# Environmental and Human Health Impacts of Cruise Tourism: a review

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## ABSTRACT

The intensive growth of cruise tourism worldwide during recent decades is leading to growing concerns over the sector's global environmental and health impacts. This review combines for the first time various sources of information to estimate the magnitude of the cruise industry's environmental and public health footprints. This research shows that cruising, despite technical advances and some surveillance programmes, remains a major source of air, water (fresh and marine) and land pollution affecting fragile habitats, areas and species, and a potential source of physical and mental human health risks. Health risks impact both the people on board (crew and passengers) and on land (workers of shipyards where cruise ships are dismantled and citizens inhabiting cities with cruise ports and shipyards). In this context, we argue that the cruise industry should be held accountable with more monitoring and regulation to prevent or minimize the growing negative environmental and human health impacts.

Key words: cruise, pollution, health, well-being, tourism, travel, oceans & human health

### Highlights

- Environmental and human health impacts of cruise tourism are increasing.
- Air, water, soil, fragile habitats and areas and wildlife are affected by cruises.
- The health of passengers, crew, residents living near cruise ports and workers of shipyards is compromised.

- The cruise industry's impacts provide an example of interconnections between human and environmental health.
- Cruises should be more closely monitored and regulated to prevent or minimize all impacts.

## 1. Introduction

Humans have always interacted with the ocean, using it for food, transportation, recreation and cultural activities, and more recently as a source of energy. However, many of the interconnections and interrelationships between healthy oceans, human activities and healthy humans are not well documented or researched. Therefore the impacts of human activities on the environment and human health have often been treated separately (Depledge et al., 2019; Fleming et al., 2019).

Up until 2020, the cruise tourism was a rapidly growing tourism sector, with an annual passenger growth rate of 6.63% from 1990-2020 globally (Carić and Mackelworth, 2014; Cruise Market Watch, 2021). The total capacity of ocean cruise ships worldwide increased to over 530,000 passengers (Cruise Lines International Association, 2018) in 2018. From 2012 to 2018, there was a 48% increase in the number of active cruise ships (reaching more than 300 in 2018) and a 100% increase in passenger capacity (reaching 500,000 in 2018) (Caric et al., 2019). Cruise tourism is therefore seen as an important contributor to economic growth: in 2018, it was estimated that the world cruise industry was worth approximately $150 billion (Giese, 2020). However, the outbreak of the coronavirus (COVID-19) pandemic hit the cruise market hard and put the entire global travel and tourism industry on hold (Statista, 2020a).

Several factors have contributed to this growth, including increasingly large cruise ship capacity, port availability, new technologies, and on-board and on-shore tourist activities geared toward satisfying growing consumer demands (Cruise Market Watch, 2021; MedCruise, 2017; UNEP, 2016). The supply of cruise products has also become more diversified. On one side of the spectrum, there are small-scale adventure or luxury cruises to the most remote and vulnerable marine environments (Lamers et al., 2015). The opposite side of the spectrum features large-scale cruises on vessels equivalent to floating cities, operating in established cruise destinations, e.g. the Caribbean, the Mediterranean and Northwest Europe (Lamers et al., 2015). In recent decades, cruise liners have increased in size: around 90% of cruise ships now have the capacity to carry more than 1,250 passengers and the mega-cruisers can accommodate more than 6,000 passengers and 2,000 crew (Cruise Market Watch, 2021; Seatrade Communications, 2012), performing most of the functions of a small-scale tourist resort: accommodation, catering, medical support, transport and tourist activities, and recreation (Carić and Mackelworth, 2014).

Cruises started as a regional phenomenon confined mainly to the Caribbean but they spread throughout a number of geographical areas all round the world, from the Mediterranean to Alaska and Asia. At present, the Caribbean and the Mediterranean are the world's leading markets for cruise tourism, with more than 50% of market share (Caric et al., 2019; MedCruise, 2017; Pallis et al., 2014). The Mediterranean, for example, registered 30.7 million passengers in 2019 (Statista, 2020b).

Estimating the impact of the entire life cycle of a cruise ship on both the environment and human health is challenging; and to date, there is still a lack of comprehensive data bringing all relevant aspects together (Carić and Mackelworth, 2014). There is a need for an integrative vision in light of holistic and interdisciplinary approaches that exist to frame and safeguard the health of humans and the natural environment including: One Health, EcoHealth, Planetary Health, and Oceans and Human Health (Fleming et al., 2019; Hill-Cawthorne, 2019; Lerner and Berg, 2017). In particular, the concepts of Planetary Health and particularly Oceans and Human Health, which frame the health of humans and the planet (specifically the oceans) together, are growing within the medical and public health communities (Fleming et al., 2019).

In this context, we review and combine for the first time various sources of information regarding both the environmental and human health impacts, including those derived from the Covid-19 pandemic, to estimate the magnitude of the cruise industry's environmental and public health footprints. Taking examples from several major world cruise destinations and following a holistic vision that considers all environments and people potentially affected, the environmental and human health impacts of the ocean cruise industry are analysed together for the first time. Basic recommendations to avoid or mitigate these effects are proposed for policy makers and the industry.

## 2. Methods

This literature review is based on internationally published studies on the effects of cruises on both the environment and human health. Our study used the following resources: peer-reviewed journals and books in scientific databases related to the research field (e.g., Science Direct, PubMed, Web of Science) and grey literature (e.g. papers, reports, technical notes and congress contributions). Peer-reviewed journal articles included all types of publications including narrative, systematic reviews and meta-analysis. Primary publications on cruise-related environmental and health effects (including for the people onboard and the populations living in cruising ports) were the subject of this review. The timeframe was 1980 to 2020. We also reviewed the reference lists of published review articles to locate additional relevant publications not identified during the database searches.

The following keywords and combinations of keywords were used: cruise, ports, community, health, well-being, qualify of life, shipyards, environment, and impact. We included publications from any country. Articles were limited to those that were published in English-language journals. We excluded grey literature that reported knowledge of health or environmental risks but did not report on the methodology used, as well as publications on river cruises because of the specific nature of these cruises; Tomej et al., 2020). The search was able to identify 172 publications (125 peer reviewed articles and 47 documents considered as "grey literature").

This study should not be considered a systematic review given that only key documents providing examples of the issues identified were selected. This kind of exploratory analysis allowed us to address the broad topics of environmental and health impacts of cruise industry, assessing the extent of the available evidence, and organizing it into categories of environmental and health impacts. Full-text reviews of the publications were then done independently by the interdisciplinary team of researchers. Uncertainty regarding whether publications met the inclusion criteria was resolved through discussion among these researchers. The aim was to: create a broad introduction to some of the key themes across the field in order to provide an overview or map of the available evidence regarding health and environmental impacts from cruise industry; indicate areas for further exploration; and conclude with recommendations to begin to minimize the environmental and human health impacts of the cruise industry in the future.

## 3. Results

The types of environmental and health impacts of the cruising industry studied for this review were grouped into three main categories:

(i) environmental impacts and related human health impacts (i.e. environmental and health impacts that are interconnected);

(ii) primarily environmental impacts (i.e. impacts that mostly affect the environment); and

(iii) primarily human health impacts (i.e. impacts that mostly affect the health and wellbeing of people).

Affected environment include air, water (fresh & marine), soil and land cover, sensitive habitats and protected areas, onshore & marine wildlife from near and global pollution & waste deposition. Affected people include: passengers, crew, residents living near cruise ports or dismantling docks, those in the pathways of long range air and marine global pollution, and workers in shipyards.

Detailed examples of environmental and health impacts of cruises are given in Supplementary Table 1, which support the results. Supplementary Table 2 gives basic recommendations to avoid or mitigate the observed impacts.

### 3.1 Environmental and related human health impacts

Environmental concerns still persist despite the regulations set by: the International Maritime Organization's (IMO) International Convention for the Prevention of Pollution from Ships (MARPOL), and various national frameworks aimed at preventing and minimizing pollution from ships; and the International Convention for the Control and Management of Ships' Ballast Water and Sediments, which aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments.

3.1.1 Solid waste, wastewater and ballast water

Solid waste, including marine litter, plastics and other inorganic and organic materials, is a growing global challenge. While land-based sources contribute significantly to marine pollution, ships are also a major source of solid waste (Derraik, 2002). Although cruisers make up only a small percentage (<1%)

of the global shipping industry, it is estimated that a quarter of all waste produced by shipping comes from this sector (Herz and Davis, 2002). Waste management practices on cruise ships do not always meet basic technical conditions for communal and hazardous waste disposal, resulting in emissions of hazardous substances such as dioxins (through incineration), floating macro waste, and micro and nano plastics, with consequent impacts on marine fauna (Caric, 2011). Furthermore, incineration remains (ash) have often been dumped into the sea (Herz and Davis, 2002).

Wastewaters, including “black water” (contaminated wastewater from toilets) and “grey water” (wastewater generated from bathing and washing onboard), are also a growing problem. Wastewater can result in a decrease of available dissolved oxygen, and the potential for algal blooming when released, particularly in shallow or enclosed waters (Caric et al., 2019). In addition, micropollutants such as pharmaceuticals (including antibiotic substances), personal care products (including UV-filters) (Westhof et al., 2016), and pathogens (e.g. bacteria and viruses) (Caric et al., 2019; Gerba et al., 2013) can be released into the sea and transferred to other organisms via untreated ‘black” and “grey” waters of cruises. The presence of faecal microorganisms and antibiotic compounds (e.g. triclosan) in the wastewater of cruise ships could potentially lead to the generation of antibiotic resistant bacteria and other organisms (Vicente-Cera et al., 2019).

Many cruise ships still treat sewage with traditional Marine Sanitation Devices, which often do not perform as expected and contain significant amounts of fecal bacteria, heavy metals, and nutrients in excess of clean water quality standards (Caric et al., 2019; Loehr et al., 2006). Therefore, major cruise companies score poorly with regards to sewage treatment, with all 18 companies reviewed in the Cruise Ship Report Card (FOE, 2020) reporting a card score ‘C’ or lower (on a scale of F to A).

The discharge of bilge water (i.e. the water that collects in the bilges of a vessel that contains fluids from machinery spaces and internal drainage systems, among other sources) is a source of hydrocarbon discharge, even when treated to reduce the oil content to levels meeting international regulations for release into the environment. Globally, chronic pollution from bilge waters and fuel released in standard ship operations accounts for as much as three times more pollution than reported acute oil spills and collisions (Clark, 2006). Fragile habitats such as seagrass meadows are highly sensitive to hydrocarbons (Bucalossi et al., 2006), while polycyclic aromatic hydrocarbons have significant consequences for populations of marine birds, as well as marine mammals and turtles (Honda and Suzuki, 2020).

Furthermore, ballast water (i.e. water held in the ballast tanks used to provide stability and manoeuvrability during a voyage) can contain wastewaters, oil and other hydrocarbons, microbes, microplastics and invasive species (Caric et al., 2019; Copeland, 2010; Naik et al., 2019; Ng et al., 2015; Stabili et al., 2017). The de-ballasting (controlled release) of ballast waters acts as a vehicle for the global distribution of pathogens (and possibly antibiotic resistant organisms) and waterborne diseases, which may have an adverse impact on humans, marine animals and the aquatic ecosystem as a whole (Ruiz et al., 2000). Microplastics in ballast waters are a source and vector for metals, antibiotics, toxic chemicals, pathogenic bacteria (*Vibrio cholerae*), and Harmful Algal Bloom (HAB)-forming dinoflagellates; and serve as ‘hotspots’ for the development and spread of multiple drug-resistant human pathogens through co-selection mechanisms (Naik et al., 2019). Ballast waters and hull fouling (when marine species attach to ship hulls) of vessels in general are among the main vectors for the introduction of non-indigenous species, which can cause declines in abundance and local extinctions of native species (Abdulla and Linden, 2008).

From the human health point of view, the ballast water of vessels may contribute to the introduction of human pathogens to non-endemic areas, which consequently increases the number of waterborne diseases, compromising not only human health but also plant or other animal health (Mouchtouri et al., 2010; Pierce et al., 1997; Ruiz et al., 2000; Takahashi et al., 2008). HABs can impact human health by inhalation (i.e. respiratory irritation, asthma), skin contact (i.e. skin irritation and lesions), or through the consumption of contaminated seafood (Berdalet et al., 2016; Friedman and Levin, 2005; Massaro et al., 2003). Furthermore, the gene transfer of antibiotic resistant genes (ARGs) might occur due to the closed system and long water retention time within ballast tanks (Thomson et al., 2003). ARGs are increasingly being recognized as an emerging contaminant, hence early detection is key in the efforts to prevent widespread dissemination of antibiotic resistance (Pruden et al., 2006).

### 3.1.2 Transfer of species by vessels

Apart from ballast water, maritime transport including cruises and ferries has been linked to the transfer of species from one part of the world to another, resulting in the introduction of vectorborne diseases in new regions where they were not previously endemic (Wilson, 1995; Wilson, 2003). Although cruise ship control measures against vectorborne diseases are at present regulated by the World Health Regulation (WHO, 2012), cruises and ferries may still play a role in the dispersion of vectorborne diseases by insects such as malaria, dengue, yellow fever, Japanese encephalitis, and Zika (Tardivel et al., 2019). Infestations with these insects can contribute to the spread of food-born protozoan diseases (Graczyk et al., 2005).

### 3.1.3 Antifouling (biocide) coatings

Vessel antifouling-related contamination is one of the most serious threats posed upon marine ecosystems (Carić et al., 2016). Before 2008, antifouling coatings used on the hulls of cruise ships contained high concentrations of tributyltin (TBT), which had serious consequences for marine organisms, and still persist in some places (Carić et al., 2016). In 2008, TBT was banned by the IMO, and since then new anti-fouling copper-based compounds have been introduced. However, high concentrations and biological impacts of TBT are still documented in some areas, raising concerns about legislation and practice (Carić et al., 2016).

Although copper, the predominantly applied biocide today, results in less toxicity compared to TBT, it is still toxic to the non-target sea organisms, inhibiting photosynthesis and Krebs cycle enzymes, inducing oxidative stress and mutations, and altering reproductive abilities (Guardiola et al., 2012). Elevated levels of copper have been associated with changes in benthic assemblages and reduced species richness (Neira et al., 2014). At a local level, this can be a major issue, particularly as cruise ships tend to use non-industrial harbours close to towns and cities and fragile sites such as marine protected areas (MPAs) (Carić, 2016; Caric, 2011; Thomas et al., 1999).

Although there are no published studies assessing the exposure to antifouling paints and the direct effects on human health, there is research demonstrating that humans may be highly exposed to these compounds when applying and removing antifouling compounds, especially those working in ports and marinas (Links et al., 2006). Furthermore, these antifouling compounds bioaccumulate through the trophic chain until they reach fish and shellfish, particularly those farmed in aquaculture, posing a threat to seafood consumers due to their toxicity and ability to bioaccumulate in these organisms (Guardiola et al., 2012; Hites et al., 2004).

Heavy metal-based antifouling paints contain high amounts of biocides that can contribute to the development of antibiotic resistance (AMR) via co-selection, turning painted ship hulls into highly mobile refuges and breeding grounds for antibiotic-resistant bacteria (Flach et al., 2017; Guardiola et al., 2012). The emergence of new strains of bacteria due to multiple mutations, in part due to climate warming, can lead to thermal adaptation in microbes, thus creating more antibiotic resistance. This poses an enormous challenge in our society totally dependent on antibiotics for the treatment of particular infectious diseases and critical for the success of advanced surgical procedures for humans and domestic animals (Davies and Davies, 2010; Qiao et al., 2018; Rodríguez-Verdugo et al., 2020).

### 3.1.4 Air pollution

Port and populated coastal areas with heavy ship traffic are affected by particulates exhausted from marine vessels including cruise ships (Mueller et al., 2011). Ship emissions constitute a large, and so far poorly regulated, source of air pollution (Jonson et al., 2020). Emissions are mainly clustered along major ship routes, both in open seas and close to densely populated shorelines. Hence, there are concerns about the contribution of the shipping industry to local and global air pollution (Transport & Environment, 2019), with the effects of ship emissions being much larger when emissions occur close to the shore than on open ocean (Jonson et al., 2020).

Shipping is an important transport sector relying on the use of fossil fuels (particularly heavy fuel oil) as the major source of energy. Unlike other transport modes, marine fuel is less refined and the standards for emission of air pollutants are less strict. Shipping exhausts generated from burning heavy fuel oil contain high levels of sulphur oxides (SOx) and nitrogen oxides (NOx), as well as heavy metals and polycyclic aromatic hydrocarbons (PAHs). Data from new studies have emerged in recent years highlighting the problem of global air pollution from cruise ships and other vessels (Transport & Environment, 2019). Figure 1 shows the heatmap of the estimated NOx emissions from cruise ships in European waters (Transport & Environment, 2019) that can serve as an indication of broader air pollution impacts.

Acid rain caused by the emissions of $SO_x$ and $NO_x$ can travel large distances from the site of emission and have the potential to effect green cover in coastal areas (EEB, 2004; Miola et al., 2010), and to erode facades and sculptures made of limestone (Varotsos et al., 2009). Furthermore, $NO_X$ and $SO_x$ emitted by ships contribute to ocean acidification by altering the pH of the water (Hassellöv et al., 2013), while NOx is a major precursor for ground-level ozone pollution (Jonson et al., 2020).

Levels of NOx in heavy cruise traffic zones such as Norway's fjords at times exceeded values that could have a negative impact on health, while NOx together with soot particles and water vapour also contributed to the formation of smoke clouds (Norwegian Maritime Authority, 2017). Estimates in Europe show that despite substantial reductions in the contributions from ship emissions to the depositions of SOx expected in European coastal regions as a result of the implementation of a 0.5 % worldwide limit of the sulfur content in marine fuels from 2020 (Jonson et al., 2020), cruise ship $SO_X$ will still remain much larger in proportion to the passenger car fleet (Transport & Environment, 2019).

Despite the evidence that ship engine exhaust impacts air quality in ports and coastal cities, little is known about how ship engine exhaust may impact the air quality on the deck of a ship. The findings of a study that measured the concentration of PM on the deck of several major cruise line ships during 2017 and 2018 (Kennedy, 2019) demonstrated that a source of PM—likely, in part from the ship's exhaust system—contributed to poorer air quality in the stern areas of cruise ships. This study also indicated that the concentrations of PM on the decks of these ships are comparable to concentrations measured in polluted cities, including Beijing and Santiago.

Recent studies commissioned by the cruise lines claim that ships operating with Advanced Air Quality Systems (exhaust gas cleaning systems or "scrubbers") consistently meet or even outperform the industry air and water benchmarks established by international organizations such as the IMO, European Union and the U.S. Environmental Protection Agency (Carnival Corporation & PLC, 2019). However, other studies have concluded that cruise ship exhaust still contains toxic constituents, including heavy metals and PAHs, highlighting the environmental risks associated with ship scrubber discharge water (Caric et al., 2019; ICES, 2020). In fact, legislation on scrubber discharge is lagging, inconsistent between countries, and is often considered insufficient to protect the environment (ICES, 2020).

Furthermore, the burning of fuel (Bunker Fuel Oil, Marine Diesel Oil and Marine Gas Oil) releases substantial amounts of $CO_2$ and hydrocarbons into the atmosphere (Faber et al., 2009; Lamers et al., 2015), which are well known greenhouse gases whose influences on global warming are well documented. High levels of greenhouse gas emissions are created by cruise ship tourists in general, with especially high levels for those visiting the Antarctic (Eijgelaar et al., 2010; Farreny et al., 2011). Climate change can have global consequences for human health and the environment (EPA, 2020; IPCC, 2020). There has been limited research into emissions factors for individual sectors of the maritime transport industry, such as calculating carbon emissions per passenger-kilometre (p-km) for cruise ships. These studies show that cruising is a highly carbon intensive activity; in fact, cruising has been demonstrated to be a more carbon intensive mode of international transport than aviation (Howitt et al., 2010).

Major cruise companies are considered to score low on air pollution, with all except one of the 18 companies reviewed in the Cruise Ship Report Card (FOE, 2020) reporting a card score 'C' or lower. Despite a 0.50% limit on sulphur in ship fuel oil required globally in 2020 under the MARPOL Convention, to date, there has been no systematic monitoring by public authorities of ship discharges; and fuel quality is very rarely monitored (Transport & Environment, 2019).

Air pollution has been closely associated with adverse health effects such as respiratory diseases (including chronic obstructive pulmonary disease and asthma) (Kim et al., 2018) and cardiovascular diseases (including atherosclerosis and stroke (Lee et al., 2014). Each of the gaseous and particulate components of cruise air pollution can have a detrimental effect on human health. In particular, $SO_X$ and $NO_X$ can cause premature death, including from lung cancer and cardiovascular disease, and morbidity, e.g., asthma (Chen et al., 2019; Gruzieva et al., 2013; Guarnieri and Balmes, 2014; Transport & Environment, 2019). However, the specific contribution of these cruise-specific components to human health (compared to other sources such as industry, etc) has not well established. Specific vulnerable groups within the general population (including children, the elderly and people with respiratory and cardiovascular disease) may be more susceptible to the harmful effects of air pollution (Kennedy, 2019).

Clinical studies have generally shown a greater impact of particulate matter (PM) air pollution on health than the gaseous components. The PM emitted from ship engines burning diesel fuel or heavy fuel oil and is primarily composed of small (less than 1 μm) solids or liquid droplets suspended in the air (Caric et al., 2019; Kennedy, 2019). PM is associated with adverse cardiovascular outcomes, increasing overall cardiovascular and respiratory mortality (Hamanaka and Mutlu, 2018). These ultrafine particles can be inhaled deep into the lungs and from there enter into the bloodstream producing detrimental effects to the cardiovascular and respiratory systems (Nelin et al., 2012). PM concentration has also been associated with other adverse health outcomes that are detailed with examples in Supplementary Table 1.

### 3.1.5 Noise pollution

Noise pollution is a ubiquitous form of marine pollution and it is particularly acute on busy maritime routes. Long-term exposure to intensive sound results in the modification of behaviour and habitat use by some fish and mammal species (Bass and McKibben, 2003; Nimak et al., 2007; Rako et al., 2013; Slabbekoorn et al., 2010; Wysocki et al., 2009). A review encompassing various human-produced underwater noise sources found noise impacts on the development of fish and invertebrates including anatomical and physiological effects affecting the population biology and ecology of the concerned species and a decrease of the ecological services performed by these animals and a loss of fishing opportunities (Weilgart, 2018).The EU's Marine Strategy Framework Directive (2008/56/EC) directly addresses the introduction of noise into marine waters, stating that noise should be limited so that the marine environment is not adversely affected (Milman, 2016). Underwater noise hotspots sometimes overlap with MPAs and/or with areas of importance to noise-sensitive marine mammal species (Maglio et al., 2016).

The generated noise by a cruise ship as well as related terminal operations and delivery traffic affects not only the marine fauna, but may also impact the people on board the vessel (crew and passengers, directly exposed to sound pressure levels) as well as the workers at the port and inhabitants of areas near the coastline and ports (Di Bella, 2014; Shi and Xu, 2019). Despite existing requirements devoted to the assessment of the comfort and health of crew and passengers, these often rely on merely simple indicators based on noise levels, without provisions for noise exposure time (Di Bella, 2014). There are few studies regarding the impact of the noise and vibration generated by cruises on human health and wellbeing, a topic that merits further investigation.

Although some studies carried out by port authorities such as Hamburg (Schuster et al., 2018) and Barcelona (Port de Barcelona, 2021) indicate that noise from cruise does not seem a major problem, other studies carried out in other ports such as Kopper in Slovenia (Čurović et al., 2021) and Charleston in United States (Litvin et al., 2015) suggest the contrary (see also Supplementary Table 1). Therefore, environmental noise generated by moored ships is a problem for at least certain port cities that should be regulated internationally.

### 3.1.6 Ship dismantling

Adding to these air problem, there is the concern about the heavy metals and other toxic substances that result from the ship (including cruise ships) dismantling industry— which dismantles old and decommissioned ships enabling the re-use of valuable materials (EU, 2007; Sarraf et al., 2010; Vuori, 2013). Nowadays two thirds or more of ships are dismantled on the beaches and river banks of developing countries such as Bangladesh, India and Turkey (EU, 2007). The recycling of scrap metals from ships reduces the need for mining and becomes a vital part of the circular economy.

However, throughout the dismantling process, workers are exposed to the formation of toxic debris including heavy metals (e.g. lead, cadmium, chromium and mercury) and other toxic substances (e.g. PCBs, asbestos and oil), and uncontrolled and controlled fires (EU, 2007; Sarraf et al., 2010; Vuori, 2013). The emissions are transmitted to the atmosphere, marine environment and the soil of the ship breaking yards (Vuori, 2013); and may also contaminate drinking water (Rehman et al., 2018). Until recently this industry has been taking place mainly in the developing countries in Asia at the expense of both the natural environment and labourers. As the awareness about the industry has risen, there is increasing pressure to invest in the sustainability of ship dismantling (Muhibbullah, 2013; Vuori, 2013; Ahamad et al., 2021). This is particularly true for passenger ships which contain a wide range of materials, including composites which are very difficult to separate and recycle (EU, 2007).

In addition to the accidents that happen at the shipyard, there is an array of biological, ergonomic, psychological and physical hazards (Vuori, 2013; Muhibbullah, 2013). Toxicity from heavy metals in humans may include neurologic and renal damage, and increasing risk of cancer (Rehman et al., 2018). Also, substances such as asbestos can induce chronic inflammation in the lung, with an increased risks of lung and other cancers (Kumagai-Takei et al., 2018).

All these environmental and health impacts may be expected to increase in the near future considering that the cruise ship dismantling market has boomed because of the crisis linked to travel restrictions during the Covid-19 pandemics (Usta, 2020).

### 3.1.7 Accidents

Cruise ship accidents pose a major environmental hazard (including oil spills and impact on fragile habitats such as coralligenous beds and coral reefs) as well as potential human tragedy. Although the issue of cruise ship accidents is a challenging and significant topic in the context of maritime safety, very few studies (selected ones in Table 1 of the annex) have focused on the review and analysis of cruise ship accidents. However, there is a suspicion that some cruise companies have purposely disobeyed laws, rules, and regulations (Klein, 2018; 2019), highlighting concerns for the vast majority of seas that are not well monitored or regulated.

## 3.2 Primarily environmental impacts

### 3.2.1 Collisions with marine mammals

Collisions with marine mammals and sea turtles represent a major issue. Cruise ship velocity and size have significantly increased in recent years, as well as the total number of cruises, and so have the chances of collisions. In many sensitive regions such as Alaskan waters and the Ligurian Sea, cruise ships have been recorded colliding with whales (Panigada et al., 2006) or disturbing small cetaceans (Campana et al., 2015; Fortuna, 2006). On a global scale, collisions with large vessels represent a significant fatal threat for whales (Cates et al., 2016). Ship strikes are made more likely by the impact of underwater noise from shipping, which can interfere with cetacean communication and prevent animals from detecting and reacting to threats (Erbe et al., 2018).

### 3.2.2 Light pollution

Light pollution poses problems for organisms that need darkness for orientation in daily and seasonal migrations, feeding and breeding. Brightly-lit cruise ships on a dark sea can disorient birds that fly low and/or migrate at night, resulting in collisions (Longcore and Rich, 2004). The creation of permanent ‘moonlight’ by ship lights may cause localized problems with migrations of zooplankton, cephalopods, fish and potentially other marine species, putting them at risk of intensive and frequent predation (Longcore and Rich, 2004). It is well documented that nesting sea turtles can be disturbed by lights along the seashore (Bourgeois et al., 2009; Salmon et al., 1995).

### 3.2.3 Effects of wakes and sediment resuspension in shallow waterbodies

The effects of ship waves (wakes) in shallow waterbodies have implications for the environmental sustainability of shipping in coastal waters. Vessel wakes generated in open sea areas decay rapidly with distance from the ship and have negligible impact on the seabed, on the nearshore areas, and on ecosystems. However, in shallow coastal areas and narrow waterways, the wake generation mechanisms, propagation patterns and impact modes may radically deviate from those typical for open sea conditions. The transit of large vessels (including cruise ships) has been shown to have ecological impacts on shallow water areas such as tidal creeks, microtidal estuaries, shores of navigable delta channels, and lagoons (Jiang, 2001; Parnell and Kofoed-Hansen, 2001; Scarpa et al., 2019). This is because ships sailing at even moderate speeds in these areas may create specific types of disturbances such as abnormal wakes, depression areas, or supercritical bores, which can impact the integrity of the sea bottom (Jiang, 2001; Parnell and Kofoed-Hansen, 2001; Scarpa et al., 2019).

Furthermore, in shallow waterbodies mega cruise ships can resuspend large amounts of sediment that drift onto nearby fragile habitats such as coral reefs, increasing turbidity and potentially juvenile coral survival and settlement success over the long term (Jones, 2011).

### 3.2.4 Other environmental impacts

Cruises have a significant effect on the increase of freshwater withdrawals. It is recognized that these cruises consume more resources than normal consumption patterns (Véronneau and Roy, 2009), and this overconsumption creates pressure in areas with fewer freshwater resources, for example the Caribbean islands. Furthermore, under climate change scenarios (e.g. less availability of freshwater in the Mediterranean region for upcoming decades, and taking into account the projected occurrence of more frequent and severe drought episodes in the region), cruise activity in Mediterranean and other ports will be severely affected because it will directly clash with other freshwater water priorities (Garcia et al., 2020).

The construction of port infrastructure facilities for cruise ships and other maritime transport activities can also lead to the deterioration of the natural environmental characteristics of the site (Caric et al., 2019). New ports have been constructed or existing ones have been extended in terms of docking and serving cruise ships; this includes the dredging of sea beds resulting in rising water turbidity due to the suspension of sediments, which represents one of the major threats to local sea-grass meadows and coral reefs (Sarkis, 1999).

Additionally, unrestricted anchoring by cruise ships and live-aboard dive cruisers poses a serious threat to the existence of coral reefs (Smith, 1998) and sensitive areas such as MPAs (Caric et al., 2019). Anchor-damaged reefs may never recover; and if they do it will be a slow process, in most cases more than 50 years (Smith, 1988).

Finally, the impacts of cruises on wildlife onshore in particular areas such as the Arctic or Antarctica have increased in recent years (Lamers et al., 2015, 2012). In the earlier days of Polar tourism when access was only by relative few scientific expedition cruise vessels, tourists arrived infrequently and in small numbers, received detailed on-board briefings about minimal-impact practices and codes of behaviour, and were always accompanied by trained guides who generally ensured that minimal-impact practices were followed. More recently, however, large-scale cruise ships have started to arrive at the same sites, often during peak seabird breeding season; these tourists are often unfamiliar with minimal-impact practices, untrained and unguided (Lamers et al., 2012, 2015).

## 3.3 Primarily health impacts

### 3.3.1 Infections

Cruise ships operate under unique circumstances that may facilitate the exposure and spread of infectious disease. Contributing factors include: close and frequent contact between passengers and crew members with many shared spaces (this provides prime conditions for person-to-person transmission via inhalation of virus in aerosols and/or droplets as well as fomites); an international passenger and crew population; and bidirectional contact of people disembarking from cruise ships and local (port) communities (Browne et al., 2016; Gupta et al., 2012; Miller et al., 2000; Minooee and Rickman, 1999; UNWTO, 2020). Furthermore, the fact that individuals are often from different cultures, with different health behaviors, immunization backgrounds. and health statuses may facilitate the spread of infectious diseases (Kak, 2015).

Cruise ships can acquire new infectious diseases reservoirs through contaminated food, water or infected passengers, spread during the journey and dispersed through people disembarking, not only spreading the disease while on the ship, but also taking these back into communities all over the world (Brewster et al., 2020; Isakbaeva et al., 2005; Jernigan et al., 1996; Mitruka and Wheeler, 2008). It has been hypothesized that mass transport systems such as cruise lines are involved in amplifying and accelerating the spread of influenza annually, and more recently coronaviruses globally (Miller et al., 2000).

According to two studies involving retrospective reviews of cruise ship medical logs, apart from injuries and seasickness, the most common diagnoses of passengers evaluated in cruise ship infirmaries were upper respiratory tract infections and gastrointestinal diseases (Mitruka and Wheeler, 2008; Peake et al., 1999). These diseases can have serious health outcomes in the general cruise population, considering that nearly half of all passengers seeking care aboard cruise ships were older than age 64 years (Mitruka and Wheeler, 2008; Peake et al., 1999).

The typical cruise passenger is often an elderly individual and may have chronic illnesses, which can make him or her more susceptible to infection and its complications (Kak, 2015). Therefore, the health of elderly people onboard may be at higher risk for infections compared to the rest of passengers and crew. Although there is some evidence that living on a cruise for extended periods of time could be cost-effective and beneficial for the health and well-being of some elderly people because of several factors (e.g. cruise ships provide 24 h medical assistance with physicians on site, escorts to meals, walk-in showers, and housekeeping/laundry services) (Lindquist and Golub, 2004; Tanne, 2004), nevertheless the majority of the documented cruise-related accidents and illnesses affect elderly people (Dahl, 1999; Oldenburg et al., 2016).

#### 3.3.1.1 Respiratory infections

Upper respiratory tract infections are the most frequent diagnosis in cruise ship infirmaries, accounting for approximately 29% of diagnoses (Peake et al., 1999); these are promoted by the semi-enclosed and crowded environment and the presence of whirlpools and water supplies that may act as reservoirs if contaminated (Isakbaeva et al., 2005; Rowbotham, 1998). The most frequent pathogens associated with cruise ship-related pneumonia outbreaks are influenza and *Legionella* (Edelstein and Cetron, 1999; Mitruka and Wheeler, 2008; Rowbotham, 1998).

Infections by Legionella may go undetected as a result of the long incubation period (2–10 days) of this disease and passengers may not develop symptoms until they have returned home. As a result, this may leave the door open for new infections on the cruise's subsequent travels (Mouchtouri et al., 2010).

Influenza outbreaks on cruise ships can occur due to the mix of large groups of international crew and passengers from parts of the world where influenza is in circulation and the potential for the introduction of antigenically drifted seasonal influenza virus strains (Brotherton et al., 2003; Fernandes et al., 2014; Rogers et al., 2017; Uyeki et al., 2003). Both passengers and crew members can serve as potential sources of influenza infection, resulting in the rapid spread of influenza; this can have serious health effects because of the large percentage of elderly and chronically ill passengers, both of whom are at higher risk for complications and death due to influenza infection (Brotherton et al., 2003; Mitruka and Wheeler, 2008; Uyeki et al., 2003).

Furthermore, cruise ships also offer the perfect combination of factors that may lead to the spreading of new pandemics, with the SARS-COV-2 the most recent example. Although there is relatively little documented evidence of sea transport accelerating the spread of influenza or other respiratory viruses to new areas (Browne et al., 2016; Mitruka and Wheeler, 2008), the recent emergence of SARS-CoV-2 and the subsequent COVID-19 pandemic demonstrated that cruise ships operate under unique circumstances that may promote the spread of infectious diseases (Correia et al., 2020; Rocklöv et al., 2020).

Finally, other infectious diseases with respiratory spread such as tuberculosis, diphtheria, varicella, measles and rubella have also been reported on cruise ships. Although the number of documented outbreaks is relatively small and mostly affects crew members, these risks should not be neglected (Stamatakis et al., 2017).

#### 3.3.1.2 Gastrointestinal infections

Gastrointestinal diseases (GI) accounts for fewer than 10% of passenger visits to the cruise ship's infirmary and the likelihood of contracting gastroenteritis aboard a 7-day journey is reportedly less than 1% (Peake et al., 1999). Of note, according to US federal regulations, when the incidence of acute gastroenteritis among passengers and/or crew is higher than 3%, it is defined as an 'outbreak' and requires a formal investigation (Isakbaeva et al., 2005).

The number of GI outbreaks reported in US cruise ships has been steadily declining since 2006 (Figure 2). However, reported outbreaks may be underestimated due to the under-detection of cases, as affected passengers may not report their illness for fear of ruining the vacation and because these passengers go home and the connection is lost, while crew members may fear losing income during isolation or being forced to disembark (WHO, 2001).

GI outbreaks can be linked to both waterborne and foodborne routes as well as other factors, and involve different pathogens depending on the origin of the outbreak. Documented factors involved in these outbreaks are mostly due to inadequate temperature control, inadequate food handling (including ice), and infected food handlers, rather than contaminated raw ingredients (Mitruka and Wheeler, 2008). This is due to cruise meals with a large variety of foods, which involve many steps of preparation by multiple food handlers. Moreover, meals are served to a large population in a short time, potentially leading to time gaps between the preparation and serving where inadequate temperature controls can promote the growth of bacteria (Mitruka and Wheeler, 2008; Rooney et al., 2004).

#### 3.3.1.3 Other infections

Varicella (chickenpox) causes frequent outbreaks aboard cruise ships; and because varicella complications occur more frequently in adults, cruise ship outbreaks have the potential to involve serious illness since most cruise ship passenger and all the crew are adults (Kak, 2015). In contrast with children, adults tend to have more severe disease and can develop severe complications such as encephalitis or pneumonia (Kak, 2015). The crew members on a cruise ship are more likely to be susceptible to varicella than the general North American or European passenger because they often are from tropical countries where varicella infection typically occurs at a later age compared to temperate areas,and also have overall lower immunization rates (Kak, 2015). The travellers at highest risk for severe disease are immunocompromised people or pregnant women without experience of or immunisation for varicella disease (Kak, 2015).

Skin infections can be spread among the passengers because of the presence of hot tubs and spas and the high density of individuals on cruise ships. The presentation of these infections often consists of folliculitis (Kak, 2015). Organisms that have been documented include *Pseudomonas aeruginosa* presenting as hot tub folliculitis (Kak, 2015).

Finally, the typical cruise ship passenger often spends time on shore on land excursions as part of the cruise. These excursions may involve overnight stays on shore, so passengers are also at risk for infections that they may acquire while on land (Kak, 2015). Therefore, infections that are endemic in the specific ports of call, such as malaria and meningitis, may appear on board or after return from the cruise, although this is relatively uncommon (Kak, 2015).

### 3.3.2 Health issues related to sexual assaults

Sexual assaults are a major problem on cruises. The US Cruise Vessel Security and Safety Act (US Department of Transportation, 2020) has reported 101 sexual assaults on board cruise ships that embarked and disembarked in the United States in 2019 (apart from other alleged criminal activities such as homicide or theft). The physical and mental health consequences of sexual assault victims are numerous and include genital injuries, nonspecific chronic pain, anxiety, sleep disorders, depression and suicide attempts (Oberoi et al., 2020; Teerapong et al., 2009).

### 3.3.3 Health issues related to working conditions of the crew

The maritime environment is unique for humans because there are physical constraints such as continuous exposure to noise and vibration, and psychological constraints such as stress, confinement, isolation and boredom (Jégaden and Lucas, 2020). Studies on the well-being and life satisfaction of cruise ship employees are scarce; however, the existing studies indicate that a large number of crew members experience significant mental health issues including homesickness and sadness while working on a cruise (Bardelle and Lashley, 2015). Furthermore, work-related injuries have profound negative effects on the well-being of cruise ship employees, contributing to unfavourable working conditions among crew members (Radic, 2019).

While onboard, cruise ship employees are exposed to prolonged harsh working conditions in the form of constant time pressure and heavy workloads coupled with the ongoing uncertainty about their next contract assignment (Gibson, 2017). These employees are on board 24 hours/day, 7 days/week for often months at a time. Moreover, unfavourable working conditions combined with the inability to psychologically detach from the work creates a negative impact on cruise ship employee well-being (Dennett, 2018). This adds to the low salaries of many cruise crews, which in some cases (e.g. room cleaners, waiters) largely rely on tips. This raises many questions about the treatment and equity of crew members within the cruise industry (Oyogoa, 2016).

Regarding the impact of noise on health and wellbeing of cruise ship employees, there is still very few information. A recent study found that loud noise from ongoing cruise ship maintenance is one of the factors that led to sleep disturbance and anxiety of the cruise ship employees (Radic et al., 2020). Furthermore, the relationship between ship noise and the occurrence of arterial hypertension in seafarers is worrying (Jégaden and Lucas, 2020). A recent review study found high quality evidence that occupational noise exposure increases the risk of hypertension (Bolm-Audorff et al., 2020); and among the studies reviewed, there are some concerning seafarers demonstrating the link between occurrence of hypertension and a high level of noise and a long duration of exposure to noise onboard (Jégaden and Lucas, 2020).

### 3.3.4 Health and wellbeing impacts related to sociocultural and economic issues

Although this paper mostly deals with the direct environmental and health effects of the cruise industry, there are also indirect health and wellbeing consequences for residents of the cruise destinations related to local sociocultural and economic impacts, which should not be neglected.

Stress (defined as anything that causes an individual psychological distress) is a potential and often neglected impact that can affect cruise tourism host community residents through tourism development activities (Jordan and Vogt, 2017). Stress is experienced through an increase in daily hassles, which, with long-term exposure, can result in negative health and behavioral outcomes and decreased quality of life (Jordand and Vogt, 2017). Stress is an intangible psychological impact of cruise tourism development, and one element of host community resident quality of life (Jordand and Vogt, 2017). Unmet expectations, crowding/congestion, increased cost of living, pollution, police harassment, displacement, and overused utilities were the causes of stress for local residents in a Jamaican cruise port (Jordand and Vogt, 2017). Overcrowding and associated mobility problems are a major concern related to cruise arrivals (Klein, 2011; Ros-Chaos et al., 2017). These problems and effects are particularly important in island destinations such as the Caribbean, where the smaller size of the island population tends to magnify the impacts of tourism on the quality of life of island residents (Kerstetter and Bricker, 2012).

It is known that individuals across various communities (particularly those with a low socioeconomic status), economic issues such as the lack of resources or resource loss related to tourism activities are a leading cause of stress (NE et al., 2000). The actual economic benefits from the cruise industry seem to be restricted to very few large corporations with relatively small economic benefits at a local level (Caric, 2010), whereas the environmental and health impacts are widespread (local, regional and global). Despite early studies which found significant passenger spending while visiting a harbor and made claims about the local, regional and national economic impact of cruise tourism, recent studies demonstrate that cruise passenger spending is overstated in part because of the failure to use appropriate sampling methods (Kayahan et al., 2018; Larsen et al., 2013).

Recent research suggests little return on investment for the local residents and smaller businesses (McCaughey et al., 2018). This is because cruise tourists tend not to stray far from their cruise ship “bubble” of comfort, generally either booking excursions from the ship itself or venturing only into a tightly controlled area surrounding the port (Jaakson, 2004). As a result, cruise tourists generally spend their money either on the cruise ship itself or on businesses that are economically tied to cruise companies, resulting in significant economic leakage away from communities hosting cruise tourism (Nicely and Palakurthi, 2012). These facts explain why cruise tourists generally spend less in a cruise destination compared to land-based tourists (Larsen et al., 2013; Larsen and Wolff, 2016). The trade-off between the value of cruise passenger spending and costs associated with infrastructure required to host ships, including cruise terminals, is a contested and arguable topic (Klein, 2011).

As several examples (such as the case of Venice in Italy (Trancoso González, 2018), Jamaica (Jordan and Vogt, 2017) and Charleston in United States (Litvin et al., 2015) have shown, the environmental and sociocultural impacts of cruise tourism negatively affects residents’ perception of the positive economic impacts of cruise tourism. Even in places such as Esperance (Australia) and Cartage de Indias (Colombia), where the perceived values by residents of cruise tourism development outweighed its perceived costs, there can be still resident dissatisfaction with the organization and management of cruise ship visits to the town and with the cruise lines conduct towards local tourism business (Brida et al., 2011; McCaughey et al., 2018)(McCaughey et al., 2018).

## 4. Discussion

The effects of the cruise industry on the environment are extensive and include air, water (fresh and marine), soil and land cover, sensitive habitats and protected areas, onshore and marine wildlife.This review also suggests that these potential cumulative environmental impacts resulting from many different (sometimes individually insignificant) effects are usually neither measured nor accounted for before they cause significant damage through this accumulation (Runge, 1998). The effects of the cruise industry on human health are also broad and include passengers, crew and people on land (citizens in ports where cruises are docked or shipyards where they are dismantled; workers in shipyards). Gastrointestinal and particularly respiratory disease outbreaks (as demonstrated by the example of the COVID-19 outbreaks reported on cruise ships in 2020) (Brewster et al., 2020), pose increasing challenges for public health. This review also shows that while leisure activities in blue spaces such as scuba diving and walking by the sea usually have positive health impacts on people enrolled in these activities (e.g. Carreño et al., 2020; White et al., 2020), the negative health impacts on passengers and especially crews can be severe.

Overall, the cruise industry is a good example of how human and environmental health are interconnected and constitute an excellent example of environment-human health connections within the framework of approaches such as EcoHealth, OneHealth, Planetary Health, and particularly, Oceans and Human Health, which have emerged in the last few decades to promote collaborations between disciplines to safeguard human, animal and environmental health (Fleming et al., 2019; Hill-Cawthorne, 2019).

One model focused on the environmental field of sustainability for the Croatian cruising tourism activity in 2007, revealing the total cost of the negative environmental externalities to be seven times larger than the benefits to local economy (Caric, 2010). The approach to market development adopted by major cruise lines has given rise to multifaceted, divisive and often opaque power relations between cruise corporations, destination and port communities, passengers, and tourism suppliers (Khoo-Lattimore et al., 2021).

It is important, therefore, to integrate biological, health, engineering, economic, and social science approaches to improve the understanding of the trade-offs between the economic benefits and the environmental and health impacts of this sector. It is also important that environmental and health public authorities undertake new regulations based on scientific evidence. Both at an international level (e.g. the MARPOL Convention, the International Convention on the Control of Harmful Anti-fouling Systems on Ships, the International Convention for the Control and Management of Ships' Ballast Water and Sediments, the Convention on Migratory Species, the Maritime Labour Convention) and at a national and regional level (e.g. the Clean Cruise Ship Act, the US Marine Mammal Protection Act, the Federal Regulations for Reporting Death or Illness on Ships Destined for the United States, the EU rules on passenger ship safety and the EU Marine Strategy), there are currently regulations and policies in place. However, more needs to be done by both the industry and governments to improve the sustainability and decrease both the human health and environmental impacts of the Cruise Industry, particularly around monitoring, enforcement and accountability.

Very few cruise companies worldwide offer information on environmentally sustainable practices (Ramoa et al., 2018). With some exceptions such as the monitoring of ship emissions inside or nearby the port area (Mocerino et al., 2020) or the monitoring of some communicable diseases (Brewster et al., 2020), there is no comprehensive monitoring system in place to assess the environmental and health impacts of the cruise industry. Monitoring is lacking and reporting is poor regarding onboard sewage treatment, water quality compliance, air pollution reduction and disease outbreaks other than gastroenteritis.

The public health significance of illness aboard cruises lies not only in possible widespread illness onboard ships, but also the spread of diseases into communities all over the world. Therefore, further investigation is required regarding the role of cruises in creating and spreading pandemics. Although sanitation and disease surveillance programs developed through the cooperation of cruise industry and public health agencies have led to the improved detection and control of some communicable diseases (Brewster et al., 2020; Rogers et al., 2017), the coronavirus disease (COVID-19) pandemic has demonstrated profound caveats. Therefore, stronger preventive measures (including planning, design, hygiene, and surveillance intervention for ships) should be considered to mitigate risk and increase preparedness for future disease outbreaks (Brewster et al., 2020).

Although the cruise industry expends considerable effort and resources to maintain a positive image with regard to corporate social and environmental responsibility, recent studies suggest, after examining cruise practices, that this image is inaccurately represented (Klein, 2018, 2019). Hence, we argue that the cruise industry should be more closely scrutinized and regulated to prevent or at least minimize the growing negative impacts on both the health of the environment and humans. In this context, key recommendations to minimize or avoid health and environmental detriment effects are compiled in Supplementary Table 2. Recommendations consider the diverse known environmental and health impacts and target the major stakeholders (policy makers, cruise industry, local communities, passengers and crew). These recommendations encourage the national and local environment and health ministries to collaborate and establish new rules for the cruise industry.

Furthermore, this review shows that there are several gaps in knowledge that should be considered in the future, relating to the monitoring of health and environmental impacts identified in this review as well as the costs of these impact; the trade-offs between the economic benefits and risks to the local economy, the environmental and health impacts and the sociocultural issues; the sustainable alternatives to cruise tourism; the risks posed by the cruise industry in particular sensible areas such as marine protected areas, heritage (UNESCO) sites, the Mediterranean Sea, the Arctic or the Antarctica; the labor rights on cruise ships and shipyards and the infrastructure saturation (water, wastewater, electricity, road, waste management, public transport, public space) related to cruise ships.

Although the lack of monitoring makes it difficult to accurately estimate the environmental and health impacts from the cruise industry, the literature reviewed demonstrates the need for the implementation of tight measures on board and in port. Unless there is greater regional and international coordination towards implementing regulatory measures, the environmental and health impacts of the cruise sector's continuing expansion will keep growing.

Finally, further research is needed into the environmental and health impacts of cruise tourism, on-board and shipyard practices (including occupational health), emissions, and the development of technologies and other strategies geared to reducing these environmental and health impacts. Meanwhile, new regulations should be implemented when there is enough evidence; and the Precautionary Principle should be applied by decision-makers when scientific evidence about an environmental or human health hazard is uncertain but the stakes to the environment and/or human health are high (EEA, 2013).

## 5. Conclusions

By linking several environmental and human health topics, this review demonstrates how the cruise industry is affecting the health of the planet (particularly the ocean) and the health of humans. Despite technical advances to reduce environmental footprint and some surveillance programmes to reduce human health risks, cruising, one of the fastest growing sectors of the tourism industry, remains a major source of environmental pollution and degradation, and a potential source of physical and mental human health risks. These risks impact both the people on board (crew and passengers) as well as to the general population, particularly those citizens inhabiting cities where cruise ports or dismantling shipyards are located.

Environmental impacts originate from multiple sources over the course of the cruise itinerary on several biological groups (from birds to marine mammals) and ecosystems (water, air and land), posing great challenges for the health of the whole environment. Cruise ship tourism produces not only significant air, water and land pollution offshore, but also cruise ship traffic routes can interact with fragile coastal and shallow areas in locations where vessels are approaching ports or passing through narrow and sensitive areas (e.g. straits, channels and marine protected areas) and very fragile regions such as the Mediterranean Sea, the Arctic and the Antarctica.

Three categories of impacts have emerged: (i) environmental impacts that are related to human health impacts (e.g. solid waste, wastewaters, ballast water, antifouling coatings, air and noise pollution); (ii) primarily environmental impacts (e.g. collisions with marine mammals; light pollution; effects of wakes in shallow waterbodies and other impacts); and (iii) primarily human health impacts (mainly infections and occupational health impacts) (Figure 3).

Overall, we can conclude that cruise tourism is a maritime activity causing major impacts on the environment and human health and wellbeing, with most likely small and doubtful local economic benefits when negative externalities are monitored and disclosed. Without new and strictly enforced national and international standardized rules, the cruise industry is likely to continue causing these serious health and environmental hazards.

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## FIGURE LEGENDS

Figure 1. Heatmap of NOx emissions from cruise ships in Exclusive Economic Zones of the European Union. Source: Transport & Environment (2019)

Figure 2. Number of gastrointestinal diseases outbreaks reported in US cruise ships, 2005-2020. Produced with data from https://www.cdc.gov/nceh/vsp/surv/gilist.htm

Figure 3. Graphical summary of the environmental and human health impacts of cruise tourism.


ICELAND
SWEDEN
FINLAND
IRELAND
BELARUS
POLAND
GERMANY
UKRAINE
FRANCE
AUSTRIA
ROMANIA
Black Sea
SPAIN
Atlantic Ocean
Ankara
TURKEY
SYRIA
Baghdad
KAZAKHSTAN
TURKMENISTAN
IRAN
Algiers
Alger
TUNISIA
Tripoli
Gulf of Sidra
ALGERIA
LIBYA
EGYPT
Cairo
ISRAEL
SAUDI ARABIA
OMAN

Figure 1


number of outbreaks
0
5
10
15
20
25
30
35
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

Figure 2

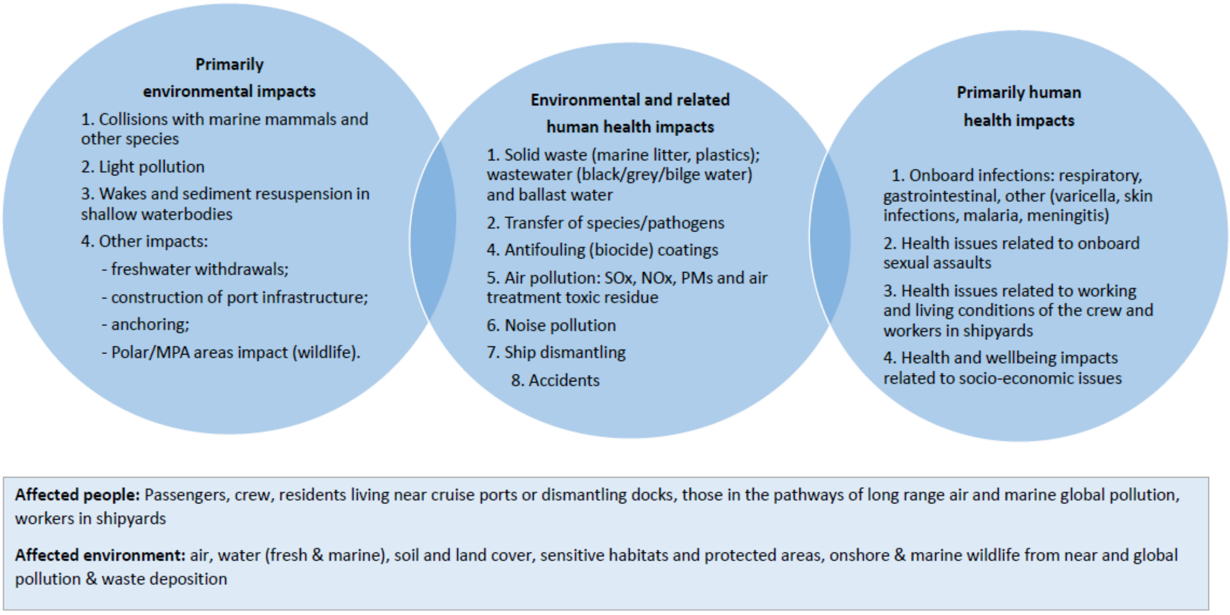
Primarily environmental impacts
1. Collisions with marine mammals and other species
2. Light pollution
3. Wakes and sediment resuspension in shallow waterbodies
4. Other impacts:
- freshwater withdrawals;
- construction of port infrastructure;
- anchoring;
- Polar/MPA areas impact (wildlife).
Environmental and related human health impacts
1. Solid waste (marine litter, plastics); wastewater (black/grey/bilge water) and ballast water
2. Transfer of species/pathogens
4. Antifouling (biocide) coatings
5. Air pollution: SOx, NOx, PMs and air treatment toxic residue
6. Noise pollution
7. Ship dismantling
8. Accidents
Primarily human health impacts
1. Onboard infections: respiratory, gastrointestinal, other (varicella, skin infections, malaria, meningitis)
2. Health issues related to onboard sexual assaults
3. Health issues related to working and living conditions of the crew and workers in shipyards
4. Health and wellbeing impacts related to socio-economic issues
**Affected people:** Passengers, crew, residents living near cruise ports or dismantling docks, those in the pathways of long range air and marine global pollution, workers in shipyards
**Affected environment:** air, water (fresh & marine), soil and land cover, sensitive habitats and protected areas, onshore & marine wildlife from near and global pollution & waste deposition

Figure 3.


Graphical abstract

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