Anthropocene Coasts

TOPICAL COMMUNICATIONS

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Enhancing the Anthropocene coastal infrastructure sustainability using the approaches developed by the London Convention and Protocol

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Abstract

The water's edge is a critically important and efficient location to trade with other partners by connecting inland water channels and sea lanes and to obtain food provisions from the biologically diverse and productive sea. Human civilization has built around the ports and harbors by constructing fixed structures to support waterborne transport and enhance or sustain city functions for millennia. These artificially fixed structures are not in natural equilibrium with the environment (water and sediment). Access channels and the sea bottom adjacent to piers are often dredged to accommodate larger ships. Bottom sediment dredging is a part of port management. Where to place the dredged material is of primary concern for port authorities because of its sheer volume and the potential to be chemically contaminated. The London Convention and the London Protocol (LC/LP) are international treaties that provide a process in preventing pollution from dumping of contaminated material at sea, and finding sound alternatives such as confined disposal facilities, and using clean dredged material in wetland creation or beach nourishment, based on the precautionary approach. The Anthropocene (Anthropocene refers to the most recent period in Earth's history when human activity started to impact significantly on the climate and ecosystems.) coast of ports, harbors, wetlands, shorelines, and beaches of the coastal megacities faces tremendous challenges in managing navigational and shoreline infrastructure in view of sea level rise and climate change. Dredged sediments are a resource and are a key to protection of shorelines. The benefits of being members of the LC/LP treaties are that there is a wealth of various national experiences on sediment management available via the network of LC/LP national experts and in the records of the LC/LP's Meetings of Contracting Parties.

Keywords Dredged material, Sediment management, Climate change, Navigational infrastructure, Wetland creation, London Convention and London Protocol

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1 Introduction

Nature's contribution to the people may be most salient along the coasts, river mouths, estuaries, and harbors. Humans have taken advantage of instant access to the food provisions provided by salt and freshwater bodies and trade opportunities with vessels. Large-scale urbanization on the seashore started with the appearance of human civilization and continues today around the globe. Jetties, piers, seawalls, and other infrastructure have been replacing the natural coastlines. For example, about 36%, 44%, 67%, and more than 90% of the total length of coastline consist of some form of artificial structure in South Korea, Japan, China, and the Netherlands, respectively (Ma et al., 2014; Hou et al. 2016; de Ruig 1998; Brand et al. 2022). Engineered structures for navigation, recreation, coastal protection, and wetland creation now occupy more than 53% of the coastline associated with thirty coastal urban centers in Australia, Canada, New Zealand, U. K., and the U.S. A portion of artificial coasts are forecasted to increase up to 76% relative to 2018 extent within the next 25 years in those countries (Floerl et al. 2021). Therefore, these shorelines can be characterized as an Anthropocene coast.

Portus Cosanus pier was constructed in Orbetello, Italy, in 273 BC and is still operational. The seawalls were built to protect the inland activities of Istanbul (203 AD) and remain today (Jackson et al. 2017). Qin Dynasty (221 to 206 BC) and following dynasties (e.g., Han, Liang, Wu, Yue, Song, Ming) continued to build seawalls to counter the incoming tidal wave from the sea (Wang et al. 2012). Seaports are an economic catalyst by supporting trade flows, generating wealth through creating added value, providing high-quality employment opportunities, and generating fiscal revenue and investment. In addition, they provide services to ships (dredging, pilotage, mooring/unmooring, berthing, repair and maintenance, supply, and bunkering) and services to cargo (stowing, loading, discharging, storage, distribution). Naturally, seaports have grown steadily to become key clusters of economic activity, and many have grown into metropolitan cities. Geographical concentration of cargo flows, trade, and industrial production often exhibit a large scale of economy and higher connectivity to the rest of the world. Therefore, coastal megacities may be characterized as densely populated and highly connected to their external partners. High connectivity and constant exposure to new external partners through R&D and universities promote innovation and collaboration (e.g., Ozer and Tang 2019; Lassen and Laugen 2017).

High population density is known to lead to a greater exchange of ideas and skills and prevents the loss of innovations (Powell et al. 2009). Megacities further fuel economic productivity, particularly in creative industries where sharing information and ideas are core parts of the production process (e.g., Abel et al. 2011). Among 33 megacities (population of more than ten million), 22 are located on the coast (UN 2018). Tokyo, Shanghai, Cairo, Mumbai, Osaka, New York-Newark, Karachi, Buenos Aires, and Istanbul are the top ten most populous coastal cities. The 22 coastal megacities supported 0.35 billion residents as of 2018. These coastal cities are likely to continue to develop various traditional and climate-related coastal infrastructures. Coastlines around the urbanized cities are populated with waterborne navigational infrastructure (port and harbor structures), engineered wetlands and public beaches, and various defense structures against saltwater intrusion, sea level rise, and increased storm surge events. The frequency of high-tide flooding at coastal cities has been observed to increase in recent decades due to sea-level rise and atmospheric pressure changes (Li et al. 2022). More creative approaches are needed to sustain the large population, and industrial activities, and to protect the built structures of port cities amid rapid climate changes.

The constantly increasing pressure from human activities in the coastal zone requires a regulatory framework to assess and control any activity that could impact this critical environment and its resources. The LC/LP has a long history in preventing the pollution from the dumping of wastes and other matter at sea through a thorough global regulatory framework, but in doing so also establishing a process that provides assessment tools and solutions for use of dredged material. Coastal states are urged to access and utilize that technical and scientific expertise. One element within the LC/LP framework for protection and enhancement of our shorelines and navigational infrastructure is to recognize dredged material as a resource, and evaluate its use for shoreline protection, such as building wetlands, sand dunes, and nourishing beaches.

2 The London Convention and the London Protocol

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (LC) was agreed in 1972 at an intergovernmental diplomatic conference hosted by the United Kingdom. Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matters including dredged material. The London Protocol (LP) is the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (LC). The LP was designed to build on and update the LC based on the evolution of the 1972 LC towards precautionary and prevention

Fig. 1 Most repeated words in the meetings of the LC/LP scientific groups in 2004-2020 based on the meeting reports

approaches and taking into account the outcomes of the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil in 1992. It will eventually replace the LC. (Hong and Lee 2015). Therefore, the LP is used throughout the text to represent the LC and the LP. Today, the two treaties have 100 Contracting Parties together.

Meetings of Parties to the LC/LP, particularly their joint sessions of the Scientific Groups (SGs) have dealt extensively with dredged material/sediment issues arising from port development and operation, coastal wetland creation, and beach nourishment. The most repeated/recurrent agenda items in the SG meetings are dredged material, sediment management, habitat enhancement, and beach nourishment (Fig. 1).

Sediment management issues are dealt largely in 3 agenda items of the annual Scientific Groups meetings: waste assessment guidance, monitoring and assessment of the marine environment, and habitat modification and enhancement. Other topics addressed include agenda items such as reporting on dumping permits and guidelines, manuals, bibliographies, and information exchange. Each year about 12 documents related to dredged material and sediment management are submitted to the Scientific Groups meeting for the purpose of sharing national experiences. They account for 20 to 50% of the total submissions (Fig. 2). Supplement 1 includes a list of of selected documents related to the sediment management submitted to the annual meetings of the Scientific Group of the London Convention and Protocol (2004–2022). These documents are available on the IMO website for LCLP members.

2.1 Scientific groups

The Consultative Meeting of Contracting Parties to the LC was confronted with several scientific issues at the first meeting in 1975. The assessment of waste is a pre-requisite to developing sound waste management options, and assessment activity is highly scientific and technical. In the first meeting of the Contracting Parties, several delegates called for an expert group on scientific and technical matters (LDC (8) (imo.org)) and established a separate ad hoc "Scientific Group" in the first Consultative Meeting in 1976 (LDC I/16, paragraph 88). The Group started to meet and generate its meeting reports from September 1977 onwards to provide scientific and technical guidance to the Consultative Meeting of Contracting Parties (LDC II/11 (imo.org)). Their recognition of the role of science in sustainable development is much earlier than the current recognition in international bodies (e.g., UNESCO Basic Science for Sustainable Development). The interpretations of "harmlessness", "trace contaminants", "significant amounts," and "de minimis level" were some of the items required for scientific scrutiny before policy decisions could be made. The Scientific Group initially met two days in conjunction with the annual Consultative Meeting of Contracting Parties, however, it grew quickly to have a 5-day meeting beginning in 1981 (LDC V/12) due to the significant amount of workload requested by Parties. Following the entry into

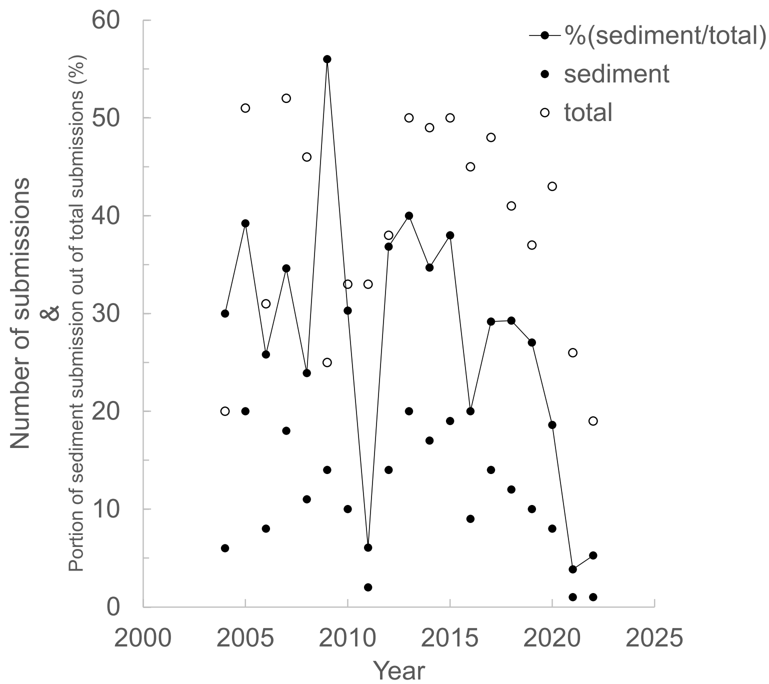

Fig. 2 Number of submitted meeting documents about the dredged material (sediment) management and percentage of dredged material (sediment) among total submissions t to the annual scientific group meeting from 2004 to 2022

force of the London Protocol in 2006, the two Scientific Groups (LC and LP) now meet jointly every spring separately from the Meetings of Parties to the LC and LP that occurs in the autumn. As this text focuses on the London Protocol as the more modern and forward-looking treaty, the LC and LP form part of a global framework that has co-developed over the last decades. Therefore, when referring to the LP we implicitly also include the LC, where relevant.

2.2 Waste assessment guidance

The LP text provides a methodology for national administrations to issue a permit for the disposal of waste or other matter in the marine environment (LP Article 4). The precautionary approach, polluter pay principle, and obligation not to transfer damage or likelihood of damage from one part of the environment to another, or transform one type of pollution into another are the overarching obligations of the parties (LP, Article 3). The issuance of permits and permit conditions need to comply with provisions of Annex 2 of the treaty. Annex 2 is the generic assessment guideline for all waste streams or other matter to be considered for dumping at sea. Under the obligations to make attempts to reduce the necessity for disposal of wastes at sea, the generic waste assessment guidance in Annex 2 set forth the steps that administrations are expected to carry out to issue a permit for disposal:

1) Waste prevention audit.
2) Consideration of waste management options.
3) Chemical, physical, and biological properties of the waste.
4) Action list.
5) Dumpsite selection.
6) Assessment of potential effects.
7) Monitoring.
8) Permit and permit conditions.

One particular area to point out in the assessment and management of dredged material is that Annex 2 of the LP states that "the goal of waste management for dredged material should be to identify and control the sources of contamination." This requirement should be achieved through the implementation of waste prevention strategies and requires collaboration between the relevant local and national agencies involved with the control of point and non-point sources of pollution. Until this objective is met, the problems of contaminated dredged material should be addressed by using disposal management techniques at sea or on land (LP Annex 2.4). The effectiveness of pollution control legislation in reducing sediment contamination over time was evidenced, and fewer incidences of contamination with toxic substances were recorded in the recently deposited sediment in the North Sea (Logemann et al. 2022).

2.3 Capacity development

The LP Parties have adopted a constructive and facilitative compliance mechanism instead of the classic punitive dispute settlement to correct the potential noncompliance issue encountered over the years. The LP recognized that scientific and technical research would play an important role in preventing, reducing, or eliminating pollution by waste disposal (LP Article 14). It further recognized that the national capacity to observe, measure, evaluate, and analyze pollution scientifically is of paramount importance to achieve the aim of the treaty, which is protection of the marine environment (LP Article 2). The Scientific Group has developed various technical guidelines to assist the parties to comply with the LP requirements, such as low-technology low-cost environmental monitoring, low-technology low-cost compliance monitoring, low-technology low-cost for assessment of dredged material, and development of action levels for dredged material. In addition, Contracting Parties have produced a detailed and practical guidance and training set over the years with the LC/LP Secretariat. Those resources are available through the IMO website (e.g., Waste Assessment Guidance Training Set, https://www.imo.org/en/OurWork/Environment/Pages/wag-default.aspx).

3 Dredged material assessment guidelines

From the second meeting (LDC 11/12), the Parties discussed the need to test chemical contaminant levels in dredged material to avoid any harmful effects that might occur in the placement or dumping at sea. Other scientific aspects of the disposal of dredged material have also been discussed from those early meetings which continue today (LDC v/12). A format for the notification of permits for dredged material was also developed in LDC VI/12 (1981). Guidelines for the application of Annex III to the LC (characteristics and composition of the matter, characteristics of dumping site and method of deposit, general considerations, and conditions) were adopted in 1984 (LDC 8/10).

Subsequently, in 1985 Parties felt that specific guidelines for the disposal at sea of dredged material (and other waste materials) was needed. Dredged material was not a primary source of contaminants and the long-term solution to the control of pollution from dredging requires the identification and control of the sources of contamination from land-based point and non-point sources. In 1986 Parties adopted the Guidelines for the Application of the Annexes to the Disposal of Dredged Material at Sea subject to regular five-year review by reflecting experience gained by the parties and the advancement of science and technology related with the management of dredged material. Several delegations also called for the Scientific Group to develop specific monitoring guidelines for the Contracting Parties in 1989.

In 1992, Parties adopted the Waste Assessment Framework (WAF) to provide an assessment procedure to implement the Annexes and the technical portions of the LC. The WAF constituted a framework for use by regulatory agencies in assessing the suitability of waste for disposal at sea (LC 15/16). Parties replaced the 'Guidelines for the application of the annexes to the disposal of dredged material' with a new "Dredged Material Assessment Framework (DMAF)" in 1995 (LC18/11/Rev.1) to address existing and future requirements under the treaty clearly and concisely.

The Dredged Material Assessment Guidelines adopted in 2014 replaced the DMAF to provide additional clarification to enable compliance with Annex 2 of the London Protocol. It recognized sediment as an important natural resource, and an essential component of freshwater, estuarine, and marine ecosystems. It also includes habitat restoration and development, sustainable relocation by retaining sediment within the natural system to support sediment-based habitats, shoreline and infrastructure, beach nourishment, shoreline stabilization, and protection through the placement of dredged material with the intent of maintaining or creating erosion protection, dyke field maintenance, berm or levee construction, and erosion control. The Scientific Group reviews it periodically and updates it accordingly.

4 Sediment as natural and economic resources

The physical, economic, and social infrastructures and their assets are highly interconnected and interdependent and form infrastructure networks and systems. The efficiency of these networks determines the quality of a given economy (e.g., HM treasury 2015). Infrastructure projects can take many years to develop and complete. Individual structures are location specific, however, the LP experience could provide insight into the development and maintenance of ports and navigational facilities, navigational waterways, waste management policies, waste disposal systems, urban flood control waterways, and coastal features as discussed above.

The valuation of natural capital that underpins coastal marine ecosystem services such as food, energy, material, aesthetic beauty, climate mitigation, and waste removal emerged around the 1990s (e.g., Costanza et al. 1997; The Millennium Ecosystem Assessment (MEA), 2005); Costanza et al. 2014) and accounting that natural capital became a part of UK's national environmental accounts in 2012 (UK 2022). The concept of natural capital was later expanded to nature's contributions to people (NCP) by the newly established Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (Pascual et al. 2017; IPBES 2019). IPBES (2019) rightly recognized that most of nature's contributions are co-produced with people or can be enhanced using scientific knowledge, physical, economic, and social infrastructures, and financial resources. Creation or restoration of coastal wetlands using dredged material is one of them.

The encouragement of beach nourishment and wetland creation already exists in the dredged material WAG and LP annex 2 (such as Article 1 of annex 2[1]). The beneficial use of wastes, in particular, dredged material, has been a long-standing agenda item of the governing bodies and the Scientific Groups for many years, as a means to share information, and experiences and promote the re-use and beneficial use of wastes as well as experiences with habitat enhancement activities. In 2021 the Scientific Groups established a Correspondence Group to develop a document synthesizing relevant information relating to the state of the practice for beneficial use of LC/LP waste streams and to provide recommendations to the Groups on how the LC/LP could further encourage beneficial use of waste materials and habitat enhancement activities (LC/SG 44/16, paragraph 9.). In 2022, a one-day symposium held by the Scientific Groups on the topic of "Alternative uses of waste" is worth noting at https://www.imo.org/en/OurWork/Environment/Pages/ScienceDay-default.aspx.

Beneficial use of dredged material, such as habitat creation and coastal protection, carries social/management aspects. Restoring water flow by dredging and creating habitat using dredged material boosted the local economy, ecosystem, fishing, tourism, and birding in Cedar Bayou, Aransas County TX, USA, https://www.aransascounty.org/happenings/cedar-bayou-kick-off-event/, is one of many examples. The US Army Corps of Engineers' website (https://budm.el.erdc.dren.mil/) dedicates the beneficial use of dredged material with several case studies. USEPA recently developed a Dredged Materials Management Tool (DMDT) to help communities characterize and quantify the environmental and social benefits of using dredged material (https://www.epa.gov/research/dredged-material-decision-tool-dmdt). Central Dredging Association (CEDA) also has a set of beneficial use case studies (https://dredging.org/ceda-environment-commission/134).

Dredging and dredged material management are also part of multilateral agreements, e.g., OSPAR, HELCOM, and EU Directives. ICES has a working group dealing with marine aggregate (sand and gravel) extraction (https://www.ices.dk/community/groups/pages/wgext.aspx). The sustainability of sands is recently addressed by UNEP such as "Sand and sustainability: finding new solutions for environmental governance of global sand resources (https://wedocs.unep.org/handle/20.500.11822/28163) in 2019 and "Sand and sustainability: 10 strategic recommendations to avert a crisis ((https://www.unep.org/resources/report/sand-and-sustainability-10-strategic-recommendations-avert-crisis) in 2022. A few cases recently reported in the LC/LP meetings are elaborated on here for illustrative purposes.

4.1 Wetland creation

The Wallasea Wetland Creation Project of the UK was brought to the Scientific Groups meetings in 2007 and 2008 as an example of beneficial use of clean dredged material. Harwich Haven port authority provided the mud (dredged material) needed to restore and create wetlands (> 700,000 tons) (LC/SG 30/INF.10; LC/SG 31/INF.5). The project created a 115-hectare intertidal area of saltmarsh, islands, and mudflats that provides mature vegetated landscape and migratory birds habitats. Subsequently, the Wallasea Island Wild Coast Project transformed an additional 170 ha of arable land into a mix of lagoons, saltmarsh, and mudflats. This was done using clean clay from the Crossrail tunneling project brought to the site by ship (https://www.rspb.org.uk/our-work/casework/cases/wallasea-island/). Another example is in the US: a long-distance conveyance (> 16 km) project was reported to transport dredged material to create coastal wetlands along the coast of the Gulf of Mexico (LC/SG 35/INF.17).

The value of tidal marsh/mangroves has increased from USD 13,786 $ha^{-1} yr^{-1}$ in 1997 to USD 193,843 $ha^{-1} yr^{-1}$ in 2011 due to the better recognition of their values derived from the outcomes of scientific research activities (Costanza et al. 2014). The national greenhouse gas inventory has allowed to include coastal wetland contribution in 2013 (IPCC 2013), and a few countries have started to report its contribution to the UN since 2017 (Crooks et al. 2018). Coastal wetlands are increasingly viewed as a viable nature-based climate solution. Blue carbon refers to the organic carbon stored in seagrass beds, salt marshes and mangroves. Restored tidal saltmarsh exhibited a factor of two larger carbon storage than the natural ones (Yang et al. 2020) provided that those sedimentary organic carbon stays in situ > 100 years (Williamson and Gattuso 2022). Therefore, the economic value of the coastal wetlands is likely to increase over time as scientists will find more benefits offered to people.

[1] The annex asks Contracting Parties to observe the overarching principle to avoid dumping as much as possible, "1 The acceptance of dumping under certain circumstances shall not remove the obligations under this Annex to make further attempts to reduce the necessity for dumping." This precautionary obligation prompts the Parties to seek the beneficial use of dredged material.

4.2 Beach nourishment

Coastal beaches and dunes are increasingly recognized as natural capital. Their ecosystem services and economic services, such as providing habitats for many biological organisms (e.g., birds and turtles), aesthetic beauty, and storm damage reduction to inland properties are well known (e.g., Stronge 2021). Beaches and dunes are subject to be eroded due to sea level rise and extreme weather events.

Hence, Parties to the LC/LP have discussed creative shoreline protection measures. According to the Dutch delegation in 2012, large parts of the Dutch coast are eroding. Dutch authorities (Rijkswaterstaat and the Provincial Authority of South Holland) adopted the Sand Motor to circumvent regular 5-year beach nourishment of about 2–5 million m^3 of sand with a 20-year nourishment scheme. Frequent beach nourishment disturbs the coastal ecosystem. The Sand Motor project dredged sand from 10 km offshore area using trailing suction hopper dredgers. It piled up sand 5 m above the sea level and constructed a hook-shaped peninsula of above 21.5 million m^3 of sand at the coast and let waves, winds, and tides redistribute those sands along the Delfland coast of the Netherlands.

Beaches are also a prime factor influencing the attractiveness of coastal tourism destinations around the world. The quality of the sand beach is directly related to the number of visitors (Torres-Bejarno et al. 2016). For example, the coral atolls and pristine sandy beaches of Maldives attract more than one million visitors a year that spend more than 9 million nights a year and grow about 6.8% every year. Tourism accounts for more than a third of government tax revenue. Tourism industry is a primary revenue sources to the inhabitants of the island (ESCAP 2019). International tourism contributed around 34% to the national GDP of Fiji (Fiji 2022).

Innovative solutions to protect shorelines from coastal flooding due to sea level rise and storm surges, such as mimicking natural and nature-based features (NNBF) and engineering with nature (EWN), have been brought out by the Parties. Parties also shared their experience on the performance of those structures, funding, policy, co-production with stakeholders, implementation, long-term monitoring, and learning at the Meeting of Parties (e.g., Palinkas et al. 2022). Sharing the experience of Parties to the LP is very helpful for those administrations responsible for beach and shoreline management. Many practical guidelines are also available and continue to be updated by reflecting the advancement of science and technology and emerging best management practices. Industry observers of the World Organization of Dredging Associations, The World Association for Waterborne Transport Infrastructure (PIANC), International Association of Ports and Harbors (IAPH) have brought their expertise to SG meetings on a regular basis.

As the above discussion has attempted to illustrate, the LC/LP experience could assist such activities, both as a regulatory framework to ensure that activities are carried out in line with the global standards, but also as a forum where expertise and experiences on approaches related to coastal infrastructure projects are shared. The Waste Assessment Guidelines also provide a structured approach to critically analyzing options for waste management, promoting beneficial use and only allowing dumping at sea as a limited and highly regulated option. The electronics age of information sharing has greatly enhanced the ability of parties to the LP to benefit from the guidance and technical and scientific expertise that is willingly shared with other Parties. Supplement 1 includes an extensive list of documents related to the sediment management submitted to the annual meetings of the Scientific Group of the LCLP. These documents are available on the IMO website for LCLP members.

5 Benefits of membership in the LP

Benefits of the LP range from better administrative regulation of wastes and sea disposal activities, economic gains through better protection of the marine environment, to social and political benefits to support various UN Sustainable Development Goals and to shape future global regulations of the marine environment. Examples of the benefits offered by the LP are further elaborated in "The London Protocol: What it is and why it is needed" and "Benefits of being a party to the London Protocol" and other LP documents on the IMO web (https://www.imo.org/en/OurWork/Environment/Pages/London-Convention-Protocol.aspx). The benefits may include 1) providing practical regulations that address the prevention of marine pollution from dumping activities and new marine activities (e.g., carbon sequestration and marine geoengineering), 2) offering guidance and best practices to address deposits into the marine environment that are done for a purpose other than disposal (e.g., placement activities like artificial reefs), 3) allowing parties to access to a wealth of practical tools, scientific information, and expertise to support the implementation of the London Protocol (e.g., generic waste assessment guidelines, specific assessment guidelines for various waste streams, monitoring guidelines, training tools, low technology low-cost guidance, etc.), 4) enabling parties to build trade relationships from an international level of environmental protection, and 5) providing opportunities as being a Party to the London Protocol to influence future international regulation in the area of marine environmental protection.

6 Need for increased membership for Countries along the Indian and Pacific Oceans

According to the United Nations Conference on Trade and Development (UNCTAD 2022), Asia is the leading maritime freight area in the world. Asian ports loaded around 4.4 billion tons of goods, amounting over 41.3% of total goods loaded in ports worldwide. About 7.0 billion tons, equivalent to 65.5% the world total goods discharged worldwide, were received by Asian ports in 2020. In 2020, developing economies still accounted for the largest share of global seaborne trade. They loaded 59.5% and discharged 69.5% of the world total. Therefore, ports in Asia (East to the West), the Pacific and Africa are expected to need to be enlarged over time, including maintenance and deepening of navigation channels. To address economic needs and sea level rise, the length of the engineered coastal lines in these regions will become longer and will require sound sediment management measures. However, the number of parties to the LP are conspicuously small in the rims of the Indian Ocean and the islands states in the Pacific Ocean (IMO 2022; Zou and Zhang 2017).

With the continued expansion of trade and human activities in this region, extending the membership to the London Protocol, managing waste disposal into ocean waters and sharing the experiences within and between regions should remain a priority. These efforts should also contribute to achieving the Sustainable Development Goals and the 2030 Agenda for Sustainable Development.

7 Conclusions

The London Convention and Protocol (LC/LP) were established to address uncontrolled waste dumping in the sea, including port and port city-related waste issues, in the 70 s and 90 s, respectively. As ports and port cities grew with time, the scale of dredged material from the navigational infrastructure became greater. The concurrent losses of beach and coastal wetlands become more evident. The economic and cultural values of beaches and wetlands have been increasingly appreciated in recent decades. Dredged material is a resource, especially in these challenging times of climate change and sea level rise. Removing contamination sources of dredged material increases the potential for beneficial use in the protection of shorelines and beaches and the enhancement of wetlands using dredged material. By developing dredged material assessment guidelines and sharing experiences dealing with dredged material, the governing bodies for the LC/LP and in particular the Scientific Groups have spearheaded to enhance of the functions of the Anthropocene coast and increased their economic and environmental value and their longevity. The meetings under the LC/LP are interdisciplinary (scientists, industry, and government sectors) knowledge center on sediment management. They directly contribute to the UN Sustainable Development Goals (e.g., sustainable cities and communities, climate action, life below water, life on land, and partnerships for the goals). The authors strongly recommend all non-LP Parties join the LP and make full use of the network of LC/LP national experts and the meeting documents for coastal public works.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1007/s44218-023-00022-w.

Additional file 1: Supplement 1. List of selected documents related to the sediment management submitted to the annual meetings of the Scientific Group of the London Convention and Protocol (2004-2022). These documents are available on the IMO website for LCLP members.

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Authors' contributions
GiHoon Hong conceived the manuscript and draft most parts of the manuscripts. Christopher Vivian provided UK examples and treaty experiences. Craig Vogt provided dredging industry perspectives and US examples. Fredrik Haag provided the international treaty perspectives and current international meeting discussions relevant to the coastal infrastructure. Fang Zuo provided developing economies perspectives from the Indian and Pacific Oceans. Kai Qin provided statistical analysis. All authors contributed to refine the manuscript several times collectively before finalizing it. The author(s) read and approved the final manuscript.

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Declarations

Availability of data and materials
All are open access materials.

Competing interests
The authors declare that they have no competing interests.

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