The global catch of commercial sponges (1950 to 2019)[1]

Lucas Martinangeli[1], Maia Fourt[2], Mark Butler[3], Athanassios C. Tsikliras[4], Nicola Smith[5], Maria-Lourdes D. Palomares[6], Brittany Derrick [6], Elaine Chu[6]
And Daniel Pauly[7]

1) Institut Agro Rennes-Anger, Rennes, France. Email: martinangelilucas@agrocampus-ouest.fr
2) Aix-Marseille Université, Marseille, France. Email: maiafourt@gmail.com
3) Institute of Environment and Department of Biological Sciences, Florida International University, Miami, Florida 33181 USA. Email: mbutleri@fiu.edu
4) Laboratory of Ichthyology, School of Biology, Aristotle University of Thessaloniki, Thessaloniki, Greece. Email: atsik@bio.auth.gr
5) *Changing Oceans Research Unit*, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, B.C., Canada, V6T 1Z4; Email n.smith@oceans.ubc.ca;
6) *Sea Around Us*, Institute for the Ocean and Fisheries, University of British Columbia, Vancouver, B.C., Canada, V6T 1Z4; emails: d.palomares@oceans.ubc.ca; b.derrick@oceans.ubc.ca; e.chu@oceans.ubc.ca; d.pauly@oceans.ubc.ca

Abstract

The fishing for commercial sponges (genera *Spongia* and *Hippospongia* of the family Spongiidae) is reviewed, with emphasis on the second half of the 20th century, when catches declined from a level in 1950 that was already much lower than near the end of the 19th century. The review covers the local and distant-water catch of Greek sponge fishers, the sponge catches of other Mediterranean countries (mainly Croatia, Libya, Tunisia, and other countries), the partly Greek- and Cuban-driven sponge fisheries in The Bahamas and Florida (U.S.), and the Cuban and Columbian sponge fisheries, and concludes with very limited data for some small Pacific sponge fisheries (especially in the Philippines). Overall, the dry weight of sponges produced in the 1950s was 300-400 tonnes (t) per year mainly from the Mediterranean vs. 200 t per year in the 2010s mainly from the Central Western Atlantic. From 1950 to 2019, the sum of sponge catches reported to the Food and Agriculture Organization (FAO) by its member countries was 11 % of the sum of the catches reported here.

Introduction

Sponges have been fished for thousands of years for ornamental, hygienic, protective or pharmaceutical purposes (Corfield 1938; Stuart 1948; Storr 1964). The origin of this practice is located in the Mediterranean Sea and especially in Greece, where the first written description of sponges and their fisheries can be found (Voultsiadou 2007). The first description of sponges comes from Aristotle (350 BC), in his *Historia Animalium*, where sponges are reported as primitive animals living attached on the substrate and being black when alive before coloured and washed (Pronzato and Manconi 2008; Voultsiadou and Vafidis 2007). In his *Halieutica*, Oppian (200 BC) was the first to describe the sponge harvesting procedure by sponge fishers including the thick rope around their waist, the heavy weight for remaining underwater, the sickle for cutting the black sponges growing on the rocks, as well as their prayers to *Apollo* before they dive (Voultsiadou *et al.* 2011).

Sponges, belonging to the Phylum Porifera, are organisms that feed by filtering plankton and dissolved organic matter from the water surrounding them through a complex system of pores (hence the name

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Porifera) and channels (Figure 1; Storr 1964; Leys *et al.* 2011; Pauly *et al.* 2022). They are sensitive to water quality conditions (Butler *et al.* 2018) so the dynamics of their populations can help us to understand the health of the ocean and the change of conditions in coastal ecosystems.

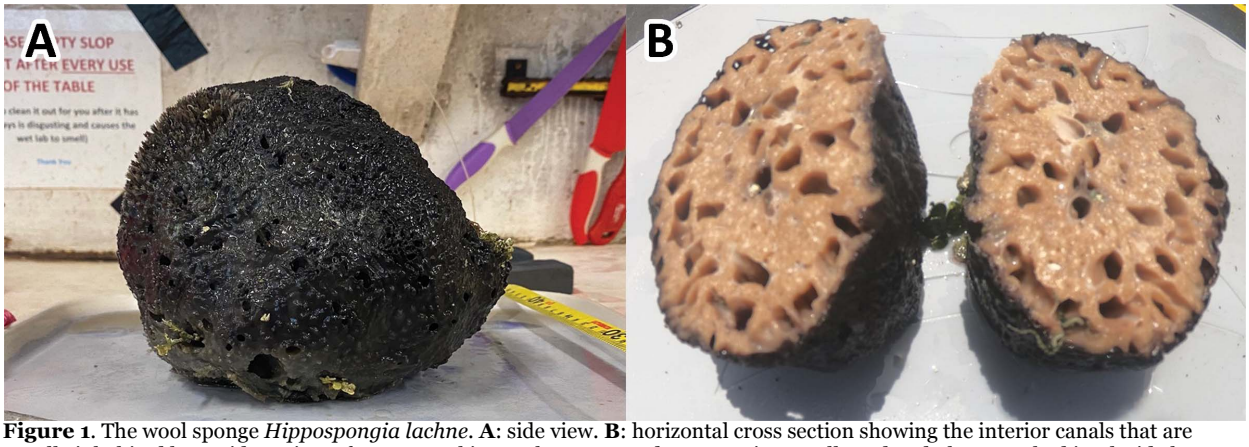

Figure 1. The wool sponge *Hippospongia lachne*. **A**: side view. **B**: horizontal cross section showing the interior canals that are usually inhabited by a wide variety of commensal invertebrates. Based on a specimen collected and photographed in Florida by M. Butler on 18 September 2021.

Commercial sponges used by humans belong to the aptly named Demospongia family (i.e., common people's sponges) and were valuable because of their capacity to absorb a large quantity of water, durability, and softness. Two genera meet these criteria, *Spongia* and *Hippospongia* (Table 1).

Only their absorbent skeleton made of spongin and which constitutes only a fraction of their wet weight (e.g., 4% of the wet weight of *H. lachne* and 11 % of *S. graminea*; Pauly *et al.* 2022) is used.

Table 1. Commercial sponge species of the genera *Spongia* and *Hippospongia* considered in this study

Scientific name	**English common name (distribution range)**
H. communis (Lamarck, 1814)	Honey comb (Mediterranean)
H. gossypina Hyatt, 1877	Velvet sponge (Central West Atlantic; Caribbean)
H. lachne (de Laubenfels, 1936)	Wool sponge (Central West Atlantic; Caribbean)
S. barbara Duchassaing & Michelotti, 1864	Yellow sponge (Central West Atlantic; Caribbean)
S. cheiris[a] De Laubenfels and Storr, 1958	---- (Central West Atlantic; Caribbean)
S. graminea Hyatt, 1877	Glove sponge (Central West Atlantic; Caribbean)
S. lamella (Schulze, 1879)	Elephant ear (Mediterranean)
S. mollissima[b] Schmidt, 1862	---- (Mediterranean)
S. obscura Hyatt, 1877	Grass sponge[b] (Central West Atlantic; Caribbean)
S. officinalis Linnaeus, 1759	Greek bathing sponge (Mediterranean)
S. pertusa Hyatt, 1877	Hardhead sponge (Central West Atlantic; Caribbean)
S. tubulifera Lamarck, 1814	Reef sponge (Central West Atlantic; Caribbean)
S. zimocca Schmidt 1862	Leather sponge (Mediterranean)
a) The status of the species is contested; see WorRMS (www.worms.org), which considers its name a junior synonym of *S. graminea*; b) *S. mollissima* may a subspecies of *S. officinalis* (Pérez and Vacelet 2014).	

Free diving and the use of a long-handled boat hook are the most common techniques used for harvesting sponges around the world, methods exported from Greece and Tunisia. From the 16th to the end of the 19th century, Mediterranean sponges dominated landings and were exported throughout Europe and, since the beginning of the 19th century, also to the United States (Voultsiadou *et al.* 2011). The Western Atlantic became a major exporter of commercial sponges at the beginning of the 19th century, especially The Bahamas and Florida in the US (Pauly *et al.* 2022), due to sponge die-offs in the Mediterranean and the subsequent emigration of Greek fishers who built on pre-existing, but small-scale sponge fisheries (Perez

and Vacelet 2014). "Scaphander" (a helmet and a diving suit made of canvas, with boots and lead weights) or hard-hat diving became a common technique in Mediterranean sponge fisheries, but it was extremely dangerous (Flegel 1908). Commercial sponges in the Western Atlantic often occur in shallow water (< 4 m) where fishers rarely dive for sponges and instead tear sponges from the seafloor using a long-handle sponge hook while standing on small dinghy boats.

In the Mediterranean in the 19th century, the fishery was largely artisanal operating from small boats along coastlines. However, distant-water expeditions were also undertaken, mainly with crews from the Dodecanese Islands of Kalymnos and Symi (Aegean Sea, Greece). These expeditions would visit the waters of several Mediterranean countries in succession over several months. The fleets were composed of dozens of small catcher boats and a larger one with quarters for the crews of the smaller boats and for the storage of the sponges (Fourt 2019), a technique still used in many sponge fisheries. In the 1850s, approximately 4,500 sponge fishers were active only in the Dodecanese Islands with the number of sponge boats exceeding 600 harvesting around 120 t dry weight annually (Voultsiadou *et al.* 2011). The use of scaphander increased the annual harvest of sponges attributed to the Dodecanese fleet and fishers to 250-300 t by the end of the 19th century (Voultsiadou *et al.* 2011).

Data for this period are more abundant than since the beginning of the 20th century when a Greek fleet of ca. 300 vessels, employing around 2,400 fishers harvested around 150 t per year with similar quantities reported for Turkey, Tunisia, and other countries (Figure 4 in Voultsiadou *et al.* 2011). The number of vessels and fishers in Greece increased between 1920 and 1940 but the harvested quantities dropped to 130 t per year (Voultsiadou *et al.* 2011).

Later, commercial sponge fishing declined because of two World Wars, regional conflicts, a sponge pandemic disease, and overfishing that reduced sponge availability and the total quantities harvested (Figure 4 in Voultsiadou *et al.* 2011). Notably, a disease outbreak which started in late 1938 in The Bahamas devasted the Gulf of Mexico and Caribbean sponge fisheries (Galtsoff 1939), and another in 1986-1987 devasted the fisheries in the Mediterranean Sea (Milanese *et al.*, 2008). More recent sponge die-offs have occurred periodically in the Florida Keys since 1991 (Butler *et al.* 1995, 2022). Also, as several countries failed to report their sponge catches because of civil wars or political instability, all previous reports on catches are a compilation of various data sources (Voultsiadou *et al.* 2011). Another complicating factor obscuring accurate reporting is that once sponges are processed into their dry (skeletal) form, they can be stocked for years. Thus, it is not rare for countries to export sponges in years when sponge fishing is banned.

Although we mention some of their antecedents, the catch time series presented here start in 1950, the year when all the catch statistics of the *Sea Around Us* begin. We are aware that in 1950 the world's catch of sponges was well past its peak but this timing permits comparisons of modern fishery catch using a standard dataset that can be analysed jointly with 70 years of spatially disaggregated catch data for fish and invertebrates, including sponges (see contributions in Pauly and Zeller 2016; Zeller *et al.* 2016).

Reconstructions of sponge catches were done for the Mediterranean based predominantly on data gathered by the SACOLEVE Program (sacoleve.imbe.fr; data available from doi.org/10.1594/PANGAEA.926825), partly for the Mediterranean focusing on the Aegean Sea (Voultsiadou *et al.* 2011), and by a co-author and her associates (Fourt 2019; Fourt *et al.* 2020, 2021), and for Cuba by Lopeztegui-Castillo (2020). This contribution, however, is the first sponge catch

reconstruction with a global scope. The sponge catch statistics reported here as dry (product) weight are also presented as wet weight as part of the catch statistics of the *Sea Around Us* (see www.seaaroundus.org), so sponge catch data can be compared with fish and other invertebrate catches that are expressed in wet (live) weight. Attempts at *in situ* farming or aquaculture of sponges have been investigated in some regions (Oronto *et al.* 2012), but to our knowledge none of those is commercially viable so those figures are not included in our summary.

Materials and Methods

Since 1950, the Food and Agriculture Organisation of the United Nations (FAO) has published annual global fisheries statistics, assembled and harmonized from annual submissions by their member countries (Garibaldi 2012; www.fao.org). These statistics include sponge catch statistics, but as also noted for other marine fisheries (Pauly and Zeller 2016), the annual submissions to FAO tend to strongly underestimate catches of fish and invertebrates (see, e.g., Brotz 2016). Thus, there was reason to 'reconstruct' the global catch of commercial sponges on a per-country basis using the same approach as developed for marine fisheries (see contributions in Pauly and Zeller 2016 and per-country accounts at www.seaaroundus.org) and, in the process, improve the taxonomic resolution of sponge catches to the extent possible. Missing years of data in otherwise credible catch time series were linearly interpolated, or forward or backward projected when required to complete time series covering the 70 years from 1950 to 2019. The 'golden age' of sponge fisheries was well over in 1950; however, 1950 is the year when FAO began to publish annual global fisheries statistics that the *Sea Around Us* use as a starting point for all its reconstructions, and we made no exception for sponges. For some countries, even tentative time series of reconstructed sponge catches could not be generated, so we included them in Table 2. Note, however, the data in Table 2 were neither included in the global totals presented in figures below, nor in the *Sea Around Us* database, because we could not find publications that documented a sponge fishery in the countries in question and/or because some countries (e.g., France) only re-exports sponges imported from Greece

Sponge catches and landings are not speciose. For example, in Florida sponge landings are comprised of *H. lachne, S. graminea* and *S. barbara*, with *H. lachne* dominating by far. However, commercial sponges represent less than 5% of all sponge taxa in fished areas (Stevely *et al.* 2010, Butler *et al.* 2017b). If the catch was not reported by species, it was assumed that the most abundant commercial species of the region was the main species caught. The Pareto ratio (80/20; see en.wikipedia.org/wiki/Pareto_principle) was applied if two species were mentioned and one identified as more abundant, and a ratio of 50/50 when the two species are listed as equally abundant. When ratios were available only for certain years, they were used for all the years without information.

Table 2. Countries other than the 12 countries in Figures 2 to 5 that reported at least 1 tonne of commercial sponge catches (in t dry weight) to FAO from 1950 to 2019. These data are highly suspect and may pertain to re-export of imported sponges or mariculture. With the exception of the data for Syria, they are not included in the *Sea Around Us* database.

Countries	Years with reported catches	Sum of 'catch' reports (all years)
Australia	1998, 2003, 2005, 2007-2011, 2019	1.3
Colombia	1958-1963, 1967-1968, 1985-2016	191.0
France	1981-2018	30.6
Italy	1981-2018	7.2
Japan	1981-2000, 2013	11.9
Montenegro	1983-1991	2.0
New Zealand	1998-2001, 2008-2019	71.9
Spain	1963-1964, 1966, 1983-2018	6.9
Syria	1950-1969, 1983-1987	151.0
Taiwan	1968, 1972, 1974, 1976, 1978, 1986-1978	4.3

Results and Discussion

The results of this study consist of catch statistics of sponges by country from 1950 to 2019 in tonnes (t, i.e., metric tons) dry weight, but which are presented in t wet weight on the website of the *Sea Around Us* (www.seaaroundus.org) to enable comparison with the biomass of other organisms removed from the marine ecosystem by fisheries[2]. The presentation of these results starts with Greece, then covers other Mediterranean countries, then the Mediterranean as a whole. Then, the results for the Western Central Atlantic are presented for The Bahamas, the US (Florida), and the Caribbean. Finally, we cover a few Pacific countries and end up with a global estimate.

The Greek sponge industry

Greece has a long and complex history of sponge fishing; notably, the island of Kalymnos is well known for its fishers and knowledge about sponges (Fourt 2019). Since Antiquity, Greek fishers have caught sponges, and gradually exported their fishing techniques to neighbouring countries, then around the world. Entire Greek communities left Greece to develop sponge fisheries, especially in Tunisia, and later in Florida and The Bahamas (Fourt 2019; Pauly *et al.* 2022).

Anon. (1949c) writes that "*Sponge fishing represents approximately 20 percent of the fishing industry in Greece (the total industry producing around $ 15 million a year, of which sponge fishing brings in about $ 3 million), and is important to the Greek Government mainly because all sponges are exported, thus providing a source of badly needed foreign exchange.*" Thus, after World War II, the Greek agricultural bank issued low-interest loans for national sponge fleets and in the 1970s, the state supported the Greek sponge fishing industry with subsidies to renew and modernize its equipment (Fourt *et al.*, 2020).

[2] For wool sponge *Hippospongia lachne*, the dry weight is set at 4% of wet weight, and at 11% for grass sponges *Spongia graminea* (from Pauly et al. 2022) which leads to an average of 7.5%, suggesting that dry weights should be multiplied by 13.3 to obtain wet weights. However, we will assume here a percentage of dry to wet weight of 10%, implying that dry weights should be multiplied only by 10 to obtain wet weights, in line with the conservative assumptions of earlier catch reconstructions as performed by the *Sea Around Us*.

Until the 1970s, in addition to the Aegean Sea (mainly Dodecanese and Cyclades Islands), Greek fleets fished in the waters of Tunisia, Libya, Italy, Egypt or Cyprus, which makes the reconstruction of Greek sponge catches taken from Greek waters particularly difficult. Their distant-water fleets allowed Greek businesses to export all four species of commercial sponges occurring in the Mediterranean Sea: *Hippospongia communis* and *Spongia zimocca, S. lamella* and *S. officinalis*.

Important events that have impacted the Greek sponge fisheries outside of Greece's Exclusive Economic Zone (EEZ) are:

- In 1952 and 1953, bans of foreign sponge fishing were proclaimed in Egypt and Libya;
- In 1953, Tunisia signed a decree defining its national waters and an overhaul of its legislation regarding costal fisheries, which involved the suppression of illegal sponge fisheries;
- From 1954 to 1959, on the basis of a new agreement, Greece was allowed to fish in Libya's waters; Greek sponge fishers operated until 1972 in Libya, probably on the basis of formal agreements between the two countries (Anon. 1965), or their fishing was both illegal and tolerated;
- In 1954, 1955, and 1956, Greek sponge fishers operated around Lampedusa Island (Italy), in addition to going there from 1956 to 2004 every 5 years or so because the trip, requiring complex logistics, was costly (and thus may have required some stock rebuilding during the years of 'fallowing');
- Greece had been fishing in Libya, Tunisia and Egypt for several years before 1950, with similar catches in each of these countries. Thus, this approximate distribution of the Greek catch in the countries was maintained until the end of the sponge fisheries in these countries by Greece;
- Egypt closed its coastal waters to Greek and other foreign fishing in 1963;
- In 1986, Greeks fished along the south coast of Sicily, because a sponge disease ravaged the Greek sponge beds;
- In 1987, an agreement was signed with Egypt to allowed 10 Greek ships to fish sponges in their waters, with Egypt keeping 30% of the catch;
- In 2008, fishers from Kalymnos Island operated in Libya on board of a Libyan boat. Only *Hippospongia communis* was fished and the catch was divided 50-50 between Greeks and Libyans;

Here, in line with the general procedures of the *Sea Around Us*, we assigned to Greece only the catch made in what is currently in Greek waters, while the 'Tunisian' catch consists of the catch by any country in what is currently the Tunisian EEZ (see Halouani *et al.* 2016), and similarly for other countries.

Figure 2A shows the catch of sponges in Greek waters, of which 90% originates from the Dodecanese Islands. It will be noted that this catch declined year after year, from 170 t in 1950 to nearly zero in 1991, especially since the epizootic disease of 1986/1987 (Voultsiadou *et al.* 2011). Annual catch dropped to less than 5 t in the late 1980s (immediately after the disease outbreak) and never recovered (Voultsiadou *et al.* 2011), with only 2 t harvested today. A similar decline also occurred in the number of sponge fishing boats from around 60 (150 crew) in the 1980s to 17 (100 crew) in the 2010s (Voultsiadou *et al.* 2011) and 10 boats (80 crew) today. Since the 2000s, the use of 'gangaves' (or '*gagava'* in Greek, i.e., small beam trawls) have been banned because of impact on the sea floor, and only scuba diving is practiced in the Greek sponge fisheries.

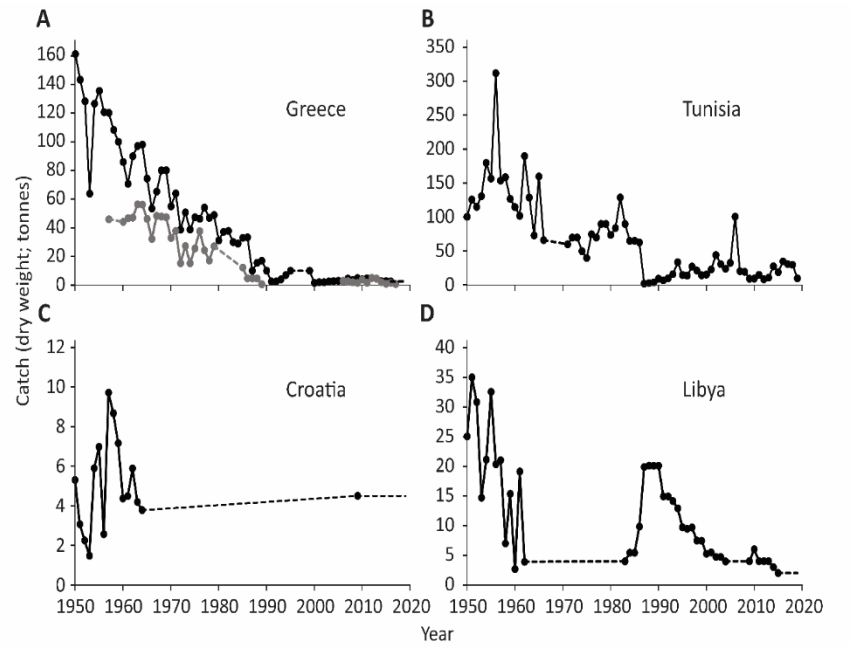

Figure 2. Catch of commercial sponges (in t dry weight) in the coastal waters of four Mediterranean countries with more or less continuous data from 1950 to 2019. **A**: Greece; note here the importance of the catch (grey dots) from the Dodecanese Islands (based mainly on Fourt 2019); **B**: Tunisia; **C**: Approximate trajectory of the catches of commercial sponges in the regions of Istria and Dalmatia (actual Croatia), consisting of annual Yugoslav catch report from 1950 to 1964 and a linear interpolation to the estimate reported by Rančić (2010) for 2009, projected forward to 2019; **D**: Libya; the data for 1983 to 2004 were read off Figure 3 in Milanese *et al.* (2008).

The Tunisian sponge fisheries

Tunisia is currently the most productive Mediterranean country with 8% of global sponge catch over the 10 last years, and one of the last areas in the region where sponge fisheries still occur. The main commercial species occurring along the Tunisian coasts are *H. communis* and *S. lamella* which, at the beginning of the 20th century, were still abundant in the north of the country, toward the Cap Bon (de Fages and Pronzevera 1908; Gaudillère 1954a, 1954b; Postel 1956). The bulk of sponge catches consist of *H. communis*, which is true to its species name in the South of Sfax, in the Gulf of Gabes, where the waters are relatively shallow (Rützler 1976; Camps-Fabrer 1996).

The second half of the 19th century saw a increase of sponge catches from Tunisian waters, when the Greek fleet introduced fishing techniques such as trawling with a '*gangave*' and diving with scaphanders whereas the main techniques used by Tunisian fishers were the use of trident from a boat and shore fishing.

Tunisia has specific terms to differentiate two types of sponge fisheries: the term "black fishery" applies to fisheries where the sponges are landed raw, while the term "white fishery" applied to fisheries which land (partly) processed (i.e., de-fleshed and dried) sponges (Anon. 1951), the only case of this distinction in a Mediterranean country. The three main Tunisian ports where sponges are landed are Sfax, Zarzis and Djerba, which are all in the Gulf of Gabes. Also, Tunisian fishers often go to Lampedusa and Pantelleria in Italy to fish sponges, but these catches are difficult to distinguish from the catch taken from Tunisian waters.

The Tunisian fishery has been severely impacted by the epizootic disease of 1986/1987 and its catches dropped from about 150 t per year 1950s to about 75 t per year in the 1970s, down to a few tonnes per year in the second part of the 1980s before stabilizing at around 20 t per year since 1995 (Figure 2B). This also had the effect of changing the habits of fishers. Sponges in waters less than 40 m were strongly impacted by the epizootic disease, which drastically reduced trident and shore-based fishing. However, the

development of hookah diving makes it possible to access sponges in deeper waters. Currently, Tunisia has the greatest variety of fishing techniques in the Mediterranean Sea (Fourt 2019).

Anon. (1953) reported that "*Tunisian sponge production in 1953 amounted to 130.8 metric tons or 13 percent more than the 115.2 metric tons produced the previous year. It is possible that the increased production was due to the currently growing efforts by the Tunisian Government to find and exploit export markets for all domestically-produced commodities including sponges. During 1953 the United States imported only 2 metric tons of Tunisian sponges as compared to 3 metric tons.*"

A large fraction of Tunisian sponges is exported to western Europe (i.e., to France or Germany), but also to the United States, where sponges are less valuable. Since 1950, the Tunisian catch, which had represented 45% of Mediterranean catch, dropped by 90% in less than 40 years, simultaneously following and shaping the Mediterranean trend (Figure 2B).

The sponge fishery of Croatia

Croatia is currently one of the three major sponge exporters in the Mediterranean Sea. Part of the ex-Yugoslavia until 1991, Croatia has a coast that is very much longer than those of Bosnia & Herzegovina and Montenegro, the other two countries with access to the Adriatic Sea spawned by the breakup of Yugoslavia. The data up to 1964 from Basioli (1965) concern the region of Istria and Dalmatia, i.e., regions of the actual Croatia.

Contrary to the other Mediterranean countries, since 1950 Croatian sponge catches have been small, but relatively stable, with *S. officinalis* representing 90% of the catch and *S. lamella* the rest (Fourt 2019). The reason for the relative stability of Croatian sponge catches may be the fact that the epizootic disease of 1986/1987 did not occur in the Adriatic Sea. Precise catch data are missing since 1965, but an estimate of 4.9 tonnes in 2009 is available (Rančić 2010) which allowed for inter- and extrapolation (see Figure 2C). FAO has data for the periods with missing catches, but these data refer to the catch of hard-hat divers which, besides sponges, include corals and various molluscs (Fourt *et al.* 2019).

The Libyan sponge fishery

Anon (1949a) described the Libyan sponge fishery as follows: *"The sponge beds of Libya extend almost the entire distance from the Tunisian border to the Egyptian border. However, the most important beds are located near Zuara and Homs in Tripolitania, and near Benghasi and Derna in Cyrenaica. The beds vary in distance from the coast from two or three miles to more than fifty miles. The most popular and productive method of harvesting sponges in Libya is through the use of machine diving boats employing fully outfitted divers. The best growths usually found in water from 75 feet to 100 feet deep, are taken by this method. The second most generally used method in Tripolitania is* dredging *with a weighted net behind a slow-moving ship, but the sea bottom is too rough in Cyrenaica to permit this type of fishing.* Fernezen *(helmet only) diving is practiced in relatively shallow water beds in both territories with fair results. Harpooning is at present used somewhat more in Cyrenaica than in Tripolitania. Nude diving is the least productive method, although used fairly extensively in Cyrenaica.*"

Data are scarce for this country mostly because of political instability since WWII and the end of the Italian colonial administration. In fact, we were unable to find quantitative information for 1963 to 1983; thus, catch data were interpolated for this period. For the period from 1984 to 2004, the catch data were read off Figure 3 in Milanese *et al.* (2008). Note that the data in the figure, which reflect the strong catch

declines in Greece and Tunisia that were due to the 1986/1987 epizootic disease, suggest that the Libyan sponge fishery was not similarly affected and indeed, may have increased the output due to the the unmet demand. However, these catches dropped from about 20 t in the 1990s to 4 t in the 2010s (Figure 2D).

In 1965, the U.S. 'Commercial Fisheries Review' informed its readers that "*The Government of Libya allowed Greek trawlers and sponge vessels to operate in certain Libyan territorial waters in 1964 after paying the following license fee: trawler […] U.S.$ 1400; sponge vessel […] $ 700 and simple fishing vessel […] $ 280* (Anon. 1965). Note that this illustrative statement does not imply that licences fees were not required from Greek fishers operating in Libya before 1964, or in other countries.

The two main commercial sponges fished in Libya are *H. communis* and *S. zimocca,* with a great dominance of the former since the 1950s; it is the only species fished today (see also Rawag *et al.* 2004). Nowadays the production of sponges is low. In 1980, only two boats were still fishing sponges (Anderson and Blake 1982). Currently, "*fishing for sponges in Libyan waters is being forbidden from 1 November to 30 May of each year*" (Anon. 2016, p. 207), and incidentally in Greece as well (M. Fourt, pers. obs.).

The sponge fishery of Turkey

Turkey was once one of the three most productive countries in terms of commercial sponge landings (Figure 3A), from 1950 to 1970 (Voultsiadou *et al.* 2011; Şahin 2013), which were nearly all exported (Arısoy 1971; Topaloğlu 2015). The Turkish government promoted this fishery in 1970 through bank loans to fishers, which may explain the massive increase of catches that followed. Turkey has access to and fisheries for sponges in three seas: the Marmara, Black Sea and Mediterranean Sea; however, catches were minimal in the Black Sea (Sariköse and Arslan 2018). Turkish archives mentioned a species called *Spongia mollissima* that was also present in Greece, Egypt, and the east coast of Libya (Fourt, 2020), and which may be a morphotype of *S. officinalis*, but described as two different species in the World Register of Marine Species (WoRMS; www.marinespecies.org/). Two other species were reported in Turkey (*H. communis* and *S. zimocca),* but they now both seem to be extirpated from Turkish waters.

The Turkish government banned sponge fishing right after the epizootic disease of 1986/1987. However, sponge exports from Turkey seem to have occurred after 1987, probably from warehouse stocks of imported sponges (Topaloğlu, 2015), or illegal fisheries.

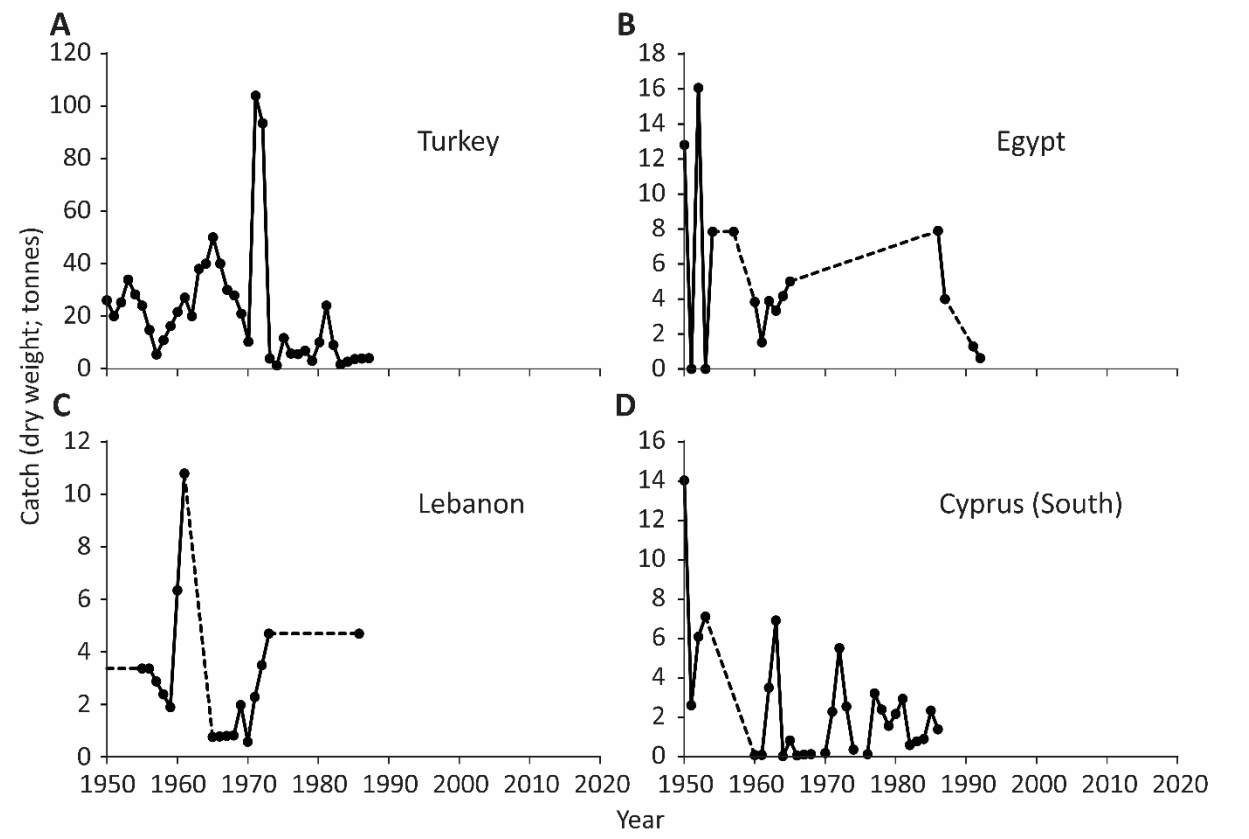

Figure 3. Catch of commercial sponges (in t dry weight) reported taken since 1950 in waters of four Mediterranean countries whose sponge fishery did not continue in the 21st century. **A**: Sponges reported as legally caught from Turkish waters from 1950 to 1987. Catches are here assumed be nil after 1987; **B**: Sponge catches from the Mediterranean coast of Egypt, 1950 to the early 1990s (note interpolations); **C**: Lebanon, as inferred from the figure of 10.8 t in 1961 of Kassis (1967), the ratio of Lebanese to Greek catches in Lebanon, and including a flat backward projection from 1955 to 1950, and a forward projection from 1973 to 1986, after which the catch is assumed to have become nil; **D**: **S**outhern Cyprus, with dotted lines represented interpolation; after 1986, the catch is assumed to have been nil.

The Egyptian sponge fishery

From 1950 to 1965, Egypt's Mediterranean waters were exploited by Greek fishers in addition to an Egyptian sponge company which, until 1949, had exclusive exploitation rights, with Egypt keeping 20% of the catch while the rest went to Greece (Anon 1949b; Anon. 1966). The species *H. communis* always was the main fished species even at the beginning of the 20th century (Fourt, 2019), but in 1949, *S. zimocca* and *S. officinalis* were also fished. This remained the case until 1987 when *S. officinalis* disappeared off the Egyptian coasts during the epizootic disease (Castritsi-Catharios 2005). The sponge fishery in Egypt ceased around 1995 (Figure 3B) and no data can be found after 1990 (Fourt, 2019).

The Lebanese sponge fishery

Possibly due to the destruction of the archives of the Departments of Fisheries Wildlife in Beirut during the Lebanese Civil War (1975-1990; Nader *et al.* 2016), time-series data on the Lebanon's sponge fishery do not appear to exist for the period considered here. Only one report was found with a production figure of 10.8 t of dry sponges in 1961 by Kassis (1967). Thus, we computed the ratio between 10.9 t and the tonnage of Lebanese sponges imported by Greece as reported (SACOLEVE; sacoleve.imbe.fr/). Assuming this ratio to be constant allowed tentative sponge catches to be estimated for Lebanon for a number of years. However, the epizootic disease of 1986/1987 seems to have also impacted sponge beds in Lebanon,

and we assume that catches dropped to near zero in 1987 and remained there (Figure 3C), as confirmed by Lelli (2017).

According to Kassis (1967), the sponge fisheries of Lebanon were regulated through bans of local and foreign fishing. On the other hand, according to Fourt (2019), interviewed Lebanese sponge fishers mentioned that they were also fishing incidents, which raised the issue of whether sponges fished in Cyprus were declared in Lebanon. According to data collected during the SACOLEVE programme (Fourt *et al.* 2021), two Lebanese boats were fishing in Cyprus in 1965, suggesting that during the Lebanese ban of sponge fishing, Lebanese fishers began to operate along the coast of Cyprus to compensate their loss. In any case, the catches involved here are very small.

The sponge fishery of Cyprus

The Island of Cyprus is divided between the North and the South (see Ulman *et al.* 2016a, 2016b), but reported catch were only found for the southern part. As in Turkey, *S. mollissima* was present but *H. communis* represented the major part of the catch. Some countries, such as Libya or Greece used to fish in this area before the epizootic disease of 1986-1987 (Fourt 2019), which strongly impacted the fishery for sponges along the Cypriot coast where sponge populations seem not to have recovered (Costa *et al.* 2018). The available time series (see Economou and Konteatis 1990) had gaps from 1954 to 1959, in 1962 and 1978 and they were filled by interpolated values (Figure 3D).

Summary: the sponge fisheries in the Mediterranean, 1959 to 2019

Until 1989 and the outbreak of the epizootic disease of 1986-1987, Mediterranean countries were the major producers of commercial sponges and represented more than 90% of the global production (Figure 4A). Currently, the 3 Mediterranean countries that produce sponges are Greece, Tunisia, and Croatia; Table 2 lists a few other Mediterranean countries with scattered sponge 'catches' that appear in FAO statistics. The most important sponge species caught in the Mediterranean is *Hippospongia communis*, distantly followed by *Spongia* species (Figure 4B).

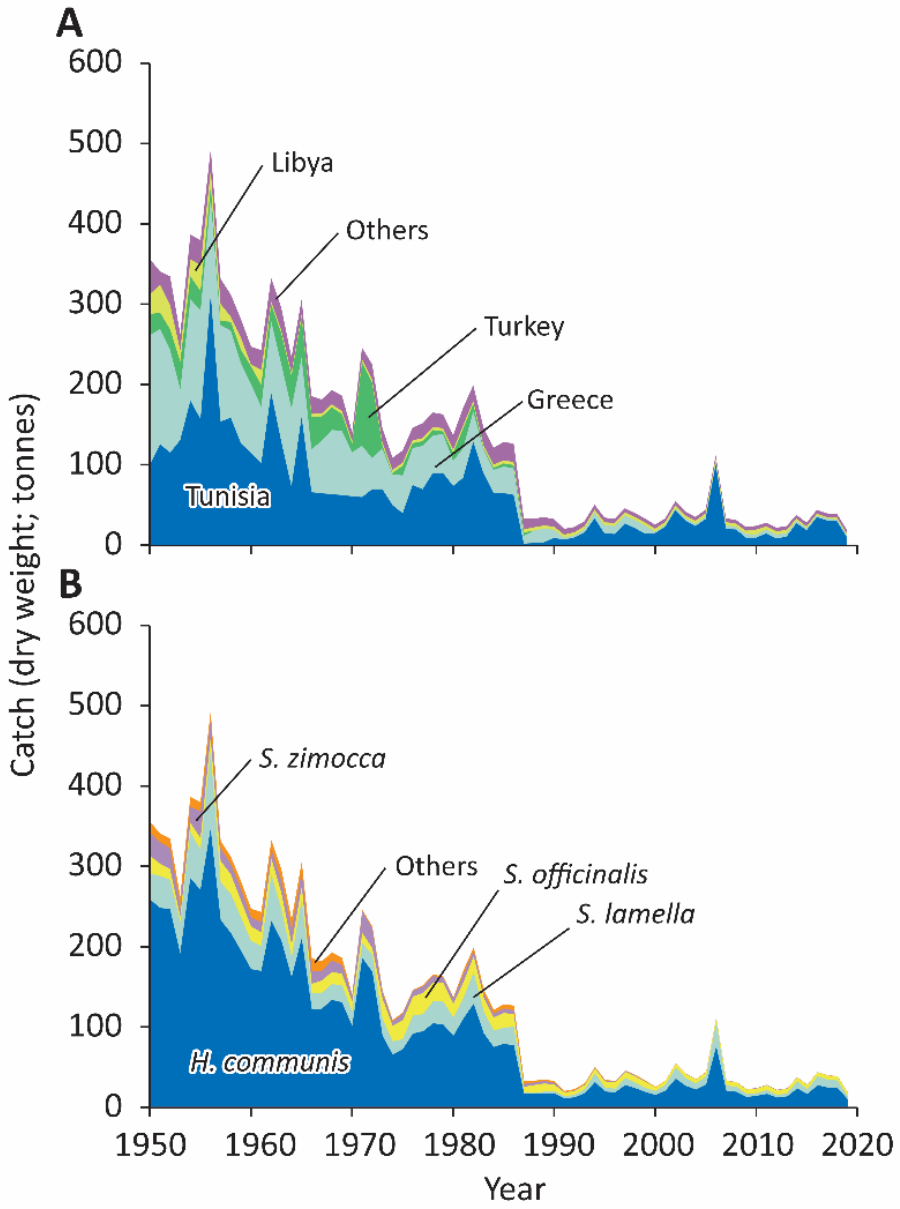

Figure 4. Sponge catches from the Mediterranean, 1950-2019. A: by major country; note the important contributions of Tunisia and Greece; **B**: by species, with *Hippospongia communis* dominating, and *Spongia lamella, S. zimocca* and *S. officinalis* also contributing.

Our coverage of the Mediterranean Sea is incomplete. Notably, we were unable to find information (beyond a few tonnes reported by FAO; see Table 2) on the catch of sponges for the period 1950 – 2019 from the coast of Syria, which was "*the main producer of Levantine sponge, or 'fine Syrie' in the nineteenth century. Its production is now completely stopped"* (Pérez and Vacelet 2014). This last point, about "production now [being] completely stopped" is made relative to the definition of 'now', because in 1964, the Syrian Government (i.e., during the period covered here) still required sponge divers to keep logbooks and "*land their catch in the locality mentioned on the permit*" (Cacaud 2005).

Sponges in the Western North Atlantic

With regard to sponges, the Western Atlantic zone covers The Bahamas, Florida in the USA, and Cuba; Table 2 also provides estimates of from the Caribbean Coast of Colombia, but they are very likely too high, and not considered further. Western Atlantic sponge catches were very high at the beginning of the 20th

century, but diseases and overfishing depleted a good part of their sponge populations and led to limits or bans on sponging. Thus, catches were low in the 1950s, but increased markedly thereafter. Indeed, since 1988, Western Atlantic countries produce between 70 to 90% of the commercial sponges, a great majority coming from the USA.

Sponging in The Bahamas

In 1841, The Bahamas became the first country in the Americas to commercially export sponges when a shipment of between 500 to 600 specimens was sold in Paris by a French merchant who had previously been shipwrecked in the small archipelago (Corfield 1938; Stuart 1948). From that point onwards, the industry quickly gained momentum. Close to its peak in 1917, the industry included the harvesting, processing, and trading of sponges and employed one-third of the Bahamian workforce (Oronti *et al.* 2012; Bethell 2017). By 1935, The Bahamas was ranked the third largest exporter of sponges globally (Bethell 2017). However, the fishery collapsed in 1938 due to a fungal disease that killed between 70% and 95% of sponges (Galstoff *et al.* 1939). Currently, there is a resurgence of the sponge fishery in The Bahamas, as global demand for natural sponges rises (Figure 5A).

At the end of the 1980s, sponge catches and exports from The Bahamas increased, most probably in response to the collapse of Mediterranean sponge population in 1986/87. In the last decades, sponge exports from The Bahamas decreased again; however, it maintained its position as the world's second most important sponging country (Moultrie *et al.* 2016).

The sponge species that currently contributes most to the catch is the grass sponge (*Spongia obscura*), distantly followed by reef (*S. tubulifera),* yellow (*S. barbara*), hardhead (*Spongia pertusa*), glove (*S. graminea*) and wool sponge (*Hippospongia lachne*).

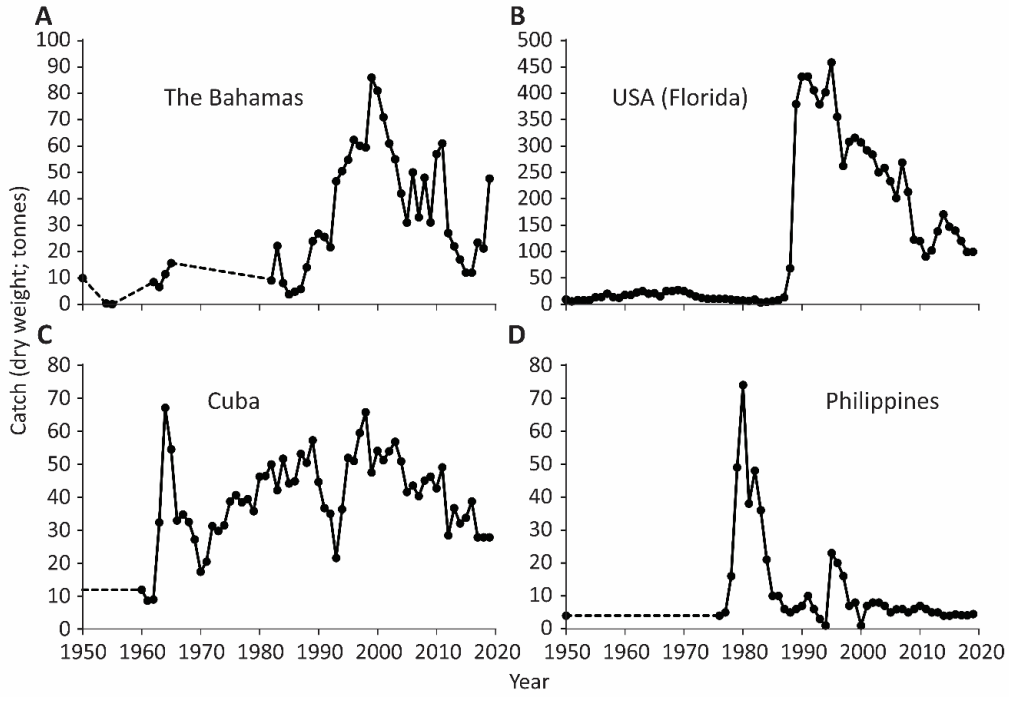

Figure 5. Catch of sponges (t dry weight in three countries of the Central Western Atlantic and one in Pacific. **A**: Reported sponge exports from The Bahamas, assembled from various sources (see Pauly *et al.* 2022). The data shown therein, referring to exports rather than catches render invisible short periods where catching sponges was banned, but warehoused stocks were available. Export figures were not available from 1966 to 1980, and the exports for these years were interpolated. **B:** Catch of sponges in Florida (USA), based for 1950 to 1962 on U.S. reports, from 1963 to 1987 on FAO data, and Florida Fish and Wildlife Reports for subsequent years. **C**: Sponge catch data from Cuba, 1950 to 2019 (based on Lopeztegui-Castillo 2020), with the 1960 catch extrapolated back to 1950. **D**: Catch of sponge in the Philippines; based on Philippine National Reports.

The sponge fishery of Florida, USA

In the USA, sponge fisheries only occur in Florida. Sponges are fished mainly from St. Marks on the northwest coast of Florida to Miami on the southeast coast (Witzell 1998). The main commercial species harvested in Florida are wool sponge (*Hippospongia lachne*; Figure 1), yellow sponge (*Spongia barbara*; Figure 6) and grass sponge (*Spongia graminea*), although the glove sponge (*S. graminea*) is also harvested. In total, the commercial sponges only represent between 2% and 5% of Florida's abundant shallow water marine sponge population (Torres *et al.* 2006; Stevely *et al.* 2010). Commercially valuable sponges do not occur on Florida's coral reefs where non-commercial sponges are especially abundant and diverse.

The first landings of sponges began in 1822 in Key West, Florida by Greek fishers who emigrated to the US; that fishery quickly became the dominant fishery in the Western Atlantic region and the most valuable one (Petrof 1967). The use of "scaphanders" or hard-hat diving suits was quickly adopted and problems of regulation raised soon after (Flegel 1908). Average production at the beginning of the 20th century was more than 200 t per year. However, overfishing, several disease outbreaks in 1937 and 1947, competition from synthetic sponges, pollution and change in temperature drastically reduced catches in mid-century (Witzell 1998; Suver 2012). The population eventually recovered, and catches increased rapidly in the mid-1980s, peaked at 450 t per year in the early 1990s, and then gradually declined to current values of 100 t per year (Figure 5B). Today, diving for sponges is permitted off the Gulf coast but forbidden in the Florida Keys, where fishers use traditional techniques developed in Cuba whereby fishers stand on dinghys and use a *kamaki* (a gear combining the properties of a harpoon and trident; Stevely *et al.* 2010) to pluck sponges from the shallow (< 4 m) seafloor. Figure 8 shows a typical commercial sponge boat.

Recent declines in landings in south Florida are due to a series of sponge die-offs caused by blooms of sponge-killing cyanobacteria (Butler *et al.* 1995) and changes in water quality in part associated with Everglades restoration (Butler *et al.* 2017a, 2018). Overfishing may also have contributed to the gradual decline in sponge harvest (Cropper and DiResta 1999), although an assessment of commercial sponge fishing impacts in the Florida Keys fishery conducted in 2003-2005 judged the fishery at that time to be sustainable but under-regulated (Butler *et al.* 2017b). The large-scale sponge die-offs in the Florida Keys also sparked research on and the development of sponge community restoration (Butler *et al.* 2021) as a means of restoring the ecosystem functions supplied by sponges, particularly: sponge filtration of bacterioplankton, biogeochemical cycling of nitrogen in the water column, and provisioning of shelter for benthic fauna and fishes (Herrnking *et al.* 1997, Peterson *et al.* 2006, Bell 2008, Valentine and Butler 2019).

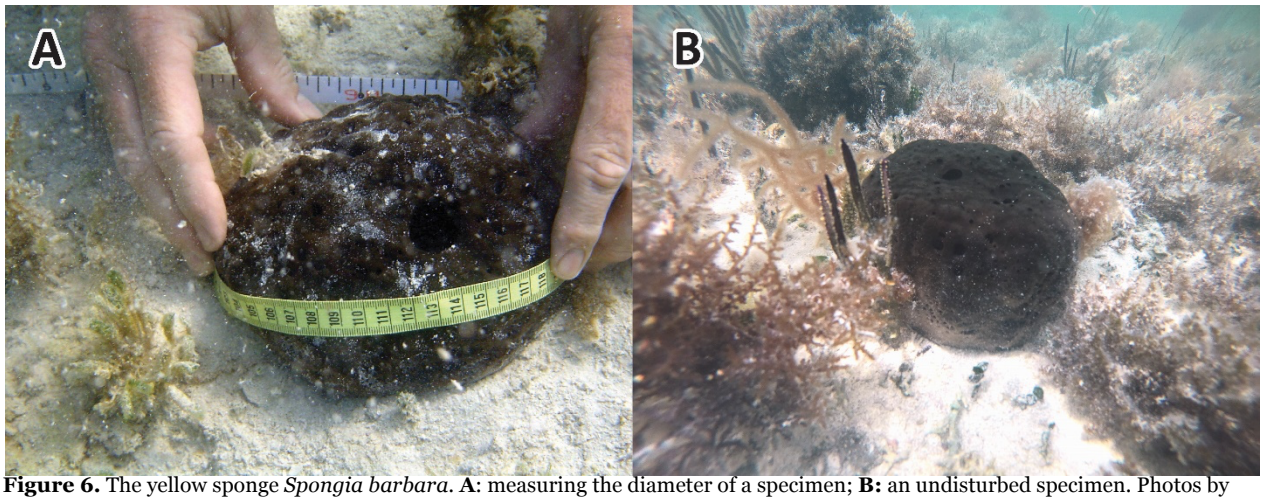

Figure 6. The yellow sponge *Spongia barbara*. **A**: measuring the diameter of a specimen; **B:** an undisturbed specimen. Photos by M. Butler.

Figure 7. A sponge "mother" boat in the Florida Keys; fishers work from smaller dinghys that supply the mother boat. Photo by M. Butler.

The sponge fishery of Cuba

Cuba was and is still an important producer of sponges, and since the beginning of the 20th century the use of the *kamaki* is the major harvesting technique (García Ramón 1970; Baisre and Páez. 1981; Abel *et al*. 2019). Currently the third biggest producer of sponges, Cuba's landings peaked at over 500 t per year in the 1920s. After a disease in the 1940s, Cuban sponge fisheries were reorganized and divided into two zones: the Gulf of Batabanó where the fishery is primarily for *Hippospongia lachne*, and the more productive Sabana-Camagüey Archipelago (Alcolado 2004), where several *Spongia* species are fished such as *S. barbara*, *S. graminea* and/or *S. obscura*, all reported as '*Spongia* spp.' (Blanco Rodríguez and Formoso Garcia 2009; Lopeztegui-Castillo 2020). Overall, since the early 1960s Cuban sponge catches increased until the end of the 20th century, then declined steadily; tentative Cuban catches in the 1950s were obtained by backward extrapolation of the catch in 1960 (Figure 5C).

Commercial sponge catches in the Pacific and the World

Sponge catches in countries bordering the Pacific Ocean

Of the countries with Pacific coastlines, only the Philippines appears to have regular, if small sponge fisheries (Figure 5D). The FAO reports occasional catches from Japan, China, New Zealand, and Australia, but no published reports on sponging in Japan or China could be found. The experimental farming of sponges for possible commercial purposes is reported from the Torres Strait, Australia and Kennedy Bay, New-Zealand (Duckworth 2007; Kelly 2004).

Sponge catches for the Philippines

The Philippines has never been a major sponging country. Approximately 3 tons were landed in 1940, and most of the catch was for local use because none of the production is exported (Anon. 1948). National reports from 1889 to 2001 are available, and were used to generate Figure 5D. The species that are exploited appear to include a "yellow sponge" similar to *Spongia zimocca* (Longakit *et al.* 2005), but is probably another species, as *S. zimocca* doesn't appear to occur outside of the Mediterranean. Figure 5D suggests that Philippine yields of commercial sponges increased rapidly at the end of the 1970s and hit 74 t in 1980 before decreasing until today to around 4 t per year; we have no explanation for the catch peak.

The global catch of sponges

Figure 9A suggests that the global catch of sponge fisheries is shaped entirely by the catch of Mediterranean and countries in the Central West Atlantic, and can be divided into two periods: 1950 to 1988 and 1989 to 2019, both with strongly decreasing trends. The first period is dominated by the catch in the Mediterranean, which dwarfed those from the Western Atlantic, whereas in the second period, the reverse was true following a massive increase in sponge landings in the Western Atlantic from 1988 to 1989. Figure 9B shows the approximate composition of the world catch, composed mainly of Mediterranean species (especially *Hippospongia communis*) from 1950 to 1987, and of Western Atlantic species from 1988 onwards (especially *Hippospongia lachne*).

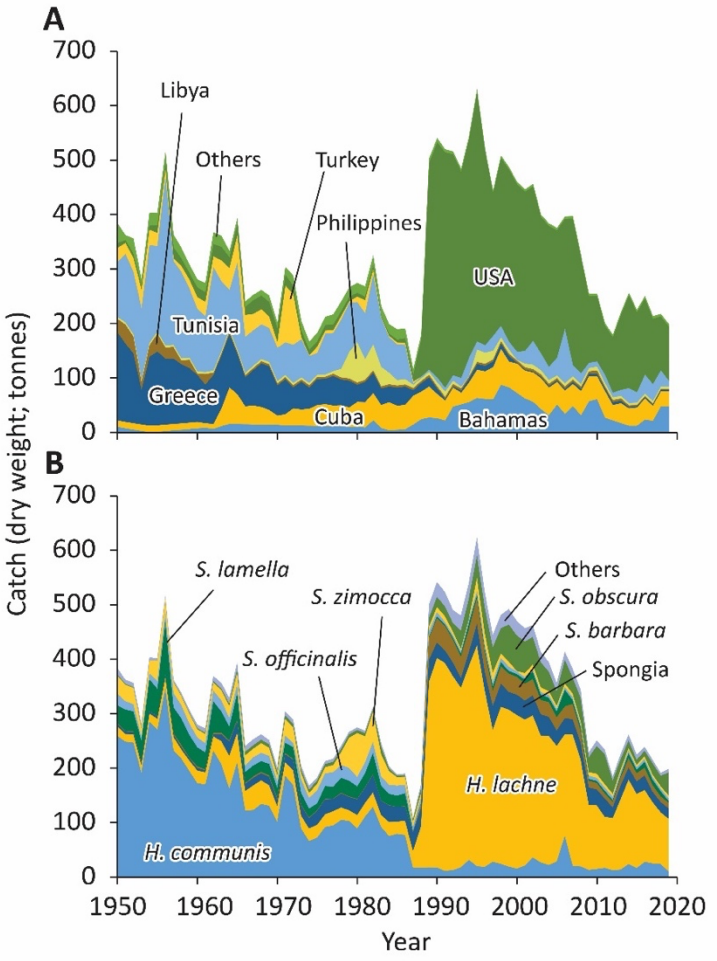

Figure 9. Global catch of sponges (t dry weight). **A:** by countries; **B**: by species. Note in A the initial dominance of Mediterranean catches, followed by that of catches from the Western Atlantic, mirrored in B by the dominance of Mediterranean species (especially *Hippospongia communis*), succeeded by Western Atlantic species from 1988 on (especially *Hippospongia lachne*).

Finally, Figure 10 shows the world catch (t, dry weight) as reconstructed here compared with the catch reported annually or occasionally to FAO by its member countries. This figure suggests that the 'official' catch of commercial sponges by FAO member countries represents only about 11% of the global catch as reconstructed here for 1950 to 2019. This degree of underestimation is high, but not impossibly so, given that similar estimates were obtained for some countries and territories in the course of reconstructing marine fish catches (see contributions in Pauly and Zeller 2016). Also note that this underestimation would be far worse if the statement that FAO reports sponge catches as wet weight were correct.

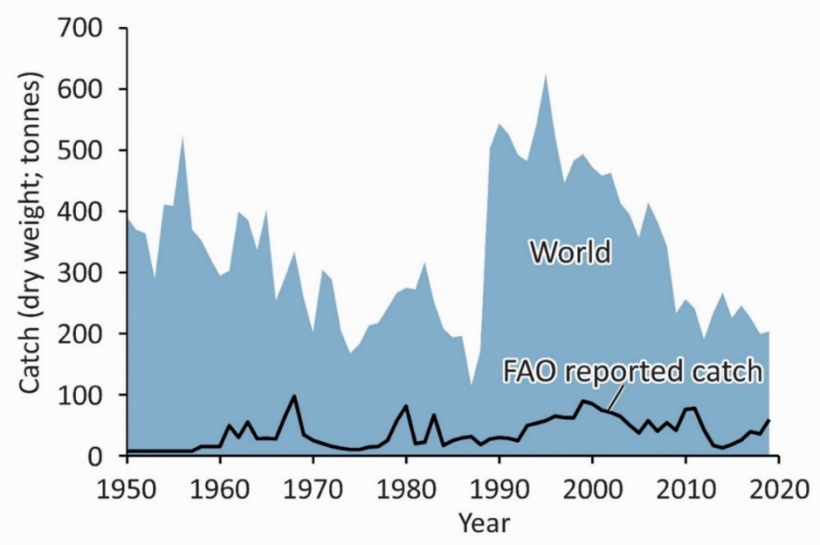

Figure 10. World catch of commercial sponges (t dry weight), contrasting the catches reconstructed here (**Figures 2-5**) complemented with the data summarized in **Table 2** (overall sum 23,220 t), to the sum of annual catches reported by FAO member countries (i.e., 2554 t).

We will abstain here from elaborating on the causes for declines of sponge fisheries. A thorough treatment of the issue would have to consider, simultaneously, market forces leading to overfishing, habitat destruction, diseases, declines in water quality and increasingly, ocean warming due to climate change, all of which are outside of the scope of this contribution (but see Webster 2007; Cebrian *et al.* 2011; Simster *et al.* 2012; Powell *et al.* 2014; Butler *et al.* 2018; Idan *et al.* 2020 and Micaroni *et al.* 2021). However, dealing with these issues will require time series of catches by eco-regions rather than countries, corresponding data on local environmental change, and experimental studies on sponge population resilience. The time-series data reported here are a step in this direction. We do not claim to have resolved all the ambiguities related to the origin of the catch of these data, or the year(s) in which some of the catches were actually made, as opposed to the year(s) when the dry sponges were exported. To the extent that such ambiguities can be resolved in the future, the sponge catches in the database of the *Sea Around Us* (see www.seaaroundus.org) will be corrected in the course of its annual updates. The documentation of these corrections and updates will, as well, correct and update the information in this contribution.

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Authors' contributions

The bulk of this work was done by L.M. during a stage of 6 months in late 2021 and early 2022 with the *Sea Around Us,* where he worked under the guidance of the D.P. and with the assistance of M.L.D., B.D.

and E.C, the co-authors who are also members of the *Sea Around Us* team. Subsequently, L.M. reached out to M.F., M.B., A.C.T., N.C and D.H who helped complete the paper.

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