have a medium low number of applications (for many sectors ,100) highlighting the quite recent development of such approaches and possible potential for their expansion.

Surprisingly, certification and labelling appear to be connected mainly to involvement of stakeholders and consumers surveys, leaving great spaces for integrating this objective with several data-driven tools that were identified with S1-S15. It is worth noting that enhancing the quality of the product does not follow the pattern, and Figure 2 actually shows that this is an objective that is tackled by several tools and solution approaches. This further leaves the impression that, although great attention and instruments are developed and applied to increase the quality of the products, they are not much exploited in the certification approach.

The lack of apparent research on satellite tools to the real time and automatic processing (O4 and O7), reflects the potential use of local transmission for information on these very delicate issues. It should be noted that, however, “automatic fish processing” might represent a poor or unused wording and this reflects the failure of searching for these terms for all possible solutions (e.g., fourth row is completely “NA”).

Figure 2: **Results of the search in the scientific literature for the objectives of the aquaculture sector crossed with the solutions. Values indicate the number of scientific works (articles, books or proceedings) containing the keywords selected (see searching string in the Supplementary material). Blue popular issue and solution (i.e., trendy solution to issues), red unpopular issue and solution (i.e., potentially areas of future development), NA potential gaps.**

Solutions	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Issues analysed in Aquaculture	satellites	information centres	portable devices	environmental buoys	sensor networks	internet of things	underwater drones and camera	data on catches	automatic vessel identification system	genetic data	market data	collecting web data (e.g., on consumers)	data processing	web/mobile applications	databases and platforms
farm activity production planning	4048	296	1260	582	745	1043	549	NA	562	413	438	NA	NA	496	NA
farm optimal placing	4886	286	1013	654	915	944	791	NA	676	749	311	NA	NA	524	NA
farm activity tracking	1324	62	215	181	396	524	380	2189	324	127	60	2511	NA	125	1506
automatic fish processing	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
forecast disease outbreak	815	60	337	85	286	372	149	1615	92	96	65	3306	NA	209	3847
anomaly detection in water quality	621	32	62	67	70	69	74	871	52	22	17	1558	NA	49	886
real time monitoring and remote control	NA	78	266	371	926	838	538	1830	237	56	62	2442	NA	211	1336
automated operation and maintenance of cages	887	34	183	155	452	494	443	649	128	29	24	1059	NA	109	765
monitor and control feeding rate	1556	123	618	301	517	633	577	4842	250	227	152	NA	NA	264	NA
monitor and control water quality	2522	81	404	509	533	390	534	4992	445	367	52	NA	NA	215	NA
monitor fish growth	63	2	9	12	32	36	36	608	8	36	6	358	4856	17	262
monitor fish biomass	172	7	11	34	19	23	200	1017	63	32	1	665	2564	14	223
monitor fish behavior	107	9	14	43	86	101	231	452	22	10	0	296	2661	17	175
control of input water and tratment	448	41	305	88	138	138	55	651	48	13	57	1968	NA	65	1703
tools for transformation of seafood	2520	134	743	310	932	1160	725	3821	380	287	161	NA	NA	453	NA
packaging and conservation	3450	206	454	335	349	444	611	NA	684	904	233	NA	NA	367	NA
development new products	95	0	29	15	15	30	8	91	3	0	17	224	773	9	87
certifications and labelling	294	52	354	43	132	208	139	876	54	69	103	1859	NA	71	1613
systems for improving quality on land	3034	209	958	429	1154	1393	598	4977	337	223	270	NA	NA	463	NA
transport, logistic and cold chain	918	57	266	173	296	362	170	1666	164	79	100	NA	NA	117	1809
ICT systems applied to transformation and marketing	24	5	46	4	56	99	8	41	9	NA	20	194	313	38	48
Circularity	184	20	100	52	73	133	48	614	34	21	53	904	4565	33	550

Finally, from the reiterated unsupervised analysis of publications, it emerges that there is large space for applications to tackle objectives of circularity and ICT systems applied to transformation and marketing.
These are some of the insights that can be gained from inspection of results of Figure 2. Clearly, values refer to non unique assignment of works to sectors or objectives, yet, each cell value gives indication of the general attention of the tool used (columns) to solve issues (rows). Further analyses might be needed, for instance, by going beyond the static picture of the number of scientific publications, but looking at their trends over time in order to distinguish between recent developments and large classic approaches well used. Looking at trends might also help determine development phases of approaches and solutions, stagnation or slow decrease in use of some approaches. These are further useful aspects to be evaluated in next steps of the approach.

Discussion

Among the main human threats insisting on our *Hydrosphere* (in a more widely accepted sense including environment, economy and society), anthropogenic impacts in very different forms (i.e., pollution, ghost gears, marine litter, overfishing, etc) have gained great attention in recent years in relation to the threat to fish populations, food security, fisher livelihoods, ecosystem integrity and services, and the welfare of entire coastal communities (Lam & Pitcher, 2012). Two important areas of intervention were identified regarding i) the need to improve and exploit better the information and ii) the need to involve more the human capital.

Data driven solutions for the sea economy

The Ocean Economy 2030 report (OECD, 2016) described the Blue Economy as the new economic frontier for growth, employment, and technological advances, basing the responsible and sustainable use of marine resources on data and information (i.e., the Infosphere). How big data might help science-, operational-, policy- and public-end users when applied to sea economy? How to create a contact area between fishery biologists, ecologists, economists, fishermen, stakeholders and Organs or Institutions designated to management Policies?
In a system mainly dominated in the past by trawling and depending on the amount of data collected at different timeframes and spatial scales, the quality and robustness of the information gathered certainly influenced the reliability of the estimations of the efficiency of management strategies (Mora et al., 2009). Data related to traditional fisheries targeting very different marine species that, despite their very different biological traits and reproductive cycles are often treated in batches, refer to distant timeframes, past data-series, and rarely contemporary information. The latter should be transferred continuously and in real time to stakeholders (up to 12 hours) following simple, clear and direct communication strategies aiming at distributing seafood products through systems based on optimised fishing effort and low fuel consumption.
Improvements in prompt data collection calibrated on target species' life traits and characteristics, as well as data on catches and effort should help better describe the dynamics of species and the

effects of fishing pressure. On the other hand, reliable information on the processing of landings and their transfer among all the actors of the fishery sector are mandatory to create effective predictive bio-economic models, taking into account both the concrete needs of producers, end-users and the rules of the marine ecosystem.

The effort required to effectively accomplish this task can be important in terms of costs of research and development, human capital formation and involvement in the economy of data-driven solutions in different sectors (both fishery and aquaculture). Biological blue sectors are always more frequently undermined by stochastic events related to climate change and diseases contributing to productive habitat shifts and establishing new synergies between human activities and biodiversity. For this reason, the desirable and progressive institutional acknowledgement and involvement of fishermen in the continuous, punctual and scientific data collection at the local scale, is fundamental, especially for small-scale and artisanal fishery (Russo et al., 2016), a data-deficient sector that is progressively gaining importance in the Adriatic Sea, in replacement of traditional trawling. Nevertheless, this replacement should be following the Technology Roadmap for big data, accompanied with interoperability, standardisation and institutionalisation of a Communitary bottom-up approach, directly and effectively involving small-scale fishermen in decision-making actions, contributing to the re-alignment between data collection and real-time management.

Examples of good practices can be identified in the aquaculture sector, where cutting edge technology (as smart buoys and artificial intelligence), are currently employed for real time monitoring of multiple data sources, as seawater chemical-physical parameters and meteorological conditions but also biological data as physiological condition of farmed animals and disease early warnings. Adaptive management of aquaculture is based on both real time monitoring and control, as well as on the availability of data time-series for trend analyses and forecasts. Both are even more compelling nowadays, given the highly variable scenarios in the light of climate and social changes, which claim for data that are at the same time open, self-evident and content-clear for all involved operators.

Sharing open data would mean engaging producers, stakeholders, consumers and citizens in general and illustrating the positive benefits of big data for organisational change, efficiency, and transparency, even using social media, websites and newspapers. Furthermore, the development and progressive adoption of technological solutions aiming at smoothing the commercialisation of fishery products (even at the very beginning of the chain of custody, e.g., at quays and docks) would also allow the rise of fishermen’s sensitivity to the data they will personally collect and the rise of their awareness about the link feeding sustainability and the assimilation of their innovative products into the market. In this perspective, the synergy between research and production should be implemented and reinforced in a dual training of both fishery and research operators. Following this direction, increasing initiatives stemming into the Blue Transition of the fishery sector and blooming into the valorisation of ecosystem services are dealing with marine pollution, responsible tourism and transportation. As a matter of fact, beside a variety of political, socio-economic and environmental measures, such as quotas, minimum/maximum catch sizes and spatial and temporal closure of fishing grounds, the optimisation of on-board operations and the use of fuel during seafood carriage and transit, the standardisation of collection, classification and disposal of marine litter, the development of alternative and more selective gears for bycatch mitigation, the minimization of discards and maximisation of the value of landed fish, and the application of electric/hybrid engines to small fishing vessels, represent ultimate and accessible targets for a sustainable, strong and long-term spatial management facing threats currently increasing in intensity and frequency.

In very recent times, cross border cooperation initiatives among neighbouring countries sharing fishery resources (as Interreg Italy-Croatia Projects as ARGOS, PRIZEFISH, CASCADE, INNOVAMARE, MARLESS, FAIRSEA, ITACA just to mention a few) capitalised their efforts on the direct involvement of producers and consumers to become more sensitive to uncertainties related to marine environment using dialogue and very different forms of technology (e.g., cards play, 3D virtual reality, mobile apps or immersive video games).

Among emerging technologies recently applied in the sea-economy sector are graphic realities and immersive situations, which proved their effectiveness for different purposes, both in the scientific field, in studying activities or in prototyping experiences. The databases created can be exploited in various fields, therefore carrying out a simulation of various situations which can be diving, underwater reconstructions of the seabed, renderings based on marine species inhabiting different areas. Different kinds of simulations can be created and contain high-fidelity specialisations that can help experts and users to collect data in the field on one hand, and to raise awareness of many important issues regarding the entire marine ecosystem on the other. Using this kind of technology it is possible to reconstruct areas with sunken wrecks for scuba diving, fishermen and tourists. Developers or technical scientists operating in the 3D virtual reality sector offer data-driven solutions that allow the opening of discussions on issues that often, when simply discussed verbally, are difficult to understand. The use of a virtual space standing between the interested parties, may improve their communication and synergy.

The economic component plays a major role when conceiving augmented reality scenarios, moreover the capital gains derived from this type of intervention can be achieved by using fairly small financing efforts. A success story is represented by the constructive consultation for MPA delineation achieved when the involved parties (fishermen, researchers, managers) were driven to experience the circumstances of the closure of a certain area and the associated benefits for the ecosystem and the economical revenues by means of virtual hands on perception (in the form of a video game or in the form of immersive films) that helps to bypass the ineffective dialogue among contrasting point of views.

Another sensitive field of intervention where accurate and trustworthy data are mandatory is the complex interaction among waste, fishing and mariculture activities, maritime transport and tourism. The economic, environmental and social cost of marine litter is still not fully perceived despite its considerable impacts on all marine ecosystem service, hampering the benefits and goods all human activities benefit from.

The very final aim regarding the Adriatic Sea fishery sector, would be avoiding the extinction/depletion/plunder of the sector itself, maintaining the richness linked to biodiversity, research, local traditions and generational turnover.

Blue careers development and sustainable entrepreneurship in the blue economy

There is no doubt that the health of our oceans is fundamental to sustaining our blue economy. The blue economy encompasses various activities, including tourism, fishing, aquaculture, and others. The sustainability of each of these blue occupations requires a good economic status and the continuous recruitment of new workers. The gradual degradation of the marine environment led to high variability and socio-economic difficulties for the population whose income depends on the sea. Climate change introduces a new level of uncertainty to the fishery sector, due to reduction of primary production, changes in species migration patterns, and occasional blooms of invasive species. Further uncertainty to the fishery sector in the Adriatic Sea is also provided by management plans for the reduction of fishing effort of bottom trawlers and mid-pelagic trawlers for small pelagic fish. This uncertainty is causing the seamen to leave the fishery job and go to other sectors, like aquaculture or tourism. The lack of crew causes the fishing boats to not meet the minimum safety requirements for sailing, thus the risk of not being allowed to navigate, and thus fishing, further reducing the exploitations and the continuation of traditional exploitations. "A sea without fish is an empty sea, but it is also a sea without fishermen". This could not be truer recently, and the fishing sector, the most traditional sector of the blue economy, is struggling to maintain its own sustainability.

There is also a high unemployment of ex fishermen because they lack the knowledge and skills for other sectors, and organising education sessions for them proved to be difficult. Furthermore, the fishing and aquaculture sector has developed over time along with the improvement of knowledge about the sea. In Italy, in the past, no previous education was required to obtain a fishing licence, which led to a low level of education of fishermen, but sufficient for the exercise of fishing activities.

Nowadays, the activities of fishermen are more complicated than in the past and require a certain knowledge of business management, regulations and informatics. The fisheries sector is subject to a variety of regulations that are becoming increasingly stringent due to the will of the European Parliament to restore the good environmental status (GES) of European seas. The Common Fisheries Policy (CFP) requires captains to keep a catch logbook, which entails further administrative tasks and requires additional technical knowledge. The introduction of more sophisticated technologies for fish detection or aquaculture monitoring also requires the acquisition of new skills. However, these innovations are a barrier for older captains and fishermen, as their introduction is not easy and requires new training. However, it is very important for young captains to have adequate technical skills in using the provided fishing electronics and equipment, as they are highly dependent on it.

The aquaculture sector also has its own difficulties. Climate change, in particular, has led to changes in the environment, primary production, and ocean temperatures. Temperature increases are causing mortality in two important aquaculture species, blue mussels and European flat oysters, particularly in semi-enclosed or enclosed bays. In some cases, inadequate sewage systems are also a problem, as untreated sewage is discharged into the bay where aquaculture is conducted, compromising the safety of the products. As a result, due to the unfavourable conditions, there is a trend among the younger generation from aquaculture families to migrate to larger cities in search of cleaner and easier jobs. The remaining farmers want to improve their skills and therefore receive support for training that would improve their opportunities.

Therefore, the key solution for the above issues is the development of a common fishermen and farmers education and preparation program between different countries. Special capacity building facilities (e.g., fisheries schools) should be developed in the Adriatic Basin to train future fisheries and aquaculture workers and to exchange expertises and experiences across the basin. Overall education centres on fisheries and blue skills allow the fishermen both in running their activities efficiently, as well as allowing acquisition of new skills and finding alternative jobs.

Staff turnover is a difficulty in maintaining fishing operations, and there is a general shortage of workers, especially young ones. The new foreign workers have their own problems, as they are not trained for the activities in the fisheries sector and are usually used for simple tasks such as sorting catches or the like. The introduction of structured training programs where basic skills can be learned, such as repairing nets, could improve the search for suitable workers. Fishery Local Action Groups (FLAGs) could play an important role in promoting blue occupation development and providing educational programs. Blue occupation development should begin in schools or special high schools where blue occupation opportunities and skills can be acquired. The workforce is an issue that impacts the entire fisheries supply chain, and therefore the ability to produce food and be independent in the EU. This is especially important for tourism regions where part of sustainable tourism is also local food identity, the ability to offer local products and preserve traditions. Such actions can create links between fishermen entrepreneurship and sustainable fishing.

Technological development in the fisheries and aquaculture sector is always viewed positively, as it helps to overcome existing difficulties and reduce operating costs. The development of new propulsion systems or alternative fuels that could reduce consumption would be particularly beneficial in reducing fuel costs. More selective fishing nets would also be particularly beneficial for improving stock status and fishermen's incomes in the long term. Some forward-thinking fishermen are eager to innovate and try these new solutions.

Planning fishing activities is another aspect that can lead to more efficient fishing, such as the application of technologies and data-driven solutions used in the ITACA project that allow predicting future sales and thus optimising fishing activities and quotas. The promotion of fishery products is another aspect that would improve the income of fishermen in this situation of overfished resources. Providing consumers with correct information and educating them about food and its seasonal availability would benefit the socioeconomic sustainability of the fishing industry.

To maintain the revenues, the fishermen are taking initiatives by improving the quality of the caught fish, shortening the supply chain, promoting the seasonal fish or adopting product certification. Similar solutions are also present in the aquaculture sector where mussel aquacultures developed local mussel brands, certified the products' organoleptic properties and promoted it to local markets.

Recruiting new young workers to blue occupations is fundamental to maintaining the sustainability of the blue economy. However, promotional activities for the blue sector in elementary and high schools have revealed a lack of correct information for the younger generation, which in turn will have a negative impact on recruitment for blue occupations. Therefore, future activities should focus on improving the promotion and education of younger generations in order to present them with the opportunities offered by blue professions.

The blue economy also needs the support of professionals, such as researchers. Well-trained and prepared researchers can find employment in universities, research institutes, government or administrative agencies, and private companies. New young researchers should therefore be able to integrate and learn about their future work. Therefore, it is important to have stakeholders from the fisheries and aquaculture sector as lecturers at the university. In addition, researchers should contribute to the improvement of the blue economy and be able to communicate well to operators, managers and stakeholders.

The Italian research sector received considerable funding in the past, starting in 1982, when the procedures to obtain funding were simpler and it was sufficient to present a fisheries-related project. This was also the case for the next 20-25 years, and many consortia were created to support the fisheries sector, which was a problem for the large institutes. This management allowed fishermen to make their voices heard directly to the management authorities through their representatives. From the 2000s, management changed as European regulations and the Common Fisheries Policy became the new reference points.

Today, support requirements have evolved and require multidisciplinary capabilities that go beyond biology to provide more integrated responses that consider the entire supply chain. This could lead to the formation of broader consortia recognised by regional authorities, allowing better access to different funding and improving interaction with research institutes, avoiding fragmentation of data and ensuring continuity of monitoring and support plans. In the case of fisheries consortia, such as the Shellfish Management Consortium, it should be good practise to select such a support consortium to provide the necessary services and advice. Thus, it is of utmost importance to convey the information that resource sustainability has a biological and ecological basis that translates into an economic basis. Therefore, management strategies should always take into account the biological status and not just offer unfounded economic solutions. Fortunately, the amount of information collected has improved over the years, so decision making based on statistics and measurement results can be improved.In addition, there are three types of data in the fisheries sector: Fisheries and aquaculture data, research data, and institutional data, where improving mutual interactions and data validation are fundamental to the proper management of fisheries issues. The listed examples and required skills provide a wide range of blue careers for scientists, technologists, and managers, as well as various employment opportunities that will support the blue economy.

Conclusion and main future priorities

What is clearly emerging from all the above-mentioned issues and arguments related to data-driven solutions for sea-economy, is that the approach that favours bidirectionality is the one absolutely winning. It is evident that there is a huge need for harmonisation between the various operators in the Blue Economy, to face all the major impelling challenges of the sector. Harmonisation that needs to include efforts from multiple stakeholders, data providers, data users and therefore multiple disciplines, merging the multifaceted contributes of the science-based operators (technologist, economist, biologist) with the ones of the production and management operators (managers, contractors, cooperatives, sales, public authorities).

The required multidirectional harmonisation is addressable through adequate access to data and advanced knowledge.

To reach this objective, however, clearly requires further steps forward with respect to the current status, given the identification of cross-border obstacles to be solved, and the priorities for the next future highlighted in the previous sections of this document.

The three main priority areas for optimization of the data-driven solutions for sea-economy to reach effective synergy between *Hydrosphere* and *Infosphere*, can be summarised as follow:

1) First of all the data collection itself must be optimised. The main need is to define shared procedures, methods, tools and that properly take the balance between costs and benefits into account. At the same time, the required cost-benefit balance should consider not only economic parameters, but more in general how much knowledge and access to this information brings advantages with regards to the ecosystems protection and resources conservation.
2) The second point is how to manage the data. Interoperability between the various data collection and acquisition platforms must certainly be encouraged, given the multiple tools and systems that have already been implemented in previous efforts, both in the research and production realms. The ultimate goal is to minimise data fragmentation and to reduce the latency between the *Hydrosphere* time frame (the moment in which the data is acquired at sea) and the *Infosphere* time frame (the moment in which the data is actually available and operable).
3) The last point that emerged throughout all the studies that were considered within this analysis is the importance of also optimising the fruition of the data, thus how the data is presented. We presented and discussed the most innovative tools linked to this objective, such as tools based on virtual augmented reality, advanced tools also from the point of view of cultural content and education purpose. The difficulty in this objective lies in the fact that often there is no single recipe that is suitable for all the possible recipients of data

communication and utilisation. Therefore each specific instance would need to find the right tools for the vast public and in particular for the new generations that must be educated and oriented as well as the different proper tools for sea-economy sector operators and entrepreneurs and finally tailored tools for policy makers, and all public stakeholders dealing with marine and maritime planning.

Acknowledgments
This paper results from the activities of the Interreg Italy-Croatia project TECHERA (A new technology era in the Adriatic Sea – Big data sharing and analytics for a circular sea economy), contract number 10417714 and it would not have been possible without the fruitful discussions and insights from all the project's partners and also from all the numerous participants to the multiple TECHERA events.

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Supplementary material

#	Objective	Searching string
Fisheries		
O1	accurate assessment of fish diversity	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean") AND "Assess*" AND "diversity" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O2	accurate assessment of fish abundance	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Abundance" OR "Biomass" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O3	accurate assessment of fish distribution	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Assess*" AND "Distribution" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O4	estimation of age	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Estimat*" AND "Age" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O5	estimation of size	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Estimat*" AND "Size" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O6	estimation of growth	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Estimat*" AND "Growth" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O7	estimation of recruitment	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Estimat*" AND "Recruitment" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O8	estimation of other biological aspects	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Estimat*" AND "Biolog*" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O9	identifying fishing zones*	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Identif*" AND ("Ground" OR "Area" or "Spot") AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O10	enforcement of fishing regulations	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Regulat*" OR "Polic*" OR "Management") AND ("Appl*" OR "Enforc*" OR "Implement*") AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O11	Monitoring fishing vessel movement	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Monitor*" OR "Track*") AND ("Vessel" OR "Boat") AND ("Activity" OR "Route") AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")

O12	Monitoring fishing gear use	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Monitor*" OR "Control*") AND "Gear" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O13	Monitoring fishing catch	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Monitor*" OR "Control*") AND "Catch" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O14	best fishing grounds*	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Identif*" AND ("Ground" OR "Area" or "Spot") AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O15	Monitoring of primary production	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Monitor*" OR "Control*") AND "Primary Production"AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O16	Risks of harmful alfal blooms	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Habitat" AND ("Harmful Algal Bloom" OR "HAB") AND ("Impact" OR "Risk") AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O17	pollution risks	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Pollut*" ("Impact" OR "Risk") AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O18	environmental monitoring	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Environment*" AND ("Monitor*" OR "Control*") AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O19	reducing gear impact on sea bottom	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Sea Bottom" OR "Seafloor" OR "Sea floor" OR "Seabed") AND "Gear" AND "Impact" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O20	improve lightening systems	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Lightning " AND "Effic*" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O21	improve catchability	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Catchability" AND "Effic*" AND "Improv*" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O22	increasing energetic efficiency and sustainability of marine operations	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Energ*" AND "Efficien*"

		AND "Sustainab*" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O23	ICT systems applied to navigation and fishing	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "ICT" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O24	reduction costs	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Produc*" AND "Cost*" AND "Efficien*" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O25	deterrents or escaping devices	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Deterrent?" OR "Escap*") AMD ("Device" OR "Tool" OR "Machine") AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O26	auxiliary tools for fishing	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Auxiliary" AND ("Gear?" OR "Tool") AND "Selectiv*" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O27	mode of use of fishing gear	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Gear" AND ("Use" OR "Using" OR "Operati*") or AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O28	improving selectivity	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Gear" AND "Selectiv*" AND "Improv*" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O29	systems for improving quality onboard	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND "Quality" AND "Onboard" AND NOT ("Aquaculture" OR "Fish farm*" OR "Mariculture")
O30	tools for transformation of seafood	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Transform*" OR "Process*") AND ("Tool*" OR "Machine*")
O31	packaging and conservation	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Packaging" OR "Conservation")
O32	development new products	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Transform*" OR "Process*") AND "Develop*" AND "New Produc*"
O33	certifications and labelling	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Transform*" OR "Process*") AND ("Certif*" OR "Label*")

O34	systems for improving quality on land	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Transform*" OR "Process*") AND ("Valu*" OR "Quality") AND "System*"
O35	transport, logistic and cold chain	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Distribut*" OR "Consum*") AND "Cost*" AND ("Transport*" OR "Logistic*" OR "Cold chain")
O36	ICT systems applied to transformation and marketing	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Distribut*" OR "Consum*") AND "ICT" AND ("Transform*" OR "Marketing")
O37	Circularity	"Fish*" AND ("Marine" OR "Coastal" OR "Sea" OR "Maritime" OR "Ocean*) AND ("Distribut*" OR "Consum*") AND "Circular*"
Aquaculture		
O38	farm activity production planning	("Aquaculture" OR "Fish farm*" OR "Mariculture") AND "Product*" AND ("Plan*" OR "Organi*")
O39	farm optimal placing	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Install*" OR "Plac*" OR "Select*" OR "Locat*") AND ("Site" OR "Location" OR "Area")
O40	farm activity tracking	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Traceability" OR "Track*") AND ("Production" OR "Activity")
O41	automatic fish processing	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Automatic Fish Processing")
O42	forecast disease outbreak	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Disease" OR "Outbreak" OR "Infect*") AND ("Forecast*" OR "Predict*")
O43	anomaly detection in water quality	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND "Water Quality" AND "Threat*"
O44	real time monitoring and remote control	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Monitor*" OR "Control*") AND "Remote"
O45	automated operation and maintenance of cages	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND "Automat*" AND ("Cage" OR "Net")
O46	monitor and control feeding rate	("Aquaculture" OR "Fish Farm*" OR "mariculture") AND "Feed*" AND ("Monitor*" OR "Control*")
O47	monitor and control water quality	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND "Water" AND ("Monitor*" OR "Control*") AND NOT "Agri*"
O48	monitor fish growth	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Estimat*" OR "Monitor*" OR "Control*") AND "Fish Growth"

O49	monitor fish biomass	("Aquaculture" OR "Fish farm*" OR "Mariculture") AND ("Fish Abundance" OR "Fish Biomass") AND ("Monitor*" OR "Control*")
O50	monitor fish behavior	("Aquaculture" OR "Fish farm*" OR "Mariculture") AND "Fish Behaviour" AND ("Monitor*" OR "Control*")
O51	control of input water and tratment	("Aquaculture" OR "Fish farm*" OR "Mariculture") AND ("Input" OR "Load*") AND "Water" AND "Treat*" AND ("Control*" OR "Monitor*")
O52	tools for transformation of seafood	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Transform*" OR "Process*") AND ("Tool*" OR "Machine*")
O53	packaging and conservation	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Packaging" OR "Conservation")
O54	development new products	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Transform*" OR "Process*") AND "Develop*" AND "New Produc*"
O55	certifications and labelling	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Transform*" OR "Process*") AND ("Certif*" OR "Label*")
O56	systems for improving quality on land	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Transform*" OR "Process*") AND ("Valu*" OR "Quality") AND "System*"
O57	transport, logistic and cold chain	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Distribut*" OR "Consum*") AND "Cost*" AND ("Transport*" OR "Logistic*" OR "Cold chain")
O58	ICT systems applied to transformation and marketing	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Distribut*" OR "Consum*") AND "ICT" AND ("Transform*" OR "Marketing")
O59	Circularity	("Aquaculture" OR "Fish Farm*" OR "Mariculture") AND ("Distribut*" OR "Consum*") AND "Circular"

#	**Solution**	**Searching code**
S1	satellites	"Satellite" AND "Telemetry" OR "remote sensing"
S2	information centres	"Information Cent*"
S3	portable devices	("Portable Device" OR "Smartphone" OR "Tablet") AND "Technolog*"
S4	environmental buoys	"Technolog*" AND "Environment*" AND "Buoy"
S5	sensor networks	"Sensor Network"
S6	internet of things	"Internet of Things"

S7	underwater drones and camera	"Underwater" AND ("Drone" OR "Camera")
S8	data on catches	("Landing" OR "Discard" OR "Catch") AND "Data"
S9	automatic vessel identification system	"VMS" OR "AIS" OR "Vessel Monitoring System" OR "Automatic Identification System"
S10	genetic data	"Population Structure" AND "Stock Identification" AND "Genetic"
S11	market data	"Market data" OR "Market intelligence" OR "Market information" OR "Price data" OR "Price series"
S12	collecting web data (e.g., on consumers)	("Web" OR "Online") AND ("Survey" OR ("Consumer?" AND "Data"))
S13	data processing	"Artificial intelligence" OR "Data mining" OR "Machine learning" OR ("Monitor*" OR "Control*" AND ("System" OR "Process"))
S14	web/mobile applications	"Mobile app*" OR "Web App*"
S15	databases and platforms	"Resource Platform" OR "Resource Database" OR "Diagnostic" OR " Repository"