The Importance of the Sargasso Sea and the Offshore Waters of the Bermudian Exclusive Economic Zone to Bermuda and its People

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

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COVER PHOTO: Bermuda coast, K. Morrison.

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Foreword

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

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

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The Importance of the Sargasso Sea and the Offshore Waters of the Bermudian Exclusive Economic Zone to Bermuda and its People

The Sargasso Sea: an abundance of life in an ocean desert

The Sargasso Sea is within an oceanic gyre that encircles the Atlantic Ocean between 30 degrees and 75 degrees west longitude, and between 20 degrees and 40 degrees latitude. The only land mass within the Sargasso Sea, and the only entity with jurisdiction over any of its resources, is Bermuda (**FIGURE 1**). The Sargasso Sea is the only sea defined by currents rather than coastline: the Gulf Stream to the west, the North Atlantic Drift to the north, the Canaries Current to the east, and the Antilles Current to the south. This makes the Sargasso Sea a distinctive ecosystem; however it is most unique for supporting a habitat of floating *Sargassum* algae. *Sargassum* floats by means of small berry-like structures that contain gas. The algae passively drift on winds and currents, gathering to form large mats that can be tens of kilometres in area. It is generally believed that these vast mats of "drift algae" have persisted within the Sargasso Sea for thousands of years (Calder 1995). *Sargassum* mats support a highly diverse community of animals and plants, which in turn supports large migratory species in the ocean, such as tunas, marlin, and sharks. Therefore, unlike other areas of open ocean, the Sargasso Sea is not a desert, but a "golden rainforest" that supports hundreds of species of invertebrates, fish, mammals and birds.

Mats of *Sargassum* algae are critical to supporting life in the vast open Atlantic. The structural complexity of *Sargassum* provides support and camouflage for a complex food web (Kingsford & Choat 1985) that includes top predators such as sharks and billfish, as well as microscopic protozoans. Over 100 species of invertebrates, more than 280 species of fish, four species of turtle (Coston-Clements et al., 1991), and 23 species of seabird (Haney 1986) all utilize *Sargassum* as a resource at some point in their life-cycle, as a food source, for protection, for nesting or spawning grounds, as a nursery, or as a method of transport. Some organisms are endemic (unique to one geographic location), found only in *Sargassum* habitats (Coston-Clements et al., 1991). Many of the permanent residents of *Sargassum*, such as the endemic *Sargassum* frogfish *Histrio histrio* and *Sargassum* pipefish *Syngnathus pelagicus*, have evolved unusual shapes or colours that help them to hide within the plants.

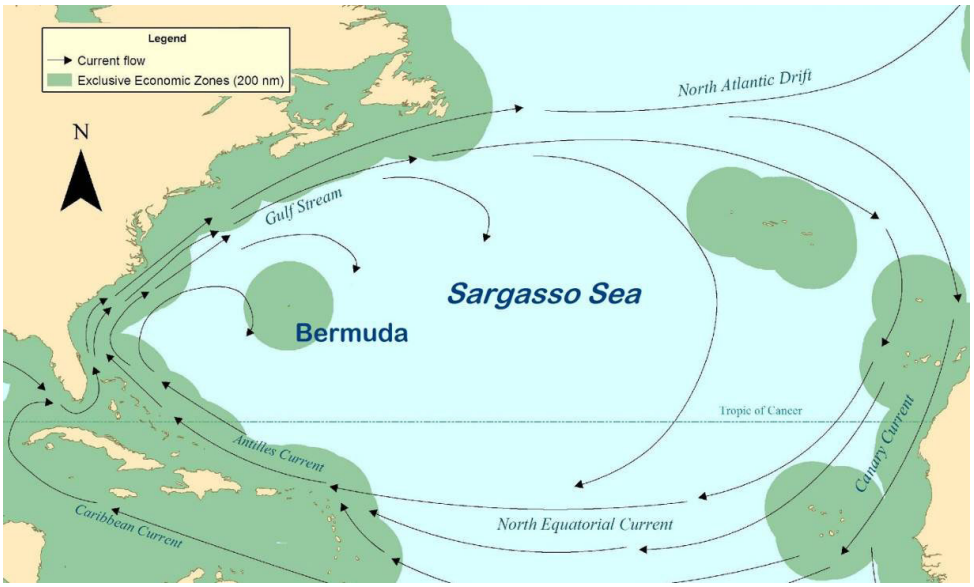

FIGURE 1. The Sargasso Sea and surrounding regions.

There are several deep water geological features within the Sargasso Sea. These include the Muir seamount chain, Bowditch seamount, Crescent seamount, Plantagenet (Argus) Bank, and Challenger Bank. The most well-studied seamount in the Sargasso Sea is the Corner Rise (Vinnichenko 1997). This seamount chain was found to have abundant populations of deep-water fish, which were heavily exploited by commercial trawls between the mid 1970s and mid1990s (Vinnichenko 1997), causing severe damage to the seamount peak communities (Waller et al., 2007). The largest feature within the Sargasso Sea is the Mid Atlantic Ridge, which runs through the area at approximately 40 degrees west. The Bermuda Islands were formed by a volcano from the Mid Atlantic Ridge, and have slowly moved west at a rate of 15–30 mm per year since their formation (Vogt & Jung 2007). Deep water fish assemblages (up to 5000 m) in the Sargasso Sea are dominated by bristlemouths, lanternfish, and viperfish (Sutton et al., 2010).

The importance of the Sargasso Sea to Bermuda

Bermuda, as the only community living within the Sargasso Sea, has a strong connection with this unique ecosystem. The ecosystem of the Exclusive Economic Zone (EEZ) around Bermuda is contiguous with the animals, plants and processes that occur across the wider Sargasso Sea region. Bermuda depends on ecosystem services and resources that are provided by the EEZ, which covers an area of 450,370 km^2 from the high water mark to 200 nautical miles offshore, encompassing vast areas of open ocean and deep water habitats such as seamounts, as well as shallow water habitats such as coral reefs and seagrass meadows. Tourism brand, culture, fisheries, and healthy corals reefs are just some of the benefits Bermuda gains from the EEZ. The islands economic history revolves around the ocean, from shipbuilding in the 1700s to today's pelagic fisheries, and the legend of the Bermuda Triangle is based on centuries old tales of missing ships in the doldrums of the Sargasso Sea becoming entrapped in *Sargassum* weed. The following sections will discuss how the waters of Bermuda's EEZ and the wider Sargasso Sea are closely linked to the ecology, the culture, and the economy of the island of Bermuda. Therefore, Bermudians are innately connected to the Sargasso Sea, benefitting from its resources in a variety of ways.

The ecological benefits of the Sargasso Sea and the EEZ to Bermuda

Many organisms that inhabit or migrate through the Sargasso Sea also occur in the Bermudian EEZ. The currents encircling the Sargasso Sea and the presence of *Sargassum* weed bring an abundance of diverse organisms to Bermuda's inshore and offshore habitats. Many important species, habitats and ecosystem functions occur within the EEZ, and the Bermudian EEZ therefore fits several criteria as an area of special ecological or biological importance under the Convention on Biological Diversity (**ANNEX 1**).

The Bermudian EEZ is a critical nursery, feeding, and spawning habitat

The Sargasso Sea and the oceanic waters of the Bermudian EEZ are essential nursery, feeding, and spawning habitats during critical life stages for many organisms of importance to Bermudians, including many threatened or endangered species. Table 1 lists species found in the oceanic waters of the Bermudian EEZ that are listed under the IUCN (International Union for the Conservation of Nature) red-list, which catalogues species depending on how threatened they are in nature, or under CITES (Convention on the International Trade of Endangered Species).

Blue (*Makaira nigricans*) and white (*Tetrapterus albidus*, more recently identified as *Kajikia albida*) marlins, popular species in the sport-fishing industry, spawn within the EEZ (Bolden et al., 2007; Luckhurst et al., 2006). Flyingfish (Exocoetidae) lay eggs within *Sargassum* in the EEZ (personal observation) and more widely in the Sargasso Sea (Coston-Clements et al., 1991). Several reef fish native to Bermuda are found as larvae or adults within *Sargassum* weed within the Bermuda EEZ and Sargasso Sea. These species include: chubs (*Kyphosus sectatrix*), sergeant majors (*Abudefduf saxitilis*), seahorses (*Hippocampus sp.*), triggerfish and filefish (Balistidae), porcupine fish (*Diodon sp.*), barracuda (*Sphyraena barracuda*), and sennet (*S. picudilla*) (Hoffmayer et al., 2005). Several fish species that are targeted by recreational and commercial fishermen spend part of their life cycle offshore and their larvae are also often found associated with *Sargassum* weed. These species include: jacks (Carangidae), snappers (Lutjanidae), triggerfish, wahoo (*Acanthocybium solandri*), swordfish (*Xiphias gladius*), yellowfin tuna, bluefin tuna, dolphinfish (*Coryphaena hippurus),* blue marlin, white marlin, and blue runner (*Caranx crysos*)

SPECIES	COMMON NAME	IUCN STATUS	CITES STATUS
Megaptera novaeangliae	**Humpback Whale**	Least Concern	Appendix 1
Physeter macrocephalus	**Sperm whale**	Vulnerable	Appendix 1
Thunnus thynnus	**Bluefin Tuna**	Endangered	
T. albacares	**Yellowfin Tuna**	Near Threatened	
T. alalunga	**Albacore Tuna**	Near Threatened	
T. obesus	**Bigeye Tuna**	Vulnerable	
Makaira nigricans	**Blue Marlin**	Vulnerable	
Tetrapterus albidus	**White Marlin**	Near Threatened	
Anguilla anguilla	**European Eel**	Critically Endangered	Appendix 2
Rhincodon typus	**Whale Shark**	Vulnerable	Appendix 2
Carcharhinus longimanus	**Oceanic Whitetip Shark**	Vulnerable	
Carcharhinus falciformis	**Silky Shark**	Near Threatened	
Carcharhinus galapagensis	**Galapagos Shark**	Near Threatened	
Isurus oxyrinchus	**Shortfin Mako Shark**	Vulnerable	
Prionace glauca	**Blue Shark**	Near Threatened	
Sphyrna lewini	**Scalloped Hammerhead**	Endangered	
Galeocerdo cuvier	**Tiger Shark**	Near Threatened	
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	**Bermuda petrel (Cahow)**	Endangered	

TABLE 1. Oceanic species resident in the Sargasso Sea and Bermuda's EEZ that are on the IUCN red-list and listed under CITES.

(Hoffmayer et al., 2005). It is likely that many of these species "raft" within *Sargassum* weed as larvae from the Caribbean, and end up growing and living in Bermuda's waters once *Sargassum* washes inshore, but this phenomenon has not been well studied. The recent introduction of Pacific lionfish (*Pterois volitans*) provides evidence of the potential for Gulf Stream eddies to transport plants and animals from the North American coast along with *Sargassum.* Since many species rely on *Sargassum* as a food source and habitat during different life stages, it is clear that healthy habitats of *Sargassum* weed must be maintained in order to maintain healthy fish populations in Bermuda.

The Bermudian EEZ is a highway for migratory species

Many species of bird, fish, and cetacean are found in the oceanic waters of the Sargasso Sea and Bermudian EEZ during migrations that can span the entire globe, thus linking Bermuda to the global ocean ecosystem. Humpback whales and their newborn calves are found within sight from the south shore of Bermuda during March and April, when they migrate past the island, feeding near the reef line on their way to productive hunting grounds in the Arctic (Stone et al., 1987). Other cetaceans that pass by Bermuda include sperm whales, minke whales (*Balaenoptera acutorostrata*), and common dolphins (*Delphinus delphis),* though these animals can also remain in Bermuda's EEZ as residents (Sterrer 1986). All whales and cetaceans are protected in Bermuda's waters.

Juvenile loggerhead, green, hawksbill and Kemp's ridley turtles migrate within *Sargassum* weed to the Bermudian EEZ. These turtle species live in Bermuda's

inshore waters during intermediate "teenage" years before migrating back to the Caribbean to nest (Carr & Meylan 1980)—in former times, turtles nested too on Bermuda and it is hoped that they may again in the future, as marine turtles are another group of animals that are afforded complete protection in Bermuda's waters.

European eels, (*A. anguilla*) which are highly endangered, and American eels (*A. rostrata)* travel through the Bermudian EEZ on their voyage from their respective continents to the Sargasso Sea to spawn. After they are born, larval eels then travel the same route back from the Sargasso Sea to streams and rivers in the continents (Kleckner & McCleave 1988).

Eleven species of tuna fish also migrate through the Bermudian EEZ during spring and summer towards cooler waters near Canada and the northern United States (Beardsley 1969; Block et al., 2005; Sterrer 1986). During this time, recreational and commercial fisheries are highly productive around the island (J. Pitt pers. comm.). Popular species that are targeted include wahoo, yellowfin, albacore, and bigeye tuna. Some smaller species of tuna and tropical species such as yellowfin, are resident in the EEZ throughout the year in smaller numbers. Billfish species are also found within the EEZ: blue and white marlin migrate through and spawn within the EEZ; swordfish and sailfish also commonly transit the area (Smith-Vaniz et al., 1999; Sterrer 1986). Eight species of sharks and rays that are on the IUCN red-list for threatened species (**SEE TABLE 1**) also migrate through Bermudian waters, including whale sharks, tiger sharks, manta rays (*Manta birostra*) and locally protected spotted eagle rays (*Aetobatus narinari*).

The Bermudian EEZ supports resident populations of seabirds

Many seabirds that migrate and feed throughout the Sargasso Sea and the Bermuda EEZ are resident in Bermuda. The endemic Bermuda petrel, locally known as the cahow, travels throughout the Sargasso Sea, including the EEZ (J. Madeiros pers. comm.). The cahow nests in Bermuda during the winter months, and flies long distances across the Atlantic Ocean to feed on squid and fish. The white-tailed tropic bird, locally known as the longtail (*Phaethon lepturus*), symbolizes the beginning of spring to Bermudians. Longtails are native to Bermuda, nesting in the hard limestone rock of Bermuda's coastline, and feeding in the Sargasso Sea and EEZ during winter months. In total, twenty-three species of seabird have been found to be associated with *Sargassum* rafts, using large swaths as a roosting spot or as a foraging ground (Haney 1986) as they fly across the open ocean.

The deep waters of Bermuda's EEZ are diverse in habitats and species

Seamounts

Bermuda's EEZ contains several deep water habitats associated with seamounts and volcanic banks. 300 km to the northeast of the island, on the very outer reaches of the EEZ (33° 32' N, 62° 27' W), is the Muir Seamount chain, at approximately 1300 m depth (Pratt 1962). There is little known about this seamount chain; however Pratt (1962) describes abundant hydroids, sponges, calcareous algae, and rubble on the surface of the seamount. To the northwest of Bermuda, 80 km from the island, is Crescent Seamount. Closer to Bermuda 40 km northeast, at a depth of 1000 m is Bowditch Seamount. Few locals have appropriate vessels or gear to fish these seamounts as they are further from the island but there is little need to travel that far since excellent fisheries are found close to shore (J. Pitt pers. comm.). Two popular and productive fishing grounds that are within easy reach of shore are Plantagenet (commonly known as Argus) and Challenger Banks. Argus Bank is 55 km southwest of Bermuda, at a depth of 55 m, and Challenger is only 20 km southwest, at a depth of 45 m. "The Banks" as locals know them are highly visited fishing grounds by locals and visitors. They are productive fishing areas, visited by whales, sharks, manta rays, spotted eagle rays, and large pelagic fishes. The benthic community of the Banks is composed largely of hard coral species, which grow deeper at this location than on the rim of the Bermuda Platform (Fricke & Meischner 1985).

Deep-water species

Several endemic species reside within Bermuda's deep water EEZ habitats. The Bank Bass fish, *Parasphyraenops atrimanus,* is known only from Argus Bank at depths of around 80 m (Smith-Vaniz et al., 1999). A small nephroid decapod discovered during experimental trap fishing, *Eunephrops luckhursti* (Manning 1997*)* and the geryonid crab, *Chaceon inghami* (Manning & Holthuis 1989), are also found in deep habitats, at depths up to 800 m (Manning & Holthuis 1989). A deep water snail, Lightbourne's Murex (*Pterynotus lightbourni),* is also found in the deep waters of the EEZ (Sterrer 1986).

Sargassum weed from Bermuda's EEZ benefits inshore and coastal habitats

Benefits to animals

Once *Sargassum* reaches Bermuda, it provides many benefits to nearshore habitats. When *Sargassum* sinks as a result of ageing or excess wave energy (Johnson &

Richardson 1977), it provides nutrients such as nitrogen and phosphorus to corals, other benthic organisms and fish. *Sargassum* weed, whether sunken or floating, could be an important source of food for detrivores and herbivores such as the endemic bream (*Diplodus bermudensis*) and chubs, which have been observed targeting *Sargassum* weed as a food source (personal observation, C. Flook and T. Murdoch pers. comm.). In the deep waters of the Sargasso Sea, *Sargassum* contributes up to 60% of the primary production occurring within the upper 1 m of the water column (Howard & Menzies 1969). This influx of nutrients to inshore habitats is likely beneficial to coral reefs as well as other habitats when found in moderate amounts. Sinking *Sargassum* is also an important source of nutrients to deep sea food webs in the Sargasso Sea, supplying up to 10% of total nutrient input to seabed organisms (Angel & Boxshall 1990).

Benefits to coastal habitats

When *Sargassum* weed reaches Bermuda, it washes up on the shoreline, piling high on beaches. The most *Sargassum* is seen on Bermuda's beaches between November and April (Butler 1983). Many people consider *Sargassum* to be a nuisance, as it impedes beach access and has a strong odour while decomposing (Feagin & Williams 2008). However, vegetation that washes up on the shoreline is critical to stabilizing the shoreline, and in the creation of the limestone of which the Bermuda islands are made. When algae washes up on the beach, it acts like glue that holds sand together. This helps the formation of beach dunes, which prevent the movement of sand, and decreases erosional forces during storm activity (Thomas 2004). Over thousands of years, sand dunes convert to hard sandstone rock, and eventually limestone. *Sargassum* also contributes to the sand that forms Bermuda's beaches, as encrusting organisms such as bryozoans, foraminiferans, barnacles, serpulid worms, and red algae could be a potentially large source of calcium carbonate input (Pestana 1985). Pestana (1985) estimates that carbonate material associated with *Sargassum* could contribute as much as 10% of sediments to Bermuda's beaches.

Benefits to dune and beach vegetation

Sargassum therefore helps to stabilize the shoreline, and has helped build the island of Bermuda. *Sargassum* provides additional benefits when it washes up on beaches. It provides food and habitat for inter tidal organisms, and shorebirds and scavengers feed on the fresh invertebrates and fishes available in the weed (Winston 1982). *Sargassum* also enhances the nutrient content of coastal soils and sediments, thus enriching the growth of dune plants by providing nitrogen and phosphorus that are otherwise scarce in these habitats (Feagin & Williams 2008). A Bermudian tradition is the collection of *Sargassum* weed that has washed up on beaches in order to fertilize home gardens. It is not known how much *Sargassum* is used for this purpose, but it is not likely causing negative ecological consequences as it is harvested recreationally in small amounts. Using *Sargassum* as fertilizer reduces the islands dependence on imported compost products, which can contain exotic species and pathogens.

Healthy *Sargassum* habitat is critical in mitigating the impacts of climate change

Bermuda is highly vulnerable to impacts associated with global climate change such as sea-level rise and ocean acidification. Bermuda is further north than Caribbean coral reefs, and colder waters absorb more carbon dioxide (Orr et al., 2005), so Bermuda's environment is likely to be affected by ocean acidification faster. Bermuda's coral reefs are particularly in danger if the ocean becomes more acidic over time, as corals secrete calcium carbonate skeletons that will dissolve in more acidic conditions. Fisheries would also be negatively affected because, in the open ocean, many of the planktonic animals at the base of the food chain that are a food source for tunas and other large fish also secrete shells composed of calcium carbonate (Orr et al., 2005).

Raven and Falkowski (1999) estimate that the oceans are a sink for as much as 30% of carbon dioxide emissions caused by humans. *Sargassum* plays a role in decreasing the impacts of global climate change, just as other plants do, because it sequesters carbon dioxide within its tissues as it grows. When *Sargassum* dies and sinks to the ocean floor, it transports carbon to the deep sea food web and removes carbon dioxide from the biogeochemical processes that are currently leading to increasingly acidic oceans. Further, other seaweeds grow on the surface of *Sargassum*, increasing the carbon sequestration activity of the algae. It is not known how much carbon dioxide *Sargassum* sequesters, but it has been suggested that, in addition to carbon fixation by terrestrial forests, the growth of algae will be play an important role in mitigating anthropogenic carbon dioxide inputs (Alpert et al., 1992).

Cultural, historical, and economic importance of the Sargasso Sea to Bermuda

The ocean around Bermuda is perhaps best known to locals and tourists for the modern legend of the "Bermuda Triangle"; however, unlike the Triangle, the Sargasso Sea is real and Bermudian culture is centred on resources from the region. Early settlers in Bermuda were heavily dependent on the ocean for food and their way of life. Turtles, which travel through the Sargasso Sea using mats of *Sargassum*, were a popular meat source to the point where local populations were heavily depleted by the late 17th century. Endemic Bermuda petrels (cahows), which travel across the Sargasso Sea to the Azores and eastern United States, were also targeted and very nearly made extinct; they are now slowly recovering due to conservation efforts made since the 1950s, when cahows were rediscovered. The ecology of the Sargasso Sea has therefore given Bermudians a historical connection to the sea, but Bermuda's economic success is also intrinsically linked to the health of the Sargasso Sea ecosystem. Tourism is the second largest industry on the island, worth nearly 5.2% of the GDP ($297 million in 2010) (Bermuda Government Department of Statistics). Recently, Bermuda's tourism brand has been highly dependent on the environment: the mild climate, clean beaches, healthy oceans, coral reefs, abundant fisheries, and to a lesser extent the presence of charismatic wildlife such as whales and turtles. All of these environmental features are a result of Bermuda's location within the Sargasso Sea.

Whaling in Bermuda: replacing 19th century harpoons with 21st century cameras

In the 19th century, whaling was an important ocean-based industry in Bermuda. Whaling occurred off the south shore of the island, where deep water is within a mile of shore. Humpback whales, which are well-known Sargasso Sea voyagers, were the main target though sperm whales were likely targeted as well. Whale oil was exported to Britain and the Caribbean, until whalers in the United States became more efficient, decreasing the need for Bermudian oil in the late 19th century (Romero 2008). By this time, populations of whale species were suffering declines globally, and whaling was becoming less viable—the practice was ended in many countries in 1935 (Clark & Lamberson 1982). Presently, whales and cetaceans enjoy complete protection in Bermuda's waters, and the opportunity to see migrating humpback whales close to shore in Bermuda has led to a highly marketable whale watching ecotourism industry. It is possible to see humpback whales migrate past Bermuda from shore, but it is popular to take boat excursions into Bermuda's offshore waters to see humpbacks and other cetaceans migrate through Bermudian waters with their calves, on the way to northern feeding grounds. There is a fairly short profitable whale tourism season in Bermuda: it is only common to see humpbacks for about four weeks from March to April. However, in 2008, whale watching tourists spent $31,900, including incidental costs such as hotel rooms and food (O'Connor et al., 2009). This is an increase of 60% since 1998, indicating that ecotourism in Bermuda is a highly viable and growing industry.

Bermuda's EEZ benefits coral reefs, which support tourism and reef-based fisheries

One of the biggest reasons visitors come to Bermuda is to enjoy SCUBA or snorkel excursions on Bermuda's vibrant coral reefs. Bermuda's coral reefs are healthier than many reefs in the Caribbean, with coral cover reaching 70% along the south shore of the island, and averaging 40% in the northern lagoon (T. Murdoch unpublished data). Coral reefs and the various ecosystem services they provide, such as pink beaches, abundant reef fish, and beautiful views, have been estimated to generate $405 million every year for the tourism industry (Bervoets et al., 2010). One of the reasons Bermuda's reefs remain so attractive and healthy to visitors and locals alike is because there is a constant flux of clean ocean water from the Sargasso Sea to inshore habitats, creating a healthier environment than that of many other reefs worldwide. Bermuda's healthy coral reefs also support populations of reef fishes, which have been consistently targeted throughout history by Bermudians.

Popular inshore reef fish caught in Bermuda include groupers (Serranids), grunts (Haemulidae), snappers, hogfish (*Lachnolaimus maximus*), jacks and triggerfish. As previously mentioned, some of these inshore species are dependent on *Sargassum* communities as juvenile habitat, and as a food source once they grow larger. Triggerfish (locally known as turbot) and jacks are especially abundant in *Sargassum* weed as larvae and as adults, and rafts of *Sargassum* weed likely help seed the local population of these species once the algae drifts into the EEZ and inshore waters. Predatory fish in Florida have been observed to travel with *Sargassum* and then swim to a reef when the algae passes over one (B. Causey pers. comm.).

The pelagic fishery in Bermuda is a growing industry that is dependent on the EEZ

The use of fish pots was banned in Bermuda in 1990, causing landings of reef fish to decline dramatically, and landings of pelagic species such as tunas to increase as Bermudian fishermen began to more intensely explore offshore fisheries (**FIGURE 2**). In Bermuda, the most popular fisheries species are yellowfin tuna and wahoo, which are abundant within close proximity to shore. These species are heavily dependent on the Sargasso Sea: they feed in association with *Sargassum* mats and yellowfin larvae grow within *Sargassum* weed (Hoffmayer et al., 2005). Therefore, the local supply of fish to stores and restaurants is highly linked to the health and productivity of the Sargasso Sea. All fish caught in Bermuda are destined to be consumed locally; there is no export market, partly due to high transport costs.

Prior to 1990, pelagic fish such as yellowfin tuna and wahoo accounted for an average of 21% of landings (**FIGURE 2**). Tuna species were not popular on the local market before 1990 because it could not be guaranteed fish were properly chilled or handled. Consumption of improperly chilled or handled tuna causes histamine poisoning, akin to having a severe allergic reaction. Market acceptance for tunas increased around 1990 as a result of a development program known as Sargasso Seafoods that improved chilling and handling techniques, reducing the likelihood that a consumer would experience histamine poisoning (J. Pitt pers. comm.). As a result of this program, pelagic species have accounted for an average of 50% of annual landings (150,000 lbs or 68,000 kg) since 1993, a jump of 29% (**FIGURE 2**). 75% of these landings are composed of yellowfin tuna and wahoo. Commercial fisheries now catch approximately $1.5 million worth of pelagic fish every year[1] and based on a study of recreational fishing that estimated landings at 17% of commercial landings, it can be calculated that the recreational pelagic fishery is worth $255,000 (Hellin 1999). It is evident that Bermudians today are much more heavily reliant on the fisheries resources of the EEZ as a local food source than 20 years ago.

Bermuda's EEZ is world-renowned for sportfishing

Though offshore recreational sport-fisheries for blue and white marlin have existed in Bermuda for many decades, these species were first directly targeted in the 1960s (Luckhurst 2003). The first international fishing event was held in Bermuda in 1974 by the Sea Horse Anglers Club, and since then, Bermuda's EEZ has gained a reputation as a great spot to catch 'grander' marlin (above 1000 lbs) (Luckhurst 2003). The presence of these world-renowned grander fish is likely due to the presence of a marlin spawning ground within the EEZ, as large, reproductive fish would be found in high numbers during summer months. Bermuda now attracts anglers from the United States for catch-and-release billfish angling during the summer, when seven international billfish angling tournaments are held. Foreign vessels arrive with crew and often spend several weeks on the island for the duration

[1] Market price for analysis was $10/pound.

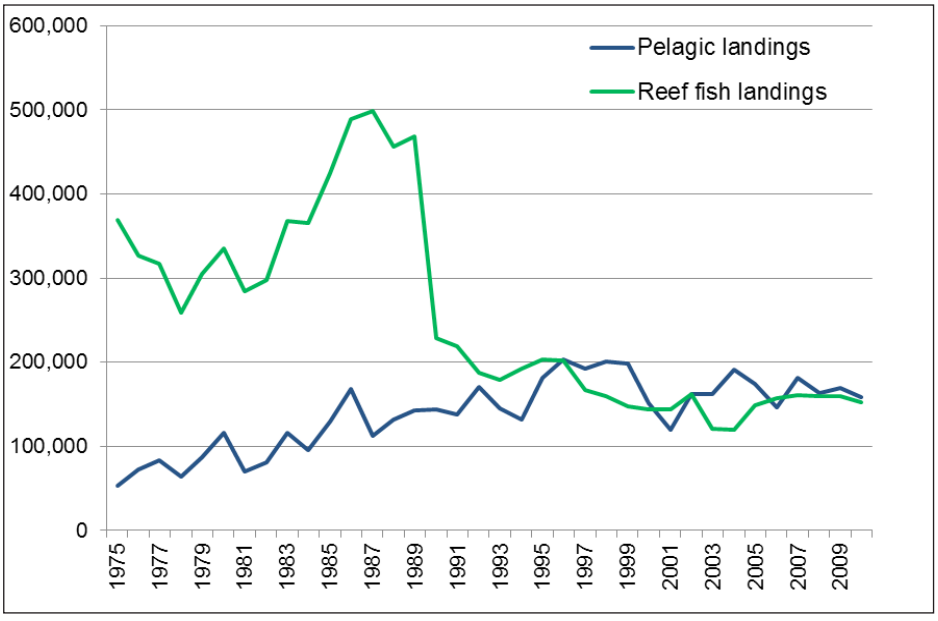

FIGURE 2. Commercial landings of pelagic and reef fish species in Bermuda since 1975. Declines in grouper species and the fish pot bans led to an increase in pelagic landings in 1990. Statistics from the Bermuda Government Department of Environmental Protection, Marine Resources Division.

of the major tournaments. During this period, crew and boat owners spend money on food and entertainment. Boat owners often fly down separately for each fishing event, and thus also incur hotel expenses. Billfish anglers are known to spend on average more than other types of anglers to pursue their sport (Ditton & Stoll 2000).

In 2010, 21 foreign vessels visited Bermuda to fish in tournaments, and in 2011, 22 foreign vessels visited. Most of these vessels arrived for late June or early July to participate. On average, these vessels carried a captain and a three-man crew, who lived on the vessel throughout the season. It is estimated that foreign boat owners spent $220,000[2] in 2010 and $250,000 in 2011 during 18–19 days of tournament fishing on boat maintenance, gas, ice, hotels, food, etc. Further, boat crews hired by these anglers spend ~$150,000 per year on food and incidentals. Two invitational events in June, one light tackle and one fly-fishing, also bring in $200,000[3] per year from visitor lodging, charter fees, entrance fees, etc. Total expenditure by foreign anglers participating in seasonal tournaments is therefore approximately $600,000 per year.

Bermuda's EEZ has attracted a strong scientific culture that is economically important to the island

Bermuda's unique position, close to deep water in the centre of the ocean and close to the United States, has led to a strong scientific culture on the island, attracting a diverse group of prominent academics and expeditions throughout history. One of the most important voyages to visit Bermuda was that of H.M.S. *Challenger,* which marked the founding of modern, quantitative oceanography. Between the years of 1872 and 1876, *Challenger* was a floating laboratory, observing a wide range of oceanographic features, such as seafloor geology, temperature, and current flow. *Challenger* stopped over in Bermuda several times during the voyage, recording some of the earliest quantitative information on Bermuda's marine environment, including coral reefs and reef fishes (Murray 1895). Another important explorer to visit Bermuda was William Beebe, known for his deep-sea dives off Bermuda. Beebe was drawn to Bermuda because of its location in the Sargasso Sea, a region which had held his interest after he found *Sargassum* weed while journeying to the Galapagos Islands (Gould 2004). Between 1930 and 1934, Beebe and Otis Barton, an engineer, used a bathysphere of Barton's design to descend into the deep ocean off Nonsuch Island, Bermuda. They were the first people to observe deep-sea animals in their native habitat, putting Bermuda at the fore-front of oceanographic science at the time (Cullen 2006). Beebe and Barton were pioneers of oceanography and deep-sea exploration, and inspired generations of scientists, including Rachel Carson, Sylvia Earle, and E.O. Wilson. Beebe was also an advocate for conservation science, understanding the delicate balance shared between humans and nature.

In 1954, 20 years after Beebe's expedition in Bermuda ended, the Bermuda Biological Station for Research (currently known as the Bermuda Institute of Ocean Sciences, BIOS), led by Henry Stommel, set up "Hydrostation S", a permanent station 28 km southeast of Bermuda that recorded ocean chemistry (Michaels & Knap 1996). Hydrostation S is the longest running, consistent time-series data of changing ocean conditions, making the Sargasso Sea and Bermuda a center for understanding global climate change and its effects on marine life. The placement of Hydrostation S led to many more monitoring and scientific stations to be placed within Bermuda's EEZ, most notably:

Bermuda Atlantic Time Series (BIOS)-1988 to present-60 nm SE of Bermuda-CTD (conductivity/salinity, temperature, depth), chemistry, photosynthetic rates, primary production, particle flux (Michaels & Knap 1996).

Ocean Flux Program (Woods Hole Oceanographic Institute)-1978 to present-75 km SE of Bermuda-time-series of particle flux between surface and deep ocean (http://ecosystems.mbl.edu/conte/ofp).

Bermuda Testbed Mooring–1994 to 2007-80 km SE of Bermuda-platform for testing and calibrating instruments for long-term data sets; meteorological measurements, currents, CTD, optical properties, trace elements (Dickey et al., 1995).

M/V Oleander Project–1992 to present–collects information on current flow and oceanographic conditions on every commercial voyage from New Jersey to Bermuda (once a week) (www.po.gso.uri.edu/rafos/research/ole/index.html).

Scientific tourism is a valuable source of income for the island that should be highly promoted. Science and research in Bermuda is currently estimated to be worth $2.3 million per year (Bervoets et al., 2010). Bermuda's position in the centre of the Sargasso Sea has stirred the interest of prominent scientists throughout history, and

[2] Based upon a study by Ditton and Stoll (2000) that determined anglers in the Mid-Atlantic region of the US spent approx. $600/day on food, drinks, tackle/bait, ice, boat maintenance, transport, lodging, entrance fees, and charter fees.

[3] $1000/day charter boat and captain, $200–300/day on lodging, food, and other costs. Approximately 10 foreign anglers are invited to each of these tournaments, and they last a total of 15 days.

this interest continues today. Bermuda boasts seven large centres that generate scientific research by locals and foreigners: BIOS, the Bermuda Zoological Society, the Bermuda Aquarium, Museum, and Zoo, the Bermuda Government Department of Environmental Protection and Department of Conservation Services, the Bermuda Underwater Exploration Institute and the Bermuda Weather Service. Scientists working through these institutions generate millions of dollars in the form of research grants, which are spent on island resources such as food, lodging, transportation, and even local help and research assistants. Bermuda has contributed a great deal of knowledge to the international scientific community, not only because of the long-term weather and oceanic observation stations present in the EEZ, but because Bermuda's marine environment is healthy. The Sargasso Sea is the most well studied region of open ocean in the world, benefiting Bermuda through international recognition for its scientific endeavours, and through the expenditure by scientists frequenting the island.

Threats to the Sargasso Sea and the Bermudian EEZ

Despite the importance of the Sargasso Sea to Bermudians, there are many human activities that are currently threatening the region. Pollution, fishing, *Sargassum* harvesting and seabed mining have the potential to harm the environment, compromising the beneficial resources that Bermudians gain from the ocean. If the marine environment is too heavily exploited, polluted, or otherwise damaged, many industries in Bermuda will suffer including tourism, fisheries and science, as they all depend on a clean, healthy ocean. Bermuda's EEZ should be considered a national treasure in its unspoiled state as it is of immense value to the island.

One of the largest threats to the Sargasso Sea and Bermudian EEZ is pollution, especially plastics and tar. These pollutants are a problem globally, but because the Sargasso Sea is encircled by currents, pollutants become concentrated. Plastic debris has been shown to mass into rafts in gyres such as the Sargasso Sea (Colton et al., 1974). These rafts mimic *Sargassum* (Winston 1982), and therefore animals that would normally live and feed within *Sargassum* may do so within the confines of the plastic instead. If animals cannot differentiate between natural and plastic habitat, there could be devastating consequences on the ecosystem. Fish, turtles, and seabirds die from malnutrition when too much plastic is ingested, as plastic can block the intestinal tract and limit food consumption (Derraik 2002). Animals can become entangled in the plastic, leading to asphyxiation or drowning (Derraik 2002). The polychlorinated biphenyls (PCBs) in plastic can cause hormonal imbalances that lead to reproductive failure in animals (Azzarello & Van Vleet 1987). The wider impact of such large quantities of plastics on the Sargasso Sea ecosystem is unknown, but the damage caused to individual animals can be considered indicative of the widespread impacts plastics can have on food webs in marine environments. There is now evidence of plastic compounds being incorporated into the oceanic food chain, including being present in fish consumed by humans (Davison & Asch 2011).

Tarballs were a large problem in the Sargasso Sea until the 1980s, up until then it was common to find large balls of tar washed up along beaches in Bermuda, especially in the south west of the island where open water is nearer to shore. Tarballs are formed when leaked oil weathers over time in the ocean and forms clumps. During the 1980s, stricter regulations and tarball fingerprinting techniques were initiated globally to hold polluters accountable for oil discharge, causing a significant decrease in the amount of tar found in the ocean and washed up on beaches in Bermuda (Smith & Knap 1985).

Another threat is from exploitive activities, such as fishing and *Sargassum* extraction. Over exploitation of marine resources can negatively impact small islands such as Bermuda that are heavily reliant on these resources. The most negative human impact in the Sargasso Sea has been fisheries exploitation, which began in the 18th century with pelagic whaling and continues today with the continued targeting of declining populations of large pelagic fishes. Industrial fishing in the high seas such as the Sargasso Sea region has led to declines in the populations of large pelagic animals such as tunas and sharks. Since the year 1900, it is estimated that 90% of predatory fish stocks across the oceans have collapsed (Myers & Worm 2003), likely because of significant increases in pelagic fisheries on the high seas in the mid-1900s (Christensen et al., 2003). In the Sargasso Sea and the Bermuda EEZ, tunas and related species have been the most heavily targeted, primarily by fishing fleets from Japan and Taiwan, but also by fleets from the Unites States, Canada, and Spain. During the 1950s and 1960s, bluefin tuna and albacore were targeted, followed by bigeye in the 1970s and 1980s, and yellowfin in the 1990s and 2000s (Hallett 2011). The shift in target species over the last 60 years reflects declines in fisheries landings and catch-per-unit-effort that are evident in fisheries records (Hallett 2011). Presently, these species are considered overfished, leading the IUCN to place them

on the red-list this year. Foreign fleets have not been allowed to fish in Bermuda's EEZ since 1994; however continued exploitation of these species outside the EEZ will affect the Atlantic populations of these fish.

Commercial extraction of *Sargassum* weed is also a potential threat to the ecosystem in the Bermudian EEZ and the wider Sargasso Sea. In the United States, *Sargassum* has traditionally been harvested for use as fertilizer and cattle feed (NOAA & NMFS 2003), but strict regulations enacted recently prevent heavy exploitation of stocks within U.S. jurisdictional waters. However, there are many new uses of *Sargassum* weed that could potentially lead to high levels of *Sargassum* extraction from the high seas, or from within Bermuda's EEZ. Extracts from *Sargassum* are presently of interest as biofuels, antibiotics, antifungals and antifouling agents (NOAA & NMFS 2003). It will likely be important in the future to protect *Sargassum* habitats from the threats of heavy commercial extraction, much like in the United States.

Historically Bermuda has been an important and heavily used shipping port. The Sargasso Sea is also one of the busiest regions in the world for shipping activities. There is a risk that the high volumes of sea traffic transiting the region may discharge large quantities of contaminants such as sewage, oil and garbage. It is also possible that ships may introduce potentially harmful exotic and invasive species through ballast water discharge. Exotic species can wreak havoc on ecosystems by competing with native animals, causing native and endemic species to go extinct.

Seabed mining is also a threat that could impact the Sargasso Sea in the future. Although there is no seabed mining occurring in the region at the moment, interest in mineral resources and their worth is rising and it is possible that Bermuda's EEZ and the wider Sargasso Sea region will become targeted for exploration. A recent news article in the Bermuda Sun highlighted the potential for Bermuda's EEZ to be mined for precious minerals and metals[4]. Seabed mining creates large plumes of sediment that can smother corals and hard bottom communities and can also clog the gills of fish. Stirring up the seabed can also release heavy metals into the water column, therefore polluting the food chain.

[4] "Deep Sea Gold Rush Could Bankroll Bermuda", Bermuda Sun, 28 Sept 2011 http://bermudasun.bm/main.asp?SectionID=24&SubSectionID=270&ArticleID=54421

Conclusions

It is evident that the resources within the Sargasso Sea and the Bermudian EEZ are critical to Bermuda and Bermudians. The ocean around the island provides key ecosystem services that support the livelihoods of many Bermudians. Without the animals and plants that inhabit the Sargasso Sea, Bermuda would not have healthy coral reefs, a lively tourism industry, or a healthy fishing industry that thrives off the abundance of pelagic fishes found close to shore. Early settlers would not have stayed on the island if not for abundant turtles, cahows, and fish. Without *Sargassum* weed to bind beach dunes, Bermuda might not have even formed to be the island it is today. Bermuda's economy can gain a great deal through protection of the EEZ, and through the promotion of positive industries such as marine science and ecotourism. Bermuda heavily depends on oceanic resources, and it is therefore clear that Bermuda should encourage conservation and protection of its culturally, economically and ecologically important EEZ. Threats to the region are large international issues that are difficult to solve, but Bermuda can help to protect its critical oceanic resources within the EEZ by ensuring that local regulations regarding shipping discharges and pollution are updated and obeyed, by continuing to promote science and education to inspire conservation of the ocean, and by taking action to establish zones in the EEZ that offer protection to all marine life against human impacts. Steps such as these will ensure that Bermuda is a world leader in marine conservation, able to sustain a healthy environment while managing human activities.

CRITERIA	FEATURES OF THE SARGASSO SEA WITHIN THE BERMUDA EEZ
Uniqueness/rarity	unique habitat of *Sargassum* weed; Marlin spawning site.
Importance for critical life history stages	Blue and White Marlin spawning site, flyingfish nests in *Sargassum*, habitat for juvenile sea turtles, feeding ground for young humpback whales and sperm whales, habitat for larvae of dozens of fish species (reef and commercial).
Importance for threatened, endangered, declining species or habitats	humpback whale (CITES), sperm whale (IUCN, CITES)and minke whale feeding ground and migratory route, tuna migratory route (IUCN), European eel (CITES, IUCN) migratory route, marlin spawning (IUCN), cahows (IUCN), Whale Sharks (CITES), turtles (IUCN, CITES), several sharks (IUCN), deep-water corals, seamount communities.
Vulnerability	vulnerable to deep-sea prospecting, fishing activity, shipping, pollution, plastics.
Biological productivity	presence of highly productive seamounts, upwelling.
Biological diversity	endemic deep-sea fish and crustaceans, high diversity and productivity on seamounts, deep-water corals.
Naturalness	not as natural as other regions of open ocean: influences of shipping, plastics, tar.

ANNEX 1. Convention on Biological Diversity criteria for an area of biological or ecological importance, with reference to the Bermudian EEZ

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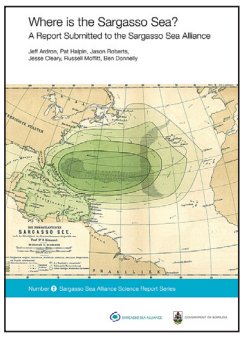
The following is a list of the reports in the Sargasso Sea Alliance Science Series. All can be downloaded from www.sargassoalliance.org:

1

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



2

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

3

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

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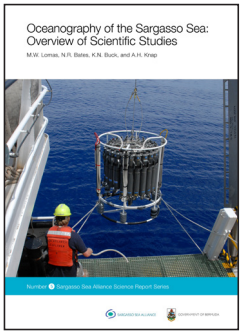
Hallett, J. 2011. *The importance of the Sargasso Sea and the offshore waters of the Bermudian Exclusive Economic Zone to Bermuda and its people. Sargasso Sea Alliance* Science Report Series, No 4, 18 pp.



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

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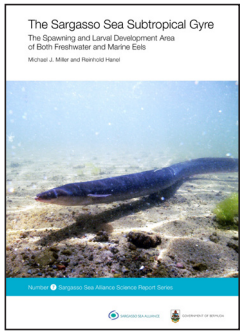

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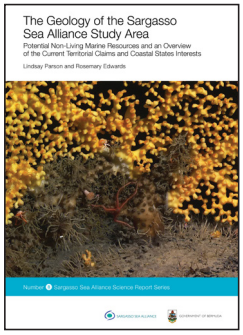

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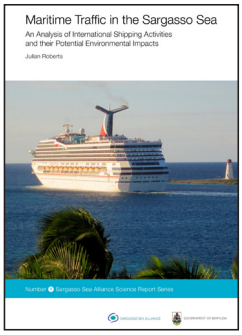
Parson, L. and R. Edwards 2011. *The geology of the Sargasso Sea Alliance Study Area, potential non-living marine resources and an overview of the current territorial claims and coastal states interests.* Sargasso Sea Alliance Science Report Series, No 8, 17 pp.



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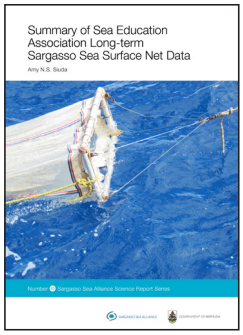

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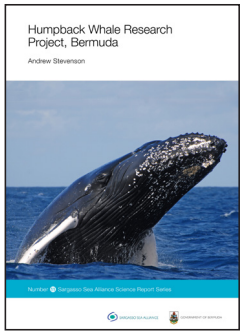

11

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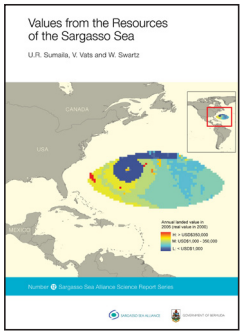

12

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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