The Protection and Management of the Sargasso Sea

The golden floating rainforest of the Atlantic Ocean

SARGASSO SEA ALLIANCE

GOVERNMENT OF BERMUDA

Summary Science and Supporting Evidence Case

BIOS Bermuda Institute of Ocean Sciences · Marine Geospatial Ecology Lab · Marine Conservation Institute · National Oceanography Centre · PML Plymouth Marine Laboratory · S·E·A · SMRU · The University of York · Woods Hole Oceanographic Institution 1930 · UBC Fisheries Centre

"You can never cross the ocean unless you have the courage to lose sight of the shore."

Christopher Columbus (c. 1451–1506)

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26 Woods Hole Oceanographic Institution, USA.

The Sargasso Sea Alliance is led by the Bermuda Government and aims to mobilise support from a wide variety of national and international organisations, governments and donors for protection measures for the Sargasso Sea. A list of the partners that form the Alliance is provided inside the back cover.

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A full version of this report and of the reports commissioned by the SSA are available for download on the website at **www.sargassoalliance.org**

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COVER PHOTO: Loggerhead turtles using *Sargassum* as nursery habitat. Credit: Masa Ushioda/imagequestmarine.com.

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Executive Summary

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 4500 m. The Sargasso Sea's importance derives from the interdependent mix of its physical structure and properties, its ecosystems, its role in global scale ocean and earth system processes, its socio-economic and cultural values, and its role in global scientific research. Despite this, the Sargasso Sea is threatened by a range of human activities that either directly adversely impact it or have the potential to do so. Being open ocean, the Sargasso Sea is part of the High Seas, the area of ocean that covers nearly 50% of the earth's surface but which is beyond the jurisdiction and responsibility of any national government, and as such it enjoys little protection. To promote the importance of the Sargasso Sea, the Sargasso Sea Alliance was created under the leadership of the Government of Bermuda in 2010. This report provides a summary of the scientific and other supporting evidence for the importance of the Sargasso Sea and is intended to develop international recognition of this; to start the process of establishing appropriate management and precautionary regimes within existing agreements; and to stimulate a wider debate on appropriate management and protection for the High Seas.

Nine reasons why the Sargasso Sea is important are described and discussed. It is a place of legend with a rich history of great importance to Bermuda; it has an iconic ecosystem based upon floating *Sargassum*, the world's only holopelagic seaweed, hosting a rich and diverse community including ten endemic species; it provides essential habitat for nurturing 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; it lies within a large ocean gyre which concentrates pollutants and which has a variety of oceanographic processes that impact its productivity and species diversity; it plays a disproportionately large role in global ocean processes of carbon sequestration; it is of major importance for global scientific research and monitoring and is home to the world's longest ocean time series of measurements; it has significant values to local and world-wide economies; and it is threatened by activities including over-fishing, pollution, shipping, and *Sargassum* harvesting.

Apart from over-fishing many of the threats are potential, with few direct causal relationships between specific activities and adverse impacts. But there is accumulative evidence that the Sargasso Sea is being adversely impacted by human activities, and with the possibility of new uses for *Sargassum* in the future, the lack of direct scientific evidence does not preclude international action through the established precautionary approach. The opportunity to recognise the importance of the Sargasso Sea and to develop and implement procedures to protect this iconic region and the wider High Seas should be taken before it is too late.

Preface

OVER 70% OF THE SURFACE OF PLANET EARTH IS COVERED by the oceans. About 64% of this watery coverage is classified as High Seas – it is deep and open ocean beyond the jurisdiction or control of any individual country with its own range of habitats, species and unique ecosystems. As such there are few measures providing protection for the High Seas in the same ways as those enjoyed by terrestrial and inshore environments. In recent years there has been growing awareness of and concern for the need to resolve this lack of protection, a need which grows increasingly more urgent as the open oceans and deep seas become increasingly exploited.

In 2009 Bermuda decided to improve the stewardship of their surrounding seas, both within their Exclusive Economic Zone and into the wider High Seas. With leading conservation and marine science organisations they began to investigate opportunities within current mechanisms for High Seas governance with the aim of affording protection for the Sargasso Sea. This resulted in the formation of the Sargasso Sea Alliance, a consortium of the Government of Bermuda, leading conservation and marine science organisations and individuals.

The Sargasso Sea Alliance initiative is already having an impact. It is informing the global ocean protection debate, and is bringing together existing knowledge of the Sargasso Sea so that its importance and value can be readily appreciated. Whether viewed environmentally, socially, economically or as a critical area for global marine research the Sargasso Sea is hugely more valuable as an intact and healthy ocean area than as one that is depleted and degraded.

This summary science and evidence case provides information on the nature and importance of the Sargasso Sea as a necessary prerequisite for seeking international recognition and appropriate agreements to better manage human impacts upon it. It could not have been compiled without the assistance of many people who have freely shared their expertise, information and advice with us.

We are extremely grateful to everyone who has helped to make this work possible.

Contents

Introduction

BERMUDIANS HAVE ALWAYS HAD A CLOSE ASSOCIATION with the ocean. It was therefore a logical step for them to look towards greater protection and management for their offshore marine environment extending into the wider ocean beyond their Exclusive Economic Zone (EEZ). These aspirations match closely with a wider and strongly-held desire from the world's leading conservation organisations to ensure that the open ocean and deep sea is afforded at least the same level of protection as that already conferred on terrestrial and coastal ecosystems. The High Seas, the area of ocean and deep sea beyond the jurisdiction and control of any individual country, covers about 64% of the world's ocean, some 50% of the world's surface area and about 90% of the volume of global living space and yet it currently lacks such protection.

In 2009, Bermuda hosted a meeting to explore opportunities for delivering better ocean protection for its surrounding seas, and the Sargasso Sea initiative was born. This initial meeting was followed by further meetings involving Bermuda, international conservation agencies and marine institutions, which in turn lead to the support of funding donors and the creation of the Sargasso Sea Alliance in the autumn of 2010 (see inside back cover).

The Sargasso Sea Alliance has four over-arching aims:

- To build an international partnership to secure global recognition of the importance and ecological significance of the Sargasso Sea, the threats that it faces, and the precautionary management it needs;
- To use existing regional, sectoral and international organisations to secure a range of protective measures for the Sargasso Sea;
- To establish appropriate management for the Sargasso Sea; and
- To use the current process as an example of what can and cannot be delivered through existing frameworks in marine areas beyond national jurisdictions to inform the global debate and provide a model for protection of other High Seas regions.

The Sargasso Sea Alliance is working with Bermuda to realise these aims and win support from key governments and organizations. Success will be measured by international and public recognition of the importance of the Sargasso Sea, by approval and implementation of appropriate protection measures, and by the establishment of capacity to monitor their implementation. Underpinning these ambitions is the need for a robust science case, which, together with supporting evidence, demonstrates the importance and values of the Sargasso Sea and the reasons why improved protection and management are both necessary and urgent.

This summary science and evidence case provides the information needed to begin the political process necessary to deliver the aspirations of the Alliance and the Government of Bermuda. To assist the preparation of this summary case a number of reports were specially commissioned by the Sargasso Sea Alliance. These are identified in the text as "unpublished literature", are listed in full at the start of the reference section and are available for download at www.sargassoalliance.org

Delineating the Sargasso Sea

THE SARGASSO SEA IS AN AREA OF OPEN-OCEAN situated within the North Atlantic Subtropical Gyre, and 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. 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).

To refine this general location and to ensure that the area of interest 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 resultant map agrees broadly with the overlap of previous delineations and is shown in Figure 1. The Sargasso Sea study area occupies ~ 4,163,499 km^2 in an area extending between 22°–38°N, 76°–43°W and centred on 30°N and 60°W.

Because the Canary current is more diffuse and variable than the other currents the eastern boundary is more ill-defined, so the eastern boundary of the Sargasso Sea is 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 EEZs of all adjacent countries except for Bermuda.

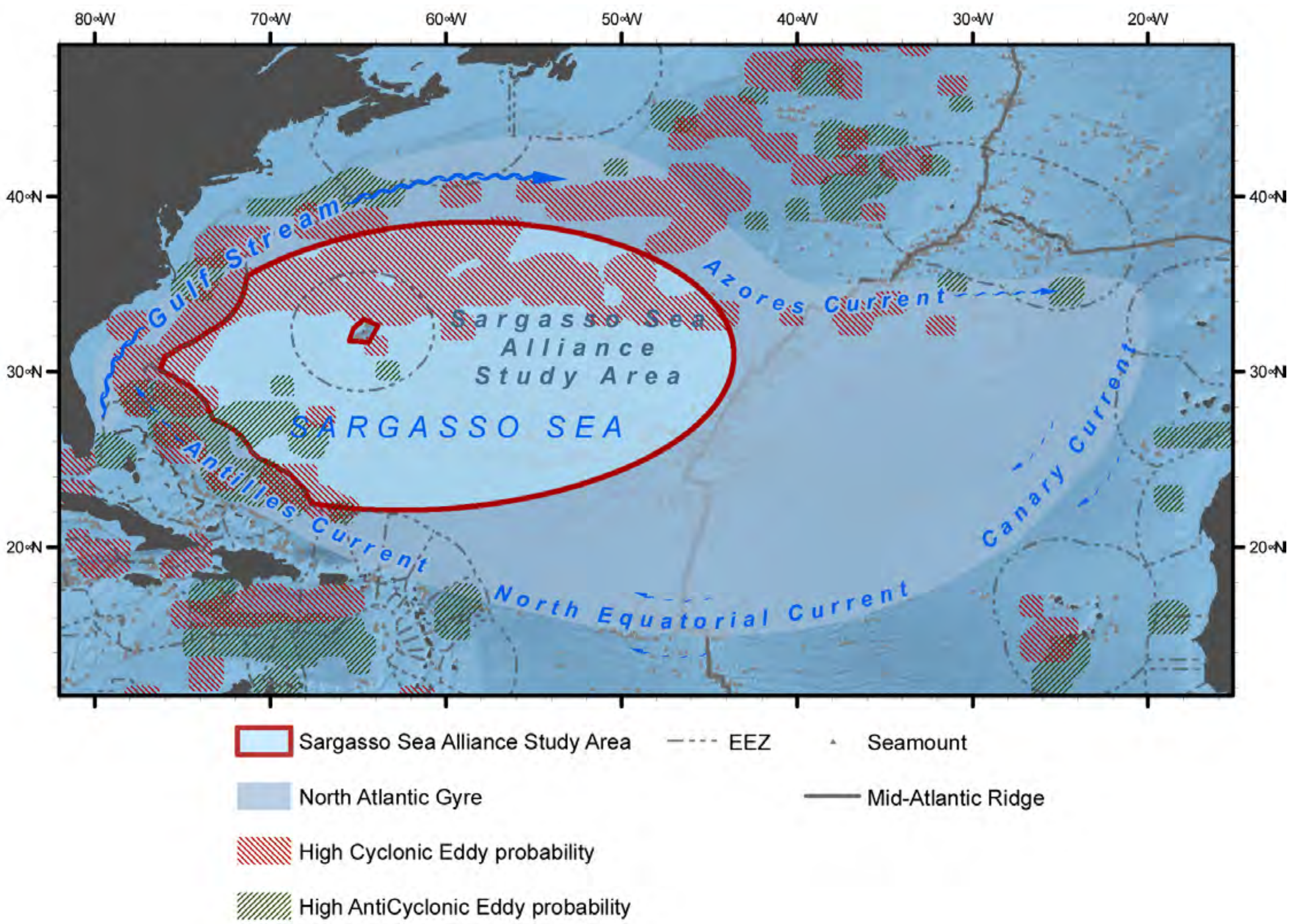


FIGURE 1. The Sargasso Sea Alliance study area including some of the major features that influence overall boundary definition and location. The line around Bermuda represents the innermost boundary of the study area marking the start of the Bermuda rise. *Credit:* Ardron *et al*. 2011, unpublished.

The Science and Evidence for Protection and Management

THE SCIENTIFIC CASE FOR PROTECTION of the Sargasso Sea lies in three interdependent areas: i) the ecosystem based upon the floating *Sargassum*, ii) the importance of the area as a cross-road in the Atlantic for species coming to it to feed, spawn and find protection amidst the mats before moving through it, and iii) its importance for local and global research and monitoring. In addition there are vital cultural and socio-economic considerations and threats, both existing and potential. Together these combine to make nine compelling reasons for recognition, protection and better management of the Sargasso Sea throughout its extent. These reasons are summarised in Table 1 and each is discussed in more detail in the following sections.

The Sargasso Sea is.....

1. ...an area of open ocean that has fascinated people for centuries and a key part of Bermuda's rich cultural maritime history and heritage.

2. ...a place of great beauty and ecological value, a golden floating forest in the surface waters of the North Atlantic.

3. ...of great biological importance as a place that provides essential habitats for nurturing many iconic marine species.

4. ...of global importance as the breeding location for endangered eel species from the USA, Canada, Europe and North Africa.

5. ... within a large ocean gyre bounded by major ocean currents that concentrate *Sargassum* and pollutants and having characteristic eddies and fronts that impact productivity and biodiversity.

6. ... an important functional part of the world ocean.

7. ... fundamentally and globally important as an area for scientific research and ocean monitoring, hosting the world's longest continuous open ocean time series.

8. ...economically important, contributing significantly to the economies of Bermuda and other countries throughout the region.

9. ...threatened and in need of precautionary management.

TABLE 1. Nine key reasons supporting the case for protection and improved management of the Sargasso Sea.

1

The Sargasso Sea is… an area of open ocean that has fascinated people for centuries and a key part of Bermuda's rich cultural maritime history and heritage ranging from legends of the Sargasso Sea as a place of mystery (The Bermuda Triangle), frustrating challenges (the 'doldrums' becalming sailors for weeks), and unfounded fears (great mats of weed trapping ships); through to Sargassum sweeping up onto the beaches, and the productivity that the Sargasso Sea confers on Bermuda and surrounding countries.

Floating *Sargassum* (figure 2) characterises the Sargasso Sea, and its name is derived either from early Portuguese sailors who compared the weed and its air-filled clusters of bladders to grapes, or from the Spanish word "sargazzo" meaning kelp. Christopher Columbus is credited with the first written account when he encountered *Sargassum* in 1492, and it was his sailors who created the early myths and legends. Columbus's ship the 'Santa Maria' became becalmed with her sister ships for three days, and because sailors recognised seaweed as a sign of shallow waters they became fearful of running aground, becoming entangled in the weed and being dragged down to the ocean floor. Columbus wrote that the windless calms (the doldrums) that they endured in the Sargasso Sea could even prevent them from returning to Spain. Such fears became entrenched in Sargasso Sea lore for centuries (Adams 1907, Deacon 1942).

In the late 19th century Jules Verne wrote in "Twenty Thousand Leagues under the Sea" (Verne and Miller 1966) "This second arm – it is rather a collar than an arm – surrounds with its circles of warm water that portion of the cold, quiet, immovable ocean called the Sargasso Sea, a perfect lake in the open Atlantic: it takes no less than three years for the great current to pass round it. Such was the region the "*Nautilus*" was now visiting, a perfect meadow, a close carpet of seaweed, *fucus*, and tropical berries, so thick and so compact that the stem of a vessel could hardly tear its way through it. And Captain Nemo, not wishing to entangle his crew in this herbaceous mass, kept some yards beneath the surface of the waves".

Further notoriety followed by association with the infamous Bermuda Triangle, the southwest area of the Sargasso Sea between Bermuda, Florida and Puerto Rico, where planes and ships apparently suddenly disappeared for no obvious reason. These rumours revived myths about portions of the Atlantic Ocean thought to be overrun by ensnaring seaweeds (Dixon 1925, Gordon 1941) and helped paint a vivid (and inaccurate!) picture of this part

FIGURE 2. The Sargasso Sea is characterised by floating mats of *Sargassum* seaweed that not only provide a 'floating golden rainforest' habitat for many species but is also the source of myths and legends across the centuries. *Photo credit:* P. Rouja.

FIGURE 3. ***Sargassum*** **cast up on the beach by waves and tides provides food and a habitat for seashore species, promotes the development of sand dunes and also provides an occasional source of fertiliser for fields inland.** ***Photo Credit:*** **S. R. Smith**

of the ocean. Disney somewhat redressed these fears with his adventures of Donald Duck in the "Secrets of the Sargasso Sea" in the 1960s (**http://www.comics.org/issue/15744/**) but the Sargasso Sea continues to engage and intrigue and has become synonymous with ocean mysteries and legends.

Ever since the '*Sea Venture*' was wrecked on the shores of Bermuda by a hurricane in 1609, starting the settlement of Bermuda, the Sargasso Sea has shaped the lives of Bermudians. The presence of *Sargassum*, both near-shore and on the beaches, is a regular reminder of the close ties to the ocean and to the productivity that results from this.

Sargassum is carried inshore mostly during the winter months between November and April (Butler, Morris, Cadwallader, and Stoner 1983). When this happens reef fish feed on the organisms within it. Sunken *Sargassum* is an important food source for species such as the endemic Bream (*Diplodus bermudensis*) (Hallett 2011, unpublished). When it is washed up on shore (**FIGURE 3**), the weed provides food and habitat for intertidal organisms, which in turn are food for shorebirds and shore scavengers; and decomposing *Sargassum* adds nutrients to coastal soils and sediments, thereby promoting the growth of dune plants (Thomas 2004). Similarly washed up *Sargassum* is used as a fertiliser by local farmers. Decomposing *Sargassum* on the beach smells and in some people's view creates a nuisance (Feagin and Williams 2008), but it is critical for stabilizing the shoreline by cementing the sand grains together. This creates dunes, which prevent the movement of sand, and decrease erosion during storm activity (Thomas 2004). In this way *Sargassum* has helped shape the island of Bermuda.

Early settlers in Bermuda were heavily dependent on the ocean and its resources. Turtles were over-exploited to such an extent that the species no longer nest on Bermuda and local populations remain very low. Endemic Bermuda petrels (*Pterodroma cahow*) were similarly targeted (Hallett 2011, unpublished). In the 19th century, whaling for humpbacks and, to a lesser extent, sperm whales was an important industry and whale oil was exported to Britain and the Caribbean, until competition from US whalers ended the trade (Romero 2008).

Bermudians have always fished. Inshore fish that are targeted include groupers (Serranidae), parrotfish (Scaridae), grunts (Haemulidae), snappers (Lutjanidae), jacks (Carangidae), and triggerfish (Balistidae). Some of these inshore species, e.g. triggerfish and jacks, depend upon the *Sargassum* ecosystem as both juveniles and adults, and *Sargassum* rafts are likely to help seed the local population of fishes as the weed drifts into Bermuda's EEZ and inshore waters (Hallett 2011, unpublished).

2

The Sargasso Sea is…a place of great beauty and ecological value, a golden floating forest in the surface waters of the North Atlantic – an oasis of marine life and the only sea without shores – containing species that are endemic to *Sargassum* and many others that are specially adapted for life amongst the floating canopy.

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, while acting as a nursery and feeding area for many species, and a migration route for others. It is a vital habitat for many species of economic importance to Bermuda and countries on both sides of the Atlantic – the Sargasso Sea is truly a 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 (**FIGURE 4**); *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, Gower and King 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 1**) 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, Settle, Hoss, and Cross 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 2005) 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

FIGURE 4. Two species of floating *Sargassum* seaweed make up the Sargasso Sea: *S. fluitans* (left) has large lanceolate leaves, whereas the smaller and finer *S. natans* (right) has a delicate fine leaf structure. *Photo credit:* J. R. Rooker.

FIGURE 5. **One of the most voracious predators, endemic to the *Sargassum* habitat, is the Sargassum Angler Fish (*Histrio histrio*), which has both camouflage and modified fins which it uses to creep around the weed while waiting for passing prey. *Photo credit:* David Shale.**

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 (*Histrio histrio*) (**FIGURE 5**), 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, McKenna, Pitt, Hemphill, Ming, Rouja, Gjerde, Causey, and Earle 2011).

In addition to the endemics 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). The *Sargassum* weed provides a habitat and for some invertebrates and juvenile fish a food source (Rooker, Turner and Holt 2006), and the fauna living within the *Sargassum* 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 (see sections 4 and 5).

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 (National Marine Fisheries Service 2003). ICCAT has also recognised 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 2011a). This is one of the first actions by ICCAT to address fish habitat.

3

The Sargasso Sea is… of great biological importance as a place that provides essential habitats for nurturing many iconic marine species such as the endemic Bermuda Petrel (the cahow), whales, tunas, swordfish and marlin. It is the place where turtles spend their 'lost years' using the *Sargassum* as a safe refuge within which to grow, and it is a breeding, nursery and feeding environment for a wide array of species occupying different ecological niches ranging from the sea surface to the ocean depths.

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. Fish living within the *Sargassum* canopy include juvenile swordfish (*Xiphius 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).

FIGURE 6. *Sargassum* provides a valuable habitat for many species including flying fish, which build bubble nests in its fronds. Long filaments on the eggs keep these attached to the weed. *Photo credit:* JP Rouja.

Oceanic fish that spawn in the *Sargassum* include flying fish (Exocoetidae) that build bubble nests for their eggs within the weed (**FIGURE 6**) 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). Wells and Rooker (2004) reported juveniles and larvae of ca 36 species of fish from *Sargassum* mats in the NW Gulf of Mexico. 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). The latter are considered in more detail in section 4.

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 –1000 m (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 500 m from Canadian waters to the Sargasso Sea where they may be pupping (Dulvy, Baum, Clarke,

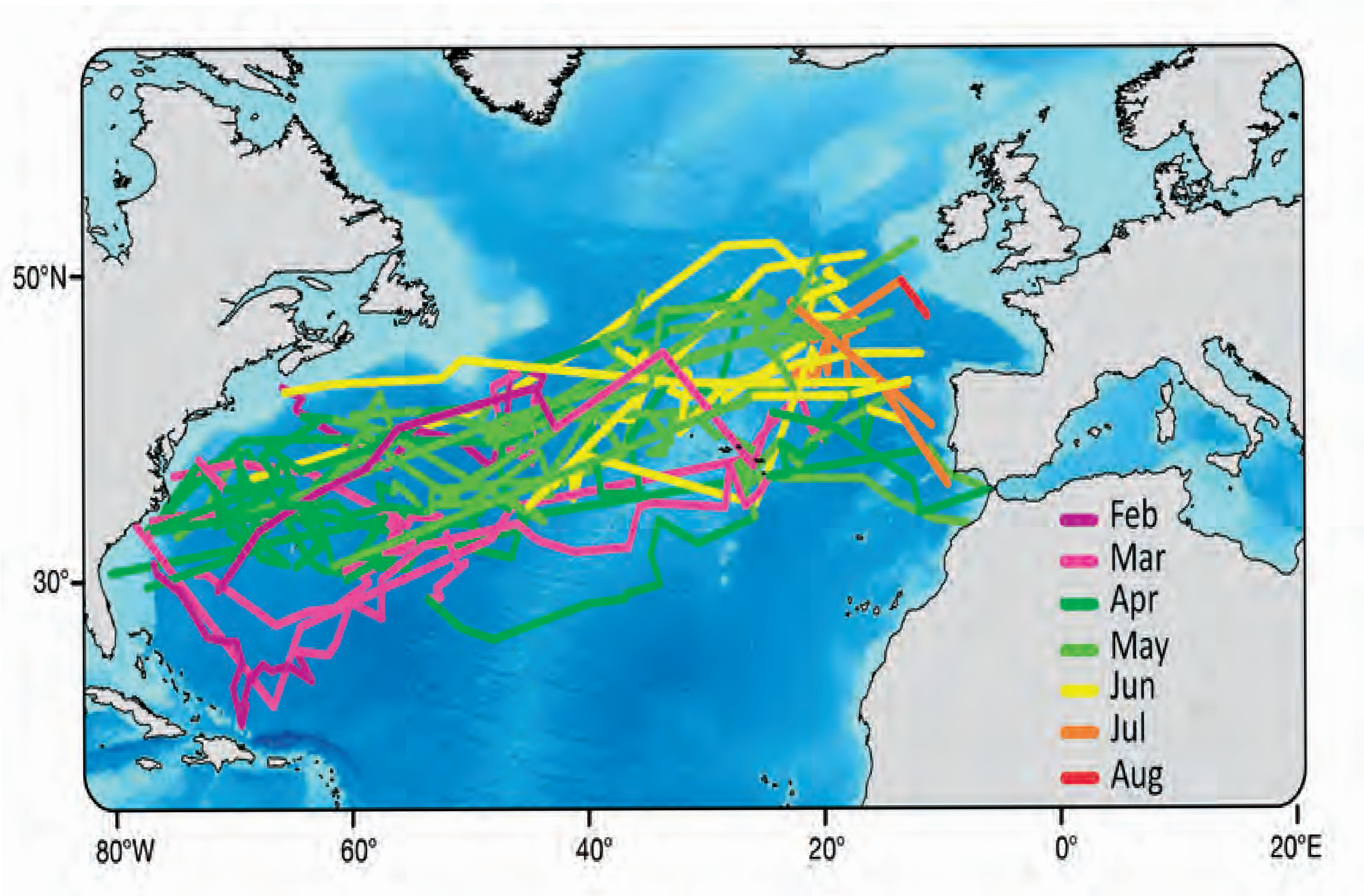


FIGURE 7. Transatlantic routes taken by tagged bluefin tuna moving from west to east. ***Credit:*** **Wilson and Block (2009).**

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) (**FIGURE 7**). 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.

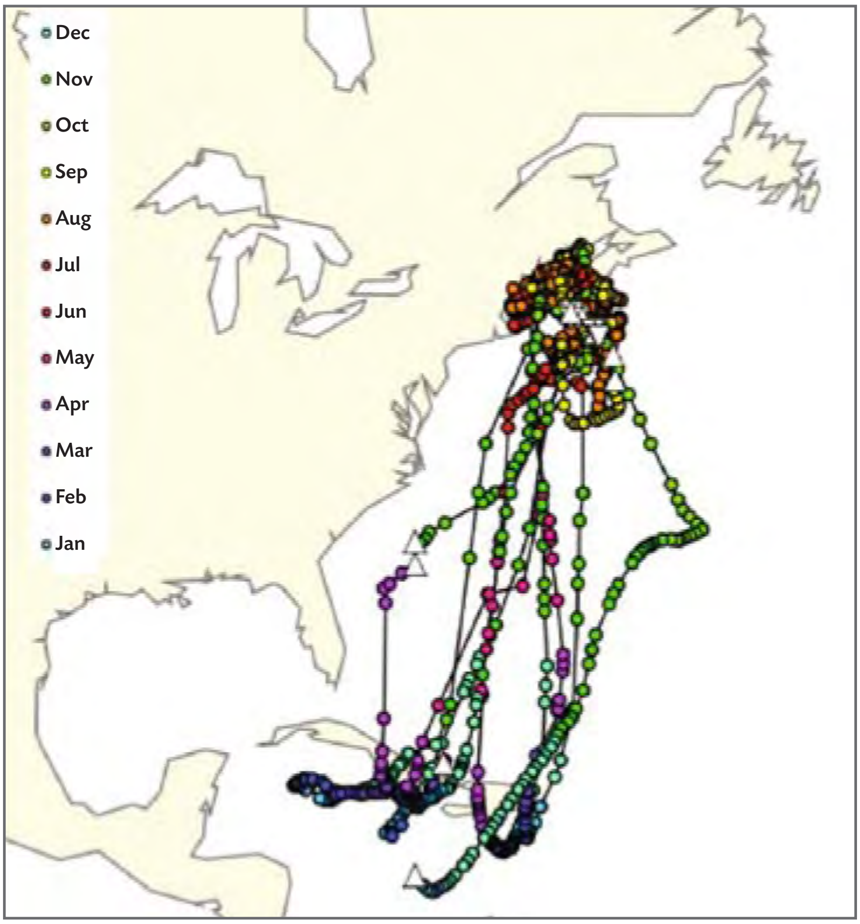
Several other tuna species, including yellowfin (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*), also move to the Sargasso Sea, and further west into coastal U.S. waters, from spawning grounds in the eastern tropical Atlantic (ICCAT 2010). Yellowfin tuna appear to migrating through the Sargasso 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 2011b).

The Sargasso Sea is also important habitat for Atlantic swordfish (*Xiphias gladius*). Commercial catches of swordfish in the West 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 (**FIGURE 8**).

While in the Sargasso Sea, swordfish make diurnal vertical movements spanning at least 1,000 m (Loefer, Sedberry and McGovern 2007, **FIGURE 9**). These vertical migrations mirror the behaviour of mesopelagic fishes that are found in surface waters during the night and at depths of 500–1500 m 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 (**FIGURE 10**). 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 (**FIGURE 11**) (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).

FIGURE 8. Estimated movements of swordfish from satellite tags deployed in 2005 and 2006, colour-coded by month. Upward triangle symbols denote the point of release, and downward triangles denote the location of the first transmission after pop-off for each tagged swordfish. *Credit:* Neilson *et al*. (2009).



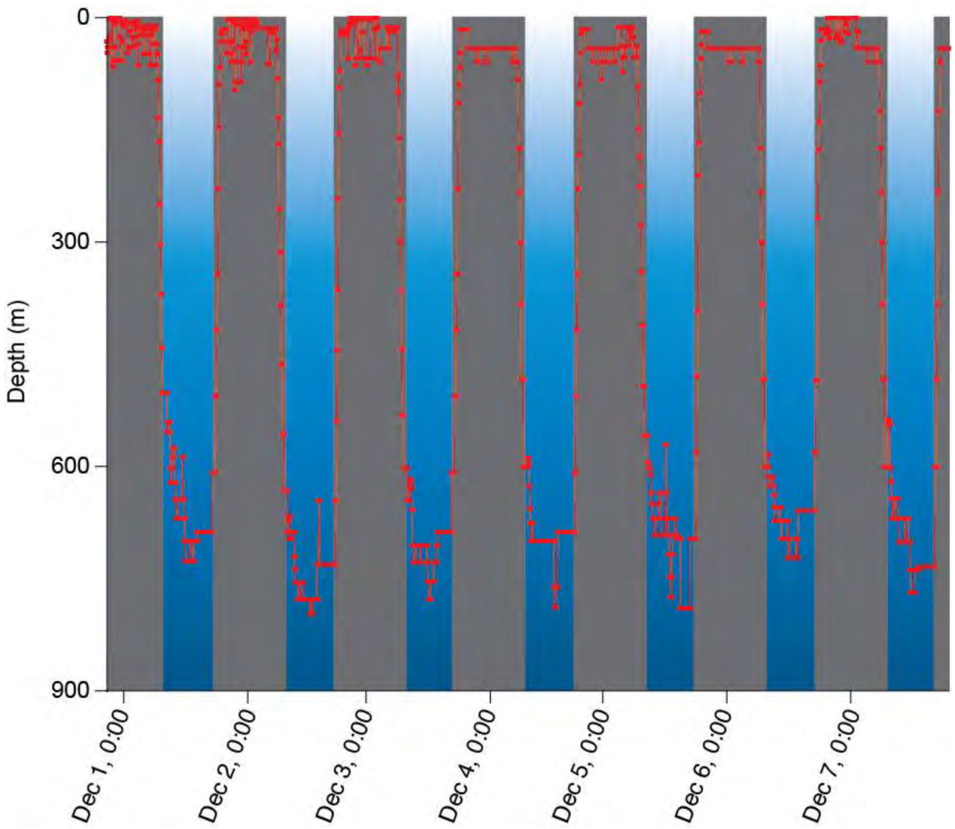


FIGURE 9. Diel vertical migration of a swordfish, tagged in 2010 in the southern Sargasso Sea, from surface waters <50 m during the night (grey vertical bars) to depths of over 800 m during daylight hours (blue vertical bars). *Credit:* Thorrold and Skomal (unpublished data).

FIGURE 10. Loggerhead turtles use Sargassum as a nursery habitat during their 'lost years'. *Photo credit:* Masa Ushioda/ imagequestmarine.com

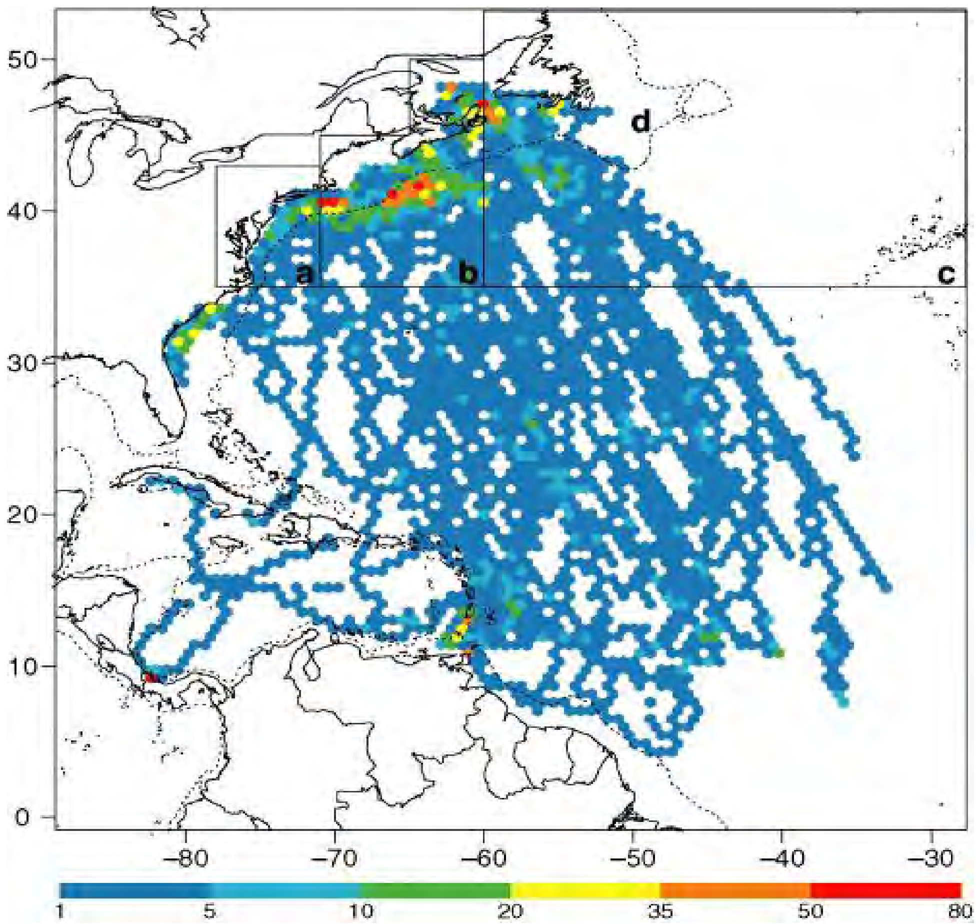


FIGURE 11. Spatial use by 38 leatherback turtles tagged with satellite tags off the coast of Nova Scotia. Colours represent number of days turtles were within each hexagon. *Credit:* James *et al*. 2005.

FIGURE 12. **Humpbacks are a frequent visitor to Bermuda on their long ocean migrations, perhaps using the surrounding waters as a staging post before heading further north.** ***Photo credit:*** **A. Stevenson.**

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*, **FIGURE 12**) that pass through the Sargasso Sea during their annual migrations (**FIGURE 13**) 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.

Bermudian waters may have been a breeding ground for humpback whales in former times and are possibly being re-occupied as the population of humpbacks recovers from previous exploitation (Stevenson 2011, unpublished,

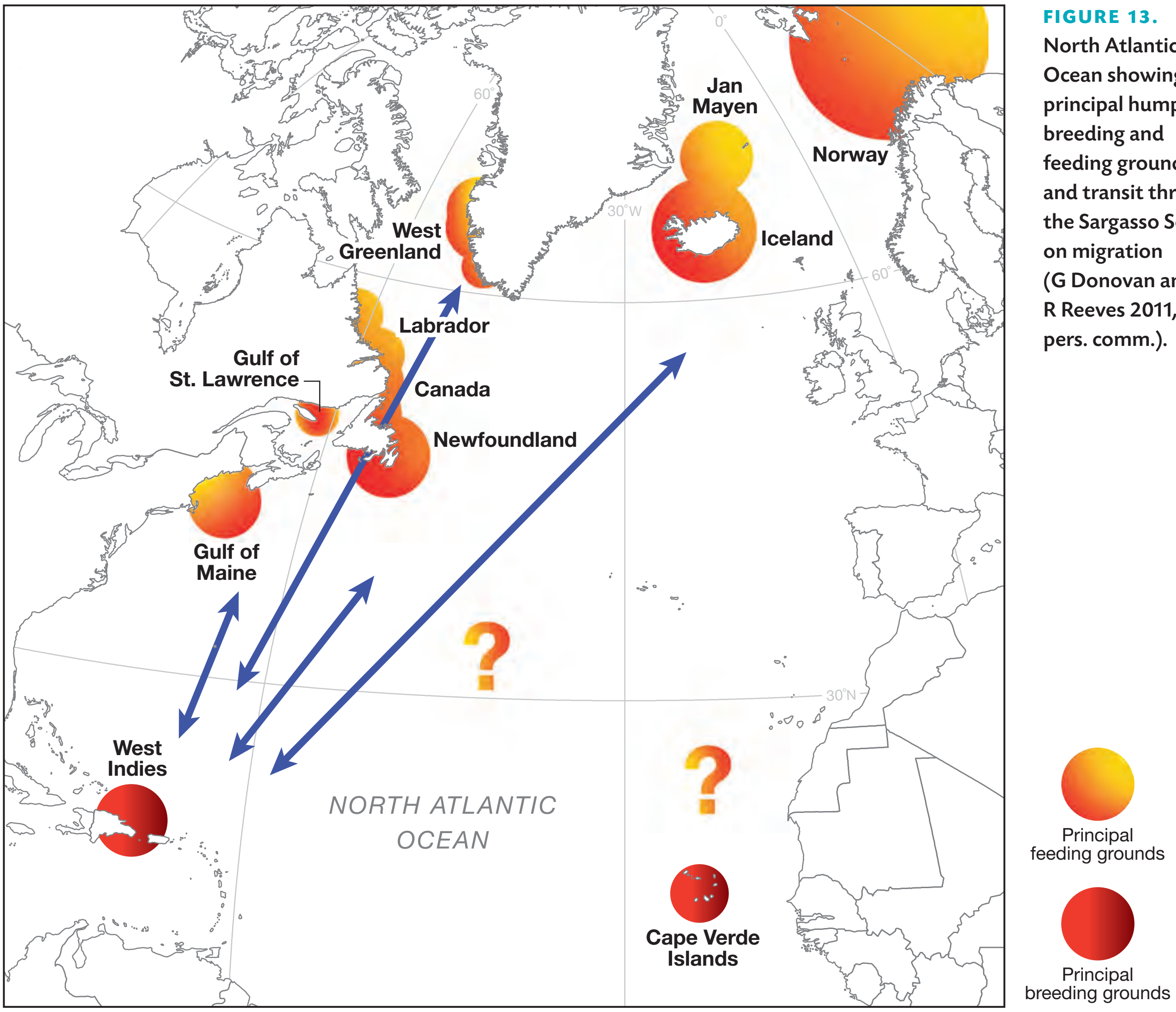


FIGURE 13. **North Atlantic Ocean showing principal humpback breeding and feeding grounds and transit through the Sargasso Sea on migration (G Donovan and R Reeves 2011, pers. comm.).**

FIGURE 12). Humpbacks are believed to use Bermuda as a way point on their migrations and perhaps they also use the mid-ocean seamounts in the Sargasso Sea as feeding and aggregation sites before heading north (Stevenson 2011, unpublished).

Humpbacks support a growing whale watching industry in Bermuda (Stone, Katona and Tucker 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 National Marine Sanctuary off the east coast of the USA (Stevenson 2011, unpublished). The importance of this connectivity (FIGURE 13) was recognised in 2011 by the signing of a collaboration arrangement between the Government of Bermuda and the Stellwagen Bank National Marine Sanctuary. Some of these individuals have also been reported further south at the Marine Mammal Sanctuary–Banco de la Plata y Banco de la Navidad off the Dominican Republic (Omar Reynoso pers. comm. **http://www.intec.edu.do/ballenas**).

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).

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.

FIGURE 14. The endangered endemic Bermuda petrel nests on Bermuda and travels throughout the Sargasso Sea and beyond. *Photo credit:* A. Dobson.

Further offshore the diversity of bird species is lower and this is reflected in Table 2 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 (FIGURE 14), protected under Appendix 1 of the Convention on Migratory Species (**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).

Black-capped Petrel *(Pterodroma hasitata)*
Cory's Shearwater *(Calonectris diomedea)*
Greater Shearwater *(Puffinus gravis)*
Audubon's Shearwater *(Puffinus lherminieri)*
Wilson's Storm-Petrel *(Oceanites oceanicus)*
Leach's Storm-Petrel *(Oceanodroma leucorhoa)*
Sooty Shearwater *(Puffinus griseus)*
White-tailed Tropicbird *(Phaethon lepturus)*
Red-billed Tropicbird *(Phaethon aethereus)*
Masked Booby *(Sula dactylatra)*
Brown Booby *(Sula leucogaster)*
Red-necked Phalarope *(Phalaropus lobatus)*
Red Phalarope *(Phalaropus fulicaria)*
Pomarine Jaeger *(Stercorarius pomarinus)*
Parasitic Jaeger *(Stercorarius parasiticus)*
Long-tailed Jaeger *(Stercorarius longicaudis)*
Herring Gull *(Larus argentatus)*
Royal Tern *(Sterna maxima)*
Common Tern *(Sterna hirundo)*
Arctic Tern *(Sterna paradisaea)*
Least Tern *(Sterna antillarum)*
Bridled Tern *(Sterna anaethetus)*
Sooty Tern *(Sterna fuscata)*

TABLE 2. Seabird species known to be associated with Sargassum and the Sargasso Sea (composite list developed from Haney 1986 & Thomas 2005).

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 **TABLE 3**). They also feature in the annexes of 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**) (**TABLE 4**). Although the geographic area of the Protocol does not extend directly to the Sargasso Sea, this protocol requires 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 in the depths below.

SPECIES	COMMON NAME	IUCN STATUS	CITES STATUS
Megaptera novaeangliae	**Humpback Whale**	**n/a**	Appendix 1
Physeter macrocephalus	**Sperm whale**	**Vulnerable**	Appendix 1
Thunnus thynnus	**Bluefin Tuna**	**Endangered**	Not listed
T. albacores	**Yellowfin Tuna**	**Near Threatened**	Not listed
T. alalunga	**Albacore Tuna**	**Near Threatened**	Not listed
T. obesus	**Bigeye Tuna**	**Vulnerable**	Not listed
Makaira nigricans	**Blue Marlin**	**Near Threatened**	Not listed
Tetrapterus albidus	**White Marlin**	**Near Threatened**	Not listed
Anguilla anguilla	**European Eel**	**Critically Endangered**	Appendix 2
Rhincodon typus	**Whale Shark**	**Vulnerable**	Appendix 2
Cetorhinus maximus	**Basking Shark**	**Vulnerable**	Appendix 2
Carcharodon carcharius	**White Shark**	**Vulnerable**	Appendix 2
Carcharhinus longimanus	**Oceanic Whitetip Shark**	**Vulnerable**	Not listed
Carcharhinus falciformis	**Silky Shark**	**Near Threatened**	Not listed
Carcharinus galapagensis	**Galapagos Shark**	**Near Threatened**	Not Listed
Lamna nasus	**Porbeagle Shark**	**Vulnerable**	Not listed
Isurus oxyrinchus	**Shortfin Mako Shark**	**Vulnerable**	Not listed
Prionace glauca	**Blue Shark**	**Near Threatened**	Not listed
Sphyrna lewini	**Scalloped Hammerhead**	**Endangered**	Not listed
Galeocerdo cuvier	**Tiger Shark**	**Near Threatened**	Not listed
Caretta caretta	**Loggerhead turtle**	**Endangered**	Appendix 1
Chelonia mydas	**Green turtle**	**Endangered**	Appendix 1
Eretmochelys imbricata	**Hawksbill turtle**	**Critically Endangered**	Appendix 1
Lepidochelys kempi	**Kemp's Ridley turtle**	**Critically Endangered**	Appendix 1
Dermochelys coriacea	**Leatherback turtle**	**Critically Endangered**	Appendix 1
Pterodroma cahow	**Cahow**	**Endangered**	Not listed

TABLE 3. 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.

SPECIES	COMMON NAME	SPAW STATUS
Puffinus lherminieri	**Audubon's shearwater**	Annex II (Article 11(1)(b))
Cetacea – all spp.	**Whales and dolphins**	Annex II (Article 11(1)(b))
Caretta caretta	**Loggerhead turtle**	Annex II (Article 11(1)(b))
Chelonia mydas	**Green turtle**	Annex II (Article 11(1)(b))
Eretmochelys imbricate	**Hawksbill turtle**	Annex II (Article 11(1)(b))
Lepidochelys kempi	**Kemp's Ridley turtle**	Annex II (Article 11(1)(b))
Dermochelys coriacea	**Leatherback turtle**	Annex II (Article 11(1)(b))
Phaethon lepturus	**White-tailed Tropicbird**	For inclusion in Annex II
Phaethon aethereus	**Red-billed Tropicbird**	For inclusion in Annex II
Sula dactylatra	**Masked Booby**	For inclusion in Annex II
Sula leucogaster	**Brown Booby**	For inclusion in Annex II
Sterna maxima	**Royal Tern**	For inclusion in Annex II
Sterna hirundo	**Common Tern**	For inclusion in Annex II
Sterna anaethetus	**Bridled Tern**	For inclusion in Annex II
Sterna fuscata	**Sooty Tern**	For inclusion in Annex II
Milleporidae – all spp.	**Fire corals**	Annex II (Article 11(1)(c))
Antipatharia – all spp.	**Black corals**	Annex II (Article 11(1)(c))
Gorgoniacea – all spp.	**Sea whips and sea fans**	Annex II (Article 11(1)(c))
Scleractinia – all spp.	**Stony corals**	Annex II (Article 11(1)(c))

TABLE 4. 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.

4

The Sargasso Sea is...of global importance as the breeding location for endangered eel species from the USA, Canada, Europe and North Africa which have suffered declines of up to 99% in parts of their adult range. How and precisely where eels breed within the Sargasso Sea remains a mystery, so protection of the Sargasso Sea spawning area is very important. Protection here will complete the protection of the life-cycle of these important species and will complement existing eel recovery plans within Europe, the USA and Canada.

FIGURE 15. An adult European eel *Anguilla anguilla*. European eels spend their adult lives in freshwater and migrate thousands of miles to the Sargasso Sea to spawn. *Photo credit:* David Curnick.

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* (**FIGURE 15**). 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 100 m of the water column (**FIGURE 16**).

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

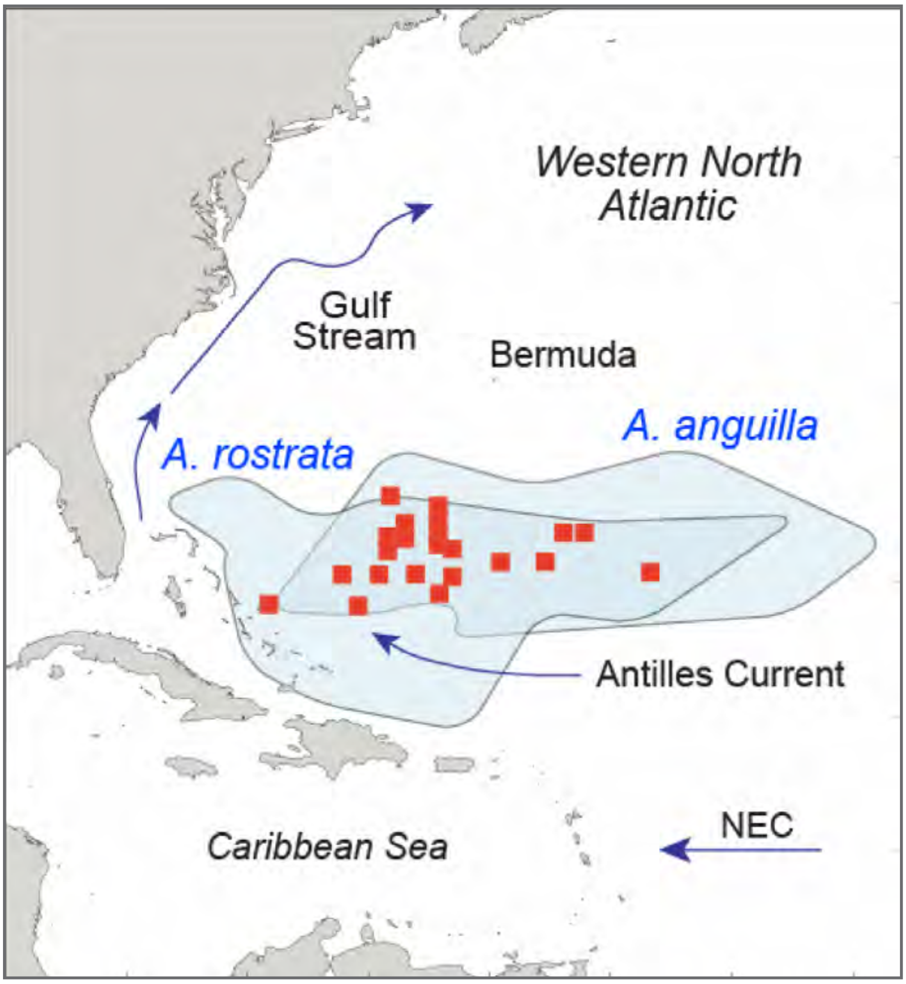


FIGURE 16. The two light blue areas are the overlapping spawning grounds of the two Atlantic eel species in the Southern Sargasso Sea based on the distributions of their small leptocephali (10 mm). Red squares indicate stations where small recently hatched larvae 7 mm or smaller of both species were collected together. *Credit:* Miller and Hanel 2011 unpublished, adapted from McCleave, Kleckner and Castonguay (1987).

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.

5

The Sargasso Sea is...within a large ocean gyre bounded by major currents that concentrate *Sargassum* and pollutants and has characteristic eddies and fronts that impact productivity and biodiversity. Beneath the gyre water depths vary down to around 4500 m, and the seabed features both abyssal plains and shallow seamounts.

THE SARGASSO SEA LIES WITHIN THE SUB-TROPICAL NORTH Atlantic gyre; such gyres cover ca 65% of the ocean surface. The encircling currents of the Sargasso Sea (**FIGURE 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 17** 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 – having diameters ranging from tens to hundreds of kilometers and 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 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 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. Other organisms also accumulate there, so the fronts are likely important feeding areas for predatory fishes and 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 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).

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 4500 m and is populated throughout by deep ocean animals. *Sargassum*, once it sinks, contributes to the food webs of these deepwater communities and provides up to 10% of the energy inputs to communities living on the sea-floor (Schoener and Rowe 1970, Rowe and Staresinic 1979 – in Angel and Boxshall 1990, Butler *et al* 1983). General accounts of deep-sea animals, 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-sea Sargasso fauna conforms to these accounts.

The Sargasso Sea has been sampled intensively by deep-sea biologists and oceanographers for over a century

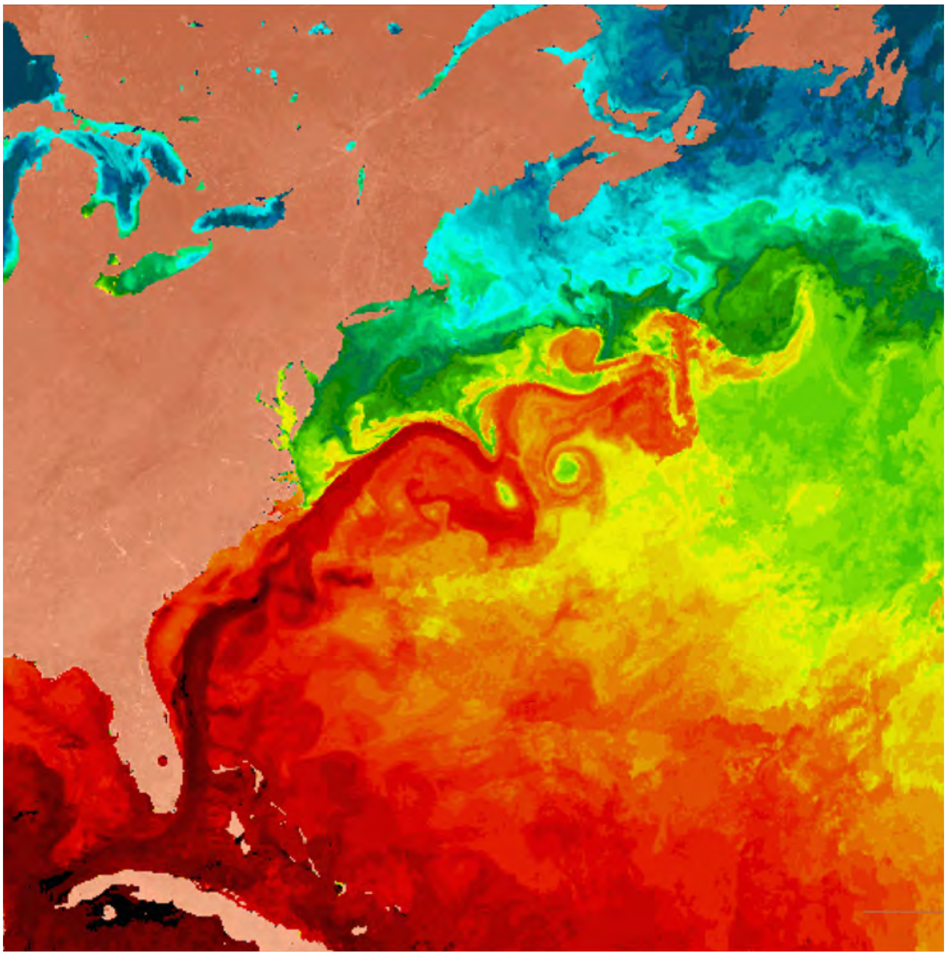


FIGURE 17. **Satellite Image of sea surface temperature showing the Gulf Stream and large rings and eddies. Red areas are warm; blue areas are cool. *Credit:* Talley 2000.**

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 that has been 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, more detailed studies show that there might be subtle differences in species composition and distribution. Porteiro (2005) found a suite of sub-tropical endemic deep-sea fish species in the northern Sargasso Sea within the Stomiatoid genera *Eustomias*, *Photonectes* and *Bathyphilus* and concluded that the area had higher levels of endemicity for this group than in other north Atlantic biogeographic provinces. 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 2000 m 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. Both stomiatoid fish and ostracods are likely to be an indicator of how little is known about the midwater inhabitants living at great depths.

The seabed and underlying geology of the Sargasso Sea 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 2000 m water depth, descends gently into parts of the Hatteras, Nares and Sohm abyssal plains, with depths reaching over 4500 m, before shallowing progressively towards the Mid Atlantic Ridge where the water depth is less than 2500 m. 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 Rise 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, DIvens 2011, Parson and Edwards 2011, unpublished) Potential mineral resources in the area include polymetallic sulphides, manganese nodules and cobalt-rich crust, hydrocarbons and gas hydrates (see Section 9).

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**). 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 Rise Seamounts (**FIGURE 18**). The latter have peaks rising as much as 4000 m 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. Benthic diversity is very high on the Corner Rise and New England Seamount chains where some 670 species have been found including numerous endemic and new species of corals which in turn host specific commensal invertebrates (Watling 2007, Watling *et al* 2007, Cho 2008, Shank 2010, Simpson and Watling 2011, Pante and Watling 2011, ICES 2011). 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 decadactylus*).

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 1,300 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 80 m (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).

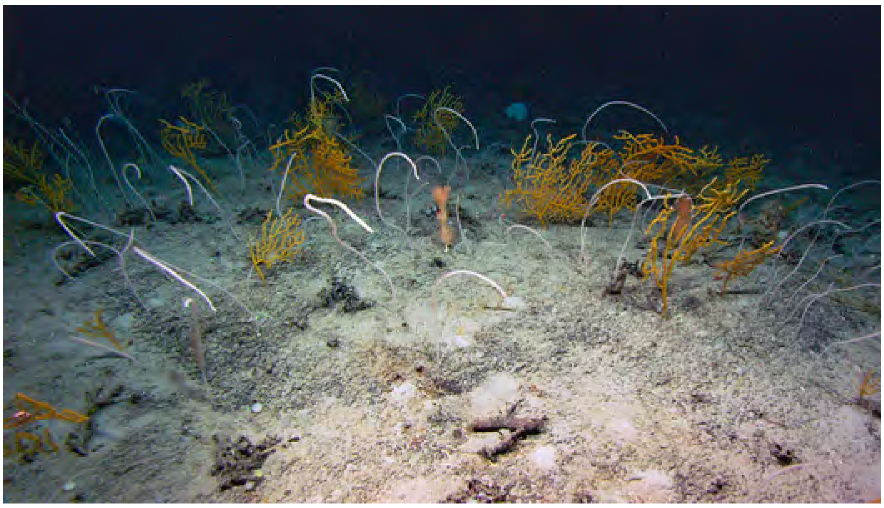


FIGURE 18. The Corner Rise Seamount has peaks rising some 4000 m from the deep seabed that support a complex sponge and coral community harbouring many species, some of which are found now where else in the world ocean. *Photo credit:* Peter Auster.

6

The Sargasso Sea is...an important functional part of the world ocean, having some of the highest primary productivity in the world and a key area for carbon sequestration into the ocean, thereby playing a major role in the global carbon cycle.

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, 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, Steinberg, Dickey, Carlson, Nelson, Condon, and Bates 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 Drifjhout 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 2011b, unpublished) and 18 – 58% of the annual North Atlantic carbon sink estimated over the period 1992 – 2006 (Ullman, McKinley, Bennington and Dutkiewicz 2009).

7

The Sargasso Sea is...fundamentally and globally important as an area for scientific research and ocean monitoring, hosting the world's longest continuous open ocean time series.

For well over a century the Sargasso Sea has been the venue for many pivotal moments in ocean exploration and discovery. The beginning of modern oceanography was the voyage of HMS *Challenger* between 1872–1876. It was during this voyage that some of the earliest quantitative investigations into Bermuda's marine environment, including observations on *Sargassum*, were made (Murray 1895).

In 1932 William Beebe and Otis Barton made the first *in situ* observations of deep-sea animals from their bathysphere off Bermuda (**FIGURE 19**), and also made the first live radio broadcasts from the deep ocean (Cullen 2006). Between 1959 and 1960 John Swallow deployed his neutrally buoyant floats (the fore-runner to the current ARGO float programme) to discover ocean eddies, the 'weather' of the ocean (Swallow 1971). Eddy dynamics and their effects remain an active research field in the Sargasso Sea as they are so characteristic of the area (see previous Sections), and understanding ocean variability at the mesoscale is essential for developing realistic models of the ways the ocean works. More recently, in the late 1980s, Chisholm, Olson, Zettler, Waterbury, Goericke and Welschmeyer (1988) revolutionised our concept of the global oxygen cycle with their discovery of the tiny (100 times smaller than the thickness of a human hair) chlorophyll-containing bacteria *Prochlorococcus* – the most abundant photosynthetic organism on earth which accounts for an estimated 20% of oxygen in the atmosphere.

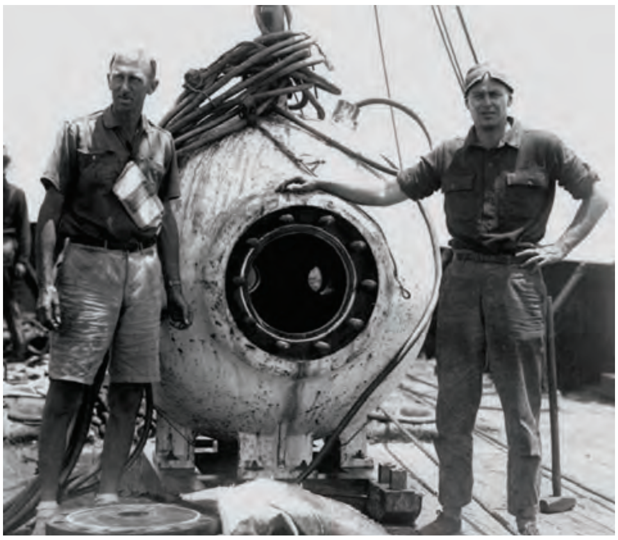


FIGURE 19. **William Beebe (left) and Otis Barton (right) with the bathysphere in Bermuda in 1932.** ***Photo credit:*** **Wikimedia Commons http://en.wikipedia.org/wiki/File:WCS_Beebe_Barton_600.jpg**

Alongside these discoveries, and of huge and continuing significance to oceanography and global science, is the time series of ocean measurements started in 1954 at 'Hydrostation S' by Henry Stommel, then at Woods Hole Oceanographic Institution, and continued to this day by scientists at the Bermuda Institute of Ocean Sciences (**FIGURE 20**). Station S and the subsequent associated measuring arrays provide the world's longest time series of measurements in the deep ocean which in turn have delivered vital understanding of the changes that have occurred in the subtropical oceans and the response of the ocean to global change. Over the past 57 years, observations at Hydrostation S have shown significant warming of the surface ocean (~0.1°C decade^{-1}) and reorganization of the global hydrological cycle shown by an increase in ocean salinity (~0.02 decade^{-1}) in the upper 300 m. Such measurements taken over a long time are critical to our understanding of global change.

The discoveries of *Prochlorococcus*, the importance of the biological pump, the surprising results of overall productivity in the Sargasso Sea and its role as a carbon sink have all come from data derived from the longest time series of measurements of ocean biogeochemistry, microbial oceanography, ocean optics and carbon export to the deep ocean that we have (Michaels 1995, Conte, Ralph and Ross 2001, Dickey, Zedler, Frye, Jannasch, Manov, Sigurdson, McNeil, Dobeck, Yu, Gilboy, Bravo, Doney, Siegel and Nelson 2001, Siegel, Nelson, O'Brien, Westberry, O'Brien and Michaels 2001, Morris, Vergin, Cho, Rappe, Carlson and Giovannoni 2005, Krause, Lomas, and Nelson 2009, Lomas *et al.* 2010, Steinberg, Lomas and Cope 2011 (In Press)). Collectively these time-series provide critical data needed to understand the time-varying fluxes and sequestration of carbon by the ocean over the last few decades. Given the changes now occurring to the global climate such long time series are critical for our understanding of such planetary processes, and for demonstrating the key role of the Sargasso Sea in these.

One such process is ocean acidification (**FIGURE 21**). Human activities have released large quantities of carbon

FIGURE 20. **Taking water samples at Hydrostation S. Started in 1954 by Henry Stommel, the world's longest time series of measurements in the deep ocean is continued to this day by scientists at the Bermuda Institute of Ocean Sciences. *Photo credit:* T. Wardman.**

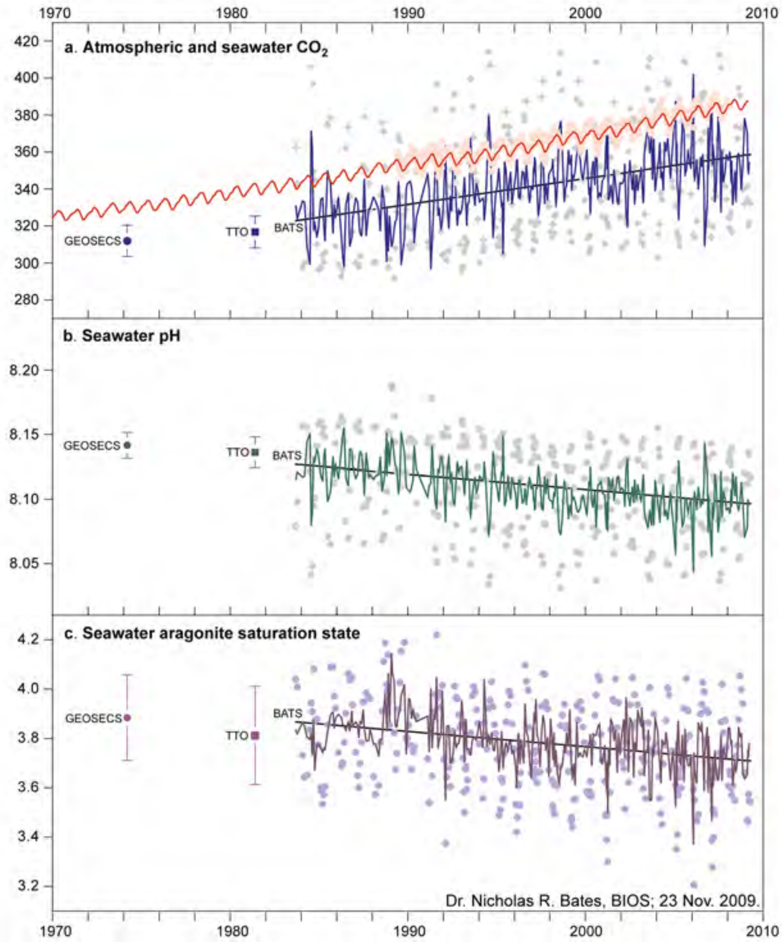


FIGURE 21. **Time series trends in atmospheric and ocean carbon dioxide, pH and aragonite saturation states. a) atmospheric CO2 from Mauna Loa (red line) and Bermuda (pink symbols) and surface ocean CO2 from BATS (purple line); b) surface ocean pH from BATS; and c) surface ocean aragonite saturation from BATS. For the surface ocean in each case the observed values are shown as dots together with the seasonally de-trended values as coloured lines. Previous data from GEOSECS and TTO expeditions are included for comparison (see Lomas *et al* 2011a).**

dioxide into the atmosphere (IPCC 1996, IPCC 2001, IPCC 2007, Sarmiento and Wofsy 1999, Wofsy and Harriss 2002), a significant amount of which has been taken up by the ocean (Quay 2002, Sabine, Feely, Gruber, Key, Lee, Bullister, Wanninkhof, Wong, Wallace, Tilbrook, Millero, Peng, Kozyr, Ono and Rios 2004) resulting in a trend towards more acidic conditions and a reduction in the availability of carbonate ions (Bates, Michaels and Knap 1996, Winn, Li, Mackenzie and Karl 1998, Bates 2007, Bates and Peters 2007, Takahashi, Sutherland, Wanninkhof, Sweeney, Feely, Chipman, Hales, Friederich, Chavez, Watson, Bakker, Schuster, Metzl, Yoshikawa-Inoue, Olafsson, Arnarson, Tilbrook, Johannessen, Olsen, Bellerby, de Baar, Nojiri, Wong, Delille and Bates 2009). Known as ocean acidification this effect is now being demonstrated by *in-situ* measurements although it was predicted to occur nearly four decades ago (Broecker and Takahashi 1966, Broecker, Li and Peng 1971, Bacastow and Keeling 1973).

Only four carbon dioxide time series are of sufficient duration to unequivocally show that ocean acidification is a reality and three of these are in the Sargasso Sea; two in the northwestern Sargasso Sea, BATS (Bermuda Atlantic Time-series Study, 31°40'N, 64°10'W, initiated in 1988) and Hydrostation S (31°50'N, 64°10'W; first sampled in 1974); whilst the third is in the Canary Current region of the northeastern Sargasso Sea, ESTOC (European Station for Time-series in the Ocean Canary Islands, 29°10'N, 15°30'W, initiated in 1994). The Intergovernmental Panel on Climate Change (IPCC) models (Prentice, Farquhar, Fasham, Goulden, Heimann, Jaramillo, Kheshgi, Quéré, Scholes and Wallace 2001) estimate that surface ocean pH will decrease by a further 0.3-0.5 units over the next century and beyond (Caldeira and Wickett 2003, Caldeira and Wickett 2005); a projected 3- to 5-fold increase in ocean acidity. These time series make the Sargasso Sea one of the most critical locations for understanding global ocean acidification and the far reaching consequences of this for the future.

To support these various Sargasso time series and complementary research, U.S. Government bodies including the National Science Foundation, NOAA, NASA, the U.S. Department of Energy as well as other research foundations have spent nearly $100M over the last fifty years. Taken together with earlier studies of marine biology, this research effort makes the Sargasso Sea one of the best studied ocean regions in the world, providing unparalleled information on a changing ocean and its responses to global issues such as climate change.

8

The Sargasso Sea is... economically important, contributing significantly to the economies of Bermuda and other countries throughout the region.

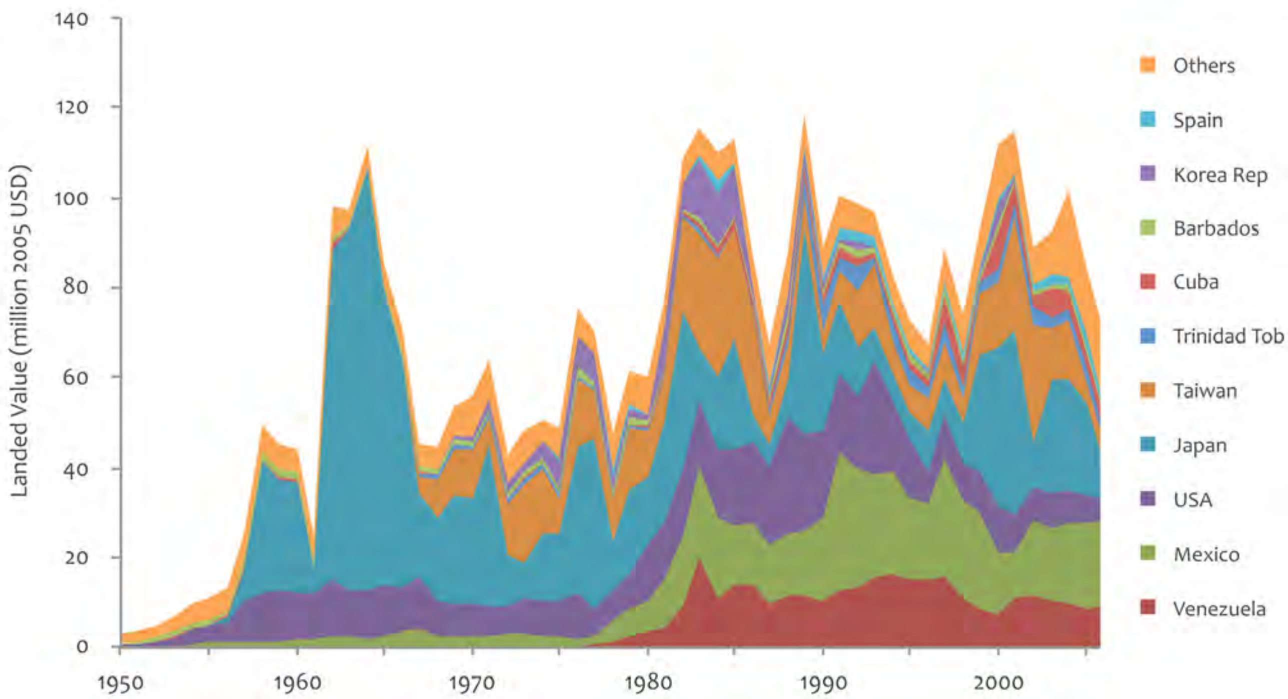


FIGURE 22. **Sargasso Sea landed values by country of commercially caught fish. *Credit:* Sumaila *et al.* 2011, unpublished.**

The economic importance of the Sargasso Sea to both local and global economies is considerable and made up of direct exploitation and indirect benefits accruing from ecosystem services.

The most obvious source of direct economic value is from fisheries. Many of the commercially important fish species caught in the Sargasso Sea are exploited by both local and international fisheries. In Bermuda pelagic species like wahoo and yellowfin tuna dominate the local commercial fishery and make up approximately half of the total annual landings valued at around US$1.5 million per annum over the past decade (Bermuda Department of Environmental Protection 2011, pers.comm).

Global fisheries data used here are taken primarily from the FAO data base supplemented by the Sea Around Us Project (**www.seaaroundus.org/**) and the methods used in subsequent analysis are described in a specially commissioned report (Sumaila, Vats and Swartz 2011, unpublished). Fish landings from the Sargasso Sea increased from the 1950 to the 1980s, and then stabilized until the early 1990s when they began to decline (**FIGURE 22**), but there are wide annual fluctuations in both catches and landed values perhaps because fishers use the Sargasso Sea as a fall back when they fail to meet their targets elsewhere. The greatest values and largest catches are taken from High Seas areas in the western Sargasso Sea with much smaller catches from the Bermuda and Bahamas EEZs (**FIGURE 23**). Taking into account the landed values, the cost of fishing and subsidies, and then using appropriate multipliers for the economic impact of the fishery, the values in terms of resource rents (the surplus after costs have been deducted from landing value), household income and economic impact generated directed or indirectly by fisheries from the Sargasso Sea are, respectively, $36 million, $50 million and $171 million per year based on 2005 figures (Sumaila *et al*, 2011, unpublished).

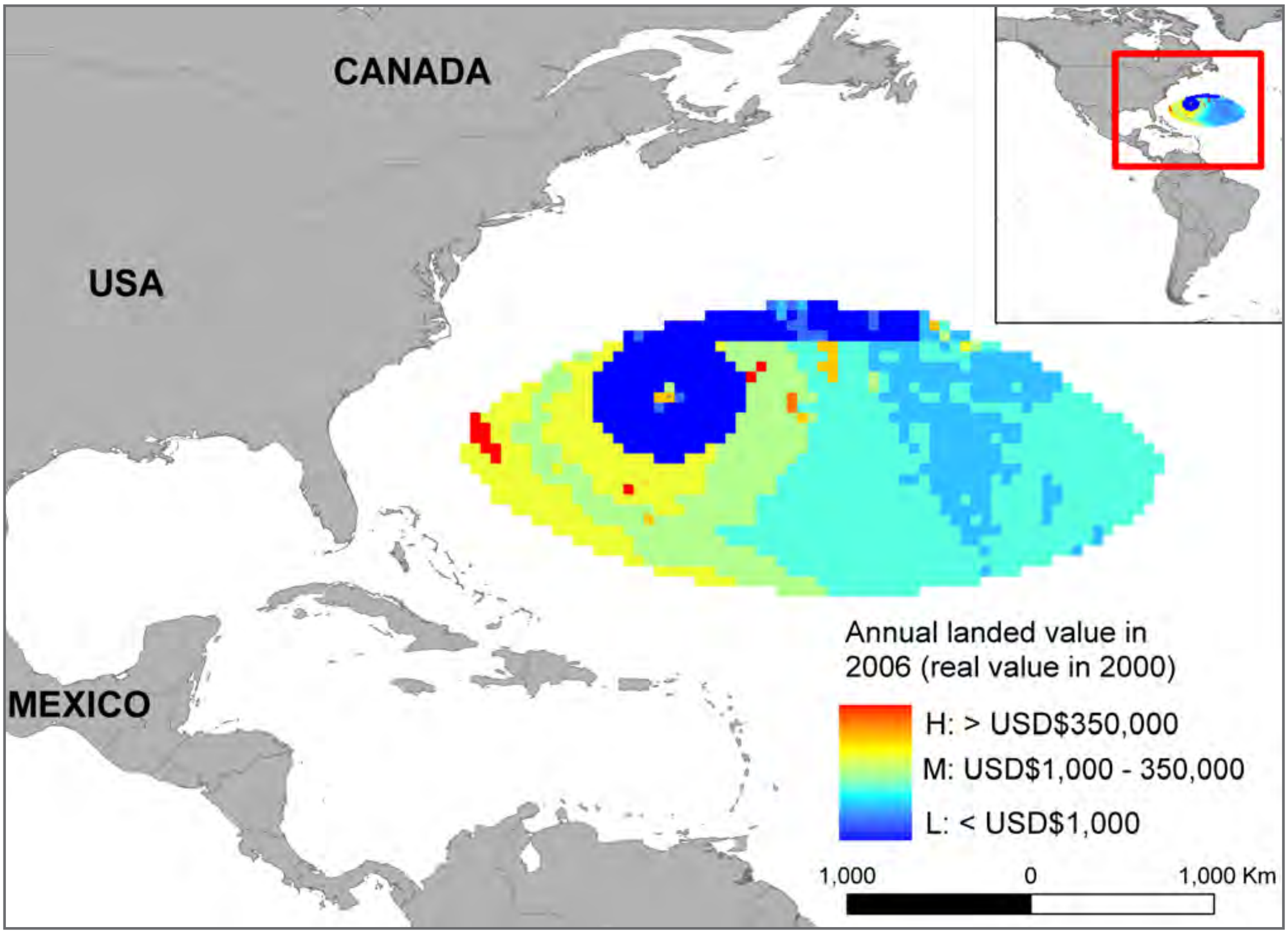
Extrapolations from the FAO dataset indicate that Venezuela, Mexico, the U.S. and Japan are currently the most active fishing fleets in the Sargasso Sea with Mexico currently showing the largest landed value (**FIGURE 22**, Sumaila *et al.* 2011, unpublished). However, the high values reported from Mexico and Venezuela result from significant catches in the coastal Spanish mackerel fishery, which influenced the results of the final extrapolation, and not because of catches in the Sargasso Sea. The United States and Japan currently have the largest fishing fleets within the High Seas of the Sargasso Sea. In terms of fishing gear, gillnets and longlines are most frequently used to catch fish in the Sargasso Sea, other gears include purse seines, traps and driftnets.

In addition there are fisheries for the two eel species that are dependent upon the Sargasso Sea for their spawning grounds (see Section 4). The European eel is critically endangered (Dekker 2003, ICES 2010) and the American eel is presently being considered for listing under the US Endangered Species Act. As described earlier, the decline in both European eel recruitment and harvestable eels could be as high as 99% in some areas (Gollock, Curnick and Debney 2011). It is estimated that around 11,000 tonnes of eel that originate from the Sargasso Sea are caught each year in North America and Europe. This generates resource rent of about $36 million a year. The resultant household income and economic impacts are estimated at over $60 million and $360 million a year respectively. These numbers, though impressive, are lower than their potential given the current depleted state of eel stocks in these countries (Sumaila *et al*. 2011, unpublished).

Other fish that are dependent upon the Sargasso Sea and which are harvested inhabit the Bermuda reefs. Reef fishing and recreational fishing for both offshore and reef fish (including lobsters) has an estimated value at 2007 prices of $5 million to Bermuda (Beukering, Sarkis, McKenzie, Hess, Brander, Roelfsema, Looijenstijn, van der Putten and Bervoets 2010) and the role of the *Sargassum* weed and reefs as nursery areas for commercial fish will have an additional but currently unquantified value.

The economic and biological importance of *Sargassum* to recreational and commercial fishing extends well beyond the boundaries of the Sargasso Sea. As rafts of *Sargassum* drift with the currents in the Caribbean Sea, the Gulf of Mexico, through the Florida Straits and up the east coast of the United States by way of the Gulf Stream, they provide critical habitat for species of fish that are targeted by the recreational and commercial fishing industries. The success of the recreational charter fishing industry in any one year in the Florida Keys can be measured against the quantity and quality of the drifting rafts of *Sargassum* in the Straits of Florida. The importance of *Sargassum* as an Essential Fish Habitat was recognized by the South Atlantic Fishery Management Council in

FIGURE 23. Spatial distribution of landed values of commercially caught species of fish in the central part of the Sargasso Sea. The highest value is derived from fishing in the western Sargasso Sea. *Credit:* Sumaila *et al*. 2011, unpublished.



2002 when they developed a Fishery Management Plan to protect and conserve *Sargassum* in a portion of the EEZ of the United States (South Atlantic Fishery Management Council 2002). The environmental and economic importance of *Sargassum* is only realized and recognized by some when it is no longer present.

Other values come from more indirect uses. Ecotourism is important to the region and is dependent upon some of the iconic and threatened species that live there. The annual migration of humpback whales past Bermuda supports local whale watching (Stone *et al*. 1987). Humpback whales are also the basis of whale watching around the Caribbean, and it has been estimated that whale watching in Antigua and Barbuda, Dominica, Dominican Republic, Grenada, Guadeloupe, St. Kitts and Nevis, St. Lucia, and St. Vincent and the Grenadines is worth over $22 million annually across the region (O'Connor, Campbell, Cortez and Knowles 2009). The numbers get even larger off New England where Stellwagen Bank whale watching accounts for 80% of a total income of $126 million. Many of the humpbacks watched off Stellwagen have migrated there from Bermuda (see Section 3).

Turtles also draw eco-tourists to the Caribbean, and the four species of turtle that use the Sargasso Sea as a nursery area and as part of their migration routes support turtle watching tourism in Antigua, Costa Rica, Dominica, Grenada, Nicaragua, St. Lucia, St. Vincent and the Grenadines, Trinidad and Tobago and the Gulf and Southeastern states of the United States, including Puerto Rico. Bird watching is also popular throughout the Caribbean and, although the role of migratory seabirds in bringing tourists to the region has not been quantified, the seabirds that use the Sargasso Sea contribute to the diversity of birdlife found in the region.

A recent study (Beukering *et al*. 2010) has estimated the Total Economic Value (TEV) of Bermuda's coral reefs by bringing together values for coral reef associated tourism, reef associated fisheries (referred to earlier), impacts on real estate, the provision of physical coastal protection, the provision of reef associated cultural and recreational values, and existing research and educational values. Based on 2007 values the authors estimate an annual TEV of the reef system to Bermuda as $722 million representing about 12% of Bermuda's GDP. As the authors' comment "preserving the coral reefs...in Bermuda pays off in the economic sense". Clearly the well-being of Bermuda's reefs depends in part on the well-being of the ocean surrounding Bermuda.

More broadly, two global studies of values from ecosystems have been published. The first, by Costanza, d'Arge, de Groot, Farber, Grasso, Hannon, Limburg, Naeem, O'Neill, Paruelo, Raskin, Sutton and Van den Belt (1997) had a profound impact on how ecosystem services were considered, as it brought worldwide awareness to the fact that humans receive a host of valuable benefits from the environment, even if these are not traded in the market. The second (de Groot, Kumar, van der Ploog and Sukhdev 2010) introduced the concept of "the economics of ecosystems and biodiversity" (TEEB).

SOURCE OF VALUE	MEAN VALUE (US$ per ha per year)	SARGASSO SEA VALUE (million US$)
Climate regulation	**30**	**1.3**
Conservation of genetic diversity	**2,539**	**105.4**
Moderation of extreme events	**6,149**	**255.3**
Nutrient cycling	**19,979**	**829.4**
Water purification, waste management	**33,966**	**1410.1**
Habitat/nursery service	**3,800**	**157.7**
Total		**2,759.1**

TABLE 5. Selected Sargasso Sea indirect use values based on reported mean values from TEEB (de Groot *et al*. 2010).

De Groot *et al* (2010) estimated the economic value per hectare per year of various biomes including the open ocean. Multiplying these estimates by the area of the Sargasso Sea (41,515 hectares-see p8, FIGURE 1) Sumalia *et al*. (2011, unpublished), estimate that the indirect use value from the Sargasso Sea is over US$ 2.7 billion per year (Table 5). The definitions of the various categories are given by de Groot *et al* (2010), but climate regulation is the balance and maintenance of the chemical composition of the atmosphere and oceans by living marine organisms; conservation of genetic diversity is preventing the loss of genetic diversity; moderation of extreme events includes hurricanes and tsunamis; nutrient cycling is the enhancement of ecological re-cycling; and the final two categories are water purification and waste management, and the (ocean's) role as a habitat/nursery. The highest value is attributed to water purification (US$1.4 billion), followed by nutrient cycling at about $0.8 billion (de Groot *et al*. 2010).

It is difficult to reconcile these various economic analyses with each other, and also difficult to evaluate the reality of some of the large estimates of economic values, but it is clear that the Sargasso Sea, both in the open ocean and the inshore environment around Bermuda contributes significantly to global and local economies. These various data and estimates emphasise the need for precautionary management to protect and maintain current values and to restore those areas of the ecosystem that are less than optimal, so that the Sargasso Sea can continue to provide these ecosystem services for future generations.

9

The Sargasso Sea is...threatened and in need of precautionary management. Human activities impact the Sargasso Sea in a variety of ways; real and potential threats include over-fishing, shipping, pollution and even exploitation of *Sargassum.*

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).

Current threats to the Sargasso Sea include:

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

Impacts of fishing and over-fishing: Fisheries for many key species in the North Central Atlantic, including the Sargasso Sea, have declined significantly in the last 50 years. With the exception of swordfish, all targeted tuna and tuna-like species regulated by ICCAT are now on the IUCN Red List (see Table 3). According to ICCAT databases, between 1950 and 2008 there have been notable changes in dominant targeted species from bluefin tuna (*T. thynnus*) in the 1960s, to albacore (*T. alalunga*), swordfish (*X. gladius*), and bigeye tuna (*T. obsesus*), in the 1970s and 1980s, to yellowfin tuna (*T. albacores*), in the 1990s and 2000s (**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, all of which show a marked decline in catch per unit effort over this time (Hallett 2011b).

According to ICCAT (2010), yellowfin and bigeye tuna, white marlin and blue marlin, the northern albacore, western stocks of bluefin tuna and sailfish have all been overfished in the past, and swordfish may have been. At present, the western bluefin tuna and blue marlin are still being overfished, sailfish and bigeye tuna may be being overfished, and white marlin may be being overfished but the status of this species is complicated because of confusion of this species with the roundscale spearfish (*Tetrapturus georgii*). Stocks of yellowfin tuna, northern albacore, skipjack tuna, and swordfish are not being overfished at present, although, with the exception of skipjack, biomass of these stocks is lower than it could be because of the historic over-fishing. Stock assessments and catch limits are in place for all of these species individually, but this is not the case for the group of miscellaneous species lumped together by ICCAT as "small tunas". These include species like wahoo, Spanish mackerel and blackfin tuna, which ICCAT recognize are all of high socio-economic value to local fisheries. Despite their importance, there are few stock data and no management regulations in place for these species, some of which spawn in the Sargasso Sea.

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**). 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

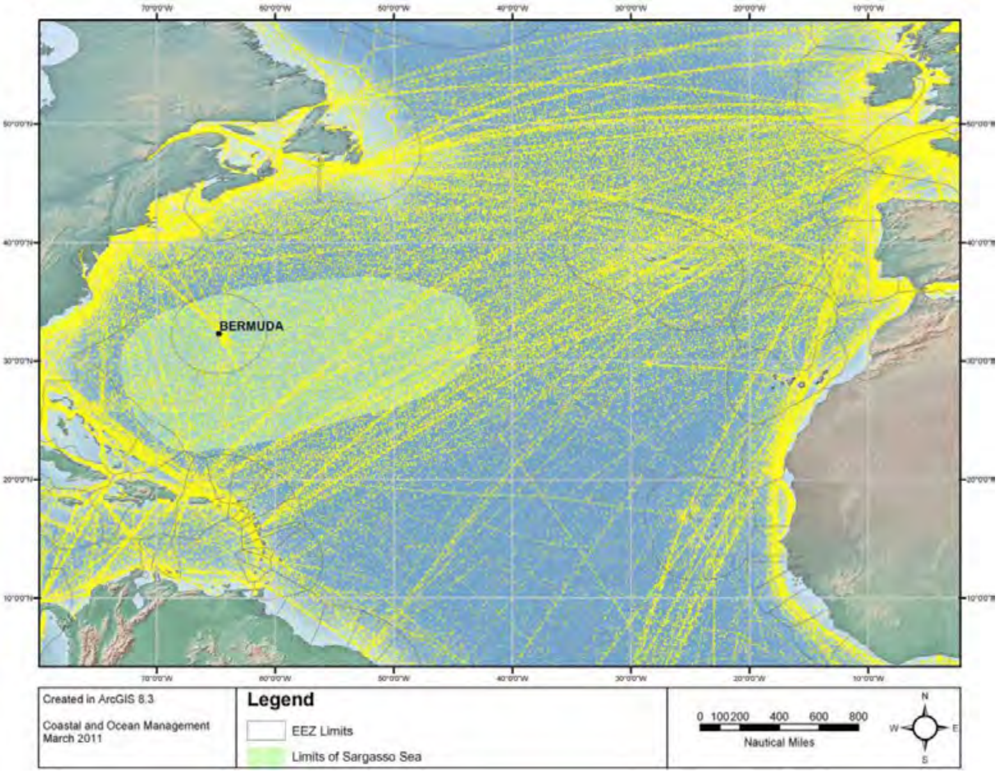


FIGURE 24. **A spatial plot of real time ship reporting position provided by the Voluntary Observing Ship (VOS) programme using data from 2010. The VOS programme represents around 4500 vessels and so give an indication of overall movements, but does not provide a comprehensive track of all ships that transit the Sargasso Sea. (*Credit:* Roberts 2011, unpublished).**

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 is potentially particularly vulnerable from 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**), 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).

Although the present state of the stocks of many of the species managed by ICCAT is below historical levels, ICCAT have in the past imposed time-limited closed areas and moratoria on fishing near floating objects in efforts to protect juvenile bigeye, yellowfin and skipjack. However they recognize (ICCAT 2010) that the present closed areas are too small to be very effective (and are also in an area of low fishing effort). A much more ambitious use of marine protected areas as a management tool for tuna fisheries and conservation of offshore marine pelagic ecosystems was put forward within ICCAT by Fonteneau (2007). Fonteneau discussed several potential MPAs one of which is in the North Atlantic between ca 30-43^{0}N 34-63^{0}W and which overlaps the present area of interest in the Sargasso Sea. Clearly any moves by ICCAT to establish such large scale MPAs should be encouraged, as should more recent initiatives (ICCAT 2011c) to establish time/area closures aimed at protecting marlin. At the same ICCAT (2011c) meeting conservation measures for porbeagle sharks were tabled by both Canada and the UK Overseas Territories with the EU. No consensus was reached but again ICCAT should be encouraged to develop and implement these various conservation measures.

In addition to these fisheries, deep pelagic and bottom trawling by the USSR and Russia on the Corner Rise Seamount between 1976 and 1995 caught some 19,000 tons of fish – predominantly alfonsino, and caused extensive destruction of the benthic fauna (Vinnichenko, 1997, Waller, Watling, 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, 2007. This closure was recently extended until December 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 faunas are destroyed and 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, Simpson and Watling 2011, Pante and Watling 2011, ICES 2011). 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.

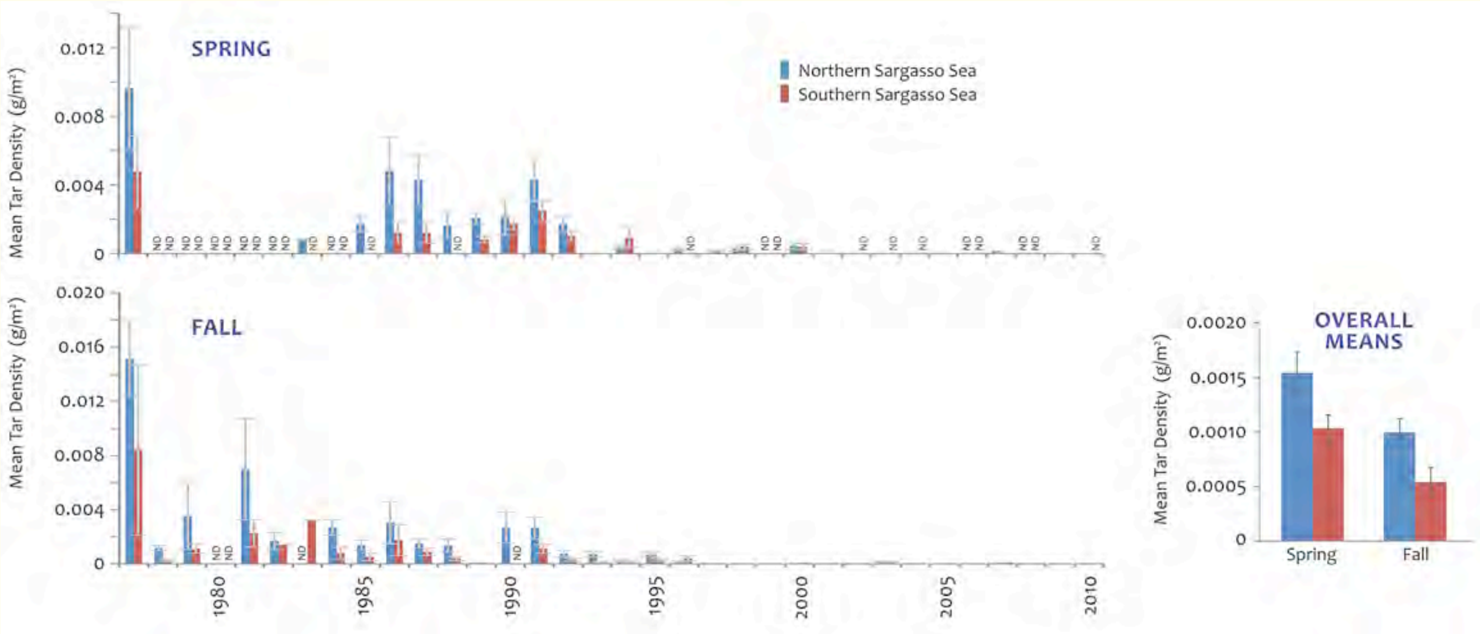
Shipping and shipping related impacts: The Sargasso Sea lies within one of the world's busiest international shipping areas and is crossed by a large number of vessels each year **(FIGURE 24)**. The full range of vessel types operate in these waters, with many following distinct routeing patterns according to the vessel type and the nature of the cargo carried (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). Further research is needed to identify and quantify any such risks.

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 McGillivary 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 **(FIGURE 25)** (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

FIGURE 25. Mean tar density in the northern and southern Sargasso Sea during spring and fall of each sampling year. Right: Overall mean tar densities for northern and southern Sargasso Sea during spring and fall. ND indicates no data. *Credit:* Siuda 2011, unpublished.



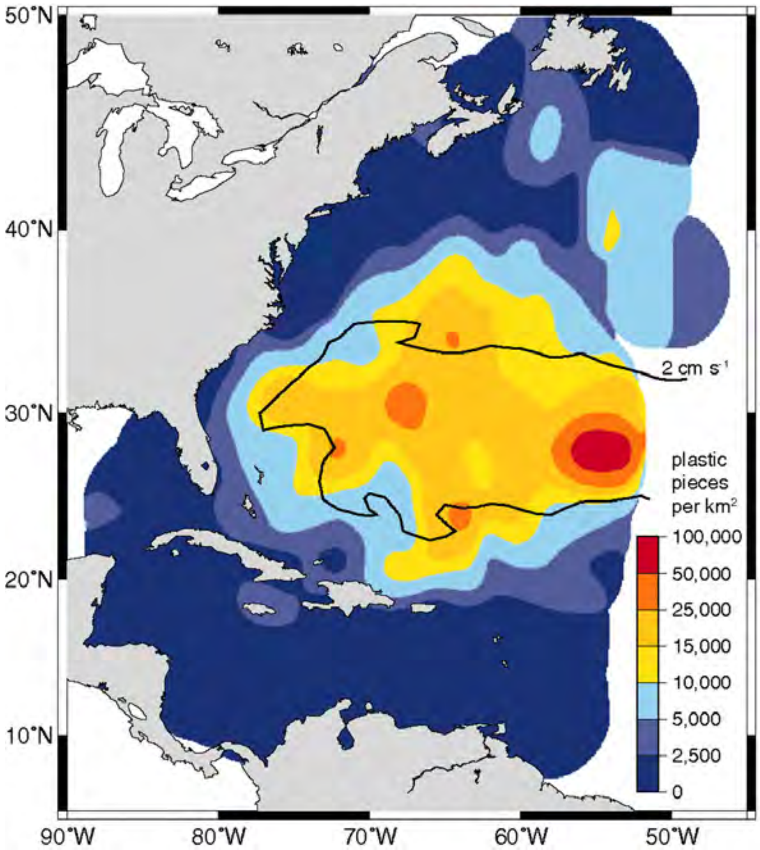


FIGURE 26. Map showing the plastic density/km2 in the North Atlantic. ***Credit:*** **From Law** ***et al*****. 2010. Reprinted with permission from AAAS.**

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 breathe, 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 no evidence is available on this aspect 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 impacts 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 **(FIGURE 26)**.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 defined in this report, the concentration of plastic particles taken from plankton tows on occasions reached in excess of an equivalent of 200,000 pieces km-2.

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. The impact of microplastics on the marine environment has recently been reviewed (Cole, Lindeque, Halsband, and Galloway 2011), and plastic pollution in the Sargasso Sea is specifically referenced in a recent report (STAP 2011). The latter summarises the extent and increasing problems associated with marine debris especially plastics but also discarded fishing gear. "Plastic debris is unsightly; it damages fisheries and tourism, kills and injures a wide range of marine life, has the capacity to transport potentially harmful chemicals and invasive species and can represent a threat to human health"(STAP 2011). The report makes recommendations to reduce the problems.

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 or if they are ingested by marine species (Rios, Moore and Jones 2007).

Commercial extraction: Commercial 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 a portion of 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, and Lenstron, van Haal and Reith (2011) have recently proposed a scheme to harvest *Sargassum in situ* from artificially fertilised areas of the Sargasso Sea. A recent 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 latter seems unlikely since many species of *Sargassum*-including *S natans*, contain antibacterial properties which will inhibit microbial decomposition and fermentation (see eg Nadal 1961, Patra,Rath,Jena,Rathod and Thatoi 2008).

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 200 m in the area of Blake Spur (UN, 2009).

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 these in the Sargasso Sea is unknown.

With the exception of over-fishing, many of the threats discussed here are potential or possible – few direct causal relations between threats 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 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 becoming a 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 presents an opportunity to explore new ways to do this and protect the ocean.

Conclusion

THIS SUMMARY SCIENCE AND SUPPORTING EVIDENCE CASE sets out the many reasons for the international importance and values of the Sargasso Sea, and why protection and improved management is both urgent and necessary. Whether viewed environmentally, socially, economically, or as a critical area for research, the Sargasso Sea is not only vitally important to Bermuda and the surrounding countries but also to the world at large.

However to maintain the Sargasso Sea environment and to prevent degradation both now and in future it is necessary to address the various threats that impact upon it. As the site of the longest-term monitoring of the ocean environment, it is most likely to be a critical source for the earliest warnings of environmental change. This insurance will be compromised if the region is allowed to deteriorate through negligence or lack of will. Addressing these threats will require international agreements and actions to directly target particular threats, but in addition to these, precaution should play a major role in determining appropriate activities. The precautionary approach was globally endorsed by the Rio Declaration (UNCED 1992) and the Seabed Disputes Chamber of the International Tribunal for the Law of the Sea recently recognized "a trend towards making this approach part of customary international law" (ITLOS, 2011; Freestone, 2011). It has been included in virtually every marine environmental treaty in the last twenty years and, and should be used to underpin specific conservation measures to ensure that the Sargasso Sea continues to be an iconic and critical part of the world's ocean.

This summary science and evidence case is a contribution to the process leading to international recognition and protection of the Sargasso Sea. It will be supported by more detailed information, as well as by future engagement with both the public and appropriate expert communities.

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The Sargasso Sea Alliance thanks the National Oceanography Centre, UK for providing library facilities and overall support for this work.

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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