Global impacts of COVID-19 on sustainable ocean development

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The abrupt outbreak of coronavirus disease in 2019, also known as COVID-19, has led to an unprecedented global public health crisis. Current studies have paid immense attention to the impacts of COVID-19 posed to the atmosphere and the land-based sectors in areas such as air quality, carbon emission, economic sentiment, educational and social equality, etc. It is depicted that carbon emission had dropped about 8.8% in the first half of 2020 compared to 2019, significant reductions of air pollutants such as PM2.5 and NO2 were moreover reported at national, regional, and global levels. On the flip side, the amount of attention paid to the ocean during this pandemic has been nearly negligible despite its prominent functions of supporting livelihoods for 40% of the global population, absorbing ~30% of anthropogenic CO2 emissions, and processing over 90% of excess heat in our climate system. Both direct and indirect effects of the pandemic are insufficiently understood in the ocean, which include their key roles in blue carbon sequestrations, ocean-atmosphere and ocean-land interactions, sea-level changes, and their impacts to human beings.

To control the rapid spread of COVID-19, a range of measures have been taken by governments around the world, including lockdowns, travel restrictions, work-from-home policies, and school closures. Although the world had experienced decline of productivity in light of the added constraints on manufacturing sectors, the ocean enjoys a rare recuperating period to restore its ecological functions. Globally, countries have gone through different stages of the pandemic with various levels of policy stringency, so the implications of COVID-19 for the ocean vary across space and sectors (Figure 1). Despite challenges ahead, this is a great opportunity to chart a sustainable path to preserve healthy ecosystem services and perform a stable output in socio-economic development.

EFFECTS OF THE COVID-19 PANDEMIC ON MARINE ENVIRONMENTAL DIMENSIONS

As more people reside in highly urbanized coastal cities, the marine ecosystem suffers with mounting environmental burdens. However, the COVID-19 lockdown or restriction has slowed down a lot of human stressors such as nutrients, CO2, noise, odor, and litter disposal on beaches and coastal waters. Globally, a cooling response of 0.5°C in mean sea surface temperature was observed over most of the coastal regions that resulted from the CO2 reduction, associating with a prominent decrease in chlorophyll-a concentrations of the coasts around Alaska, North Europe, South China, and Southeast USA.2 Improved coastal water quality, cleaner beaches, enhanced fish density, and reduced underwater noise have been reported in most countries. As the nationwide quarantine in Italy started, Venice’s usually dark, murky waterways were observed with improved water transparency and less containment due to the decreasing number of tourists and motorboats. Besides, marine traffic and other non-essential activities near the coasts had a huge reduction, contributing to the decrease in the levels of underwater noise and water turbidity, the improvement in benthic ecological status, and the enhancement of marine species density. It was found that fish and dolphins had a 65% increase in their communication ranges. In Polynesia, the overall reef fish density increased by 143%, while the density of the commonly harvested species increased by 215% due to relieved pressures. Furthermore, the decrease of maritime transportation intensity has also contributed to the reduction of ship-based greenhouse gas emission. However, multiple waves of COVID-19 outbreaks have been sweeping across the world vigorously, restricting the conduction of...
systematic field surveys and leaving fewer scientific budgets allocated to marine conservation. Moreover, the increase of medical waste along with the number of confirmed cases has been worrisome. As indicated, 350 billion face masks were used in Asia and Europe annually. More than 25 thousand tons of pandemic-associated plastic waste have been discharged into the ocean, including medical wastes from hospitals, personal protection equipment (e.g., face masks, gloves), and delivery packages from online shopping. The pandemic-associated wastes, such as discarded face masks and gloves, are moreover sources of microplastics. As coastal waters are the ultimate sinks for municipal waste and sewage, these pollutants, as well as potential pharmaceutical residue, are posing immense disturbances to the blue carbon ecosystems, such as the fauna and flora in the mangrove forest, thus reducing the ocean’s capacity as the largest active carbon sink on Earth for climate change mitigation. Combining the benefits from decreased marine traffic and the disturbances from marine pollution, the ecological impacts of COVID-19 to the ocean remain complicated, unclear, and underexplored.

**EFFECTS OF THE COVID-19 PANDEMIC ON MARINE SOCIO-ECONOMIC DIMENSIONS**

During the COVID-19 lockdown period, fishers, laborers, and other workers of the fisheries value chain suffered from income reduction, economic loss, and unemployment owing to transport restrictions, lower consumer demand, reduced fish price, and lack of storage facilities for fish. Low demand for fish and decline in the prices have disrupted countless livelihoods of the fishing communities. Most fishers around the world could not sell their fish, forcing them to borrow high interest loans from local money lenders, especially in developing countries such as Bangladesh and Indonesia. For small-scale fishers in coastal areas of Argentina, most of them were even struggling against the depletion of their savings by sailing illegally during the COVID-19 lockdown.

Global capture fishery and aquaculture industries were severely damaged by the pandemic. As a top importer and exporter of seafood, the United States has suffered a 40% loss of fresh seafood catches and 37% and 43% reduction in seafood imports and exports since the outbreak of COVID-19. In India, it was estimated that the shrimp aquaculture sector had an economic loss of 1.5 billion USD and a reduction of 40% in shrimp production. Furthermore, the socio-economic consequences on marine tourism were enormous. There was more than half (52%) of a decrease in marine traffic density compared to 2019, with passenger vessels suffering from long-term decline. The coastal communities had an ~40% income loss due to the closure of hotels, restaurants, and the dramatically decreasing number of tourists. Small island developing states (SIDS), whose economies are more dependent on the tourism industry, have thus suffered larger economic shocks.

**COVID-19 IMPLICATIONS FOR THE OCEANS SUSTAINABLE DEVELOPMENT: SDG 14**

The United Nations’ Sustainable Development Goals (SDGs) adopted globally by heads of states and governments in 2015 were composed of 17 goals addressing various looming crises across societies, economies, and the environment. Among those goals, SDG 14 (life below water), also known as the "Ocean Goal," emphasizes the conservation and sustainable use of oceans, seas, and marine resources. On the other hand, a healthy ocean also brings more opportunities to accomplish other goals such as SDG 1 (ending poverty), SDG 2 (ending hunger), SDG 11 (creating sustainable cities), and SDG 13 (climate action). It indicates that a healthy condition of the ocean is one of the major keys toward sustainable development.

COVID-19 has given oceans "a breathing space" through temporary shutdown of human activities. However, it should be noted that the marine environment is also facing long-term problems caused by increased plastic wastes. Governments and researchers should therefore pay more attention to sustainable waste management (production, processing, and recycling) to reduce marine pollution (SDG 14.1) in the contemporary context, which would benefit both marine wildlife and the society. The interaction between oceans and human activities pre- and post-COVID-19 requires more understanding. Restoration and conservation of the typical marine ecosystems and areas (SDG 14.2 & 14.5) are still vital keys to reverse the impacts of mounting anthropogenic stress under COVID-19. Besides, the positive response of global oceans to the pandemic-related emissions is significant for the Earth’s climate system and the minimization of ocean acidification (SDG 14.3). Yet, it has not been fully understood. Although COVID-19 has given the fish stock a temporary chance to recover, the livelihoods of coastal communities around the world were severely disrupted. Achieving a right balance between fisher’s livelihoods and seafood harvesting activities requires the regulation of sustainable fishing and termination of harmful subsidies (SDG 14.4 & 14.6) in the future. Only sustainable use of marine resources can bring more economic benefits, especially for SIDS and least developed countries (SDG 17.7). The pandemic has affected and will continue to affect various aspects of human lives and the environment. Achieving SDG14 needs us to comprehensively consider the coupling interactions between humans, land, and ocean.

Future research directions could focus on land-ocean integrated management to reduce pollution, human interventions on marine ecosystem health, marine socio-economic resilience, the ocean's contribution to climate change mitigation, and adaptation for carbon neutrality in the post-pandemic era. Besides, the combined effects of coastal urbanization and COVID-19, as well as climate change and COVID-19, would be worthy to study. COVID-19 provides a powerful incentive and opportunity to address the interconnected issues of humans, oceans, and climate change. The marine ecosystem can bring co-benefits for human health and climate change. For example, restoration and protection of mangroves can enhance carbon sequestration and support wild biodiversity, thus contributing to carbon neutrality and improving human relations with animals. To fight against climate change and other possible epidemics in the future, it is critical to strengthen the resilience of densely populated coastal urban areas. Incorporating the marine ecosystem into socially adaptive capacity building could be an essential way for coastal cities around the world. Moreover, governance and education in these areas should be emphasized for the future of the global ocean economy to strengthen the capacity of effective crisis responses. A sustainable ocean economy, or blue economy, is essential for the well-being of coastal populations. Like much attention given to the terrestrial ecosystem during COVID-19, the neglected human-ocean systems also call for our close attention.

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**DECLARATION OF INTERESTS**

The authors declare no competing interests.