

# Submission of Scientific Information to Describe Ecologically or Biologically Significant Marine Areas

## Name of Area

The Sargasso Sea

## Presented by

**The Sargasso Sea Alliance; edited by Howard S. J. Roe<sup>27</sup>**

**Based upon “The Protection and Management of the Sargasso Sea” (in draft) by**

Laffoley, D.d’A.<sup>1</sup>, Roe, H.S.J.<sup>2</sup>, Angel, M.V.<sup>2</sup>, Ardron, J.<sup>3</sup>, Bates, N.R.<sup>4</sup>, Boyd, I.L.<sup>25</sup>, Brooke, S.<sup>3</sup>, Buck, K.N.<sup>4</sup>, Carlson, C.A.<sup>5</sup>, Causey, B.<sup>6</sup>, Conte, M.H.<sup>4</sup>, Christiansen, S.<sup>7</sup>, Cleary, J.<sup>8</sup>, Donnelly, J.<sup>8</sup>, Earle, S.A.<sup>9</sup>, Edwards, R.<sup>10</sup>, Gjerde, K.M.<sup>1</sup>, Giovannoni, S.J.<sup>11</sup>, Gulick, S.<sup>3</sup>, Gollock, M.<sup>12</sup>, Hallett, J.<sup>13</sup>, Halpin, P.<sup>8</sup>, Hanel, R.<sup>14</sup>, Hemphill, A.<sup>15</sup>, Johnson, R.J.<sup>4</sup>, Knap, A.H.<sup>4</sup>, Lomas, M.W.<sup>4</sup>, McKenna, S.A.<sup>9</sup>, Miller, M.J.<sup>16</sup>, Miller, P.I.<sup>17</sup>, Ming, F.W.<sup>18</sup>, Moffitt, R.<sup>8</sup>, Nelson, N.B.<sup>5</sup>, Parson, L.<sup>10</sup>, Peters, A.J.<sup>4</sup>, Pitt, J.<sup>18</sup>, Rouja, P.<sup>19</sup>, Roberts, J.<sup>8</sup>, Roberts, J.<sup>20</sup>, Seigel, D.A.<sup>5</sup>, Siuda, A.N.S.<sup>21</sup>, Steinberg, D.K.<sup>22</sup>, Stevenson, A.<sup>23</sup>, Sumaila, V.R.<sup>24</sup>, Swartz, W.<sup>24</sup>, Thorrold, S.<sup>26</sup>, Trott, T.M.<sup>18</sup>, and V. Vats<sup>1</sup> 2011.

<sup>1</sup> International Union for Conservation of Nature, Switzerland.

<sup>2</sup> National Oceanography Centre, UK.

<sup>3</sup> Marine Conservation Institute, USA.

<sup>4</sup> Bermuda Institute of Ocean Sciences (BIOS), Bermuda.

<sup>5</sup> University of California, USA.

<sup>6</sup> NOAA Southeast Office of National Marine Sanctuaries, USA.

<sup>7</sup> Independent Consultant, Germany.

<sup>8</sup> Duke University Marine Geospatial Ecology Lab, USA.

<sup>9</sup> Sylvia Earle Alliance, USA.

<sup>10</sup> Maritime Zone Solutions Ltd, UK.

<sup>11</sup> Oregon State University, USA.

<sup>12</sup> Zoological Society of London, UK.

<sup>13</sup> University of York, UK.

<sup>14</sup> Institute of Fisheries and Ecology, Germany.

<sup>15</sup> Independent Consultant, USA.

<sup>16</sup> University of Tokyo, Japan.

<sup>17</sup> Plymouth Marine Laboratory, UK.

<sup>18</sup> Department of Environmental Protection, Bermuda.

<sup>19</sup> Department of Conservation Services, Bermuda.

<sup>20</sup> Independent Consultant, UK.

<sup>21</sup> Sea Education Association, USA.

<sup>22</sup> Virginia Institute of Marine Science, USA.

<sup>23</sup> Humpback Whale Research Project, Bermuda.

<sup>24</sup> University of British Columbia, Fisheries Centre, Canada.

<sup>25</sup> Sea Mammals Research Unit, UK.

<sup>26</sup> Woods Hole Oceanographic Institution, USA.

<sup>27</sup> Sargasso Sea Alliance

Contact Dr David Freestone (Executive Director) at [dfreestone@sargassoalliance.org](mailto:dfreestone@sargassoalliance.org) or  
Kate K. Morrison, (Programme Officer) at [kmorrison@sargassoalliance.org](mailto:kmorrison@sargassoalliance.org)

## Abstract

The Sargasso Sea is a fundamentally important part of the world's ocean, located within the North Atlantic sub-tropical gyre with its boundaries defined by the surrounding currents. It is the only sea without land boundaries with water depths ranging from the surface coral reefs of Bermuda to abyssal plains at 4500m. The Sargasso Sea's importance derives from the interdependent mix of its physical structure and properties, its ecosystems, and its role in global scale ocean and earth system processes. It is a place of legend with an iconic pelagic ecosystem based upon floating *Sargassum*, the world's only holopelagic algae, which hosts a rich and diverse community including ten endemic species, and provides essential habitat for a wide diversity of species, many of which are endangered or threatened. It is the only breeding location for the threatened European and American eels and is on the migration route of numerous other iconic and endangered species. It lies within a large ocean gyre which concentrates marine debris and pollutants and which has a variety of oceanographic processes that impact its productivity and species diversity, and it plays a disproportionately large role in global ocean processes of oxygen production and carbon sequestration. The sea floor has several seamounts, each home to specialized, fragile and endemic communities. Both pelagic and benthic ecosystems are impacted by a range of human activities. The Sargasso Sea meets all of the CBD EBSA criteria.

## Introduction

The features proposed here for international recognition are the pelagic communities dependant upon the holopelagic algae *Sargassum* spp, the pelagic species that migrate into or through the area and the specialized benthic communities that live on the seamounts. Together these communities and species occupy the Sargasso Sea from the surface to the sea-floor.

## Description of the Area

### Oceanography

The Sargasso Sea is one of the best known areas of the world's ocean. Research began here with the voyage of HMS Challenger in the 1870s and has continued ever since, with pivotal discoveries such as the first *in situ* observations of deep sea animals by Beebe and Barton in 1932, the discovery of deep ocean eddies (the weather of the sea) by Swallow (1971), and the discovery of the tiny chlorophyll-containing bacteria *Prochlorococcus* which is the most abundant photosynthetic organism on earth and accounts for an estimated 20% of oxygen in the atmosphere (Chisholm, Olson, Zettler, Waterbury, Goericke and Welschmeyer 1988). The Sargasso Sea is home to the world's longest time series of ocean measurements, started in 1954 at Hydrostation S which continue to provide critical data needed to understand the variability in ocean processes which impact directly upon global changes.

First recorded by Columbus and named after its characteristic floating brown algae *Sargassum*, the Sargasso Sea is an area of open-ocean situated within the North Atlantic Subtropical Gyre, bounded

on all sides by the clockwise flow of major ocean currents. The Gulf Stream and North Atlantic Drift form the western and northern boundaries, the Canary Current forms a more diffuse eastern boundary, and the North Equatorial Current and Antilles Current form the southern boundary (Figure 1). As these currents vary, the precise boundaries of the Sargasso Sea also vary (Ryther 1956, Butler, Morris, Cadwallader, and Stoner 1983, Coston-Clements, Settle, Hoss, and Cross 1991).

The encircling currents of the Sargasso Sea (Fig 1) trap water at the core of the Sargasso Sea for estimated periods of up to ca 50 years (Maximenko, Hafner and Niller 2011) and concentrate *Sargassum*, plastics and other pollutants. The environment of the Sargasso Sea is further influenced by rings and eddies that may persist as distinct entities for many months (McGillicuddy, Johnson, Siegel, Michaels, Bates and Knap 1999). Figure 2 shows Gulf Stream rings trapping cold shelf water (Green blobs) that have moved into the Sargasso and conversely a warm water ring (Red ring off New York) that has trapped water from the Sargasso Sea. The 'cold water rings' (Richardson, Cheney and Worthington 1978) have a cyclonic circulation and can persist for years (Cornillion, Evans and Large 1986). In contrast warm core rings have an anticyclonic circulation that transports Sargasso Sea water westwards where they eventually coalesce into the Gulf Stream. In addition to these rings there are smaller mode water eddies-lenses of uniform water density that form in midwater and rotate in an anticyclonic direction beneath the surface. These features are collectively referred to as mesoscale eddies and have diameters ranging from 10s to 100s km. The different types of eddies create localised upwelling and downwelling and impact the upper layers of the Sargasso Sea by mixing surface and deeper waters. This affects nutrients, heat and salinity which together create localised areas of high productivity (Volk and Hoffert 1985, Glover, Doney, Mariano, Evans and McCue 2002, Benitez- Nelson and McGillicuddy 2008) or low productivity (Maurino-Carballido and McGillicuddy 2006). They also impact the biodiversity by the currents 'capturing' and bringing 'foreign species' into the area whose relic populations may persist for months or conversely by spinning species out into the Gulf Stream (Boyd, Wiebe and Cox 1978, Wiebe and Boyd 1978, Ring Group 1981).

Another important feature of the western Sargasso Sea is the Subtropical Convergence Zone (STCZ, 20° – 30°N) where warm and cold water masses meet (Figure 2) and create distinct temperature fronts in the upper 150 m of the ocean in the fall to spring seasons (Katz 1969, Weller 1991). Two or three bands of these fronts form each year and are a dynamic seasonal feature of the Sargasso Sea. Water converges from both sides into these fronts causing strong frontal jets or eastward counter currents to form (Mied, Shen, Trump and Lindemann 1986, Eriksen, Weller, Rudnick, Pollard and Regier 1991, Weller, Rudnick, Eriksen, Polzin, Oakey, Toole, Schmitt and Pollard 1991, Pollard and Regier 1992). Because of this convergence, *Sargassum* weed accumulates at the surface of the fronts forming large rafts of weed, and other organisms also accumulate there, so the fronts are likely important feeding areas for predatory pelagic fishes and migratory marine mammals in the Sargasso Sea. These fronts also form zoogeographic boundaries between the distributions of pelagic fishes (Backus, Craddock, Haedrich and Shores 1969) and of anguillid and other marine eel larvae (Miller and McCleave 1994), and the associated frontal jets appear to transport some leptocephali and presumably many other organisms eastward further offshore into the Sargasso Sea (Miller and McCleave 1994). As the surface waters of the STCZ get warmer in the late spring and summer the frontal zones move further north (Ullman, Cornillon and Shan 2007).

## Productivity

Despite having low nutrient levels and therefore being officially classed as 'oligotrophic', the Sargasso Sea, per unit area, has a surprisingly high net annual primary production rate that matches levels found in some of the most productive regions in the global ocean (Steinberg, Carlson, Bates, Johnson, Michaels and Knap 2001, Rho and Whitledge 2007, Lomas, Moran, Casey, Bell, Tiahlo, Whitefield, Kelly, Mathis and Cokelet 2012). This is due to a complex combination of factors - the production of carbon in the surface waters by photosynthesis, the location of the Sargasso Sea in the sub-tropics thereby having a deep euphotic layer, and differences in phytoplankton and associated nitrogen fixation.

Annual net community production, the balance of primary production and plankton respiration, in the euphotic zone can be higher in sub tropical regions than in some sub-polar regions - in contrast to the widely held belief that the latter are more productive (Emerson, Mecking and Abell 2001). Integrated over the entire area of the Sargasso Sea the annual net primary production is estimated to be some three times higher than in the Bering Sea (Steinberg et al 2001, Lomas et al 2012), conventionally regarded as one of the world's most productive seas. The essential difference between these two seas in terms of net community productivity is that in the Bering Sea (as in other polar seas, Carlson, Ducklow, Hansell and Smith 1998) a major fraction (>50%) of the net primary production is channeled efficiently into harvestable resources (e.g. crab, shellfish, pollock) (Mathis, Cross, Bates, Moran, Lomas, Mordy and Stabeno 2010, Moran, Lomas, Kelly, Prokopenko, Granger, Gradinger, Iken and Mathis 2011) whereas in the Sargasso Sea most of the production is recycled by bacteria in the so-called microbial loop (Carlson, Ducklow and Sleeter 1996, Steinberg et al. 2001).

As a result of this high primary productivity, to which must be added the annual production of *Sargassum* weed which is now being estimated from satellite measurements (Gower and King 2008, 2011), the Sargasso Sea plays a key role in the global ocean sequestration of carbon. As the amount of anthropogenic carbon dioxide released to the atmosphere has increased over time (Le Quéré, Raupach, Canadell, Marland et al. 2009), so the ocean uptake of carbon dioxide has increased (Friedlingstein, Houghton, Marland, Hackler, Boden, Conway, Canadell, Raupach, Ciais and Le Quéré 2010). The world's ocean sequesters large quantities of carbon dioxide from the atmosphere by a combination of physico/chemical processes moving dissolved inorganic carbon from the surface into deeper water via current movements, and by biological processes of photosynthetic fixation of carbon dioxide into particulate matter. This particulate matter ultimately sinks to the deep ocean - a process known as the biological pump. These processes are major factors in controlling the concentration of carbon dioxide in the lower atmosphere and thus impact the global climate system (IPCC 1996, IPCC 2001, IPCC 2007).

In the Sargasso Sea the overall contribution of biological and physical processes to carbon sequestration is approximately equal, but the processes vary seasonally and geographically. The annual carbon cycle in the Sargasso Sea can be summarized as a release of carbon dioxide from the sea surface to the atmosphere in the summer followed by absorption of carbon dioxide by the ocean during the winter. The overall winter absorption is greater than the summer release because of winter cooling and surface mixing in the northern Sargasso Sea resulting in a strong net sink into the

ocean in the winter (Bates, Pequignet, Johnson and Gruber 2002). The strength of this sink has been increasing along with increases in primary production and phytoplankton biomass (Lomas et al. 2010). In addition, since 1988, twice the amount of dissolved inorganic carbon has been accumulating in the deeper water layers throughout the Sargasso Sea (Klein and Hogg 1996, Jenkins 1998, Alfutis and Cornillon 2001, Hanawa and Talley 2001), compared to the shallow surface waters (Bates et al. 2002, Gruber, Bates and Keeling 2002) as a result of winter cooling and mixing in mode water formed at the Sargasso Sea's northwestern boundary to the north that subsequently sinks and moves southward into the Sargasso Sea (Klein and Hogg 1996, Hazeleger and Drifhout 1998). The overall effect of these processes is that the net sink of carbon dioxide in the Sargasso Sea represents ca 7% of the global net biological carbon pump (Lomas, Bates, Buck and Knap 2011, unpublished) and 18 – 58% of the annual North Atlantic carbon sink estimated over the period 1992 – 2006 (Ullman, McKinley, Bennington and Dutkiewicz 2009).

## Sea Bed Geology

The seabed and underlying geology of the Sargasso Sea (Figure 3) reflects the evolution of the ocean basin floor over a period of approximately 150 million years. The bathymetry from west to east passes from the continental rise of the North American continental margin at around 2000m water depth, descends gently into parts of the Hatteras, Nares and Sohm abyssal plains, with depths reaching over 4500m, before shallowing progressively towards the Mid Atlantic Ridge where the water depth is less than 2500m. This regional relief is modified dramatically by extinct volcanoes that form the Bermuda Islands, seamounts and associated Bermuda Rise, and the New England and Corner Seamount chains further north. Several major fracture zones, the Atlantis, Northern, Kane and Blake Spur cross the area. The entire region is underlain by igneous oceanic crust formed at the Mid-Atlantic Ridge, which is covered by sediments formed by pelagic deposition and turbidity currents from the USA continental margin of the USA east coast and Bermuda. (See e.g. Detrick, White and Purdy 1993, Uchupi, Phillips and Prada 1970, Voygt and Jung 2007, Dlvens 2011, Parson and Edwards 2011, unpublished).

## Location

To refine the location of the area considered here and to ensure that this incorporates essential oceanographic and environmental characteristics the Sargasso Sea Alliance commissioned a new map based on criteria such as ocean current and eddy occurrence, remote sensing of *Sargassum* weed, and seabed topography (Ardron, Halpin, Roberts, Cleary, Moffitt, and Donnelly 2011, unpublished). The boundaries of the resultant map were then refined to take into account the variable eastern boundary current and the EEZs of adjacent countries. The Canary current is more diffuse and variable than the other currents surrounding the Sargasso Sea hence the eastern boundary is more ill-defined, so the eastern boundary of the Sargasso Sea is here pragmatically considered to lie to the west of the mid-Atlantic Ridge in the western basin of the Atlantic Ocean. Again for pragmatic reasons all of these boundaries were placed outside the current EEZs of all adjacent countries except for Bermuda.

The resultant map agrees broadly with the overlap of previous delineations and is shown in Figure 4. ***The area of the Sargasso Sea considered here occupies ca 4,151,565 km<sup>2</sup> and extends between 22° – 38°N, 76° – 43°W centred on 30°N and 60°W.***

## Feature descriptions of the proposed area

### ***Sargassum* and *Sargassum* Communities**

The Sargasso Sea is a refuge of life in the open ocean with a characteristic surface ecosystem based upon *Sargassum*, which hosts its own unique communities, acts as a nursery and feeding area for many species, and as a migration route for others. It is a vital habitat for many species of economic importance both locally and to countries on both sides of the Atlantic – the Sargasso Sea is truly a ecological cross-roads of the Atlantic Ocean.

The surface ecosystem is based upon two species of floating *Sargassum* both of which reproduce solely by fragmentation and are thus holopelagic and distinct from all other seaweeds (Deacon 1942, Stoner 1983). Floating *Sargassum* evolved over 40 million years ago from benthic species (Butler et al 1983, Stoner and Greening 1984, South Atlantic Fishery Management Council 2002). Both species are golden brown in colour and float due to small gas-filled bladders; *S. natans* has a delicate fine leaf structure, whereas *S. fluitans* has large lanceolate leaves. Together they form clumps or large floating mats that often aggregate into characteristic regularly spaced lines or ‘windrows’ that stretch for considerable distances parallel to the wind. These mats have been likened to a golden floating rain forest filled with life.

The Sargasso Sea is the only area of significant *Sargassum* distribution where it grows in truly open ocean, thereby providing a rare form of valuable habitat in deep open water far from land. Recently the MERIS satellite has been used to track the movements of *Sargassum* and to estimate a biomass of around one million tonnes in the Sargasso Sea (Gower and King 2008, 2011)

The Sargasso Sea contains the most northerly persistent ecosystem formed around this floating seaweed. It is part of a broader tropical western Atlantic distribution of *Sargassum*. The weed drifts through the Caribbean, into the Gulf of Mexico and up the eastern seaboard of the United States of America in the Gulf Stream. Some is swept away into more northern waters, but significant amounts are trapped in the Sargasso Sea by eddies of water that break away from the southern edge of the Gulf Stream and spin into the central gyre. Once there the *Sargassum* is retained by the clockwise movement of currents circulating around the gyre (see Figure 2) and is replenished annually. This overall distribution pattern has probably been maintained for thousands of years (Calder 1995).

Together with its persistence, it is the great area and thickness of the floating *Sargassum*, which in turn attracts a great density and diversity of associated organisms, that distinguishes this floating ecosystem from that of any other drift algae (Coston-Clements et al. 1991, Moser, Auster and Bichy 1998, Casazza and Ross 2008). Other drift algae habitats exist (e.g. Kingsford and Coat 1985, Kingsford 1995, Salovius, Nyqvist and Bonsdorff 2004) but these generally occur in coastal waters and are short-lived. As the *Sargassum* drifts round it collects “passengers” which increases the diversity of attached invertebrates that settle upon it; this biodiversity varies seasonally, as well as with location in the gyre and the age of the algae (Stoner and Greening 1984).

Given the long evolutionary history of *Sargassum* in the Sargasso Sea it is not surprising that many species have become specially adapted for life in this floating forest (Hemphill 2005). Ten species are known to be endemic to floating *Sargassum* -the Sargassum crab (*Planes minutes*), Sargassum shrimp (*Latreutes fucorum*), Sargassum pipefish (*Syngnathus pelagicus*), Sargassum anemone (*Anemonia sargassensis*), the Sargassum slug (*Scyllea pelagica*), the Sargassum snail (*Litiopa melanostoma*), the amphipods *Sunampithoe pelagica* and *Biancolina brassicacephala*, and the platyhelminth *Hoploplana grubei*. Most of the endemics are camouflaged in some way and perhaps the most iconic is the Sargassum Angler Fish (*Histrionotus histrio*), which has both camouflage and modified fins which it uses to creep around the weed (Coston-Clements et al. 1991, South Atlantic Fishery Management Council 2002, Trott et al. 2011).

In addition to the endemic species the *Sargassum* is home to a rich community of small invertebrates and fishes. More than 145 invertebrate species have been recorded in association with *Sargassum*, including a variety of gastropod and nudibranch molluscs, portunid and amphipod crustaceans, pycnogonids, serpulid and nereid polychaetes, flatworms, bryozoans and hydroids (Fine 1970, Morris and Mogelberg 1973, Butler et al. 1983, Coston-Clements et al. 1991, Sterrer 1992, Calder 1995, South Atlantic Fishery Management Council 2002, Trott et al 2011).

*Sargassum* also provides a habitat for over 127 species of fish and, although some of these species may be limited to coastal areas, at least 80 species have been recorded offshore (Dooley 1972, Fedoryako 1980, Coston-Clements et al. 1991, South Atlantic Fishery Management Council 2002, Casazza and Ross 2008, Sutton, Wiebe, Madin and Bucklin 2010). Whilst the *Sargassum* weed provides a habitat, the fauna living within this reciprocates by providing essential nutrients to the weed (Lapointe 1995), thereby maintaining a balance within the community. This diverse community of organisms living at the surface also interacts with the typical oceanic fauna of fishes and invertebrates that are similar to those found worldwide at these latitudes, many of which migrate vertically up at night and down during the day, thus providing connectivity between the surface community and the deep-sea.

The overall importance of *Sargassum* for fish has been recognised by the USA which, following the Fishery Management Plan set out in 2002 (South Atlantic Fishery Management Council 2002), has designated *Sargassum* as essential fish habitat (NMFS, 2003). ICCAT has also recognized the importance of *Sargassum* as fish habitat and has requested that Contracting Parties assess the ecological status of *Sargassum* as habitat for tuna, billfish and sharks. It has also asked countries to report on activities that may affect the abundance of *Sargassum* (ICCAT 2005, ICCAT 2011b)). This is one of the first actions by ICCAT to address fisheries habitat.

### ***Sargassum* as a Feeding/Nursery Resource**

The rich community of invertebrates and small fish hosted by the *Sargassum* forms the prey of many large species of fish of considerable conservation interest and also economic value both locally and more widely. Fish living within the *Sargassum* canopy include juvenile swordfish (*Xiphias gladius*), juvenile and sub-adult jacks (Carangidae), juvenile and sub-adult dolphinfish (Coryphaenidae), filefish and triggerfish (Balistidae), and driftfish (Stromateidae) (Fedoryako 1980, Coston-Clements et al. 1991, South Atlantic Fishery Management Council 2002, Casazza and Ross 2008, Rudershausen,

Buckel, Edwards, Gannon, Butler and Averett 2010). Larger predatory species that prey on these smaller fish include jacks (*Caranx* spp.), amberjacks (*Seriola* spp.), rainbow runners (*Elagatis bipinnulata*), dolphins (*Coryphaenus* spp.), barracudas (Sphyraenidae), various mackerels, wahoo and tunas (Scombridae), and billfishes (Istiophoridae) (Gibbs and Collette 1959, Stephens 1965, Dooley 1972, Fedoryako 1980, Manooch and Hogarth 1983, Manooch and Mason 1983, Manooch, Mason and Nelson 1984, Manooch, Mason and Nelson 1985, Coston-Clements et al. 1991, South Atlantic Fishery Management Council 2002, Casazza and Ross 2008, Rudershausen et al. 2010, Trott et al 2011).

Oceanic fish that spawn in the Sargassum include flying fish (Exocoetidae) that build bubble nests for their eggs within the weed and have eggs with long extensions for attaching to the weed (Dooley 1972, Sterrer 1992). These form a major component of the diet of other fish such as dolphin, wahoo and tunas, on which pelagic fisheries and recreational fisheries are based (Manooch and Hogarth 1983, Manooch and Mason 1983, Manooch et al. 1984, Manooch et al. 1985, Rudershausen et al. 2010). Other fish that spawn in the Sargasso Sea include white marlin (*Tetrapturus albidus*), and blue marlin (*Makaira nigricans*) (South Atlantic Fishery Management Council 2002, Luckhurst, Prince, Llopiz, Snodgrass and Brothers 2006, White Marlin Biological Review Team 2007) and various species of eels, of which the European and American eels are the most iconic (Schmidt 1922, Schoth and Tesch 1982, Kleckner and McCleave 1988, McCleave and Miller 1994, Miller and McCleave 1994, Miller 2002, Miller and McCleave 2007).

Above the sea surface, Haney (1986) observed seabirds foraging in association with *Sargassum* mats to the west of the Gulf Stream off the Georgia coast and recorded 26 different species, with bird densities being up to 32 - 43 times greater in areas with *Sargassum* than in areas without. Further offshore the diversity of bird species is lower and this is reflected in Table 1 which combines Haney's observations (1986) with those of Thomas (2005) who examined the oceanic bird habitat further from land. The endangered endemic Bermuda petrel, the cahow (*Pterodroma cahow*), protected under Appendix 1 of the Convention on Migratory Species ([http://www.cms.int/documents/appendix/cms\\_app1.htm](http://www.cms.int/documents/appendix/cms_app1.htm)) travels throughout the Sargasso Sea and beyond (Hallett 2011, unpublished) to feed on squid and fish. White-tailed tropic birds, (*Phaethon lepturus*), masked boobies (*Sula dactylatra*), and bridled terns (*Sterna anaethetus*) apparently concentrate near to *Sargassum* patches, which provide a focus for food and which can be dense enough for some birds, notably bridled and sooty terns (*Sterna anaethetus*, and *Sterna fuscata*) to roost upon (Haney 1986).

### **Sargasso Sea as a Migration Area**

A number of species of sharks and rays inhabit or migrate through the Sargasso Sea including whale sharks, tiger sharks, manta rays and spotted eagle rays (Hallett 2011, unpublished). New satellite tagging data has revealed that the Sargasso Sea is important habitat for several shark species that have only recently been reported to occur there. For instance, basking sharks (*Cetorhinus maximus*) make regular seasonal movements to the Sargasso Sea during winter months at depths of 200-1000m meters (Skomal, Zeeman, Chisholm, Summers, Walsh, McMahon and Thorrold 2009). Satellite tagging has also recently shown that large female porbeagle sharks (*Lamna nasus*) migrate over 2,000 km at depths of up to 500m from Canadian waters to the Sargasso Sea where they may

be pupping (Dulvy, Baum, Clarke, Compagno, Cortés, Domingo, Fordham, Fowler, Francis, Gibson, Martínez, Musick, Soldo, Stevens and Valenti 2008, Campana, Joyce, and Fowler 2010). Most recently, a large female white shark (*Carcharodon carcharias*) was tracked from coastal Massachusetts to Sable Island on the Scotian Shelf, and then down into the Sargasso Sea during winter months of 2010/2011 (G. Skomal and S. Thorrold 2011, pers. comm.). The observation of large, potentially pregnant females of several threatened shark species in the Sargasso Sea raises the intriguing possibility that this area represents critical nursery habitat for these species.

Eastern and western populations of Atlantic bluefin tuna (*Thunnus thynnus*) migrate through or to the Sargasso Sea (Lutcavage, Brill, Skomal, Chase and Howey 1999, Block, Dewar, Blackwell, Williams, Prince, Falwell, Boustany, Teo, Seitz, Walli and Fudge 2001, Block, Teo, Walli, Boustany, Stokesbury, Farwell, Weng, Dewar and Williams 2005, Wilson and Block 2009). Both populations are in decline and are below 15% of the unfished, historical baseline (ICCAT 2008). Lutcavage et al. (1999) noted that some of the giant bluefin tuna tagged in their study were in the Sargasso Sea at the same time as other giants were located in a known spawning ground in the Gulf of Mexico. This evidence, along with anecdotal observations from earlier researchers documented by Lutcavage and co-authors, suggested that the Sargasso Sea was, and may still be, a spawning location for bluefin tuna in the western Atlantic Ocean.

Several other tuna species, including yellowfin (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*), also move through the Sargasso Sea, and further west into coastal U.S. waters, from spawning grounds in the eastern tropical Atlantic (ICCAT 2010). Yellowfin tuna appear to migrate through the Sargasso Sea to frontal boundaries along the Gulf Stream. Bigeye tuna on the other hand may be residing for some time in the Sargasso Sea based on tagging and depth distribution data. Albacore tuna (*Thunnus alalunga*) are also regular visitors to the Sargasso Sea, although the centre of distribution for the North Atlantic stock remains in the eastern Atlantic (ICCAT 2010). Nonetheless, albacore are believed to spawn in the Sargasso Sea (ICCAT 2011a).

The Sargasso Sea is also important habitat for Atlantic swordfish (*Xiphias gladius*). Commercial catches of swordfish in the western Atlantic are focused on the Gulf Stream and associated frontal zones (ICCAT 2010). However, many (perhaps most) of these fish move through the Sargasso Sea as part of a seasonal migration from the tropical Atlantic to temperate northwest Atlantic waters.

While in the Sargasso Sea, swordfish make diurnal vertical movements spanning at least 1,000m (Loefer, Sedberry and McGovern 2007). These vertical migrations mirror the behaviour of mesopelagic fishes that are found in surface waters during the night and at depths of 500-1500m during the day. These fishes undoubtedly transfer a significant fraction of primary production from the epipelagic (near-surface) zone of the Sargasso Sea to mesopelagic depths. It is therefore probably no coincidence that apex predator abundance in the Sargasso Sea is dominated by species such as swordfish and bigeye tuna that spend considerable time at mesopelagic depths (Loefer et al. 2007, Arrizabalaga, Pereira, Royer, Galuardi, Goñi, Artetxe, Arregi and Lutcavage 2008).

The hatchling and juvenile stages of several species of turtles that nest on the beaches of the Caribbean and the Americas use *Sargassum* weed for hiding and feeding, spending their so called 'lost years' amongst the weed. All are endangered or critically endangered. Green turtles (*Chelonia mydas*), hawksbill turtles (*Eretmochelys imbricate*), loggerhead turtles (*Caretta caretta*), and Kemp's

Ridley turtles (*Lepidochelys kempii*) use *Sargassum* as a nursery habitat (Carr and Meylan 1980, Carr 1987, Schwartz 1988, Manzella and Williams 1991). Hatchlings of green and loggerhead turtles swim hundreds of miles to the Sargasso Sea, where the few that survive this journey hide in the *Sargassum* to feed and grow in relative safety (Carr and Meylan 1980, Carr 1987, Schwartz 1988, Luschi, Hays, and Papi 2003). Adult leatherback turtles (*Dermochelys coriacea*) also migrate north through the Sargasso Sea from nesting sites in the Caribbean Sea (Ferraroli, Georges, Gaspar and Le Maho 2004, Hays, Houghton and Myers 2004), and seasonally to the Sargasso Sea from foraging locations in coastal waters of New England and Nova Scotia (James, Myers and Ottensmeyer 2005). A significant number of green and hawksbill turtles leave the *Sargassum* habitat and use Bermuda's extensive reefs and seagrass beds as a developmental habitat for many years (Meylan, Meylan and Gray (2011)

Thirty cetacean species (whales and dolphins) have been recorded from the Sargasso Sea (<http://www.smru.co.uk/data-gateway.aspx>). Of particular note are humpback whales (*Megaptera novaeangliae*) that pass through the Sargasso Sea during their annual migrations between the Caribbean and the northern North Atlantic (Martin, Katona, Mattila, Hembree and Waters 1984, Stone, Katona and Tucker 1987, G Donovan and R Reeves 2011, pers. comm.). Adults are often seen within sight of the south shore of Bermuda during March and April with their newborn calves. Humpbacks support a growing whale watching industry in Bermuda (Stone et al. 1987) and individual animals can be recognised by their distinctive markings. The same individuals are seen year after year at Bermuda and further north in the Stellwagen Bank Marine Sanctuary off the east coast of the USA (Stevenson 2011, unpublished). The importance of this connectivity was recognised in 2011 by the signing of a collaboration arrangement between the Government of Bermuda and the Stellwagen Bank National Marine Sanctuary.

The other large whale seen regularly in the Sargasso Sea is the sperm whale (*Physeter catodon*). Sperm whales occur throughout the Sargasso Sea and were once so numerous in Bermudan waters that the noise of their gambolling kept the settlers awake at night! They are much less numerous now but groups including calves are commonly seen (Antunes 2009) and it is likely that they feed in the frontal convergence, around the boundaries of Gulf Stream rings and above the seamounts (National Marine Fisheries Service 2010).

## Threatened Species

Many of the species considered previously are of considerable global conservation interest. They appear on the International Union for the Conservation of Nature (IUCN) Red List of endangered species, and/or are listed under the Convention on International Trade in Endangered Species (CITES) banning or restricting trade (Hallett 2011, unpublished,) (see Table2). They also feature in the annexes of the 1990 Specially Protected Areas and Wildlife Protocol to the Convention on the Protection and Development of the Marine Environment of the Wider Caribbean Region (SPAW Protocol, <http://www.cep.unep.org/cartagena-convention/spaw-protocol>). Although the geographical area of the Protocol does not extend directly to the Sargasso Sea, the Protocol does require countries in the Caribbean region to implement conservation measures to protect and recover and, where relevant, to maintain populations of these species at optimal levels. Species of relevance to the Sargasso Sea include seabirds in the air above, turtles in the floating *Sargassum*,

cetaceans in the waters below, and a wide variety of corals on seamounts rising from the seabed (Table 3). Tables 2 and 3 list examples of threatened species, they are only an indication of the numbers of endangered species that occur in the Sargasso Sea.

### **European and American Eels (*Anguilla spp*)**

The Sargasso Sea is of considerable international importance as the spawning area for the economically valuable American and European eels, *Anguilla rostrata* and *A.anguilla*. Both species spend their adult lives in freshwater and migrate thousands of miles to the Sargasso Sea to spawn (Schmidt 1922, Kleckner, McCleave and Wippelhauser 1983, Friedland, Miller and Knight 2007). The larvae of both species develop in the Sargasso Sea and migrate along the Gulf Stream back to their respective freshwater habitats in North America and Europe, where they metamorphose into juvenile “glass eels”. Eel larvae can take anywhere between 7 and possibly 24 months to make the trip (ICES 2010) before arriving back in coastal or freshwater areas as glass eels or elvers on both sides of the Atlantic. Both species of eel are the subjects of important fisheries, as both baby “glass eels” and as adults (Wirth and Bernatchez 2003). Recruitment and populations of both species are in significant decline, with the European eel listed by CITES and classified by IUCN as ‘critically endangered’ and at increasing risk of global extinction.

The exact location and circumstances of eel spawning in the Sargasso Sea remain unknown although there is evidence that oceanographic features such as thermal fronts may direct eels to spawning locations (Kleckner and McCleave 1988). Spawning occurs to the south of distinct temperature fronts that are consistently present in the Sargasso Sea during the spawning season in late winter and early spring (Kleckner and McCleave 1988, Munk, Hansen, Maes, Nielsen, Castonguay, Riemann, Sparholt, Als, Aarestrup, Andersen and Bachler 2010). Once spawned the small larvae, or leptocephali, of both species have broad distributions in overlapping areas of the Sargasso Sea and tend to be most abundant in the upper 100m of the water column.

Glass eel recruitment everywhere has declined significantly over the last few decades. Tentative links have been proposed between changes in the Sargasso Sea and the decline of both American and European eel species (Friedland et al, 2007). These include changes in location of their spawning areas, changes in wind driven currents that transport eel larvae to adult habitats in Europe and North America, and potential changes to feeding success for eel larvae (Miller, Kimura, Friedland, Knights, Kim, Jellyman and Tsukamoto 2009). A range of other causes has been suggested to affect the juveniles and adults including pollution (particularly substances like PCBs) (Robinett and Feunteun 2002, Pierron, Baudrimont, Bossy, Bourdineaud, Brèthes, Elie and Massabuau 2007), the effects of the swimbladder parasite (*Anguillicoloides crassus*) (Gollock, Kennedy and Brown 2005, Gollock 2011, unpublished), the poor condition of migrating silver eels (Svedäng and Wickström 1997), and the destruction of their freshwater habitat (Haro, Richkus, Whalen, Hoar, Busch, Lary, Rush and Dixon 2000). The evidence for some of these factors is greater than others (often varying with region), but it is unlikely that there is one single cause.

Because their oceanic migrations are difficult to monitor, recovery plans focus on improving conditions within estuarine and inland areas. In 2007 the European Union adopted an eel recovery plan (EC 2007). This plan directs European member states that have natural habitats for populations of the European eel to reduce eel fishing efforts by at least 50% relative to average efforts deployed

from 2004 to 2006. They are also required to achieve a target escapement rate of 40% of adult silver eels from all river basins relative to pristine levels – considered to be the levels that existed prior to 1980 (EC 2007). Similarly in Canada, the American eel has been identified as an Endangered Species under Ontario’s Endangered Species Act of 2007 which prohibits the killing, harming, harassing, possessing, buying, selling, trading, leasing or transporting of this species. Quebec, Newfoundland and Labrador, have also introduced measures to regulate eel fishing and eel escapement back to the sea.

Protecting the Sargasso Sea will complement such measures and strongly enhance existing protection of both eel species.

### **Deep Water Pelagic Species**

Much of the previous discussion has focussed on surface or near-surface fauna, or on species that are directly of value to commercial or conservation interests. However beneath the *Sargassum* layer the Sargasso Sea descends to depths of around 4500m and is populated throughout by deep ocean animals. General accounts of these, their distribution patterns, and their adaptations to life in the open ocean and deep sea are found in numerous books (e.g. Marshall 1979, Herring 2002), and the deep Sargasso Sea fauna conforms with these accounts.

The Sargasso Sea has been sampled intensively by deep-sea biologists and oceanographers for over a century and there are numerous accounts of particular animal groups or communities, their distributions, abundance, migrations and life-styles which show that Sargasso Sea assemblages of species are generally similar to those found throughout the subtropical Atlantic. Recent examples include fish taken during the 2006 Census of Marine Life Programme (Sutton et al 2010), amphipod crustaceans (Gasca 2007), and chaetognaths (Pierrot-Bults and Nair 2010), whilst a selection of older work includes decapod crustacean (Donaldson 1975), general zooplankton (Deevey 1971), biomass profiles (Angel and Baker 1982, Angel and Hargreaves 1992), and ostracod crustaceans (Angel 1979). Gelatinous zooplankton are well-represented in the Sargasso Sea, being a heterogeneous assemblage of generally large-bodied, jellyfish-like species including medusae, siphonophores, ctenophores, thaliaceans and some polychaetes and pteropods. Salps are diverse and frequently abundant in the vicinity of Bermuda, where some species make diel vertical migrations to 600 m. (Madin, Kremer and Hacker 1996). *Pyrosoma*, a colonial thaliacean, also migrates over similar distances. The only really different feature of deep-sea animals in the Sargasso Sea is the impact of Gulf Stream rings and mesoscale eddies upon their distribution described earlier. The impact of Gulf Stream rings on groups ranging from protozoa to fish has been well documented (Weibe and Boyd 1978, Fairbanks, Wiebe and Bé 1980, Backus and Craddock 1982, Wiebe and Flierl 1983). In addition to these relatively conventional studies using a variety of nets and sampling gear, the Sargasso Sea is one of the few ocean areas that has been studied recently using cutting edge intensive DNA barcoding efforts to document the biodiversity of its inhabitants at all different depths (Bucklin et al. 2010; Sutton et al. 2010).

Despite the apparent overall similarity between the midwater communities in the Sargasso Sea and elsewhere it is worth noting that Angel (2010) in drawing up an inventory of planktonic ostracods for the Atlantic ocean observed that 10% of the species caught below 2000m were new to science and that if the sampling had reached the benthopelagic zone within a few metres of the sea-

bed the novel component would have soared. The ostracods are likely to be an indicator of the potential numbers of new species yet to be discovered in the deep ocean.

## **Benthic Communities**

The biology of the abyssal plains is best known through work done on a repeated transect between Bermuda and Gay Head in the USA in the 1960s and 70s (Sanders, Hessler and Hampson 1965) - work that remains a milestone in our knowledge of deep-ocean bottom faunas. Very recently a new observational programme on the larger bottom fauna has started using baited cameras (MBARI Sargasso Sea Expedition 2011 [www.mbari.org](http://www.mbari.org)). The seamounts increase significantly the biodiversity of the bottom fauna, and as elsewhere in the world ocean such features provide a haven for marine life but have been extensively damaged by destructive benthic trawling (Watling, Waller and Auster 2007, Shank 2010). Deep-sea and seamount fish stocks are particularly vulnerable to exploitation because the fish are very long lived, take many years to reach sexual maturity, and have very low fecundities (Norse, Brooke, Cheung, Clark, Ekeland, Froese, Gjerde, Haedrich, Heppell, Morato, Morgan, Pauly, Sumaila and Watson 2012).

In the open ocean the best known seamounts in the area are the New England Seamount chain and the Corner seamounts. The latter have peaks rising as much as 4000m from the abyssal plain and support complex coral and sponge communities that provide habitat for diverse invertebrate and fish species, many of which are endemic. Both the Corner Rise and New England Seamounts are home to numerous endemic and novel species of coral which in turn host specific commensal invertebrates (Watling 2007, Watling et al. 2007, Cho 2008, Simpson and Watling 2011, Pante and Watling 2011, ICES 2011, Shank 2010). These seamounts also host abundant populations of deep-water fish, which have been heavily exploited commercially since 1976 (Vinnichenko 1997), but despite this they remain important as aggregating and spawning areas for the alfonsino (*Beryx splendens*)

Within Bermuda's EEZ the seamounts and volcanic banks include the Muir seamount chain, Bowditch seamount, Crescent seamount, Argus Bank, and Challenger Bank (Hallett 2011, unpublished). The Muir seamount chain, for example, is 300 km to the northeast of Bermuda, on the very outer reaches of the EEZ, at approximately 1300 m depth. Little is known about this seamount chain, though limited observations show that its surface is covered with abundant hydroids, sponges, calcareous algae, and rubble (Pratt 1962). Several endemic benthic species occur within Bermuda's EEZ. The bank bass fish (*Parasphyraenops atrimanus*) is known only from Argus Bank at depths of around 80m (Smith-Vaniz, Collette and Luckhurst 1999). The nephroid decapod (*Eunephrops luckhursti*), the geryonid crab (*Chaceon inghami*) and Lightbourne's murex snail (*Pterynotus lightbourni*) also occur in deeper water (Manning and Holthuis 1989, Sterrer 1986).

## Feature Condition and Future Outlook of the Area

Despite its remote location in the Atlantic, the Sargasso Sea is not immune from the impacts of human activities. A recent global analysis of human impacts on marine ecosystems concluded that the Sargasso Sea has sustained moderate to high impacts over time (Halpern, Walbridge, Selkoe, Kappel, Micheli, D'Agrosa, Bruno, Casey, Ebert, Fox, Fujita, Heinemann, Lenihan, Madin, Perry, Selig, Spalding, Steneck and Watson 2008).

### Human activities that adversely impact the Sargasso Sea include:

- Over-fishing
- Shipping and shipping related impacts
- Pollution, including plastics, of the *Sargassum* community and waters retained within the gyre
- The potential for commercial-scale extraction and innovative uses of *Sargassum*.

### Over-Fishing

Fisheries for many key species in the North Central Atlantic, including the Sargasso Sea, have declined significantly in the last 50 years. All targeted tuna and tuna like species regulated by ICCAT are now on the IUCN Red List, except for swordfish (see Table2). According to ICCAT databases for tuna or tuna related species between 1950-2008 there have been notable changes in dominant targeted species from bluefin tuna (*Thunnus thynnus*) in the 1960s, to albacore (*Thunnus alalunga*), swordfish (*Xiphias gladius*), and bigeye tuna (*Thunnus obsesus*), in the 1970s and 1980s, to yellowfin tuna (*Thunnus albacores*), in the 1990s and 2000s ([www.iccat.int](http://www.iccat.int)). The maximum total tuna catch in the region was reported as 18,327 tonnes in 1986 whereas the total catch in 2008 was reported as 2,658 tonnes. Historically albacore have accounted for the largest share of the total catch, but this has declined from over 70% in the early 1970s, to less than 30% in 2008. Yellowfin tuna and swordfish jointly accounted for 60% of the total tuna catches in 2008 (Sumaila et al. 2011, unpublished). As elsewhere, the fishery has progressed from high value bluefin tuna to fish lower down the food chain and lower in value (Pauly and Watson 2005, Pauly, Watson and Alder 2005).

There is evidence that Japanese longline fishing in the Atlantic made progressively greater incursions into the eastern Sargasso Sea from 1975 through 2000 (Yokawa and Uozumi 2001), but the major country involved is now the USA catching yellowfin tuna. Since 2000 the total effort by longline fleets, as measured by number of hooks set, has declined from nearly 50 million in 2000 to 3.8 million in 2008 (Sumaila et al. 2011, unpublished).

In terms of catch per unit effort, the most complete data available from the ICCAT database (<http://iccat.int/en/accesingdb.htm>) is that for the catches of albacore, yellowfin and bigeye tuna by Taiwan between 1968 and 2008 (Hallett 2011b). All three species show a marked decline in catch per unit effort over this time and ICCAT(2010) regard the first two species as being overfished and it is likely that bigeye are in a similar state. The western population of bluefin tuna is known to be heavily over-exploited (Safina and Klinger 2008).

In addition to direct fishing impacts on targeted species, the type of fishing gear used has potential impact upon by-catch. Approximately two thirds of the landings from the Sargasso Sea over the last decade have been from longlines ([www.iccat.int](http://www.iccat.int)). With best practice, longlining can generate low levels of by-catch compared to other commercial fishing methods (Bjordal and Løkkeborg 1996). However other (unspecified) gear recorded as catching yellowfin tuna may include purse seines, which can take significant amounts of by-catch, particularly of juvenile and other small tunas (Amandè, Ariz, Chassot, Delgado de Molina, Gaertner, Murua, Pianet, Ruiz and Chavance 2010). The Sargasso Sea ecosystem is potentially particularly vulnerable to purse-seining because nets set close to floating objects, e.g. rafts of *Sargassum*, take more by-catch. Lost and abandoned fishing gear can also have negative impacts.

Gill nets are still used in the Sargasso Sea and these are known to have high by-catch (Kelleher 2005). Their use for fishing for tunas and related species is limited ([www.iccat.int](http://www.iccat.int)), but they may be used by fisheries for smaller pelagic species that are not managed by ICCAT. Finally there is potentially some illegal, unregulated and unreported (IUU) fishing in the Sargasso Sea, but this has not been evaluated and recent controls on the trade in large pelagic species managed by ICCAT has reduced IUU activity targeting these species (Agnew, Pearce, Pramod, Peatman, Watson, Beddington, and Pitcher 2009, MRAG 2005).

In addition to these fisheries, deep pelagic and bottom trawling by Russia and the USSR, between 1976-1995, on the Corner Rise Seamount caught some 19,000 tons of fish-predominantly alfoncino (*B. splendens*), and caused extensive destruction of the benthic fauna (Vinnichenko, 1997, Waller, Watlin, Auster and Shank, 2007, Shank 2010). As a precautionary management measure, 13 fishable seamounts, including 25 peaks shallower than 2,000 m on the New England and Corner Rise seamounts were closed to demersal fishing by the Northwest Atlantic Fishery Organization (NAFO) from January 1<sup>st</sup> 2007. This closure was recently extended until Dec 31 2014 (NAFO 2011). Norse et al (2011) reviewed the sustainability of deep-sea fisheries and concluded that these are generally unsustainable and more akin to mining, i.e. eliminate a resource before moving on. It is not only fish that are adversely impacted by bottom trawling, corals and associated benthic fauna are destroyed and resumption of trawling on these seamounts will severely degrade the habitats and pose very serious risks to their biodiversity and it is important to maintain the present prohibition.

## **Shipping and shipping related impacts**

The Sargasso Sea lies within one of the world's busiest international shipping areas and is crossed by a large number of vessels each year. The full range of vessel types operate in these waters, with many following distinct routing patterns according to the vessel type and the nature of the cargo carried (Roberts 2011, unpublished).

While it is reasonable to argue that areas having the greatest volume of ship traffic are most vulnerable to environmental impacts from this, there is little direct evidence for such impacts in the Sargasso Sea, although this may be due to lack of appropriate research aimed at defining and quantifying any such impacts (GESAMP 2009). Nevertheless taking into account the volume of shipping traffic that crosses the area each year the potential for adverse impacts certainly exists. Potential risks include the discharge of harmful pollutants e.g. sewage, oil, chemicals, and "foreign"

organisms in ballast water by transiting ships (South Atlantic Fishery Management Council 2002, Halpern et al. 2008, Roberts 2011, unpublished).

Oil and tar balls from ship discharges, distant extraction and processing facilities or accidents have historically been recorded in the area (Burns and Teal 1973, Wade and Quinn 1975, Butler et al. 1983, South Atlantic Fishery Management Council 2002) and residues of petroleum hydrocarbons and tar have been found in and on *Sargassum* and its community including crabs, snails, and post-hatchling loggerhead turtles ( Burns and Teal 1973, Gieselman 1983, Witherington 1994, Richardson and McGillivray 2001). However stricter regulations on discharging oil have been successful in reducing oil and tar pollution, with the frequency of tar balls in the Sargasso Sea decreasing to nearly zero from the mid-1990s onwards (Siuda 2011 unpublished), illustrating that appropriate regulation does have a positive environmental impact. A measurable decline in tar stranding on Bermuda's beaches was reported in this time period by Smith and Knap (1985) and Butler, Wells, Johnson and Manock (1998).

Another shipping related concern is underwater noise generated by ships and the potential impact of this on those animals, especially whales and dolphins, which rely upon hearing and sound production for navigation, feeding and social interactions (Wright et al. 2009). Within the ocean, human generated background noise at the same frequencies as those used by many marine animals has increased 100-fold in some locations over the last 50 years (Wright et al. 2009). Problems caused by this increasing level of anthropogenic noise can be exacerbated by loud noises or particular frequencies that can cause death in some whales. Whilst there is no direct evidence for noise related problems in the Sargasso Sea, the high level of shipping traffic suggests that there is a high level of anthropogenic underwater noise which may be harmful to marine life. Research is needed to evaluate this.

Given the volume of shipping crossing the Sargasso Sea there is a risk of collision with whales and dolphins. While it is difficult to obtain data for the Sargasso Sea, historical records around the world 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 (Laist, Knowlton, Mead, Collet and Podesta 2001). Ship collisions involving at least 11 species of large whale have occurred world-wide (Jensen and Silber 2003). Amongst the large whales, fin whales are most commonly reported as being hit by ships. Ship strikes have also been reported for small cetaceans (Panigada, Pavan, Borg, Galil and Vallini 2008). Turtles need to come to the surface to breath, and are also exposed to the risk of ship strikes; this has become a major challenge for marine turtle conservation worldwide (Panigada et al 2008).

The volume of shipping transiting the Sargasso Sea may also have a direct impact on the *Sargassum* mats. Whilst there is no evidence for this, it is reasonable to assume that ships cutting into large mats and churning up the waters with their propellers and wakes could have an effect on breaking up mats and locally destroying the integrity of the floating community. Research is needed on this aspect to quantify if this is a real or perceived threat.

## Pollution

While risks of pollution caused by shipping are not obvious in the Sargasso Sea, pollution from debris that accumulates amongst the floating *Sargassum* is evident as it is trapped by the oceanic gyre. The same oceanographic processes – Langmuir circulation, fronts, eddies and their associated convergence – that draw drift algae together and form oases of abundant and diverse marine life, also concentrate pollutants and human waste. Floating plastic particles in the Sargasso Sea were reported in 1972 (Carpenter and Smith 1972), and today the North Atlantic gyre has a patch of floating debris akin to the more famous North Pacific garbage patch (Law, Morét-Ferguson, Maximenko, Proskurowski, Peacock, Hafner and Reddy 2010). It can be seen from Law et al. (2010) that in the Sargasso Sea study area shown in Fig4 the concentration of plastic particles taken from plankton tows on occasions reached in excess of an equivalent of 200,000 pieces km<sup>-2</sup>.

Marine animals including birds, turtles and fish may become entangled in this plastic debris leading to choking and strangulation, or they may eat it, compromising their nutrition, and possibly exposing them to toxic chemicals in the plastics. Witherington (1994) found a high incidence of plastics, including plastic bags and strips, caulking materials and vermiculite in post-hatchling loggerhead turtles.

*Sargassum* and its associated animal community accumulate arsenic, mercury and germanium (Johnson and Braman 1975) but we are not aware of any background data for these chemicals in the water of the Sargasso Sea. However polychlorinated biphenols (PCBs) are four times more concentrated in the water within *Sargassum* 'windrows' as compared to open ocean water (Bidleman and Olney 1974). More recently, high levels of persistent organic pollutants have been found on floating plastic resin pellets at sea, adding another level of risk when (if) they are ingested by marine species (Rios, Moore and Jones 2007).

## Commercial exploitation of *Sargassum*

Extraction of *Sargassum* has the potential to pose a direct threat to the Sargasso Sea ecosystem though it is not thought to be taking place in the western Atlantic at present. In the recent past, *Sargassum* has been harvested on both artisanal and commercial scales for use as fertilizer and cattle feed. A management plan exists for its regulation within the US Exclusive Economic Zone, but not for the high seas (South Atlantic Fishery Management Council 2002, McHugh 2003). With respect to International Protection of *Sargassum* and the Sargasso Sea, the Fishery Management Plan for Pelagic *Sargassum* Habitat of The South Atlantic Region explicitly recommends: "*Because of the importance of the extra-jurisdictional pelagic Sargassum occurring in the Sargasso Sea outside the EEZ, the United States should pursue all other options under the Magnuson-Stevens Act and other laws to protect Sargassum in international waters*" (South Atlantic Fishery Management Council 2002, p. 125).

There is increasing concern that the growth of new and novel uses of *Sargassum* weed could radically increase demand and increase pressures for large-scale exploitation and harvesting. Recently there has been a proposal to fertilise areas of the Sargasso Sea and to harvest *Sargassum in situ* (Lenstron, van Haal and Reith 2011). A website search by the Sargasso Sea Alliance has revealed nearly 90 distinct patents referencing *Sargassum*. Various industrial, medical and nutritional uses are

proposed including applications focused on inhibiting HIV infection, as an antibiotic, antifungal and antifouling substance, and as biofuel.

The impact of potential seabed mining is another concern. Within or on the seabed there are a number of mineral resources that are potentially important including polymetallic sulphides, manganese nodules and cobalt-rich crusts, gas hydrates, and, in the thick sediment deposits in the west of the area, hydrocarbons. The commercial attractiveness of these resources depends upon the state of the industry, economic and technical considerations. None of these resources is presently exploited in the Sargasso Sea region but the potential for future mining and extraction remains. An indication of future interests is that both Russia and China have recently applied to the International Seabed Authority for exploration licenses for polymetallic sulphides in areas of the mid-ocean ridge in the Atlantic and Indian Oceans (Parson and Edwards 2011, unpublished). More directly, there are pending or future claims to some of the outer continental shelf underlying the Sargasso Sea high seas by adjacent coastal States with corresponding rights over exploration and exploitation of mineral and sedentary resources. For example, the Bahamas has announced its intention to claim outer continental shelf beyond 200m in the area of Blake Spur (UN, 2009).

### **Submarine Cables**

Also on the seabed there are numerous submarine communications cables (Telegeography 2011) but the impact of these and the potential impact of any deep-water repairs to them on the Sargasso Sea is unknown.

### **Conclusions**

With the exception of over-fishing and the accumulation of plastic debris, many of the impacts discussed here are potential or possible - few direct causal relations between these and environmental degradation in the Sargasso Sea have been detected, perhaps because of the great area and lack of appropriate studies (GESAMP 2009). However the cumulative impact of these activities may be significant, as shown by Halpern et al (2008), who concluded that the Sargasso Sea has already sustained moderate to high impacts. GESAMP (2009) concluded that the amount of information on pollutants in the open ocean was generally poor in comparison with shelf areas - nevertheless the report concluded that there was generally a good understanding of the environmental impacts of such substances and that paucity of data does always critically hamper assessment of substances in the open ocean. Thus lack of direct evidence should not preclude the establishment of a protective regime. The precautionary approach that received global acceptance in the Rio Declaration (UNCED 1992) should play a major role in determining future protection and management actions in the Sargasso Sea. In the last thirty years the precautionary approach has evolved as a key precept of good environmental governance, and has been recognised by the International Tribunal on the Law of the Sea (ITLOS, 2011) as something that is becoming part of customary international law. The history of our exploitation of the ocean is that we have often acted too late and with inadequate ambition to safeguard the very ecosystems and services that support economic values. The Sargasso Sea is an opportunity to explore new ways to do this and protect the ocean.

## Figure and Table Legends

Figure 1. The central Atlantic Ocean, showing the Sargasso Sea and surrounding currents with the location of Bermuda and the extent of Bermuda's Exclusive Economic Zone. (Adapted from United States Army Service Forces, 1943, by Trott, McKenna, Pitt, Hemphill, Ming, Rouja, Gjerde, Causey, and Earle 2011).

Figure 2. : Satellite image of sea surface temperature showing the Gulf Stream and large eddies. Red areas are warm; blue areas are cool (from Talley 2000).

Figure 3. Map of the Seafloor beneath the Sargasso Sea showing the positions of the various Seamounts.

Figure 4. The Sargasso Sea Alliance study area including some of the major features that influence overall boundary definition and location. (Ardron et al. 2011, unpublished)

Table 1. Seabird species known to be associated with *Sargassum* and the Sargasso Sea (composite list developed from Haney 1986 and Thomas 2005).

Table 2. Oceanic species using the Sargasso Sea and Bermuda's EEZ that are on the IUCN Red List of threatened or endangered species and listed under CITES.

Table 3. Endangered and threatened species commonly associated with the Sargasso Sea and waters around Bermuda requiring conservation measures in the wider Caribbean region to protect and recover and, where relevant, to maintain their populations at optimal levels. These species are examples taken from the annexes of the Convention on the Protection and Development of the Marine Environment of the Wider Caribbean Region (SPAW Protocol). For a comprehensive list of all species covered by the SPAW Protocol please see <http://www.cep.unep.org/cartagena-convention/spaw-protocol>

## Assessment against EBSA criteria

(Discuss the area in relation to each of the CBD criteria and relate the best available science. Note that a candidate EBSA may qualify on the basis of one or more of the criteria, and that the boundaries of the EBSA need not be defined with exact precision. And modeling may be used to estimate the presence of EBSA attributes. Please note where there are significant information gaps)

CBD EBSA Criteria (Annex I to decision IX/20)	Description (Annex I to decision IX/20)	Ranking of criterion relevance (please mark one column with an X)			
		Don't Know	Low	Some	High
<b>Uniqueness or rarity</b>	Area contains either (i) unique (“the only one of its kind”), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanographic features.				X
<p><i>Explanation for ranking</i>            The two species of <i>Sargassum</i> are the world’s only holopelagic large algae. Both algae and their associated communities occur in the Caribbean and Gulf of Mexico as well as in the Sargasso Sea, but the areal extent of the <i>Sargassum</i>, its longevity, the thickness of <i>Sargassum</i> mats and the great diversity of its dependant communities make the Sargasso Sea unique. The <i>Sargassum</i> hosts ten endemic species.            On the sea floor the New England seamount chain, the Corner Sea Rise and the seamounts on the Bermuda Rise all host specialized and endemic species and communities</p>					
<b>Special importance for life-history stages of species</b>	Areas that are required for a population to survive and thrive.				X
<p><i>Explanation for ranking</i>            Abundant <i>Sargassum</i> is essential for the survival of its diverse communities and endemic species. The mats of <i>Sargassum</i> and the associated communities which live on or amongst the mats are essential habitats as nursery, spawning and feeding areas for many species of fish, seabirds, and turtles. The fauna that are sheltered by the mats reciprocate by providing essential nutrients to the <i>Sargassum</i>. Below the surface the Sargasso Sea is the only known spawning area in the world for the European and American eel.            The Seamounts are essential for the development and sustainability of the diverse but fragile communities that live there and nowhere else</p>					

<b>Importance for threatened, endangered or declining species and/or habitats</b>	Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.			X
<p><i>Explanation for ranking</i></p> <p>Examples of endangered or threatened species that occur in the Sargasso Sea are given in Tables 2 and 3. The Sargasso Sea is the only spawning area for the European and American eel. The <i>Sargassum</i> mats are essential habitat for the juveniles of four species of turtle-Kemp's Ridley, Hawksbill, Loggerhead and Green. The mats are used as a feeding area by the endangered Bermudan Petrel. Some 30 cetacean species live or migrate through the Sargasso Sea as do several species of endangered or threatened tuna and sharks. Porbeagle sharks migrate to the area to pup, Leatherback Turtles migrate through the area. The Sargasso Sea is a true ecological cross road in the Atlantic Ocean, linking its own distinct ecosystem with Europe, Africa and the Americas, and with the Caribbean and temperate NE Atlantic.</p> <p>The distinct Seamount communities are rare habitats which too often are destroyed by fishing activity.</p>				
<b>Vulnerability, fragility, sensitivity, or slow recovery</b>	Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.			X
<p><i>Explanation for ranking</i></p> <p>The Sargassum mats and dependant communities are sensitive to damage by chemical pollution, and from the accumulation of plastic debris. They may also be adversely impacted by being broken up as ships pass through the mats. The <i>Sargassum</i> based ecosystem risks severe damage if current ideas to harvest <i>Sargassum</i> come to fruition. Overfishing is apparent in several tuna species (bluefin, albacore, bigeye and yellowfin) whilst populations of previously exploited species of turtle, whales and the cahow remain vulnerable.</p> <p>Fragile seamount ecosystems have been severely damaged by trawling on the Corner and New England sea mounts; the animals living in such communities are fragile and vulnerable, being typically long-lived and slow growing; recovery rates for damaged populations are very slow.</p>				

<b>Biological productivity</b>	Area containing species, populations or communities with comparatively higher natural biological productivity.				X
<p><i>Explanation for ranking</i></p> <p>The discovery of <i>Prochlorococcus</i> and the development of techniques able to evaluate the role of picoplankton in production measurements have revolutionized our perceptions of the productivity of the Sargasso Sea and subsequently of the global ocean. Conventionally the Sargasso Sea was regarded as an area of low nutrients and low productivity, enhanced by localized upwellings associated with fronts, mesoscale eddies and rings. We now know that the Sargasso Sea is some three times as productive as the Barents Sea-conventionally regarded as a highly productive area. The difference between the two areas is essentially one of visibility-production in the Barents Sea goes into sustaining populations of large commercially important species, whereas in the Sargasso Sea production is recycled within the microbial loop and does not support large populations of commercial species. It is however vital for the global production of oxygen and the role it plays in the sequestration of carbon into the deep ocean. The biomass of <i>Sargassum</i> is now being estimated from satellite measurements and is estimated to be ca 1 Mtons, some of which falls to the seabed where it acts as a food source for benthic communities.</p>					
<b>Biological diversity</b>	Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.				X
<p><i>Explanation for ranking</i></p> <p>The biodiversity of the Sargasso Sea itself is greatly enhanced by the diverse population of species that live on or amongst the <i>Sargassum</i>, ca 150 species of invertebrates and ca 130 species of fish are associated with Sargassum-many of which would not live in the open ocean without the floating algae. The diversity of oceanic plankton and micronekton within the central gyre is enhanced as species are drawn into this from the surrounding currents via rings and eddies.</p> <p>Benthic diversity is very high on the Corner and New England seamount chains where some 670 species have been found, and the diversity of fauna living on and within the abyssal plain may well be amongst the highest on the planet.</p>					
<b>Naturalness</b>	Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.			X	

*Explanation for ranking*

The naturalness of the Sargasso sea-like all ocean areas has been adversely impacted by human activities especially fishing and hunting which has removed most of the top predators and large species. Hence the populations of whales, turtles, large tuna and tuna-like species are much reduced from their natural state. Deep sea trawling has destroyed several seamount communities, and the cumulative effects of pollution and disturbance have likely impacted adversely the *Sargassum* communities.

Despite this much of the Sargasso Sea is apparently in good shape and the *Sargassum* mats and their associated fauna have been described as the golden rain forest of the sea! The *Sargassum* community continues to provide essential habitat for a variety of animals, the populations of whales, turtles and the cahow are slowly increasing, and the recognition given to the importance of *Sargassum* as fish habitat by the USA and ICCAT is very encouraging. Similarly the protection from benthic trawling now given to the seamounts by NAFO is very welcome. The observed reduction in oil pollution following legislation is another welcome sign that recovery is possible with appropriate measures in place.

The communities living on the abyssal plan and in deep midwater are probably still in their original natural state, whilst the abundant picoplankton may be impacted by future global climate change in ways that are not yet understood.

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