Maritime Traffic in the Sargasso Sea

An Analysis of International Shipping Activities and their Potential Environmental Impacts

Julian Roberts

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The Sargasso Sea Alliance is led by the Bermuda Government and aims to promote international awareness of the importance of the Sargasso Sea and to mobilise support from a wide variety of national and international organisations, governments, donors and users for protection measures for the Sargasso Sea.

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COVER PHOTO: Comparison of reported data from liquid tankers and crude transport data prepared by ITOPF.

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Foreword

BETWEEN 2010 AND 2012 a large number of authors from seven different countries and 26 separate organisations developed a scientific case to establish the global importance of the Sargasso Sea. A summary of this international study was published in 2012 as the "Summary science and Supporting Evidence Case." Nine reasons why the Sargasso Sea is important are identified in the summary. Compiling the science and evidence for this case was a significant undertaking and during that process a number of reports were specially commissioned by the Sargasso Sea Alliance to summarise our knowledge of various aspects of the Sargasso Sea.

This report is one of these commissioned reports. These are now being made available in the Sargasso Sea Alliance Science Series to provide further details of the research and evidence used in the compilation of the summary case. A full list of the reports in this series can be found in the inside back cover of this report. All of them can be downloaded from **www.sargassoalliance.org.**

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Executive Summary

The Sargasso Sea lies within one of the world's busiest international shipping areas and, due to its unique characteristics, is vulnerable to a range of environmental risks posed by international shipping activities. The full range of vessel types operate in these waters, with many following distinct routeing patterns according to the vessel type and the nature of the cargo carried. Analysis of annual shipping movements using a geographic information system illustrates complex routeing patterns throughout the Sargasso Sea and broader North Atlantic Ocean and gives some indication of the spatial extent of the threat posed to this region.

Although shipping is often argued to be one of the least environmentally harmful forms of transport, the range of threats posed by shipping to the marine environment is broad and complex. However, the effects from shipping are not uniform and different vessel types may give rise to different types and magnitudes of environmental impact. This is despite comprehensive international efforts to regulate most of the environmental aspects associated with international shipping. Furthermore, most efforts to regulate these activities have focussed mainly on protection of coastal and EEZ waters and there are many uncertainties surrounding the magnitude of such impacts on the high seas.

Any attempts to regulate high seas shipping activities, particularly in and around the Sargasso Sea, will require a comprehensive understanding of the nature of international shipping activities in this region and the actual and potential environmental threat posed by such activities. Shipping data currently available may need to be augmented from other sources to provide a detailed picture of the threat posed by international shipping. Nonetheless, such information, when analysed in the context of the environmental baseline of the Sargasso Sea will provide strong support for the adoption of international legal measures aimed at providing greater protection to the Sargasso Sea from the impacts of international shipping.

Acknowledgements

The Sargasso Sea Alliance thanks the U.S. Coast Guard, which provided general (non-specific) factual shipping data through cooperation with the U.S. National Oceanic and Atmospheric Administration for use in this report.

The data provided was in full accordance with the requirements of SOLAS V/19-1 and IMO MSC Res. 243(83) to use the data for environmental protection purposes. However, the provision of the data does not, in and of itself, indicate U.S. government (or any department or agency thereof) support for any specific proposal contained in this report or that the Sargasso Sea Alliance might put forth using that data in the future.

The financial support from IUCN which made this report possible is gratefully acknowledged.

Abbreviations and Acronyms

AIS Automatic Identification Service

AMVER Automated Mutual Assistance Vessel Rescue System

BWM Ballast Water Management

CDEM Construction, Design, Equipment and Manning

EEZ Exclusive Economic Zone

GESAMP Group of Experts on the Scientific Aspects of Marine Environmental Protection

GHG Greenhouse Gas

GIS Geographic Information System

IBC Code International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk

ICOADS International Comprehensive Ocean-Atmosphere Data Set

IMDG Code International Maritime Dangerous Goods Code

IMO International Maritime Organization

ITOPF International Tanker Owners Pollution Federation

MEPC [IMO] Marine Environment Protection Committee

NIMS Non Indigenous Marine Species

NO_2 Nitrogen Dioxide

OECD Organisation for Economic Co-operation and Development

PAH Polyaromatic Hydrocarbon

RoRo Roll On-Roll Off

SO2 Sulphur Dioxide

STS Ship Transfer at Sea

TBT Tributyltin

UNCTAD United Nations Conference on Trade and Development

VOC Volatile Organic Compound

VOS Voluntary Observing Ship

WMO World Meteorological Organization

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1: Introduction

The Atlantic Ocean has been a focus of global trade ever since the New World was exploited by Europeans. It is estimated that, by 1960, 60% of world maritime trade involved the North Atlantic. According to Endresen et al.,[1] 80% of all maritime traffic now operates in the Northern Hemisphere with 32% operating in the North Atlantic alone. This makes the North Atlantic the busiest ocean in the world in terms of maritime traffic. Since much of this traffic is in transit from Europe to the east coast of the USA, and *vice versa*, it logically follows that the Sargasso Sea lies within one of the busiest international shipping areas.

Since it is reasonable to argue that those areas that experience the greatest volume of traffic are the most vulnerable to the risk of shipping related environmental impacts, shipping may pose a significant threat to the Sargasso Sea. In fact, this conclusion is supported by a recent study by Halpern et al., who found this area to be one of the most impacted marine areas from shipping (**FIGURE 1.1**).[2]

This report provides an overview of the current threats posed by international shipping to the Sargasso Sea and the wider North Atlantic Ocean.

The terms of reference for the contract require *inter alia* consideration of the following:

1. Identify vessel traffic characteristics (ie. operational factors, vessel types, traffic characteristics and harmful substances carried, as detailed in the IMO revised PSSA Guidelines Resolution A.982(24)) that may impact the wider Sargasso Sea ecosystem;
2. Liaise with Bermuda government Maritime Authority and IMO and others to get access to the information on year on year trends for shipping; and

[1] Ø, Endresen, E. Sørgård, J. Sundet, S. Dalsøren, I. Isaksen, T. Berglen and G. Gravir, "Emission from international sea transportation and environmental impact" (2003) 108 (D17) *Journal of Geophysical Research* doi:10.1029/2002JD002898, p. 12.

[2] B. Halpern, S. Walbridge, K. Selkoe, C. Kappel, F. Micheli, C. Agrosa, J. Bruno, K. Casey, C. Elbert, H. Fox, R. Fujita, D. Heinemann, H. Lenihan, E. Madin, M. Perry, E. Selig, M. Spalding, R. Steneck and R. Watson, "Global map of human impact on marine ecosystems" (2008) 329 *Science* pp. 948-952. Available online at www.sciencemag.org/content/319/5865/948.

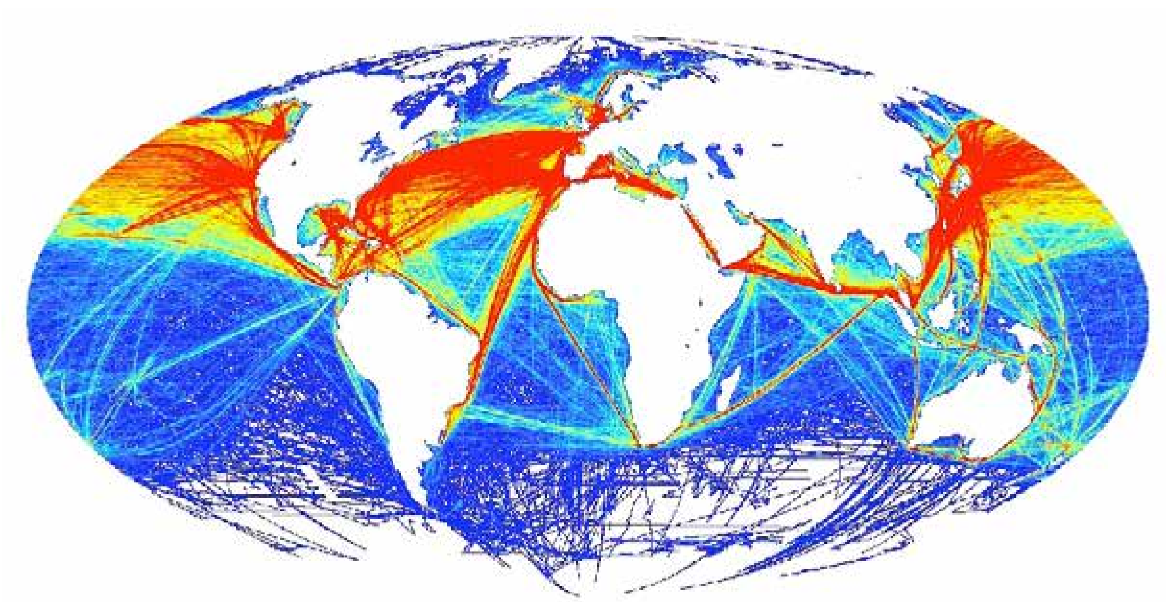

FIGURE 1.1. Relative weighted environmental impact of international shipping on the marine environment. Low impact (Blue) to High Impact (Red). After Halpern et al.,[1]

[1] (note 2), map files available at www.nceas.ucsb.edu/globalmarine/impacts.

3. Analyze information sources to assist in the assessment of vulnerability of the Sargasso Sea ecosystem to damage by international shipping activities, in consultation with Sabine Christiansen, as well as indications or evidence of actual damage or likely damage.

After discussing the range of environmental threats posed by international shipping activities, the report provides an overview of the current legal regime governing the control of pollution from shipping. In order to provide an understanding of the extent of the threat posed by international shipping, a comprehensive spatial analysis of international shipping movements in the North Atlantic is presented. The analysis presents both an overview of the general shipping picture in the North Atlantic and Sargasso Sea area and specific information on the types of vessels operating in these waters.

The specific impacts that may be associated with each type of vessel are also discussed to provide an understanding of the specific threat posed to the Sargasso Sea from shipping in the region.

SUBSTANCE		VECTOR
CO2		Atmosphere, Shipping
VOCs		Atmosphere, Shipping
Nutrients	Fe, N, P, Zn, Co	Atmosphere
POPs, PBTs, CFCs		Atmosphere
PAH		Atmosphere, Shipping
Heavy metals	Pb, Hg, Cd, As, Ni, Cu	Atmosphere
Particles		Shipping
NO_2		Shipping
Oil	Accidental spills, Operational discharges, Wrecks, Exploration & Production, Natural seeps	Shipping, Oil & Gas
Chemicals	Accidental spills, Operational discharges, Exploration & Production	Shipping, Oil & Gas
Sewage		Shipping
Marine debris		Mainland sources, Shipping
Ballast water		Shipping
Noise		Mainland sources, Shipping
Dumped waste		Shipping

TABLE 1. Inventory of contaminants in the open ocean[1]

[1] GESAMP, *Pollution in the open ocean: A review of assessments and related studies*, GESAMP Reports and Studies No. 79 (UNEP/UNESCO-IOC, 2009), p.14.

2: Nature of the Impacts of Shipping

While it is beyond the scope of this report to address the impacts of shipping on the marine environment in detail, a broad appreciation by the reader of the subject is desirable. In particular it should be recognised that, although the emphasis has historically been placed on the control and impacts of ship-sourced oil pollution, ships can constitute an environmental hazard to the marine environment in a number of ways, including operational and accidental discharges and physical harm. Accordingly, this section provides a summary of the main impacts and some of the recent literature on this subject.

2.1: Operational Pollution Discharges

The most common sources of ship-sourced pollution derive from the normal operation of a ship.[3] These so called "operational discharges" include certain automatic releases as well as intentional discharges incidental to normal operations (**TABLE 1**).[4] The extent to which such sources of pollution represent an environmental

[3] Despite catastrophic oil spills resulting from tanker accidents, the principal source of ship-source pollution remains routine operational discharges. See for example the recent report of the OECD Maritime Transport Committee: OECD, *Cost savings stemming from non-compliance with international environmental regulations in the maritime sector*, OECD Document DSTI/DOT/MTC(2002)8/FINAL, (OECD, Paris, 2003), pp.10-11; See also the most recent estimates of oil inputs into the sea published by the US National Research Council: National Research Council (NRC) Ocean Studies Board and Marine Board *Oil in the sea III: Inputs, fates and*, (National Academic Press, Washington DC, 2002), chapter 3.

[4] G. Timagenis, *International control of marine pollution* (Oceana Publications, Inc., Dobbs Ferry, N.Y., 1980), p.18.

threat will depend on the degree of compliance with the relevant international conventions. Operational discharges of oil into the marine environment by ships depend on several factors. These include: type and age of ship; level of maintenance of ship and engines; presence of oil-water separators and other equipment designed to curtail discharges of oil; practice of the LOT (load-on-top) principle; training and vigilance of the crew; level of shipping activity; and the presence of adequate port reception facilities.[5]

As such, while international environmental law permits certain operational discharges within specified limits (discussed in section 3 below), non-compliance by ships, with these standards represents a significant ongoing problem (see **FIGURE 2.1**). In the end, elimination of such problems relies on construction, design, equipment and manning (CDEM) standards, and compliance monitoring and enforcement with respect to international standards.[6]

[5] GESAMP (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), *Estimates of oil entering the marine environment from sea-based activities* GESAMP Reports and Studies No. 75 (IMO, London, 2007), pp 15-23.

[6] Timagenis, p.18 (note 4)

Oil and Hazardous Noxious Substances

Since the introduction of severe restrictions on the disposal of residues containing oil and other harmful substances there has been a noticeable reduction in the quantities of these substances discharged to the marine environment.[7] Nonetheless, oil is routinely discharged from the engine spaces of ships, and in the form of dirty ballast water and cargo residues from cargo tanks.[8] Operational discharges from ships therefore form a significant part of the total inputs of oil to the marine environment.[9] The impacts of these discharges are generally similar to that of any

[7] See NRC (note 3) p.88 who provide chronological data to support the view that there has been a temporal reduction in operational discharges of oil to the marine environment; See also M. E. Huber, "Oceans at risk" (1999) 38 *Marine Pollution Bulletin*, p. 435.

[8] See for example F. Wiese, *Seabirds and Atlantic Canada's ship-source oil pollution: Impacts, trends, and solutions*, (WWF Canada, Toronto, 2002), p.6. Oil collected from bird plumage in Atlantic Canada and the North Sea over the last 10 years showed that over 90 per cent of the oil collected was composed of heavy fuel oil mixed with lubricant oil, the type found in bilges of large ocean-going vessels.

[9] GESAMP reports that the annual input of oil to the marine environment from operational shipping activities is 208,000 tonnes from ship and cargo related activities (i.e. engine rooms, ballast water, crude oil washing and venting of VOC from cargo tanks, although most of this derives from fuel oil sludge). This represents approximately 45% of the total annual input of 457,000 tonnes from shipping. GESAMP (note 5) p. viii.

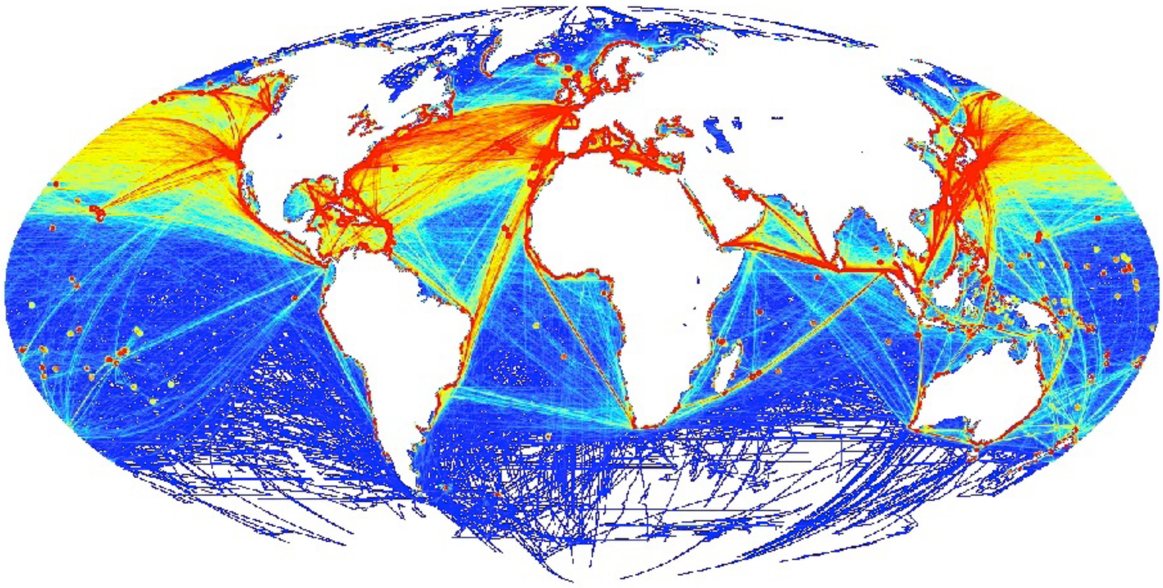

FIGURE 2.1. Relative weighted environmental impact from ocean based pollution on the marine environment. Low impact (Blue) to High Impact (Red). After Halpern et al.[1]

[1] (note 2) map files available at www.nceas.ucsb.edu/globalmarine/impacts. Ocean-based pollution is assumed to derive from commercial and recreational ship activity. Since no data on global recreational ship activity currently exist, this analysis is modeled using a combination of the commercial shipping traffic data and port data. The shipping data provide an estimate of the occurrence of ships at a particular location, and therefore an estimate of the amount of pollution they produce (via fuel leaks, oil discharge, waste disposal, etc.). For a more in depth discussion of the analysis refer to the *Supporting Online Material for A Global Map of Human Impact on Marine Ecosystems* available at: www.sciencemag.org/content/suppl/2008/02/12/319.5865.948.DC1/Halpern_SOM.pdf.

crude oil or petroleum products released to the marine environment. In the open ocean impacts are likely to be temporary since the oil tends to evaporate and disperse over a period of weeks following discharge.[10] This may not however be true for discharges of bilge and fuel oil which tends to persist for long periods and may impact fauna on the surface of the water.

While there exists a strict international regime aimed at controlling these discharges, numerous cases of non-compliance with these regulations are reported annually.[11] Furthermore, these annual global inputs are not evenly distributed. Pollution levels measured along the main shipping routes in particular still show considerable quantities of illegally discharged oil. In some areas the volume and frequency of ships is such that there is virtually a continuous presence of high volumes of ships, thereby constituting a potentially chronic source of such pollution.[12] In some cases the extent of such discharges can be spectacular such as the case off the east coast of Canada on the Grand Banks.[13] However, although oil is a highly visible pollutant and when spilled in large quantities can cause severe local effects, it is not regarded as a significant pollutant on a global scale.[14]

Tank ships and dry bulk carriers carry a large variety of hazardous substances other than oil. They are subject to similar operational constraints. Hence, like oil, noxious liquid substances may be discharged in the form of cargo residues as the result of cargo tank washing. Little if any information is published on the potential harm such substances present to the environment. However, it is important for the protection of the marine environment that tanks are first stripped of their bulk liquid cargo to the maximum extent. This is also clearly in the economic interests of the owner. Tanks containing cargoes deemed to be particularly hazardous to the marine environment, or those with high viscosity, generally require a pre-wash after emptying to remove clinging material, in which case the residues are discharged to shore.[15]

While reception facilities for both oil and noxious liquid substances are available at many major ports and harbours, they are absent in many parts of the world. In the absence of shore reception facilities in which to dispose of such residues, many ships simply discharge the residues illegally into the sea.

Transfer of Aquatic Invasive Species

The role of commercial shipping in transporting alien species in ballast tanks and as hull fouling has been widely acknowledged as the most dominant vector for transporting alien species. Such unintentional transport by vessels is exacerbated by the dense global traffic patterns, the large number of vessels (both commercial and recreational), and the diverse transport niches they provide, such as in ballast water and sediments or through hull fouling. It has been estimated that 3,000 – 4,000 species are being transported by vessels every day.

Ballast Water

The use of water for stability when sailing partially laden or without cargo has long been a vector for the movement of exotic/non-indigenous species from one region of the world to another.[16] The introduction of non-native species via the discharge of ballast water

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[10] GESAMP (TABLE 1, note 1) p. 35.

[11] See for example the case studies presented by the OECD (note 5) ap. 20-21.

[12] S. Raaymakers, "Maritime transport and high seas governance: Regulation, risks and the IMO regime" in *Proceedings of the International Workshop on Governance of High Seas Biodiversity Conservation*, (Cairns, Australia 17-20 June 2003), p. 8; New research indicates that the chronic oil pollution along the southeast coast of Newfoundland has not been reduced over the last two decades, and that pollution levels in Atlantic Canada are the highest in the world. Wiese, p. 3 (note 8).

[13] Major shipping routes between North America and Europe converge here and overlap with the range of more than 40 million pelagic birds that are estimated to reside or migrate annually through the Grand Banks, an area considered to be the most important wintering ground for seabirds in the North Atlantic, and one of the most productive marine areas in the world. Operational discharges of oil from the huge numbers of vessels present throughout the year continue to put millions of Atlantic Canada's seabirds at risk a conservative estimate that about 300,000 seabirds are killed each winter in the waters of Atlantic Canada, by chronic operational discharges of oil at sea. Imposed fines and enforcement efforts in Atlantic Canada are not on a par with those of other countries along the Great Circle Route between Europe and North America, and it appears that the coastal area of Atlantic Canada is economically the most feasible location into which ship operators can dump their bilges. Wiese, generally (note 8).

[14] See GESAMP, *A sea of troubles.* GESAMP Reports and Studies No. 70 (UNEP, 2001) p 3. M.E., Huber, R.A. Duce, M.J. Bewers, D. Insull, L. Jeftic and S. Keckes, "Priority problems facing the global marine and coastal environment and recommended approaches to their solution", (2003) 46 *Ocean & Coastal Management,* p. 480.

[15] GESAMP, *The revised GESAMP hazard evaluation procedure for chemical substances carried by ships*, GESAMP Reports and Studies No. 64. (IMO, London, 2002), p. 6.

[16] The shipping industry is estimated to transfer approximately 10-12 billion tonnes of ballast water across the globe each year. Relatively recent changes in the speed of ships and the consequent reduction in voyage time, along with the increase in the size of ships and their ballast tanks, have combined to increase the probability of species survival, so overcoming the natural barriers in the world's oceans. See for example I. White and F. Molloy, "Ships and the marine environment", Conference paper presented at *Maritime Cyprus 2001*, (Limassol, Cyprus, 23-26 September 2001), p. 5.

is therefore, well documented.[17] The effects of such species can be significant as they can be detrimental to local species through competition for space or nutrients, or they can be toxic and affect local fisheries.[18] There can also be economic damage to marine resources and amenities as a result of damage to infrastructure and the costs associated with control measures.[19] This reduction in biodiversity has the potential to be permanent, and is considered by some to represent one of the most critical threats to the marine environment at present.[20]

Currently mid-ocean ballast water exchange and heat treatment appear to be the best options available for managing ballast water and while there is very little information on the potential risks of open ocean ballast exchange, this practice is considered to be relatively safe.[21] However, there have been suggestions that the practice of mid-ocean ballast exchange may pose a threat to islands down current from the exchange area since species discharged in the ballast water may be carried downstream and settle.

In the context of the Sargasso Sea, this risk could be exacerbated by the presence of *Sargassum* mats throughout the area, which act as a 'surrogate' benthic habitat. Parallels could be drawn between invasions in coastal regions arising from alien species discharged in ballast water and potential impacts to *Sargassum* and the wider Sargasso Sea. However, no evidence exists that such impacts have occurred and a counter argument is that mid water ballast water exchange is unlikely to occur in regions where *Sargassum* is prevalent due to the operational risks associated with its uptake into the ballast water system.

At this stage, little, if anything, is known about the operational ballast management practices of ships operating in the region so, at best, the risk associated with ballast water exchange is conjecture. However, given the almost impossible task of eradicating alien species that have established in the marine environment, such a risk may still warrant application of the precautionary principle to avoid impacts in the future.

Hull Fouling

While ballast water has been identified as the primary causal mechanism and has been the major focus of investigations concerned with marine invasion vectors,[22] transport of non-native species on vessel hulls has been given less consideration.[23] However, a number of recent studies suggest that despite technological advances aimed at reducing vessel fouling, the attachment of organisms on the hulls of vessels remains a significant vector, possibly equal to ballast water.[24]

It is notable that the majority of established exotic species occur in port regions. Ships converge on port regions, and may remain there for some days, and this may explain the preponderance of exotics there. Different ports have widely varying numbers of exotics but they would appear to be most frequent in shallow, partly enclosed harbours. The smaller numbers in coastal regions appearing between ports could be attributed to range expansions from port areas or due to other vector processes.[25]

Antifouling

The application of antifouling compounds to ships' hulls is widely used to control hull fouling and thereby reduce drag. These coatings inhibit the growth of unwanted organisms

[17] See for example: J.T. Carlton, "Transoceanic and interoceanic dispersal of coastal marine organisms: the biology of ballast water" (1985) 23 *Oceanography and Marine Biology: An Annual Review,* pp. 313-371; J.T. Carlton, "Mans role in changing the face of the ocean: Biological invasions and implications for the conservation of near-shore environments" (1989) 3 *Conservation Biology,* pp. 265-273; J.K. Kelly, "Ballast water and sediments as mechanisms for unwanted species introductions into Washington State", (1993) 12 *Journal of Shellfish Research,* pp. 405-410; J.T. Carlton, "The scale and ecological consequences of biological invasions in the world's oceans", In O. T. Sandlund, P. J. Schei, and Å. Viken, (Eds), *Invasive Species and Biodiversity Management, (*Kluwer Academic Publishers, Dordrecht, 1999), pp. 195-212; S. Raaymakers, "The Ballast Water Problem: Global Ecological, Economic and Human Health Impacts" Paper Presented at the *RECSO / IMO Joint Seminar on Tanker Ballast Water Management & Technologies* (Dubai, UAE 16-18 Dec 2002).

[18] See for example the impact that the European Zebra mussel has had on the Great Lakes ecosystems by competing with and displacing the native mussels. S.A. Ahlstedt, "Invasion and impacts of the zebra mussel in the United States," (1994) 13 *Journal of Shellfish Research*, p. 330; The ctenophore *Mnemiopsis leidyi* was imported from the US East coast to the Black Sea, probably in ballast water and has led to a catastrophic alteration in the whole trophic web and contributed to a huge reduction in stocks of commercial fisheries – see GESAMP, *Opportunistic settlers and the problem of the ctenophore Mnemiopsis leidyi invasion in the Black Sea*, GESAMP Reports and Studies No. 58 (IMO, London, 1997) 84 p.

[19] The costs associated with control and eradication of the Zebra Mussel in the Great lakes is estimated at US$5 Billion (White & Molloy, p. 5 (note 16).

[20] See for example GESAMP, pp. 13-14 (note note 14) who rank habitat alteration and damage by *inter alia* the introduction of alien species as one of the five most significant issues for the marine environment.

[21] GESAMP (TABLE 1, note 1) p. 42.

[22] L.S. Godwin "Hull fouling of maritime vessels as a pathway for marine species invasions to the Hawaiian Islands" (2003) 19 (Suppl) *Biofouling* pp. 123-31.

[23] A.D. Coutts, K.M. Moore and C.L. Hewitt, "Ships' sea-chests: an overlooked transfer mechanism for non-indigenous marine species?" (2003) 46 *Marine Pollution Bulletin* pp.1504-15.

[24] S. Gollasch 'The importance of ship hull fouling as a vector of species introductions into the North Sea' (2002) 18 *Biofouling* pp. 105-121.

[25] D. Minchin and S. Gollasch, 'Fouling and ships' hulls: how changing circumstances and spawning events may result in the spread of exotic species' (2003) 19 (Suppl) *Biofouling* pp. 111-22.

through the controlled release of biocides which are, by their nature, harmful to a range of marine organisms. The nature of the toxicity is chronic and can affect such functions as morphology, growth and reproduction of a range of marine species. The most common and effective chemical used to date in antifouling is tributyltin (TBT).[26]

Research during the early 1980s indicated that populations of shellfish in some European waters were under pressure for unknown reasons. These populations coincided with areas of heavy boating. Further investigations revealed high levels of TBT.[27] Since the discovery of these problems, in 2001 the IMO adopted a new convention aimed at limiting the application of harmful antifouling substances. As such the use of TBT antifouling paints is now prohibited. However, this policy is hampered by the lack of equivalent substitutes for TBT.[28] In addition, there are concerns that other materials might in time prove to be equally as harmful to the marine environment, since they too contain biocidal products.[29]

Garbage and Sewage

The discharge of raw sewage and garbage from ships is directly correlated to the number of persons on that ship. As such, commercial vessels such as tankers, bulk cargo carriers and container ships present very little problem in this regard. However, the global increase in cruise ship holidays and the trend towards larger vessels does present a potential problem.[30]

Sewage

The global discharge of sewage from ships is relatively low when compared to both treated and untreated sewage from land-based sources. Ships' sewage mainly consists of water-borne human waste, and of wastewaters generated in preparing food, washing laundry, dishes and in showering. The contents that are commonly termed pollutants include biodegradable organic matter, inorganic nutrients and pathogens (principally *Coliform*). However, while concerns have been raised about the localised effects of sewage in coastal areas and ports, it is generally considered that in open ocean waters with high rates of dilution, the impacts are considerably reduced as the oceans are capable of assimilating and dealing with raw sewage through natural bacterial action, therefore global rules prohibit ships from discharging untreated sewage within a specified distance of land.[31] With a view to discharges in waters within 12 nm from land the U. S. EPA concludes that the mixing of cruise ship effluents due to vessel movement and propulsion is sufficient to dilute the pollutant concentrations to acceptable levels within short distance from the vessel.

Much of the focus on sewage has related to pathogens and health impacts rather than to environmental impacts *per se*. However, sewage discharges may be a significant source of nutrient input (particularly nitrogen, ammonia and phosphorous) to the marine environment, if discharged in sufficient quantities – such as from cruise ships. The majority of ship based sewage treatment systems only treat pathogens and do not remove nutrients and suspended solids. Hence, nutrient input could have a significant impact if discharged into waters that were sensitive to changes in the levels of background nutrients. Another issue relating to sewage treatment is the use of chemical bacteriocides such as chlorine. Again, if discharged in sufficient quantities into sensitive receiving waters, these discharges could have an impact.

Marine Debris

Marine debris is a serious and widespread problem although the extent of inputs of marine litter globally is still very poorly understood.[32] It is clear that the majority of waste entering the seas is derived from land-based sources.[33] However, in some areas it is clear that shipping is a major source of marine litter, since ships often find it convenient to disgard

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[26] M. Ryle, "Are TBT alternatives as good?" (1999) 80 *MotorShip*, p. 35.

[27] See for example generally: G.W. Bryan, P.E. Gibbs, G.R. Burt and L.G. Hummerstone, "The decline of the gastropod *Nucella lapillus* around southwest England: evidence for the effects of tributyltin from anti-fouling paints", (1986)) 66 *Journal of the Marine Biological Association of the United Kingdon*, pp. 611-640; S. J. de Mora (Ed) *Tributyltin: Case Study of an Environmental Contaminant*, (Cambridge University Press, Cambridge, Year); C. Alzieu, "Tributyltin: case study of a chronic contaminant in the coastal environment" (1998) 40 *Ocean and coastal Management*, pp. 23-36.

[28] For a general discussion of the development of alternatives to TBT antifouling see for example: I. Omae, "Environment, Biology and Toxicology Organotin antifouling paints and their alternatives", (2003) 17 *Applied Organometallic Chemistry*, pp. 81-105.

[29] Concerns have been raised for example over the accumulation of the herbicides Triazine and Irgarol, which are common constituents of the most commonly used copper based antifouling systems. In particular there are concerns over the potential impacts these substances might have on primary ocean production and the health of coral reefs. For a detailed overview and review of the literature see for example: R. Owen, A. Knap, M. Toaspern and K. Carbery, "Inhibition of coral photosynthesis by the antifouling herbicide Irgarol 1051", (2002) 44 *Marine Pollution Bulletin,* 623-632; N. Kobayashi, and H. Okamura, "Effects of new antifouling compounds on the development of sea urchin", (2002) 44 *Marine Pollution Bulletin*, pp. 748-751.

[30] GESAMP, at p. 24 note that on average cruise ships generate about 4,400 kg of waste per day compared with 60 kg a day produced by cargo ships (note 14).

[31] GESAMP (TABLE 1, note 1) p. 33

[32] L. Jeftic, S. Sheavly and E. Adler, *Marine litter – A global challenge* (United Nations Environment Programme, Nairobi, 2009), p.8.

[33] *Ibid*, p.9.

rubbish overboard rather than dispose of it in ports. This problem is further exacerbated in developing small island countries who are unable to provide appropriate reception and waste disposal facilities.[34]

Plastic waste presents a specific problem due to its persistence in the marine environment. According to GESAMP[35] plastics causes at least six significant types of impact including physical damage to marine fauna, smothering of the seabed and damage to sensitive ecosystems. A particular problem is the degradation of plastics to "micro-plastics" which persist for decades in the environment.

Although marine debris is widespread, most of the available literature relates to coastal and shelf areas with very little information available with respect to marine debris in the open ocean. That said, GESAMP argues that deposits of debris on remote island shores provides a good indicator of ocean-derived debris such as gear from fishing vessels and waste from vessels.

Atmospheric Emissions

Vessels can give rise to a variety of atmospheric emissions, mostly from combustion of fuel in power plants. Significant discharges of polycyclic aromatic hydrocarbons (PAH) and sulphur and nitrogen oxides are associated with the burning of heavy fuel oil and shipping is a major contributor of greenhouse gas (GHG) emissions at the global level.

While, some studies have estimated the amount of volatile organic compounds (VOCs) as a source of ship source hydrocarbons entering the marine environment,[36] most research focuses on the impacts to air quality and human health. Shipping is known to be a dominant contributor over much of the world's oceans to surface concentrations of NO_2 and SO_2. Some research suggests that SOx, NOx and CO_2 contribute to ocean acidification, which affects a variety of biochemical and physiological processes.[37]

PAH are an important group of marine environmental contaminants due to their high carcinogenic and mutagenic potential.[38] However, despite the significance of these emissions, no estimates are reported of PAH inputs to the open ocean and very little information exists on the impacts of these emission on the marine environment.

In 2007 international shipping is estimated to have contributed about 2.7% to the global emissions of carbon dioxide (CO_2). If climate is to be stabilized at no more than 2°C warming over pre-industrial levels by 2100 and emissions from shipping continue as projected, then they would constitute between 12% and 18% of the total CO_2 emissions in 2050 that would be required to achieve stabilization by 2100.

2.2: Accidental Pollution Discharges

While operational discharges of oil represent by far the most significant input of oil from ships, public perception demands that accidental discharges of oil receive the greatest scrutiny. Numerous high profile maritime casualties in recent years have demonstrated the potential significant impacts such incidents may have on both the environment and economy of coastal States. A significant literature exists on the both the environmental and socioeconomic impacts of such incidents.[39]

However, the incidence of large spills is relatively low and it is clear that the number of large spills (>700 tonnes) has decreased significantly during the last thirty years.[40] The average number of large spills per year during the period 1990-present was less than a third of that witnessed during the 1970s.[41] Most incidents are the result of a combination of actions and circumstances, all of which contribute in varying degrees to the final outcome. The causes of such incidents may broadly be categorised as follows: Operations (such as bunkering, cargo transfer etc); and Accidents (such as grounding; collision; structural failure). In most cases human error is a significant compounding factor in the causal analysis.

[34] See for example D. Johnson, "Environmentally sustainable cruise tourism: a reality check" (2002) 26 *Marine Policy,* pp. 261-270.

[35] GESAMP (TABLE 1, note 1) p 40

[36] See for example Endresen et al., (note 1) at p. 4 who provide a spatial analysis of VOC emissions from crude oil transport. GESAMP estimate that VOC emissions from tanker operations are equivalent to about 68,000 tonnes of oil per year entering the marine environment (note 5) p. 16.

[37] A. Abdulla and O. Linden, "Maritime traffic effects on biodiversity and potential mitigation measures: A synthesis" in *Maritime traffic effects on biodiversity in the Mediterranean Sea – Volume 1 Review of impacts, priority areas and mitigation measures,* A. Abdullah and O. Linden (eds) (IUCN, Switzerland, 2008) p. 163.

[38] *Ibid*, p.38.

[39] Fingus, provides a comprehensive list of 175 major oil spills that have occurred since the Torrey Canyon in 1967. See M Fingus, *Basics of oil spill cleanup* 2nd Ed (CRC Press LLC, Boca Raton, Florida, 2001), pp. 10-14.

[40] Data from the International Tanker Operators Pollution Federation (ITOPF) suggests that in the period 1970-1979 3.14 million tonnes of oil was spilled in tanker accidents, whereas during the period 1990-199 less than half that volume (1.14 million tonnes) was spilled. Furthermore, a few very large spills are responsible for a high percentage of the oil spilt in any one year. As such large accidents have the potential to contribute significantly to the overall data: www.itopf.org.

[41] The International Tanker Operators Pollution Federation, *The ITOPF Handbook 2008/2009*, (ITOPF, London, 2009), p. 9.

It should be noted that these data represent all spills greater than 7 tonnes. However, accidents involving collisions and groundings generally give rise to much larger spills, with almost a fifth involving quantities in excess of 700 tonnes.

Tankers present by far the greatest risk of accidental pollution from shipping due to the large volumes carried in a single vessel. However, the amount of oil released into the marine environment from tanker accidents varies considerably from year to year and is highly influenced by the number of very large spills that occur.[42] That is not to suggest that non-tanker vessels do not cause accidental spills of oil, however, the amounts of oil spilled from non tankers is typically two orders of magnitude smaller than for tankers.[43]

Non oil chemical spills from tankers are relatively rare events and likely to have only localised impacts depending on the nature of the substance involved, the amount spilled, the prevailing environmental conditions and the sensitivity of the receptors.[44]

2.3: Physical Harm and Disturbance

Less emphasis is generally placed on the physical impacts that vessels may cause. However, the physical impacts of shipping are becoming more and more apparent. Such impacts may include, engine and machinery noise; physical damage to organisms and habitats (ship strike and anchor damage); and wake and wash effects associated with high speed passage in narrow channels.

Noise

As a result of the introduction of propeller driven ships, shipping noise now dominates the background noise over the frequency ranges (20Hz – 300Hz) throughout the oceans. As well as the noise generated inadvertently from ship's engines and propellers, other loud sounds are generated for specific purposes. These include sounds from sonar and seismic surveys (used by geologists for oil exploration), which can be some of the loudest sources of underwater noise.[45] However, 90% of anthropogenic acoustic energy emitted to the marine environment is generated by ships propulsion. The seas of the northern hemisphere are particularly prone to high levels of vessel sourced noise due to the large volume of shipping.[46] As a result, shipping is now the largest source of low-frequency sound and there is a direct correlation between the level of noise and increased vessel size, speed and load. The acoustic pollution they cause is constant and may affect very large areas of open ocean.[47] One of the major concerns is that this low frequency noise is also at the same frequency as that used predominantly by baleen whales for communication.

Noise has been shown to have significant effects on marine species, although most research has focussed on cetaceans. Continuous exposure to acoustical pollution can cause physical injury, disrupt behaviour, mask communication and other biologically important signals, affect species' ability to hear at certain critical frequencies and increase their sensitivities to disturbance.[48]

A number of mitigation measures have been proposed to reduce the impact of ship sourced noise and the topic is gaining increasing attention at the international level.

While most interest in this topic has focussed on cetaceans, there is increasing concern regarding the impact of such noise on fish, other vertebrates such as aquatic and diving birds and marine invertebrates (including crustacea).[49] There is a small but growing body of literature demonstrating a broad range of impacts on fish although further investigation is required.

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[42] GESAMP (note 5) at p. viii reports that accidental discharges account for approximately 36% of all oil entering the marine environment from shipping.

[43] *Ibid*, p. 30.

[44] GESAMP (TABLE 1, note 1) p. 34.

[45] For an overview of the impacts of noise on marine mammals see C. Perry, *A review of the impact of anthropogenic noise on cetaceans*, (Environmental Investigation Agency, London, 1998) Report No.SC/50/E9; W. Richardson, C. Greene, C. Malme and D. Thompson, *Marine mammals and noise*, (San Diego Academic Press, San Diego, 1995), Chapter 5 generally.; J. Gordon and P. Tyack, "Sound and cetaceans" M. P. Evans and J Raga (eds) *Marine Mammals: Biology and Conservation* (Kluwer Academic, New York, 2001), pp. 139-196 generally.

[46] K.N. Scott, "International regulation of undersea noise" (2004) 53 *International and Comparative Law Quarterly*, p. 289; P.G. Evans, *The natural history of whales and dolphins*, (Christopher Helm Publ. Ltd, London, 1987), p. 286.

[47] S. Panigada, G. Pavan, J.A. Borg, B.S. Galil and C. Vallini, "Biodiversity impacts of ship movements, noise, grounding and anchoring", in *Maritime traffic effects on biodiversity in the Mediterranean Sea – Volume 1 Review of impacts, priority areas and mitigation measures* A. Abdullah and O. Lindend (eds) (IUCN, Switzerland, 2008) p. 10.

[48] GESAMP (TABLE 1, note 1) p. 39.

[49] Panigada et al., (note 47) p. 11.

Ship Strikes

Historical records suggest that ship strikes fatal to whales first occurred late in the 1800s, as ships began to reach speeds of 13–15 knots, remained infrequent until about 1950, and then increased during the 1950s–1970s, as the number and speed of ships increased.[50] There also appears to be a link between noise and collisions where collisions may be related to high-density maritime traffic, increased masking ambient noise and impairing cetaceans' ability to avoid the collision area due to the intensity of shipping noise in the area.

To date, evidence has emerged of ship collisions with at least 11 species of large whale.[51] Of these, the fin whale is the species most commonly reported as being hit by ships worldwide. Ship strikes have also been reported for small cetaceans.[52]

Significant international attention has been focussed on the critically endangered North Atlantic right whale, for which vessel strikes may account for over 35% of total deaths.[53] This population nearly became extinct due to commercial whaling and now numbers only around 350 individuals. The whales spend most of their lives close to busy shipping areas off the east coast of the United States and Canada.

Other marine vertebrates, such as sea turtles that need to come to the sea surface to breath, are also exposed to the risk of shipstrikes. According to Panigada et al.,[54] this has become a major challenge for marine turtle conservation worldwide.

[50] For a comprehensive overview of this issue see for example D.W. Laist, A.R. Knowlton, J.G. Mead, A.S. Collet and M. Podesta, "Collisions between ships and whales" (2001) 17 *Marine Mammal Science,* pp. 35-75.

[51] A.S. Jensen, and G.K. Silber, *Large whale ship strike database* US Dept of Commerce, NOAA Technical Memorandum NMFS-F/OPR-23, (NOAA, Washington DC, 2003), p. 2.

[52] Panigada et al., (note 47) p. 33.

[53] See for example A.R. Knowlton, and S.D. Kraus, "Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western North Atlantic Ocean" (2001) 2 (Special Edition) *Journal of Cetacean Research and Management,* pp. 193-208.

Physical Damage

In fragile marine environment such as coral reefs, ships may cause harm by running aground or by the use of anchors. Although published data on the effects of anchoring of large vessels are lacking, anchor damage has been widely recognised as a significant threat to the coral reefs of the Florida Keys and the Gulf of Mexico.

Physical damage may in some cases also result in long term environmental contamination caused by the deposition of harmful antifouling substances in localised parts of the environment.[55] However, by definition, physical effects on benthic habitats and species arising from groundings are restricted to shallow water areas.

[54] Panigada et al., (note 47) p. 39.

[55] On 2 November 2000, the 184-m cargo ship *Bunga Teratai Satu* ran aground on Sudbury Reef, within the Great Barrier Reef Marine Park. Although no cargo or fuel was lost, the ship remained aground for 12 days and a large quantity of antifoulant paint containing TBT, zinc, and copper was scraped from the hull during the grounding and subsequent refloating operation. This resulted in extensive contamination of the reef sediments for up to 250 m surrounding the grounding site.

3: Regulation of Ship Sourced Pollution

Shipping is arguably one of the most heavily regulated of all marine activities. Over the years, the International Maritime Organization (IMO) has adopted and revised a broad range of instruments that respond directly or indirectly to the broad range of threats posed by international shipping.

IMO treaties aimed at protection of the marine environment centre around three distinct types of measures, namely discharge standards, construction, design, equipment and manning (CDEM) standards, and navigation standards.

The IMO safety conventions mainly regulate measures to prevent accidents endangering human life and goods at sea. However, these include many regulations aimed at preventing marine pollution and other forms of harm occurring as a result of these accidents. Among the most important treaties dealing mainly with safety of navigation are SOLAS[56] and the COLREGS.[57] These are not addressed below but should be considered for specific types of environmental threat such as those characterised as physical harm and disturbance in section 2.3 above.

The IMO environmental treaties almost exclusively regulate pollution through the application of discharge

[56] *The International Convention for the Safety of Life at Sea*, 1 November 1974. In force 25 May 1980. 1184 *U.N.T.S* 2

[57] *Convention on the International Regulations for Preventing Collisions at Sea 1972*, 20 October 1972. In force 15 July 1977. 1050 *U.N.T.S* 16 (hereafter COLREGS). The COLREGS, in line with Article 39 of the LOSC, sets forth detailed rules relating to the operation of vessels, including safe speeds, rights of way, actions to avoid collisions, lighting, signalling and provisions for traffic separation schemes.

and CDEM standards, irrespective of whether the discharge of such substances arise as the result of an accident or from the normal operation of the ship. The main treaties that deal with the prevention of pollution are MARPOL 73/78,[58] the International Convention on the Control of Harmful Anti-Fouling Systems on Ships[59] and the International Convention for the Control and Management of Ships' Ballast Water and Sediment.[60]

3.1: MARPOL 73/78

MARPOL 73/78 and its predecessor OILPOL 54 are the only regulatory conventions that contain both CDEM standards and discharge/emission standards.[61] MARPOL 73/78 therefore covers the technical aspects of pollution from ships except the disposal of waste by dumping, and applies to all ship types. The Convention consists of a number of articles and some regulations, but the substantive content of the convention is contained within the six Annexes, each dealing with a different category of pollutant (**TABLE 2**). States acceding to the Convention are obliged to accept the provisions of Annexes I and II, the other annexes being optional.

With the exception of Annex III, each of the six Annexes has discharge standards that are modelled to particular substances, which are discussed in more detail below. The criteria for discharge standards include factors such as the distance from the nearest land; the degree of dilution (or concentration) of the pollutant; and the speed at which the vessel must be travelling before discharge is permitted. Furthermore, Annexes I, II, V and VI provide for the establishment of Special Areas where more stringent discharge standards may apply.[62] It is worth noting, however, that the complete prohibition of discharges is limited to a small number of situations.

MARPOL 73/78 recognises three situations that constitute exceptions to the discharge obligations. First, in situations of force majeure, where discharges are made "for the purpose of securing the safety of a ship or saving life at sea". Second, for incidents in which a discharge is a result of "damage to a ship or its equipment". Third, for the purpose of combating specific pollution incidents for example where the discharge of oil dispersing chemicals may be used to respond to a spill of oil.

ANNEX	POLLUTANT CATEGORY
I	Oil
II	Noxious liquid substances (NLS) carried in bulk
III	Harmful substances in packaged form
IV	Sewage
V	Garbage
VI	Air pollution

TABLE 2. **MARPOL Annexes and Pollutant Categories**

3.2: MARPOL Annex I – Oil

Annex I to MARPOL 73/78 is extensive and contains regulations on how tankers and other ships shall be constructed to minimise the risk of pollution. The Annex also contains criteria and limits for permissible discharges of oil and oily residues under different circumstances.

The Annex may, for practical reasons, be split up into the two groups: oily waste from machinery spaces including oil contaminated bilge water (operational waste) and ballast and tank-cleaning water from cargo tanks and pump rooms of oil tankers (cargo related waste).

Operational discharges of oil from tankers are permitted under specific conditions (**TABLE 3**). No discharge is permitted from the cargo spaces of a tanker within 50 nautical miles of the nearest land.[63] Parties must ensure the provision of adequate reception facilities for oily wastes in their ports.

Ship-to-Ship Oil Transfers

With increasing frequency, maritime shipping is engaging in the transfer of oil and other harmful substances between vessels coming alongside each other outside harbour limits or beyond the jurisdiction of the nearest states. The matter is as yet unregulated outside national jurisdiction and it may be a relevant issue with respect to the Sargasso Sea.

The activity, while unregulated, does present a

[58] *International Convention for the Prevention of Pollution from Ships 1973 as modified by the Protocol of 1978 relating thereto*, 1 June 1978. In force 2 October 1983. 1340 *U.N.T.S* 61.

[59] *International Convention on the Control of Harmful Anti-Fouling Systems on Ships*, 5 October 2001. In force 17 September 2008.

[60] *International Convention for the Control and Management of Ships' Ballast Water and Sediment*, 13 February 2004. Not yet in force.

[61] See: L. B. Sohn, "Implications of the Law of the Sea Convention regarding the protection and preservation of the marine environment," *The Developing Order of the Oceans – 18th Annual Conference of the Law of the Sea Institute*, San Francisco, (Honolulu: The Law of the Sea Institute, 1984), p. 104.

[62] MARPOL Annex VI, relating to air emissions, includes a provision for the designation of SOx Emission Control Areas (SECA) where the standards for sulphur emissions are more stringent than the general MARPOL standard. Thus while they are not referred to as Special Areas, they serve the same purpose.

[63] The term "from the nearest land" means from the baseline from which the territorial sea of the territory in question is established in accordance with international law.

VESSEL/VOYAGE TYPE/AREA	SUB-CATEGORY	DISCHARGE CONDITIONS
Oil tankers **All waters**	**Oily waste from cargo tanks**	• More than 50 nautical miles from the nearest land; and • Tanker is proceeding en route; and • Instantaneous rate of discharge < 30 litres per nautical mile; and • Total quantity discharge does not exceed 1/15,000 or 1/30,000 of the total cargo (depending on the age of the vessel); and • Oil discharge monitoring and control system and slop tank arrangement to be operating.
All vessels >= 400 gross tons **All waters**	**Machinery space bilges**	• Oil and all oily mixtures retain onboard for on shore disposal OR • Proceeding en route; and • Oil content less than 15 parts per million; and • Oil discharge monitoring and control system and oil filtering equipment to be operating Note: Vessel must be underway when undertaking discharge.
All vessels <400 gross tons **All waters**	**Machinery space bilges**	• Oil and all oily mixtures retain onboard for on shore disposal OR • Proceeding en route; and • Has in operation equipment of a design approved by the administration that ensures oil content less than 15 parts per million. Note: 15ppm discharges can be anywhere at sea. Vessel must be underway when undertaking discharge.

TABLE 3. **MARPOL Annex I Discharge Standards**

potential threat of pollution during the inter-ship oil transfer or supply operations. In response to concerns raised by some States over this threat, the IMO has adopted amendments to Annex I of MARPOL 73/78. IMO Resolution MEPC.186(59) contains a new Chapter 8 to MARPOL Annex I on the prevention of pollution during the transfer of oil cargo between oil tankers at sea. The new regulation requires all oil tankers of 150 gross tonnage and above engaged in the transfer of oil cargoes between tankers at sea (STS Operations) to have on board an approved STS Operations Plan.

3.3: MARPOL Annex II – Chemicals (Noxious Liquid Substances)

The carriage of bulk noxious liquid substances and chemicals is covered by regulations in SOLAS Chapter VII and MARPOL Annex II, as well as by the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code). This sets international standards for the safe transport by sea in bulk of liquid dangerous chemicals, by, *inter alia*, prescribing the design and construction standards of ships involved in such transport and the equipment they must carry so as to minimize the risks to the ship, her crew and the environment, given the hazards (e.g. flammability, toxicity, corrosivity and reactivity) of the products covered by the Code.

For ease of understanding Annex II can be divided into two parts: (1) the pollution categories; and (2) ship type requirements. Additionally it also includes operational requirements.

Pollution Categories

Under revisions to both Annex II and the IBC Code, which entered into force in 2007, four categories of noxious liquid substances are rated by their potential impact on the environment:

Category X: Noxious Liquid Substances which, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a major hazard to either marine resources or human health and, therefore, justify the prohibition of the discharge into the marine environment;

Category Y: Noxious Liquid Substances which, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a hazard to either marine resources or human health or cause harm to amenities or other legitimate uses of the sea and therefore justify a limitation on the quality and quantity of the discharge into the marine environment;

Category Z: Noxious Liquid Substances which, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a minor hazard to either marine resources or human health and therefore justify less stringent restrictions on the quality and quantity of the discharge into the marine environment; and

Other Substances (OS): substances which have been evaluated and found to fall outside Category X, Y or Z because they are considered to present no harm to marine resources, human health, amenities or other legitimate uses of the sea when discharged into the sea from tank cleaning of de-ballasting operations. The discharge of bilge or ballast water or other residues or mixtures containing these substances are not subject to any requirements of MARPOL Annex II.

The bulk carriage of any liquid product other than those defined as oil (subject to MARPOL Annex I) is prohibited unless the product has been evaluated and categorised for inclusion in Chapter 17 or 18 of the IBC Code. The marine pollution hazards of thousands of chemicals have been evaluated by the GESAMP Evaluation of Hazardous Substances Working Group, giving a resultant 'GESAMP Hazard Profile' which indexes the substance according to its bio-accumulation; bio-degradation; acute toxicity; chronic toxicity; long-term health effects; and effects on marine wildlife and on benthic habitats. The IBC Code lists some 250 chemicals and their hazards and specifies the ship type required to carry a given chemical and its environmental hazard rating. Discharge of residues is allowed only into reception facilities unless certain conditions (which vary with the category of the substances involved) are complied with. No discharge of residues containing noxious substances is permitted within 12 nautical miles of the nearest land.

Ship Type Requirements

Ships constructed after 1986 carrying substances identified in Chapter 17 of the IBC Code must follow the requirements for design, construction, equipment and operation of ships contained in the IBC Code,[64] which provides detailed standards for the construction and equipment of three types of chemical tankers.

Ship Type 1 is a chemical tanker intended for the transportation of products considered to present the greatest overall hazard. The quantity of cargo required to be carried in a Type 1 ship should not exceed 1,250 m^3 in any one tank

Ship Type 2 is intended to transport products with appreciably severe environmental and safety hazards which require significant preventive measures to preclude escape of such cargo. The quantity of cargo required to be carried in a Type 2 ship should not exceed 3000 m^3 in any one tank

Ship Type 3 is a chemical tanker intended to transport products with sufficiently severe environmental and safety hazards. These products require a moderate degree of containment to increase survival capability in a damaged condition. There is no filling restriction for chemicals assigned to Ship Type 3.

Annexes II and III set out discharge criteria and measures for the control of pollution by chemicals carried in bulk, in packaged form and on chemical tankers (**TABLE 4**).

3.4: MARPOL Annex III – Packaged Goods

MARPOL Annex III includes regulations for the prevention of pollution by harmful substances in packaged form and includes general requirements for the issuing of detailed standards on packing, marking, labelling, documentation, stowage, quantity limitations, exceptions and notifications for preventing pollution by harmful substances. For the purpose of Annex III, "harmful substances" are those identified as "marine pollutants" in the International Maritime Dangerous Goods (IMDG) Code.

The IMDG Code was developed as a uniform international code for the transport of dangerous goods by sea covering such matters as packing, container traffic and stowage, with particular reference to the segregation of incompatible substances. The IMDG Code includes products classified as marine pollutants according to the GESAMP evaluation.

Marine pollutants are specifically identified so that they can be packed and stowed on board ship in such a way as to minimize accidental pollution and to assist in their recovery by using clear marks to distinguish them from other (less harmful) cargoes. Jettisoning of harmful substances carried in packaged form is prohibited, except where necessary to secure the safety of the ship or saving life at sea. Furthermore, appropriate measures based on the physical, chemical and biological properties of harmful substances shall be taken to regulate the washing of leakages overboard, provided that compliance with such measures would not impair the safety of the ship and persons on board.

[64] Verlan, 'Marine biodiversity, environmental conservation and maritime traffic: An overview of opportunities under the law of the sea to improve marine environmental conservation affected by maritime traffic' in *Maritime Traffic Effects on Biodiversity in the Mediterranean Sea, Volume 2 – Legal Mechanisms to Address Maritime Impacts on Mediterranean Biodiversity*, N. Oral and F. Simard (eds) (IUCN, Switzerland, 2008), p. 18.

VESSEL/VOYAGE TYPE/AREA	SUB-CATEGORY	DISCHARGE CONDITIONS
Chemical and Product Tankers	**Category X**	• Tanks to be prewashed before leaving unloading port, residues to be pumped ashore until the concentration of the substance in the effluent is 0.1% by weight or less. Remaining tank washings to be discharged to reception facility until the tank is empty. Appropriate entries to be made in the Cargo Record Book. Any water subsequently added may be discharged if: • Ship is proceeding en route at a speed of at least 7 knots; and • Discharge below the waterline; and • Ship is > 12 nm from nearest land and depth of water is >25m.
	High-viscosity or solidifying Category Y	• Prewash in accordance with Convention, residues to be pumped ashore until tank is empty. Any water subsequently added may be discharged if: • Ship is proceeding en route at a speed of at least 7 knots; and • Discharge below the waterline; and • Ship is > 12 nm from nearest land and depth of water is >25m.
	Category Y Category Z	• Ship is proceeding en route at a speed of at least 7 knots; and • Concentration of substance in wake of ship < 1 part per million; and • Amount not to exceed $1m^3$ or 1/3,000 of tank capacity, whichever is greater; and • Discharge below the waterline; and • Ship is > 12 nm from nearest land and depth of water is >25m.
MARPOL Harmful Packaged Substances (Annex III)	**Vessels carrying Harmful Packaged Substances Labelling requirements**	• Jettisoning prohibited.

TABLE 4. MARPOL Annex II & III Discharge Standards

VESSEL/VOYAGE TYPE/AREA	SUB-CATEGORY	DISCHARGE CONDITIONS
Vessels on international voyages	Comminuted and disinfected sewage using an approved sewage treatment system	• 3 nm from nearest land.
	Sewage stored in holding tanks (untreated and treated sewage)	• 12 nm from nearest land; and • discharged at a moderate rate;* and • ship proceeding en route at a speed of at least 4 knots. * The rate of discharge must be approved by the Administration.
	Treated sewage effluent discharged through an IMO approved sewage treatment plant (STP) Also integrated system where the STP includes • grey water input • food processing input.	• Effluent not to produce visible floating solids nor cause discolouration of the surrounding water. • When within port limits, check with port authority as permission may be required

TABLE 5. MARPOL Annex IV Discharge Standards

3.5: MARPOL Annex IV – Sewage

Annex IV contains a set of regulations regarding the discharge of sewage into the sea, ships' equipment and systems for the control of sewage discharge, the provision of facilities at ports and terminals for the reception of sewage, and requirements for survey and certification. The current Annex entered into force on 1 August 2005 and applies to ships engaged in international voyages, of 400 gross tonnage and above or which are certified to carry more than 15 persons.

It is generally considered that on the high seas, the oceans are capable of assimilating and dealing with raw sewage through natural bacterial action and therefore the regulations in Annex IV of MARPOL prohibit ships from discharging sewage within a specified distance of the nearest land, unless they have in operation an approved treatment plant (TABLE 5).

Ships may not discharge sewage within 12 nautical miles of the nearest land unless they have in operation an approved treatment plant, and they may only discharge such treated (i.e. comminuted and disinfected) sewage using an approved system at a distance of more than three nautical miles from the nearest land. Untreated sewage may be discharged more than 12 nautical miles from the nearest land. Parties must ensure the provision of adequate sewage reception facilities at ports and terminals.

3.6: MARPOL Annex V – Garbage

Annex V regulates disposal of different types of garbage. Annex V explicitly prohibits the disposal of plastic anywhere into the sea and regulates the disposal of other types of garbage at sea. Under Annex V, garbage includes all kinds of food, domestic and operational waste, excluding fresh

GARBAGE TYPE	CURRENT	NEW
Plastics. This includes synthetic ropes, synthetic fishing nets, plastic garbage bags and incinerator ashes from plastic products, cigarette filters, fibreglass/laminated structures piping, insulation, carpets paints and finishes, electrical components, sheeting, floats fishing nets strapping band rope and line.	No discharge	No discharge
Dunnage, lining and packing materials which will float (eg: pallets, cardboard, plywood)	Outside 25nm	No discharge
Food wastes	If comminuted outside 3nm. If untreated outside 12nm unless comminuted.	Ship must be en route. If comminuted outside 3nm. If untreated outside 12nm unless comminuted. In Special Areas must be 12nm from land or ice shelves. In the Antarctic must not contain poultry products unless sterile.
Cargo residues	Outside 3nm.	Ship must be en route Must not be a marine pollutant. Outside 12nm. In Special Areas only when contained in hold wash water and where ship not leaving the area between ports and no reception facilities exist.
Paper products, Rags, Glass, Metal, Bottles, Crockery, Incinerator ash	If comminuted outside 3nm. If untreated outside 12nm unless comminuted.	No discharge
Cleaning agents for deck washing	Not regulated.	Discharge allowed with wash water but must not be a marine pollutant.
Animal carcasses	Not regulated.	Outside 100nm Maximum possible water depth. Split to ensure they sink.
Non-Synthetic fishing gear	Not regulated.	No discharge except in emergencies to protect vessel, crew or environment.

TABLE 6. **MARPOL 73/78, ANNEX V – Summary of Proposed Amendments and Permitted Discharges**[1]

[1] GESAMP, *Proceedings of the GESAMP international workshop on microplastics particles as a vector in transporting persistent, bioaccumulating and toxic substances in the ocean*, GESAMP Reports and Studies No. 82 (UNESCO-IOC, Paris, 2010), p. 33.

fish, generated during the normal operation of the vessel and liable to be disposed of continuously or periodically.

It is broadly recognized that Annex V has struggled to achieve its goals and in 2006 a comprehensive revision of the Annex commenced. A new draft text of the Annex which was approved at MEPC in October 2010 was finally adopted by MEPC at its 62nd Session in July 2011. An overview of the revised Annex V is given in **TABLE 6**.

The above changes once adopted would lead to a strengthened regulation with more extensive record keeping, through which it would be clearer to all that disposal of garbage at sea is in principle prohibited unless under very special circumstances such as emergencies.

3.7: MARPOL Annex VI – Air Pollution

In 1997 a new annex was added. The Regulations for the Prevention of Air Pollution from Ships (Annex VI) seek to minimize airborne emissions from ships and their contribution to global air pollution and environmental problems. Annex VI (see **TABLE 7**) sets limits on sulphur oxides (SOx) and nitrogen oxides (NOx) emissions from ship exhausts, VOC emissions and prohibits deliberate emissions of ozone-depleting substances (ODS).

3.8: Special Discharge Restrictions

As can be seen from the discussion above, under MARPOL 73/78, all sea areas are protected, to some degree, from the discharge of harmful substances. Most sea areas have a level of protection that is considered adequate. However, where additional protection is deemed necessary, MARPOL 73/78 provides for the designation of 'special areas' and imposes correspondingly more stringent restrictions on the discharge of harmful substances. Special areas are provided for in three of the six MARPOL Annexes currently in force.[65] While each Annex has slightly different wording, the definition in Annex I reflects the general intent of what a special area is:

> A sea area where, for recognised technical reasons in relation to its oceanographic and ecological condition and to the particular character of its traffic, the adoption of special mandatory methods for the prevention of sea pollution by oil is required.

[65] Annexes I, II and V of MARPOL 73/78 provide for special areas to be designated in respect of the discharge of oil, noxious liquid substances and garbage respectively. In addition, Annex VI of MARPOL 73/78 provides for a type of special area called a SOx (Sulphur Dioxide) Emission Control Area (SECA) which deals exclusively with discharges to air (Regulation 14 of Annex VI). To date, only the Baltic Sea area and the North Sea area have been designated as SECAs.

VESSEL/VOYAGE TYPE/AREA	SUB-CATEGORY	DISCHARGE CONDITIONS
All vessels	Ozone-Depleting Substances	Prohibited
	Nitrogen Oxides	Operation of diesel engines >130kW prohibited unless engine is certified to meet prescribed emission standards. *New Engines* • Tier I–7 g/kW from 1 January 2000 • Tier II–14.4 g/kW from 1 January 2011 • Tier III–3.4 g/kW from 1 January 2016 (in Emission Control Areas (ECA)) *Existing Engines* (installed on ship on or between 1 January 1990 to 1 January 2000) • 17g/kW for diesel engine with power output >5000kW and displacement per cylinder => 90 litres • Approved method by Administration
	Sulphur Oxides	• Sulphur content of fuel oil not to exceed 4.5%.* • From 1 January 2012, sulphur content of fuel oil not to exceed 3.5% • From 1 January 2020 sulphur content if fuel oil not to exceed 0.5% *FO purchased from a registered supplier
	Incinerators	• Incinerators installed after 1 January 2000 must be type approved and certified to meet prescribed emission standards. • Do not use within port limits.

TABLE 7. **MARPOL 73/78, ANNEX VI – Air Emission Standards**

SPECIAL AREAS	IN EFFECT FROM
ANNEX I: OIL	
Mediterranean Sea	2 Oct 1983
Baltic Sea	2 Oct 1983
Black Sea	2 Oct 1983
Red Sea	*
"Gulfs" area	1 Aug 2008
Gulf of Aden	*
Antarctic area	17 Mar 1992
North West European Waters	1 Aug 1999
Oman area of the Arabian Sea	*
Southern South African waters	1 Aug 2008
ANNEX II: NOXIOUS LIQUID SUBSTANCES	
Antarctic area	1 Jul 1994
ANNEX IV: SEWAGE	
Baltic Sea	(Adopted) 15 July 2011
ANNEX V: GARBAGE	
Mediterranean Sea	1 May 2009
Baltic Sea	1 Oct 1989
Black Sea	*
Red Sea	*
"Gulfs" area	1 Aug 2008
North Sea	18 Feb 1991
Antarctic area (south of latitude 60 degrees south)	17 Mar 1992
Wider Caribbean region including the Gulf of Mexico and the Caribbean Sea	1 May 2011
ANNEX VI: PREVENTION OF AIR POLLUTION BY SHIPS (EMISSION CONTROL AREAS)	
Baltic Sea (SOx)	19 May 2006
North Sea (SOx)	22 Nov 2007
North American (SOx and NOx)	1 August 2012

*The Special Area requirements for these areas have not taken effect because of lack of adequate reception facilities.

TABLE 8. Special Areas designated under Annexes I, II and V of MARPOL 73/78

Therefore, under MARPOL 73/78 special areas are afforded a higher level of protection than other marine areas. Thus, for example, according to MARPOL Annex I, the discharge of oil from oil tankers and from other ships of 400 gross tonnes and above is wholly prohibited. While in such areas, ships shall retain on board all oil drainage and sludge, dirty ballast, and tank washing waters, and then discharge them only to reception facilities.[66]

Until very recently, Annex IV of MARPOL 73/78, which governs the discharge of sewage, did not include the concept of Special Areas. Concerns had been raised that the regulations were insufficient to protect sensitive areas (especially semi-enclosed or closed seas) from nutrient emissions from international shipping. Such concerns may be valid for the Sargasso Sea, even though this does not qualify as being semi-enclosed or closed. However, in response to a request made by several Baltic States, MEPC recently adopted amendments to Annex IV to designate the Baltic Sea as a Special Area under Annex IV.[67] Given the concerns raised in regard to nutrient input to the Sargasso Sea, this opens the possibility of considering Special Area status under Annex IV for the Sargasso Sea.

Similarly, given the current focus on open-water ballast exchange, no spatial controls on the discharge of ballast water on the high seas exist and future regulations will focus on global "discharge quality" standards.

[66] V. A. Kiselev, "Special areas for preventing pollution of the sea," (1988) 12 *Marine Policy* p. 242.

[67] IMO, *Draft Report of the Marine Environment Protection Committee on its Sixty Second Session* (11 – 15 July 2011), IMO Doc. MEPC 62/WP.1-Add 1, at para. 6.36[1].

A special area may encompass the maritime zone of several States, or even an entire enclosed or semi-enclosed area.[68] Special area designation must be made on the basis of the criteria and characteristics set out in the IMO's Guidelines for the Designation of Special Areas under MARPOL 73/78.[69] The criteria are grouped under the following three categories, with a number of conditions being listed for each (a copy of the guidelines and the criteria contained therein is attached at Appendix A of this report for reference):

- Oceanographic conditions;
- Ecological Conditions; and
- Vessel traffic characteristics.

Unlike the designation of PSSAs, the designation of a special area requires that one of the conditions for each of the three categories should be satisfied and that information be provided on each of the categories. Of particular note is the criteria for vessel traffic characteristics which requires that:

> The sea area is used by ships to an extent that the discharge of harmful substances by ships when operating in accordance with the requirements of MARPOL 73/78 for areas other than Special Areas would be unacceptable in the light of the existing oceanographic and ecological conditions in the area.[70]

Furthermore, other considerations may be taken into account, for instance, as the threat to amenities posed by non-maritime sources of pollution such as land-based sources, dumping of waste and atmospheric deposition.[71] In addition to meeting the criteria set out in the special area guidelines, the requirements of a special area can only become effective when adequate reception facilities have been provided for, in accordance with the provisions of MARPOL 73/78.[72] This requirement for adequate reception facilities has delayed the coming into force of some special areas covering the EEZs of more than one nation.

[68] Examples of such areas include the Baltic, Black and Mediterranean Seas.

[69] Annex 1 to IMO resolution A.927(22) *Guidelines for the designation of special areas under MARPOL 73/78 and guidelines for the identification and designation of particularly sensitive sea areas.* Adopted 29 November 2001. "Guidelines for the designation of special areas under MARPOL 73/78" (Special Area Guidelines).

[70] *Ibid*, para 2.6

[71] J. Wonham, "Special areas and particularly sensitive sea areas," in P. Fabbri (ed) *Ocean Management in Global Change: Proceedings of the Conference on Ocean Management in Global Change* (Genoa, Italy: Routledge EF, 1992), p. 365.

[72] Special Area Guidelines, para. 2.7 (note 69). However, the Antarctic has been treated differently since wastes must be kept on board until ships have left the area.

To date, a total of 11 special areas have been designated under the three Annexes (**TABLE 8**). Since the North Atlantic has not been designated as a Special Area under any Annex of MARPOL the standard discharges requirements set out above in **TABLES 3-7** will apply to the Sargasso Sea.

3.9: Ballast Water Management

Although the IMO adopted the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (BWM Convention) in February 2004, the Convention is still not in force due to the insufficient number of contracting parties.

As such, while many countries have adopted national regulations aimed at minimising the risk of aquatic invasive species, at the global level, current ballast water management practices are voluntary, in line with the IMO's "Guidelines for the control and management of ships' ballast water, to minimise the transfer of harmful aquatic organisms and pathogens". Management and control measures recommended by the Guidelines include:

- Minimising the uptake of organisms during ballasting, by avoiding areas in ports where populations of harmful organisms are known to occur, in shallow water and in darkness, when bottom-dwelling organisms may rise in the water column.
- Cleaning ballast tanks and removing muds and sediments that accumulate in these tanks on a regular basis, which may harbour harmful organisms.
- Avoiding unnecessary discharge of ballast.
- Undertaking ballast water management procedures, including:
    - Exchanging ballast water at sea, replacing it with 'clean' open ocean water. Any marine species taken on at the source port are less likely to survive in the open ocean, where environmental conditions are different from coastal and port waters.
    - Non-release or minimal release of ballast water
    - Discharge to onshore reception and treatment facilities

All of the approaches recommended under the IMO Guidelines are subject to limitations. Although re-ballasting at sea currently provides the best-available risk minimisation measure, but is subject to serious ship-safety limits, and is less than 100% effective in removing organisms from ballast water.

The BWM Convention seeks to address these limitations by establishing *inter alia* a ballast water exchange standard and a ballast water performance standard. Ballast water exchange could be used to meet the performance standard:

Ballast Water Exchange Standard – Ships performing ballast water exchange shall do so with an efficiency of 95% volumetric exchange of ballast water which effectively requires pumping through three times the volume of each ballast water tank.

Ballast Water Performance Standard – Ships conducting ballast water management shall discharge less than 10 viable organisms per cubic metre greater than or equal to 50 micrometers in minimum dimension and less than 10 viable organisms per millilitre less than 50 micrometres in minimum dimension and greater than or equal to 10 micrometers in minimum dimension; and discharge of the indicator microbes shall not exceed the specified concentrations.

The indicator microbes, as a human health standard, include, but are not be limited to:

- Toxicogenic *Vibrio cholerae* with less than 1 colony forming unit (cfu) per 100 milliliters or less than 1 cfu per 1 gram (wet weight) zooplankton samples;
- *Escherichia coli* less than 250 cfu per 100 millilitres;
- Intestinal *Enterococci* less than 100 cfu per 100 millilitres.

Under the convention, all ships must implement a Ballast Water and Sediments Management Plan, carry a Ballast Water Record Book and carry out ballast water management procedures to a given standard. Parties may take additional measures, which are subject to criteria set out in the Convention and to IMO guidelines.

While it appears possible to designate areas where ballast water exchange should occur, there exist no provisions either under the current guidelines or the BWM Convention for the spatial designation of areas where ballast water exchange should not occur. As such, it would be reasonable to explore such restrictions specifically in the context of a PSSA.

4: Vessel Traffic Characteristics in the North Atlantic and Sargasso Sea

4.1: Structure of the Global Shipping Fleet

International shipping can be broadly divided into two categories: (1) Liquid cargo, such as oil and petroleum products; and (2) Dry cargo. Dry cargo is made up of bulk goods, the five most important being iron ore, coal, grain and oil bearing seeds, phosphates and bauxite.[73] Other dry cargo consists of bulk materials such as non-ferrous metal ores, feed and fertilizers, and particularly a variety of goods packaged in smaller transportation units.

As a result, the global shipping fleet is made up of ships specifically constructed for different types of freight:[74]

- Liquid tankers for crude oil, petroleum products, chemicals, liquid gas and palm oil;
- Bulk carriers for bulk goods such as ores, coal, grain and for large-volume unit loads such as motor vehicles and iron;
- Refrigerated vessels ("reefers") for perishable goods;
- General cargo ships;
- Container ships, which are increasingly taking on the tasks of general cargo ships on long-haul routes; and
- Ferries for shipping trucks as well as roll-on/roll-off (Ro-Ro) ships, which carry articulated lorries to drive the cargo onto the ship. These two are taking over the tasks of general cargo vessels on short-haul routes.

According to the International Chamber of Shipping (ICS), as at 31st October 2010, the world trading fleet consisted of 50,054 ships[75] made up as follows (**TABLE 9**):

In terms of carrying capacity in dwt, however, the great variation in ship sizes gives quite a different picture. From this perspective liquid tankers account for about 39%, bulk carriers 35%, container ships 13%, general cargo ships 9% and passenger vessels less than 1%.[76]

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[73] UNCTAD, *Review of Maritime Transport 2010* (UN Conference on Trade and Development, Geneva, 2010) p. 9.

[74] The Future Ocean, *World Ocean Review 2010 – Living with the Oceans* (Maribus GmbH, Hamburg, 2010), pp. 167-169.

[75] www.marisec.org/shippingfacts/worldtrade/number-of-ships.php. Note that this figure varies depending which source you refer to. The ICS data is limited only to merchant vessels over 1,000 GT but compares well with statistics published by Equasis in 2010 (www.equasis.org/EquasisWeb/public/HomePage?fs=HomePage). However, according to Lloyds' Register of Shipping there are approximately 97,000 merchant vessels (classified as being greater than 100 GT) although these include a broader range of vessel types such as large fishing vessels, research vessels, tugs and support vessels.

[76] UNCTAD (note 73) p. 30.

VESSEL TYPE	NUMBER OF VESSELS IN FLEET	% OF WORLD FLEET
General Cargo Ships (incl. reefers)	16,224	32.4
Bulk Carriers	8,687	17.4
Container ships	4,831	9.7
Tankers	13,175	27.4
Passenger ships	6,597	13.2

TABLE 9. Makeup of world maritime fleet (2010)

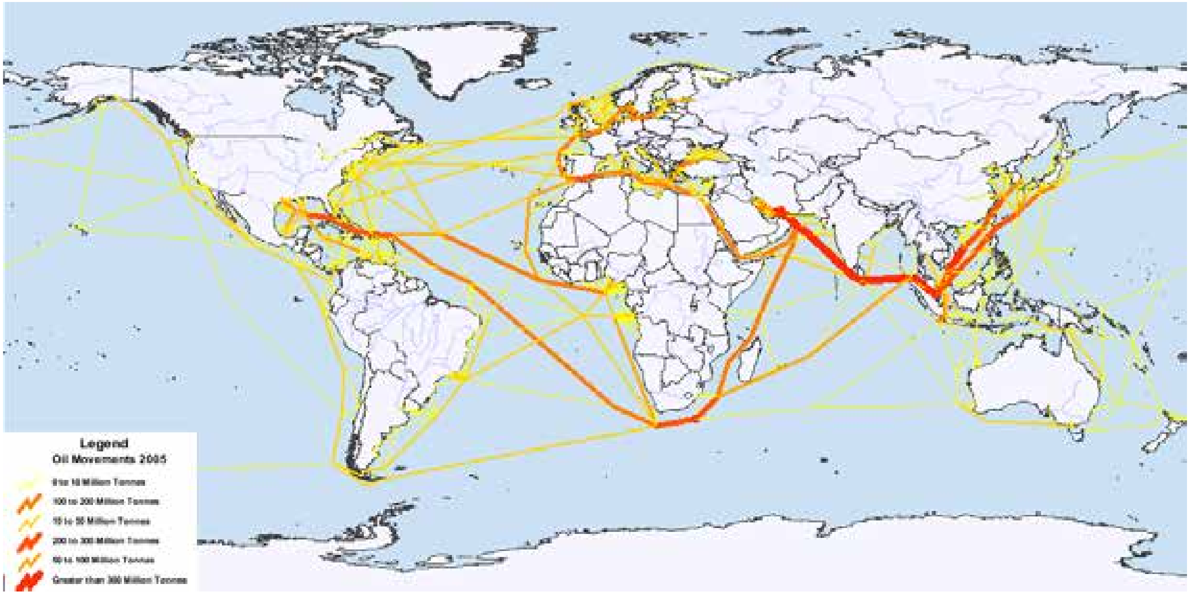


FIGURE 4.1. Vessel movements during 2005 for tankers of handy size (15,000 to 50,000 tons) and above. Source ITOPF.[1]

[1] International Tanker Owners Pollution Federation (ITOPF). www.itopf.com/website/ITOPFWebGIS/viewer.htm. Note that the data does not represent actual routes but simply the relative amounts of crude transported between set way points for the year of 2005.

4.2: Profile of Global Cargo Movements

Liquid cargo

The single most significant type of cargo worldwide is crude oil, which accounts for approximately 25% of all cargo transported by sea. The major importers are the European Union, the USA and Japan.

All three are supplied by the Middle East. North America also obtains oil from West Africa and the Caribbean, while Europe imports from North and West Africa. The main tanker routes therefore extend westward from the Arabian Gulf around the Cape of Good Hope or through the Suez Canal, and from Africa northward and westward to Europe and North America (**FIGURE 4.1**). Others connect the Arabian Gulf to East Asia and the Caribbean to the Gulf Coast of the United States.[77] Increasingly, crude is being shipped from Russia through the Baltic and it seems likely that increasing amounts of crude will be exported from the Arctic region in the future. Hence, the North Atlantic is one of the busiest crude oil transport regions.

Smaller, product tankers carry refined petroleum products from major peripheral refinery locations to the consumption areas of North America and Japan.

[77] WOR (note 74) p. 169.

Dry cargo

In terms of quantity, iron ore and coal are significant dry-bulk goods. Iron ore is transported mainly from Brazil to Western Europe and Japan, and from Australia to Japan. The most important coal routes are from the major export countries of Australia and South Africa to Western Europe and Japan and also from Colombia and the East Coast of the United States to Western Europe, as well as from Indonesia and the West Coast of the United States to Japan.

Dry bulk goods also include grain and oil-bearing seeds (wheat, barley, rye, oats, sorghum and soya beans). Here however, the quantities and direction of transport routes fluctuate much more than other vital commodities depending on harvest seasons and yields. The USA, Canada, Argentina, Australia and France are the major grain exporters. Africa and East Asia are major importers due to frequent local shortages.

Container shipping

Over the last two decades, the global container shipping fleet has increased significantly, from 1,051 vessels in 1987 to 4,677 vessels in 2010[78] and today most dry cargo that is not transported in bulk is transported in this type of vessel. In terms of capacity, global container trade (in tonnes) is estimated to have increased at an average annual rate of 9.8%, while the share of containerized cargo in the world's total dry cargo is estimated to have increased from 7.4% in 1985 to 24 % in 2006. This significant growth in container trade will change the pattern of vessel traffic and therefore shipping impacts.

4.3: Mapping Shipping Routes across the North Atlantic

Analysis of global shipping movements using GIS allows the identification of areas of greatest shipping density at both a global and regional level, and hence the major shipping routes. A range of data sources can be used for this purpose, each with its own distinct advantages and disadvantages. Data sets include data collected by the US Coast Guard under its Automated Mutual Assistance Vessel Rescue (AMVER) programme; data collected by the World Meteorological Organization (WMO) Voluntary Observing Ship (VOS) programme; data collected by coastal States using coastal Automatic Identification Systems (AIS); and, more recently, data collected from Long Range Identification and Tracking (LRIT) of vessels. For the purposes of this study, both VOS and LRIT data were utilised.

[78] UNCTAD (note 73) p. 31.

WMO VOS Data

Ships from many countries voluntarily collect and report meteorological data globally under the WMO Voluntary Observing Ship programme.[79] As of the 30 September 2010, the total VOS-fleet includes about 4,500 vessels,[80] and includes a broad range of different vessel types (**TABLE 10**).

The ship location data are based on reporting of routine meteorological observations, ideally at 6-hour intervals according to procedures by the WMO. Hence the data points from ship reports can be used as a spatial proxy of global shipping traffic. This is based on the assumption that the reporting fleet is representative of the world fleet and that the spatial distribution of ship reporting frequencies represents the distribution of ship traffic intensity.[81]

The efficacy of this approach has been verified

[79] See *The World Meteorological Organisation run Voluntary Observing Ship (VOS) Programme: An enduring partnership* (Geneva, Switzerland: Ocean Affairs Division, WMO). Available at www.bom.gov.au/jcomm/vos/vos.html#introduction. The VOS programme is an international scheme by which ships plying the various oceans and seas of the world are recruited by National Meteorological Services for taking and transmitting meteorological observations.

[80] Source, WMO Publication No. 47 – *International List of Selected, Supplementary and Auxiliary Ships*. Available at: www.wmo.int/pages/prog/www/ois/pub47/pub47-home.htm . Accessed 22 March 2011.

[81] C. Wang, J. Corbett and J. Firestone, "Modeling energy use and emissions from North American shipping: Application of the ship traffic energy and environment model" (2007) 41 *Environmental Science & Technology*, p. 3226.

• Barge	• Gas Tanker	• RoRo Ferry
• Bulk Carrier	• Ice Breaker	• RoRo Container
• Cable Ship	• Livestock Carrier	• Refrigerated Cargo
• Closed Container	• Liquid Tanker	• Research Vessel
• Coast Guard Vessel	• Light Vessel	• Support Vessel
• Container Ship	• Mobile Rigs	• Trawler
• Dredger	• Military Ship	• Tug
• Passenger Ferry	• Ocean Weather Ship	• Vehicle Carrier
• FPSO	• Pipe Layers	• Yacht
• Fishing Vessel (Other)	• Cruise Ships	• Other
• General Cargo		

TABLE 10. Vessel types reporting in the VOS programme

by a number of authors. For example Wang et al.,[82] used data from the International Comprehensive Ocean – Atmosphere Data Set (ICOADS) – a data set which includes VOS mobile ship reporting data – as a proxy for global ship traffic on the basis that the data represented fleet-wide spatial activity and temporal dynamics.[83] Similarly, Halpern et al., used an annual dataset from VOS to map shipping impacts at a global level (see **FIGURE 1.1**).[84]

By studying the spatial and temporal dynamics of global ship traffic patterns derived from historical locations where ships reported to ICOADS, Wang et al., confirmed that ships travel along well-established shipping lanes between pair-ports. A further analysis comparing this data set with a comparable but different data set derived from the Automated Mutual Assistance Vessel Rescue (AMVER) programme validated this assumption by comparing two independent data sources. [85] Annual changes of the geographic distribution of global ship traffic are not significant.[86] Furthermore, Wang et al.,[87] found that the ICOADS/VOS dataset over-samples for the North Atlantic, making this dataset particularly useful for the purposes of this analysis.

For the purposes of this study, data was collected for the 12 month period beginning 1st January 2010. The data includes unique identifier codes (call signs) for ships, which allows each data point to be classified according to ship type (**TABLE 11**), since the VOS dataset identifies both the vessel ID and the type of vessel.

A total of 444,114 ship data points from a total of 4,276 commercial and research vessels were analysed. The number of individual vessels included in this analysis represents approximately 95% of the total VOS fleet suggesting that the dataset used is highly representative and confirmed the finding of others that the VOS data is heavily biased towards the North Atlantic. While this represents a significant bias when undertaking such analysis at the global level, such a bias is not observable when only analysing data for the North Atlantic. **FIGURE 4.2** presents the results of this analysis as a simple map showing the distribution of the data points, each one representing the position of a vessel when it reports.

[82] See for example: C. Wang, J. Corbett and J. Firestone, "Improving spatial representation of global ship emissions inventories", (2008) 42 *Environmental Science & Technology*, pp. 193-199.

[83] *Ibid* p. 193.

[84] B. Halpern, S. Walbridge, K. Selkoe, C. Kappel, F. Micheli, C. Agrosa, J. Bruno, K. Casey, C. Elbert, H. Fox, R. Fujita, D. Heinemann, H. Lenihan, E. Madin, M. Perry, E. Selig, M. Spalding, R. Steneck and R. Watson, "Global map of human impact on marine ecosystems" (2008) 319 *Science* pp. 948-952.

[85] Wang et al., (note 81) p. 3228.

[86] Wang et al., (note 83) p. 194.

[87] *Ibid*.

VESSEL TYPE	NO. OF PARTICIPATING VESSELS	VESSEL TYPE	NO. OF PARTICIPATING VESSELS
Barge	1	**Mobile Rigs**	0
Bulk Carrier	400	**Military Ship**	0
Cable Ship	0	**Ocean Weather Ship**	0
Closed Container	0	**Pipe Layers**	0
Coast Guard Vessel	58	**Cruise Ships**	150
Container Ship	1200	**RoRo Ferry**	17
Dredger	0	**RoRo Container**	200
Passenger Ferry	60	**Refrigerated Cargo**	60
FPSO	5	**Research Vessel**	152
Fishing Vessel (Other)	0	**Support Vessel**	188
General Cargo	333	**Trawler**	41
Gas Tanker	185	**Tug**	22
Ice Breaker	0	**Vehicle Carrier**	1
Livestock Carrier	1	**Yacht**	17
Liquid Tanker	405	**Other**	780
Light Vessel	0		

TABLE 11. **Number of vessels of different types reporting in the 2010 VOS analysis**

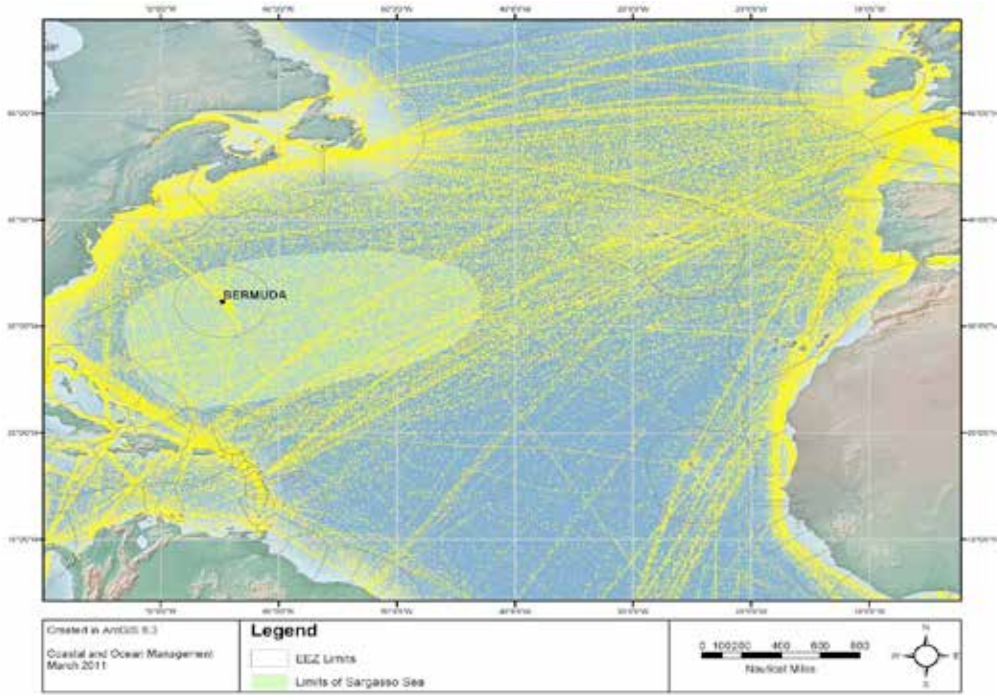


FIGURE 4.2. Spatial plot of real time ship reporting position from the VOS programme (n = 4,276)

As might be expected, **FIGURE 4.2** shows that real-time reports from the VOS are heavily concentrated along the major shipping routes, which reflects the relatively high number of ships sailing along these routes.

A similar analysis, undertaken for the Pacific region, confirms that the correspondence between the actual and inferred tracks is generally quite high.[88] Notably, the Pacific study found that some of the actual recorded tracks did not correspond to any previously identified 'normal routes'. The VOS ships varied their courses substantially from voyage to voyage, producing a diffuse pattern of positions in some areas, for example on passages between New Zealand and South America/Cape Horn.[89] This suggests that the VOS data represents a better data set than the static mapped ships routes that are regularly published for global shipping movements.[90]

While it is clearly possible to visually identify areas of higher density of shipping traffic from **FIGURE 4.2** and key shipping routes, the value of GIS is that it allows quantitative analysis of this data in order to clearly highlight the areas of actual greatest shipping density. Thus, in order to more accurately represent the areas of highest traffic density in the North Atlantic, individual positions were summed in a 0.1° x 0.1° spatial grid and then allocated a series of density ranges to represent different vessel densities from 'Low' to 'High'.

The resulting density plot (or 'heat map') is presented in **FIGURE 4.3** and shows that the areas of highest shipping density are located on coastal shipping routes along the West Coast of Africa, Western Europe, the East Coast of the USA and Canada and on the approaches to the Caribbean, where traffic from different regions converges before, presumably, transiting through the Panama Canal. Both figures 4.2 and 4.3 show clear vessel routes running through the Sargasso Sea region. Analysis of ship types indicates that much of this traffic is container traffic (**FIGURE 4.10B**).

This analysis compares well with a previous analysis using the same approach by Wang et al.,[91] based on data from 2005. Their results are illustrated in Figure 4.4 below and show great correspondence with the 2010 data although it is clear that there were less ships included in their analysis.

4.4: LRIT Data

The Long Range Identification and Tracking (LRIT) of ships was established as an international system through

[88] Edward Anderson Marine Sciences, *Marine Pollution Risk Assessment for the Pacific Islands Region – Volume 1*. Prepared for the South Pacific Regional Environment Programme (SPREP), July 2003, section 4.5. See also, S. Nawadra and T. Gilbert, "Risk of marine spills in the Pacific Islands region and its evolving response arrangements," in *Proceedings of the International Oil Spill Conference (SPILLCON)*, (Manley Australia: September 2002).

[89] Edward Anderson, *ibid.*

[90] See for example *Ocean Passages for the World 5th Edition*, Admiralty Charts and Publications No. NP 136 (Taunton, UK: UKHO, 2005).

[91] note 83.

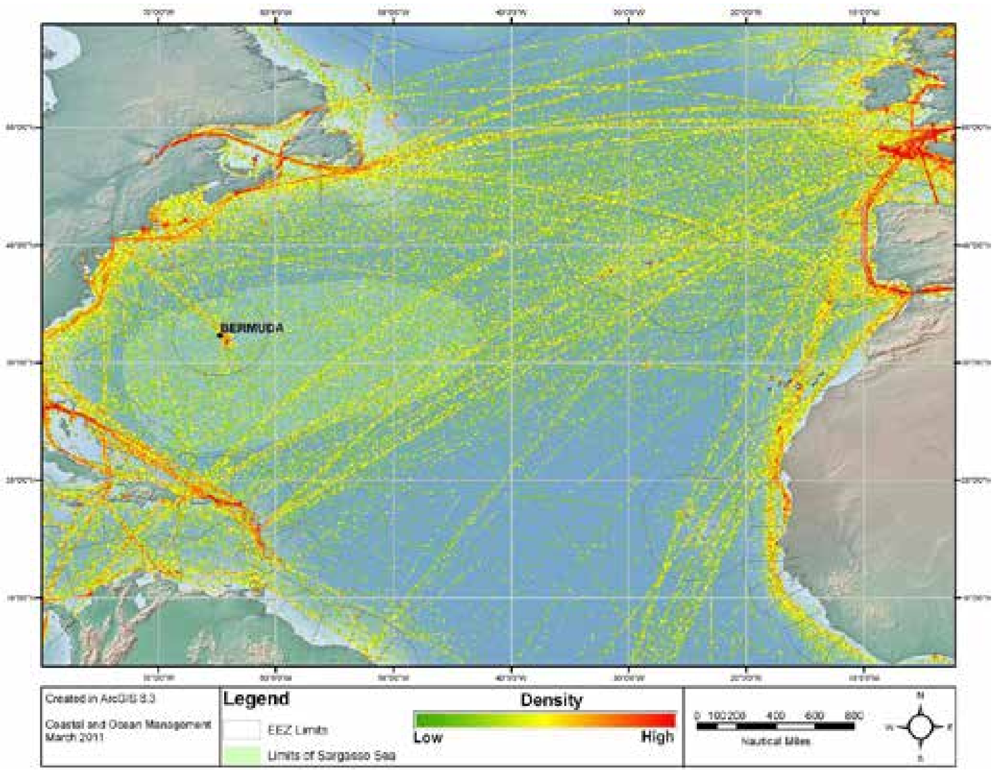


FIGURE 4.3. Relative densities of ship reporting positions from the VOS programme. All positions mapped in a 0.1° x 0.1° spatial grid

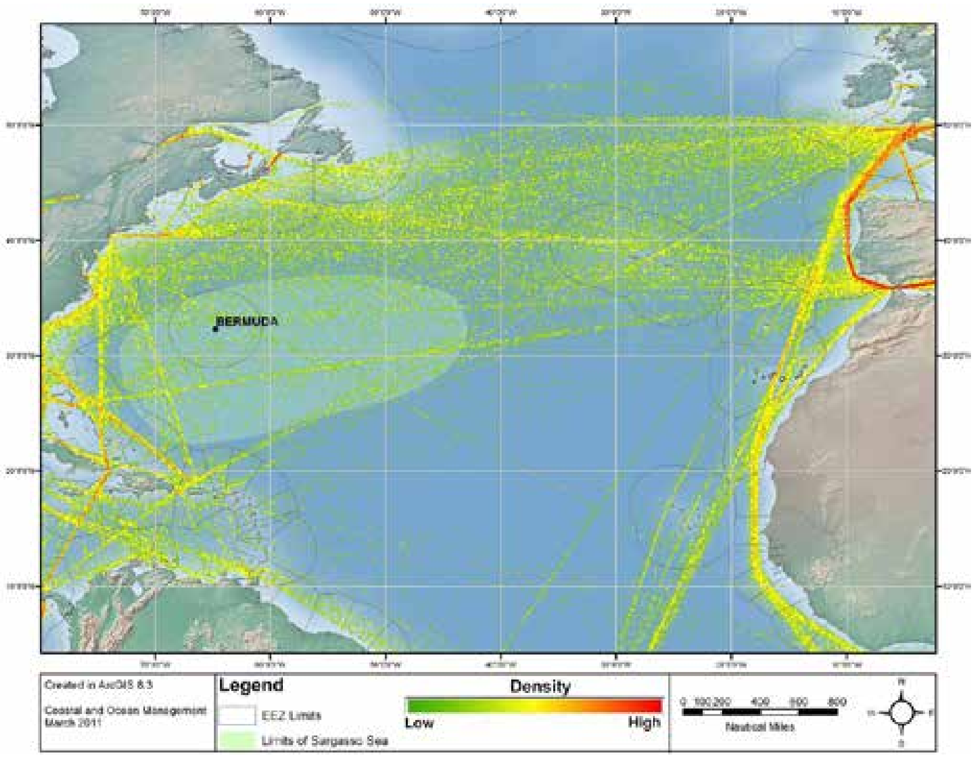


FIGURE 4.4. Data from Wang et al., presented as a density plot. All positions mapped in a 0.1° x 0.1° spatial grid

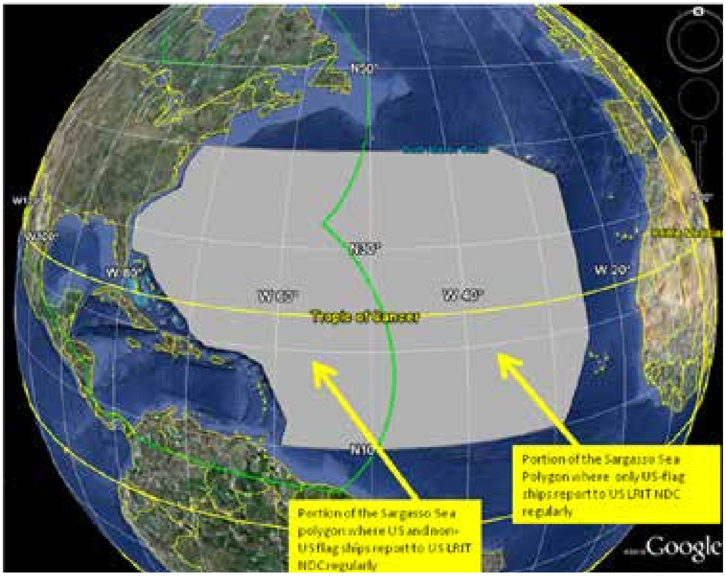


FIGURE 4.5. Limits of LRIT coverage (Courtesy USCG)

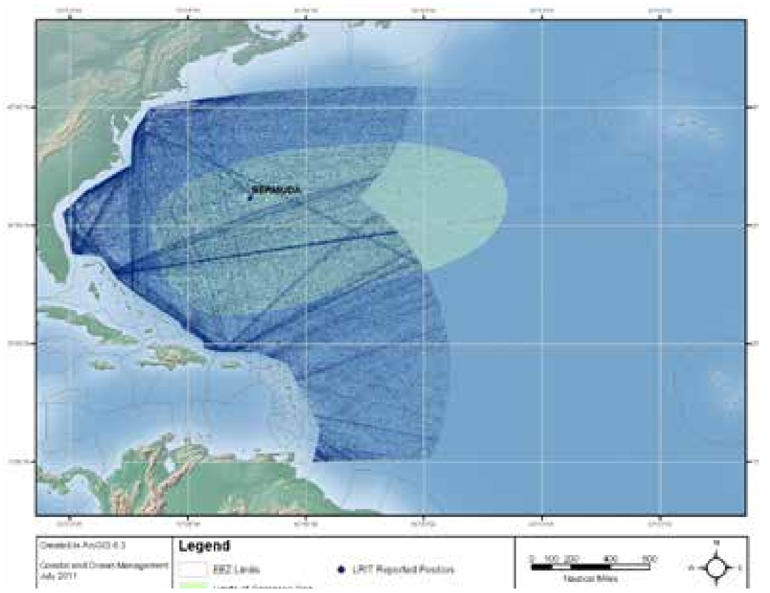


FIGURE 4.6. Spatial plot of real time LRIT positions (n = 8,295)

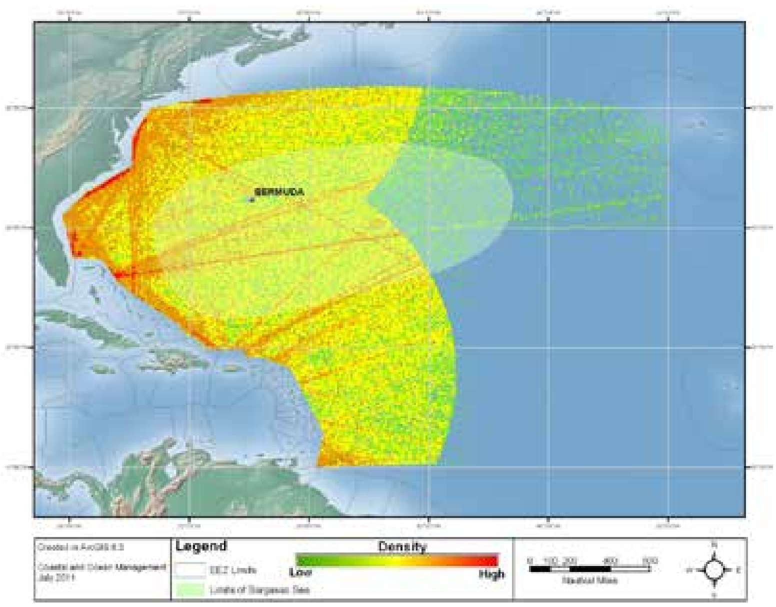


FIGURE 4.7. Heat map of LRIT reported positions (n = 8,295)

amendments to SOLAS in 2006.[92] LRIT is mandatory for all passenger ships, high-speed craft, mobile offshore drilling rigs, and cargo ships over 300 GRT engaged in international voyages, and has been in force since 1 July 2009. The regulations maintain the right of the flag State to protect appropriate information about its own ships, while giving coastal States access to information about ships navigating off their coasts.

Under the SOLAS regulations, coastal States are entitled to receive information about ships navigating within a distance of 1,000 nautical miles off their coasts. Moreover, port States may request information on those ships that have declared their intention to enter one of their ports, irrespective of their location (on receipt of the Notice of Arrival).Vessels must report their position to the flag State at least four times a day. Most vessels set their existing satellite communications systems to automatically make these reports. Other contracting governments may request information about vessels in which they have a legitimate interest under the regulation.

In January 2009 the USA become one of the first SOLAS Contracting Governments to implement a National Data Centre to comply with the LRIT regulation, which now collects LRIT data for all ships transiting towards its coast. This enables US Coast Guard (USCG) to receive information about all vessels within 1,000 nautical miles of US territory providing the vessel's flag administration has not excluded the US from receiving such information.

Although initially implemented in response to security concerns, IMO subsequently adopted a resolution which explicitly provided for the use of LRIT as a tool for environmental protection purposes.[93]

For the purposes of this study, the USCG has provided LRIT data for the period 15/09/2009 – 14/06/2011. These data are presented below, using the same approach used for the VOS data. Although the data is more comprehensive and a more accurate representation of the vessel traffic in the area, the 1,000 nautical mile limit imposes a spatial boundary on the data that can be captured by the USCG (**FIGURE 4.5**). Hence, the data provided does not cover the same area as the VOS data, but does provide an accurate picture on vessels movements for most of the Sargasso Sea area.

An initial plot of actual reported position using a comparable data set to the VOS data (01/01/2010 – 01/01/2011) is presented (**FIGURE 4.6**) followed by a heat map using the same data but using a higher resolution grid (0.05o X 0.05o) due to the smaller area covered by the data (**FIGURE 4.7**).

A further analysis is also presented using monthly data, to determine whether there are any temporal shifts or changes in vessel movements during the year (**FIGURES 4.8A-E** where n= number of ships reporting).

It should be noted that, although it appears that traffic densities have increased substantially during the analysis period, in fact this is a result of sample intensity. LRIT tracking started during in 2009 and did not capture 100% of vessels in the area. As sample capture rates increased, so too did the number of reported positions up to approximately July 2010 when sampling intensity stabilised.

The plots indicate that the most heavily trafficked routes are transit routes between the Mediterranean and the Caribbean/Gulf of Mexico and between Western Europe and the Caribbean/Gulf of Mexico. A number of very heavily trafficked routes are clearly discernible through the Sargasso Sea, with the two routes previously mentioned being the most traffic intense in the whole region.

4.5: Mapping Different Vessel Types

One of the benefits of the VOS dataset is that it allows differential analysis of the different vessel types participating in the VOS scheme. The number of positions reported by each type of ship is a function of the number of vessels, operating profile (e.g. time at sea) and the reporting frequency of that type of ship.[94]

In an analysis of shipping movements based on automatic identification system (AIS) data Kaluza et al., found that different ship types move in distinctive patterns.[95] Container ships typically follow set schedules visiting several ports in a fixed sequence along their way, thus providing regular services. Bulk dry carriers, by contrast, appear less predictable as they frequently change their routes on short notice depending on the current supply and demand of the goods they carry. Oil tankers also follow short-term market trends, but, because they can only load oil and oil products, the number of possible destinations is more limited than for bulk dry carriers.

[92] IMO, Adoption of Amendments to the International Convention for the Safety of Life at Sea, 1974, as Amended (19 May 2006), IMO Resolution MSC 202(81). The Resolution introduced comprehensive amendments to Part V SOLAS, which establishes a system of LRIT for ships.

[93] IMO, Use of the Long-Range Identification and Tracking Information for Maritime Safety and Marine Environment Protection Purposes (12 October 2007), IMO Resolution MSC 242(83).

[94] Wang et al., (note 83) p. 195.

[95] P. Kaluza, A. Kölzsch, M.T. Gastner and B. Blasius, "The complex network of global cargo ship movements" (2010) 7 *Journal of the Royal Society Interface,* 1093-1103 first published online 19 January 2010. Available at http://rsif.royalsocietypublishing.org/content/7/48/1093.full.pdf+html

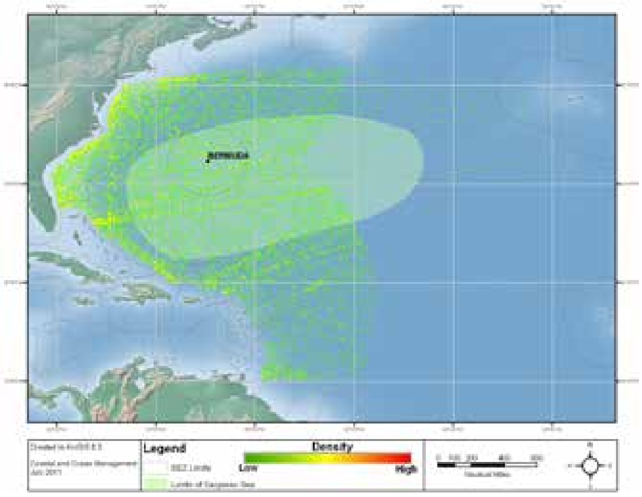


FIGURE 4.8A. Monthly LRIT heat map plot –October 2009 (n = 1,351)

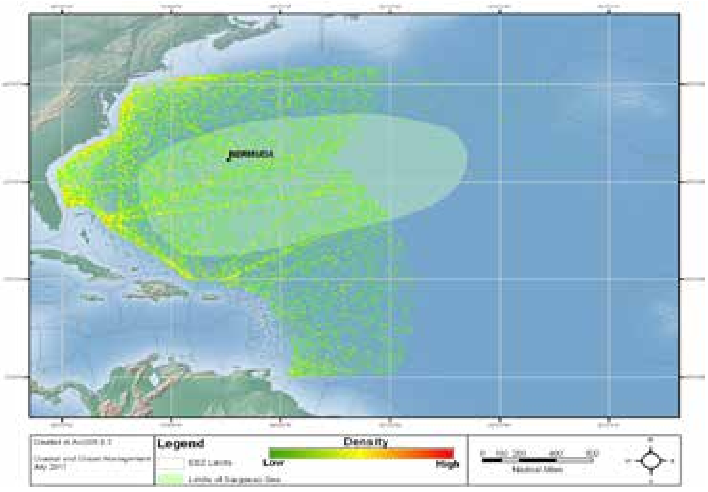


FIGURE 4.8D. Monthly LRIT heat map plot – July 2010 (n = 1,857)

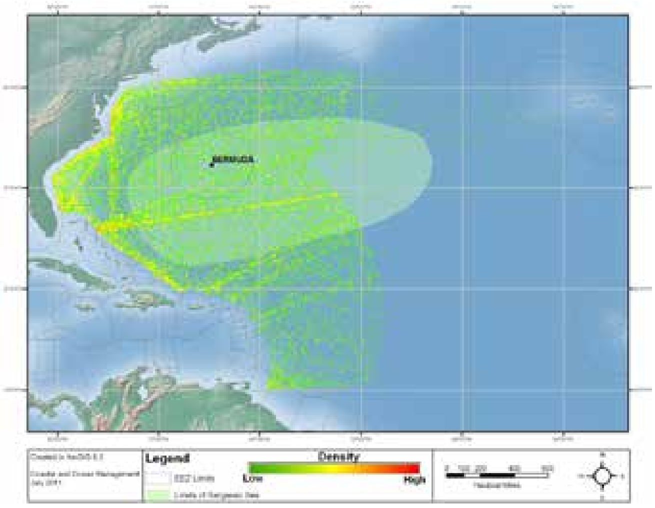


FIGURE 4.8B. Monthly LRIT heat map plot – January 2010 (n = 1,403)

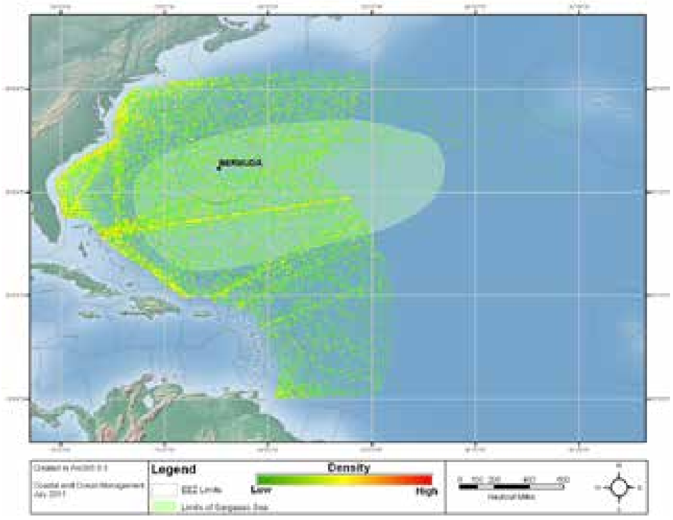


FIGURE 4.8E. Monthly LRIT heat map plot – October 2010 (n = 1,967)

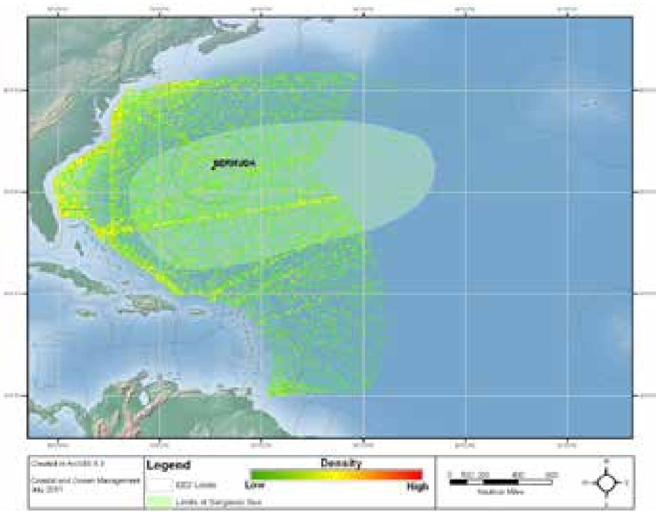


FIGURE 4.8C. Monthly LRIT heat map plot – April 2010 (n = 1,940)

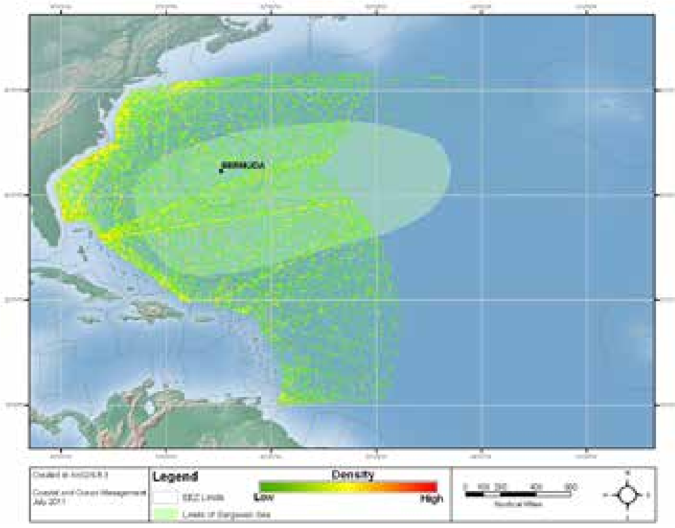


FIGURE 4.8F. Monthly LRIT heat map plot – January 2011 (n = 2,101)

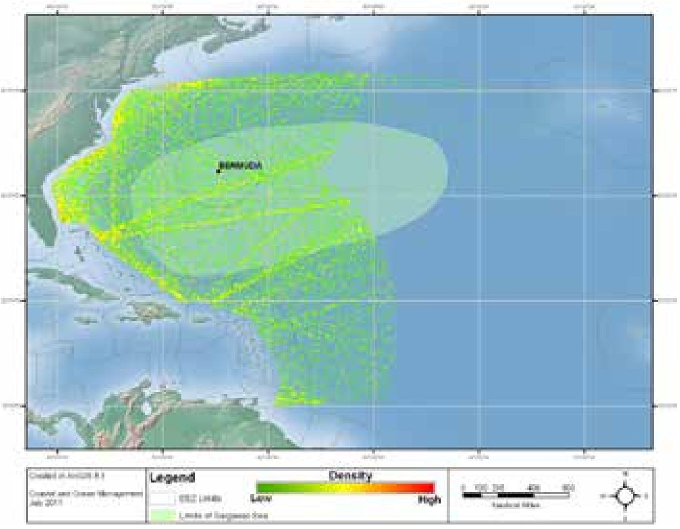


FIGURE 4.8G. **Monthly LRIT heat map plot – April 2011 (n = 2,185)**

FIGURES 4.10A-H show the reported positions of the following types of vessel: Bulk Carriers; Container Ships; Cruise Ships; Gas Tankers; General Cargo; Liquid Tankers; Refrigerated Vessels and RoRo Cargo. These results tend to agree with the observations made by Kaluza et al., and also bear out the reporting bias for different ship types observed by Wang et al.,[96] In particular, the data for tankers appears to be significantly unrepresented.

A similar analysis by Endresen et al.,[97] also shows a similar pattern at least for bulk carriers and containers ships (**FIGURE 4.9**).

The analysis shows that all vessel types are present to some degree in the Sargasso Sea. However, some vessel types are more represented than others and some show much more defined shipping routes. Specific observations for each vessel type are provided below.

[96] note 81.

[97] Ø, Endresen, H.L. Behrens, S. Brynestad, A.B. Andersen and R. Skjong, "Challenges in global ballast water management" (2004) 48 *Marine Pollution Bulletin* p. 617.

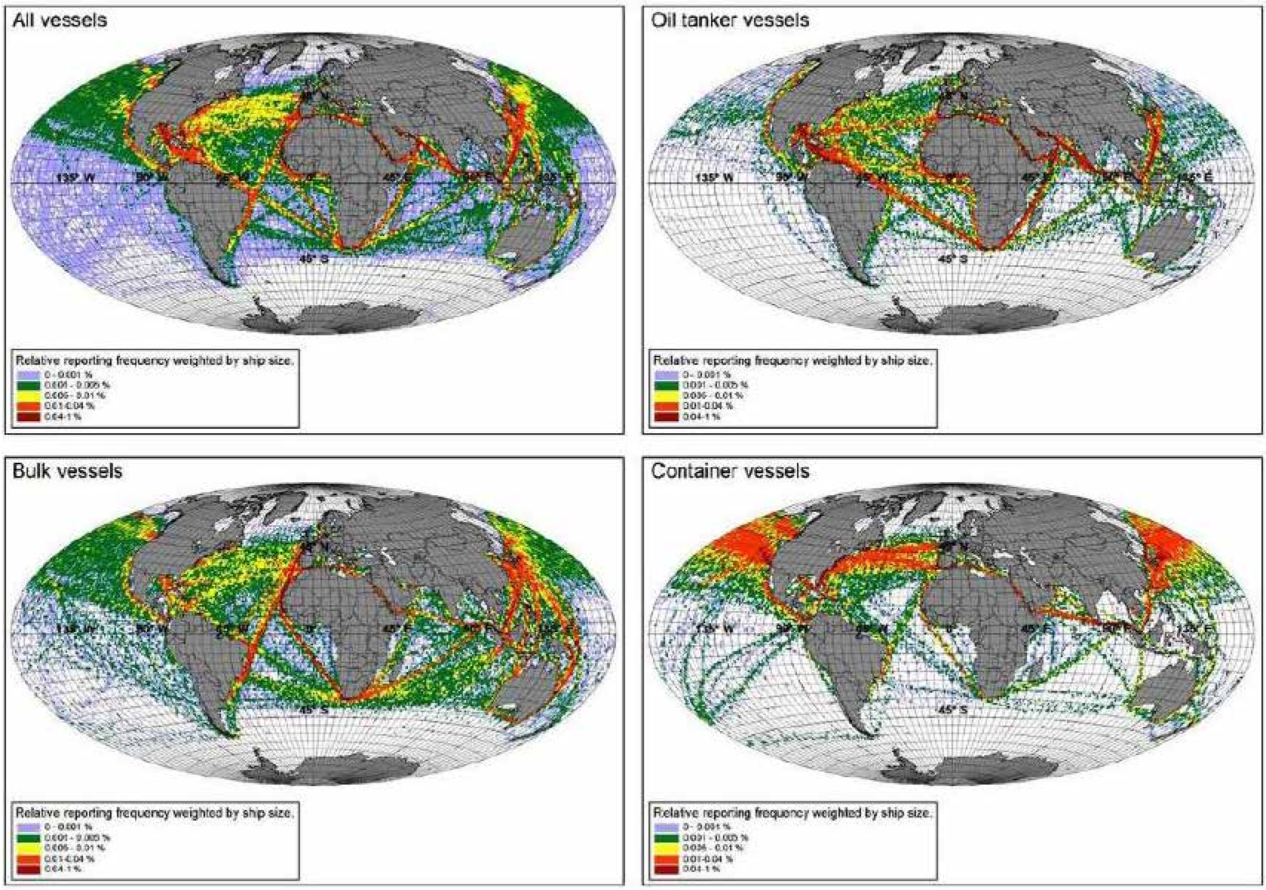


FIGURE 4.9. **Movement of different vessel types (after Endresen et al., 2004)**

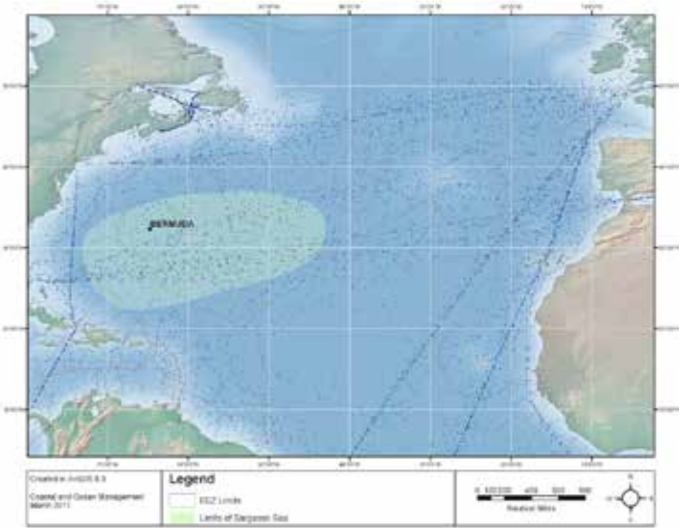


FIGURE 4.10A. Reported positions from bulk carriers in 2010 (n = 400).

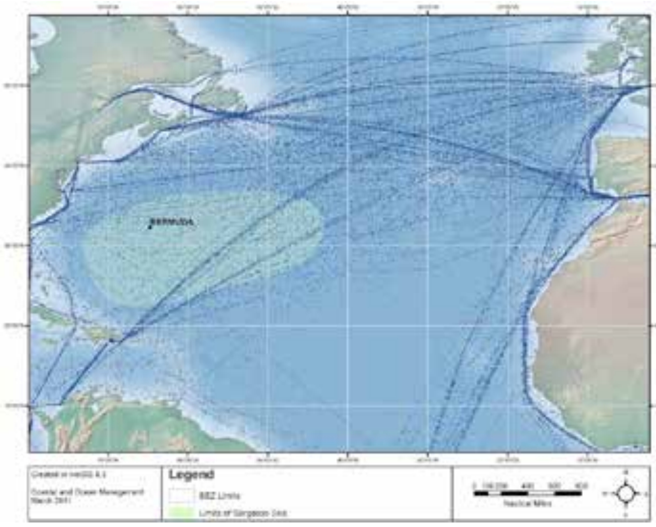


FIGURE 4.10B. Reported positions from container ships in 2010 (n = 1,200).

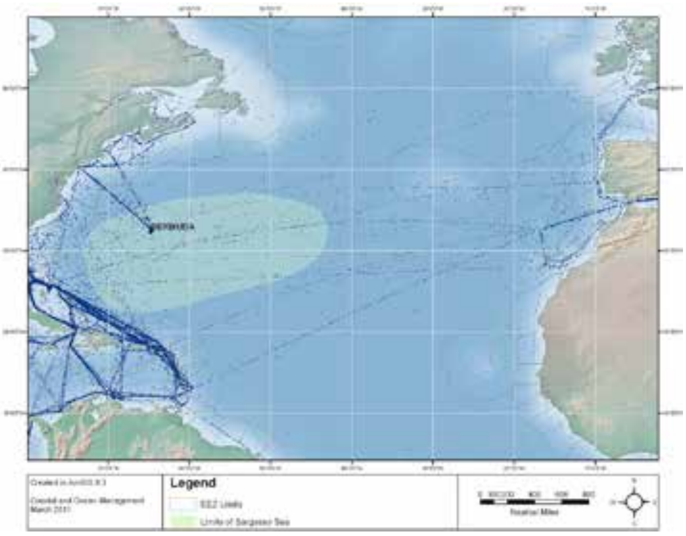


FIGURE 4.10C. Reported positions from cruise ships in 2010 (n = 150).

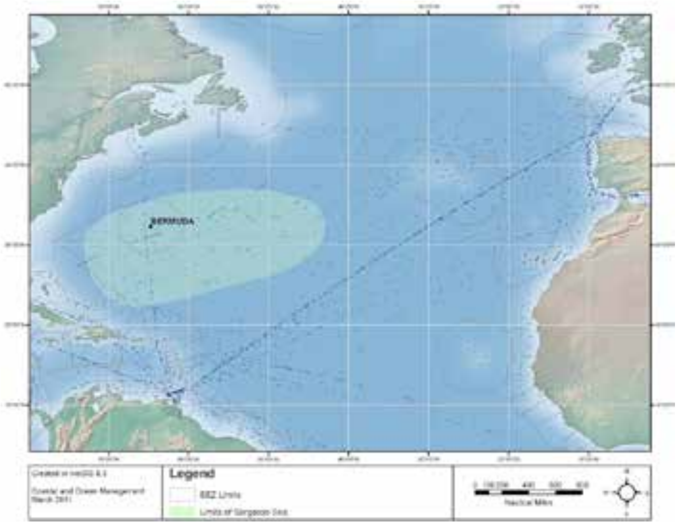


FIGURE 4.10D. Reported positions from gas tankers in 2010 (n = 185).

FIGURE 4.10E. Reported positions from general cargo vessels in 2010 (n = 333).

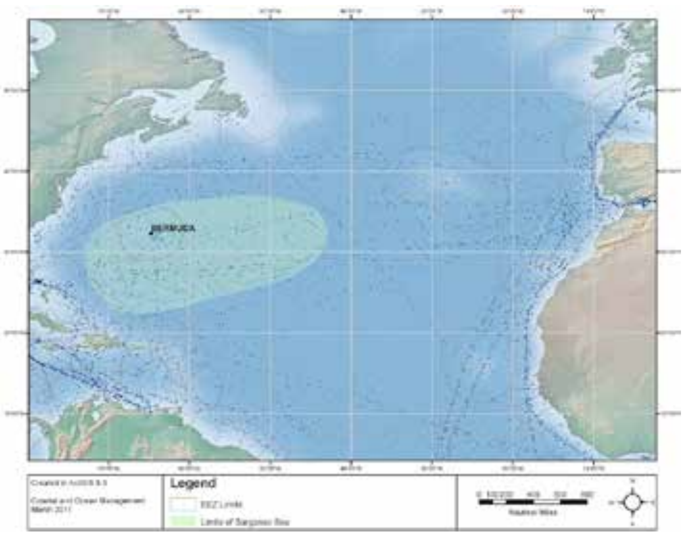


FIGURE 4.10F. Reported positions from liquid tankers in 2010 (n = 405).

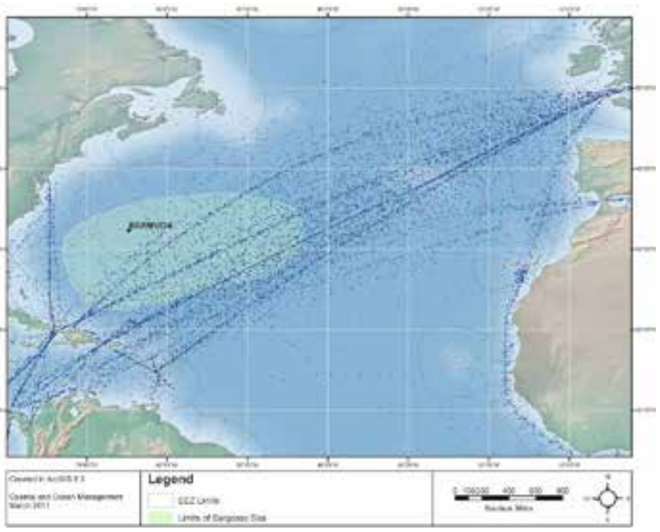


FIGURE 4.10G. **Reported positions from refrigerated cargo carriers in 2010 (n = 60).**

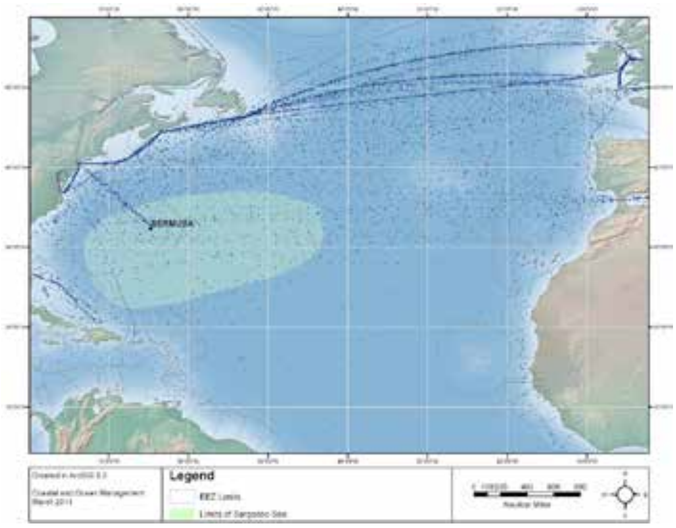


FIGURE 4.10H. **Reported positions from Ro-Ro cargo vessels in 2010 (n = 200).**

Bulk Carriers

TABLE 10 shows that bulk carriers are the third largest vessel class represented in the data set. The most discernible routes run from the east coasts of both South America and the USA to the English Channel. Some traffic from the Gulf of Mexico appears to fan out through the Sargasso Sea and bulk carriers are clearly present throughout the Sargasso Sea.

Container Ships

Container ships are by far the most significant type of vessel in the data set. It is clear from **FIGURE 4.10B** that they follow a number of well defined routes including several that transit the Sargasso Sea on approach to the Caribbean. There is significant container ship traffic between Europe and North America making the North Atlantic one of the busiest container traffic areas.

Cruise Ships

Cruise ship traffic is not well represented in the data set. However, two areas of high intensity are clearly visible, namely the eastern fringe of the Caribbean to Florida and from Bermuda to the US mainland. Some trans-Atlantic traffic is clearly visible within the Sargasso Sea but not in high numbers.

Gas Tankers

Gas tanker routes are well defined and limited to one or two key routes. However, this vessel type is not well represented in the data set and the presence of gas tankers in the Sargasso Sea appears limited.

General Cargo Vessels

Of all the vessel types, general cargo vessels appear to show the least tendency to follow specific routes in the North Atlantic. **FIGURE 4.10E** shows that this type of vessel is widely distributed through the Sargasso Sea and wider Atlantic in quite large numbers.

Liquid Tankers

As noted in the discussion above, the VOS data underestimates tanker traffic as this type of vessel is not well represented in the reporting fleet. This fact is apparent in the result of the analysis (**FIGURE 4.10F**), which does not show large densities of vessel although they are the third largest vessel type data subset in the analysis. However, the data that is available tends to show clearly defined routes including through the Sargasso Sea.

In order to improve the understanding of tanker movements across the North Atlantic, data from the International Tanker Operators Pollution Federation (ITOPF) was also analysed and compared with the VOS data. The ITOPF data is somewhat old (the annual data set is from 2005) and does not represent actual vessels routes. Instead the data digitised data on tanker voyages using a set of defined waypoints. Traffic density and the amount of oil transported along these specific routes was then calculated.[98]

For the purposes of this analysis, the ITOPF data for the North Atlantic was extracted and digitised. Thus, this data can be compared with the actual reported data for tankers (**FIGURE 4.11**) .

It is clear that, while considerable amount of tanker traffic does transit the North Atlantic and the Sargasso Sea, this region is not one of the highest density areas for crude traffic. Further, given the current Port States Control regulations in force both in the EU and the USA the standard of tankers operating in these waters is likely to be very high.

Refrigerated Carriers

Although not well represented in the data set, refrigerated cargo vessels show very well defined routes from the Caribbean to Europe including a number of routes that transit the central and eastern part of the Sargasso Sea.

[98] For a full descriptio of the ITOP analysis see: C. O'Hagan, *Use of GIS for assessing the changing risk of oil spills from tankers*. Availabe online at www.itopf.com/information-services/publications/papers/documents/arctic_shipping.pdf

RoRo Container Ships

RoRo containers are a specific type of vessel and appear to follow very specific routes across the northern part of the Atlantic. Some general traffic is apparent throughout the North Atlantic including transit routes through the Sargasso Sea. However, the main bulk of the traffic follows a very defined northern great circle routes between the UK and Ireland and the east coast of Canada.

It is interesting to note that there appears to be a specific RoRo trade between Bermuda and the east coast of the USA.

4.6: Limitations of the Datasets

As useful as this analysis is, it must be appreciated that both the VOS and LRIT data sets do have certain limitations.

Because the VOS programme is voluntary, much commercial shipping traffic is not captured by these data. Therefore the estimates of shipping movements are biased (in an unknown way) to locations and types of ships engaged in the programme. In particular, high traffic locations may be strongly underestimated and areas identified as without shipping may actually have low levels of ship traffic. However, the relative difference between low and high density traffic areas does appear to be adequately reflected in the grid analysis. Furthermore, because ships report their location

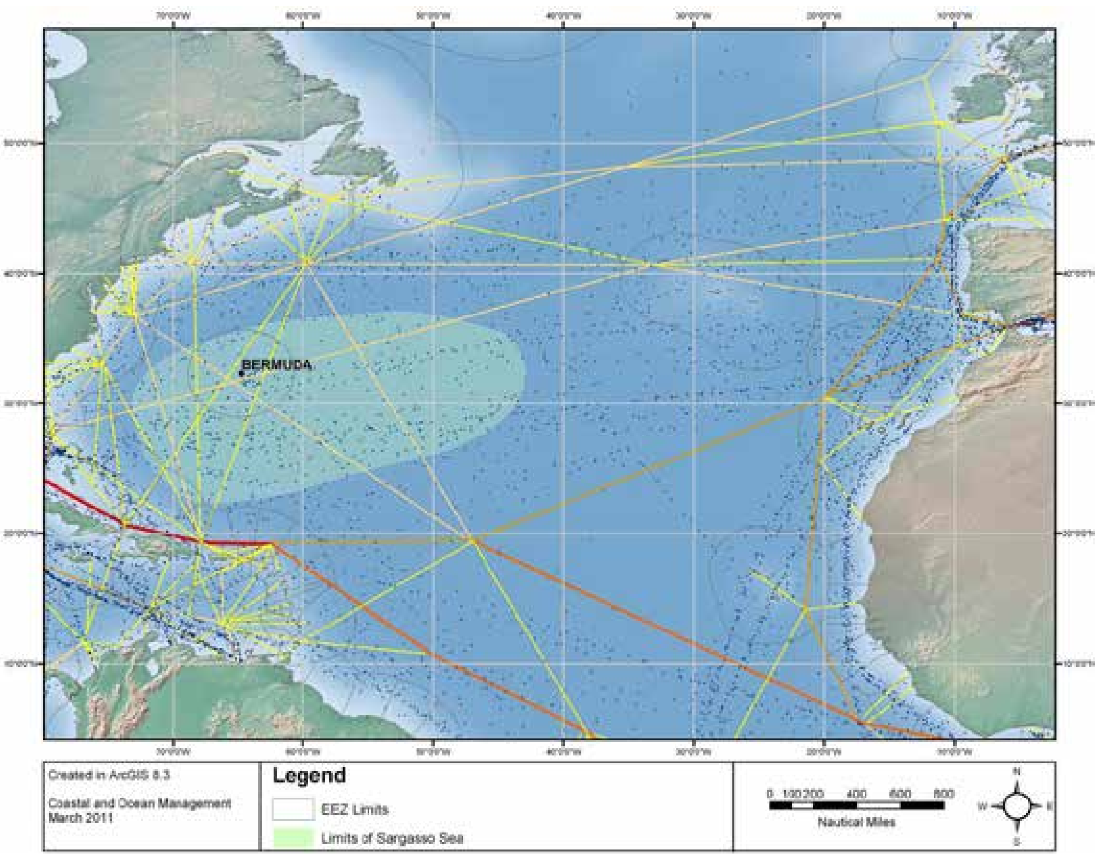


FIGURE 4.11. Comparison of reported data from liquid tankers and crude transport data prepared by ITOPF.

with varying distance between signals, ship tracks are estimates of the actual shipping route taken i.e. it is assumed that ships travel in a straight line between points.

A second limitation in the dataset is the sample size. A peak in total VOS was reached in 1984/85 when about 7,700 ships worldwide were on the WMO VOS Fleet List. Since then there has been an irregular but marked decline and there are currently estimated at only about 4,500 ships worldwide.

The different ship reporting data sets used by different authors appear to oversample specific (and different) types of vessels. AMVER for example over samples bulk carriers, container ships and tankers whereas ICOADS/VOS under samples tankers and general cargo vessels and oversamples container ships and reefer traffic.[99] It is clear from the analysis that the data on tankers is not comprehensive and may present a highly inaccurate picture of tanker traffic in the Sargasso Sea Some form of validation is required, maybe from the Bermuda Maritime Authority.

A large number of the reported positions in the dataset are unclassified. Since these are taken from the VOS reports it is considered that they are vessels rather than floating buoys. However the numbers, while contributing to the overall picture of vessel traffic in the region, cannot be used to analyze specific vessel types, thereby reducing the dataset for this purpose.

Conversely the LRIT dataset captures the vast majority if not all vessels operating in the area. However, due to the operational limit of 1,000 nautical miles for reception of reporting positions, in order to achieve the same geographic coverage it would be necessary to use data received from a number of Data Centers on both sides of the Atlantic. This option will be explored further in the future but at this stage, the LRIT data is more geographically limited.

Another limitation with the LRIT data is that it is not possible, at this stage, to also receive vessel specific data from the USCG. This means that, while the data can be effectively used to provide an overall picture of traffic in the area, it is not possible to undertake the same sort of vessel specific analysis that was undertaken using the VOS data.

[99] Wang et al., (note 83) p. 196.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Bulk Carrier (including gravel ships)	7	12	13	10	13	16	11	4	17	8	8
Cable Ship	27	31	18	6	15	3	5	8	8	1	5
Cement Carrier	7	5	5	6	11	1	3	14	7	11	6
Chemical Tanker	2	1	2	1	0	3	1	3	2	0	1
Container Ship	134	140	143	139	145	134	135	141	139	143	136
Fishing Vessel	0	1	2	1	0	0	1	10	1	1	0
General Cargo	11	7	7	12	15	10	3	5	18	3	4
LPG Tanker	10	9	7	9	6	9	14	8	4	2	3
Military	22	13	3	15	21	9	3	3	3	26	4
Oil Tanker	4	4	5	6	3	1	4	5	18	17	24
Passenger Ship	170	141	142	158	165	162	192	197	138	138	151
Product Tanker	10	15	15	13	16	15	12	11	9	5	7
Refrigerated Cargo	2	1	3	1	2	1	0	5	4	2	1
Research Vessel	65	62	58	68	68	71	50	40	42	33	46
Submarine	23	14	12	4	1	2	2	0	2	2	0
Training Ship	1	5	2	4	3	4	3	6	5	3	2
Tug	4	2	2	2	3	3	0	2	4	2	2
Vehicle Carrier	12	12	12	12	11	13	13	12	13	13	12
Other	4	3	5	4	4	1	6	1	4	2	3
Total	515	478	456	471	502	458	458	475	438	412	415

TABLE 12. Analysis of Ships calling at Bermuda for the Years 2000-2010[1]

[1] Data courtesy of the Bermuda Maritime Operations Centre and Bermuda Maritime Radio, July 2011.

Location Specific Shipping Data

At this stage, the shipping information provided is based purely on ship reported data and information extrapolated from that data. No specific spatial data has been obtained with regard to the nature of vessels travelling close to the coast of Bermuda and it would be useful to further explore whether the Bermudan Maritime Authority has access to either AIS data or LRIT data that could augment the existing data. However, that notwithstanding, quantitative data on vessel movements to and around Bermuda has been provided by the Bermuda Maritime Operations Centre and is presented in **TABLES 12 AND 13**.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Bulk Carrier	63	40	31	96	97	92	79	65	86	70	52
Chemical Tanker	8	4	6	7	7	13	11	19	23	15	9
Container Vessel	41	23	24	51	51	72	66	58	59	30	43
General Cargo Vessel	20	12	18	22	22	26	27	30	46	39	27
Oil Tanker	12	16	17	54	55	48	36	40	33	38	31
Product Tanker	15	13	16	35	35	37	38	22	23	28	19
Sub-Total for above ship categories	159	108	112	265	267	288	257	234	270	220	181
Total Ships in Transit	191	206	123	142	313	355	306	274	312	264	215

TABLE 13. Vessel Traffic Surveillance Data (ships passing within 30 miles of Bermuda) for the Years 2000-2010

5. Vessel Specific Impacts

Although it is a reasonable assumption that areas with more shipping traffic are more at risk from the impacts of those vessels, not all vessel types pose the same level of threat. In the context of the impacts discussed in section 2 above, different vessel types will give rise to different impacts. In order to fully appreciate the threat posed by international shipping to the Sargasso Sea it is useful to consider the specific threat each type of different may present. The simple matrix included in Appendix B illustrates the degree to which each vessel type analysed might give rise to the different impacts discussed in section 2 above.

A critical element of any PSSA proposal is an analysis to demonstrate the specific environmental values that are at threat from shipping and what that threat is. As such, having defined the environmental attributes of the Sargasso Sea (undertaken separately from this study) there is a need to combine the scientific/environmental data with the impact and traffic routeing data contained within this report to establish the specific areas of vulnerability that need to be addressed through IMO legal measures.

One way to do this will be in the form of a matrix combining the shipping data and the environmental data. It would be best if this were an iterative Delphic process involving a range of experts working on this project.

6. Conclusions

Spatial analysis of vessel movements throughout the North Atlantic clearly shows that the routes passing through the Sargasso Sea, from the Gulf of Mexico/ Caribbean to Western Europe and the Mediterranean, are the most heavily trafficked routes in the region. Traffic densities do not appear to show significant seasonal variations and numbers of vessels appear relatively stable. Hence, this continuous presence of vessels in the Sargasso Sea has the potential to give rise to a number of environmental effects.

Shipping may give rise to a broad range of impacts, depending on the particular environmental values present. In the case of the Sargasso Sea, concern should focus around the risks posed by the discharge of untreated sewage, the possible impacts of invasive species carried and discharged in ballast water and the additional contribution of garbage from shipping in the area. That is not to say that other impacts are unlikely and some additional work should be undertaken in respect of the impacts of the physical impacts of shipping on marine flora, most notably noise and ship-strikes.

A range of options are available through the IMO to address many of the risks identified. Customising the protective measures to the threats identified will ensure that the measures address the risks actually posed to the Sargasso Sea. Moreover, such an approach can be justified both to the shipping industry and to maritime states with an interest in this area.

Appendix A

IMO GUIDELINES FOR THE DESIGNATION OF SPECIAL AREAS UNDER MARPOL 73/78

1 Introduction

1.1 The purpose of these Guidelines is to provide guidance to Contracting Parties to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) in the formulation and submission of applications for the designation of Special Areas under Annexes I, II, and V to the Convention. These Guidelines also ensure that all interests - those of the coastal State, flag State, and the environmental and shipping communities–are thoroughly considered on the basis of relevant scientific, technical, economic, and environmental information and provide for the assessment of such applications by IMO. Contracting Parties should also review and comply with the applicable provisions of Annexes I, II, and V to the Convention in addition to these Guidelines.

2 Environmental Protection for Special Areas Under Marpol 73/78

General

2.1 MARPOL 73/78, in Annexes I, II and V, defines certain sea areas as Special Areas in relation to the type of pollution covered by each Annex. A Special Area is defined as "a sea area where for recognised technical reasons in relation to its oceanographical and ecological conditions and to the particular character of its traffic, the adoption of special mandatory methods for the prevention of sea pollution by oil, noxious liquid substances, or garbage, as applicable, is required." Under the Convention, these Special Areas are provided with a higher level of protection than other areas of the sea.

2.2 A Special Area may encompass the maritime zones of several States, or even an entire enclosed or semi-enclosed area. Special Area designation should be made on the basis of the criteria and characteristics listed in paragraphs 2.3 to 2.6 to avoid the proliferation of such areas.

Criteria for the designation of a Special Area

2.3 The criteria which must be satisfied for an area to be given Special Area status are grouped into the following categories:

- oceanographic conditions;
- ecological conditions; and
- vessel traffic characteristics.

Generally, information on each category should be provided in a proposal for designation. Additional information that does not fall within these categories may also be considered.

Oceanographic conditions

2.4 The area possesses oceanographic conditions which may cause the concentration or retention of harmful substances in the waters or sediments of the area, including:

1. particular circulation patterns (e.g. convergence zones and gyres) or temperature and salinity stratification;
2. long residence time caused by low flushing rates;
3. extreme ice state; and
4. adverse wind conditions.

Ecological conditions

2.5 Conditions indicating that protection of the area from harmful substances is needed to preserve:

1. depleted, threatened or endangered marine species;
2. areas of high natural productivity (such as fronts, upwelling areas, gyres);
3. spawning, breeding and nursery areas for important marine species and areas representing migratory routes for sea-birds and marine mammals;
4. rare or fragile ecosystems such as coral reefs, mangroves, seagrass beds and wetlands; and
5. critical habitats for marine resources including fish stocks and/or areas of critical importance for the support of large marine ecosystems.

Vessel traffic characteristics

2.6 The sea area is used by ships to an extent that the discharge of harmful substances by ships when operating in accordance with the requirements of MARPOL 73/78 for areas other than Special Areas would be unacceptable in the light of the existing oceanographic and ecological conditions in the area.

Implementation

2.7 The requirements of a Special Area designation can only become effective when adequate reception facilities are provided for ships in accordance with the provisions of MARPOL 73/78.

Other considerations

2.8 The threat to amenities posed by the discharge of harmful substances from ships operating in accordance with the MARPOL 73/78 requirements for areas other than Special Areas may strengthen the argument for designating an area a Special Area.

2.9 The extent to which the condition of a sea area is influenced by other sources of pollution such as pollution from land-based sources, dumping of wastes and dredged materials, as well as atmospheric deposition should be taken into account. Proposals would be strengthened if measures are being, or will be, taken to prevent, reduce and control pollution of the marine environment by these sources of pollution.

2.10 Consideration should be given to the extent to which a management regime is used in managing the area. Proposals for designation of a Special Area would be strengthened if measures are being taken to manage the area's resources.

3 Procedures for the Designation of a Special Area

3.1 A proposal to designate a given sea area as a Special Area should be submitted to the Marine Environment Protection Committee (MEPC) for its consideration in accordance with the rules adopted by the IMO for submission of papers.

3.2 A proposal to designate a sea area as a Special Area should contain:

1. a draft amendment to MARPOL 73/78 as the formal basis for the designation; and

2. a background document setting forth all the relevant information to explain the need for the designation.

3.3 The background document should contain the following information:

1. 1 a definition of the area proposed for designation, including its precise geographical co-ordinates. A reference chart is essential.

2. an indication of the type of Special Area proposed. Proposals may be made simultaneously with respect to Annexes I, II and V of MARPOL 73/78, but proposals for each Annex should be presented and evaluated separately.

3. a general description of the area, including information regarding:

- oceanography
- ecological characteristics
- social and economic value
- scientific and cultural significance
- environmental pressures from ship-generated pollution
- other environmental pressures
- measures already taken to protect the area.

This general description may be supported by annexes containing more detailed material, or by references to readily available documentation.

4. an analysis of how the sea area in question fulfils the criteria for the designation of Special Areas set out in paragraphs 2.3 to 2.6.

5. information on the availability of adequate reception facilities in the proposed Special Area.

3.4 The formal amendment procedure applicable to proposals for the designation of Special Areas is set out in article 16 of MARPOL 73/78.

Detailed discharge requirements

3.5 For detailed requirements relating to discharges under Annexes I, II and V to MARPOL 73/78, please refer to the latest version of the Convention in force.

Appendix B: Vessel Impact Matrix

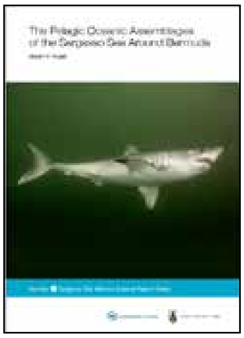
	VESSEL TYPE							
	BULK CARRIER	CONTAINER SHIP	CRUISE SHIP	GAS TANKER	GENERAL CARGO	LIQUID TANKER	REFRIGERATED CARIER	RoRo CARGO
OIL	• Depends on compliance with MARPOL but cargo vessels responsible for much of oil input to sea	• Depends on compliance with MARPOL but cargo vessels responsible for much of oil input to sea	• Likely to be low due to public profile and visibility to passengers	• Depends on compliance with MARPOL but cargo vessels responsible for much of oil input to sea	• Depends on compliance with MARPOL but cargo vessels responsible for much of oil input to sea	• Responsible for small amount of total operational oil discharges (GESAMP)	• Depends on compliance with MARPOL but cargo vessels responsible for much of oil input to sea	• Depends on compliance with MARPOL but cargo vessels responsible for much of oil input to sea
HNS	• Not carried	• Not carried or carried in low volumes as packaged goods	• Not carried	• Should be no operational HNS spills	• Not carried or carried in low volumes as packaged goods	• Cargo residues may be discharged	• Not carried	• Not carried
INVASIVE SPECIES	• More likely to be in ballast at some stage. • Responsible for 39% of all BW transported annually • Hull fouling risk may be higher depending on speed of vessel and maintenance history. • Also tend to travel between widely different regions	• Less likely to have a lot of ballast exchange. • Ballast mainly used for trimming • Hull fouling risk may be lower due to relatively high speed but tend to visit large number of ports	• Less likely to have a lot of ballast exchange • Ballast mainly used for trimming • Hull fouling risk may be lower due to relatively high speed but tend to visit large number of ports	• Less likely to have a lot of ballast exchange. • Ballast mainly used for trimming Ballast mainly used for trimming • Hull fouling risk may be lower due to relatively high speed • Vessel destinations limited	• Moderate ballast exchange. • Hull fouling risk may be higher depending on speed of vessel and maintenance history. • Also tend to travel between widely different regions	• More likely to be in ballast at some stage. • Responsible for 37% of all BW transported annually • Hull fouling risk may be higher depending on speed of vessel and maintenance history. • Also tend to travel between widely different regions	• Less likely to have a lot of ballast exchange. • Ballast mainly used for trimming • Hull fouling risk may be higher depending on speed of vessel and maintenance history. • Also tend to travel between widely different regions	• Less likely to have a lot of ballast exchange. • Ballast mainly used for trimming
ANTI-FOULING	• All vessel types will have antifouling. • Depends on age of antifouling and integrity of	• All vessel types will have antifouling. • Depends on age of antifouling and integrity of	• All vessel types will have antifouling. • Depends on age of antifouling and integrity of	• All vessel types will have antifouling. • Depends on age of antifouling and integrity of	• All vessel types will have antifouling. • Depends on age of antifouling and integrity of	• All vessel types will have antifouling. • Depends on age of antifouling and integrity of	• All vessel types will have antifouling. • Depends on age of antifouling and integrity of	• All vessel types will have antifouling. • Depends on age of antifouling and integrity of
SEWAGE	• Generate low volumes due to low number of personnel 10-30 • May be more likely to have poorly operated equipment	• Generate low volumes due to low number of personnel 10-30 • May be more likely to have poorly operated equipment	• Generate large volumes due to high occupancy • Likely to have well operated equipment and may contain all on board	• Generate low volumes due to low number of personnel 10-30 • May be more likely to have poorly operated equipment	• Generate low volumes due to low number of personnel 10-30 • May be more likely to have poorly operated equipment	• Generate low volumes due to low number of personnel 10-30 • May be more likely to have poorly operated equipment	• Generate low volumes due to low number of personnel 10-30 • May be more likely to have poorly operated equipment	• Generate low volumes due to low number of personnel 10-30 • May be more likely to have poorly operated equipment

VESSEL TYPE								
	BULK CARRIER	CONTAINER SHIP	CRUISE SHIP	GAS TANKER	GENERAL CARGO	LIQUID TANKER	REFRIGERATED CARIER	RoRo CARGO
MARINE DEBRIS	• Generate low volumes due to low number of personnel 10-30 • May have more cargo related waste	• Generate low volumes due to low number of personnel 10-30	• Generate large volumes due to high occupancy • Likely to have well operated equipment and may contain all on board	• Generate low volumes due to low number of personnel 10-30	• Generate low volumes due to low number of personnel 10-30 • May have more cargo related waste	• Generate low volumes due to low number of personnel 10-30	• Generate low volumes due to low number of personnel 10-30	• Generate low volumes due to low number of personnel 10-30
AIR EMISSIONS	• Will depend on fuel quality, size and speed of vessel. • Likely to be high due to scheduling • Large umber of vessels	• Will depend on fuel quality, size and speed of vessel. • Likely to be high due to scheduling • Large number of vessels	• Likely to use better quality oil • Have more fuel burning ancillary equipment	• Will depend on fuel quality, size and speed of vessel. • Low number of vessels	• Will depend on fuel quality, size and speed of vessel. • Likely to be high due to scheduling • Large number of vessels	• Will depend on fuel quality, size and speed of vessel. • Likely to be high due to scheduling • VOC emissions from cargo venting high	• Will depend on fuel quality, size and speed of vessel. • Low number of vessels	• Will depend on fuel quality, size and speed of vessel. • Low number of vessels
OIL SPILLS	• Fuel oil only. Volumes 1,000-7,000 T. range • Typical fuel oil is highly persistent in the marine environment	• Fuel oil only. Volumes 1,000-7,000 T. range • Typical fuel oil is highly persistent in the marine environment Fuel oil only. Volumes 1,000-7,000 T. range	• Fuel oil only. Volumes 1,000-7,000 T. range • Typical fuel oil is highly persistent in the marine environment Fuel oil only. Volumes 1,000-7,000 T. range	• Fuel oil only. Volumes 1,000-7,000 T. range • Typical fuel oil is highly persistent in the marine environment Fuel oil only. Volumes 1,000-7,000 T. range	• Fuel oil only. Volumes 1,000-7,000 T. range • Typical fuel oil is highly persistent in the marine environment Fuel oil only. Volumes 1,000-7,000 T. range	• Carried in bulk. Risk of spills	• Fuel oil only. Volumes 1,000-7,000 T. range • Typical fuel oil is highly persistent in the marine environment Fuel oil only. Volumes 1,000-7,000 T. range	• Fuel oil only. Volumes 1,000-7,000 T. range • Typical fuel oil is highly persistent in the marine environment Fuel oil only. Volumes 1,000-7,000 T. range
HNS SPILLS	• Not carried	• Not carried or carried in low volumes as packaged goods	• Not carried	• Unclassified as a LNG spill will be a safety /fire hazard rather than a marine environmental hazard	• Not carried or carried in low volumes as packaged goods	• Carried in bulk. Risk of spills	• Not carried	• Not carried
UNDERWATER NOISE	• Related to engine and propeller noise • Largest vessel types and high speed	• Related to engine and propeller noise • Present in greatest numbers.	• Related to engine and propeller noise	• Related to engine and propeller noise	• Related to engine and propeller noise • Largest vessel types and high speed • Widely distributed	• Related to engine and propeller noise • Large vessels with large engines • Large number of vessels	• Related to engine and propeller noise • Low number of vessels	• Related to engine and propeller noise • Low number of vessels

	VESSEL TYPE							
	BULK CARRIER	CONTAINER SHIP	CRUISE SHIP	GAS TANKER	GENERAL CARGO	LIQUID TANKER	REFRIGERATED CARIER	RORO CARGO
SHIP STRIKES	• General risk present	• Present in greatest numbers. • Largest vessel types and high speed	• General risk present	• General risk present	• Present in large numbers	• General risk present	• General risk present	• General risk present
PHYSICAL DAMAGE	• Depends on compliance with routeing measures and navigation control • Anchor damage may be an issue as Bulk Carriers tend to wait offshore for cargo berths	• Depends on compliance with routeing measures and navigation control • Anchor damage likely to be less than for bulk carrier due to tight scheduling	• Operate in coastal areas where grounding may be an issue. • Anchor damage likely to be high due to number of port stops	• Depends on compliance with routeing measures and navigation control	• Depends on compliance with routeing measures and navigation control	• Depends on compliance with routeing measures and navigation control • Tankers tend to follow routeing better than other types of vessels	• Depends on compliance with routeing measures and navigation control	• Depends on compliance with routeing measures and navigation control

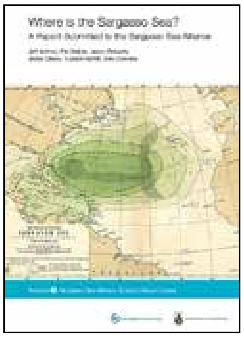
Sargasso Sea Alliance Science Series

The following is a list of the reports in the Sargasso Sea Alliance Science Series. All can be downloaded from www.sargassoalliance.org:



1

Angel, M.V. 2011. *The pelagic ocean assemblages of the Sargasso Sea around Bermuda.* Sargasso Sea Alliance Science Report Series, No 1, 25 pp.

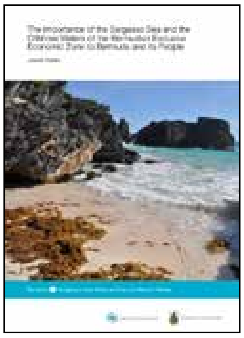


2

Ardron, J., Halpin, P., Roberts, J., Cleary, J., Moffitt, M. and J. Donnelly 2011. *Where is the Sargasso Sea?* Sargasso Sea Alliance Science Report Series, No 2, 24 pp.

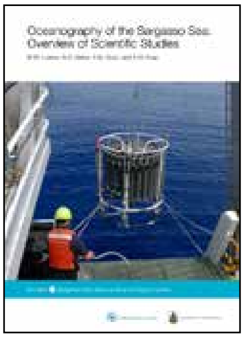
3

Gollock, M. 2011. *European eel briefing note for Sargasso Sea Alliance.* Sargasso Sea Alliance Science Report Series, No 3, 11 pp.



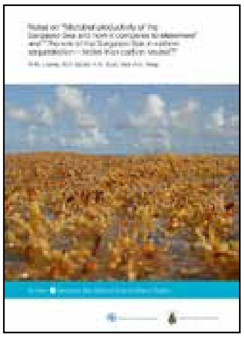
4

Hallett, J. 2011. *The importance of the Sargasso Sea and the offshore waters of the Bermudian Exclusive Economic Zone to Bermuda and its people. Sargasso Sea Alliance* Science Report Series, No 4, 18 pp.



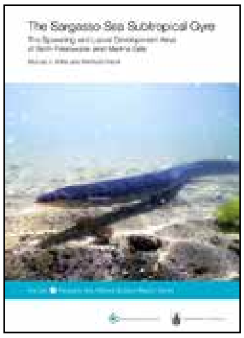
5

Lomas, M.W., Bates, N.R., Buck, K.N. and A.H. Knap. (eds) 2011a. *Oceanography of the Sargasso Sea: Overview of Scientific Studies.* Sargasso Sea Alliance Science Report Series, No 5, 64 pp.



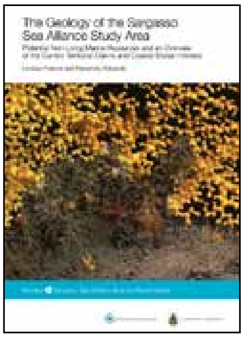
6

Lomas, M.W., Bates, N.R., Buck, K.N. and A.H. Knap. 2011b. *Notes on "Microbial productivity of the Sargasso Sea and how it compares to elsewhere" and "The role of the Sargasso Sea in carbon sequestration—better than carbon neutral?"* Sargasso Sea Alliance Science Report Series, No 6, 10 pp.



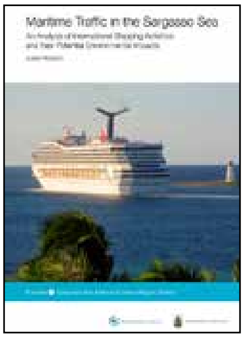
7

Miller, M.J. and R. Hanel. 2011. *The Sargasso Sea subtropical gyre: the spawning and larval development area of both freshwater and marine eels.* Sargasso Sea Alliance Science Report Series, No 7, 20 pp.



8

Parson, L. and R. Edwards 2011. *The geology of the Sargasso Sea Alliance Study Area, potential non-living marine resources and an overview of the current territorial claims and coastal states interests.* Sargasso Sea Alliance Science Report Series, No 8, 17 pp.

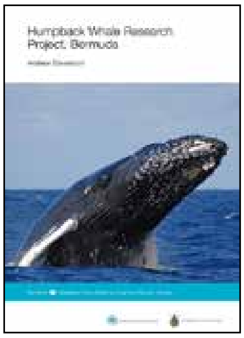


9

Roberts, J. 2011. *Maritime Traffic in the Sargasso Sea: An Analysis of International Shipping Activities and their Potential Environmental Impacts.* Sargasso Sea

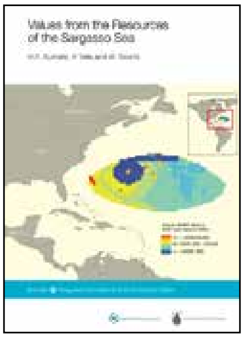
10

Siuda, A.N.S. 2011. *Summary of Sea Education Association long-term Sargasso Sea surface net data.* Sargasso Sea Alliance Science Report Series, No 10, 18 pp.



11

Stevenson, A. 2011. *Humpback Whale Research Project, Bermuda.* Sargasso Sea Alliance Science Report Series, No 11, 11 pp.



12

Sumaila, U. R., Vats, V., and W. Swartz. 2013. *Values from the resources of the Sargasso Sea.* Sargasso Sea Alliance Science Report Series, No 12, 24 pp.

SARGASSO SEA ALLIANCE

Since the initial meetings the partnership around the Sargasso Sea Alliance has expanded. Led by the Government of Bermuda, the Alliance now includes the following organisations.

PARTNER	TYPE OF ORGANISATION
Department of Environmental Protection	Government of Bermuda
Department of Conservation Services	Government of Bermuda
Mission Blue / Sylvia Earle Alliance	Non-Governmental Organisation
International Union for the Conservation of Nature (IUCN) and its World Commission on Protected Areas	Multi-lateral Conservation Organisation
Marine Conservation Institute	Non-Governmental Organisation
Woods Hole Oceanographic Institution	Academic
Bermuda Institute for Ocean Sciences	Academic
Bermuda Underwater Exploration Institute	Non-Governmental Organisation
World Wildlife Fund International	Non-Governmental Organisation
Atlantic Conservation Partnership	Non-Governmental Organisation