Chapter 3
Impacts and Threats of Marine Litter in African Seas

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Summary With a focus on plastic pollution, this chapter discusses the impacts of marine litter on the natural environment, the people and the economies of Africa. The impacts of marine litter will depend on various factors such as distribution, exposure time, size and type of organism. This chapter focusses on different impacts of marine litter at various scales, from ocean to coast, as well as more localised scales. The emphasis is on the coastal countries of the African continent, where information from Africa is lacking, and relevant data from other regions is used to infer possible impacts. Throughout this chapter, the environmental, social, economic and human impacts are discussed separately, although it should be remembered that these topics are intimately interlinked.

Keywords Environmental impacts · Economic · Social and human impacts · Waste management · Marine and coastal litter

3.1 Introduction

The first global accounts of plastic debris in the marine environment were reported in the 1970s (Carpenter & Smith, 1972; Carpenter et al., 1972; Cundell, 1974). One particular observation was made in 1971 during the 'Ra' Expedition (Heyerdahl, 1971) in the waters of Cape Verde, one of the African Small Island Developing States (SIDS). A brief history of marine litter research shows that since the 1960s concerns grew about the potential impacts of marine litter. From the first anecdotal reports of entanglement and plastic ingestion in the 1960s, scientific publications followed in

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the 1970s, these were succeeded by a series of meetings on marine debris in the early 1980s which resulted by the end of the twentieth century in a better understanding of the marine litter issue and search for solutions (Ryan, 2015). Those early reports provided a first indication of the environmental catastrophe, which was in the making.

Scientific research on the impacts of plastic pollution is still ongoing, but the more we learn about the impacts of plastics, the gloomier the picture. The environmental impacts threaten the livelihoods of coastal populations through social, economic and human aspects. Throughout this chapter, the limited information on the impacts of marine pollution across Africa is highlighted. Even though the scientific interest in plastic pollution has increased over the years, the knowledge of the impacts on African countries is still largely unknown with most information restricted to South Africa (Fig. 3.1a–b). The scarceness of studies in Africa is indicative of limited funding across scientific fields, and the contribution of the African continent to global scientific knowledge was estimated at 2.8% in 2020 (Diop & Asongu, 2021). Interestingly, the Africa's contribution to the global GDP was also estimated at 2.8% (International Monetary Fund, 2021), showing that though limited, the studies are in line with what is available economically. It is noted, that even with knowledge gaps, enough is known about the impacts of marine litter and plastic pollution specifically, to implement mitigating actions and drive change ('Precautionary Principle'). Currently, most of the available data in Africa focusses on the presence, distribution and source determination of marine litter. This type of data provides a strong foundation to set baselines and determine impacts. Several global scientific initiatives such as capacity building, technology transfer and collaborations can contribute to promote marine plastic pollution research in Africa.

Box 3.1: The Special Case of Africa's Island States

During the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992, SIDS were recognised as a discrete group of developing states facing specific social, economic and environmental vulnerabilities. These island states have limited land area, but they possess large exclusive economic zones at sea. Considering that a coastal population is commonly defined as the population residing within 100 km of the shoreline, the inhabitants of SIDS are exclusively coastal (Nicholls & Small, 2002; Small & Nicholls, 2003). The six African countries with SIDS status are Guinea-Bissau, Mauritius, Seychelles, Sao Tomé and Principé, Comoros and Cape Verde. Local economies are closely associated with the ocean as coastal tourism, fishing and related activities, aquaculture and more recently biotechnology are the main sectors included in the oceanic economy of SIDS.

Taking into account the remoteness and small, though dense, populations of these island states and their small contribution to marine plastic pollution, the impacts felt are uneven and disproportionate (Duhec et al., 2015; Onink et al., 2021). One particular example is Aldabra Atoll of the Seychelles. Designated as a UNESCO World Heritage site since 1982, this inhabited region harbours not only the largest population of giant tortoises in the world but also a wide variety of endemic animals. In March 2019, 25 tonnes of plastic litter were removed from the atoll at a cost of $224,537. This represented only 5% of the marine litter accumulated on the atoll. Removing the remaining litter would cost around $4.68 million and require 18,000 person-hours of labour (Burt et al., 2020).

3.2 Environmental Impacts of Marine Litter

Kühn et al. (2015) reviewed global publications on marine debris and reported that 557 species were affected by marine debris. The number of species reported to be affected by marine debris increased from 557 to 817 by 2016 (CBD, 2016). These studies showed that as with classification studies (refer to Chap. 2), plastic is the most encountered form of litter in the marine environment from an impact perspective.

Environmental impacts of marine litter are well known globally; however, information about the effects of marine litter in Africa is poor. Gall and Thompson (2015) categorised marine litter research per region, finding that the majority of studies ($n = 110$) were from North America, with only 12 impact studies from Africa. Marine litter is the cause of various negative environmental impacts globally, and these effects are arguably more pronounced in Africa due to the combination of poor waste management and rich biodiversity (see Chap. 1).

Akindele and Alimba (2021) reviewed 59 articles on the prevalence of plastic pollution from African aquatic environments in the period 1987–2020. Geographically, research outputs reported were as follows: 15 from North Africa (Algeria, Egypt, Morocco and Tunisia), six from East Africa (Ethiopia, Kenya, Tanzania and Uganda), 13 from West Africa (Ghana, Guinea-Bissau, Mauritania and Nigeria) and 25 studies from South Africa. The prevalence and effects of macro litter are the most prominent types of published research in Africa (Akindele & Alimba, 2021). Entanglement, smothering and ingestion by larger animals are well publicised due to the visible effects reported on marine mammals,

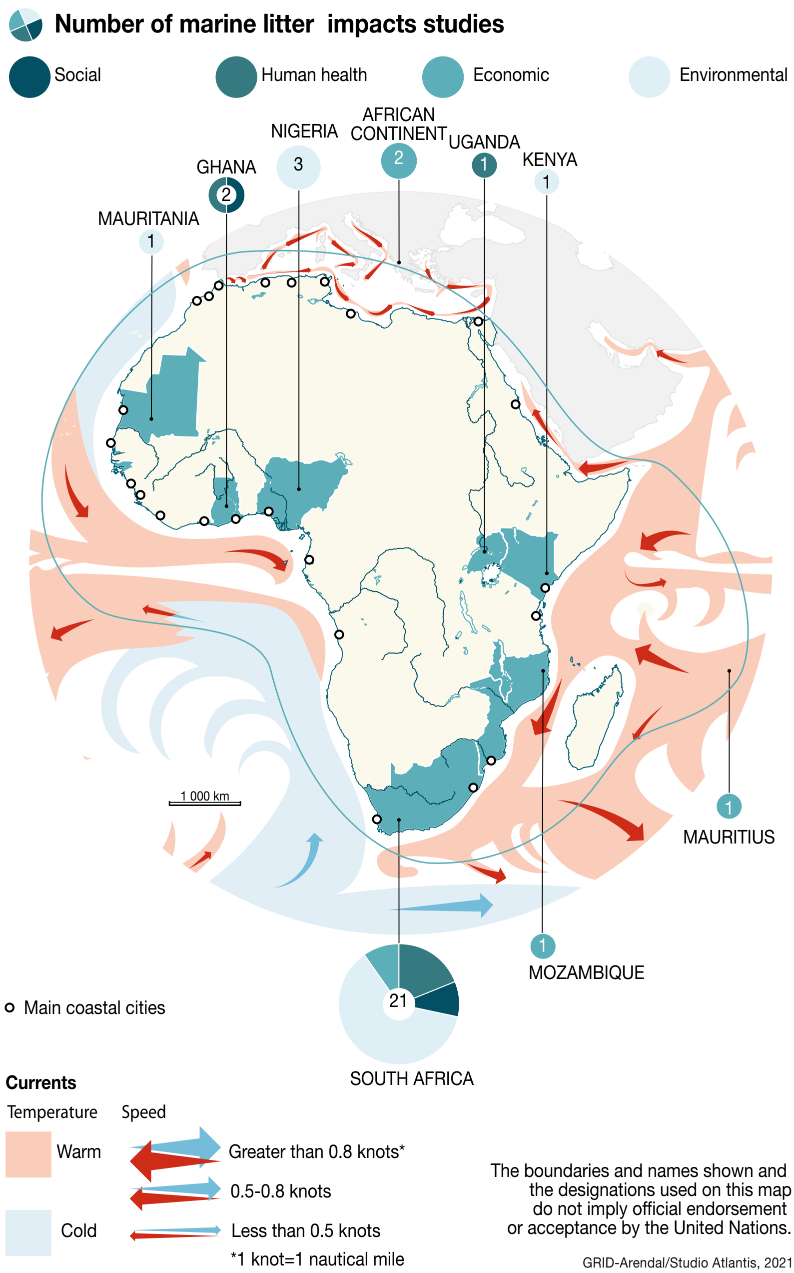

Fig. 3.1 **a** Total number of marine litter impact studies published across Africa in peer-reviewed journals (excluding quantification studies, which are covered in Chap. 2). *as of December 2021. **b** Total number of marine litter impact studies, by size fractionate, published across Africa in peer-reviewed journals (excluding quantification studies, which are covered in Chap. 2). *as of December 2021

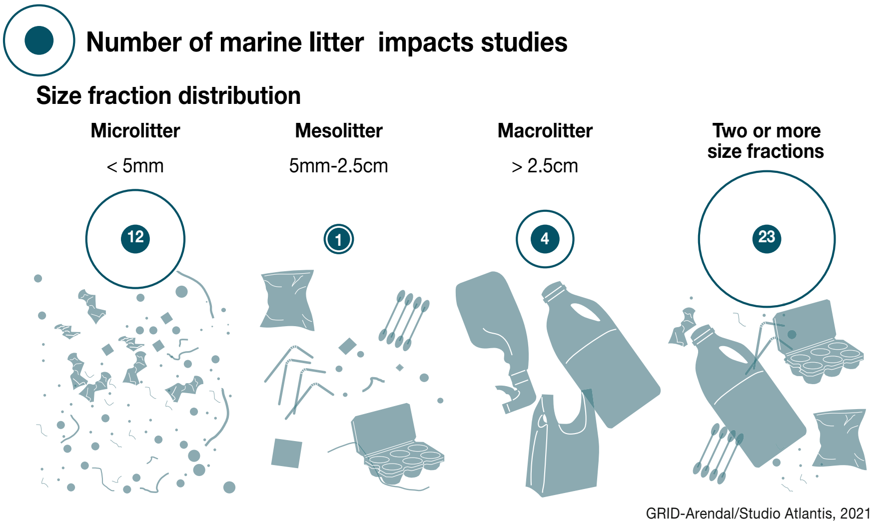

Fig. 3.1 (continued)

turtles and birds (Gregory, 2009; Ryan, 2018). The impacts of marine litter are often complex and the effects difficult to contextualise from micro to macroscale in terms of animals (cellular to biodiversity) and environments (localised to global). Although the following sections are compartmentalised, it should be noted that the impacts of marine litter in the environment are complex and interconnected.

3.2.1 Ingestion/Feeding

The ingestion of marine litter has been reported in over 519 species of animals (CBD, 2016), with records of publications increasing steadily (Ryan, 2015). Globally, ingestion of marine plastic litter has been recorded in at least 36% of seabird species (Ryan, 2018), 100% of turtle species, 59% of whale species and 36% of seal species (Kühn et al., 2015). Ingestion can be direct (primary ingestion) or indirect (secondary ingestion). Primary ingestion can be intentional or accidental. Intentional or deliberate ingestion of marine litter is when plastic items are mistaken for prey items and is influenced by foraging strategy, debris colour, age and sex of animals as well as characteristic of the litter (e.g. colour, size and chemical composition). Accidental ingestion occurs passively, mainly by non-selective feeders (e.g. filter feeders) (Kühn et al., 2015; Ryan, 2016). Secondary ingestion occurs by predators (and scavengers) consuming prey and food containing plastic items.

Ingestion studies tend to focus on the amount of plastic in the digestive tract of an organism. This amount is dependent on the ingestion rate and retention time (how long before removal via excretion and/or regurgitation). Thus, the amount of plastic in an organism will be dependent on the pollution level of the area the species forages in and its retention time (Ryan, 2016).

The main impacts of plastic ingestion (Derraik, 2002; Gregory, 2009; Mouat et al., 2010; Napper & Thompson, 2020) include:

- Accumulation of plastics in the digestive tract leading to damages such as wounds, scarring and ulceration, which in extreme cases can result in infection, starvation and eventually death.
- Mechanical blockage of the digestive tract.
- Reduced quality of life and reproductive capacity.
- Drowning, increased susceptibility to predators and death due to changes in buoyancy and/or impaired mobility.
- Reduced feeding capacity resulting in malnutrition, general debilitation, starvation and possibly death.
- Chemical poisoning from synthetic additives and contaminants comprising polymers that leads to reproductive disorders, increased risk of diseases, altered hormone levels and ultimately death.

Chemical effects from contaminants taken up through ingestion is dependent on equilibrium setting and thus retention times and partitioning coefficients. Chemical uptake is likely to be enhanced by longer retention times. Thus, '*species with broad, generalist diets that retain indigestible prey items in their digestive tracts for extended periods, probably are most likely to obtain large body burdens of hazardous chemicals from ingesting plastic items*' (Ryan, 2016). Further information round chemical impacts can be found under Sect. 2.5 Chemical Impacts.

A review of research on plastic ingestion in Africa between 1987 and 2020 found recorded ingestion in 63% of vertebrate species and 37% of invertebrate species studied (Akindele & Alimba, 2021). It is noted that this review excluded pre 1987 research. This meta-analysis of ingestion in Africa showed that plastic was found in 46% of examined fish species, 17% of birds species, 17% of molluscs species, 3% of plankton species and 7% of annelids species. Many of the species studied were reported as bioindicators of plastic ingestion or served as seafood across Africa (Akindele & Alimba, 2021). However, most of the research on plastic ingestion across Africa has been focused on fish species (Akindele & Alimba, 2021), most likely due to ease of access, as well as dependency on fish as a source of protein across the continent.

Most studies on plastic pollution across Africa come from South Africa (42% of reports) (Akindele & Alimba, 2021). Plastic ingestion by vertebrates in South Africa has been recorded in numerous species of birds ($n = 36$), sharks ($n = 10$), bony fish ($n = 7$) and turtles ($n = 1$) (Naidoo et al., 2020). Plastic ingestion by marine birds in South Africa is particularly well documented (Naidoo et al., 2020). Ryan (2008) reported that seabird ingestion of plastic particles consisted of mainly industrial pellets, but this may be changing, given the increase in fragmented plastics entering the environment (Ryan et al., 2020). The release of contaminants associated with plastic ingested by birds is important as these may be further contributing factors of the total impact of ingested plastics. Ryan et al. (2016) reported 60% of juvenile loggerhead turtles ($n = 24$) that died after stranding in the southern Cape of South Africa, contained ingested marine debris, of which 99% was plastic debris.

There is little information on ingestion of plastic by intertidal invertebrates that are not marine resources. One such example is Weideman et al. (2020a) who investigated the uptake of macroplastics by sea anemones (invertebrates) in southern Africa. These authors found that sandy anemones *Bunodactis reynaudi* in Cape Town, South Africa, often ingest plastic, mainly bags and other flexible packaging. These authors found that 491 litter items ingested by sandy anemones from 52 sampling events (9.4 $\pm$ 14.9 items month^{-1}) were mainly plastics, white in colour and correlated with high levels of beach litter items. Ingestion was more frequent during autumn, when the first winter rains had washed more litter into the sampling area. In addition to the field sampling, experiments indicated that sandy anemones *B. reynaudi* preferentially selected high-density polyethylene (HDPE) bags that were previously suspended in seawater for up to 20 days, suggesting that biofilms may enhance the potential for ingestion of plastic bags (Weideman et al., 2020a).

Microplastic ingestion is widespread across benthic and pelagic ecosystems where organisms feeding mechanisms do not allow for discrimination between prey and plastic items (Moore et al., 2001) or feed directly on microplastics, mistaking them for food (Moore, 2008). Microplastic ingestion research has increased over the past few years in Africa (see Table 3 in Alimi et al. (2021) and has been reported in freshwater birds (Reynolds & Ryan, 2018), fish (Bakir et al., 2020; Mbedzi et al., 2019; McGregor & Strydom, 2020; Naidoo et al., 2016; Shabaka et al., 2019; Sparks & Immelman, 2020), invertebrates such as zooplankton (Kosore et al., 2018), polychaetes (Nel & Froneman, 2018), mussels (Sparks, 2020; Wakkaf et al., 2020) and sea cucumbers (Iwalaye et al., 2020).

Research on marine and coastal microplastics in biota in Africa has been reported for marine resources (Abidli et al., 2018, 2019; Bakir et al., 2020; Sparks et al., 2021; Wakkaf et al., 2020). A study by Bakir et al., 2020 documented the levels of microplastics in three commercially important small pelagic fish species in South African waters, namely European anchovy (*Engraulis encrasicolus*), West Coast round herring (*Etrumeus whiteheadi*) and South African sardine (*Sardinops sagax*).

A higher concentration of microplastics for *S. sagax* (mean of 1.58 items individual^{-1}) compared to *Et. whiteheadi* (1.38 items individual^{-1}) and *En. encrasicolus* (1.13 items individual^{-1}) was found. The authors proposed *E. whiteheadi* as a bio-indicator for microplastics in South Africa.

Several studies that have shown that filter feeders, essentially shellfish, tend to accumulate microplastics in their gut (Karlsson et al., 2017; Lusher et al., 2017). Globally, coral polyps are known to have a particular taste for microplastic particles (Allen et al., 2017; Hall et al., 2015). Although most of the particles are rejected, 10–15% remain in the polyps. Additionally, Brown et al. (2008) showed that microplastics can even translocate to the circulatory system of mussels. The sorption of heavy metals, such as mercury, on the surface of microplastics is also of concern and can potentially contribute to the bioaccumulation of these toxic metals in shellfish, albeit this is dependent on equilibriums (Fernández et al., 2020).

Microplastics have been shown to impact invertebrates at a community level. Mussels in South Africa were able to produce more byssal threads when exposed to microplastic leachate seawater (when compared to a control), implying that mussel beds are influenced by plastic pollution (Seuront et al., 2021). An increased mortality in oysters who were chronically exposed to environmental relevant high loads of microplastics was observed in the laboratory. The results suggested that competitive abilities of intertidal bivalves may affect their ability to tolerate disturbance and ultimately influence their capacity as autogenic ecological engineers (Seuront et al., 2021). Marine animals are able to transfer ingested microplastics to predators when they occur in the natural environment. Maes et al., (2020a, b) found microplastics in North-East Atlantic porbeagle shark spiral valves, suggesting that these apex predators were consuming prey that had consumed microplastics. Southern mullet (*Chelon richardsonii*) sampled from a surf zone in South Africa recorded varied volumes of microplastics in guts from different ontogenetic stages (0–80 microplastic fibres across stages, 0–2 microplastic fragments across stages). This suggests that these fish are potential sources of microplastics (and associated contaminants) to be transferred up the food chain (McGregor & Strydom, 2020). Although microplastics are being reported at different trophic levels, the transfer and effects of contaminants associated with microplastics require further investigation in Africa's coastal ecosystems. Recently, the impacts of nanoplastics have been documented. They enter the marine organisms at the cellular level and have a wide range of impacts depending on the invaded organism (Piccardo et al., 2020). This is an emerging field of research in Africa and globally.

3.2.2 Entanglement

Entanglement in nets, ropes and other debris poses a significant risk to marine animals and has been recorded in 0.06% ($n = 92$) of invertebrate species such as corals (Schleyer & Tomalin, 2000), 0.27% ($n = 89$) of fish species, all 7 sea turtle species (Kühn et al., 2015), 36% of 414 seabird species (Ryan, 2018), 67% of 33 seal species and 31% of 80 marine mammal species worldwide (Kühn et al., 2015). It is important to note that entangled animals may be consumed by predators at sea or die and quickly sink, thereby eliminating them from potential detection in surveys (Gregory, 2009). Entanglement by marine litter is caused mostly by plastic items, in 91% of 205 species investigated for entanglement, 71% was due to plastic rope and netting (Gall & Thompson, 2015), and other specific items considered to be of high risk for entanglement of marine species are packing straps and six-pack rings (Ryan, 1990, 2018).

The main effects of entanglement (Akindele & Alimba, 2021; Derraik, 2002; Gall & Thompson, 2015; Gregory, 2009; Kühn et al., 2015; Laist, 1997; Mouat et al., 2010; Provencher et al., 2017; Sheavly & Register, 2007) include:

- Abrasions, cuts and wounds which can lead to infection, ulceration and ultimately death.
- Suffocation, strangulation and drowning of air-breathing species.
- Asphyxiation of species that require constant motion for respiration.
- Impaired mobility and reduced predator avoidance.
- Reduced fitness and increased energy cost of travel, due to entangled debris.
- Reduced ability to acquire food, which may ultimately lead to starvation.
- Restricted growth and prevention of circulation to limbs.
- Increased risk of sessile organisms being pulled off rocks by increased drag (e.g. corals, macroalgae, etc.).

Most research on entanglement in Africa has been reported in southern Africa. Naidoo et al. (2020) summarised marine plastic debris impacts in South Africa and reported plastic entanglement in sharks ($n = 8$ species), turtles ($n = 2$), mammals ($n = 5$) (Naidoo et al., 2020) and bird species ($n = 48$) (Ryan, 2018).

Ghost fishing refers to lost or abandoned fishing gear, including fish aggregating devices (FADs) (Balderson & Martin, 2015), which continues to entangle and ultimately kill organisms, as well as, destroy benthic habitats (Mouat et al., 2010). Ghost fishing affects an array of animals such as turtles, seabirds, seals and cetaceans, as well as commercially valuable and non-targeted fish species (Mouat et al., 2010; Stelfox et al., 2016). In addition to derelict fishing gear, other kinds of marine litter such as balloons, plastic bags and sheets are also known to cause entanglements (Kühn et al., 2015). It is also worth noting the difficulty in distinguishing between active and ghost gear at the time of entanglement, but the net effects are considered to be the same.

Anthropogenic factors relating to the mortality of 55 southern right whales (*Eubalaena australis*) off southern Africa between 1963 and 1998 indicated that five deaths were due to entanglement with active fishing gear (bycatch), with another 16 showing signs of non-fatal entanglements (Best et al., 2001). Between 1972 and 1979, Cape fur seals were reported to be affected by litter, specifically, fishing gear (nets, rope and lines), string, and plastic straps (Shaughnessy, 1980). Entanglement of fish (mainly sharks) in South Africa was mainly caused by plastic straps (from bait boxes and other packaging) in the 1980s (Ryan, 1990) and entanglement in shark nets (nets used for protection of bathers along beaches of KwaZulu Natal) (Cliff et al., 2002). Entanglement has also been recorded in other parts of (mainly northwest) Africa, which includes turtles (Duncan et al., 2017), seabirds (Rodríguez et al., 2013) and seals (Karamanlidis et al., 2008), with entanglement material often stemming from discarded fishing gear (Rodríguez et al., 2013).

3.2.3 Smothering

A large fraction of plastic marine litter tends to float in aquatic environments. As these litter items become heavier due to biofouling (Lobelle & Cunliffe, 2011), they have the potential to sink and settle on the seafloor (Fazey & Ryan, 2016), covering a variety of habitats from riverine, intertidal and near shore zones to abyssal environments (Gregory, 2009). The remaining plastics, that are denser the seawater, will sink and settle quicker, with the same impacts as their more buoyant counterparts. Plastic litter items settling on the seafloor may cause organisms to be smothered. This is of particular concern for marine vegetation and corals which also rely on light for primary production (Derraik, 2002; Kühn et al., 2015). Accumulation of litter may prevent gas exchange, resulting in reduced oxygen availability (Eich et al., 2015) and anoxic conditions in bottom waters, which themselves may be promoting climate-change conditions as a result of greater ocean stratification. The resulting impact on ecosystem functioning may be the covering of benthic organisms and changes in benthic ecosystem species composition and ecological interactions (Kühn et al., 2015; Napper & Thompson, 2020).

Although there are currently no reports on smothering caused by marine litter in Africa, Naidoo et al. (2020) reported that while South African coral reef diversity and associated sediments have been characterised, the susceptibility of these systems to marine debris was unclear.

3.2.4 Impact of Marine Litter Transport (Habitats and Dispersal)

The transport of fouling organisms and introduction of invasive species in habitat niches, such as in the African SIDS, has also been documented (Beaumont et al., 2019; Lachmann et al., 2017; Naidoo et al., 2020; Newman et al., 2015). The movement of flotsam is a natural occurrence, with wood, macroalgae and volcanic pumice being natural agents of flotsam dispersal for millions of years (Kiessling et al., 2015). Unlike natural flotsam, marine litter has no nutritive value (unless covered in a biofilm) and the additional amounts and features of litter (e.g. surface texture) are likely to influence colonisation and succession rates (Bravo et al., 2011). The 'plastisphere' is a term introduced by Zettler et al. (2013) to describe microbial communities on plastic marine debris. Plastics provide a substrate for proteins to develop biofilm formations that enable the debris to function as artificial 'microbial reefs' (Zettler et al., 2013). On entering the environment, biofilm and plastisphere development commences, further determining the pathway and fate of marine litter items.

Given the buoyant properties of many plastic items, oceanic and aquatic currents are able to transport plastic marine litter over vast areas (van Sebille et al., 2020). Most litter released from the coastal environment into the open ocean, if not settled on the benthos, eventually reaches beaches or remains afloat in the water column

(Onink et al., 2021). Depending on ocean current dynamics, marine litter has the potential to drift across entire oceans to other continental coastal areas (Ryan, 2020a), creating rafts which move alien species, pathogens, bacteria and hazardous substances including endocrine disruptors, persistent organic pollutants (POPs) and metals around the world (Naik et al., 2019). The durability of plastics also provides a platform to transport species from the sea surface, through the water column to ocean depths (Napper & Thompson, 2020). The movement of litter on the seafloor may also physically translocate benthic organisms (Naik et al., 2019). It is important to monitor floating litter, in terms of transport dynamics, estimation of fluxes of invasive species as well as assessment of the sources and pathways of litter in coastal areas. For example, Ryan (2020b) reported that plastic litter from local sources became less prominent with increased distance from urban areas in Kenya and South Africa (Ryan, 2020a), suggesting that localised sources of litter are major contributors to plastic pollution in urban coastal areas in the African sites sampled, with long-distance drift and transboundary transport being a varied concentration source across urban and remote areas. To develop a better understanding and to test policy interventions, a mass balance approach should be developed. Key information is missing for Africa and globally on plastic mass input, transfer and sink terms. The rates of accumulation, the dispersal pathways, the residence times in each compartment and the degradation rate into microplastics are unknown (Harris et al., 2021).

3.2.5 Chemical Impacts

Plastic contain additives, added during the production process, which can leach into the environment. High concentrations of chemical additives have the potential to be transferred from plastic litter to biota (Napper & Thompson, 2020; Rochman, 2015). Additionally, legacy pollutants including metals, POPs and endocrine disruptors (EDs) are sorbed onto plastic marine litter (Rochman, 2015). POPs have been reported in the marine and terrestrial environments and organisms in Africa (Alimi et al., 2020; Bruce-Vanderpuije et al., 2019). Ryan et al. (2012) showed plastic found in the marine and coastal environment to contain sorbed POPs. Hosoda et al. (2014) show more evidence of absorption of toxins, polychlorinated biphenyls (PCBs) from e-waste sorbed into plastics. Alimi et al. (2021) include a review of 14 studies of POPs and metals found in microplastics in the marine environment of Africa. Interestingly, Ryan (1988) found a correlation between the concentrations of PCBs in seabirds and the mass of ingested plastics, indicating that plastics can be a pathway for PCBs into organism tissues. More recently, Yamashita et al. (2021) identified flame retardants and legacy POPs in the preen gland oil of seabirds. The finding of these contaminants in blue petrals (*Halobaena caerulea*), who's range is limited to the remote region south of the Antarctic Polar Front is of particular interest.

The impact of POPs and metals on organisms when ingested is well studied, and their threats understood (as seen by the creation of the Stockholm Convention) (Mearns et al., 2018). Though it is acknowledged that the impact through ingestion of contaminated plastic is less studied, microplastics have been reported to adsorb POPs from its surrounding environment, and these POPs could be released following ingestion and/or be a pathway for transfer into tissues of animals (Galloway et al., 2017). The effect of plastics with regard to contaminant transfer is dependent on the context and linked to the setting of chemical equilibriums. In most cases, the net contribution of plastic ingestion to bioaccumulation of hydrophobic contaminants in marine biota is likely to be small in comparison with uptake of contaminants directly from water, sediment or food (Bakir et al., 2012; Koelmans et al., 2016). Ecotoxicological research on pollutants in marine debris has, however, shown that organic pollutants and metals have the potential to degrade the structure and function of ecosystems (Rochman, 2015). The impact of microplastics becomes evident at the onset of physiological processes being disrupted (subcellular protein function) causing diseases (Guzzetti et al., 2018), impaired activities such as reduced mobility and impaired reproduction (Sussarellu et al., 2016). The chemical impacts of plastic sorption and its pathways within the marine environment needs further research. The threat of absorption of contaminants from plastics to animals will depend on concentration and retention time, and bioaccumulation may have effects through the food chain. When considering plastics as a vector of contaminants, and their impacts, multiple sources and stress effects should be considered. It is imperative that such research is undertaken as contaminants sorbed to plastics have been shown to induce mutagenic or carcinogenic risks, endocrine disruption, genetic disruptions, inflammation, fibrosis and reproductive impairment (Arienzo et al., 2021). These effects are extrapolated to population, community and ecosystem levels and ultimately affect the productivity of entire ecosystems (Wright et al., 2013).

Box 3.2: Chemical Pollutants Found in the Marine Environment

As plastics can sorb and act as a vector for contaminates, concern arises for plastics to transport contaminants into different environmental compartments or remote areas, far from their sources, as well as provide a pathway, via ingestion, for bioaccumulation in species through bio-magnification and bio-concentration.

Litter of all sizes has been identified as a vector for toxic chemicals. For example, plastics are composed of the base monomer along with additives such as colourants, plasticisers, lubricants and flame retardants (Rochman et al., 2019). As the plastic materials are degraded into smaller plastic items in the environment, some of these residual monomers and chemicals are released into the aquatic system (Amelia et al., 2021; Dasgupta, 2021). Plastic particles in the oceans may sorb chemicals from the surrounding media (Näkki et al., 2021), and multi-stressor effect still need to be considered.

Persistent Organic Pollutants (POPs)

Plastics can sorb and act as a vector for POPs (Andrady, 2017; Ryan et al., 2012). POPs are highly toxic and are derived from diverse sources, including the combustion of some organic-bearing materials such as plastics and tyres that lead to the formation of 'unintentionally produced' furans, dioxins and polycyclic aromatic hydrocarbons. Some POPs have important industrial applications as pesticides, fire-retardants and as oil additives for electrical transformers. POPs undergo long-range transport in the environment and can easily reach the marine environment from land-based hotspots and diffuse sources, which include aerial deposition at sea. POPs can persist for decades in the environment and have been detected in coastal and marine environments of various sub-regions of Africa. Pesticide use in agricultural activities is believed to be the most likely source of POPs in southern Africa (UNEP/GPA, 2006).

In South Africa, Ryan et al. (2012) used PE pellets obtained from three beaches to monitor the concentrations of POPs over two decades and observed that there was a trend towards decreasing concentrations. In Lagos, Nigeria, phthalate esters were found to have been absorbed onto microplastics collected from littoral sandflat sediments at five beaches and three lagoon locations (Benson & Fred-Ahmadu, 2020). Total phthalate esters concentrations ranged from 0 to 164 mg kg^{-1} dry weight, dominated by di(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DnBP) and dimethyl phthalate. It was suggested that future studies of POPs in total sediment versus the microplastics fraction might be useful for refining ecological risk assessments. Similarly, at eleven different beaches of the Ghanaian coastline, plastic resin pellets were found to contain PCBs (Hosoda et al., 2014). PCB concentrations (13 congeners) were higher in beaches off Accra and Tema (39–69 ng g^{-1}-pellets) than those in smaller coastal towns (1–15 ng g^{-1}-pellets) which are close to global backgrounds, indicating local inputs of PCBs near urban centres. Mansour (2009) reported various POPs in waters and sediments of the Nile River and some lakes close to the coastal zones of Egypt since the early 1980s. Several studies have also been conducted in Nigeria in which environmental media were shown to be contaminated with POPs (Adeyemi et al., 2019, Williams and Mesubi, 2013). Pesticide use in agricultural activities is believed to be the most likely source of POPs in southern Africa (UNEP/GPA, 2006). Most African countries are parties to the Stockholm Convention, the international treaty that seeks to eliminate the global scourge of POPs in the environment (Chap. 4). Adherence to the principles of the convention will assist African countries to ultimately and significantly reduce their burdens of toxic POPs.

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Heavy Metals

Hazardous metals have been detected in both the marine environment and marine organisms. For example, at several locations off the coasts of Cameroon in central Africa, marine sediments showed enrichment of arsenic, cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, vanadium and zinc (Biney et al., 1994). Similar findings have been reported in the literature for Côte d'Ivoire (Affian et al., 2009), Nigeria (Bamanga et al., 2019), Morocco (Maanan, 2008) and South Africa (Orr et al., 2008). Plastics can also sorb and act as a vector for metals (Naik et al., 2019). Metals have been observed in microplastics in Nigeria (Fred-Ahmadu et al. 2020).

In South Africa, mercury contamination of the marine environment has also been reported by Walters et al. (2011), while a long-term (1985–2007) dataset on heavy metals (copper, cadmium, iron, lead, mercury, zinc and manganese) in the marine environment is available from the International Mussel Watch Programme. The mussel watch data indicates that metal concentrations in *Mytilus galloprovincialis* showed no detectable increase over the study period (Sparks et al., 2014).

Petroleum Hydrocarbon

Lastly, plastic absorbs oil from seawater (Aboul-Gheit et al., 2006). Petroleum hydrocarbon oil pollution of the marine environment occurs due to releases from coastal and offshore oil exploration and production activities, as well as accidental and deliberate spillages which occur from ships that traverse the busy African and international waterways.

Oil spillage is particularly common around the coasts of African countries that are major oil producers such as Nigeria, Angola and Gabon (UNEP, 2013, 2021). The East African route is also characterised by heavy use of oil tankers. Oil spills are particularly detrimental to marine ecosystem quality, rendering the water largely unusable for aquaculture, recreation and transportation, and killing many large and small organisms within a short period. In some cases, seafood is tainted with smell of the petroleum hydrocarbons, making seafood unusable for human consumption. The Niger Delta and nearby coastal regions are particularly well known for the environmental degradation and security crisis that has been caused to the areas by oil spills to land and water (Kadafa, 2012). Recent global statistics have revealed that oil spill incidents of varied magnitudes are known to have occurred around and off most coastal seaports in the African continent (ITOPF, 2020). More recently, in July 2020, about

1000 tonnes of oil was accidentally spilled off the coast of Mauritius when the cargo ship MV Wakashio ran aground on a coral reef on the southeast tip of the country and smeared about 1.5 km stretch of the coastline (Lewis, 2020).

Marine litter is considered to be an emerging marine contaminant, especially given increased knowledge about chemicals associated with microplastics. The known impacts are centred around entanglement, ingestion and subsequent physical (Wright et al., 2013) and toxicological effects on biota (Browne et al., 2013). Larger microplastics (0.1–5 mm) may impact digestive systems (Lusher, 2015), while smaller, nano-sized particles are able to permeate lipid membranes of invertebrates, resulting in deformed membrane structure and ultimately cellular dysfunction (Alimba et al., 2021; Rossi et al., 2014).

3.2.6 Climate Change and Ecological Impacts

Plastics in the environment are contributing to the climate change, with current greenhouse emissions from the plastics industry estimating to contribute to a global temperature increase of 1.5 °C by 2050 (Hamilton et al., 2019). Additionally, plastics act as threat multipliers to climate change (UNEP, 2021); for example, the plastic pollution acts as an insulator increasing the temperature of beaches, which in addition to increasing global temperatures can affect the biodiversity of the beaches (Lavers et al., 2021; Sevwandi Dharmadasa et al., 2021). In an effort to mimic the effects of climate change on microplastics uptake, sea cucumbers sampled from KwaZulu-Natal, South Africa, were fed polyethylene fragments at different concentrations and at different temperatures. Ingestion rates increased with higher microplastic concentrations and temperatures up to 28 °C (ingestion rates decreased at temperatures >28 °C). More microplastics were also retained at 28 °C, with these results suggesting that the effects of microplastics on biota will become more pronounced with increasing temperature related to climate change (Iwalaye et al., 2021). Similar to the social, economic and human tragedies associated with climate change, the environmental impacts of marine plastic pollution directly affect the livelihoods of coastal populations.

Ecological impacts of litter are complex. Although open waste disposal or dump sites provide migratory and resident birds with nesting and feeding sites, there are risks of birds ingesting plastics and becoming entangled in litter. This changes the ecology of the species involved, specifically natural ecological activities pertaining to foraging and reproduction in natural habitats (Reusch et al., 2020). The exact effect on an ecological level is unknown, as supplemental feeding will have a positive effect on survival rates, which may offset entanglement and ingestion effects. Given the poor waste management across Africa (Willis et al., 2018), it is probable that the prevalence of large amounts of plastic litter may be far reaching, across the entire continent.

Changes in biodiversity, from entanglement and ingestion of marine litter, may have implications for survival of endangered species (CBD, 2016; Gall & Thompson, 2015). In some cases, the changes in landscape, food and ecological interactions, due to marine litter, may result in an increase in biodiversity. For example, due to litter aggregating in marine benthic regions, new habitats become available where organisms settle on plastic items (Song et al., 2021; Weideman et al., 2020b).

Box 3.3: COVID-related impacts

The COVID-19 pandemic has resulted in an increase in the use of personal protective equipment (PPE) for both citizens and frontline workers (e.g. face masks, face screens, gloves, portable hand sanitizer and full protective clothing). Due to poor waste management practices, an increase in PPE has been observed in the environment globally and in Africa (Okuku et al., 2021; Ryan et al., 2020). The increased observation of littered PPE (Okuku et al., 2021; Ryan et al., 2020; Thiel et al., 2021) is detailed in Chap. 2.

PPE such as masks is comprised of polymers such as polypropylene and/or polyethylene, polyurethane, polystyrene (Ammendolia et al., 2021; Fadare & Okoffo, 2020; Selvaranjan et al., 2021) and gloves comprised of PVC, latex and nitrile (De-la-Torre & Aragaw, 2021). Once the PPE ends up in the coastal environment, these degrade and contribute to microplastics contamination (Fadare & Okoffo, 2020).

In coastal organisms, the presence of PPE can cause impacts due to entanglement, ingestion and smothering—though depending on numbers this impact of PPE specifically may be trivial compared to overall marine litter. The monitoring of effects and mitigation measures of PPE is limited both globally and across Africa.

3.3 Social, Economic and Human Impacts

The interaction between humans and the ocean is important for our social, economic and mental well-being. Humans rely on the marine environment for food sources both from a subsistence and economic perspective (refer to Chap. 1). The ocean also plays an important role in terms of recreation, shipping and tourism (Newman et al., 2015), see Chap. 1 for more details. The presence of marine litter can impact these activities, as well as have a potential negative impact on human health (Van der Meulen et al., 2014). The social and human health impacts of marine litter are not well understood worldwide, even less so in Africa. There is a lack of published literature that explores the impacts of marine litter on the economic and social well-being of humans and its effects on human health. This section focuses on what is known about the social, economic and human impacts of marine litter in Africa. Most literature of social impacts of marine litter focuses on South Africa, albeit still with many gaps in knowledge. The remaining African countries had little, to no, literature available.

3.3.1 Social Impacts

The social impacts of marine litter consider its effects on the quality of peoples' lives, which can include: the loss of non-use values, impacts on cultural services, recreation and aesthetics (Ballance et al., 2000; Mouat et al., 2010). The interconnected social and economic impact on safety and navigation is also discussed below.

Loss of Non-Use Value and Cultural Services

Non-use value relates to the positive impact on a person in knowing that an ecosystem, species or resource exists, and that it will be around for future generations. This value is unaffected by whether or not the person visits the place (Mouat et al., 2010). Studies have found that visiting the ocean can have positive impacts on people's mood and can even reduce an individual's blood pressure (UN Environment, 2017). However, the presence of marine litter on a beach can result in negative mood changes (Arabi & Nahman, 2020; Beaumont et al., 2019; GESAMP, 2015; UNEP, 2016).

The marine environment contributes towards emotional and/or cultural services. People can feel attached and attracted to animals such as dolphins, whales and turtles. They also form part of cultural heritage to some groups. The potential loss of these animals can have an impact on peoples' well-being (Beaumont et al., 2019; UNEP & GRID-Arendal, 2016).

The marine environment contributes to spiritual and/or religious services. Many religions identify the interface between land and sea as a place where they can receive intercession with their deity (Preston-Whyte, 2008). In the African SIDS particularly, there is a strong spiritual link to the sea. Indeed, the ocean represents both freedom from oppression and a memorial for all the lives lost at sea during transportation and exploitation in colonial times (Baderoon, 2009). There is ancient symbolism in the cleansing during immersion that takes place during religious beach ceremonies, for example: in South Africa, black South Africans in Durban have a strong cultural connection with the beach (Preston-Whyte, 2008). It is common to experience the sound of drums together with singing which announces the pre-dawn ceremony. Worshippers pray and sing and are dowsed in the waves as part of ceremonial rituals (Preston-Whyte, 2008).

No studies were found in Africa that show specifically the impacts of marine litter on non-use or cultural values.

Reduced Recreational Activities and Aesthetic Value

Beaches and oceans are used for a variety of recreational activities such as swimming, diving, paddle boarding, scuba diving, kitesurfing and wave surfing. Surfing is a recreational sport but can also be considered having a cultural value to many communities, defining their way of life (Booth, 2005). The presence of marine litter can have negative impacts on recreational users from both an aesthetic and safety perspective (Beaumont et al., 2019).

Box 3.4: Case Study—Marine Litter Impact on Tourism:
A study by Balance et al. (2000) in Cape Town, South Africa, interviewed local and non-local beach users to determine the perceived importance of beach cleanliness. Foreign tourists in particular rated beach cleanliness as the number one factor in choosing a beach to visit. Approximately half of the people interviewed stated that they were willing to spend more than seven times an average trip cost to visit a clean beach (it is noted that this is a stated preference, not an actual measured response). In addition, 44% of residents were willing to travel 50 km or more to visit a clean beach. The presence of more than 10 large litter items per meter of beach would deter 97% of visitors from visiting that beach again, reducing the recreational value by R300,000 per year. The total impact on the regional economy could equate to a loss of billions of Rands per year. The estimated total annual recreational value of specific beaches in the Cape Peninsula was at least R3–23 million.

The presence of marine litter on a beach results in a loss of aesthetic value, which impacts the way people enjoy the environment (Beaumont et al., 2019; Werner et al., 2016), thus affecting a person's quality of life. Not visiting the coast due to the presence of litter can also have physical, mental and emotional health implications due to reduced physical activity and the lack of social interactions with family and friends (Arabi & Nahman, 2020; Beaumont et al., 2019). A study in Accra, Ghana, found that residents are concerned about unclean beaches. Unclean beaches were one of the top issues identified by the participants of the study (Van Dyck et al., 2016). People in Accra seem to be desensitised to years of litter campaigns and consider authorities to be responsible for the issue of marine litter (Van Dyck et al., 2016). People tend to litter more in areas that are already littered (Van Dyck et al., 2016). The negative impacts on the aesthetics of a beach due to the presence of litter have been seen along the Benin coasts and Port Bouet, Vridi, Grand Bassam in Côte d'Ivoire, which are popular tourist beaches (UNEP, 1999). Sharp objects in marine litter can also cause health issues by injuring beach users and can discourage local people from using the beach for recreational activities such as playing football or exercising.

From an education and social change perspective, a study in Durban, South Africa found that beach goers had a negative perception towards single-use plastics and had a high understanding of the impacts of single-use plastics on the environment. These beachgoers stated that they were willing to reduce their use of single-use plastics to dampen these environmental impacts (Van Rensburg et al., 2020).

Safety and Navigational Hazards

Litter, particularly plastics tend to clog drains, waterways and sewers when there is heavy rainfall. This results in damage to properties, weakening of infrastructure and can be of risk to lives (Sambyal, 2018; Turpie et al., 2019). In 2018, clogged drains during a heavy rainfall event in Accra, Ghana, resulted in the loss of 150 lives (Sambyal, 2018). In Malawi, flooding has become a common occurrence where, in 2019, flash flooding in the City of Lilongwe damaged 179 households and possibly two lives were lost due to the clogging of drains by plastic litter (Turpie et al., 2019). The building up of litter in drains and rivers and the subsequent flushing of high volumes of litter during rainfall events (as observed in Biermann et al., 2020) is also likely to increase navigation issues. These problems need to be addressed by improving waste management, urban planning and draining maintenance. However, this is costly and most African countries cannot afford to implement such activities (Turpie et al., 2019). The Emergency Services Department in Malawi clears drains monthly or on an *ad-hoc* basis. The collected waste is left on the side of the road because the Department does not have the resources to transport the waste for disposal so the waste re-enters the environment resulting in a continuous cycle (Turpie et al., 2019).

The presence of marine litter in ocean waters, particularly discarded fishing gear, ropes and plastic bags present hazards to navigation of vessels and personnel. From other regions, we know that propellers get tangled by discarded ropes and fishing lines resulting in vessel instability, plastic bags clog water intakes resulting in damage to pumps and collision with litter can result in damage to propellers which can cause injuries to personnel or even death (Mouat et al., 2010; Newman et al., 2015; Ten Brink et al., 2009; Turpie et al., 2019; UNEP, 2016).

Impacts on safety and navigation have both a social and economic impact. In 2010, the estimated cost of repairs and lost time at sea, from fishing gear and other macroplastic blocking inlet pipes and entangling propellers, was approximately 5% of total fishing revenue (Mouat et al., 2010).

Marine litter can delay the response time of emergency services in cases of rescue missions at sea due to the entanglement of propellers and clogging of inlet valves of rescue vessels. This delay in responding to a rescue mission can result in death of personnel that may have required urgent medical assistance (Abalansa et al., 2020).

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The impacts of marine litter have been seen on occasion in the Port of Durban, South Africa, after heavy rainfall events. These events also result in considerable unplanned cleaning costs for Ports and municipalities. Estimated clean-up costs of marine litter due to storm events in the Port of Durban in 2019 ranged between ZAR52 800 (USD3 400) and ZAR1 046000 (USD68 400) and totalled ZAR4 350000 (USD284 800) during that period alone (Arabi & Nahman, 2020). The costs related to the impacts of marine litter can be quite significant and have longer term impacts on the economics of a country.

3.3.2 Economic Impacts of Marine Litter

The economic impacts of marine litter consider its negative effects of a monetary nature, specifically affecting safety and navigation (discussed in Sect. 3.3.1.3, Safety and navigational hazards), fisheries, cultural services and ecosystem services. In 2005, the World Resources Institute published the Millennium Ecosystem Assessment (MEA), which provided a framework that categorises ecosystem services into provisioning services, supporting services, regulatory services and cultural services (Ecosystems & Human Well-being, 2005). Each of these categories includes several economic actors (e.g. fisheries and aquaculture) that are directly impacted by marine plastic pollution (Haines-Young & Potschin, 2012). The MEA categorisation of ecosystem services is used to discuss the impacts on fisheries, cultural services and ecosystem services below. The economies of plastic stakeholders are also discussed below. The interconnected social and economic impact on safety and navigation is discussed above under social impacts.

The Economies of Marine Litter

Environmental economics considers marine litter to be a ‘public bad’ which is both non-excludable and non-rivalrous (Common & Stagl, 2005). As is the case for most environmental ‘public bad’, marine plastic pollution is an example of market failure that can be attributed to both a missing market and negative externalities (Common & Stagl, 2005; Oosterhuis et al., 2015). The missing market results from the absence of a definition of an acceptable level of marine litter from those involved in the production of plastic and those requesting a reduction in marine plastic litter. Finding agreement between the two groups is not an easy task considering the large number of individuals, private companies, organisations and governments involved. In the middle, we have the consumers, who contribute, both directly and indirectly, to marine litter. The involvement of waste managers and recyclers is also essential in these discussions. Such negotiations, although difficult to put in place, can result in the conception of suitable schemes and initiate the setting up of a circular economy. The Ellen MacArthur Foundation initiated such discussions internationally in 2017 and the Global Commitment 2020 Progress Report attests to the resultant benefits (Ellen MacArthur Foundation, 2017, 2020). Nevertheless, with the exception of South Africa, African states are not yet involved in this initiative. For further discussions on the circular economy, see Chap. 4. The market failure in the marine plastic litter problem is also ascribed to the existence of negative externalities. These are usually described as adverse side effects of the actions of the producers and the consumers that impact the welfare or production of others. For example, the fisheries and the tourism industry are adversely affected by marine litter (Beaumont et al., 2019; UNEP, 1999; Viool et al., 2019). Since the costs of the undesired side effects are not incurred by the producers and those involved in the act of marine littering, there is no financial incentive to promote a behavioural change on individual, industrial or institutional scale.

The plastic manufacturing industry is flourishing due to the high demand for plastic products and the low price of the plastic raw materials. Babayemi et al. (2019) reported that from 1990 to 2017, 117.6 Mt of plastics entered the African continent through 33 countries: 86.1 Mt of primary plastics (pellets) and 31.5 Mt as final products. This figure excludes local production, for industrialised countries like South Africa, where local production outstrips importation. Six countries with significant contributions to this imported amount were Egypt (18.4%), Nigeria (16.9%), South Africa (11.6%), Algeria (11.2%), Morocco (9.6%) and Tunisia (6.9%). By 2030, the continent is predicted to consume 344 Mt of plastic (Babayemi et al., 2019). To put this figure into perspective, in 2019, almost 370 Mt were produced globally (Plastic Europe, 2019). The setting up of a circular economic strategy is a sustainable and necessary solution, but it involves significant financial investment. Dedicated and location specific life cycle analysis are required to determine most cost effective, humane and environmental options. In some cases, alternatives to plastics can be more costly and may have less efficient physical properties or other adverse environmental effects. In a linear economy, focusing on financial benefits of the producers, manufacturing plastic remains a better strategy. When taking into account the impacts of marine plastic pollution on ecosystem services and their associated values, the cost for the production of new virgin plastic would rise significantly, and a circular economy would become more attractive.

Impacts on Provisioning Services: Fisheries and Aquaculture

The fisheries sector is probably one of the economic actors that is the most impacted by marine litter, while paradoxically being a major contributor to the problem (Arabi & Nahman, 2020). It is estimated that abandoned, lost, discarded fishing gear (ALDFG) from industrial and artisanal fishing makes up 48% of the mass of plastic in the infamous North Pacific gyre Lebreton et al. (2018) and less than 10% by volume of the plastics found in the ocean overall (Macfadyen et al., 2009). Commonly known as ‘ghost gear’, they continue to catch fish years after they have been lost in the ocean. Consequently, ghost fishing contributes to the ongoing depletion of fish stocks. Several studies indicate that ghost fishing decreases landed catches of market species by 0.5–30% in various regions and competes effectively against fishers for their daily catch (Brown & Macfadyen, 2007; Laist, 1987; Sancho et al., 2003; Santos et al., 2003; Sukhsangchan et al., 2020).

Although ALDFG is often blamed for decreasing fish stocks in Europe and North America, scientific data is lacking for the African continent (Gilman et al., 2016). East of Africa, Al-Masroori et al. (2004) investigated the catch rate of simulated lost fish traps near Muscat and Mutrah, Sultanate of Oman. The study estimated that ghost fishing mortality was 1.34 kg/trap/day. An exponential model was used to evaluate the total mass of fish caught over different time periods, and it predicted that each trap would catch 67 and 78 kg during 3 and 6 months, respectively (Al-Masroori et al., 2004). More recently, Randall (2020) summarised the potential impacts of ALDFG on the South African fisheries sector by extrapolating the Global Ghost Gear Initiative (GGGI) methodology to estimate the impacts of several gear classes. The report suggests that the fishing sector with the greatest risk of ALDFG is the gillnet sector, the second highest risk is in the sectors of West Coast rock lobster (trap only, not hoopnet), South Coast rock lobster and the exploratory octopus trap fishery. The remaining fisheries have a low risk of creating ALDFG (Randall, 2020). Richardson et al. (2019) provide a baseline estimate that can be extrapolated to Africa, i.e. 5.7% of all fishing nets, 8.6% of all traps and 29% of all lines were lost to the world's oceans in 2017 (Richardson et al., 2019). The absence of data does not imply that ghost fishing is not affecting African countries. On the contrary, a reduction in fish catch on the African continent can potentially have severe repercussions on the availability of food. An initiative is underway by the Sustainable Seas Trust, through the African Marine Waste Network, to estimate the socioeconomic costs of ALDFG in African seas (Sustainable Seas Trust, 2021).

The cost of navigational interference by ALDFG and other litter is covered in Sect. 3.3.2.1. Safety and navigational hazards. Furthermore, the cleaning and repair of fishing gear with trapped plastic debris is among the additional activities that most industrial fishing companies have to consider in their operations (Macfadyen et al., 2009).

Another economic sector that is both affected and contributes to the ocean plastic problem is caged aquaculture, particularly the shellfish farming industry. Typically, the farming structures are made of metal wires coated with PVC or other equivalent plastics, to protect them from rusting. Furthermore, a considerable number of polypropylene ropes is used for mooring purposes. Over time, these ropes wear and photodegrade, breaking down into microplastics that can be easily ingested by wild and farmed marine organisms. Though there is global literature on the contribution of aquaculture to marine litter, there is an absence of data on how the plastic material is managed during and after its usage or affect the organisms in and outside these commercial farms. In general, there is an absence of scientific studies on the distribution and impacts of marine litter, and plastics from sea-based sources and the African continent is no exception (Gilardi et al., 2020). The aquaculture industry is relatively small in Africa, but growing (see details in Chap. 1), and so its contribution to marine litter, and marine litters effects on it are expected to increase.

The impacts of plastic litter on individual organisms, as discussed in the Sect. 3.2 Environmental impacts of marine litter, are well documented, but translating these impacts to fish stocks is not an easy task. Considering that several other stress factors, such as over-fishing and climate change, also contribute significantly to marine fish stock depletion, the distinct impact of marine litter is difficult to assess and can often be considered a threat multiplier (UNEP, 2021), rather than a standalone stressor.

A practical fishing technique that is growing worldwide among needy communities is the use of mosquito nets as fishing gear. This practice is used in at least 15 African countries (Short et al., 2018). Mosquito nets are either cheap or free in countries affected by malaria and are used as beach seines or drag nets. However, the small mesh size (0.6–1.2 mm) catches juvenile fishes and contributes to fish stock depletion (Jones & Unsworth, 2020). As they are not built for fishing purposes, they often break while in operation. The effect of these nets and anti-mosquito chemicals they often carry as marine litter is unknown.

In 2016, fisheries and aquaculture directly contributed 1.3% to the African GDP and employed over 12 million people (58% in the fishing and 42% in the processing sector) (Tall et al., 2016). Employment multiplier effects are remarkable in certain regions: for example, for every fishers' job, 1.04 additional onshore jobs are created in Mauritania, and this ratio increases to 3.15 in Guinea (de Graaf & Garibaldi, 2014). From an economic perspective, these ratios demonstrate the potential for further job creation through value chain development in the African fisheries and aquaculture sector. Therefore, considering the existing global pressures on the fisheries sector, a reduced daily catch as a result of marine litter should by all means be prevented to protect the regional economic drivers of this sector in the coming years.

Economic Impacts on Cultural Services: Recreation, Aesthetics and Heritage

Another economic sector that is directly impacted by marine litter is the tourism industry. Pre-COVID, tourism contributed on average 9–10% of the GDP of SIDS (World Bank Group, 2015). For example, tourism contributed 24.4% of the GDP of the Seychelles in 2013 (World Bank Group, 2013) compared to 7% in continental Africa.

The SIDS tourism relies on beautiful, clean, sandy beaches, yet these island states are the most disproportionately impacted by marine litter (van der Mheen et al., 2020). With small land areas and relatively small human populations, the consumption of plastics is proportionally modest when compared to continental states. However, their large exclusive economic zones harbour a considerable amount of plastic originating from the most polluting states (Lachmann et al., 2017). The Seychelles is a good example. Computational models generated from sea surface currents and windage, as well as empirical evidence from brand audits, have shown that the majority of plastic debris accumulating on their beaches originate from South East Asia (Duhec et al., 2015; Dunlop et al., 2020).

The tourism industry responds by continuous cleaning of targeted beaches at an additional cost. However, remote areas are left to accumulate large litter loads (Burt et al., 2020). Quite often, voluntary clean-up commitments by NGOs or government work programmes (such as Working for the Coast Programme, South Africa) are the sole clean-up campaigns for these regions (Ryan & Swanepoel, 1996). In the current global COVID pandemic, travel restrictions and temporary closure of borders are common. The resulting impacts on the tourism industry are severe, with considerable loss of revenue (Škare et al., 2021). Several hotels are on technical temporary closure pending a return to normal (Chummun & Mathithibane, 2020). Their beaches are currently not being cleaned.

Impact on Ecosystem Services

As described thoroughly in the previous sections (see Sect. 3.2.4), marine organisms are interacting with this unprecedented presence and abundance of plastic. A recent laboratory study on four globally distributed coral species indicates that ingested microplastics are encrusted in the calcium carbonate structure (Hierl et al., 2021). The long-term effects on these reef-building organisms are not known, but corals may become an unexpected microplastic sink. Considering that coral reefs are already under enormous pressure caused by global phenomena such as ocean acidification and climate change, the ever-growing amount of plastic in the marine environment will worsen the strain on corals. The threat of marine litter to ecosystem services, from a global perspective, is captured in Chap. 1. Data for Africa on this topic is lacking; however, marine litter is considered a threat multiplier for coastal ecosystems (UNEP, 2021).

Box 3.5: IOC Study

Aware of the threats posed by unmanaged plastic waste, the Indian Ocean Commission (IOC) has initiated programmes for its member countries, which include three African SIDS (Mauritius, Seychelles and Comoros), as well as La Réunion and Madagascar. In 2014, an initial study evaluated and mapped waste management systems in the region (Fig. 3.2). The resulting report included several recommendations to optimise waste management in the IOC member states (Indian Ocean Comission, 2021a). One noteworthy recommendation is the need to address waste management at the regional level. In 2019, the IOC published an ambitious regional action plan to specifically enhance the regional plastic waste management system and also to pave the way for the Expédition Plastique dans l'Océan Indien (ExPLOI) project that is expected to start in 2021 (Indian Ocean Comission, 2021b).

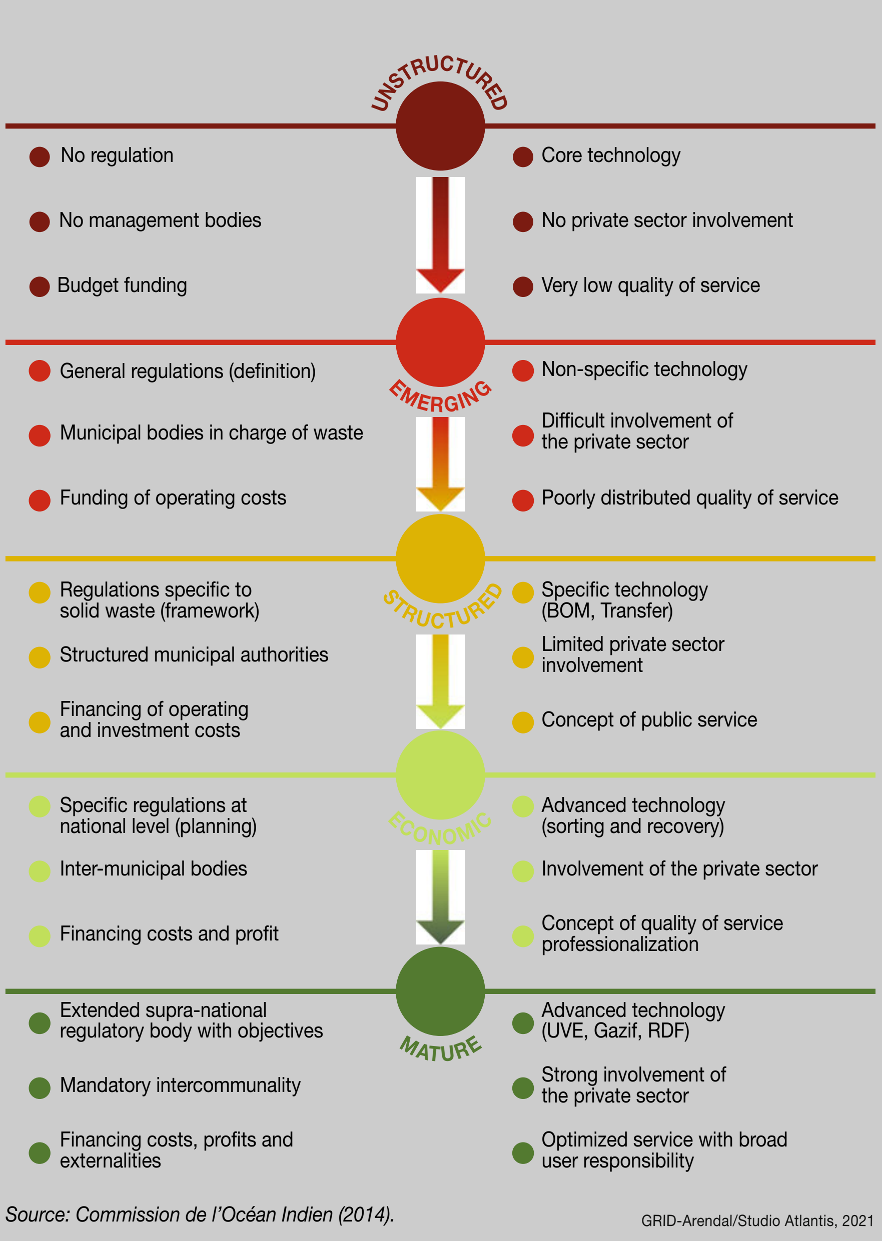

Fig. 3.2 Status of waste management in the IOC member countries (2014–2019)

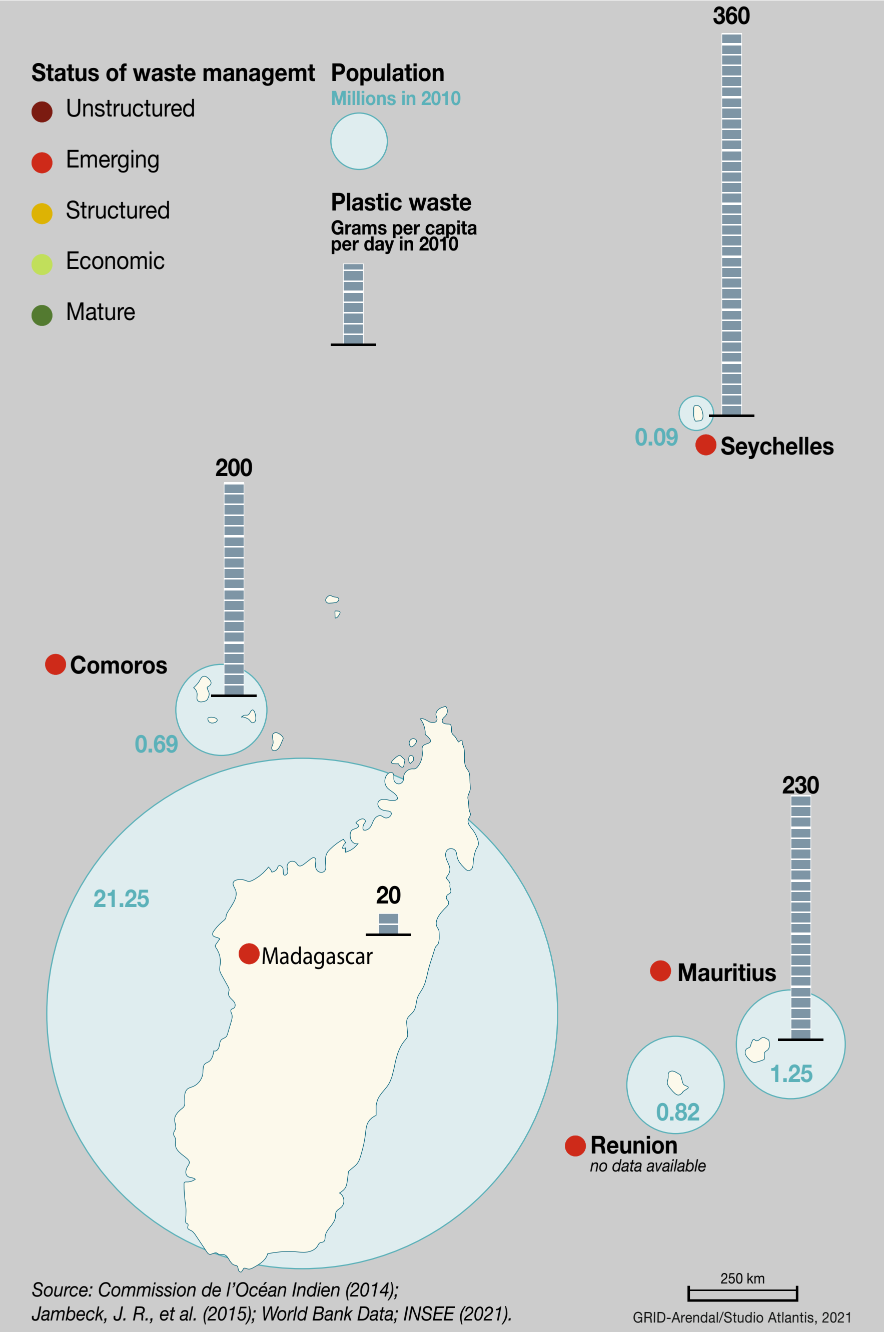

Fig. 3.2 (continued)

Financed by the Agence Française du Developpement, this ambitious endeavour intends to address the different aspect of plastic waste and pollution management in the region. Through the SWIOFISH2 programme, the IOC is extending the regional initiative to the AIODIS (Indian Ocean and African Island Developing States) (Indian Ocean Comission, 2021c). This unique platform of eight countries that include all the African SIDS (Cape Verde, Guinea-Bissau, Sao Tome and Principe, Comoros, Mauritius, Madagascar, Maldives and Seychelles) is an opportunity to collaborate, to share experiences and meet specific challenges such as improving the sustainable management of their vast maritime territories, developing their Blue Economies and promoting circular economies. Marine plastic pollution is on the priority list of this collaboration. Even if the data is cruelly scarce on plastic pollution and the related impacts in the African island states, the ongoing collaborative projects and initiatives will contribute to narrowing the gap in the near future.

3.3.3 Human Health Impacts

Considering the reliance of subsistence fishing as a food source particularly in Africa, the potential impacts of marine litter on human health are concerning. Human health impacts could be direct as a result of injuries and death, as well as indirect, e.g. ecosystem decline, loss of nutrition, chemical and other risks. Discarded containers have been shown to influence the seasonal distribution of dengue mosquitoes in rural settings in India (Shukla et al., 2020). Focused research is needed to understand the extent of this risk. Once we understand the risks, mitigation measures can be put in place to educate and advise communities of the impacts of marine litter on their health. It is worth noting that the World Health Organization (WHO) regards microplastics as a minor human health issue at this time (Naidoo et al., 2020; WHO, 2019).

Transfer Through the Food Chain

Microplastics present in the marine environment are ingested by marine organisms. When organisms are consumed as a whole, this forms a direct pathway to humans through the food web, thereby potentially affecting human health. Microplastics have been found in fish and shellfish which are commonly consumed by humans. It is of particular concern in shellfish, oysters, mussels, sea urchins, sea cucumbers and small fish which tend to be eaten whole without removal of the digestive tract (Arabi & Nahman, 2020; Landrigan et al., 2020; Turpie et al., 2019; UNEP, 2016;

Werner et al., 2016). In Tunisia, it is estimated that consumption of local mussels results in the ingestion of an estimated 4.2 microplastics capita^{-1}, year^{-1} (Wakkaf et al., 2020). For South Africa, human consumption of microplastics by mussels was estimated to be 3.03 microplastics capita^{-1} year^{-1} (Sparks et al., 2021). Three commercially important small pelagic fish species in South African waters, namely European anchovy (*E. encrasicolus*), West Coast round herring (*E. whiteheadi*) and South African sardine (*S. sagax*), were found to contain on average at least 1 microplastic per fish (Bakir et al., 2020). It should be noted that microplastics can also be ingested via other food sources, including honey, beer and tap and bottled water. Due to their small size, microplastics can also be inhaled, similar to fine particulate matter (Chen et al., 2020; De-la-Torre, 2020); however, no studies exist on these topics in Africa yet.

To date, research looking at the incidences of endocrine disruption and the ingestion of plastics are largely lacking. Although certainly possible, there is currently only limited evidence to support it (Amereh et al., 2019; Chen et al., 2021; Rochman et al., 2014). Guttered fish are still an area of potential concern. The consumption of dried fish is popular in South Africa and dates back to the seventeenth century. Although these are gutted, and therefore microplastics in the gut may be removed, there is still the potential for chemical accumulation in other tissues (Naidoo et al., 2020). In addition, the drying process requires a large amount of salt which has also been found to be contaminated with microplastics (Naidoo et al., 2020).

Endocrine disruption has been associated with chemical additives used in the plastics industry such as bisphenol A (BPA), phthalates and brominated flame retardants. Endocrine disrupting chemicals can affect the unborn foetus, children at early developmental stages and adolescents, as well as the general population. These can have human health impacts if introduced into the human body either for medical purposes or through accidental inhalation or ingestion (Arabi & Nahman, 2020; Godswill & Gospel, 2019; Turpie et al., 2019; UNEP, 2016). Studies have also looked at the ability of plastics to sorb environmental pollutants such as heavy metals, POPs, including polychlorinated biphenyl (PCBs), polybrominated diphenyl ethers (PBDEs), organochlorine pesticides (OPCs) such as dichlorobiphenyl trichloroethane (DDTs), hexachlorocyclohexanes (HCHs), polycyclic aromatic hydrocarbon (PAHs) alkylphenols, bisphenol A (BPA), parabens, estrogenic steroids and metals (cadmium, aluminium and zinc) on their surfaces (Menéndez-Pedriza & Jaumot, 2020; Scutariu et al., 2019). Newer unregulated compounds replacing previously identified toxic chemicals are also a concern. In addition, there is concern of marine plastics interacting with pharmaceuticals such as antibiotics, antidepressants and beta-blockers (Menéndez-Pedriza & Jaumot, 2020; Scutariu et al., 2019). The extent of the impacts of these on organisms, including humans, is not understood. Plastic pollutants have been found in over 83% of tap water samples around the world. This study suggested that individuals could be consuming 3000–4000 plastic particles from tap water annually (Godswill & Gospel, 2019), as such ingestion of plastic through seafood needs to be considered in line with other ingestion pathways as well as the sorption potential of chemicals in those pathways.

The large amounts of marine debris in the ocean have resulted in a substrate for microbial colonisation and a new potential route of dispersal, thereby supporting microbial communities (Werner et al., 2016), including antibiotic-resistance bacteria (Moore et al., 2020). This causes concerns regarding the transport of pathogens on marine litter and its possible impact on environmental and human health aspects (Naidoo et al., 2020; Turpie et al., 2019; UNEP, 2016; Werner et al., 2016). The need for further research on this is imperative to fully understand the scale of the problem which could have possible implications for the aquaculture sector and the Blue Economy in Africa. See Chap. 1 for details on the Blue Economy in Africa.

Spreading of Diseases

As discussed earlier, litter clogs drains and storm water which could lead to flooding during periods of high rainfall. The plastic containers and hollow surfaces can hold water themselves, increasing the risk of mosquito breeding grounds and therefore increasing the risks of malaria. There is also some evidence of marine litter supporting cholera and bacteria that cause gastrointestinal diseases (Krystosik et al., 2020; Newman et al., 2015; UNEP, 2016). In Kampala, Uganda, flooding led to five cholera outbreaks between a period of 11 years. Increased risk of disease outbreak due to a lack of proper waste disposal has been found in Malawi during the wet season. In 2018, 929 cholera cases were recorded which resulted in 30 deaths (Turpie et al., 2019). *Aedes aegypti* is a species of mosquito that breeds in stagnant water in artificial substrates such as discarded tyres, cans and plastic containers and has been linked to the spread of the Zika virus. In 2007, a Zika virus outbreak occurred in West Africa and spread into subtropics. The spread of such a virus is exacerbated by poor waste collection and management (UNEP, 2016). A study conducted in Dar es Salaam City, Tanzania, in 2014 during a dengue fever virus outbreak found that the most common breeding grounds for *Aedes* mosquitoes were discarded plastic containers and tyres (Mboera et al., 2016).

An increase in sea level, wind speed, wave height and altered rainfall conditions will lead to an increased amount of floating plastic debris along coastal areas. These increased amounts of plastic debris can result in negative health impacts for recreational ocean users (Keswani et al., 2016). Plastic debris, microplastic particles and fibres in the marine environment can transport hazardous microorganisms, including vectors for human disease (Keswani et al., 2016; Landrigan et al., 2020). In a study in Zanzibar, plastic litter from four rural sites was analysed for bacteria. Diverse bacterial species, of which many were multidrug resistant, were found on the plastic waste items including three human pathogens: *Citrobacter freundii*, *Klebsiella pneumoniae* and *Vibrio cholerae*. Plastics were therefore confirmed to act as reservoirs for bacterial growth which can lead to the transmission of infectious diseases and antimicrobial resistance (Rasool et al., 2021). *Escherichia coli* and other pathogenic species have been detected on plastics in the marine environment and on public beaches resulting in the exposure of humans to these pathogens (Keswani et al., 2016; Landrigan et al., 2020). There is a need for more focused research in this area to identify all the risks related to marine litter on beaches and the ocean with regards to the spreading of diseases.

Hazards to Swimmers, Divers and Waste Pickers (Cuts, Abrasions and Needle Injuries)

Beach users are at risk of injury due to the presence of broken glass, pieces of metal, sharp plastic fragments and medical waste often found in marine litter. A risk that is often not considered is the exposure during clean-ups, or by individuals (e.g. beach combers, waste pickers and homeless individuals) who in countries such as Sierra Leone sort through marine litter containing broken glass and sharp objects such as needles (Sankoh, 2021, personal communications). Some of these communities do not have the necessary protective equipment such as masks and gloves when sorting through waste and are therefore more exposed to possible injury or to pathogens which can lead to respiratory infections, skin diseases, chronic diseases and mental illness. They often lack the knowledge of the impacts of exposure to waste on their health (Made et al., 2020). A study in Johannesburg, South Africa, found that waste pickers at dumpsites tend not to visit clinics for medical help and assessments due to the fear of being judged or discriminated against (Made et al., 2020).

Discarded fishing nets and ropes can cause risk to swimmers and divers who can get tangled in them (Beaumont et al., 2019; Tsagbey et al., 2009; Werner et al., 2016). In a study in Accra, Ghana, representatives from four different environmental organisations experienced injuries such as wounds, diseases and discomfort from marine litter on beaches (Van Dyck et al., 2016).

Leaching of Poisonous Chemicals

Components of plastics like plasticizers and additives can be toxic to human health due to the leaching of chemicals. The amount of toxic chemicals in the ocean is relatively low, but this can become important when large amounts of debris with high levels of toxic compounds are accidentally deposited into the ocean (Werner et al., 2016), such as during the M/V X-Press Pearl nurdle spill. Exposure to combustion, heat and chemicals led to agglomeration, fragmentation, charring and chemical modification of the plastic, creating an unprecedented complex spill of visibly burnt plastic and unburnt nurdles. This added chemical complexity included combustion-derived polycyclic aromatic hydrocarbons. A portion of the burnt material contained petroleum-derived biomarkers, indicating that it encountered some fossil-fuel products during the spill (de Vos et al., 2021).

3.4 Conclusions

Most of the African data available on marine plastic litter focuses on the distribution and sources (refer to Fig. 2.1a–b, Chap. 2). This provides a strong foundation and an optimistic outlook for the coming years in understanding the impacts of marine litter. A similar profile in terms of research can be found in Europe where the best represented topics within European projects were 'Policy, Governance and Management' and 'Monitoring'. Comparatively 'Risk Assessment', 'Fragmentation' and 'Assessment Tools' were underrepresented (Maes et al., 2019). Several global scientific initiatives such as capacity building, technology transfer and collaborations can contribute to promote marine plastic pollution research in Africa. The African continent needs to put research effort into understanding the impacts of marine plastics specifically on human health, the economy of the continent as well as the social impacts associated with it. In order to develop policies and management strategies to aid with how to handle plastics from a manufacturing, use and reuse perspective, we need to understand the impacts holistically. However, in a continent stricken by poverty, environmental research is seldom prioritised. Public expenditure tends to focus on areas such as education, agriculture and health. For example, in the current context of the global COVID-19 pandemic, improving sanitation, hygiene and access to potable water is a high priority to reduce the spread of the virus (Jiwani & Antiporta, 2020; Marcos-Garcia et al., 2021). Improving sanitation, sewage systems and hygiene will also reduce marine litter inputs, and cross benefits should be sought where possible. Nevertheless, taking into account the current and forthcoming impacts of marine plastic litter, there is a need to address the problem with innovative measures. There is a need for knowledge transfer and capacity building to reduce plastic where possible, while implementing better waste management systems and infrastructure throughout Africa.

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Annex 3.1 Total Number of Marine Litter Impact Studies Published across Africa in Peer-Reviewed Journals as of December 2021

Impact	Country/region	Total number of studies	Citations
Social	South Africa	4	Preston-Whyte (2008), Ballance et al. (2000), Van Rensburg et al. (2020), Arabi and Nahman (2020)
	Accra, Ghana	1	Van Dyck et al. (2016)
Human health	South Africa	2	Naidoo et al. (2020), Made et al. (2020)
	Accra, Ghana	1	Van Dyck et al. (2016)
Environmental	South Africa	13	Mbedzi et al. (2019), Ryan et al. (2016) Reynolds and Ryan (2018), Weideman et al. (2020a, 2020b), Naidoo et al. (2016), Bakir et al. (2020), Nel and Froneman (2018), Iwalaye et al. (2021), Sparks (2020), Sparks and Immelman (2020), Best et al. (2001) Shaughnessy (1980), Cliff et al. (2002)
	Nigeria	3	Biginagwa et al. (2016), Akindelea et al. (2019), Adeogun et al. (2020)
	Kenya	1	Kosore et al. (2018)
	Mauritania, Canary Islands	1	Rodríguez et al. (2013)
	South Atlantic Ocean	1	Ryan et al. (1988)
Economic	South Africa	~~2~~	Ryan and Swanepoel (1996), Arabi and Nahman (2020)
	Mauritius	1	Chummun and Mathithibane (2020)
	Mozambique	1	Jones and Unsworth (2020)
	African Continent	2	Škare et al. (2021)
	sub-Saharan, Indian Ocean nations	1	Short et al. (2018)

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