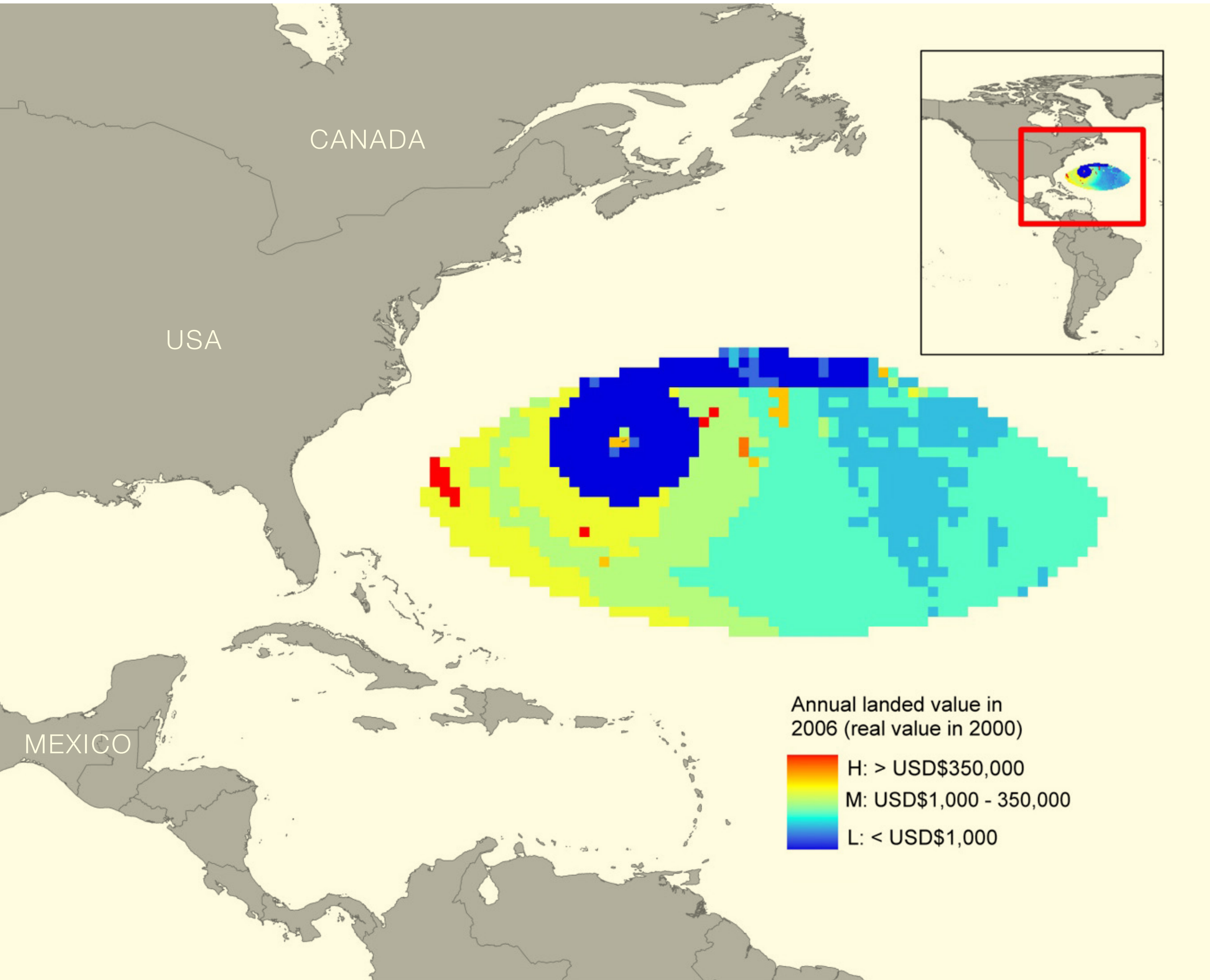
Values from the Resources of the Sargasso Sea

U.R. Sumaila, V. Vats and W. Swartz



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N.B The Indirect Values of the Sargasso Sea (Section 8) replace those given earlier in Laffoley, D.d'A., et al. *The protection and management of the Sargasso Sea: The golden floating rainforest of the Atlantic Ocean. Summary Science and Supporting Evidence Case. Sargasso Sea Alliance,* 44 pp.

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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Website is **www.sargassoalliance.org**

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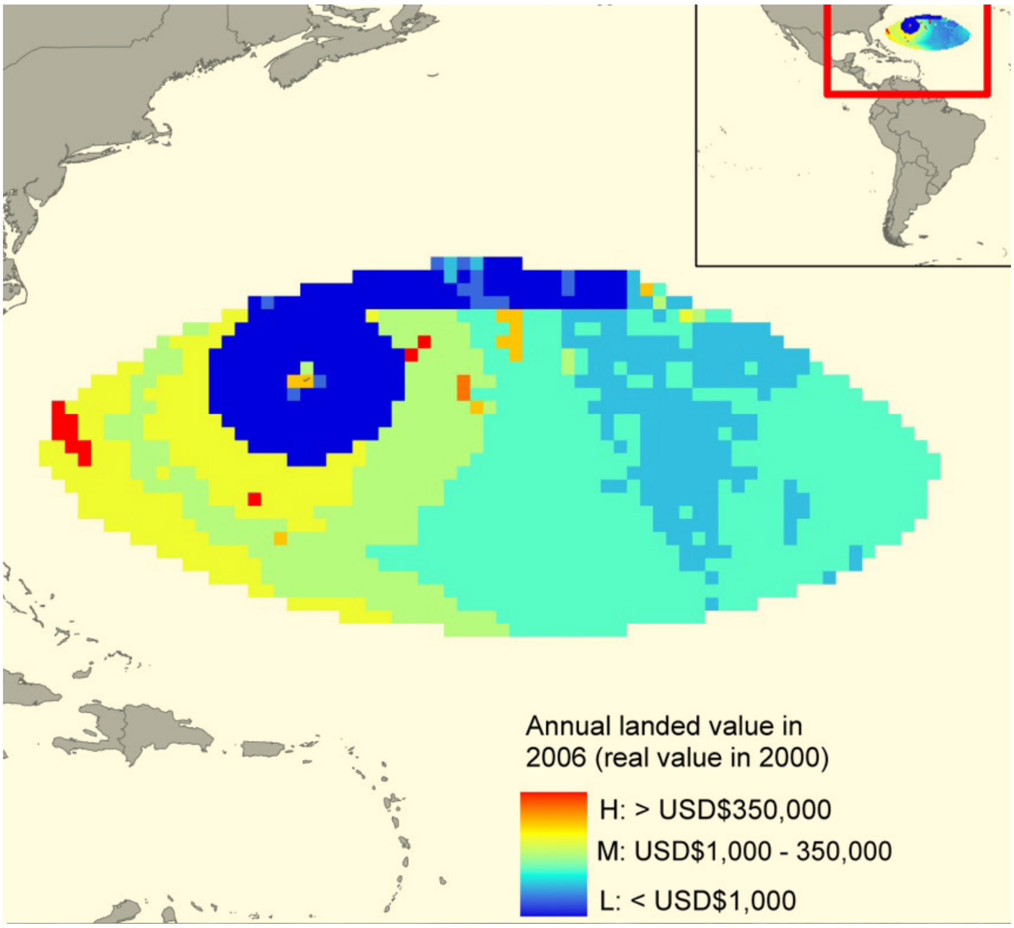

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Foreword

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.**

Professor Howard Roe
Science Advisory Committee Chair
Sargasso Sea Alliance

Professor Dan Laffoley
Science Coordinator
Sargasso Sea Alliance

Values from the Resources of the Sargasso Sea

1. Introduction

This report seeks to promote sustainable development in the open ocean areas of the Sargasso Sea by providing stakeholders with an economic analysis for decision-making based on the economic value of the resources of the Sargasso Sea. The ultimate goal is to i) collect, compile data and measure the economic value of the key ecosystem goods and services in the Sargasso Sea (e.g. commercial fishing, recreation and *Sargassum* harvesting); and ii) measure the incomes and other benefits generated by these goods and services.

Specifically, we seek to (a) measure the economic value of the Sargasso Sea and the resources it supports, and their contribution to economies; and (b) use the economic results to provide resource managers with some management recommendations.

2. Theoretical Framework for Economic Valuation

Economists recognize that people value an ecosystem for many purposes, which can be classified into *use values* and *non-use values* (Arrow et al., 1993). *Use values* refer to the ecosystem goods and services that directly support economic activity and human wellbeing, either the direct use of resources such as fish or recreation, or the indirect support provided by ecosystem goods and services (Berman & Sumaila, 2006). We care about indirect use values because they are essential inputs to producing something with direct use value. For example, a mangrove forest has an indirect use value for the habitat service it provides for fish (a direct use value) as well as an indirect use value for the shoreline protection service it provides for human settlements (a direct use value). Option value refers to the value of maintaining the option to enjoy direct or indirect use of natural and environmental resources in the future. *Non-use values* refer to the value we place on simply knowing that the ecosystem will be available to future generations (bequest value) and on the intrinsic value of the ecosystem itself (existence value). An estimate of the total value of ecosystem goods and services should include all use and non-use values (Heal, 1998).

For this project, however, we first provide a description of the resources of the Sargasso Sea, and then focus on direct and indirect use values from the Sargasso Sea because of the limited time and resources available for this phase of the project. The planned analysis will lay the foundation for future studies that can build on results produced herein to estimate the total economic value (including non-use values) of the resources of the Sargasso Sea.

3. Background

The Sargasso Sea (**FIGURE 1**) covers an area of approximately 4,163,499 km^2. The Sargasso Sea contains a collection of commercially and ecologically valuable resources including fish species and *Sargassum spp.*, a genus of brown macroalgae commonly used as fertilizer, cattle feed and other commercial extracts.

Sargassum within the Sargasso Sea is primarily composed of two species, which jointly create a dynamic structural habitat of the region (SAFMC, 2002). *S. natans* (approximately 90% of total drift macroalgae) and *S. fluitans* range in size from 20-80 cm in diameter and form aggregations known as algal mats, which are found at or near the sea surface (SAFMC, 2002). *Sargassum* habitat extends primarily between 20°N and 40°N latitudes and between 30°W longitude and the western edge of the Florida Current/Gulf Stream. The highest concentrations of *Sargassum* are found within the North Atlantic Central Gyre, located within the Sargasso Sea. The biomass of *Sargassum* is estimated at a standing crop size of 4-11 million metric tonnes. SAFMC (2002) provides more details on the distribution of *Sargassum* species within the Northwest Atlantic.

Most commercially important fish stocks in the Sargasso Sea are tuna stocks such as albacore, yellowfin tuna, and bluefin tuna. These stocks are known to spawn in the Sargasso Sea and migrate throughout the high seas and EEZs of the Atlantic, where they encounter pressures from commercial fisheries (**FIGURE 2**).

Eels are another commercially important fish stocks that are highly dependent on the Sargasso Sea through the course of their life cycles. The region is a key spawning ground for both European and American eels and, although these species are not directly exploited within the Sargasso Sea, large fisheries for both species exist throughout North America, Europe, and Africa, both for food consumption and as brood stocks for capture-based aquaculture. **FIGURE 3** depicts the historical range of eels

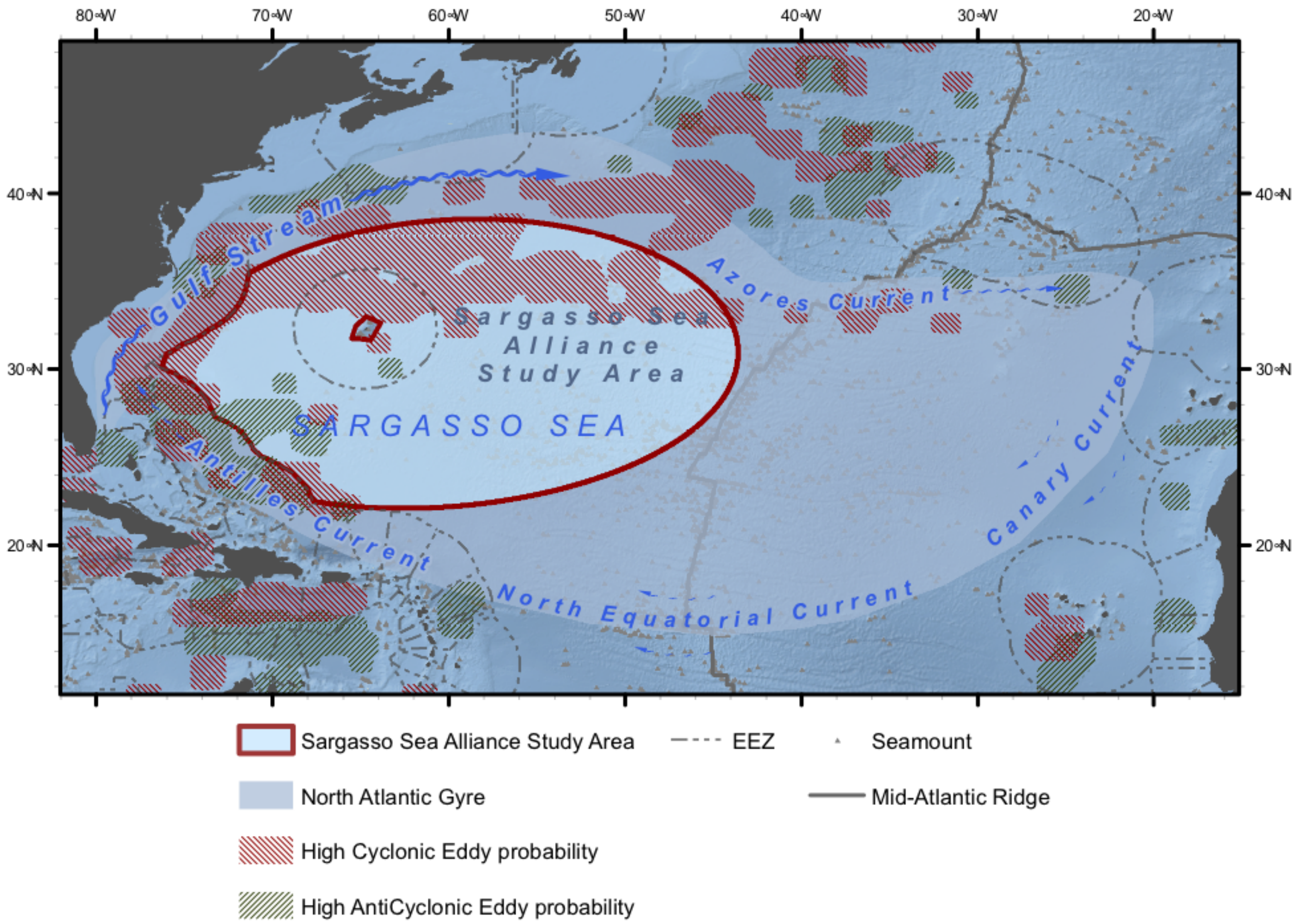

FIGURE 1. The Sargasso Sea Alliance study area. Credit: Laffoley et al., 2011 unpublished.

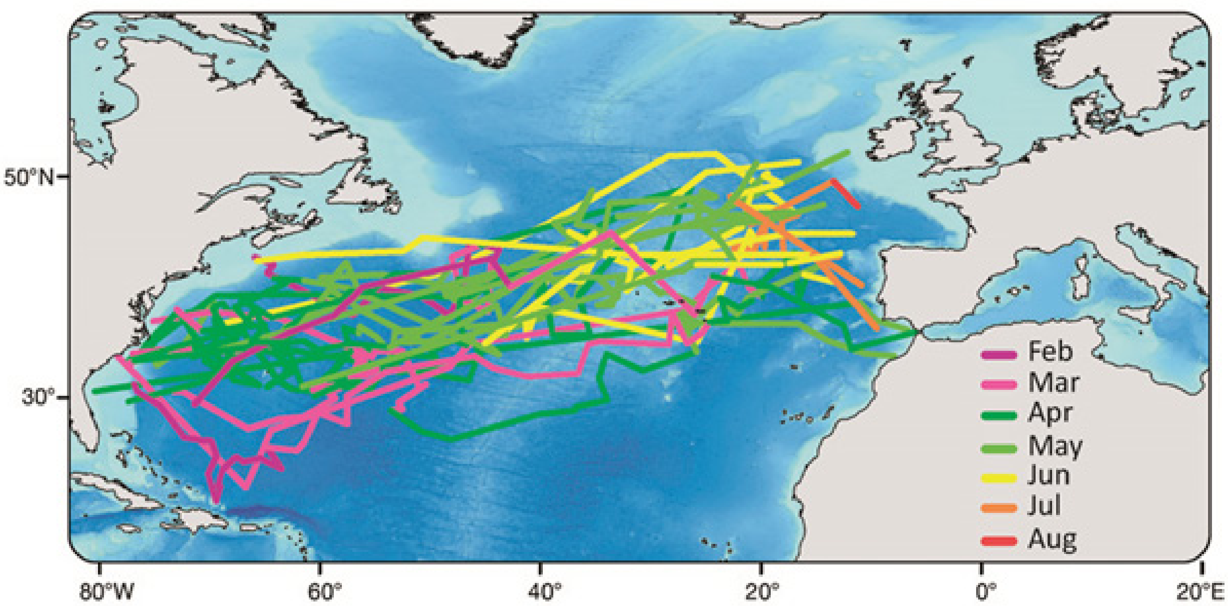

FIGURE 2. Transatlantic routes taken by tagged bluefin tuna moving from west to east. Credit: Wilson and Block (2009).

spawning in North America, and shows the importance of the Sargasso Sea in this important stage in the life of eels.

Ottolenghi et al., (2004) provides information on the characteristics of European and American eels and details of global trends of these fisheries including catch statistics from 1991-2000, information regarding capture of glass eels (juveniles) for aquaculture and commercial statistics such as prices, trade routes, market and their total global values.

In addition to the information available in Ottolenghi et al., (2004), detailed information regarding a description of American eels, price per pound of various life stages, management of this resource by the United States as well as descriptions of U.S. fisheries and landings of the various life stages can be found in ASMFC (2002). Information on Canadian commercial eel fisheries is found in DFO (2010).

Ringuet et al., (2002) describes the biological cycle of both American and European eels and explores the role of the Sargasso Sea habitat for both species. This paper also includes a description of European eel fisheries in Europe and provides estimated catches and details for fisheries of the different life stages. The authors also provide a section on the international trade of eels and the evolution of prices for glass eel fisheries highlighting the increased demand by Asian countries for European fished eels. Finally, the publication outlines the various retail markets for eels.

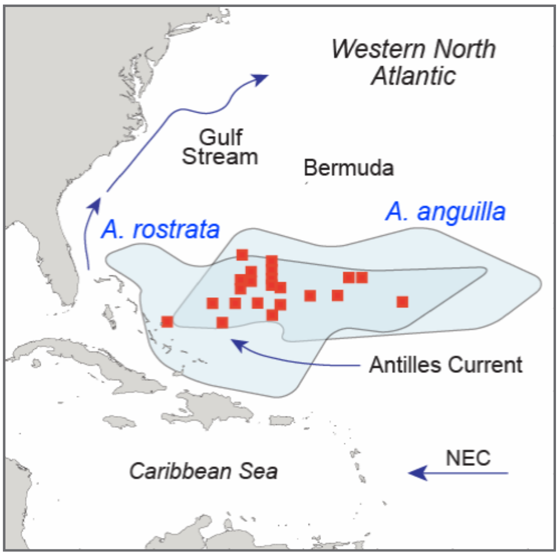

FIGURE 3. Eel spawning map: The two light grey areas are the overlapping spawning grounds of the two Atlantic eel species in the Southern Sargasso Sea based on the distributions of their small leptocephali (10 mm). Red squares indicate stations where small recently hatched larvae 7 mm or smaller of both species were collected together. Credit: Miller and Hanel 2011 unpublished, adapted from McCleave, Kleckner and Castonguay (1987).

4. Fisheries Values

The Model

To provide a broad picture of direct use values, we estimate and present the following economic indicators; (i) landings; (ii) landed values or total revenues; (iii) resource rent; (iv) income effect; and (v) economic impact and throughout the wider economy.

Landed value or total revenue is the product of ex-vessel price and catch in the case of commercial fisheries; resource rent is the surplus after all costs are deducted; income effect is the amount of income generated in an economy for every dollar of landed value of fish; and the economic impact is the amount of economic activity generated throughout an economy for every dollar of landed value of fish made.

Total revenue, income effect and economic impact are assumed to be functions of landings (L) in the following manner:

$$Total\ Revenue = L * p$$
$$Income\ effect = L * p * Mincome$$
$$Economic\ Impact = L * p * Mimpact$$

where p, c represent price and costs per tonne, respectively.

The parameters, *Mincome* and *Mimpact,* denote the income effect and economic impact multipliers for a dollar of landed fish in the fishing country. These parameters are taken from Dyck and Sumaila (2010).

We calculate resource rent, R, according to the following equation:

$$R = LV - (C + S)$$

Where LV represents the value of officially reported marine landings. The total variable cost of fishing is represented by C and subsidies are represented by S.

The present value of a given economic indicator, i, over time, t, is expressed as:

$$PV_i = \sum_{t=0}^{T} \delta_i^t X_{i,t}$$

where $X_{i,t}$ represents economic indicator i at time $t=0 \ldots T$ and the parameter δ is the discount factor determined using the appropriate rate of discount applicable to the United States. The discount factor is calculated using a real discount rate of 3.0% as implied by the arguments in Weitzman (1997) and Sumaila (2004), and Sumaila and Walters (2005).

The Data

Catch/Landings

Catch statistics of the commercial fisheries operating within the Sargasso Sea were obtained from the *Sea Around Us* Project (**www.seaaroundus.org**). The data is based on the FAO global fisheries database (FAO FishStat) and is supplemented, when possible, by regional and national sources, included results of catch reconstruction studies. The catch statistics of the *Sea Around Us* Project are presented in a system of ½ x ½ lat-long grid, with the improved spatial resolution provided by a series of algorithms and proxy information including biological distribution of the reported catch taxa (approximated from additional information such as habitat types) and known areas of operations for distant water fleet (based on fishing access agreements). Details of the methods and procedures of this spatial allocation are described in Watson et al., (2004).

We extract catch data spatially for the Sargasso Sea from this database for our analysis and present them in **TABLE 1.**

Ex-Vessel Fish Price Database

For ex-vessel fish prices, we relied on the database described in Sumaila et al., (2007), which contain annual average ex-vessel prices for all marine fish taxa caught from 1950 to the present. Through their extensive search of publicly available, but widely scattered and incompatible,

COUNTRY	LANDINGS (T)	PRICE ($/T)	COST ($/T)	SUBSIDIES ($/T)	INCOME MULTIPLIER	IMPACT MULTIPLIER
Mexico	13132.87	1446	1312	54	0.12	0.61
Venezuela	9346.86	938	362	136	0.44	1.06
Spain	3204.45	1014	642	642	1.00	3.86
Japan	3038.59	6654	763	781	0.86	2.75
USA	1908.61	3220	1636	310	1.29	3.10
Trinidad Tob	1846.69	1909	669	935	0.28	1.22
Cuba	1767.31	1969	421	362	0.28	1.22
St Vincent	1292.74	2082	495	1106	0.28	1.22
Taiwan	955.98	4321	800	213	0.97	3.28
Brazil	743.78	1839	477	724	0.81	2.39
Vanuatu	688.59	9938	596	2223	0.65	3.34
Barbados	584.39	1606	399	159	0.29	1.21
Grenada	427.18	1993	655	2130	0.28	1.21
Honduras	255.61	2515	267	1145	0.78	3.46
Bermuda	236.09	2581	281	1132	1.31	7.34
Nicaragua	179.27	1908	415	994	0.41	1.50
NethAntilles	155.10	2515	638	47	0.28	1.21
Costa Rica	101.85	1905	463	326	0.52	2.16
Belize	69.91	820	397	1503	0.78	3.46
Puerto Rico	59.22	1746	1636	310	0.28	1.21
US Virgin Is	49.20	1858	1636	310	0.28	1.22
Colombia	41.38	1090	455	158	1.43	3.14
Guatemala	29.82	2429	603	529	0.52	1.87
Cayman Is	23.99	2515	281	1132	0.28	1.22
Bahamas	19.26	1113	281	1132	0.28	1.22
Korea Rep	3.83	3838	667	365	0.62	2.91
Portugal	3.28	2131	625	503	1.52	4.78
Greenland	0.21	6677	529	26	1.32	7.38
Canada	0.03	5818	1625	687	1.07	3.30

TABLE 1. **Summary data used in analysis**

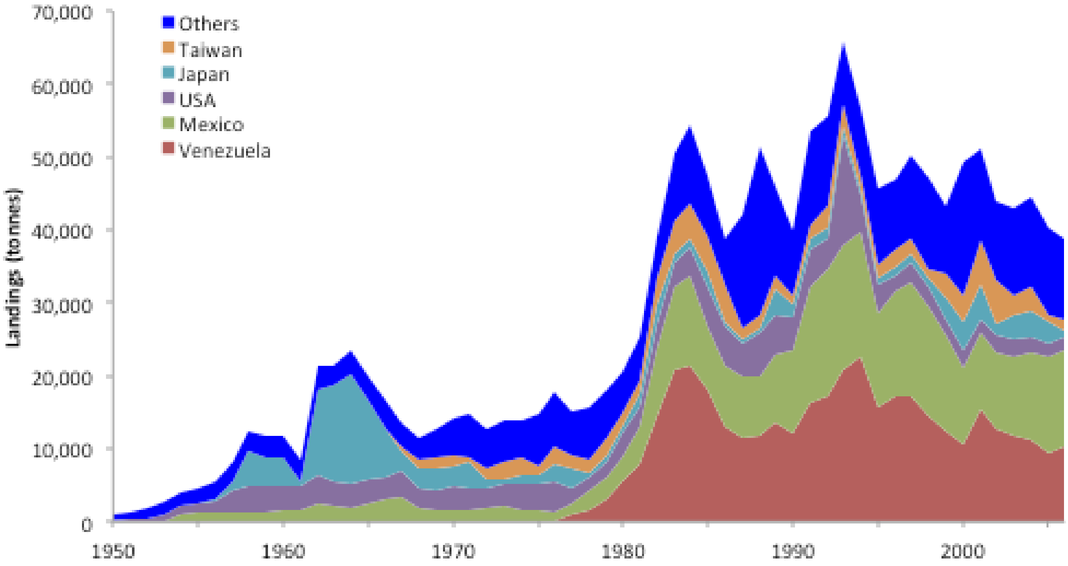

FIGURE 4. Marine fisheries landings in the Sargasso Sea, by flag country.

national and regional statistical reports and grey literature, Sumaila et al., (2007) accumulated over 31,000 records of observed ex-vessel prices in 35 countries, representing about 20 percent of the global landings over the 60 year period under study. In order to 'fill the gaps' in the database, a series of rules were developed whereby all catches with no reported prices were inferred to have an estimated price computed from the reported prices from related taxa, similar markets or years. Since the database was published, new reported prices have been included from various additional sources, and rules as to how prices relate across taxa, markets or years have been modified to improve the quality of the estimated prices. We extract landed values of the fish landed, which are computed by combining the spatially allocated catch data with the ex-vessel price database for the Sargasso Sea and use it for our analysis (**TABLE 1**).

Fisheries Subsidies Database

Fisheries subsidies are financial transfers, directly or indirectly, from government to the fishing industry. Sumaila et al., (2010) is the most recent collection of publicly available data on fisheries subsidies at the global level, spanning the years 1990 to the present. Each record in the database represents expenditure in one of twenty-six identified subsidy categories for a given country and year combination. Where qualitative information indicates the presence of a subsidy program, yet quantitative data are not available, the database records the expenditure data as 'missing' for estimation. A summary of subsidies data used in the analysis are given in **TABLE 1.**

Fishing Cost Database

Lam et al., (2011) developed a global database of fishing costs capturing two types of fishing cost, variable (operating) and fixed costs in 144 maritime countries, representing approximately 98% of global landings in 2005. Each record in the database represents each country and gear type combination. The gear types included in the database are based on the gear categorization system of the *Sea Around Us* Project (Von Brandt, 1984; Watson et al., 2004). Fishing cost data are collected from secondary sources in major fishing countries in the six FAO regions.

The Results

Landings

FIGURE 4 shows that fish landings from the Sargasso Sea have, in general, been increasing from the 1950 to the 1980s then stabilized until the early 1990s when it began to decline. More countries have been fishing in the Sargasso Sea over time, but currently Venezuela, Mexico, the U.S.A. and Japan are the big fishing countries active in the Sargasso Sea.

FIGURE 5 depicts the landings from the Sargasso Sea by EEZ and High Seas. We see from this figure that most of the landings are taken from the high seas, with smaller landings taken from the Bermuda and Bahamas EEZs.

In **FIGURE 6**, we plot landings from the Sargasso Sea by gear type. The figure shows that gillnets and longlines have been and continue to be the top gears used to catch fish in the Sargasso Sea. Other gears that are important are purse seines, traps and driftnets.

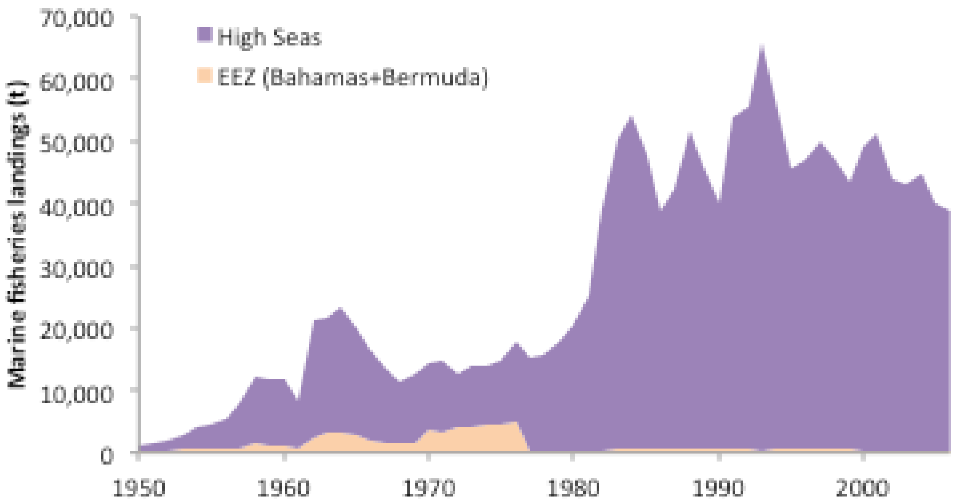

FIGURE 5. Marine fisheries landings in the Sargasso Sea, by region (i.e., high seas and EEZs). Note that the large majority of the catch occurs in the high seas.

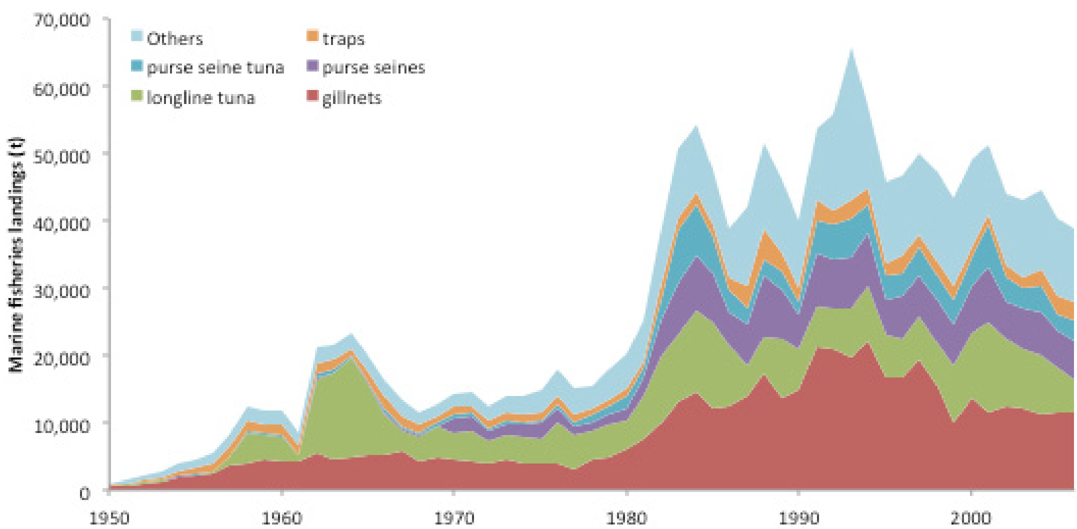

FIGURE 6. Marine fisheries landings in the Sargasso Sea, by gear type.

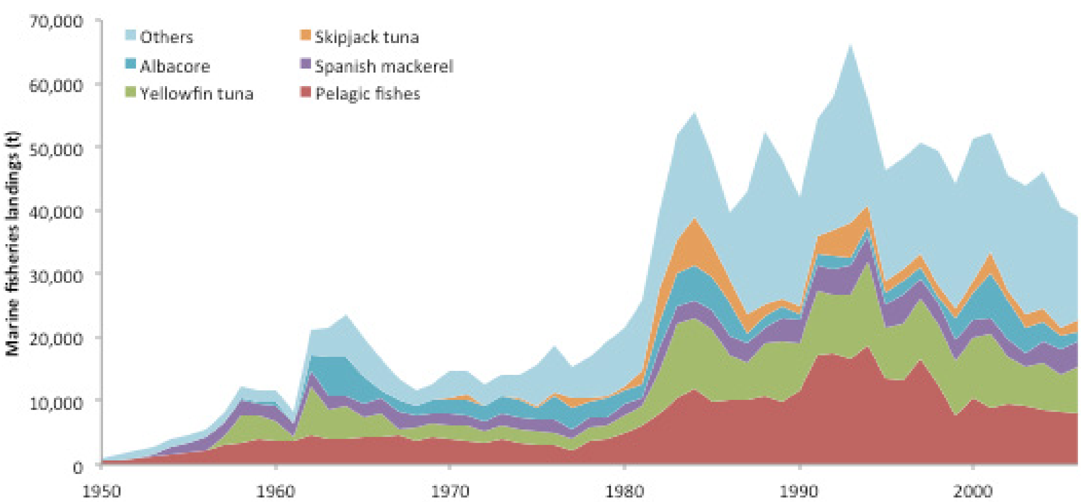

FIGURE 7. Marine fisheries landings in the Sargasso Sea, by species.

FIGURE 7 presents landings by species, and shows that pelagic species, in particular, large pelagics such as the tunas dominate the landings.

We provide a spatial distribution of landings from the Sargasso Sea in **FIGURE 8.** The red regions are areas of high catch while the blue regions depict regions of low catch.

Landed Values

FIGURES 9-12 depict the landed values from the Sargasso Sea by (i) country; (ii) high seas and EEZs; (iii) gear; and (iv) species.

FIGURE 9 reveals some differences between landings and landed values. While the landings profile shows a clear peak in the early 1990s, landed values were more stable between 1980 and 2000, indicating that prices have been trending upwards as catches have declined. We observe a declining trend after 2000. According to the data available to us, Mexico is the country that currently makes the largest landed value from the Sargasso Sea.

The pattern depicted in **FIGURE 10** is similar to that in **FIGURE 6** for landings, where the high seas clearly dominates.

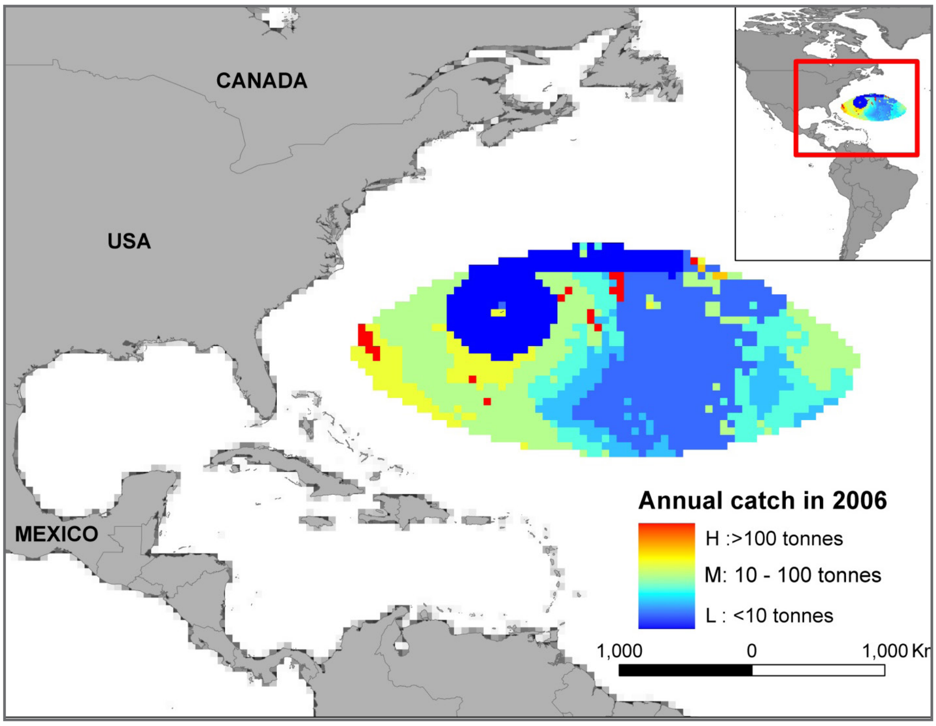

FIGURE 8. Spatial distribution of catches in the Sargasso Sea.

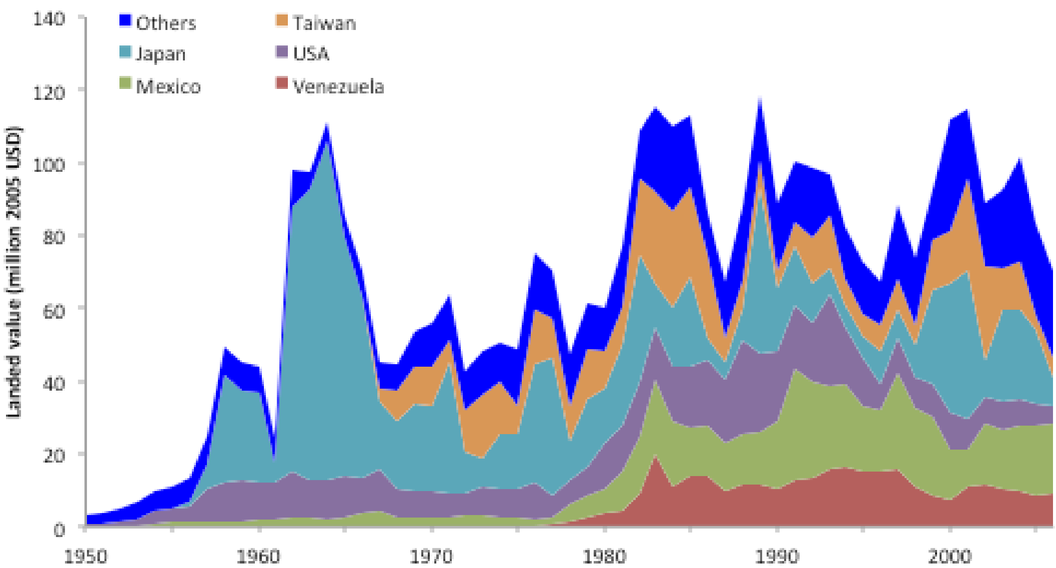

FIGURE 9. Marine fisheries landed values (in real 2005 USD) of the Sargasso Sea, by flag country.

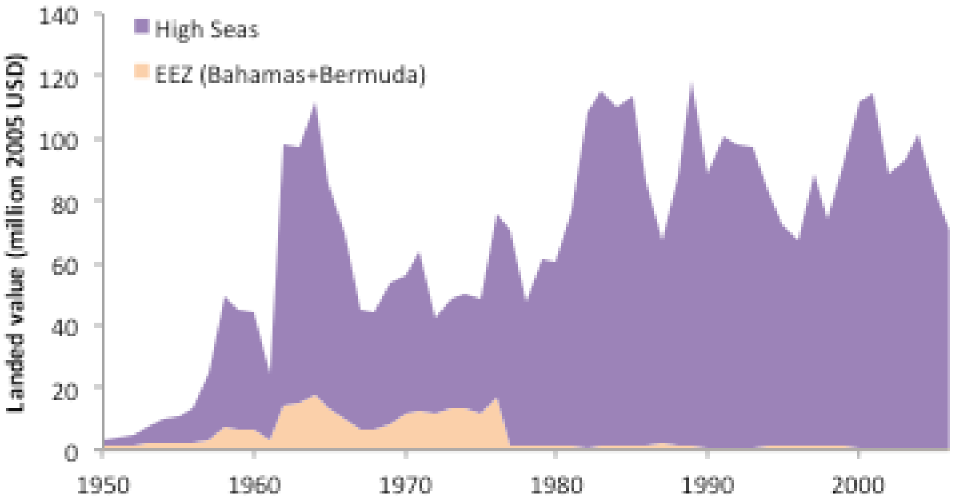

FIGURE 10. Marine fisheries landed values (in real 2005 USD) of the Sargasso Sea, by region (i.e., high seas and EEZs). Note that the high seas accounts for the large majority of the value generated in the Sargasso Sea.

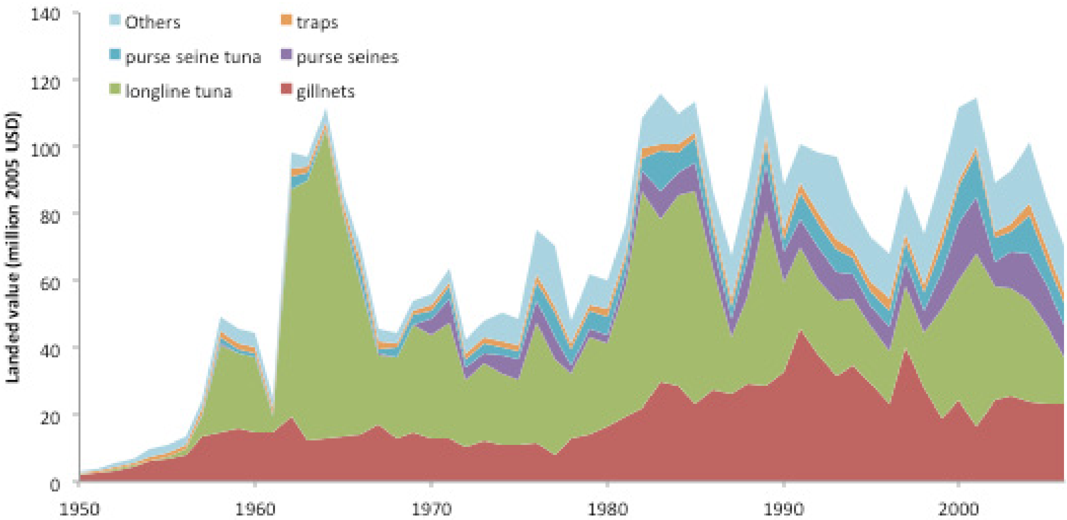

FIGURE 11. Marine fisheries landed values in the Sargasso Sea, by gear type.

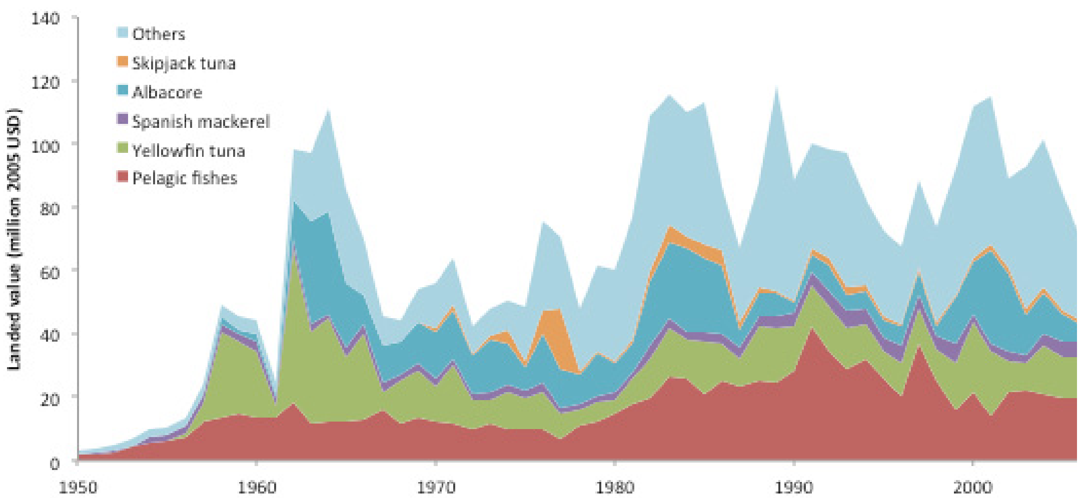

FIGURE 12. Marine fisheries landed values in the Sargasso Sea, by species.

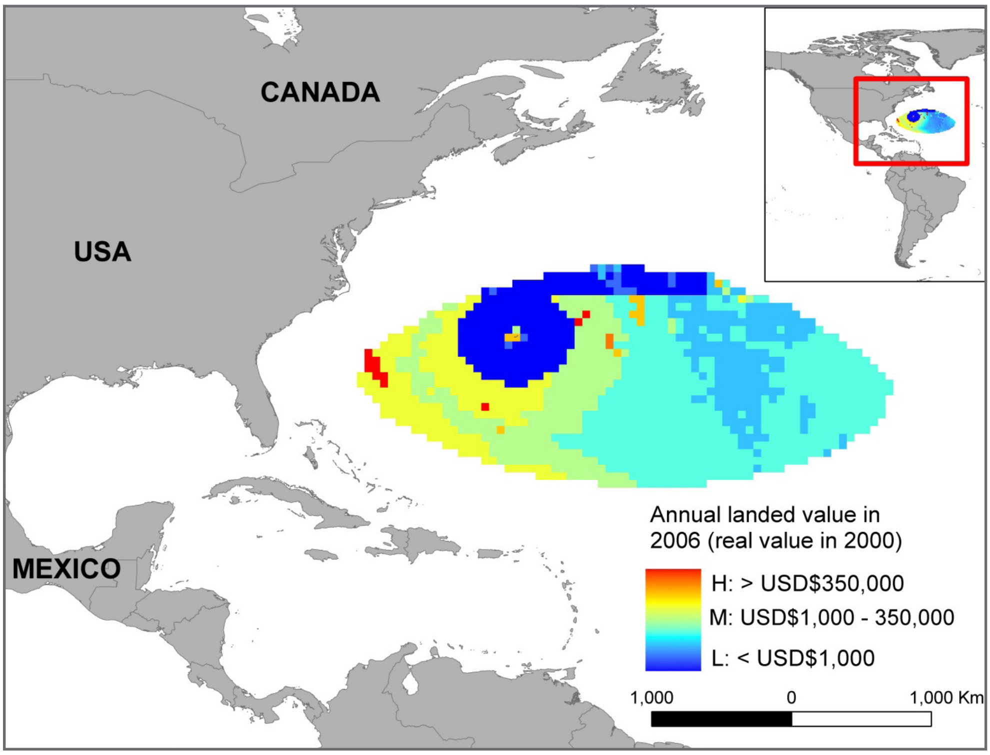

FIGURE 13. Spatial distribution of landed values in the Sargasso Sea.

From **FIGURE 11**, we see that as in the case of landings, gillnets and longline tuna get the largest catch values for their landings.

FIGURE 12 shows that pelagic fishes and the tunas contribute the most landed values obtained by exploiting the resources of the Sargasso Sea.

One pattern that shows throughout the figures above is the wild fluctuations in catch and landed value over time. This may be because fishers use Sargasso Sea resources as a fall back activity to make up when their main fishing grounds are not meeting the catch targets.

Finally, we display in **FIGURE 13,** a spatial distribution of landed values derived from the Sargasso Sea. The more reddish a given area the more landed value is taken from it.

Resource Rent

A summary of the data used in our analysis are given in **TABLE 1,** and a summary of the results obtained are presented in **TABLE 2** and **TABLE 3**. We see from **TABLE 2** that the total landed value in 2005 is about $84 million while the cost of fishing is estimated at about $33 million. Hence, the resource rent before subsidies are deducted is $51 million a year. When subsidies of about $15 million are deducted, the adjusted resource rent is estimated at $36 million a year (**TABLE 2**).

Economic impact and income effect

The economic impact and income effect multipliers for the countries fishing in the Sargasso Sea are given in **TABLE 1**. Combining these with the landed values reported in **TABLE 2**, we compute the income effects and economic impacts of the fisheries dependent on the Sargasso Sea in 2005. The results obtained are reported in **TABLE 2**.

We see from this table that the total income effect and economic impacts of fishing in the Sargasso Sea are about $50 and $171 million a year, respectively.

Present value of flow of use values

Using the formula stated in the modeling section, we compute the present value of resource rent both with and without subsidies adjustment, the income effect and the economic impact of fishing in the Sargasso Sea, and report these in **TABLE 3**, using a discount rate of 3% and calculating this for 10, 20 and 50 year time horizons

The estimated resource rents adjusted for subsidies are $311, $542 and $938 million for the 10, 20 and 50 year time horizons, respectively. The equivalent numbers for income effects and economic impacts are $435, $758 and $1,311 million and $1,500, $2,616 and $4,525 million, respectively.

COUNTRY	LANDED VALUE ($'000)	TOTAL COST ($'000/T)	TOTAL SUBSIDY ($'000)	RENT ($'000)	RENT LESS SUBSIDIES ($'000)	INCOME EFFECT ($'000)	ECONOMIC IMPACT ($'000)
Bahamas	21.4	5.4	21.8	16.0	-5.8	6.1	26.0
Barbados	938.6	233.2	92.7	705.4	612.7	267.7	1140.2
Belize	57.4	27.7	105.0	29.6	-75.4	44.8	198.6
Bermuda	609.4	66.2	267.3	543.2	275.9	799.8	4471.5
Brazil	1367.8	354.5	538.3	1013.3	475.1	1111.7	3275.6
Canada	0.2	0.0	0.0	0.1	0.1	0.2	0.6
Cayman Is	60.3	6.7	27.2	53.6	26.4	16.8	73.7
Colombia	45.1	18.8	6.6	26.3	19.7	64.4	141.6
Costa Rica	194.0	47.2	33.2	146.8	113.7	100.9	419.2
Cuba	3480.0	744.3	639.4	2735.7	2096.3	990.5	4228.4
Greenland	1.4	0.1	0.0	1.3	1.3	1.9	10.6
Grenada	851.6	279.7	909.9	571.9	-338.1	241.3	1034.0
Guatemala	72.4	18.0	15.8	54.4	38.7	37.8	135.5
Honduras	642.8	68.3	292.8	574.5	281.7	501.7	2225.3
Japan	20218.3	2318.5	2372.7	17899.8	15527.1	17421.7	55688.4
Korea Rep	14.7	2.6	1.4	12.1	10.7	9.0	42.7
Mexico	18987.3	17227.5	708.7	1759.8	1051.2	2242.0	11552.8
NethAntilles	390.0	99.0	7.3	291.0	283.7	109.8	472.9
Nicaragua	342.1	74.5	178.2	267.6	89.5	139.5	514.5
Portugal	7.0	2.0	1.6	4.9	3.3	10.6	33.4
Puerto Rico	103.4	96.9	18.3	6.5	-11.8	29.3	125.6
Spain	3247.9	2057.4	2057.4	1190.5	-866.9	3246.7	12549.2
St Vincent	2692.1	639.3	1430.3	2052.8	622.4	765.5	3271.2
Taiwan	4130.5	765.0	203.4	3365.5	3162.1	4000.8	13546.9
Trinidad Tob	3525.4	1235.5	1726.9	2289.9	563.0	1003.6	4284.5
US Virgin Is	91.4	80.5	15.2	10.9	-4.3	26.0	111.2
USA	6145.8	3122.9	590.7	3022.9	2432.1	7957.3	19023.3
Vanuatu	6843.2	410.5	1531.0	6432.6	4901.6	4429.5	22882.5
Venezuela	8769.0	3383.2	1275.0	5385.8	4110.8	3890.4	9266.1
Total	**83850.4**	**33385.4**	**15068.1**	**50465.0**	**35396.8**	**49467.3**	**170745.9**

TABLE 2. **Summary results**

ECONOMIC INDICATOR ($ MILLIONS)				
TIME HORIZON	RENT	RENT LESS SUBSIDY	INCOME EFFECT	ECONOMIC IMPACT
10	**443**	**311**	**435**	**1,500**
20	**773**	**542**	**758**	**2,616**
50	**1,337**	**938**	**1311**	**4,525**

TABLE 3. **Present value of rent, economic impact and income effect**

Sargasso Sea tuna fisheries as presented by the International Commission for the Conservation of Atlantic Tunas (ICCAT)

The ICCAT Secretariat maintains multiple databases on the tuna fisheries in the Atlantic, many of which are publicly accessible via the ICCAT website (**www.iccat.es**). For the purpose of estimating the level of fisheries operation in the Sargasso Sea, two such databases were used: the CATDIS Catch database and the Task II Catch & Effort database. Both databases were accessed 8 August, 2012.

The CATDIS Catch database contains estimates of total catches for the nine major tuna and tuna like species managed by ICCAT, stratified in time (trimester) and space (5x5 degree squares). CATDIS uses the time/space distribution of Task II partial catch data (obtained from sampled catch and effort reports, see below) as a representative of overall annual catches and distributes them accordingly. The database presents catches by flag, fleet, gear and stock and covers the time period from 1950 to 2009.

The Task II Catch & Effort database contains data obtained from sampling a portion of the individual fishing operations of a given fishery in a specified period of time. The time and space resolution is higher than those reported in CATDIS (monthly and in 1x1 degree squares for all surface gears and 5x5 degree square for longliners); however, the catch coverage can range from 5% to almost 100% depending on the fishery. Catch and effort in the Task II database are reported by flag, fleet, gear type and include catches of 9 major tuna species, small tunas, billfishes and sharks and effort reported in various forms from number of vessels and gears to days at sea.

With both databases using the 5x5 degree grid system, the catch and effort for the Sargasso Sea were extracted using the boundaries defined in **FIGURE 14**. As noted above, some of the records in the Task II database are reported at a finer spatial resolution (i.e., 1x1 degree); however, with longliners, which report at 5x5 degree, accounting for over 98% of the tuna catches in the region, improvements in the data quality using the 1x1 degree system would be minimal.

Catch profiles of the 9 major tuna and swordfish species in the Sargasso Sea are presented in **FIGURE 15** (as reported by CATDIS). To compute the value of the catch, we applied the latest (2010) US ex-vessel prices from the US National Marine Fisheries Service (**www.nmfs.noaa.gov**). Note, for consistency, we applied a fix price for each species, regardless of year and flag

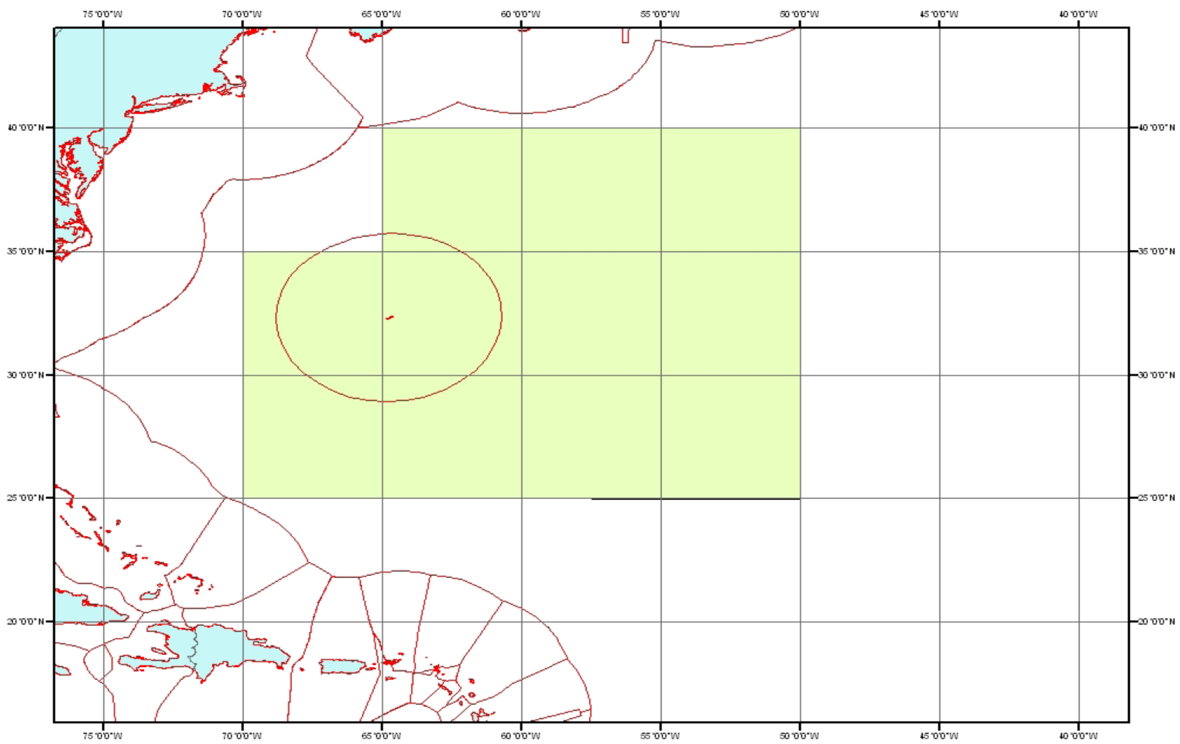

FIGURE 14. Sargasso Sea defined using 5x5 degree grids for the purpose of extracting data from the ICCAT databases. The grids are those that fit within the Sargasso Sea Study area (see FIG1) and, with the exception of Bermuda, are entirely open ocean.

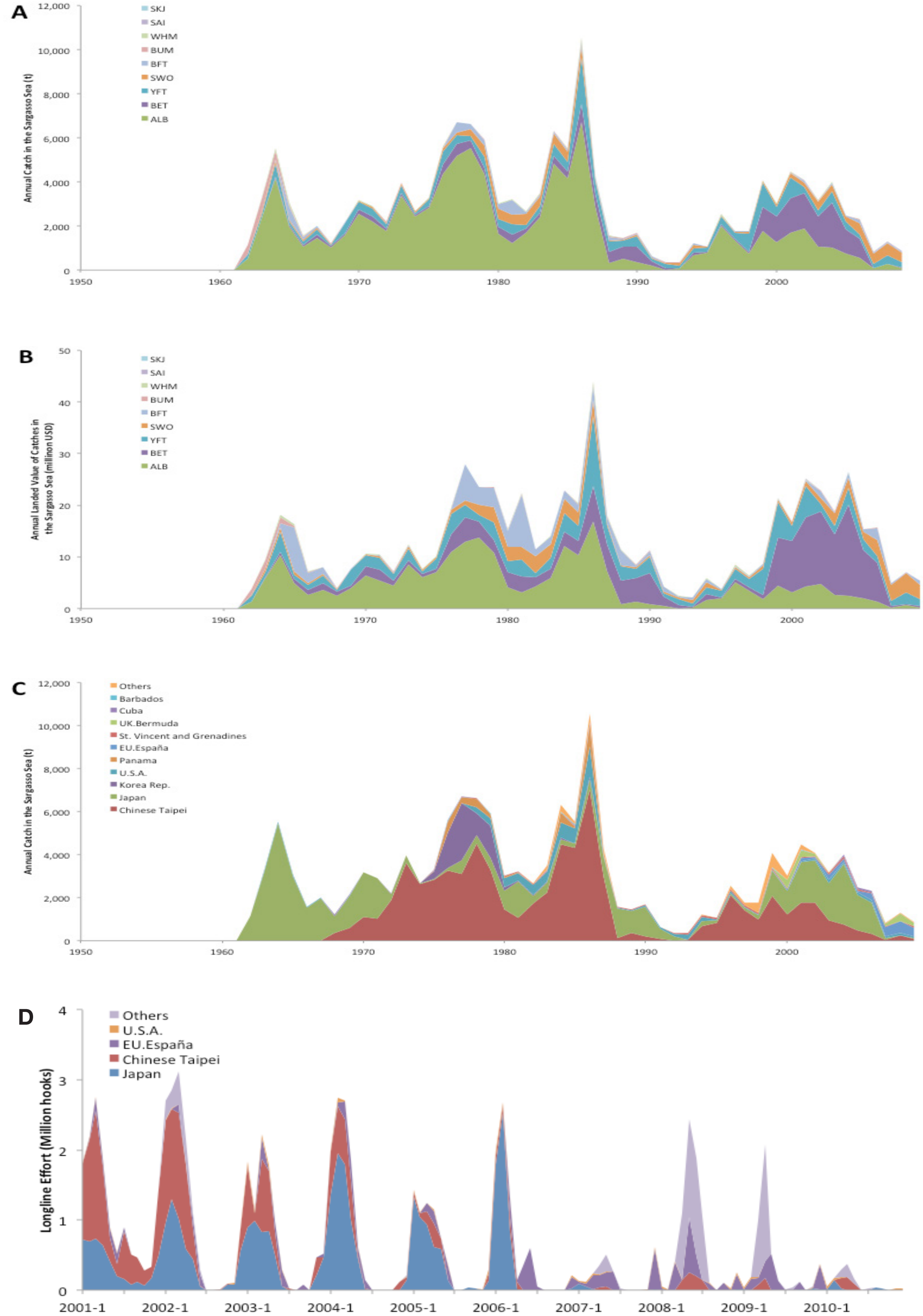

FIGURE 15. Annual catches of the 9 major tuna and swordfish species in the Sargasso Sea (1950 - 2009), by species (A & B) and by flag state (C & D), expressed in volume (A & C) and in value (B & D). (Data from ICCAT and US Nat Mar Fish Service-see text)

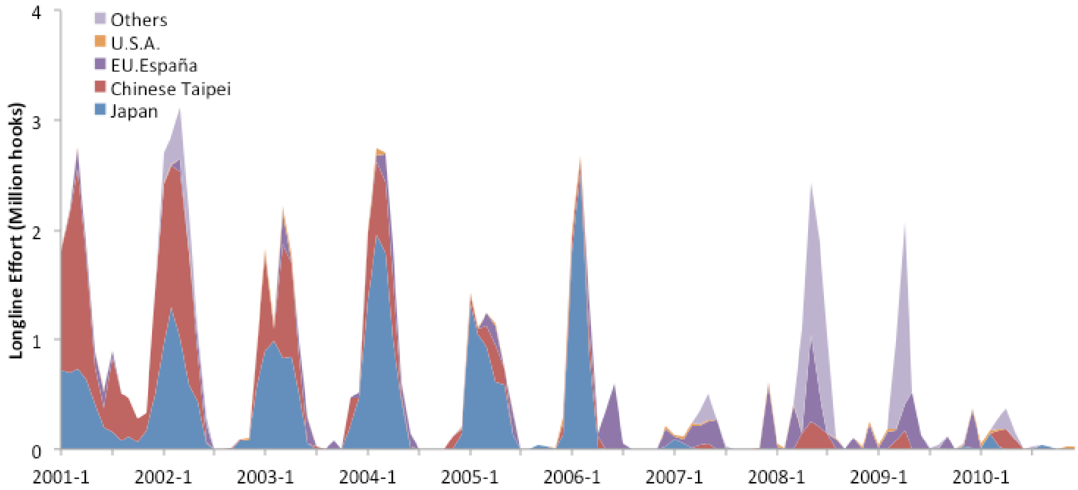

FIGURE 16. Sampled monthly fishing effort by flag state as reported in the ICCAT Task II Catch & Effort database. Effort figures are of longline fleets only, excluding Belize, which reported unusually high values (10.7 million hooks in April 2010) for 2010.

state. The total tuna catches in the Sargasso Sea was 855t (USD 5.5 million) in 2009. No catches were reported in the Sargasso Sea prior to 1962, followed by three periods of relatively high catches in the mid-1960s, late 1970s and mid-1980s when the annual catch exceeded 10,000 t. During these periods, albacore accounted for the majority of the catch, including nearly 90% in 1974 (FIGURE 15A). Following a period of low catches through the late-1980s and early 1990s, there was a period of increased catch in albacore, bigeye and yellowfin tunas, jointly recording catches over 4,200 t in 2001. However, there has been a considerable decrease in the catches of these three species, particularly of bigeye tuna (24 t in 2009, compared to 2,046 t in 2004).

Chinese Taipei is the largest fishing entity in the region, accounting for close to 50% of the total catch since 1950 (FIGURE 15C). In the 1960s, Japan accounted for nearly all of the tuna catch in the region; however, Chinese Taipei underwent a significant increase in its fisheries through the 1970s, exceeding Japanese catches by 1972. Chinese Taipei and Japan jointly accounts for nearly 80% of the total catch in the region, although their share has decreased to less than 25% in 2009 with the emergence of the Spanish fleet in the last 10 years. Spain surpassed Chinese Taipei to become the largest fishing entity in the region for the first time in 2006.

An examination of the monthly effort by the longline fleets (based on the Task II database) indicates that the tuna and swordfish fisheries in the Sargasso Sea is seasonal, with the majority of the fishing occurring in the first half of the year (FIGURE 16). It should be noted, however, that the Task II database is incomplete and may not represent the total fishing effort in the region.

In all, tuna fisheries in the Sargasso Sea represent a fraction of the total North Atlantic catch in all stocks (FIGURE 17 and TABLE 4). In 2009, the share of total catch originating from the Sargasso Sea ranged from 3.6% (swordfish, north Atlantic stock) to less than 0.1% (bigeye tuna, Atlantic stock and skipjacks, western Atlantic stock).

5. Eel Values and Management

The Sargasso Sea is the single largest spawning area of the two species of freshwater eels: the European eel, *Anguilla anguilla L.*, and American eel, *Anguilla rostrata*. Both these eels do not reproduce in captivity, due to a hormonal inhibition of maturation. In the wild, they migrate to the Sargasso Sea to spawn.

The European eel is considered to be outside safe biological limits (Dekker, 2003). The actual decline in both European eel recruitment and populations could be as high as 99% in some catchments (Gollock et al., 2005). A number of anthropogenic and natural causes have been identified as reasons for the decline including climate change, overfishing, habitat loss, destruction of migrating routes, pollution, parasites and diseases.

Several recent political actions and regulations have been taken both at global and regional levels to restore and conserve freshwater eel populations in the America and Europe. In 2007, the Convention on International Trade in Endangered Species listed the European eel in its Appendix II to control its international trade because

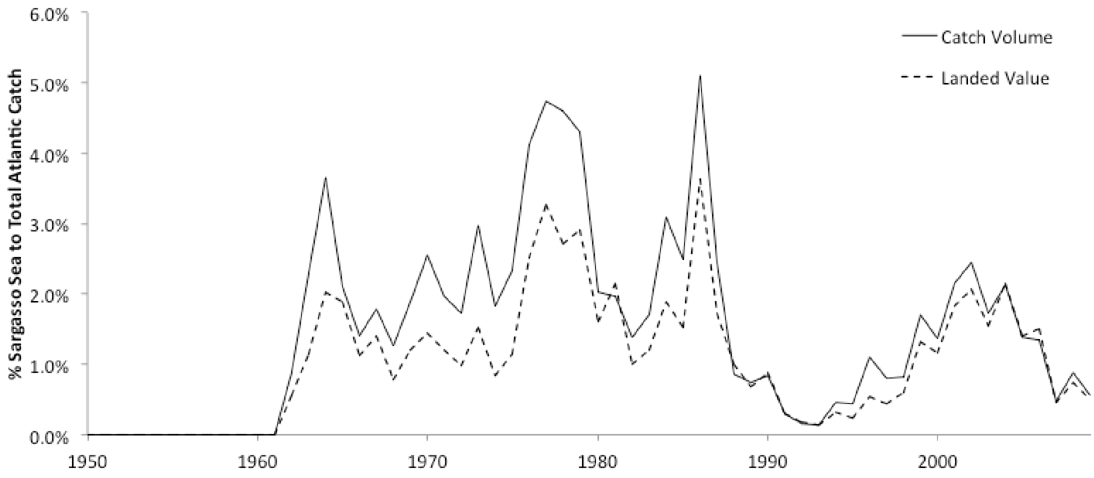

FIGURE 17. **Proportion of the Atlantic tuna fisheries occurring in the Sargasso Sea in volume (solid) and value (dash).**

SPECIES	SARGASSO SEA CATCH		ATLANTIC CATCH (BY STOCK)		% SHARE
	VOLUME (t)	VALUE (USD)	VOLUME (t)	VALUE (USD)	
ALB	103	257,468	15,383	38,457,537	0.7%
BET	24	202,195	81,613	701,869,946	0.0%
YFT	224	1,410,689	18,835	118,663,325	1.2%
SWO	446	2,762,801	12,277	76,115,690	3.6%
BFT	47	711,991	1,980	30,288,699	2.4%
BUM	1	3,445	1,530	4,284,518	0.1%
WHM	1	4,687	180	738,412	0.6%
SAI	35	96,684	1,415	3,961,051	2.4%
SKJ	6	22,114	27,149	108,596,055	0.0%
Total	**885**	**5,472,075**	**160,362**	**1,082,975,233**	**0.6%**

TABLE 4. **Annual catches of the 9 major tuna and swordfish species in the Sargasso Sea and the Atlantic Ocean (2009). Atlantic catches represent total catches for each stock (i.e., Atlantic for BET, western Atlantic for BFT, SAI, SKJ, YFT and northern Atlantic for ALB, BUM, SWO, WHM). (Data sources as before)**

of the poor state of the biomass. In the same year, the European Union adopted an eel recovery action plan (EC No 1100/2007). Accordingly, those EU member states that have constituent natural habitats for populations of the European eel within their waters were directed to develop eel management plans to take appropriate actions to reduce eel fishing efforts by at least 50% relative to average efforts deployed from 2004 to 2006, and to achieve a target escapement rate of 40% adult silver eels from all river basins relative to pristine levels – considered to be the rate applicable before 1980.

Similarly, the American Eel population in Ontario, Canada has been identified as an Endangered Species under Ontario's Endangered Species Act (2007), which prohibits the killing, harming, harassing, possessing, buying, selling, trading, leasing or transporting of this species. Several other Canadian provinces, Quebec and Newfoundland-Labrador, have also introduced measures to regulate eel fishing and eel escapement.

The recent decline of eel populations has both direct and indirect economic consequences on eel anglers and fisheries, local communities and governments.

We report in **TABLE 5** the estimated landings, prices and landed values of eels spawned in the Sargasso Sea but caught in waters of Europe and North America. The detail sources of data are provided in Annex1.

COUNTRY	LANDING (T/YEAR)	PRICE (US$ PER KG)	LANDED VALUE (MILLION USD)
Denmark (1)	579.5	11	6.4
Netherlands (2)	920.0	11	10.1
UK (3)	15.6	11	0.2
Ireland (4)	113.7	11	1.3
USA (5)	635.0	3.4	2.2
Estonia (6)	30.9	11	0.3
Total	**2,295.0**		**20.4**
Europe (7)	**10,500.0**	**11**	**115.5**

Notes: (1) Year of data is 2006; (2) Year of data is 2004; (3) Year of data is 2007; (4) Year of data is 2007; (5) The average annual eel catch in the USA for the Atlantic coast (Maine-Florida) between 1983 and 1995; (6) Year of data is 2007; (7) Total eel landing in 2009.

TABLE 5. Estimated landings, prices and landed value of eel species originating in the Sargasso Sea.

Adding the landings in Europe in 2009 to the average annual US landings reported in **TABLE 4** gives a total eel catch of 11,135 t a year. This generates a total landed value of about US$120 million annually. Assuming that the cost of fishing is 70% of landed value, this would generate profits of about US$36 million a year. If we assume economic and income multipliers of 3 and 0.5, this will generate economic impact and household income effects of over US$360 and US$60 million a year, respectively. These numbers, even though impressive, are lower than their potential given the current depleted state of eel stocks in these countries.

6. Reef-associated Tourism, Recreational and Cultural Values

Sargassum in the Sargasso Sea lacks nutrients to attract commercially valuable fish. But many small marine animals, including tiny crabs, shrimp and octopuses, live on and among the Sargassum. For the purpose of this report, we have used values of Bermuda only. This is reasonable because, as far as we can tell there is little or no recreational fishing taking place in other parts of the Sargasso Sea. According to Hellin (1999), recreational fishing in Bermuda is mainly carried out in small vessels, used in lagoon or inshore waters.

The majority of Bermudians do recreational fishing primarily for strengthening bonds with friends and family, and for enjoyment, rather than fishing for food. On average, 72% of the catch is made up of shallow reef fish. Deep "reef" fish (>26m depth) and deep sea fish (e.g., Tuna) are targeted by a minority of recreational fishermen. Bait fishing was recorded as being only 4% of the recreational total catch. Lobsters and mussels were reported to be least targeted by the fishermen interviewed, and made up <1% of the recreational total catch.

TABLE 6 provides the recreational fishing values for the Bermuda region, as well as annual total economic value of tourism services of Bermuda, based on 2007 data and prices.

Reef Associated Tourism

The main reef-associated tourism activities for Bermuda coral reef includes: scuba diving, snorkeling and touring the reef. According to Sarkis et al. (2010), the total reef-associated tourism gross revenue for Bermuda is estimated at US$406 (range of 325 to 487) million in 2007 (**TABLE 6**).

ECOSYSTEM SERVICE	AVERAGE VALUE (MILLION USD)
Reef associated tourism	**406**
Recreational fishing	**37**

Note: The gross recreational fishing value of the whole Bermuda region in 2007. (2) The gross commercial fishing value of the whole Bermuda region in 2007.

TABLE 6. Total economic value of various ecosystem services in Bermuda in 2007. Source: Sarkis et al. (2010).

Recreation and Culture

The majority of Bermudians do recreational fishing primarily for strengthening of bonds with friends and family, and enjoyment, rather than fishing for food. On average, 72% of the catch is made up of shallow reef fish. Deep "reef" fish (>26m depth) and deep sea fish (e.g., Tuna) are targeted by a minority of recreational fishermen. Bait fishing was recorded as being only 4% of the recreational total catch. Lobsters and mussels were reported to be least targeted by the fishermen interviewed, and made up <1% of the recreational total catch. Sarkis et al. (2010), estimate the value of recreation and culture at US$37 (range: 17 to 66) million a year (**TABLE 6**).

Therefore, the total value of recreation, culture and reef-associated tourism comes to US$443 million per year. With assumed economic and income multipliers of 3 of 0.5, the economic-wide impacts and income effects of these activities comes to US$1,329 million and US$222 million per year, respectively.

7. *Sargassum* values

The United States has strongly regulated the harvest of *Sargassum* within its EEZ since 2002 with Environmental Impact Statements filed in both 1998 and 1999 (see action 7 on p. 9 and summary on p. vi of SAFMC (2002)). The U.S. (in 2002) stated a maximum sustainable yield for *Sargassum* at 100,000 t per year.

Sargassum harvest within the US EEZ was historically conducted off the North Carolina coast of the United States by a single company, Aqua-10 Laboratories from 1976-1997 (with no harvest between1991-1994). A total of 448,000 lb wet weight was harvested during this time frame. *Sargassum* was dried and then processed both as a fertilizer concentrate as well as a livestock feed supplement (SAFMC 2002). Naylor (1976) states that practical difficulties in addition to the high cost of both exploitation and the bringing of product to market probably impact attempts to harvest *Sargassum* as the Sargasso Sea because the region is remote from the main markets for seaweed products or are virtually inaccessible by land'.

During the time of harvest average price of *Sargassum* from the Sargasso Sea reached $30 per pound processed product, with the average revenues generated from 1995-1997 harvests of *Sargassum* of $43,000 per year. But harvesting of *Sargassum* in the Sargasso Sea has now been banned, and therefore there is no direct use value derived from it.

However, *Sargassum* plays a vital role in the ecosystems, providing a host of indirect values (see later section). By creating a dynamic structural habitat, *Sargassum* supports a large variety of marine organisms, including approximately 145 species of invertebrates, over 100 species of fish, a variety of marine birds, 6 species of listed whales, and 5 species of highly migratory endangered marine turtles.

Sargassum weed provides key habitat to over 100 species of fish, and plays a key role in the early life history of many species, as well as in the migration patterns of others. The biomass of *Sargassum* is positively correlated to fish abundance. The most abundant fishes found in association with Sargassum weed include the carangids and balistids. *The Sargasso Sea* also provides key habitat for a number of commercially important fish species. These include seasonal abundances of jacks (*Caranx* spp), cobia (*Rachycentron* canadum), wahoo (*Acanthocybrium solandri*), eels (*Anguilla* spp.), tunas (*Thunnus* sp.), billfishes, rainbow runner (*Elagatis bipinnulata*), amberjacks (*Seriola* spp.), mahi mahi (*Coryphaena hippurus*), red porgy (*Pagrus pagrus*), mullet (*Mugil* spp.), American butterfish (*Peprilus triacanthus*), and grey triggerfish (*Balistes capriscus*), among others (SAFMC, 2002).

One simple but powerful indicator of the potential future value of *Sargassum* is the number of patents filed with the United States Patent and Trademark Office and the World Intellectual Property Organization on using algae from the genus *Sargassum* either in whole or extract form for a wide range of uses including medical, industrial, biofuel, cosmetic and food-related. An internet search by the SSA (see Laffoley et al., 2011) revealed an astonishing close to 100 such patents filed as at July 2011. Even though not all of these patents would ever realise any market value, this tell a story. In fact, the patent on biofuels is particularly worth watching because of the increasing need to find alternative fuels.

8. Indirect Use Values

In addition to direct use values such as those presented earlier in this paper, marine ecosystems also provide a host of indirect use and non-use values. Two global studies of values from ecosystems have been published recently. The first by Costanza et al., (1997) and the second by de Groot et al., (2012) as a contribution of The Economics of Ecosystems and Biodiversity (TEEB: **www.teebweb.org**). The Costanza study was very controversial but had a profound impact on how the world treated ecosystem services as it served to bring worldwide awareness to the fact that humans receive a host of valuable benefits from the environment even if these were not traded in the market.

We rely on the estimates of TEEB to estimate some of the indirect use values provided by the Sargasso Sea

BIOME	PROPORTION OF TOTAL AREA	MEAN VALUE (US$ PER HA PER YEAR)	SARGASSO SEA VALUE (BILLION US$): MEAN VALUES
Open Ocean	0.9996	490	204
Coral Reefs	0.0001	352,915	15
coastal Systems	0.0002	28,917	2
Coastal wWetlands	0.0001	193,845	8
Total	**1**		**229**

TABLE 7. Total monetary value of the bundle of ecosystem services per biome (Values in Int.$/ha/year, 2007 price levels). Source of per ha values is Table 3 in de Groot et al., (2012). Total area of Sargasso Sea estimated at 4,163,000 km^2.

because it is more recent and therefore more up to date with respect to methodology and data. The TEEB study, which was hosted by the United Nations Environmental Program (UNEP), conducted an extensive review of the economic valuation literature, made up of hundreds of publications that provided estimates of particular ecosystem services, and used these to arrive at estimates of value for 11 biomes, of which four are relevant to oceans, namely, the open ocean (excluding the continental shelf regions, islands, and reefs), coral reefs; coastal systems (continental shelf regions, and all coastal areas except reefs and wetlands) and coastal wetlands (tidal marshes and mangroves). We present in **TABLE 7**, the total per ha value for biomes as reported in de Groot et al., (2012) that are relevant to the Sargasso Sea ecosystem. These values are then multiplied by the total area of the Sea assumed to be of the relevant biome.

We see from the table that the Sargasso Sea, based on mean reported indirect use values reported in de Groot et al., (2012), contributes a total of over US$ 229 billion per year. It should be noted this amount is strongly related to the realistic assumption that the Sargasso Sea is mainly open ocean. This amount may seem high but it much less than the market value of Apple Computer and only double that of Intel.

9. Discussion and Conclusion

We set out in this contribution to estimate direct use values (fisheries, eel, recreational, Sargassum values) and indirect use values, including climate regulation, nutrient cycling water purification and waste treatment, moderation of extreme events, habitat/nursery serves and conservation of genetic diversity.

Based on the information available to us, we found that the Sargasso Sea contributes significant values not only to residents of the Sargasso Sea but the global community at large. Fisheries values in terms of profits, the income that households working in the sector make and economic impact generated directed or indirectly from the resources of the Sargasso Sea through their contribution to other sectors of the economy were, respectively, $36 million, $50 million and $171 million per year.

We estimate that a total of about 11,135 t of eel that originate from the Sargasso Sea are caught per year in North America and Europe. This generates resource rent of about US$36 million a year. The equivalent economic and income effects generated over US$360 million and US$60 million a year, respectively. These numbers, even though impressive, are lower than their potential given the current depleted state of eel stocks in these countries.

The total recreation, culture and reef associated tourism values amount to about US$443 million per year, which generates economic impacts and household income effects of US$1,329 and US$222 million, respectively. Finally, we estimate the indirect use value from the Sargasso Sea to be over US$ 229 billion per year. The computed values from the Sargasso Sea underscore the urgent need to not only protect the current values but restore the ecosystem such that it can continue to provide and sustain the services it provides through time, and for the benefit of all generations.

Annex 1

In the **TABLE 5** estimated landings, landing prices and landed value of eel species originating in the Sargasso Sea are obtained from the International Council for the Exploration of the Sea Working Group on Eel country reports, along with data on official eel landings from FAO FishStat (from within the report). Those two datasets did not include aquaculture production.

Discontinuities have been noted in both the data series, i.e., data officially reported to FAO and the best estimates presented in the Country Reports. Implementation of the EU Eel Regulation will require Member States to implement a full catch registration system. This will lead to considerable improvement of the coverage of the fishery, i.e. under-reporting will probably reduce markedly.

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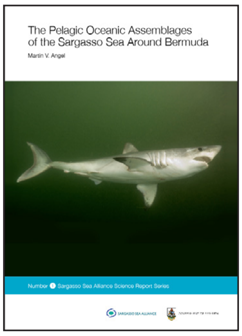
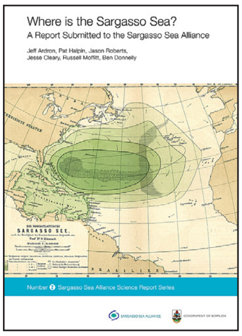
Sargasso Sea Alliance Science Series

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



1

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



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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.

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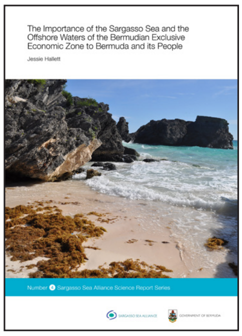

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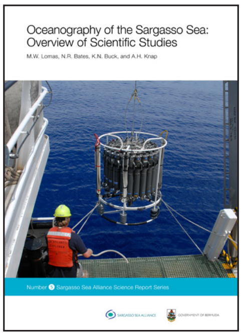
Hallett, J. 2011. *The importance of the Sargasso Sea and the offshore waters of the Bermudian Exclusive Economic Zone to Bermuda and its people. Sargasso Sea Alliance Science* Report Series, No 4, 18 pp.



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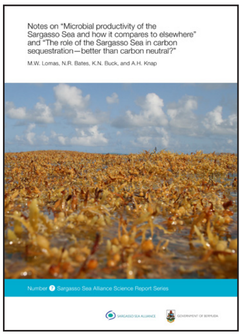

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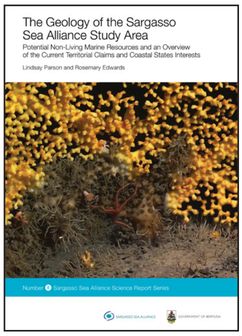
Lomas, M.W., Bates, N.R., Buck, K.N. and A.H. Knap. 2011b. *Notes on "Microbial productivity of the Sargasso Sea and how it compares to elsewhere" and "The role of the Sargasso Sea in carbon sequestration–better than carbon neutral?"* Sargasso Sea Alliance Science Report Series, No 6, 10 pp.

7

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



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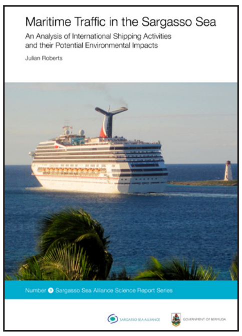
Parson, L. and R. Edwards 2011. *The geology of the Sargasso Sea Alliance Study Area, potential non-living marine resources and an overview of the current territorial claims and coastal states interests.* Sargasso Sea Alliance Science Report Series, No 8, 17 pp.



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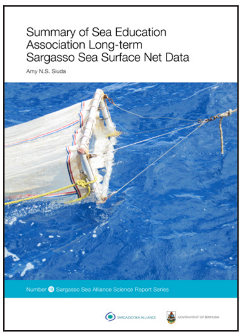
Roberts, J. 2011. *Maritime Traffic in the Sargasso Sea: An Analysis of International Shipping Activities and their Potential Environmental Impacts.* Sargasso Sea



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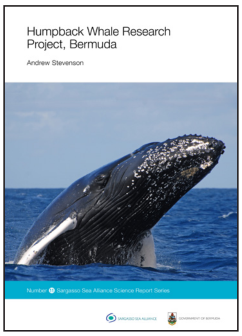
Siuda, A.N.S. 2011. *Summary of Sea Education Association long-term Sargasso Sea surface net data.* Sargasso Sea Alliance Science Report Series, No 10, 18 pp.



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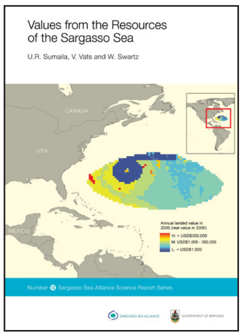
Stevenson, A. 2011. *Humpback Whale Research Project, Bermuda.* Sargasso Sea Alliance Science Report Series, No 11, 11 pp.



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

SARGASSO SEA ALLIANCE

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

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