Chapter 2: Threats to the Marine Environment: Pollution and Physical Damage

The oceans have always been subject to human activities. To a varying extent, these activities have adverse impacts on the state of the marine environment. Detrimental environmental effects depend upon the nature of human interference with nature. Two types may broadly be distinguished: pollution and physical destruction.

As far as threats to the marine environment are concerned, pollution is by far the more significant. It therefore forms the main focus of this chapter. Its internationally recognised definition for the marine sector was developed by GESAMP and reads: "Introduction of man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazard to human health, hindrance to marine activities including fishing, impairment of quality for use of sea-water, and reduction of amenities."[109] In contrast to this very comprehensive definition, physical damage merely comprises those cases in which a marine habitat is destroyed or degraded by direct impact. They are essentially limited to damage by groundings of ships, anchorage or construction works. Consequently, habitat destruction will only be addressed in relation to environmental threats from shipping.

In dealing with threats to the marine environment, I shall first give a brief overview of the main sources of pollution. Subsequently, I will turn to the major substances that may cause pollution. With respect to the scope of this treatise, in the third part of this chapter, I will pay special attention to threats to the marine environment posed by international shipping, i.e. operational and accidental pollution, as well as habitat destruction.

I. Sources of Pollution

Three sources of pollution may broadly be distinguished, namely coastal sources, including river influx, atmospheric deposition and offshore inputs.

Coastal sources are either point sources or diffuse sources. Point sources include direct outfall through pipes discharging contaminated water from coastal industry, sewage discharges and development sites.[110] Contrary to site-specific discharges, diffuse sources result from broad-scale activities, e.g. agriculture and forestry, and are mostly associated with leakage of nutrients into groundwater, which are later transported into the sea.[111] Both point and diffuse sources may also

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[109] See GESAMP, *Impact of Oil and Related Chemicals and Wastes on the Marine Environment*, GESAMP Report and Studies No. 50 (London: IMO Publication 1993), p. iii.

[110] Robert B. Clark, *Marine Pollution*, Fifth Ed. (Oxford: OUP 2001), p. 5 et seq.; GESAMP, *Protecting the Oceans from Land-Based Activities,* GESAMP Report and Studies No. 71 (Nairobi: UNEP Publication 2001), p. 17.

[111] GESAMP, *supra*, note 110, p. 17.

be located far away from the coast, in the upper reaches of a river, where contaminants are introduced into the watercourse.[112] Via their estuaries, they carry possibly large quantities of contaminants into the sea. Finally, coastal urban areas still represent significant sources of pollution. In many parts of the world, especially in developing countries, municipal waste and sewage are still discharged into the sea without receiving proper treatment.

Only air emissions from planes are true atmospheric sources of marine pollution. However, they share certain features with pollutants that originally stem from either land-based or offshore activities: all of them are possibly distributed over large areas depending on prevailing winds and weather conditions. With respect to pollutants that are deposited through the atmosphere, two broad distinctions may be drawn. First, materials stay for either a short time or a long time in the atmosphere. In the case of the former, they are mostly deposited close to their sources; in the case of the latter, they are widely distributed on a regional or even a global scale.[113] Secondly, substances usually enter the sea in rain – in contrast, particulate matter may also just fall out.[114] It has been noted that it is very difficult to estimate precisely how atmospheric deposition contributes to the pollution of the marine environment. Nevertheless, it is widely accepted that their contribution is very large.[115] In particular, atmospheric deposition is the most likely way into the marine environment for POPs, many of which are volatile and considered to be highly toxic.[116] Furthermore, a topical concern is the increasing input of nutrients, such as nitrogen, into usually nitrogen-poor areas of the open oceans through atmospheric deposition, which will have marked impacts on the extent of biological production and the composition of species.[117]

Offshore marine pollution mainly emanates from vessel-source pollution. Although vessels contribute to the pollution of the marine environment in a variety of ways, the share of their overall contribution is not very large – about 10 per cent.[118] A brief note suffices here; details will be given in the third part of this chapter. Other offshore sources include offshore industrial activities, such as oil extraction and the extraction of mineral resources.

II. Types of Pollutants

Marine pollution must remain an elusive idea without reference to the major substances that actually cause pollution. Many noxious or hazardous substances

[112] Robert B. Clark, *supra*, note 110, p. 6.
[113] GESAMP, *supra*, note 110, p. 17.
[114] Robert B. Clark, *supra*, note 110, p. 7.
[115] *Ibid.*
[116] GESAMP, *supra*, note 110, *loc.cit.* See further Sec. II.2. of this chapter.
[117] GESAMP, *A Sea of Troubles*, GESAMP Report and Studies No. 70 (Nairobi: UNEP Publication 2001), p. 18; and GESAMP, *supra*, note 110, p. 51 et seq.
[118] Land-based activities account for roughly 80 per cent of released pollutants; cf. UN Doc. A/60/63, *Oceans and the Law of the Sea – Report to the 60th session of the General Assembly*, 4 March 2005, para. 104.

find their way into the sea from the above-mentioned sources. In the following section, I shall highlight their main chemical properties and elucidate how these substances harm the environment. The account is limited to those substances considered to be environmentally and toxicologically most significant, namely hydrocarbon compounds, persistent toxic substances, heavy metals, radioactive materials and nutrients. It should be kept in mind that very few substances are added to the sea in a chemically pure state, but most are part of complex liquid or gaseous solutions.

It should also be noted that most of the polluting substances occur naturally in the marine environment. Contamination, i.e. elevated concentrations of substances in flora or fauna, may only be labelled pollution if human-induced, because "a pollutant is a resource out of place."[119] Pollution, furthermore, requires substances to have a measurable adverse effect on the population of a certain species.[120]

1. Hydrocarbon Compounds

By far the most familiar hydrocarbon compounds are petroleum hydrocarbons, commonly referred to as oil. These hydrocarbons are grouped into four chemical classes: alkanes, naphthenes, aromatics and alkenes.[121] Crude oil, which constitutes the original form of oil before it is refined to yield, e.g. petrol, contains a complex mixture of these classes. Sulphur, nitrogen, oxygen and vanadium compounds may also be present; these and other compounds comprise up to 25% of crude oil.[122] Released into the sea, it usually floats, although parts may eventually sink, as certain fractions evaporate over time.[123] All components of crude oil are, at varying rates, degradable by bacteria.[124] Numerous contributory sources can be identified; it may be discharged into the sea by vessels either accidentally or willingly, or leaked from offshore oil platforms or on-shore refineries.[125] The refined products of crude oil share some of crude oil's features but are unique

[119] GESAMP, *supra*, note 110, p. 20
[120] Robert B. Clark, *supra*, note 110, p. 8. It is interesting to note that while most pollutants stem from industrial activities, recent research results have shown that pollution already occurred in the pre-industrial era, cf. Heike K. Lotze, "Ecological History of the Wadden Sea: 2000 years of Human-induced Change in a Unique Coastal Ecosystem", 30 *Wadden Sea Newsletter* (2004), No. 1, pp. 22-23. More information available from <http://www.hmapcoml.org/Default.asp?ID=209>; (accessed on 30 September 2006).
[121] Cf. Jerzy W. Doerffer, Oil Spill Response in the Marine Environment (Oxford et al: Pergamon Press 1992), p. 9 et seqq.; Michael J. Kennish, *supra*, note 4, p. 83.
[122] GESAMP, *supra*, note 109, p. 19 et seqq. Alkenes are gaseous at room temperature and are relatively rare in crude oil, but common in many refined products.
[123] James W. Nybakken and Mark D. Bertness, *Marine Biology – an Environmental Approach*, Sixth Ed. (San Francisco: Benjamin Cummings 2005), p. 476.
[124] Robert B. Clark, *supra*, note 110, p. 74.
[125] See table 4.1 in Robert B. Clark, *supra*, note 110, p. 65.

inasmuch as they have well-defined, predictable characteristics and tend to be less toxic. Petroleum products include gasoline, kerosene, diesel fuel and fuel oils.[126]

The environmental impacts of oil comprise physical and chemical alterations, as well as the toxication of marine habitats. Adverse physical effects, in particular in the aftermath of large spills, mainly concern smothering of floral and faunal organisms.[127] As far as phytoplankton are concerned, this effect reduces the light available for photosynthesis processes. With respect to larger animals, birds get coated and their feathers lose their waterproofing qualities; causing them to sink and drown. Marine mammals are not particularly at risk, though sea otters' furs function in a similar way to the plumage of a seabird, making them equally vulnerable to floating oil.[128] With respect to chemical effects and the toxication of marine organisms, much depends on the crude oil's composition, as it may contain benzene, toluene, xylene and polycyclic aromatic hydrocarbons (see below), all of which are highly toxic. These substances tend to bioaccumulate in fish and shellfish, as well as in sediments, posing a long-time threat to benthic organisms.[129] Oil can yield immediate lethal effects for flora and fauna which are trapped, smothered and suffocated, because it soon interferes with cellular processes. So-called sublethal effects may have an impact on organisms in the days and weeks after a spill, as toxic constituents of the oil impair the ability of the organisms to obtain food, to move or to reproduce.[130]

Hydrocarbon compounds further embrace substances labelled as *polycyclic aromatic hydrocarbons* (PAHs), many of which are potential carcinogens, mutagens and teratogens (causing abnormalities in embryos).[131] Because of their low solubility and hydrophobic nature, PAHs are often deposited in marine sediments, where they tend to be persistent and may accumulate to high concentrations.[132] Finally, among the most persistent and toxic hydrocarbon compounds are *halogenated hydrocarbons* that contain halogens, such as chlorine, bromine, fluorine and iodine.[133] Many substances in these two categories have been included in a category called persistent toxic substances, which shares major features with non-hydrocarbon compounds and will thus be addressed separately in the next section.

[126] IMO, *Manual on Oil Pollution – Section IV, Combating Oil Spills* (London: IMO Publication 2005), p. 6.
[127] For a detailed account of different coastal habitat types, such as salt marshes and coral reefs, see Jerzy W. Doerffer, *supra*, note 121, p. 67 et seqq.
[128] Robert B. Clark, *supra*, note 110, p. 89; Jerzy W. Doerffer, *supra*, note 121, p. 58 et seqq.
[129] Michael J. Kennish, *supra*, note 4, p. 86.
[130] *Ibid.*; and GESAMP, *supra*, note 109, p. 75 et seq.
[131] Michael J. Kennish, *supra*, note 4, p. 141 et seqq.
[132] Licia Guzzella and Adolfo de Paolis, "Polycyclic Aromatic Hydrocarbons in Sediments of the Adriatic Sea", 28 *MPB* (1994), pp. 159-165, at 159.
[133] Michael J. Kennish, *supra*, note 4, p. 177 et seqq.; Robert B. Clark, *supra*, note 110, p. 126 et seqq.

2. Persistent Toxic Substances

The term "persistent toxic substances" (PTS) refers to a wide range of diverse substances that are mainly long-lived, noxious substances, but also less persistent substances that, because of their continuing use and dissemination, may give rise to chronic exposures over large temporal and spatial scales.[134] Prevalent chemicals include perfluorooctanyl sulfonates, used in the surface treatment of fabric, and brominated flame retardants, often integrated into components of electronic goods. While the production of some PTS has been banned, others continue to be used. Their existence in terrestrial, as well as aquatic ecosystems is thus widespread.[135]

Among substances classed as PTS, some organic compounds are particularly harmful and non-degradable. These are usually called persistent organic pollutants (POPs), referring to a group of substances that to varying extents resist photolytic, biological and chemical degradation. POPs are often halogenated or chlorinated and characterised by low water solubility and high lipid solubility, leading to their bioaccumulation in fatty tissues.[136] They are also semi-volatile, enabling long-range transport through the atmosphere. Most substances can be classified as halogenated hydrocarbons; however, metallic compounds may also have POP properties. Prominent examples include tributyl tin (TBT) and its derivatives, dibutyl tin and monobutyl tin, that are suspected of being endocrine disruptors.[137] POPs originate from anthropogenic sources, even though some organochlorines are known also to have natural sources. They are either pesticides or industrial chemicals that were once thought to possess significant societal benefits, or unintended by-products of combustion processes, such as dioxin.

The growing concern that these substances evoke is reflected by the fact that after lengthy negotiations, an international convention was signed in 2001 aiming at measures to eliminate or reduce the release of POPs into the environment.[138] Twelve substances (informally referred to as the "dirty dozen") were subjected to

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[134] GESAMP, *supra*, note 110, p. 21.

[135] For a very recent assessment of the spatial distribution of POPs on a worldwide basis, see Karla Pozo et al, "Toward a Global Network for Persistent Organic Pollutants in Air: Results from the GAPS Study", *Environ. Sci. Technol.* (2006), ASAP Web Release Date: 28 June 2006, DOI: 10.1021/es060447t, 7 pages.

[136] IPCS, *Persistent Organic Pollutants – An Assessment Report*, December 1995, available from <http://www.pops.int/documents/background/assessreport/en/ritteren.pdf>; (accessed on 30 September 2006), p. 8 et seq.

[137] GESAMP, *supra*, note 110, p. 49. Simon Walmsley, *Tributyltin Pollution on a Global Scale, An Overview of Relevant and Recent Research: Impacts and Issues* (2006), reproduced in MEPC 55/Inf.4, *Evidence of the Continuing Global Impact of Organotin highlighting the Need to urgently ratify the AFS Convention*, 7 July 2006, annex. Even though most uses of organotin compounds have now been banned, they still represent a source of concern, cf. SRU, *Marine Environment Protection for the North and the Baltic Seas – Special Report* (Baden-Baden: Nomos-Verlagsgesellschaft 2004), p. 59 et seq. and p. 92.

[138] Adopted on 21 May 2001, in force as from 17 May 2004, 40 *ILM* (2001) 532; hereafter POPs Convention; further information available from the Convention's official website <http://www.pops.int>; (accessed on 30 September 2006).

the strict rules of the POPs Convention, but the convention provides for a mechanism to add further chemicals to its regime.[139] The POPs Convention, expanding the usual definition, also applies to "pollutants [that] are transported, through air, *water and migratory species*, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial *and aquatic* ecosystems."[140]

3. Heavy Metals

Definitions of the term "heavy metals" differ.[141] Most often they are referred to as a group of metallic elements having atomic weights between 63.546 and 200.590 and specific gravities greater than 4.0; the term excludes alkali metals, alkaline earths, lanthanides and actinides.[142] Heavy metals are natural components of the Earth's crust. Trace amounts of some of them, including cobalt, copper and zinc, are essential micronutrients maintaining critical metabolic functions, while excessive levels can have detrimental effects. In contrast, other heavy metals such as mercury, lead and cadmium have no known vital or beneficial effect on organisms, but may have severe adverse impacts.[143] Heavy metals generally share most of the features of persistent toxic substances, since they are non-degradable, they bioaccumulate and they produce acute or chronic toxic effects. Toxicity and adverse health effects vary widely depending on the type of metal: for instance, while some forms of mercury, even if absorbed in small doses, cause severe damage to the brain and the central nervous system, short-term exposure to nickel does not produce any effect while long-term exposure may cause skin irritation or liver damage.

The existence of heavy metals in the marine environment can be detected in all parts of the world, in particular in sedimentary habitats.[144] Most of the metals find

[139] Chemicals currently covered by the 2001 POPs Convention are pesticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex and toxaphene), industrial chemicals (hexachlorobenzene (also a pesticide) and polychlorinated biphenyls (PCBs)), and unintended by-products, i.e. polychlorinated dibenzo-p-dioxins (PCDDs) and hepta-chlor-polychlorinated dibenzo-furans (PCDFs). Details about these substances can be found in IPCS, *supra*, note 136, p. 18 et seqq.

[140] Cf. first recital of the POPs Convention; emphasis in italics added.

[141] Some even argue that the term should not be used for the classification of metals, e.g. John H. Duffus, "'Heavy Metals' – A Useless Term?", 74 *Pure and Applied Chemistry* (2002), pp. 793-807, at 803 et seq.

[142] Michael J. Kennish, *supra*, note 4, p. 253. For an overview of definitions currently used, see John H. Duffus, *supra*, note 141, p. 796 et seqq.

[143] Aldo Viarengo, *supra*, note 10, pp. 153-158. For effects on individual organisms, see G.W. Bryan, "Pollution due to Heavy Metals and their Compounds", in Otto Kinne (ed.), *Marine Ecology, Volume V, Part 3: Pollution and Protection of the Seas – Radioactive Materials, Heavy Metals and Oil* (Chichester: John Wiley & Sons 1984), pp. 1289-1431, at 1363 et seqq.

[144] Cf. SRU, *supra*, note 137, p. 49 et seqq and p. 87 et seqq.; A. Pastor et al, "Levels of Heavy Metals in Some Marine Organisms for the Western Mediterranean Area (Spain)",

their way into the marine environment either through river influx or atmospheric deposition; direct discharges from industrial sources have decreased.[145] Yet they are still used in industrial processes, despite long-established bans on the most toxic compounds. Sedimentation of metals in heavily polluted areas such as estuaries and ports is a common phenomenon; spoil from regular dredging of shipping channels thus contains large amounts of contaminated material, which is later dumped at sea.[146]

4. Radioactive Materials

Alpha, beta and gamma radiation (radioactivity) due to the emission of both particles and electromagnetic waves from unstable isotopes of some chemical elements is a common natural phenomenon. Thus, seawater is naturally radioactive; this so-called background radioactivity mainly stems from potassium-40, as well as from decay products of uranium and thorium.[147] Human activities, however, have led in some areas to a marked increase in radioactivity. Scientific developments in the last century have enabled humans to create unstable isotopes, whose instability is remedied by returning them to a stable state; during this process, radiation energy is emitted that can be utilised, for instance, to produce electricity or to fuel engines. Anthropogenic sources of marine radioactive pollution include discharges of cooling water from nuclear power plants and waste water from reprocessing plants, loss of radioactive cargo from ships, military weapons testing and dumping of solid nuclear waste[148] – even though the latter is by now largely prohibited by the London Dumping Convention.[149]

Threats to humans and the environment very much depend on the activity, the biodistribution and the half-life of the radioisotope.[150] Chronic exposure to elevated levels of radioactivity is generally considered to contribute to different forms of cancer and other diseases, as well as to genetic disorder.[151] However,

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28 *MPB* (1994), pp. 50-53; E. Helmers et al, “Temporal and Spatial Variations of Lead Concentrations in Atlantic Surface Waters”, 21 *MPB* (1990), pp. 515-518.

145 Robert B. Clark, *supra*, note 110, p. 99 et seq. The atmospheric input pathway is more important for open ocean areas; heavy metal pollution in coastal areas originates mainly from riverine inflow, see SRU, *supra*, note 137, p. 54.

146 Robert B. Clark, *supra*, note 110, p. 101.

147 For a complete list of radionuclides occurring in the oceans naturally, cf. *ibid.*, table 7.1, p. 154.

148 OSPAR Commission, *Quality Status Report 2000* (London: OSPAR Commission 2000), p. 97.

149 Adopted on 29 December 1972, in force as from 30 August 1975, 1046 *UNTS* 120; hereafter LDC. There is currently a binding moratorium on the dumping of nuclear waste for parties to the LDC, adopted by amendment of Annex I of the LDC in 1993. Cf. Louise de la Fayette, “The London Convention 1972: Preparing for the Future” 13 *IJMCL* (1998), pp. 515-536, at 528.

150 For a detailed account of the effects of radioactivity on marine organisms, see D.S. Woodhead, “Contamination due to Radioactive Materials”, in Otto Kinne (ed.), *supra*, note 143, pp. 1111-1287, at 1201.

151 Robert B. Clark, *supra*, note 110, p. 169 et seq.

lethal damage is difficult to detect in short-term tests, as actual damage does not usually occur immediately after exposure. Likewise, sublethal genetic damage may only be detected in following generations.

The most significant inputs of radioactive materials into the marine environment originate from nuclear industry activities and the dumping of radioactive waste.[152] Infamous examples include radioactive waste-water discharges from the reprocessing plant in Sellafield (UK) and the dumping of spent nuclear fuel from warships in Russian waters. With respect to the former, the radioactivity of effluents, in particular in the 1970s and early 1980s, was very high.[153] It is estimated that continued releases of waste water have accumulated in sediments in the Irish Sea and now amount to a total of 200 kg of plutonium alone.[154] As far as the latter is concerned, by 1992 the total volume of low radioactive waste dumped into five designated areas in the Barents Sea was 192,700 m^2, which had a total radioactivity of 12,171 Ci.[155]

5. Nutrients

Although in a strict sense not as toxic as the pollutants discussed above, nutrients can have severely damaging effects on the marine environment. Inputs of high levels of nitrogen and phosphorus compounds, in particular, often result in "eutrophication". This term denotes a process that significantly changes growth conditions for phytoplankton.[156] Nutrients in high concentrations, depending on the physical and chemical properties of the marine area affected, may lead to excessive growth of algae ("algae bloom") and phytoplankton.[157] As a consequence, oxygen concentration decreases, while concentrations of hydrogen sulphides increase. Many aquatic organisms have low resistance against hydrogen sulphides and may therefore just die off. Compounding this problem, dead algae floats on the surface and thus covers the water, making it difficult for sunlight to penetrate into the sea. Consequently, in addition to oxygen shortage, phyto-

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[152] Even though impacts of radioactive contamination are mostly restricted to a regional level, contaminated materials may be transported over long distances by marine currents. Cf. Hartmut Nies et al, *Transportmechanismen radioaktiver Substanzen im Arktischen Ozean – Numerische und experimentelle Studien am Beispiel der Barents- und Karasee* (1999), available from <http://www.bsh.de/de/Meeresdaten/Beobachtungen/Radioaktivitaet/Kara-See/karasee.pdf>; (accessed on 30 September 2006), p. 28 et seq.

[153] Figures of discharges from the Sellafield reprocessing plant are to be found in Robert B. Clark, *supra*, note 110, figure 7.4, p. 159.

[154] OSPAR Commission, *Quality Status Report 2000, Region III – Celtic Seas* (London: OSPAR Commission 2000), p. 66.

[155] See Hilary Anderson, "Russia: Spent Fuel and Radioactive Waste" (April 2001), available from <http://www.nti.org/db/nisprofs/russia/naval/waste/wasteovr.htm>; (accessed on 30 September 2006).

[156] See, generally, GESAMP, *supra*, note 117, p. 8 et seq.

[157] SRU, *supra*, note 137, p. 66.

plankton also lacks adequate amounts of light energy to maintain photosynthesis processes.[158]

Nutrients are mainly used as fertilisers in agriculture. Applied on fields, they drain away and are eventually carried into the sea by rivers. Therefore, estuaries and coastal areas are the prime sites in which eutrophication effects may occur due to high concentrations of nutrients. Areas where the exchange of water masses is low are equally vulnerable. Serious deterioration, for instance, has been observed in the Adriatic Sea over the last twenty years, especially in areas near the Po estuary. It carries about 100,000 tonnes/year of inorganic nitrogen and about 6,000 tonnes/year of inorganic phosphorus; total inputs from Italian sources into the northern Adriatic Sea amount to 270,000 and 24,000 tonnes/year respectively.[159]

III. Shipping-Related Threats to the Marine Environment

As has been seen above, a wide range of different substances may pollute the marine environment. Many of these pollutants are released by vessels – either operationally or accidentally. It is the purpose of this section to give some insights into the distinct pattern of vessel-source pollution in order to make possible an adequate examination of the existing response and prevention mechanism in the legal sphere and the creation of a new one. In addition, the potential of ships to have a physical impact on habitats and animals shall be highlighted.

1. Operational Pollution

Operational pollution denotes the phenomenon that vessel-source marine pollution is not confined to accidents. In fact, the majority of pollutants are released while the ship is on voyage rather than accidentally.[160] In this respect, activities include the chronic discharge of sewage, tank residues, bunker oils and garbage, as well as the exchange of ballast water, emissions from vessels' engines and pollution due to anti-fouling paints on ships' hulls.

The discharge of sewage is a ubiquitous problem and may cause severe bacteriological pollution, harming local fisheries and aquaculture and – in some areas – leading to an excess of nutrients.[161] Discharge of solid debris (e.g. disused packaging) is an even more serious concern, particularly in the coastal areas of

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[158] GESAMP, *supra*, note 117, p. 8.

[159] GESAMP, *supra*, note 110, p. 24 et seq.

[160] Thomas Höfer, "Marine Transport of Balk Liquids and Cargoes Spilt", 5 *ESPR* (1998), pp. 97-104, at 101 et seqq.; Volker Brenk, "Verschmutzung der Nord- und Ostsee durch die Seeschifffahrt", in J.L. Lozán et al (eds.), *Warnsignale aus Nordsee und Wattenmeer* (Hamburg: Wissenschaftliche Auswertungen 2003), pp. 107-113.

[161] MEPC 46/6/1, *Additional Protection for Particularly Sensitive Sea Areas*, 19 January 2001, Annex, para. 1.1.5.

developing countries.[162] While the majority of sources (60 to 80 per cent) are land-based, the main offshore sources are fishing vessels and cruise ships.[163] A large number of species is known to be seriously harmed and killed by plastic debris; marine animals are mostly affected through entanglement in and ingestion of plastic litter, some of which contains PCBs.[164] Observations indicate that marine litter proliferation is increasing despite efforts in various international fora.[165] Reasons include a constant lack of onshore disposal facilities and weak implementation and enforcement of existing legal instruments. Tank residues are also likely to be discharged into the sea. Many oil tankers clean their tanks or unload contaminated ballast water whilst at sea. Although environmental standards for these operations are quite strict, especially in MARPOL special areas,[166] compliance rates are very low in some areas of the world.[167] Non-compliance is largely driven by economic motivation: environmentally-friendly washing of tanks in ports with adequate reception facilities involves costs that some shipowners are keen to avoid. Furthermore, some problems result from lost bunker oil. It is kept warm in the tanks of vessels and, if discharged into the sea, forms tar balls that are extremely resistant to physical and biological degradation.[168] All coasts near major shipping lanes have a serious problem with tar balls, although the problem is said to have decreased in the last two decades.[169] Finally, pollution also occurs during terminal operations, when oil is being loaded or discharged.[170]

Problems of a different kind concern the discharging of ballast water. The uptake of ballast water is a traditional way of ensuring that a ship is perfectly balanced and stable even when unloaded. It is taken on board in one place and discharged back into the sea in another place, possibly thousand of miles away

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[162] See, generally, information disseminated by the *Global Marine Litter Information Gateway*, maintained by UNEP and IMO, available from <http://marine-litter.gpa.unep.org>; (accessed on 30 September 2006).

[163] UN Doc. A/60/63, *supra*, note 118, para. 239 et seq.; Oceana, "Contamination by Cruise Ships", available from <http://oceana.org/index.php?id=791>; (accessed on 30 September 2006).

[164] José G.B. Derraik, "The Pollution of the Marine Environment by Plastic Debris: A Review", 44 *MPB* (2002), pp. 842-852, at 842 et seqq.

[165] UN Doc. A/60/63, *supra*, note 118, para. 274 et seq.

[166] See, *infra*, Sec. I.1.a) of Chapter 5 on MARPOL standards.

[167] They are said to be particularly low in developing countries. However, many European ships also have a very bad compliance record. See Oceana, *The EU Fleet and Chronic Hydrocarbon Contamination of the Oceans* (2005), available from <http://oceana.org/uploads/media/report_marpol_eu_chronic_hydrocarbon_contamination.pdf>; (accessed on 30 September 2006), p. 16.

[168] Thomas Höfer, *supra*, note 160, p. 102.

[169] GESAMP, *supra*, note 109, p. 27 et seqq. Bunker oil is extremely ropy and much more toxic than, for instance, petrol for cars; cf. Hans Schuh, "Schwefel Ahoi!", *Die Zeit (Wissen Supplement)*, No. 35, 24 August 2006.

[170] *Ibid.*, p. 25.

from its place of intake.[171] This process, known as ballasting, was long thought to be environmentally innocent. However, increased understanding of intra-ecosystem dependencies has revealed that organisms living in the ballast water could prove to be harmful for the particular ecosystem they are discharged into, because of their potential to alter, *inter alia*, prevailing predator-prey relationships or structures of micro-organism communities. While discharge of ballast water has not yet been prohibited completely, regulatory efforts have been made to manage its handling and treatment adequately.[172]

The ship's hull is also likely to be a source of chronic pollution. Marine organisms, such as molluscs and algae, tend to grow on ships' hulls, which can cause a reduction in speed of 3 to 10 per cent.[173] As a consequence, hulls have long been coated with anti-fouling paint containing TBT, which acts as a biocide. TBT is extremely lethal to all sorts of plankton and has further sublethal effects, including reduced growth of oysters and mussels, as well as imposex.[174] The International Maritime Organization (IMO) instigated research into anti-fouling systems in 1989 and, as a result, IMO member states adopted the International Convention on the Control of Harmful Anti-Fouling Systems on Ships in 2001.[175] Research has revealed that restrictions on the use of toxic anti-fouling agents have led to a decrease in TBT concentrations and a recovery of species affected by imposex.[176]

Similar to road transport, ships have always emitted certain noxious substances, since they were equipped with petrol engines: sulphur oxide, nitrogen oxide, certain ozone-depleting substances and greenhouse gases, most notably CO_2.[177] Increasing vessel traffic has raised awareness of a need to develop cleaner and more efficient engines. A crucial issue, for concentrations of sulphurous and nitrous

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171 An instructive overview is given by the Global Ballast Water Management Programme, "The Problem", available from <http://globallast.imo.org/index.asp? page=problem.htm &menu=true>; (accessed on 30 September 2006).

172 Michael Tsimplis, "Alien Species Stay Home: The International Convention for the Control and Management of Ships Ballast Water and Sediments 2004", 19 *IJMCL* (2004), pp. 411-482, at 415 et seqq.

173 Thomas Höfer, "Environmental and Health Effects Resulting from Marine Bulk Liquid Transport", 5 *ESPR* (1998), pp. 231-237, at 234.

174 Robert B. Clark, *supra*, note 110, p. 145 et seqq. and Simon Walmsley, *supra*, note 137, p. 16 et seq. "Imposex" effects, i.e. the development of male primary sexual characteristics in females has been observed in some species of whelk and gastropod.

175 Adopted on 5 October 2001, not yet in force; text reproduced in IMO, *Anti-Fouling Systems* (London: IMO Publication 2005). Hereafter AFS Convention.

176 Thomas Höfer, *supra*, note 173, *loc.cit.*; Simon Walmsley, *supra*, note 137, p. 12 et seqq.

177 See information available from IMO, *Prevention of Air Pollution from Ships*, available from <http://www.imo.org/Environment/mainframe.asp?topic_id=1068>; (accessed on 30 September 2006). Shipping's CO_2 emissions amount to 7 per cent within the transport sector, which equals 2 per cent of overall CO_2 emissions; cf. ISL, *Nutzung der Hohen See als Transportweg – Möglichkeiten zur Erhebung von Entgelten*, Externe Expertise für das WBGU-Sondergutachten "Entgelte für die Nutzung globaler Gemeinschaftsgüter" (2002), available from <http://www.wbgu.de/wbgu_sn2002_ex01.pdf>; (accessed on 30 September 2006), p. 39.

oxides in particular, is the fuel quality.[178] Yet the use of low-grade bunker oil is still widespread. Regulations relating to fuel quality introduced under the auspices of the IMO have recently entered into force.[179] However, corresponding instruments have only been ratified by a few countries yet. Air emissions from ships are thus likely to increase.[180]

2. Accidental Pollution

Polluting substances are released accidentally due to collisions, contacts with external objects, groundings, explosions, cargo-transfer failures, sinking or loss of cargo. Ships often carry large quantities of cargo that is toxic or otherwise hazardous. The most evident examples are oil tankers, which – if involved in an accident – may spill thousands of tonnes of crude oil. Yet, oil is just one type of cargo that is dangerous for the marine environment. IMO, in its efforts to enhance the safety of marine transport, has listed about 800 pollutants in Part 3 of the International Maritime Dangerous Goods (IMDG) Code.[181] The adverse effects of accidental spills of these substances range from mere reduction of amenities to severe hazards to human health and deterioration of marine habitats.

The polluting effects of oil in the marine environment have been described in the previous section. Ecological impacts of accidental oil spills are distinct and most critical, since they usually involve an enormous amount of oil released at the same time. Typically, spilled oil spreads over the surface of the water, forming a thin film. Since large spills in the open ocean will often just burn off or disappear without detectable impact, tanker accidents are most disastrous close to land. The oil coats marine mammals and birds at sea as well as the shallow sub-tidal and intertidal ecosystems close to the shore.[182] Once the oil has drifted ashore, it poses a great danger to highly vulnerable ecosystems such as fixed vegetation, estuaries and oyster and mussel beds.[183] Areas affected by a spill may suffer from it for many years, even when they appear to have completely recovered. If enough oil penetrates the sediments, hydrocarbons alter the long-ranging trends of community structure, particularly with respect to micro-algae and worms.[184] Unfortunately, some of the most serious consequences of a spill do not result from the oil itself, but from the detergents and other highly toxic chemical substances used to disperse the oil in the water during the subsequent clean-up.[185]

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[178] Bunker oil contains up to 27,000 parts per million (ppm) of sulphur compared with ten (10!) ppm in petrol for cars. See Hans Schuh, *supra*, note 169.

[179] For an overview of MARPOL Annex VI standards and more stringent regulations in SO_x Emissions Control Areas, see, *infra*, Sec. I.1.a) and I.1.b) of Chapter 5.

[180] HELCOM, *Airborne Nitrogen Loads to the Baltic Sea* (Helsinki: HELCOM Publication 2005), p. 17.

[181] Reproduced in IMO, *IMDG Code* (London: IMO Publication 2004), p. 24 et seqq.

[182] See *supra*, Sec. II.1. of this chapter.

[183] James W. Nybakken and Mark D. Bertness, *supra*, note 123, p. 477.

[184] *Ibid.*; and Robert B. Clark, *supra*, note 110, p. 83.

[185] Thomas Höfer, *supra*, note 160, p. 100 et seq.; GESAMP, *supra*, note 109, p. 84 et seqq.

Even though oil-tanker accidents usually receive broad public attention, accidents of chemical tankers lead to probably equally damaging consequences. The most likely hazardous results include:[186] fire, explosion, outflow of toxic substances, reaction with air, water or between incompatible chemicals and nuclear radiation. Several major accidents involving chemical tankers are observed every year.[187] Apparently, not all ships carry dangerous cargoes. Nevertheless, an accident can have devastating pollution effects. Today, bunkers of large cargo ships, storing engine fuel, have a greater capacity than cargo tanks of small oil tankers.[188] In this respect, heavy fuel oil is of greatest concern. Used as a fuel by some vessels, it can pose unusual problems, since its density is higher than that of water (which may cause it to sink) and its high pour point and viscosity lowers its tendency to spread out and disperse.[189]

3. Damage to Habitats and Animals

Even without causing pollution of the marine environment, ships can harm oceanic habitats and wildlife by direct physical impact. Physical impacts on habitats are caused by anchors and grounding of ships. Coral reefs are particularly at risk from groundings or anchoring. With respect to the latter, damage is caused either by the direct impact of anchors or from the dragging and swinging of large anchor cables and chains. As the chain and anchor of a large ship can weigh up to 5 tonnes, these activities may destroy living coral heads and create gouges and scars that destabilise the reef structure.[190] For instance, in the coral-reef banks in the Tortugas Ecological Reserve and the Tortugas Bank (United States), an anchor scar that covers an area exceeding 50,000 m^2 has been found, while two other sites bear evidence of anchor damage involving areas greater than 2,500 m^2. In addition, there are hundreds of coral colonies that are abraded, fractured and toppled, apparently from the dragging of anchors or anchor cables and chains.[191] Coral formations take thousands of years to build, thus reefs may never recover from anchor damage.[192] Yet, damage by anchors is not confined to coral-reef

[186] IMO, *Manual on Chemical Pollution – Problem Assessment and Response Arrangements* (London: IMO Publication 1999), p. 28 et seq.

[187] For examples of accidents involving ships carrying hazardous chemicals, see IMO, *supra*, note 186, p. 2.

[188] Hans Schuh, *supra*, note 169.

[189] IMO, *supra*, note 126, p. 173 et seqq.

[190] Lauretta Burke and Jonathan Maidens, *Reefs at Risk in the Caribbean* (Washington, D.C.: World Resources Institute 2004), p. 29; Caroline S. Rogers and Jim Beets, "Degradation of marine ecosystems and decline of fishery resources in marine protected areas in the US Virgin Islands", 28 *Environmental Conservation* (2001), pp. 312-322, at 316.

[191] NAV 47/3/1, *No anchoring areas in the Tortugas Ecological Reserve and the Tortugas Bank in the Florida Keys*, 15 February 2001, para. 10.

[192] Caroline S. Rogers and Virginia H. Garrison, "Ten years after the crime: lasting effects of damage from a cruise ship anchor on a coral reef in St John, US Virgin Islands", 69 *Bulletin of Marine Science* (2001), pp. 793–803, at 795 et seqq. For a recent account of

habitats, as research on anchoring effects on seagrass communities has shown.[193] Grounding can cause similar damages to sensitive habitats, in particular coral reefs and other shallow areas. It may also result in long-term impacts, if the wreck, following the initial grounding, shifts.[194]

Direct physical harm to marine mammals is either caused by collisions with the ship itself or with the ship's propellers; ship strikes are a major cause of the deaths of large marine mammals such as whales.[195] Injuries comprise severed tailstocks and blunt trauma.[196] An infamous example is the Northern Right Whale, whose population is increasingly affected by ship strikes.[197] In 1999, the US established two protected areas where vessels are required to report to an onshore station when entering one of the areas.[198] Mariners are informed of locations where right whales have recently been sighted. However, in spite of efforts in some marine areas, lethal collisions generally still constitute a major threat to marine animals.[199]

threats to coral reef ecosystems, see Wiebke Rögener, "Untergang unter Wasser", *Süddeutsche Zeitung*, No. 122, 26 September 2006, p. 18.

[193] Patrice Francour, Anne Ganteaume, and Maxime Poulain, "Effects of Boat Anchoring in *Posidonia Oceanica* Seagrass Beds in the Port-Cros National Park (North-Western Mediterranean Sea)", 9 *Aquatic Conservation: Marine and Freshwater Ecosystems* (1999), pp. 391-400, at 395 et seqq.

[194] MEPC 46/6/1, *supra*, note 161, para. 1.1.13.

[195] An overview is provided by Aleria S. Jensen and Gregory K. Silber, *Large Whale Ship Strike Database. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-OPR-25*, 2003, available from <http://www.nero.noaa.gov/shipstrike/news/shipstrike03.pdf>; (accessed on 30 September 2006). Note that this database provides a minimum count of strikes as most go undetected.

[196] Leslie I. Ward-Geiger et al, "Characterization of Ship Traffic in Right Whale Critical Habitat", 33 *Coastal Management* (2005), pp. 263-278, at 266. A further problem is underwater noise, that can cause damage to mammal's auditory systems and makes it more difficult for them to detect approaching vessels: see Ship Strikes Working Group of the IWC, *First Progress Report to the Conservation Committee*, May 2006, available from <http://www.iwcoffice.org/_documents/commission/IWC58docs/58-CC3.pdf>; (accessed on 30 September 2006), p. 2.

[197] Information on this issue was also submitted for discussion to various bodies of the IMO. See, for instance, NAV 45/Inf.3, *Ship Strikes of Endangered North Atlantic Right Whales in the Waters of Eastern Canada*, 13 July 1999.

[198] Leslie I. Ward-Geiger et al, *supra*, note 196, p. 266 et seqq.

[199] Cf. Ship Strikes Working Group of the IWC, *supra*, note 196, p. 4 et seqq.

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