



Insights on the environmental management system of the European port sector

Martí Puig^a, Sahar Azarkamand^a, Chris Wooldridge^b, Valter Selén^c, R.M. Darbra^{a,*}

^a Resource Recovery and Environmental Management (R2EM), Department of Chemical Engineering, Universitat Politècnica de Catalunya BarcelonaTech, Diagonal 647, 08028 Barcelona, Catalonia, Spain

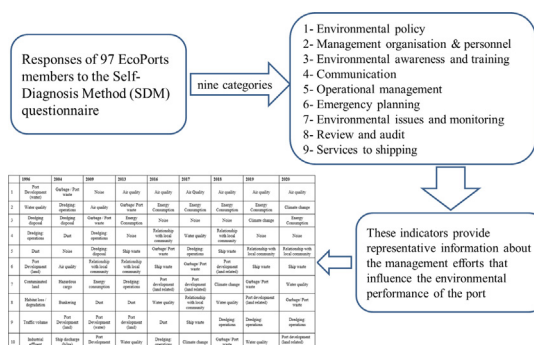
^b School of Earth and Ocean Sciences, Cardiff University, Main Building, Park Place, Cardiff CF10 3AT, United Kingdom

^c European Sea Ports Organisation (ESPO), Treurenberg 6, B-1000 Brussels, Belgium

HIGHLIGHTS

- This paper presents the trends on environmental management of European Ports.
- Almost all ports have an environmental policy & an inventory of significant aspects.
- Climate change is the issue that raised the most recently, up to the 2nd position.
- Waste, energy efficiency and water consumption are the most monitored issues.
- Ports are increasing Green services to shipping (LNG, OPS and differentiated fees).

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 7 July 2021

Received in revised form 2 September 2021

Accepted 20 September 2021

Available online 24 September 2021

Editor: Damia Barcelo

Keywords:

Environmental management
Ports
Indicators
Sustainability
Policy

ABSTRACT

This research focusses on assessing the environmental performance of European Ports based on a wide representation of EcoPorts members. The data is extracted from the Self-Diagnosis Method (SDM), a concise checklist against which port managers can self-assess the environmental management of their port in relation to the performance of the EcoPorts membership. A total number of 97 ports from 18 different European Maritime States contributed to this evaluation. They have answered questions related to the main components of internationally recognized Environmental Management System (EMS) standards. Similar periodic assessments have been carried out since 2013, allowing for the identification of benchmark performance. The geographical representation and characteristics of the participating ports are given along with the perceived ranking of priority environmental issues based on regular reviews. Air quality has been the top environmental priority for many years, followed by climate change, which has risen rapidly to the second position. Most of the ports have an environmental policy in place (96%) and a compilation of an inventory of significant environmental aspects (92%). Transparency is also very important to ports, with 91% of ports communicating their environmental policy to stakeholders, and 86% of ports making it publicly available on their website.

Around 80% of ports have set up an environmental monitoring program, with port waste being the most monitored issue.

With regard to services to shipping, more than half of the responding ports are offering on shore power supply (OPS), and one third of them have made LNG bunkering available. In parallel, an increasing number of ports compared with previous exercises (57%) provide differentiated dues for ships that go beyond regulatory standards,

* Corresponding author.

E-mail addresses: marti.puig@upc.edu (M. Puig), sahar.azarkamand@upc.edu (S. Azarkamand), valter.selen@espo.be (V. Selén), rm.darbra@upc.edu (R.M. Darbra).

with air emissions, waste and climate change being the main target of these discounts. In general, trends over the years have shown a clear improvement of the environmental port performance.

© 2021 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Ports are important infrastructures for economic growth and development. They have strategic importance to a nation, acting as gateways to trade. They also constitute a key node in the global supply chain (Wright, 2013). However, at the same time, they are very complex systems, since each port is unique in terms of activities, geography or applicable laws.

Due to the range and nature of the activities, products and services carried out in the port area, multiple environmental aspects may be generated contributing to the port environmental footprint. These can be originated in maritime activities, in-port operations and in the hinterland transport. As transport activity has increased, so to have the intensity and range of impacts such as air pollution, noise pollution, CO₂ emissions, and congestion (Chiu et al., 2014). Port authorities have progressively needed to take into account not only the impact of their activities and operations within the port area (OECD, 2011; Comtois and Slack, 2007), but also now their role and influence with shipping, the city, logistic chain operations and the overall hinterland connections (Ng and Song, 2010; Winnes et al., 2015).

In order to reduce these negative impacts, greening and sustainability issues have become more important in the maritime industry in recent years due to the legal requirements coming from international regulatory bodies such as International Maritime Organization (IMO) and the European Union (EU), and also due to external pressure by stakeholders in the industry. Moreover, the rising tide of political interest in combining growth with green (European Green Deal) is an explicit item on the agenda of many countries (Asgari et al., 2015; González-Laxe et al., 2016). Port sector organizations, such as the European Sea Ports Organisation (ESPO), showed its clear purpose to comply with the Green Deal objectives through the implementation of its Road Map. European ports want to be a partner in implementing Europe's ambition to be the first net-zero carbon emission continent by 2050 (ESPO, 2020a). In order to do so, carrying out a proper environmental management is essential.

In the context of port activities and operations, Environmental Management may be defined as the functional organization necessary to deliver environmental protection and sustainable development to the highest possible standards of compliance and accountability (Barrow, 2005). Over the last twenty-five years, port authorities have come under increasing pressure from an ever-widening group of stakeholders to not only deliver compliance with legislation and regulation, but also to actively demonstrate their competence and to provide evidence of their environmental performance (ESPO, 2020b).

Since 1994, ESPO has consistently taken a pro-active approach on behalf of its members through direct involvement with, and support for, research-based tools and methodologies to assist port managers in improving their environmental management which involves delivery of compliance, cost- and risk-reduction, and sustainable development. Details of the sector's environmental initiatives are provided in, inter alia, EcoPorts, ESPO Green Guide (ESPO, 2012a, 2021) and the PORTOPIA European Port Industry Sustainability Report 2017 (ESPO, 2017). In addition, ESPO has also launched a continuously updated database of good green practices from European ports, which is available to the public via www.espo.be/practices.

Despite these initiatives to improve the environmental performance in ports, it is important to mention that the pandemic has triggered a global health and economic crisis with wide-ranging implications for maritime transport and trade. Restrictions introduced in response to

the pandemic have caused disruptions affecting ports, shipping, and supply chains (UNCTAD, 2020). Applying good environmental management practices under the current dynamics of the circumstances imposed by the Covid-19 pandemic has made further demands on implementation, resources and monitoring (Rume and Didar-UI Islam, 2020; Zambrano-Monserrate et al., 2020).

It is within these circumstances of scientific and political uncertainty that the professional port manager responsible for the day-to-day environmental safeguards must endeavour to address the port's liabilities and responsibilities in terms of achieving a Corporate Environmental Management, which will allow implementing and operating an effective EMS (Mazurkiewicz, 2004; Erauskin-Tolosa et al., 2019). This can be certified under the internationally known ISO 14001 (ISO, 2015) and EMAS (European Commission, 2017) standards or PERS (Port Environmental Review System) which is the port sector's own, independently verified, international standard – the only International EMS dedicated to the port sector (available at www.ecoport.com).

The purpose of this paper is to assess the extent to which port authorities (members of EcoPorts) are implementing procedures and processes necessary to operate an effective Environmental Management System (EMS).

2. Methodology

2.1. Survey background

Table 1 shows that this initiative is not new; in fact, this is the tenth time that an environmental survey is conducted by ESPO in the last 25 years. The title of the survey has changed over the years, but the objective has been always the same, that is, assessing the environmental performance of the European Ports in terms of adopting and implementing an EMS and establishing a Benchmark for the European port sector. Practically, each year, more than 90 ports have participated in the surveys from a wide range of countries. This establishes what may be considered to be a credible data base from which to assess progress and establish trends.

The initiative began in 1996 when ESPO commissioned the first environmental survey to assess the ports' response to release of the ESPO Environmental Code of Practice (ESPO, 1994). Later in 2004, a new survey was sent out to the ports by regular mail and 129 ports responded. The results were published in 2005 (ESPO, 2005).

In 2009, in collaboration with Ecoports Foundation, ESPO published the results from another major environmental survey where ports from 20 different countries participated (ESPO, 2009). This was the first time that the survey was submitted online and it included more questions to

Table 1
ESPO environmental surveys over the years.

Survey name	Year	Ports (no.)	Countries (no.)
Environmental ESPO Questionnaire	1996	281	15
ESPO Environmental Survey	2004	129	–
ESPO/Ecoports Port Environmental Review	2009	122	20
European Port Performance Dashboard	2012	58	–
ESPO Port Performance Dashboard	2013	79	21
European Port Industry Sustainability Report	2016	91	20
ESPO Sustainability Report	2017	91	21
ESPO Environmental Report	2018	90	19
ESPO Environmental Report	2019	94	19
ESPO Environmental Report	2020	97	18

have a more comprehensive picture of the port environmental management performance.

The research project PPRISM (Port Performance Indicators: Selection and Measurement) (2010–2011) established the basis for the culture of a performance measurement in European Ports. As a result, a first European Port Performance Dashboard was published (ESPO, 2012b). One year later, a more comprehensive data collection was carried out, including a section with selected Environmental Performance Indicators (EPIs). The results were presented in the ESPO Port Performance Dashboard (ESPO, 2013).

Within the framework of another European project PORTOPIA (2013–2017), the European Port Industry Sustainability Report was produced (ESPO, 2016). It included a section devoted to Environmental and Occupational Health, Safety and Security indicators. There the results of the environmental performance of 91 ports were presented. The EPIs used were comparable to those of the previous surveys. In the following year, an update of this report was also published (ESPO, 2017).

Since 2018, ESPO decided to conduct the survey in annual basis and called it ESPO Environmental Report (ESPO, 2018, 2019, 2020b). This document expands the findings of the last report and conducts a deeper analysis of the results.

2.2. Data collection

The data presented in this paper comes from the responses of 97 EcoPorts members to the Self-Diagnosis Method (SDM) questionnaire. SDM is a tool that allows port managers to periodically assess the quality of the environmental management and the progress achieved through time in their ports (Darbra et al., 2004).

The SDM was developed in the ECOPORTS project (2002–2005) and since then it has been used by hundreds of ports on a periodic basis. Every two years, EcoPorts members fill in the questionnaire. Responses from the 1st of September 2018 until 1st of September 2020 were included in this research. The data was taken straight-forward from the results of the update sample of the EcoPorts SDM. The authors compiled the updated data, classified them in different categories, and analysed the results.

SDM is available for European Ports through ESPO (www.espo.be) but also around the world through EcoSLC Foundation (www.ecoslc.eu). The tool has been updated in several occasions to reflect any changes in the requirements and criteria of the EMS standards (PERS, ISO 14001, and EMAS). The current version of the tool is from July 2020 and it includes 316 questions. SDM is divided into nine sections, as it can be seen in Table 2. The right column of the table indicates the number of Environmental Performance Indicators (EPIs) selected to present the results in Section 3.

2.3. Characteristics of the sample and limitations of the study

The data gathered for this paper comes from 97 ports from 18 different countries, all of them being members of ESPO. These include the

Table 2
SDM sections and number of questions. Number of selected EPIs.

Section	Title	Questions (no.)	Selected EPIs (no.)
A	Environmental policy	114	8
B	Management organization & personnel	12	2
C	Environmental awareness and training	7	4
D	Communication	22	4
E	Operational management	21	3
F	Emergency planning	19	6
G	Environmental issues and monitoring	30	17
H	Review and audit	25	5
I	Services to shipping	66	9

European Union countries plus Norway, which is a member of the European Economic Area, and plus United Kingdom, which was still a member of the European Union at the time of the data extraction (1st of September 2020). Table 3 provides the list of countries represented, the number of participating ports of each country and the percentage. United Kingdom is the country with the highest percentage of participant ports (15.5%), followed by Spain (14.4%). After that, France and Germany are occupying both the 3rd position with an equal percentage (10.3%). These four main contributor countries have remained the same since 2018.

With reference to the setting and configuration of the participant ports, Fig. 1 demonstrates that it is quite diverse. The embayment, protected coast and marine inlet are the most common characteristic settings of the contributing ports (36%). The estuaries and the engineered coastline ports occupy the 2nd and 3rd position with a similar percentage. Finally, the inland ports are represented with 13%.

Fig. 2 shows that small ports (<5 million tons/year) make up the highest percentage of respondents (39%). This has been the consistent pattern for many years. They are followed by medium (5 < 15 million tons/year) and large (15 < 50 million tons/year) sized ports with 22%. Just 17% of the ports handle more than 50 million tons per year.

The use of surrounding land is highly significant in terms of the scope and effectiveness of a port's EMS. As it can be seen in Fig. 3, most of the ports are surrounded by cities and industry.

97 ports may seem a significant number for statistical purposes. However, in Europe there exist around 1200 ports (Global Trade, 2021). This means that the sample of the survey represents 8% of the European ports. This is a limitation of this study. Nevertheless, the broad spectrum of geographical locations, port size and countries of the participant ports helps the sample to be representative of the whole set of the European Ports.

Another limitation of the study is the fact that the sample varies from year to year. This makes the comparison over the years not identical. However, in general terms, the authors consider that the differences can be dismissed.

Finally, the fact that the questions of the survey are qualitative (i.e. Yes/No answer) implies a certain loss of information. In addition, it has to be assumed that the answers are always true.

3. Benchmark performance 2020

The results are displayed following the same sections as they are grouped in the Self Diagnosis Method (SDM). It consists of nine categories, namely i) Environmental policy, ii) Management organization & personnel, iii) Environmental awareness and training, iv)

Table 3
List of countries and number of participating ports.
Source: ESPO (2020b).

Country	Number of ports	Percentage (%)
United Kingdom	15	15,5
Spain	14	14,4
France	10	10,3
Germany	10	10,3
Netherlands	9	9,3
Denmark	7	7,2
Greece	6	6,2
Sweden	5	5,2
Finland	5	5,2
Ireland	3	3,1
Italy	3	3,1
Norway	2	2,1
Portugal	2	2,1
Bulgaria	2	2,1
Lithuania	1	1,0
Latvia	1	1,0
Estonia	1	1,0
Romania	1	1,0

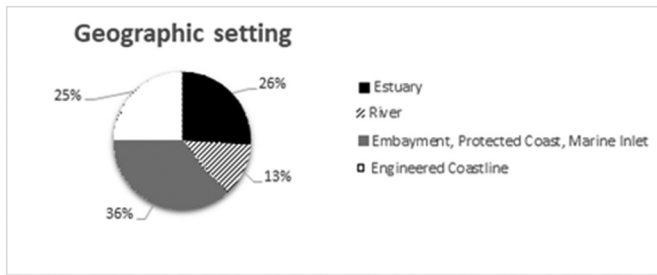


Fig. 1. Geographical characteristics of the sample.
Source: ESPO (2020b).

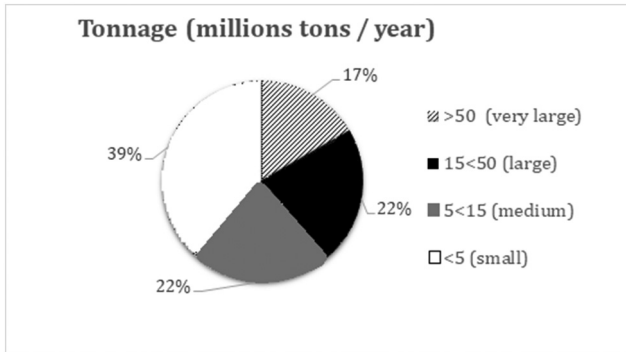


Fig. 2. Tonnage characteristics of the sample.
Source: ESPO (2020b).

Communication, v) Operational management, vi) Emergency planning, vii) Environmental issues and monitoring, viii) Review and audit, and ix) Services to shipping. A total number of 58 indicators have been selected out of the total number of 316 indicators currently comprised within the SDM, as the most representative of the sector's performance and trends. The responses are expressed as the percentage of positive responses. In addition, some examples of best practices currently undertaken by ports have been pointed out in each one of the above-mentioned categories of environmental management.

3.1. Environmental policy

The Environmental Policy section is the first and the most comprehensive section of the Self Diagnosis Method. It currently includes a total number of 114 questions, including enquiries on the Environment

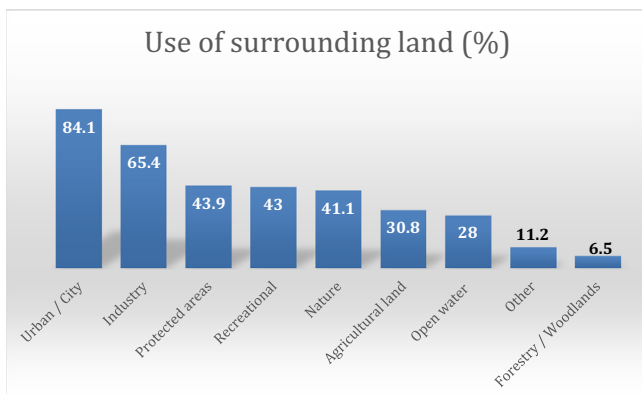


Fig. 3. Number of ports and the use of surrounding land of the sample.

Policy document, Environment Policy scope, Environmental Aspects of port activities, objectives and targets for environmental improvement, and resources and budget allocated to Environmental Management. Table 4 presents the results on this section.

It is encouraging for the sector that 96% of respondent ports declare that they have an Environmental Policy. It is arguably the most significant attribute because the policy drives the whole environmental management program and the associated Environmental Management System (EMS). It is the lead statement in terms of identifying priorities, highlighting issues, and developing objectives and action plans. The Inventories of Legislation and Aspects feature strongly and are key requirements of any credible EMS (Iraldo et al., 2011). The formal recognition and implementation of ESPO environmental policy and guidance documentation is still a topic for progress – an auditor may reasonably expect the Authority to recognize, endorse and implement the guidelines of its own sector's representative organization, particularly on issues concerning policy.

3.2. Management organization & personnel

Two questions out of 12 from the section of management organization and personnel were selected.

Almost all the participant ports have, at least, one environmental manager with responsibilities clearly defined (97%). This may be interpreted as a strong level of commitment in terms of managing their environmental liabilities and responsibilities.

The fact that the manager's responsibilities are documented (85%) is important for delivering and demonstrating organizational competence within the Port Authority and for purposes of quality control, decision-making and auditing.

Most of the largest European ports have at least one environmental/sustainability manager, who is ensuring that the port complies with both external legislative environmental standards and internal environmental requirements set by the port.

A study from Denisova (2018) reveals that within the interviewed ports, the Port of Aalborg (Denmark), the port of Amsterdam (the Netherlands) and the port of Stockholm (Sweden) were the ones with a higher number of environmental employees. The reason for that they follow an approach of spreading environmental responsibilities among many employees, while also having one environmental coordinator, who ensures that those responsibilities are fulfilled.

3.3. Environmental awareness and training

The third section of the SDM is about the topic environmental awareness and training. It is considered that if employees are aware of impacts, they are more likely to reduce risks, follow protocols and assist

Table 4

Benchmark performance 2020 on environmental policy.

Environmental policy	% Yes
Does the port have an environmental policy? ^a	96
Is the policy publicly available on the port's website? ^b	86
Does the policy include reference to improvement of environmental standards beyond those required under legislation?	84
Does the environmental policy make reference to the implementation of ESPO environmental policy and guidance documentation? ^b	43
Does the port have an inventory of relevant environmental legislation and regulations related to its liabilities and responsibilities? ^a	91
Does the port have an inventory of Significant Environmental Aspects for the port area? ^a	92
Have objectives and targets for environmental improvement been defined? ^a	88
Does the port have a budget specifically for environmental management? ^b	79

Notes:

^a Indicates that the question is related to a requirement of the International EMS Standards of PERS, ISO 14001 and EMAS.

^b Indicates that the question is related to a requirement of PERS.

with implementation and operation of good practice. Awareness of potential impacts is essential for implementation and successful management of routine and emergency operations. Out of the seven questions included in the SDM on this topic, four were selected to demonstrate the performance of the sector (see Table 5).

The response that has the highest positive feedback (90%) is the employees' awareness on the environmental policy. It is relevant to mention that Environmental Awareness and Training are widely recognized throughout the sector and industry in general as particularly time and cost-effective mechanisms for the actual implementation and operation of an Environmental Management Program and an effective Environmental Management System (EMS).

It is also pertinent to point out that the inclusion of environmental issues in induction programs is undertaken by 67% of ports and more than the half of the respondent ports have implemented a training program for its employees (55%). Implementing a training program and awareness-raising activities is expected assist in the delivery of continuous improvement in environmental performance, since it provides employees with the skills to do their work more efficiently, make them more aware of their roles and responsibilities and stimulate people to develop new ideas through consultation and discussion. In addition, 58% of ports consider that the environmental training to employees is fitted to their activities and responsibilities.

An example of good practices concerning training within the sector can be found in Ports de la Generalitat de Catalunya (Spain), which promotes the motivation and ongoing training of own staff or those who work on behalf of the organization, as well as users or entities. It collaborates with different administrations, NGOs, public and private entities in the search for more global solutions to environmental problems (Ports de la Generalitat, 2020).

3.4. Communication

The following section of the SDM deals with environmental communication, which includes 22 questions concerning this topic. For the purposes of the present research, four questions were selected, as shown in Table 6.

It may be considered that, out of the four previous indicators, the most relevant one is the publication of a publicly available Environmental Report (69%), which is a requirement of various EMS standards (i.e. EMAS and PERS). It is widely seen by the sector as a good practice in terms of transparency and progress. In addition, it enables ports to demonstrate its environmental credentials, standards and continuous improvement.

Nevertheless, the question with the higher positive feedback (92%) is the existence of procedures to communicate environmental information internally between the key environmental personnel. Therefore, this high percentage may be considered as a strength of the sector in terms of procedures to disseminate information and effective interaction between environmental personnel.

A best practice within the sector on environmental communication may be found in the Peel Ports Group (United Kingdom), since they ensure that their staff and contractors are given appropriate and relevant

Table 6
Benchmark performance 2020 on communication.

Communication	% Yes
Does the port publish a publicly available environmental report?	69
Does the report conform to standard practice of the Global Reporting Initiatives (GRI)?	26
Are there procedures to communicate environmental information internally between the key environmental personnel?	92
Does the port exchange environmental information with stakeholders (including industry, research institutions and NGOs)?	87

environmental information. The group maintains communication with relevant regulators and authorities where there are common environmental interests and they prepare, publish, and monitor environmental objectives and targets with the view of continual improvement. They communicate and engage with employees, stakeholders and port users on environmental matters (Peel Ports Group, 2020).

Another example is the one of Copenhagen Malmö Port. They have three-day training program twice a year which is performed through not only communication of environmental themes to staff, but also an active participation of employees in decreasing environmental impact of the port (Denisova, 2018).

Examples of ports that report according to the Global Reporting Initiative, one of the indicators present in Table 6, are Antwerp, Rotterdam, Ferrol, Sines, Los Angeles and Vancouver (Maigret, 2014).

3.5. Operational management

Operational management section compiles a set of 21 indicators related to environmental management programs. For the purpose of this report, three questions were selected,

The results confirm the positive performance of the sector in relation to these three issues: environmental management programs (82%), non-compliance with standards (82%) and environmental management manual (62%). The last one concerning Environmental Management Manual is the one in which there is more scope for further progress. Although a Manual is not a requirement of the international EMS standards, its compilation and update provide a systematic profile of the port's own EMS. It may serve as a useful training tool in its own right, and it is often a useful overview of responsibilities and communication links.

A sector example of establishing an environmental management plans is the one of the Port Authority of Valencia's (PAV) Strategy towards zero emissions by 2030. It is driven by the port's clear commitment to align itself with the European Green Deal, highlighting the urgent need to reduce GHG emissions from the maritime transport sector. The main objectives of the Strategy include (Port Authority of Valencia, 2020):

- Promoting the decarbonisation of the Spanish port system, including the incorporation of the circular economy in port construction projects and port operations.
- Fostering the digital transformation of the Spanish port system.

3.6. Emergency planning

Within the topic of emergency planning, a set of 19 indicators are currently included in the Self Diagnosis Method, mostly related to the characteristics of the port emergency and contingency plan. Specifically, the questionnaire asks whether a set of accidents (e.g., fire, explosion, floods, spills) are included in the plan. It also enquires if the responsibility and role of different stakeholders (e.g. port authority, operators, ship agents) are specified in the plan. Six questions were selected as being the most significant for this nature of review, which are listed in Table 7.

Table 5
Benchmark performance 2020 on environmental awareness and training.

Environmental awareness and training	% Yes
Are all employees aware of their responsibility to conform to the environmental policy and management objectives?	90
Does the port authority have an environmental training program for its employees?	55
Is the environmental training fitted to employees' activities and responsibilities?	58
Are environmental issues included in induction programs for new employees?	67

Table 7
Benchmark performance 2020 on emergency planning.

Emergency planning	% Yes
Does the port have an emergency and contingency plan?	96
Does the plan specify: responsibility and role of Port Authority personnel?	94
Does the plan specify: responsibility for follow-up and reporting	86
Does the plan specify: responsibility and role of tenants and operators?	86
Does the plan specify: responsibility and role of external competent authorities?	81
Does the plan specify: responsibility and role of ship agents?	66

Nearly all the participant ports have an emergency and contingency plan (96%). It is a written plan which should detail step-by-step procedures to follow in case of emergencies such as fire, chemical spill, or a major accident. It specifies procedures for handling sudden or unexpected situations. The responsibility and role of Port Authority personnel is specified in 94% of respondent ports.

An example of an initiative to improve Emergency planning is the one of the Port of Rotterdam Authority (The Netherlands) together with the Port of Antwerp (Belgium), the Port of Mannheim (Germany), the Port of Strasbourg (France) and the Port of Switzerland (Rhine Port Group). They commissioned a study on emergency and incident response for LNG on the inland waterways as part of the LNG Master plan for Rhine-Main-Danube. The aim of the study was to explore the existing knowledge regarding the transportation of LNG and the use of LNG powered vessels on the waterways as well as to determine the possible scenarios involving an LNG leak that an incident response team could face. The information gained as a result of the study was used to increase awareness in handling such incidents, make recommendations concerning the resources required for a response and provide guidelines for the training required for incident response (LNG Master plan Consortium, 2015).

3.7. Environmental issues and monitoring

The section on environmental issues and monitoring is composed of 30 questions: the first one concerns the environmental issues (priorities) of the port, and the rest deals with the monitoring plan and climate change. For this reason, the results provided below on this topic are divided in two parts: firstly, the top ten environmental priorities of ports, providing the results split by port size and location and, secondly, the results on the monitoring section.

3.7.1. Top ten environmental priorities

The regular update of the top ten environmental priorities of the sector is a significant exercise because it shows the current priority issues of the port sector. The results of the priorities of the sector in 2020 are

displayed in the first column of the Table 8, along with the priorities of each type of location, according to the categories shown previously in Fig. 1. These results are relevant because they identify the high priority environmental issues on which ports are working and sets the framework for guidance and initiatives to be taken by the sector.

There is generally a strong link between port activities and operations, and its geographical/hydrographic setting. The priority issues are strongly related to the inventory of Significant Environmental Aspects because the whole environmental management program should be designed to control their impacts on the environment.

The analysis of the results by the different port location reveals some pointers as to local influences and geographical characteristics. In general, air quality remains as the main priority, except for estuary ports which have climate change (where periodic flooding may have an obvious local impact). The issues of climate change, energy efficiency, noise and relationship with local community are also priorities shared by all the categories of ports.

Conservation areas, ranked 5th priority for estuary ports, is an item that is not shared by any other category. The two priorities related with Dredging (operations and disposal) are also solely selected by estuary ports. It may be explained by the fact that estuarial ports may have to carry out maintenance dredging more frequently compared to other ports, due to the sedimentation regime controlled by riverine and marine hydrodynamics.

Concerning the top ten priorities by size, the results are provided in Table 9.

The analysis of the results by the size of ports shows that air quality is the main priority for large and very large ports. Energy efficiency can be seen in the first position in small ports and in the second position in medium ports, which may be related to the costs devoted to the energy supply and in the potential ways to become more efficient. In contrast, large and very large ports recognize climate change as the second priority by ranking, this being perhaps recognition of the global concern over the issue and the impact that ports are deemed to make.

The importance of the relationship with the local community is specially focused on large and very large ports since it is the 3rd priority topic. This shows the concern of ports regarding the interaction with their stakeholders. In contrast, noise is a priority shared mostly by small and medium ports which also give a higher priority to garbage/port waste compared with large and very large ports- this may reflect scale of waste management operations and overall resources.

Since it may be suggested that large ports are more likely to undertake infrastructure and capital development, port development, both land and water related, is considered as a priority by very large ports. It is also seen that dredging operations and disposal is a major priority of large ports, which may be explained with reference to scale of operations, size of vessels involved and the associated navigational requirements.

Table 8
Top ten environmental priorities by location.

Sector 2020	Embayment, protected coast, marine inlet	River	Estuary	Engineered coastline
1 Air quality	Air quality	Air quality	Climate change	Air quality
2 Climate change	Energy efficiency	Climate change	Air quality	Energy efficiency
3 Energy efficiency	Climate change	Energy efficiency	Energy efficiency	Climate change
4 Noise	Ship waste	Noise	Relationship with local community	Noise
5 Relationship with local community	Relationship with local community	Dust	Conservation areas	Relationship with local community
6 Ship waste	Noise	Dredging: operations	Noise	Dredging: disposal
7 Water quality	Garbage/port waste	Garbage/port waste	Dredging: operations	Port development (land related)
8 Garbage/port waste	Water quality	Water quality	Dredging: disposal	Ship waste
9 Dredging: operations	Port development (land related)	Relationship with local community	Ship exhaust emissions	Garbage/port waste
10 Port development (land related)	Dredging: operations	Habitat/ecosystem loss (land)	Habitat/ecosystem loss (water)	Port development (water related)

Table 9
Top ten environmental priorities by size.

Sector 2020	Small	Medium	Large	Very large
1 Air quality	Energy efficiency	Climate change	Air quality	Air quality
2 Climate change	Air quality	Energy efficiency	Climate change	Climate change
3 Energy efficiency	Noise	Air quality	Relationship with local community	Relationship with local community
4 Noise	Climate change	Noise	Energy efficiency	Ship exhaust emissions
5 Relationship with local community	Ship waste	Garbage/port waste	Ship waste	Noise
6 Ship waste	Water quality	Port development (land related)	Dredging: operations	Conservation areas
7 Water quality	Garbage/port waste	Ship waste	Noise	Energy efficiency
8 Garbage/port waste	Relationship with local community	Water quality	Dust	Port development (land related)
9 Dredging: operations	Dust	Dredging: disposal	Dredging: disposal	Port development (water related)
10 Port development (land related)	Port development (land related)	Relationship with local community	Water quality	Garbage/port waste

An example of the port working on its identified priority issues is Copenhagen Malmö Port (CMP) in Denmark, which is working with three main areas of priority to secure a strong connection to the relevant Sustainable Development goals: Protecting Water, Protecting Air, Climate and Water (CMP, 2021). This port is considered a large port according to the cargo moved every year (15.5 million tonnes/year) and its priorities are in line with those of Table 9 for these types of ports.

The same happens with the Niedersachsen Port (Germany), another large port (30 million tonnes/year), which actively implements measures to protect the environment in topics such as greenhouse gas (GHG) emissions, air pollutants and energy. In this regard, direct greenhouse gas emissions have been reduced by a further 25% compared with 2017 and 100% of the outdoor lighting on Ports-operated areas has been converted to LEDs (Niedersachsen Port, 2019).

In the following section the benchmark performance of the monitoring issues is provided.

3.7.2. Monitoring issues

The results of the indicators provided in this section support the statement that the culture of monitoring environmental parameters is well-established across the sector. Monitoring consists in characterising the quality of the environment, and it is becoming increasingly important to port authorities since its results confirm compliance, track trends and establish its 'license to operate'. Table 10 shows the percentage that some specific issues are monitored by ports within their monitoring programs.

It is widely acknowledged that monitoring the current state of the elements of air, water, soil, sediments, ecosystems and habitats etc. is essential for assessing the quality of the environment; and but it is

Table 10
Benchmark performance 2020 on monitoring issues.

Monitoring issues	% Yes
Has the port identified Environmental Performance Indicators (EPIs) to monitor trends in environmental performance?	70
Does the port have an environmental monitoring program?	81
Does the program address port waste?	79
Does the program address energy efficiency?	75
Does the program address water consumption?	69
Does the program address water quality?	67
Does the program address air quality?	67
Does the program address sediment quality?	59
Does the program address noise?	54
Does the program address carbon footprint?	52
Does the program address marine ecosystems?	46
Does the program address soil quality?	41
Does the program address terrestrial habitats?	41

also vital to disseminate these results among the stakeholders and the community.

There is an apparent anomaly where 70% of ports state that they have identified appropriate EPIs and yet, 81% of respondent ports declare the existence of a monitoring program. Table 10 shows the priority ranking of indicators that are monitored. The results reflect the significance attached to local indicators and the considerations given to cost and risk-reduction; and environmental quality per se.

Table 11 shows that the environmental issues perceived as significant by the sector are generally well-represented in the list of monitoring programs. Rankings vary but this in itself reflects the inherent generalizations when comparing sector to individual port initiatives. 6 out of the 10 issues are directly monitored, and all are effectively taken into account to some extent or another through direct association e.g. dredging and sediment quality, or port development and soil quality.

As seen previously, climate change is the second top environmental issue of the port sector in 2020, and it is specifically the top priority issue for medium sized ports and for estuary ports. In the recent years, three indicators related to climate change were added to the SDM, which are included and presented in the present paper in Table 12.

It is relevant to mention that half of the respondent ports has already experienced operational challenges related to climate change, and therefore, perhaps unsurprisingly, 71% of ports has considered the adaptation to climate change as part of the new development projects.

With regards to the topic of climate change in ports, a collaborative initiative of the sector is the CLIMEPORT (Mediterranean Ports' Contribution to Climate Change Mitigation) project. This is a European project that involved six ports committed to climate change mitigation. These ports were the Port Authority of Valencia (Spain), acting as a leader of the project, along with the other port authorities of Algeciras Bay (Spain), Marseille (France), Livorno (Italy), Koper (Slovenia) and Piraeus (Greece). The objective of this project was to provide a common

Table 11
Priority issues and monitoring.

Priority ranking	Environmental priority of sector	Monitoring program
1	Air quality	Port waste
2	Climate change	Energy efficiency
3	Energy efficiency	Water consumption
4	Noise	Water quality
5	Local community	Air quality
6	Ship waste	Sediment quality
7	Water quality	Noise
8	Port waste	Carbon footprint
9	Dredging	Ecosystems
10	Port development	Soil quality

Table 12
Benchmark performance 2020 on climate change.

Climate change	% Yes
Has your port experienced any operational challenges that may be related to climate change (e.g. more frequent storms, flooding, changes in wind or wave conditions)?	52
Has your port taken any action to strengthen the resilience of its existing infrastructure in order to adapt to climate change?	65
Has your port considered climate change adaptation as part of new infrastructure development projects?	71

methodology for port authorities and their collaborators in order to assess their initial situation related to GHG emissions (MED, 2012).

3.8. Review and audit

The section of the SDM on review and audit contains 25 questions concerning the environmental audit process including issues that are covered in an audit (e.g. compliance, environmental issues, trends, operators), and the body that conducted it (e.g. local government, own staff, external consultants). A set of five indicators were selected and presented in Table 13.

The highest positive response and perhaps the most significant, is the percentage of ports that have conducted an environmental audit (73%). In the percentages of entities that have undertaken them, it is seen that in most of the cases, they are undertaken by external consultants (64%).

Another relevant issue to analyse in this paper is the number and type of Environmental Management System (EMS) certifications to an internationally recognized standard. Fig. 4 presents the types of Environmental certification schemes that have been awarded. A total number of 63 ports out of the 97 are EMS certified: 40 of them have ISO 14001, 11 have PERS and 1 is certificated under EMAS. Several ports have a combination of certificates: 5 with ISO 14001 and PERS, 1 with ISO 14001 and EMAS, and 5 with the three certifications.

3.9. Services to shipping

This section analyses the extent to which port authorities are influencing and rewarding the development of 'green shipping'. Although this section of the SDM comprises 66 questions, this analysis is based on 9 indicators. The initiatives provided by port authorities to promote green shipping are based on the application of environmentally differentiated port dues in order to reward greener vessels visiting the ports, the provision of Onshore Power Supply (OPS) (in high and low voltage), and the provision of Liquefied Natural Gas (LNG) bunkering facilities.

Out of the three mentioned initiatives, the one that has higher implementation is the provision of Onshore Power Supply in one or more berths (58%), closely followed by the provision of differentiated port dues (57%). The provision of LNG bunkering is currently a green initiative that still has a large margin for improvement (Table 14).

Regarding to OPS initiatives, the Master Plan for Spanish Ports aims at drafting a plan to supply electric power to ships at berth in Spanish

Table 13
Benchmark performance 2020 on review and audit.

Review and audit	% Yes
Has an environmental audit been conducted?	73
Was the audit conducted by external consultants?	64
Was the audit conducted by own staff?	43
Was the audit conducted by Environmental Enforcement Agency?	22
Was the audit conducted by local government?	10

Ports (OPS Master Plan, 2021). It is part of the National Action Framework for the development of infrastructures for the use of alternative fuels in the transport sector (EU Directive 2014/94) (European Commission, 2014). During this Project implementation, pilot cases will be carried out, by including the provision of electrical equipment in piers and ports of general interest, as well as the adaptation of the ships that dock there. In addition, the project will allow the realization of a series of technical studies to identify the barriers that exist today for the implementation of this new and environmentally green technology (OPS Master Plan, 2021).

Another example of good practice related with OPS is in the city of Hamburg. It is pursuing a sustainable improvement of air quality. One major contributor to reaching this goal is the port. The emissions of air pollutants and noise by shipping vessels in close vicinity to the city centre can be reduced by the provision of OPS facilities. Container vessels, as well as cruise ships at berth, will be supplied with CO₂-neutral electricity from the public power grid. By the year 2025 all OPS sites are expected to be in operation and make a significant contribution to achieve the objective to become a carbon neutral port by 2040 and allowing vessel owners to reduce their carbon footprint (WPSP, 2021).

4. Trends over time

The aim of this section is to compare the performance of 2020 (which has been detailed in the previous section) with the performance reported in previous analysis (e.g. Puig et al., 2015, 2017, 2020).

4.1. Environmental management

These indicators provide representative information about the management efforts that influence the environmental performance of the port. Although they are highly recommended indicators to be implemented within the port environmental management plan, they are voluntary initiatives and, therefore they are not considered as legal obligations.

Table 15 presents the percentage of positive responses to the environmental indicators of the present review in 2020, compared with the responses obtained in questionnaires in 2018 (90 participants), 2013 (79 participants), 2016 (91 participants), 2017 (91 participants), in order to analyse the variations over time.

The indicator that has had a higher increase between 2013 and 2020 is the existence of environmental responsibilities of key personnel documented (+14%). In contrast, the indicator that has had a higher decrease is also related to personnel, in this case in the provision of environmental training (−11%). The existence of a certified EMS (+11%) and the publication of a publicly available environmental report (+7%) are also substantive improvements over the previous 7 years.

An Environmental Management Index has been calculated in the previous years based on the ten indicators present in Table 15. This is calculated on the basis of a specific weighting applied to the significance of these key environmental management components. It is argued that this index is particularly appropriate since it is a measure of competence and capability to deliver the environmental imperatives. The Environmental Management Index is calculated by multiplying the weightings associated to each environmental management indicator (see Table 15 and formula below) to the percentage of positive responses. The final score is calculated by applying the following formula:

$$\text{Environmental Management Index} = A * 1.5 + B * 1.25 + C * 0.75 + D * 1 + E * 1 + F * 1 + G * 0.75 + H * 1 + I * 1 + J * 0.75.$$

The numerical value of each letter is the percentage of positive response divided by 100 (e.g. A is 0.65 in the results of 2020 as showed in Table 15). The resulting index for the performance of the port sector is provided in Table 16.

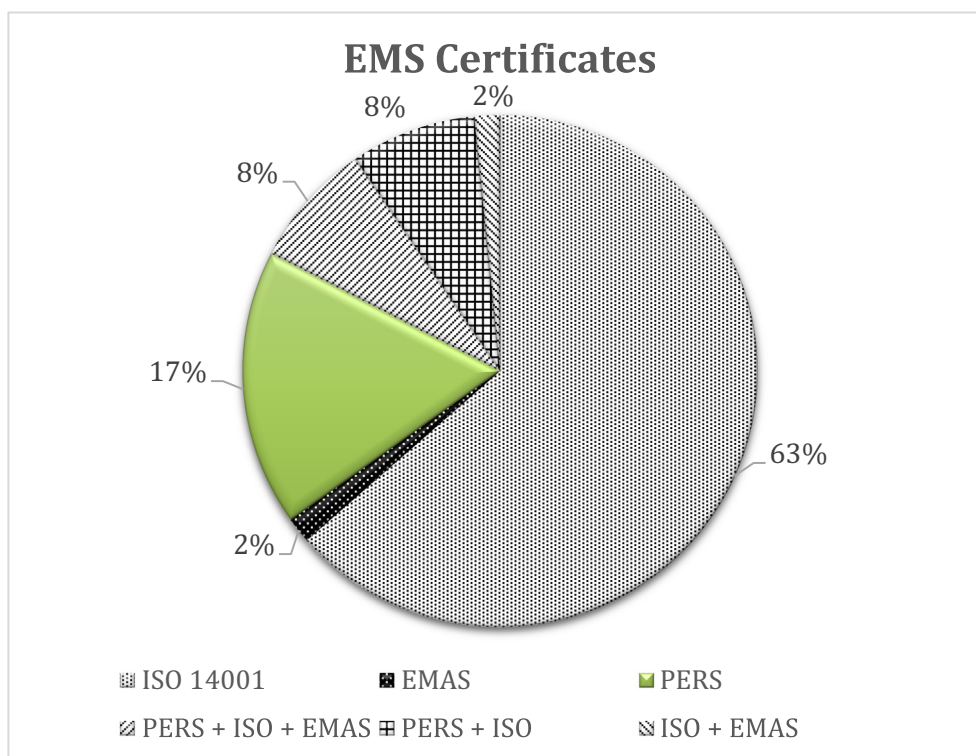


Fig. 4. Types of EMS certificates awarded.

4.2. Top 10 environmental priorities

The second part of this section presents the evolution of the Top 10 environmental priorities of the sector. It is a significant exercise since

Table 14
Benchmark performance 2020 on services to shipping.

Services to shipping	% Yes
Does the port differentiate dues for 'Greener' vessels?	57
Is OPS available at one or more of the berths?	58
If yes, low voltage?	51
If yes, high voltage?	27
Is LNG bunkering available in the port today?	33
- If yes, by trucks?	33
- If yes, by barge?	11
- If yes, through a non-mobile installation?	7
- If no, are there currently ongoing LNG bunkering infrastructure projects in the port?	22

Table 15
Percentages of positive responses to the environmental management indicators.
Source: ESPO (2020b).

Indicators	2013 (%)	2016 (%)	2017 (%)	2018 (%)	2020 (%)	% change 13–20
A Existence of a certified Environmental Management System (EMS) – ISO, EMAS or PERS	54	70	70	73	65	+11
B Existence of an Environmental Policy	90	92	97	96	96	+6
C Environmental Policy makes reference to ESPO's guideline documents	38	34	35	36	43	+5
D Existence of an inventory of relevant environmental legislation	90	90	93	97	91	+1
E Existence of an inventory of Significant Environmental Aspects (SEA)	84	89	93	93	92	+8
F Definition of objectives and targets for environmental improvement	84	89	93	93	88	+4
G Existence of an environmental training program for port employees	66	55	68	58	55	–11
H Existence of an environmental monitoring program	79	82	89	89	81	+2
I Environmental responsibilities of key personnel are documented	71	85	86	86	85	+14
J Publication of a publicly available environmental report	62	66	68	68	69	+7

it shows the priority issues of the sector over the years. This data is important because it identifies the high priority environmental issues on which ports are working and sets the framework for guidance and initiatives to be taken by ESPO. The 2020 exercise on the top 10 priorities comes to complement the results of the previous ESPO surveys that initiated back in 1996, and that are provided in Table 17.

The update on the Top 10 environmental issues confirms that Air quality remains as the top environmental issue of the sector since 2013. This could be attributed to the successive introduction of new legislation and its emergence as a priority issue of concern for citizens of port cities and urban areas in general. It was published that every year, air pollution causes about 400,000 premature deaths in the EU and hundreds of billions of euros in health-related external costs (ECA,

Table 16
Progress of the Environmental Management Index over the years.

	2013	2016	2017	2018	2020
Environmental Management Index	7.25	7.72	8.08	8.08	7.80

Table 17

Top 10 environmental priorities of the port sector over years.

Source: ESPO (2020b).

	1996	2004	2009	2013	2016	2017	2018	2019	2020
1	Port development (water)	Garbage/port waste	Noise	Air quality	Air quality	Air quality	Air quality	Air quality	Air quality
2	Water quality	Dredging: operations	Air quality	Garbage/port waste	Energy consumption	Energy consumption	Energy consumption	Energy consumption	Climate change
3	Dredging disposal	Dredging disposal	Garbage/port waste	Energy consumption	Noise	Noise	Noise	Climate change	Energy consumption
4	Dredging: operations	Dust	Dredging: operations	Noise	Relationship with local community	Water quality	Relationship with local community	Noise	Noise
5	Dust	Noise	Dredging: disposal	Ship waste	Garbage/port waste	Dredging: operations	Ship waste	Relationship with local community	Relationship with local community
6	Port development (land)	Air quality	Relationship with local community	Relationship with local community	Ship waste	Garbage/port waste	Port development (land related)	Ship waste	Ship waste
7	Contaminated land	Hazardous cargo	Energy consumption	Dredging: operations	Port development (land related)	Port development (land related)	Climate change	Garbage/port waste	Water quality
8	Habitat loss/degradation	Bunkering	Dust	Dust	Water quality	Relationship with local community	Water quality	Port development (land related)	Garbage/port waste
9	Traffic volume	Port development (land)	Port development (water)	Port development (land)	Dust	Ship waste	Dredging: operations	Dredging: operations	Dredging: operations
10	Industrial effluent	Ship discharge (bilge)	Port development (land)	Water quality	Dredging: operations	Climate change	Garbage/port waste	Water quality	Port development (land related)

2018). As with the impact of traffic and other industrial activities, air quality has become a key determinant of public “acceptance” of port activity in the years to come. With more than 90% of European ports being urban ports, it is no surprise that port managing bodies have this concern high on their agendas.

Additional pressures driving awareness include EU legislation addressing air pollution related to the implementation of the Sulphur Directive, the new National Emission Ceiling Directive, the introduction of the global 0.5% sulphur cap on marine fuels in 2020, and the IMO NOx Tier III requirements for vessels built from 1-1-2021 operating in the North and the Baltic Seas (NECAs).

Climate change appeared for the first time in 2017 and it gained more importance in the recent years, currently becoming the second Top environmental issue. This seems to follow a general trend in ongoing EU and national policy discussions, as the issue of climate change continues to attract growing political and social attention and concern. This makes compliance with climate legislation, the reduction of carbon emissions and climate-proofing port infrastructure very important priorities for European ports.

In addition, Climate Change is closely interlinked with the third top priority of the sector Energy Efficiency, since one influences the other to a great degree. In that sense, the absolute ranking of top priorities is less significant compared to the fact that these priorities have consistently remained the same over time, indicating the commitment and awareness of ports of the need for collaborative action in the sector on these issues.

Noise, relationship with the local community and ship waste continue in the same position compared to 2019, in fourth, fifth and sixth, position, respectively. Water quality has gained some importance, and port waste, dredging operations and port development (land related) are the ones that complete the chart.

It is interesting to note that the issues identified as the Top 10 environmental priorities have been the same over the last four years (2017–2020). However, their relative positions have changed over time. For example, issue such as Air Quality and Energy consumption

has occupied top positions for many years. The relationship with local community has been in an intermediate position in top 10 since 2009 when it appeared for the first time. Noise has been moved down due to the increasing presence of Climate Change. These changes reflect the tendencies and priorities of the port and maritime sector.

4.3. Environmental monitoring

This section focusses on the evolution of specific components of environmental monitoring. The results obtained consistently since 2013 allow to draw and analyse the variations along this period.

The results demonstrate that air quality has been the indicator with a higher increase (+15%) in environmental monitoring since 2013. It is in line with the increase in port waste (+12%), along with water consumption, water quality and marine ecosystems (all three with +11%). On

Table 18

Percentage of positive responses to environmental monitoring indicators.

Source: ESPO (2020a,b).

Indicators	2013 (%)	2016 (%)	2017 (%)	2018 (%)	2020 (%)	% change 2013–2020
Port waste	67	79	88	84	79	+12
Energy efficiency	65	73	80	80	75	+10
Water consumption	58	62	71	72	69	+11
Water quality	56	70	75	76	67	+11
Air quality	52	65	69	67	67	+15
Sediment quality	56	63	65	58	59	+3
Noise	52	57	64	68	54	+2
Carbon footprint	48	47	49	47	52	+4
Marine ecosystems	35	36	44	40	46	+11
Terrestrial habitats	38	30	37	38	41	+3
Soil quality	42	44	48	38	41	–1

the contrary, soil quality has been the only issue that has not achieved an increase during this complete period (Table 18).

4.4. Services to shipping

This section demonstrates the evolution of the indicators related to services to shipping, as provided in Table 19. In this case, the data on these indicators was obtained for the first time in 2016, when the SDM was updated with the objective of incorporating questions on this topic.

The results demonstrate that this topic is gaining more recognition and uptake in the recent years, especially in the expectations of offering OPS during the next 2 years (+13%) and in the current provision of LNG bunkering in the port (+11%). Concerning environmental differentiated port dues, the forthcoming requirements under the Port Reception Facility Directive (EC, 2019) may have a direct impact on this issue, since its mandates rebate on indirect waste fees for “green vessel”.

5. Conclusions

Despite the difficult current Covid-19 pandemic, the findings of this paper show a general trend of European ports being pro-active in terms of environmental management. There are a significant number of programs and procedures specifically aimed at protection of the environment and sustainable development, and ports are increasingly showing improvement over time when it comes to the key indicators analysed in this study.

Trends in terms of the uptake and application of the key components of a credible EMS, such as the existence of a comprehensive Environmental Policy (96%) and the critically important Inventory of Environmental Aspects (92%), indicate that the significant aspects of environmental management are well-established and consistently applied by respondent ports.

The fact that the performance of some indicators has decreased compared to 2019 has caused a slight decrease in the Environmental Management Index (EMI). However, from a wider perspective, taking into account the scores over the last six years, the EMI is positive and on an overall trend of improvement. Nonetheless, there is a need for additional efforts from ESPO and European ports to ensure that this downward trend is halted and reversed. To this end, the EcoPorts network will continue to provide ports with the necessary tools to improve on key indicators, especially when it comes to becoming certified by an EMS and in creating an inventory of relevant environmental legislation.

With reference to monitoring of environmental issues, port waste and energy efficiency has remained in the top priority positions since 2013. Most of the environmental monitoring programs have increased their percentage of positive responses (i.e. soil quality and marine ecosystems). Air quality is the monitoring issue with the highest increase since 2013.

Concerning the Top 10 priorities, the first environmental priority of the European port sector, Air Quality, has remained the same for the last eight years. Climate change has climbed to the second position, while its first appearance in the ranking was in 2017.

The increasing importance of green services in ports has led to deeper investigation of the three indicators. More than half of the ports offer the option of differentiated fees for ships going beyond regulatory standards. Discounts for ships that reduce their air emissions beyond law limits are the most common ones followed by conducting enhanced waste management on board. Concerning OPS, there has been a rise in the number of ports offering OPS. However, in the case of high voltage OPS the trends are steady, probably due to the taxes that have to be paid to use the electricity and the cost of the infrastructure. In most of the cases OPS is done through fixed installations. There has been a clear increase up to 40% of ports willing to install OPS in the future. LNG bunkering is available today in about one third of the ports, with an increasing trend since 2016. There is now a tendency to move away from fossil fuel due to the need for transition to a carbon neutral economy and a decarbonised shipping sector. In this process, LNG infrastructure could be used for blending and substituting normal LNG for biomethane (bio-LNG) or e-gas. The picture for hydrogen is not so clear, since the use of hydrogen and its derivatives in shipping will require dedicated infrastructure and significant space in the port area. Efforts by policymakers and port managers to decide on specific decarbonisation pathways are made more difficult due to the lack of readily available substitutes for fossil marine fuels, while there are many contenders for the alternative fuel of the future (Deloitte and ESPO, 2021).

For port authorities, the main challenge in the greening process is often the limited influence it can have on many of the activities and operations taking place in the port. Successful greening often requires co-operation between relevant port stakeholders, that do not always have aligned interests. Other challenges to successful environmental management include local, regional, national, and EU legislative barriers or inconsistencies, where port managers balance occasionally conflicting requirements. This involves prioritising the efforts of the port that most effectively meet legal requirements without endangering other relevant environmental considerations.

The results of this paper demonstrate that application of EcoPorts methodology by network members helps port authorities put ESPO Environmental Policies into place. Together with the various iterations of the ESPO Green Guide and other available environmental management tools, the EcoPorts Network continues to both encourage and facilitate the implementation of good practices throughout the sector. The growing network continues to provide essential assistance in delivering on the top environmental priorities of European ports, and is likely to increase in relevance as the environmental imperative becomes an even more significant priority for European port professionals charged with the responsibilities of compliance and sustainability.

CRedit authorship contribution statement

Martí Puig: Writing original draft, graphics preparation, highlights. **Sahar Azarkamand:** Investigation, Formatting, Writing examples, Graphical Abstract. **Chris Wooldridge:** Conceptualization, Writing Introduction & Abstract, Reviewing and Editing. **Valter Selén:** Data obtention, Writing Conclusions and Introductory part. **R. M. Darbra:**

Table 19

Percentage of positive responses to services to shipping indicators.
Source: ESPO (2020b).

Indicator	2016 (%)	2017 (%)	2018 (%)	2020 (%)	% change 2016–2020
Is On-shore Power Supply (OPS) available at one or more of the berths?	53	48	51	58	+5
If YES, high voltage?	38	40	47	46	+8
If YES, low voltage?	90	84	82	88	–2
Does the port plan to offer OPS during the next 2 years?	–	–	27	40	+13
Does the port offer differentiated dues for “Greener” vessels?	62	51	54	57	–5
Does the port plan to introduce environmentally differentiated port dues during the next 2 years?	–	–	–	30	–
Is Liquefied Natural Gas (LNG) bunkering available in the port today?	22	22	30	33	+11
Are there currently ongoing LNG bunkering infrastructure projects in the port?	–	–	24	22	–2

Conceptualization, Supervision, Writing Methodology, Reviewing and Editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors acknowledge the support and coordination of the ESPO secretariat and Stavros Kokosioulis in the process of data compilation from the Self-Diagnosis Method (SDM), as well as the participating ports of this survey.

References

- Asgari, N., Hassani, A., Jones, D., Nguye, H.H., 2015. Sustainability ranking of the UK major ports: methodology and case study. *Transp. Res. Part E Logist. Transp. Rev.* 78, 19–39.
- Barrow, C.J., 2005. Environmental management and development. Routledge Perspectives on Development. Taylor and Francis Group, London.
- Chiu, R.-H., Lin, L.-H., Ting, S.-C., 2014. Evaluation of green port factors and performance: a fuzzy AHP analysis. *Math. Probl. Eng.* 2014, 1–12.
- Comtois, C., Slack, B., 2007. Restructuring the marine transportation industry: global overview of sustainable development practices. *Transportation Systems*.
- Copenhagen Malmö Port (CMP), 2021. Environment. <https://www.cmpport.com/about-cmp/sustainability/environment/>.
- Darbra, R.M., Ronza, A., Casal, J., Stojanovic, T.A., Wooldridge, C., 2004. The self diagnosis method: a new methodology to assess environmental management in seaports. *Mar. Pollut. Bull.* 48, 420–428.
- Deloitte and ESPO, 2021. Europe's ports at the crossroads of transitions. A Deloitte and ESPO Stud. <https://www.espo.be/publications>.
- Denisova, V., 2018. Environmental Sustainability Practices in European Ports. Master Thesis in Economics and Business Administration Energy, Natural Resources and the Environment. Norwegian Schools of Economics. <https://openaccess.nhh.no/nhhxhtmlui/bitstream/handle/11250/2560497/masterthesis.PDF?sequence=1&isAllowed=y>.
- EC (European Commission), 2019. Directive (EU) 2019/883 of the European Parliament and the Council of 17 April 2019 on port reception facilities for the delivery of waste from ships, amending Directive 2010/65/EU and repealing Directive 2000/59/EC. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:JOL_2019_151_R_0004.
- ECA (European Court of Auditors), 2018. Air pollution: our health still insufficiently protected. Special Report N° 23. https://www.eca.europa.eu/Lists/ECADocuments/SR18_23/SR_AIR_QUALITY_EN.pdf.
- Erauskin-Tolosa, A., Zubeltzu, E., Heras-Saizarbitoria, I., Boiral, O., 2019. ISO 14001, EMAS and environmental performance: a meta-analysis. *Bus. Strateg. Environ.* 29 (6).
- ESPO (European Sea Ports Organisation), 1994. Revise 2003. Environmental Code of Practice. ESPO, Brussels. <https://docplayer.net/1663660-Espo-environmental-code-of-practice.html>.
- ESPO (European Sea Ports Organisation), 2005. ESPO Environmental Survey 2004. <https://www.espo.be/media/espopublications/ESPOEnvironmentalSurvey2004-ReviewofEuropeanPerformanceinPortEnvironmentalManagement.pdf>.
- ESPO (European Sea Ports Organisation), 2009. ESPO/Ecoports Port Environmental Review 2009. Available at: <https://www.espo.be/media/espopublications/ESPOEcoPortsPortEnvironmentalReview2009.pdf>. (Accessed 2 April 2021).
- ESPO (European Sea Ports Organisation), 2012a. ESPO Green Guide; Towards Excellence in Port Environmental Management and Sustainability. Available at: ESPO, Brussels. https://www.ecoports.com/assets/files/common/publications/espo_green_guide_october_2012_final.pdf. (Accessed 7 January 2021).
- ESPO (European Sea Ports Organisation), 2012b. European Port Performance Dashboard. Available at: https://www.espo.be/media/espopublications/espo_dashboard_2012.pdf. (Accessed 2 April 2021).
- ESPO (European Sea Ports Organisation), 2013. ESPO Port Performance Dashboard. https://www.espo.be/media/espopublications/espo_dashboard_2013%20final.pdf.
- ESPO (European Sea Ports Organisation), 2016. European Port Industry Sustainability Report. <https://www.espo.be/media/news/EuropeanPortIndustrySustRep2016-dimished.pdf>.
- ESPO (European Sea Ports Organisation), 2017. ESPO Sustainability Report. <https://www.espo.be/media/2017.11.08%20Sustainability%20report%202017%20Review%20final.pdf>.
- ESPO (European Sea Ports Organisation), 2018. ESPO Environmental Report. <https://www.espo.be/publications/environmental-report-2018>.
- ESPO (European Sea Ports Organisation), 2019. ESPO Environmental Report. <https://www.espo.be/publications/espo-environmental-report-2019>.
- ESPO (European Sea Ports Organisation), 2020a. ESPO's Roadmap to implement the European Green Deal objectives in ports. https://www.espo.be/media/ESPO%20Green%20Deal%20position%20paper%20Green%20Deal-FINAL_3.pdf.
- ESPO (European Sea Ports Organisation), 2020b. ESPO Environmental Report. <https://www.espo.be/publications/espo-environmental-report-2020>.
- ESPO (European Sea Ports Organisation), 2021. ESPO Green Guide. <https://www.espo.be/media/11.25%202805%20ESPO%20Green%20Guide%20-%20ESPO%20Conference%20Regatta%20Presentation.pdf>.
- European Commission, 2014. Directive 2014/94/EU. <https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32014L0094>.
- European Commission, 2017. The revised annexes of the EMAS regulations. https://ec.europa.eu/environment/emas/pdf/factsheets/EMAS_revised_annexes.pdf.
- Global Trade, 2021. European Ports. <https://www.globaltrademag.com/european-ports/>.
- González-Laxe, F., Bermúdez, F.M., Palmero, F.M., Novo-Corti, I., 2016. Sustainability and the Spanish port system. analysis of the relationship between economic and environmental indicators. *Mar. Pollut. Bull.* 113, 232–239.
- Iraldo, F., Testa, F., Melis, M., Frey, M., 2011. A literature review on the links between environmental regulation and competitiveness. *Environ. Policy Gov.* 21 (3), 210–222.
- ISO (International Standard Organization), 2015. Environmental Management Systems – Requirements With Guidance for Use. Third edition. <https://www.iso.org/standard/42190.html>.
- LNG Master plan Consortium, 2015. LNG master plan for Rhine-Main-Danube. <https://www.portofrotterdam.com/sites/default/files/Emergency-and-incident-response-study.pdf?token=USaOPou5>.
- Maigret, A., 2014. Sustainability Reporting in the Port Sector. Is GRI the Way Forward? Master Thesis in Environmental Management and Policy. IEEE. Lund University. <https://library.net/document/q0x5ovvq-sustainability-reporting-in-the-port-sector.html>.
- Mazurkiewicz, P., 2004. Corporate Environmental Responsibility: Is A Common CSR Framework Possible. 2. World Bank, pp. 1–18. <https://documents1.worldbank.org/curated/en/577051468339093024/pdf/421830csrframework01PUBLIC1.pdf>.
- MED (Europe in Mediterranean), 2012. ABACUS. A Port Area Energy Consumption and CO2 Footprint Calculation Tool. https://www.programmemed.eu/uploads/tx_ausybibliomed/CLIMEPORT_7_ECO_ABACUS_User_manual_EN.pdf.
- Ng, A.K.Y., Song, S., 2010. The environmental impacts of pollutants generated by routine shipping operations on ports. *Ocean Coast. Manag.* 53, 201–311.
- Niedersachsen Port, 2019. Sustainability Report. https://www.nports.de/media/Unternehmen/Nachhaltigkeit/NPorts_Sustainability_Report_2019.pdf.
- OECD (Organisation for Economic Co-operation and Development), 2011. Environmental Impacts of International Shipping: The Role of Ports. OECD Publishing.
- OPS Master Plan, 2021. OPS Master Plan for Spanish Ports project. http://poweratberth.eu/?page_id=219&lang=en.
- Peel Ports Group, 2020. Environmental Policy Statement. <https://www.peelports.com/media/6285/pol-030-pgg-hse-environmental-policy-display-40.pdf>.
- Port Authority of Valencia, 2020. Port of Valencia – strategy towards zero emissions by 2030. <https://sustainableworldports.org/project/port-of-valencia-strategy-towards-zero-emissions-by-2030/>.
- Ports de la Generalitat, 2020. Ports de la Generalitat quality and environmental policy. <https://ports.gencat.cat/en/quality-control-and-environmental-policy>.
- Puig, M., Wooldridge, C., Michail, A., Darbra, R.M., 2015. Current status and trends of the environmental performance in european ports. *Eur. Sci. Policy* 48, 57–66.
- Puig, M., Michail, A., Wooldridge, C., Darbra, R.M., 2017. Benchmark dynamics in the environmental performance of ports. *Mar. Pollut. Bull.* 121, 111–119.
- Puig, M., Raptis, S., Wooldridge, C., Darbra, R.M., 2020. Performance trends of environmental management in European ports. *Mar. Pollut. Bull.* 160, 1–11.
- Rume, T., Didar-Ui Islam, S.M., 2020. Environmental effects of COVID-19 pandemic and potential strategies of sustainability. *Heliyon* 6 (9), e04965.
- UNCTAD, 2020. COVID-19 and Maritime Transport: Impact and Responses. Transport and Trade Facilitation Series. No. 15. <https://unctad.org/webflyer/covid-19-and-maritime-transport-impact-and-responses>.
- Winnes, H., Styhre, L., Fridell, E., 2015. Reducing GHG emissions from ships in port areas. *Res. Transp. Bus. Manag.* 17, 73–82.
- WPSP (World Port Sustainability Program), 2021. Hamburg Port Authority – Onshore Power Supply (OPS). <https://sustainableworldports.org/project/port-of-hamburg-onshore-power-supply-ops/>.
- Wright, P., 2013. Impacts of climate change on ports and shipping. *MCCIP Sci. Rev.* 263–270.
- Zambrano-Monserrate, M.A., Ruano, M.A., Sanchez-Alcalde, L., 2020. Indirect effects of COVID-19 on the environment. *Sci. Total Environ.* 2020, 138813.