CHAPTER 1

On the current status of *Spongia officinalis* (the sponge by definition), and implications for conservation. A review

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Keywords: Endangered species; Bath sponges; Mediterranean Sea; Over-fishing; Sponge Disease; Sponge Farming; Porifera.

Abstract: *Spongia officinalis* is, and will remain, the oldest nominal species of the phylum Porifera, and its name is the only one still valid among those originally described by Linnaeus. As for the biogeographic pattern, records of *S. officinalis* are known at the global scale, but its geographic range is probably restricted to the Mediterranean Sea. Over 500 taxa have been described under the genus *Spongia*, but only 41 species are verifiably valid. *S. officinalis* is notably plastic. Due to re-modelling of morphotraits, it is difficult to describe it in a precise and accurate way and to distinguish and identify it among the many other Mediterranean and extra-Mediterranean bath sponge species. An irreversible depletion of the bath sponge banks of the Mediterranean Sea, due to the combined effects of over-fishing and disease, has brought several populations to the brink of extinction since the mid-1980s.

The recovery of affected populations has been long and difficult, despite the sponge's extraordinary regenerative capability due to the perennial morphogenesis of the sponge body. *S. officinalis* has undergone a major population decline. Since 1999 the situation has evolved dramatically for *S. officinalis*, and some of the few populations for which ascertained historical data are available are definitely extinct in the Mediterranean. This could be considered the beginning of a final catastrophe. On the other side of the Atlantic Ocean, due to similar feral events, the species *Hippospongia gossypina* has also become locally extinct from the Florida coasts, and other commercial sponge species are disappearing from the waters around Cuba. In principle, mariculture techniques are available which make it possible to perform *in situ* culture of sponges, as a way of dealing with this population depletion. For *Spongia officinalis*, it is possible that the wild populations will die out and only the "domestic" variety will survive, and that by means of farming.

Historical notes (the beginning)

Spongia is the pre-Linnaean term (meaning sponge in the Latin language) used in the very early days of natural history to indicate any species of sponges. This name entered into scientific usage in the Middle Ages among surgeons such as Nicholas of Salerno (late XIIth century), Theodoric of Lucca (1205-1298), Al Koff (1232-1286) and Arnold of Villanova (Arnaldus Villanovanus) (1238-1310 ca.) (Keil, 1989; Al-Bakri *et al.*, 1999; Pronzato *et al.*, 2012). *Spongia somnifera* was a medieval milestone in the history of general anaesthesia. The "soporific sponge" was applied to the nostrils of the patient after boiling the sponge in a mixture of opium and hemlock, together with juice of mandragora, ivy and unripe mulberry. The anaesthetic effect of this cocktail was usually interrupted by applying a sponge soaked in vinegar to wake the patient after surgery.

On the other hand, numerous references to the treatment of goitre are found in Chinese medical writings. According to Bircher (1922) the ashes of sea sponges (*Spongia usta*) in vine or as powder and pill form were used by the Chinese in the treatment of goitre as far back as 1500 BC. The book *Pen T'Sao Kang-Mu*, on Chinese medicinal plants (1578 final edition), recommends medicinal algae, including sponges, for the treatment of goitre (see T.A.H, 1936; Hume, 1948). The Greeks have had the same experience, as indeed have probably all the other ancient peoples living on the shores of the Mediterranean Sea. In the twelfth century, Ruggiero Frugardi (Roger of Salerno) recommended an *Electruarium* containing the ashes of sea sponges for the treatment of goitre, and this remedy has been used for centuries (Matovinović & Ramalingaswami, 1958).

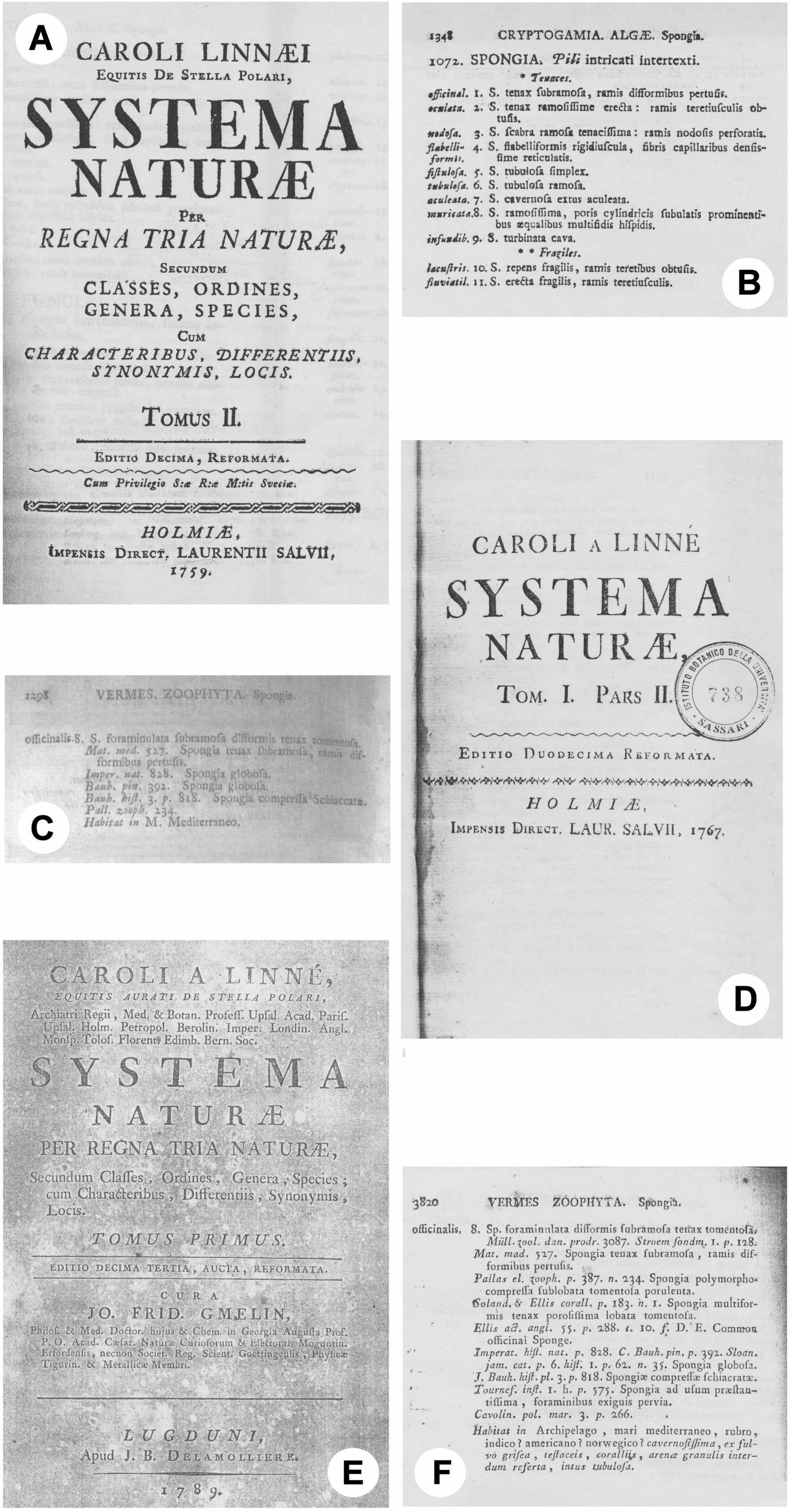
The *Bibliography of Sponges from 1551 to 1913* by Vosmaer (1928) reports ca. 80 titles of pre-Linnaean books and papers discussing sponges, prior to the first edition of *Systema Naturae* (1735). Linnaeus listed 11 sponge species in the second volume of the Xth edition (1759), including two freshwater species, all ascribed to the genus *Spongia* (Fig. 1 A, B). The XIIth edition (1767) reports 16 species, and supplies synonyms and geographic distribution. As for *S. officinalis*, the junior synonyms were *S. globosa* and *S. schiaccatae* from the Mediterranean Sea (Fig. 1 C, D). In the XIIIth edition (1789), the geographic range of *S. officinalis* is extended to "*Mari Mediterraneo, Rubro, Indico?, Americano?, Norvegico?*" (Fig. 1 E, F), marking the beginning of a persistent biogeographical confusion that continues to the present day. Thereafter, up to date, new records determined the enlargement of the geographic range up to the global level with the consequent status of *S. officinalis* as a "false" cosmopolitan species.

Only an integrative revision of diagnostic morphotraits vs. molecular traits at the population level for the entire geographic range of *S. officinalis* could address the existence of species complexes.

At the local scale (Mediterranean Sea), on the basis of a significant amount of variation detected by molecular analyses between the Aegean Sea vs. Gulf of Lions populations, Dailianis *et al.* (2011) propose that *S. officinalis* can be viewed as a single, morphologically variable species. The same authors suggest also the existence of a cryptic species from the Gibraltar area (Dailianis *et al.*, 2011).

Although its biogeographic pattern – extended up to the Macaronesian subregion (East Atlantic) – needs to be tested, at present we consider *S. officinalis* a Mediterranean endemic excluding the Black Sea.

Figure 1 [below]: In the Xth edition of *Systema Naturae*, Linnaeus (1759) lists 11 sponge species ascribed to the genus *Spongia* (A, B). Synonyms and geographic distribution were supplied in the 1767 XIIth edition, reporting 16 species; as for *S. officinalis*, the junior synonyms are *S. globosa* and *S. schiaccatae*; the habitat is the Mediterranean Sea (C, D). In the 1789 XIIIth edition, the geographic range is extended to "Mari Mediterraneo, Rubro, Indico?, Americano?, Norvegico?" (E, F). Source: Different editions of *Systema Naturae*.



A

CAROLI LINNÆI
EQUITIS DE STELLA POLARI,
SYSTEMA
NATURÆ
PER
REGNA TRIA NATURÆ,
SECUNDUM
CLASSES, ORDINES,
GENERA, SPECIES,
CUM
CHARACTERIBUS, DIFFERENTIIS,
SYNONYMIS, LOCIS.
TOMUS II.
EDITIO DECIMA, REFORMATA.
Cum Privilegio S:æ R:æ M:tis Sveciæ.
HOLMIÆ,
IMPENSIS DIRECT. LAURENTII SALVII,
1759.

B

1348 CRYPTOGAMIA. ALGÆ. Spongia.

1072. SPONGIA. *Pili* intricati intertexti.

* *Tenaces.*

officinal. 1. S. tenax ſubramoſa, ramis difformibus pertuſis.
oculata. 2. S. tenax ramoſiſſime erecta: ramis teretiuſculis obtuſis.
nodoſa. 3. S. ſcabra ramoſa tenaciſſima: ramis nodoſis perforatis.
flabelliformis. 4. S. flabelliformis rigidiuſcula, fibris capillaribus denſiſſime reticulatis.
fiſtuloſa. 5. S. tubuloſa ſimplex.
tubuloſa. 6. S. tubuloſa ramoſa.
aculeata. 7. S. cavernoſa extus aculeata.
muricata. 8. S. ramoſiſſima, poris cylindricis ſubulatis prominentibus æqualibus multifidis hiſpidis.
infundib. 9. S. turbinata cava.

* * *Fragiles.*

lacuſtris. 10. S. repens fragilis, ramis teretibus obtuſis.
fluviatil. 11. S. erecta fragilis, ramis teretiuſculis.

C

1298 VERMES. ZOOPHYTA. Spongia.

officinalis. 8. S. foraminulata ſubramoſa difformis tenax tomentoſa.
Mat. med. 527. Spongia tenax ſubramoſa, ramis difformibus pertuſis.
Imper. nat. 828. Spongia globoſa.
Bauh. pin. 392. Spongia globoſa.
Bauh. hiſt. 3. *p.* 818. Spongia compreſſa Schiaccatæ.
Pall. zooph. 234.
Habitat in M. Mediterraneo.

D

CAROLI A LINNÉ
SYSTEMA
NATURÆ,
TOM. I. PARS II.
EDITIO DUODECIMA REFORMATA.
HOLMIÆ,
IMPENSIS DIRECT. LAUR. SALVII, 1767.

E

CAROLI A LINNÉ,
EQUITIS AURATI DE STELLA POLARI,
Archiatri Regii, Med. & Botan. Profeſſ. Upſal. Acad. Pariſ. Upſal. Holm. Petropol. Berolin. Imper. Londin. Angl. Monſp. Toloſ. Florent. Edimb. Bern. Soc.
SYSTEMA
NATURÆ
PER REGNA TRIA NATURÆ,
Secundum Claſſes, Ordines, Genera, Species; cum Characteribus, Differentiis, Synonymis, Locis.
TOMUS PRIMUS.
EDITIO DECIMA TERTIA, AUCTA, REFORMATA.
CURA
JO. FRID. GMELIN,
Philoſ. & Med. Doctor. hujus & Chem. in Georgia Auguſta Prof. P. O. Acad. Cæſar. Naturæ Curioſorum & Electoral. Moguntin. Erfordenſis, necnon Societ. Reg. Scient. Goettingenſis, Phyſicæ Tigurin. & Metallicæ Membri.
LUGDUNI,
Apud J. B. DELAMOLLIERE.
1789.

F

3820 VERMES ZOOPHYTA. Spongia.

officinalis. 8. Sp. foraminulata difformis ſubramoſa tenax tomentoſa.
Müll. zool. dan. prodr. 3087. *Stroem ſondm.* 1. *p.* 128.
Mat. mad. 527. Spongia tenax ſubramoſa, ramis difformibus pertuſis.
Pallas el. zooph. p. 387. *n.* 234. Spongia polymorpho-compreſſa ſublobata tomentoſa porulenta.
Soland. & Ellis corall. p. 183. *n.* 1. Spongia multiformis tenax poroſiſſima lobata tomentoſa.
Ellis act. angl. 55. *p.* 288. *t.* 10. *f.* D. E. Common officinal Sponge.
Imperat. hiſt. nat. p. 828. *C. Bauh. pin. p.* 392. *Sloan. jam. cat. p.* 6. *hiſt.* 1. *p.* 62. *n.* 35. Spongia globoſa.
J. Bauh. hiſt. pl. 3. *p.* 818. Spongiæ compreſſæ ſchiacratæ.
Tournef. inſt. 1. h. *p.* 575. Spongia ad uſum præſtantiſſima, foraminibus exiguis pervia.
Cavolin. pol. mar. 3. *p.* 266.
Habitat in Archipelago, mari mediterraneo, rubro, indico? americano? norwegico? *cavernoſiſſima, ex fulvo griſea, teſtaceis, coralliis, arenæ granulis interdum referta, intus tubuloſa.*

Taxonomy (and taxonomists) in confusion

Although over 500 taxa have been ascribed, including varieties and sub-species, to the genus *Spongia* L., 1759 only around 40 of them are considered valid species, if focusing strictly on the subgenus *Spongia (Spongia)* (Table I) (see also Van Soest *et al.*, 2018). These numbers can change, depending on the sources cited; if one includes also the species that are deemed to be "*inquirenda*" (insufficiently studied), the number of valid taxa rises considerably, and in practical terms cannot be determined.

A very intriguing problematic status characterises the taxonomic history of some species of this genus, as in the case of *S. zimocca*, whose type specimen displays morphotraits diagnostic for *S. officinalis* (Pronzato & Manconi, 2011), or the recently solved problematic co-specificity of *S. lamella* and *S. agaricina* (Pronzato & Manconi, 2008). In other cases, there has been general disagreement among specialists as regards the status of *S. mollissima* vs. *S. officinalis*, which can be seen either as two separate species, as in our opinion (Pronzato & Manconi, 2008), or as synonyms (Voultsiadou, 2002 a, b).

In any event, *Spongia officinalis* is and will remain the older nominal species of the phylum Porifera, being the only one out of the 11 species described by Linnaeus still valid under its original name.

As for its biogeographic status, the genus *Spongia* is considered to be cosmopolitan (Van Soest *et al.*, 2018) and consists of almost 41 species from all the seas; many of them are restricted to small geographic areas, including extreme cases in which the species (e.g. *S. spinosa* and *S. sweeti*) is known only from the type locality (Table I).

Other species show a disjoined distribution (Table I), suggesting unreliable specimen identification by several authors, as in the cases of *S. virgultosa* and *S. zimocca*, which, despite various extra-Mediterranean reports, can be considered as putative Mediterranean endemics.

Knowledge regarding the geographic distribution, abundance and population traits of *S. officinalis* is really scarce, as in general with Porifera, due to confusion, inaccuracy and lack of data. A clear example is the case of the 175 findings of freshwater sponges from the African continent, with 30 species recorded only once exclusively from the type locality out of 58 African species (Manconi & Pronzato, 2009). Among marine sponges, a high percentage of calcareous species, out of ca. 80 Mediterranean species, is recorded only from the type locality or from few others sites (Longo & Pronzato, 2011). Moreover, for many geographical areas, knowledge has not been updated since the nineteenth century. Despite the limited and fragmented nature of the data set, we have attempted to depict the present status of biogeographic pattern and affinities for the species presently ascribed to the genus S*pongia* (Tables I-II; Fig. 2). As expected, this analysis provides very little information about the phylogeny of the taxon. The species richness of *Spongia*, at the level of large marine costal Realms (*sensu* Spalding *et al.*, 2007), is higher in some temperate and tropical Realms and in the Southern Hemisphere. The Arctic Realm is devoid of *Spongia* species, while the Antarctic and Southern Ocean harbour two species. Only two widespread species are present in six Realms, whereas the majority of species (n=26) are reported only from a single Realm, often only from the type locality (Tables I-II; Fig. 2).

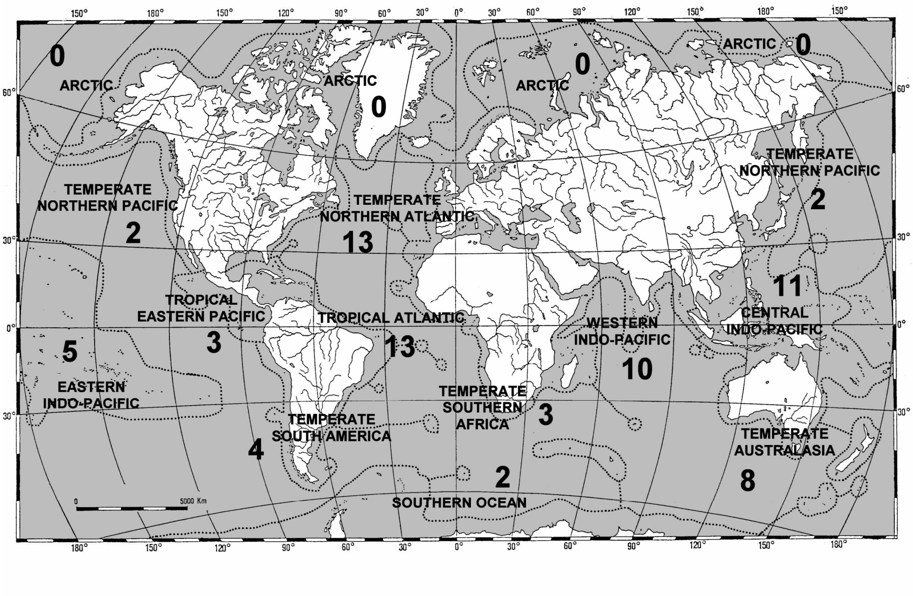


Figure 2: Genus *Spongia*. Geographic distribution and species richness (numbers) in the Coastal Marine Realms. See also Tables I and II. Source: Original.

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The intriguing case of *Spongia officinalis*: how to recognise it

From a taxonomic point of view the hierarchic status of *Spongia officinalis* is as follows.

Porifera (Phylum)

Demospongiae (Class)

Keratosa (Subclass)

Dictyoceratida (Order)

Spongiidae (Family)

Spongia (Genus)

Spongia (*Spongia*) (Subgenus)

Spongia Linnaeus, 1759 (senior synonym)

Ditela Schmidt, 1862 (junior synonym)

Euspongia Bronn, 1859 (junior synonym)

Spongia officinalis Linnaeus, 1759

In order to avoid further confusion, here we consider, arbitrarily, only the Mediterranean population of this species, which is the most studied and well-known. We attempt to provide an exhaustive and complete description following a recent revision of the status of the Mediterranean "horny" sponges (Pronzato, 2011; Pronzato & Manconi, 2011; Pronzato *et al.*, 2012; Manconi *et al.*, 2013).

Description. Growth form massive-lobate, surface finely conulose, single oscules scattered or at the apex of lobes, preoscular cavities well evident. Colour *in vivo* from light grey to black. Ectosomal skeleton as apices of primary fibres joining secondary fibres to form the conical reticulum which supports the conules. Choanosomal skeleton network reticulate, dense with irregular polygonal meshes of secondaries joining to form ascending primaries mainly developed and evident towards the surface. Primary fibres (50-100 µm in diameter) cored with sand grains and allocthonous spicules along the main axis, typically twisted (dry condition) with ornamentations as parallel ridges. Secondary fibres (20-35 µm in diameter) with ornamentations as parallel ridges (dry condition) along the twisted main fibre axis and characterised by concentric layers of compact spongin layer surrounding the compact axial core without inclusions.

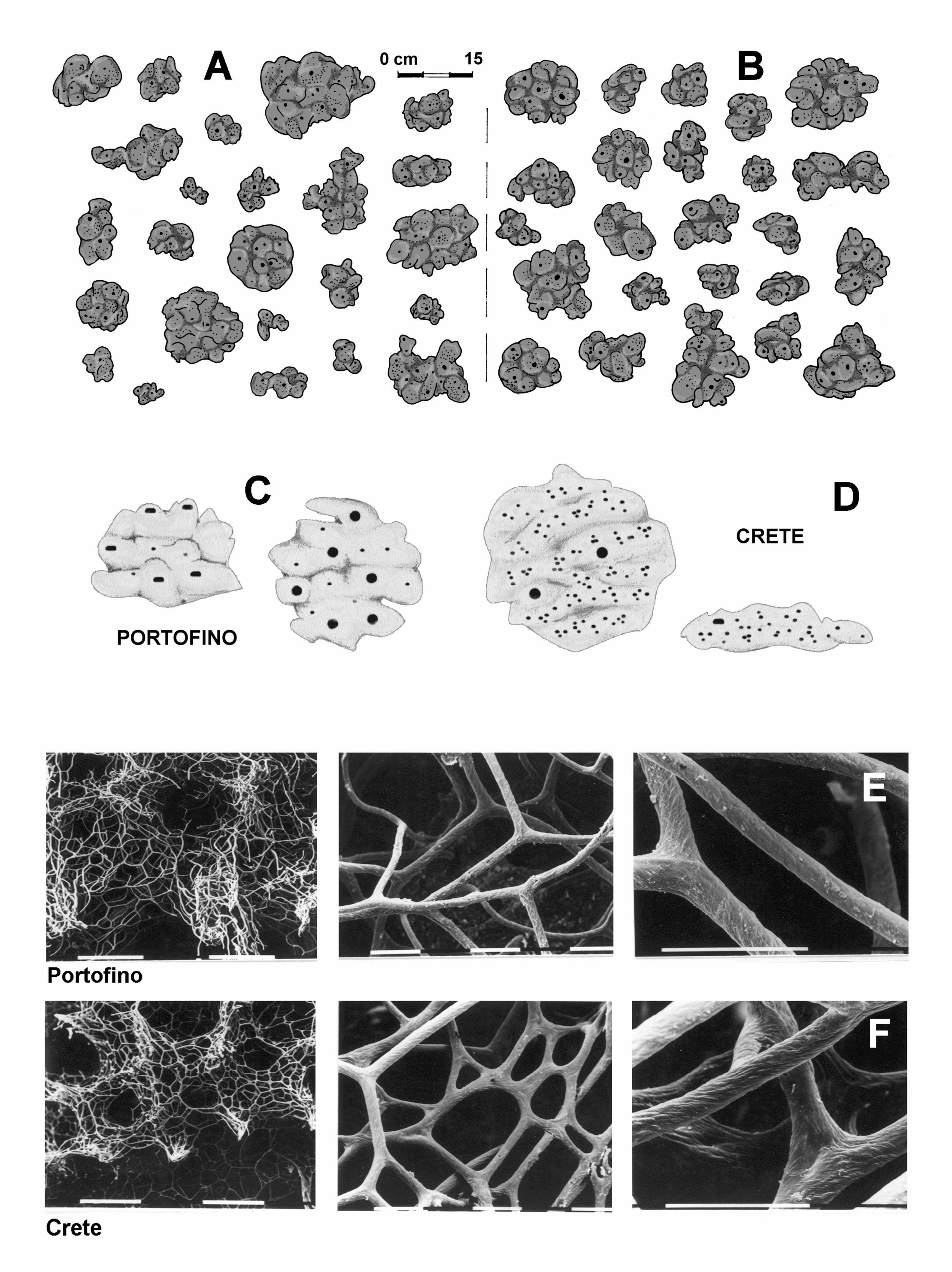
Mediterranean Habitats. Coralligenous community, rocky/detritic/muddy/sandy bottoms, marine caves, lagoons, *Posidonia oceanica* meadows, Adriatic rocky carbonatic outcrops (*tegnue*). Bathymetric range 1-70 m.

Geographic Distribution. Cosmopolitan? Adriatic Sea (Dalmatia, Tremiti, Bari), Ionian Sea (Leuca, Taranto), Tyrrhenian Sea (Stagnone di Marsala, Panarea, Naples, Pozzuoli, Ischia, Policastro, Porto Ercole, Sardinia), Ligurian Sea (Portofino, Bogliasco, San Fruttuoso, Punta Chiappa), Sardinian Sea (Alghero, Bosa), Corsica, Gulf of Lions (Port Cros, Marseille, Cap Ferrat), Balearic Sea (Catalunya, Blanes, Girona, Valencia, Baleares-Cabrera, Medas Islands), Alboran, Gibraltar, Algeria (La Calle), Tunisia (Tunis, Gabès, Djerba, Kerkennah, Messioua, Hallouf, Zarzis), Libya, Egypt, Lebanon? Syria?, Aegean Sea (Greek and Turkey coasts, Karpathos, Sporades, Cyclades), Albania?

Also reported from Atlantic Ocean (Azores, Canaries, Madeira, Biscay, North Atlantic, Norway, West Indies, Puerto Rico, Puerto Cabello, Southwest Bahia, and West Africa, Congo), Indian Ocean (Red Sea, Mauritius, Sri Lanka), Pacific Ocean (Puerto Cabello, Sulawesi, New Guinea, and Australia), and Eastern-Central Indo-Pacific.

Remarks. The original Linnaean description of *S. officinalis* is short but precise. The junior synonym *S. adriatica* Schmidt, 1862 diagnosis is the closest to the senior *S. officinalis*. According to that, the neotype (BMNH 83.12.4.28) selected by Burton (1934), among the Schulze material preserved since 1883 in London, is correct as being a Mediterranean historic specimen.

Figure 3 [below]: *Spongia officinalis*. Growth form of different specimens from the Portofino Promontory (Ligurian Sea) at depths of 8-10 m (A) and 20-25 m (B). Morphotypes of Portofino (C) and Crete (D) populations. The skeletal fibres (SEM) from Portofino (E) and Crete (F). Scale bars (E, F) = 2 mm, 100 µm, 100 µm, from left to right. Source: Modified from Pronzato *et al*., 2003.



The six Mediterranean *Spongia* species are all soft and elastic due to the skeleton of spongin. The main morphological characters diagnostic to distinguish these species are few. *S. lamella* (Schulze, 1879) is characterised by a growth form ranging from cup- to fan-shaped (elephant ear), and capable of reaching very large sizes (Fig. 4).

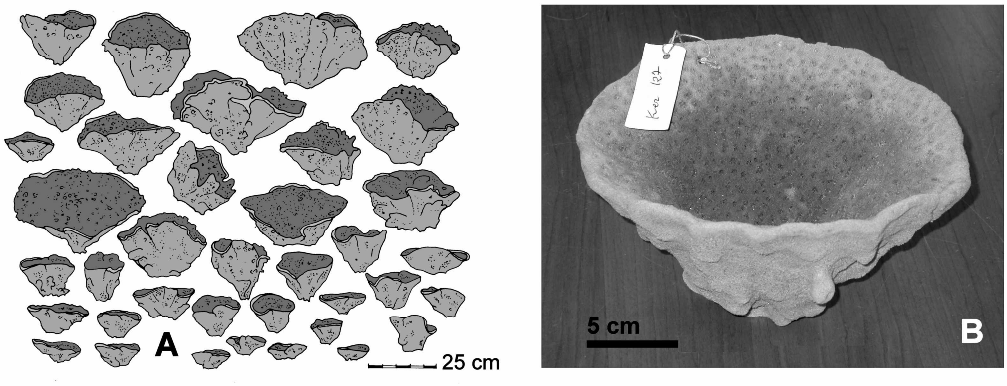


Figure 4: *Spongia lamella.* Growth form of several specimens from the Eastern Mediterranean (A). Skeleton of a specimen from the Strait of Sicily (B). Source: Modified from Pronzato & Manconi, 2011.

A second unmistakable species with a small body size is *S. virgultosa* (Schmidt, 1868) whose vertical funnel-like inhalant and exhalant outgrowths (*virgultum* in Latin means "shoot") growing from a small encrusting base are species-specific traits (Fig. 5).

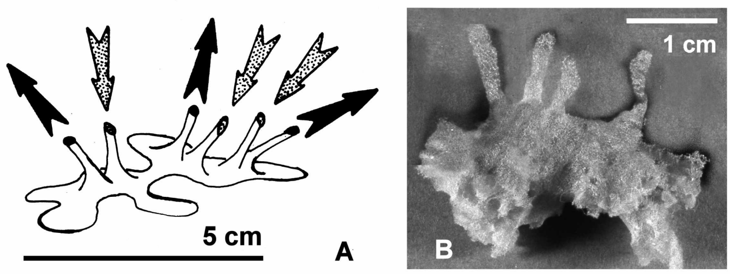


Figure 5: *Spongia virgultosa.* A schematic drawing showing inhalant and exhalant funnels (A). The spongin skeleton of a large specimen (B). Source: Modified from Pronzato & Manconi 2011.

As for a reliable identification of *S. nitens* (Schmidt, 1862), it is necessary to consider microtraits. The network of the spongin skeleton fibres shows a unique double weaving (large and heavy/slim and thin) network (Fig. 6). For that reason the species was primarily ascribed to the previous genus *Ditela* Schmidt, 1862 (meaning "double network" in Latin).

To summarise: *S. lamella* is cup- or elephant-ear-shaped; *S. virgultosa* shows vertical cylindrical funnels; and *S. nitens* has a double skeleton network.

As for the growth form, the species *S. nitens* is massive, irregularly lobate, with a finely conulose surface. Colour ranges from light grey/light brown to dark brown/dark grey/black. All these traits are, however, shared with the following 3 species (Figs 6, 7).

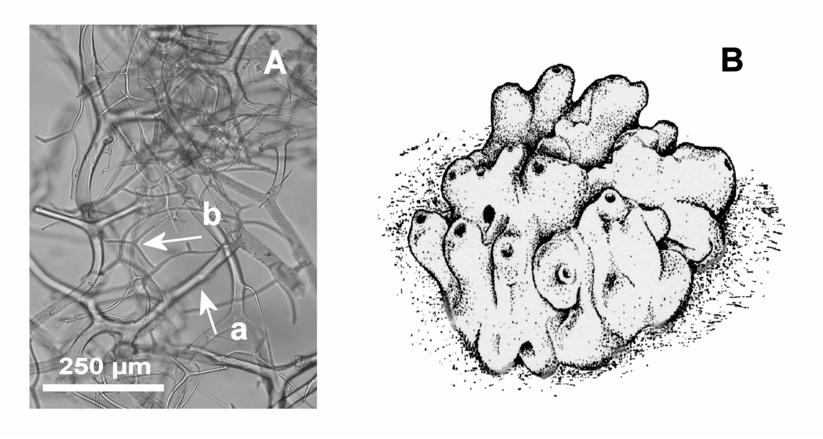


Figure 6: *Spongia nitens*. The double skeletal network, thicker (a) and thinner (b), of spongin fibres by LM (A). A drawing of a massive irregular *S. nitens* specimen (B). Source: Modified from Pronzato & Manconi, 2011.

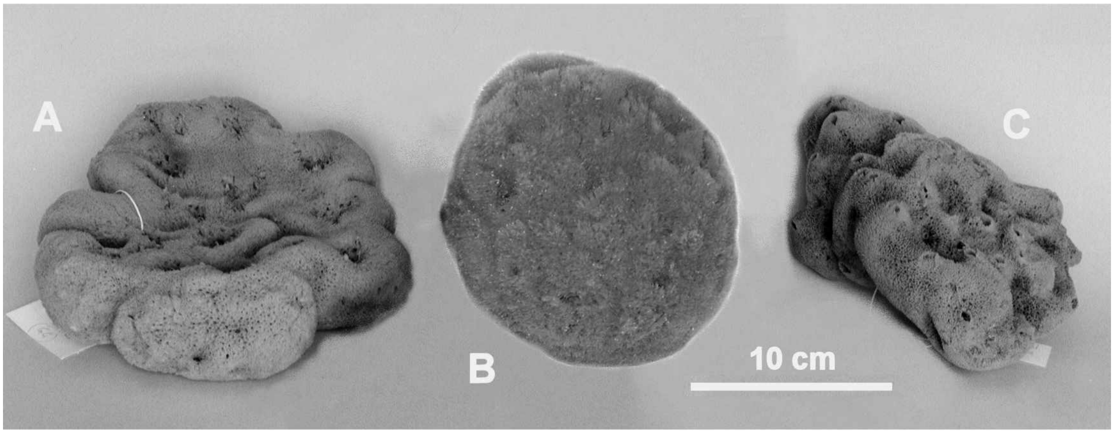


Figure 7: *Spongia mollissima* (A), *S. zimocca* (B), and *S. officinalis* (C) as cleaned spongin skeletons after treatment for trade. Source: Original.

The specific name of *S. zimocca* Schmidt, 1862 is derived from the Turkish and means that the sponge, after treatment for the marketing, is not very elastic. This is not a robust taxonomic character and only long and patient observation can help in a correct identification. Moreover there remains an unresolved debate regarding this species (Jan Vacelet and Rob Van Soest, *in litteris*).

S. mollissima (Schulze, 1879) and *S. officinalis* are considered synonyms by many authors.

In *S. mollissima* the ectosomal skeleton has the apices of primaries fibres in anastomosis with superficial secondaries to form the conical reticulum of very high conules supporting large oscular processes, normally grouped in the central top sponge surface (Fig. 7).

In *S. officinalis* the oscules are smaller and scattered (Fig. 7).

Distinguishing between the latter three species is a very difficult task, and microtraits observed by both Light and Scanning Electron Microscopy give very little help (Fig. 3 E, F).

The latter two species are those with the greater economic value and they have suffered from heavy over-fishing (Pronzato, 1999; Milanese *et al.*, 2008; Pronzato & Manconi, 2008). *S. mollissima*, the "Levantine sponge" of commerce, is rare (few records in literature) and is apparently restricted to the Eastern Mediterranean basin.

The wide variation in the external traits of *S. officinalis*, at the population level (Fig. 3 A-D), both in time and space, enables sponge traders to recognise several "geographic varieties" (e.g. fina, dalmata, capadica, etc.) for this species (Pronzato *et al.*, 2003). Wiedenmayer (1977) reported that the vernacular names and identifications used by sponge fishers are often more reliable than the scientific names. In contrast with those, Dalianis *et al.* (2011) report that no distinction concerning varieties has been evidenced. The huge variability of growth form and gross morphotraits of the surface at the intra-specific level may further complicate the correct identification of the various specimens. On the other hand, micro-traits of the skeleton are constantly homogeneous at the intra- and inter-population level (Fig. 3 E, F).

The literature on *S. officinalis* is abundant, indicating large and dense population along all the coasts of the Mediterranean Sea, with the exception of the Black Sea (Van Soest *et al.*, 2018).

S. officinalis is one of the species that has been reported (incorrectly?) as having the widest distribution (Tables I, II) starting from the time of Linnaeus. Moreover, many other extra-Mediterranean species belonging to the genus *Spongia* (e.g. *S. arabica, S. barbara, S. cerebralis, S. hispida, S. illawarra, S. irregularis, S. magellanica, S. obliqua, S. oceanica,* and *S. pertusa*), among the species well illustrated and described, are very similar to *S. officinalis* and difficult to distinguish for the untrained eye.

Man and sponges: A halfway reflection

S. officinalis is considered one of the most common Mediterranean bath sponges and has been broadly in use since ancient times. Its specific name (epithet) *officinalis* literally means in Latin "belonging to an *officina*", the *officina* being the storeroom of a monastery, where medicines were processed and kept. Linnaeus gave the specific name *officinalis*, in the 1735 first edition of his *Systema Naturae*, to several herbs and plants whose medical use had been established in preceding millennia. Although there are more than 60 plants bearing the specific epithet *officinalis, Spongia officinalis* and the common cuttlefish (*Sepia officinalis* L., 1758) are, almost certainly, the only animals.

Notwithstanding its millennial "cohabitation" with *Homo sapiens* L., 1758, *S. officinalis* continues to be misunderstood by most people. Most people would be capable of recognising a Dalmatian dog, a San Marzano tomato or a Lipizzaner horse in the midst of domestic species and races, but not the most common Mediterranean bath sponge. Why are sponges so difficult to insert into an exact specific taxonomic category?

Sponges are basal invertebrates whose entire body is involved in a perennial morphogenetic process (Gaino *et al.*, 1995). Different specimens belonging to the same species can acquire different growth forms even within a single local population (i.e. different microhabitats), and they can change their growth form over time according to the dynamics of environmental conditions (i.e. phenotypic plasticity) (Pansini & Pronzato, 1990; Pronzato *et al.*, 1998a, 1999, 2003). The conclusion is that *S. officinalis*, the sponge by definition, is something "protean" with a morphology in continuous variation, displaying short-term changes and difference specimen vs. specimen, that are difficult to describe in precise and accurate detail even by expert taxonomists.

In any case, a bath sponge is easy to recognise for students and traders, regardless of the species to which it belong. The fine differences among *S. officinalis, S.*

zimocca and *S. mollissima* remain a puzzle only for scientists locked in their ivory towers.

In general many people are not able to make distinction between a natural and a synthetic sponge, and the media do little to support the education of young people in this field, as suggested by the cartoon character "Sponge Bob", who lives in the sea but displays a synthetic-like body shape that is not typical of a natural sponge. This contrasts with the realistic representation of body shapes of the other marine animals in the same cartoon (octopus, starfish, squid, and gastropods).

Overfishing, disease, and local extinction

S. officinalis is not included in the *IUCN Red List of Threatened Species*, although the necessity of a conservation plan has been strongly proposed (Ben Mustapha & Vacelet, 1991; Pronzato *et al.*, 2012). For the European Union, it is listed, together with *Spongia lamella* and *Spongia zimocca*, in appendices II and III of the Barcelona Convention, as "protected species of the SPA/BIO protocol" of the Habitat Directive (issued by WCMC). All Mediterranean *Spongia* species are components of protected biocoenosis areas, e.g. marine caves registered as Habitat II.4.3, Habitat IV.3.2, and Habitat V.3.2, categorised respectively as mid-littoral caves, semi-dark caves, and dark caves (Relini & Giaccone, 2009; Relini & Tunesi, 2009; Manconi *et al.*, 2013).

Over-fishing. During the Ancient and Middle Ages, very little effort was expended in harvesting to exploit sponges, whereas the increase in market demand during the 19th century led to a large and excessive expansion in the number of vessels and fishermen working on sponges (Bidder, 1896). Just to give some examples, ca. 850 vessels and over 2,000 workers were engaged in exploitation of the sponge banks along the coast from Tunis to Zarziz in the winter of 1882 (Hennique, 1888), and exploitation of the Tripolitania and Cyrenaica coasts, from 1860 to 1890, involved 100–200 vessels per season, with ca. 2,000 workers (Sella, 1912). In 1878, a single fisherman with an air-supplied "diving suit" was able to harvest 25,000–35,000 sponge specimens at Benghazi during a single harvesting season; in 1893 over 2,000,000 sponge specimens were collected in Libya (Sella, 1912). These are all clear cases of over-fishing (Fig. 8).

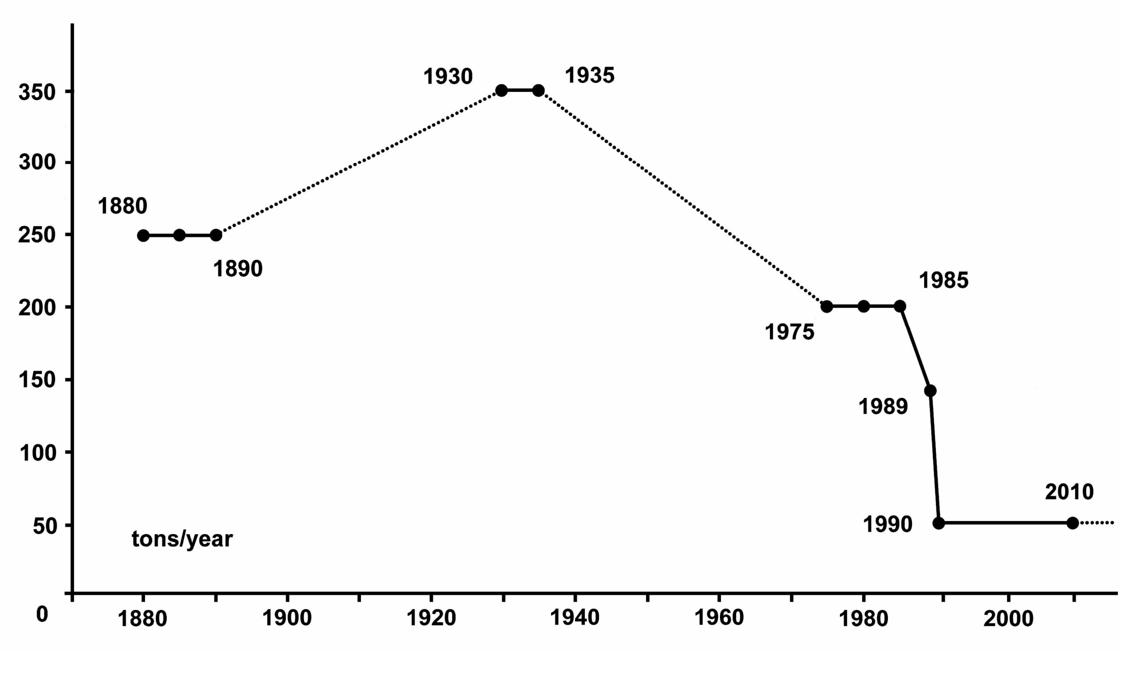


Figure 8: Sponge fishery trends in the Mediterranean Sea, with a dramatic fall in the last decades. Dotted line refers to absence of data. Source: Original.

Ascertained data on sponge trade trends date back to the second half of the 19th and the beginning of the 20th century. The fishing campaign produced over 200 tons of sponges from the North Africa coasts at the end of the century (Pronzato, 2011). Statistical data of the Italian colonial government indicate that a fishing effort of over 30 tons/year was considered the rule for more than a decade, up to 1911, accounting only the harvests of Italian fishermen, and only from the Gulf of Sirte (Sella, 1912).

Around 1930, the sponge trade reached ca. 100 tons/year in both Great Britain and Germany (Arndt, 1937), whereas this value was 30 tons/year in Italy, Holland and France (around 350 tons in total world-wide trade).

The Euro-Mediterranean export figures report an oscillating trend from 1980 to 1990, from ca. 150 to ca. 250 tons/year (Haywood, 1991).

There are no (or only scattered) official data for long periods of time (Fig. 8). Data on the Euro-Mediterranean area are again available from 1975 (190 tons also in 1980, increasing up to 200 tons in 1985), while a decrease is reported for the following years (145 tons in 1989) (Josupeit, 1991). In 1990, a very negative trend was outlined (Verdenal & Vacelet, 1990), bringing the figure down to 50 tons (Fig. 8).

In the decade 2000–2010 the Mediterranean sponge fishery fluctuates around 50 tons/year (Milanese *et al.*, 2008) with Tunisia, Greece and Libya figuring as major “sponge-producers”.

Over-fishing in the Mediterranean Sea is reported only by a few long-term studies on *S. officinalis.* Local fishermen regularly exploited several small sponge banks along the eastern Ionian coasts. The values of population density ranged from ca. 20 specimens/100 m^2 (1970) to 10 specimens/100 m^2 (1980) and 5 specimens/100 m^2 (1990) with a mean diameter ranging from 15 cm to 12 cm and 7 cm respectively (Pronzato *et al.*, 1996) (Fig. 9).

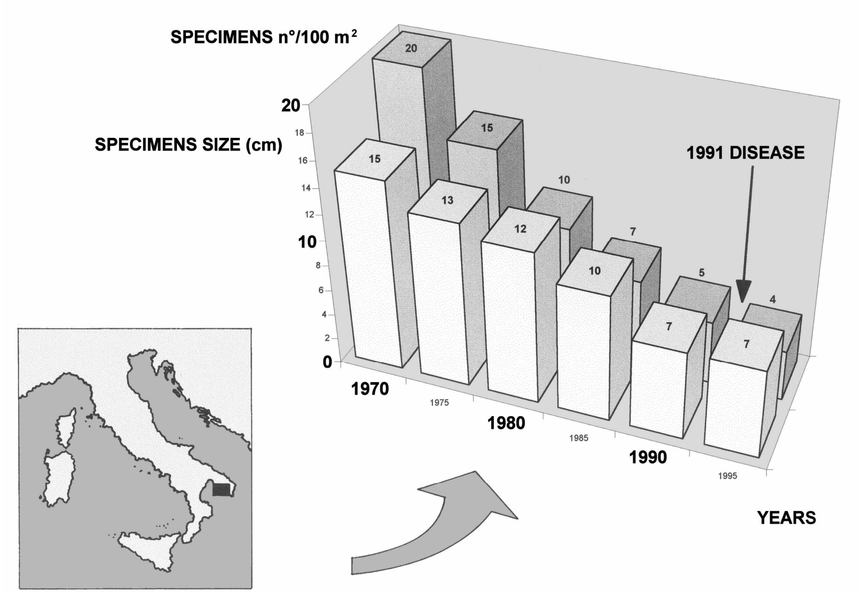


Figure 9: *Spongia officinalis*. The long-term study focusing on specimen density and size (over 30 years) shows the slow, but continuous, decline in a population of the Ionian Sea. The body size of specimens and the population density are indicated by mean diameter (cm =Ø) and mean specimens n°/100 m^2, respectively. Source: Modified from Pronzato *et al.*, 1996.

Disease. Starting from 1920–1930, "sponge disease" severely affected commercial sponge populations, driving this millennial Mediterranean natural resource to the brink of extinction; over time the epidemics became more frequent and merciless. Around 1990, the sponge stock decline was progressive and dramatic, driving the sponge fishery to zero. In Greece, Turkey, Cyprus, Syria, Egypt and Tunisia, sponge harvesting was stopped for almost two harvesting seasons. The synergy of over-fishing and disease was catastrophic (Pronzato & Gaino, 1991; Gaino & Pronzato, 1992).

The year 1985 saw the first scientific investigation of Mediterranean sponge-disease (Economou & Konteatis, 1988, 1990; Gaino & Pronzato, 1989, 1990; Vacelet *et al*., 1994). During the occurrence of the disease, sponges are firstly covered by a "thin white layer" of pathogenic micro-organisms; in a second phase, collagen and cells disappear from the mesohyl; finally spongin fibres are also attacked by excavating bacteria, resulting in an extreme fragility of the fibrous skeleton (Gaino & Pronzato, 1990).

The 1985–89 epidemics were absolutely severe and in some historically studied populations almost all specimens of *S. officinalis* apparently died (R. Pronzato pers. obs.).

However, at the Portofino promontory, over 60% of specimens involved in the epidemic were able to recover, starting from a small healthy remaining fragment of sponge (Gaino *et al*., 1992).

At the population level, sponge recovery has been reported as very slow. The Sicilian population of *S. officinalis*, apparently totally extinct from the Stagnone of Marsala in 1987, re-appeared five years later after a process of recolonisation, while a total recovery took ca. 10 years to reach density values similar to those detected in 1986. That notwithstanding, after 10 years of observations the average size of re-colonising specimens was less than a half of the values measured before the disease (Corriero, 1989; Rizzello *et al*., 1997) (Fig. 10).

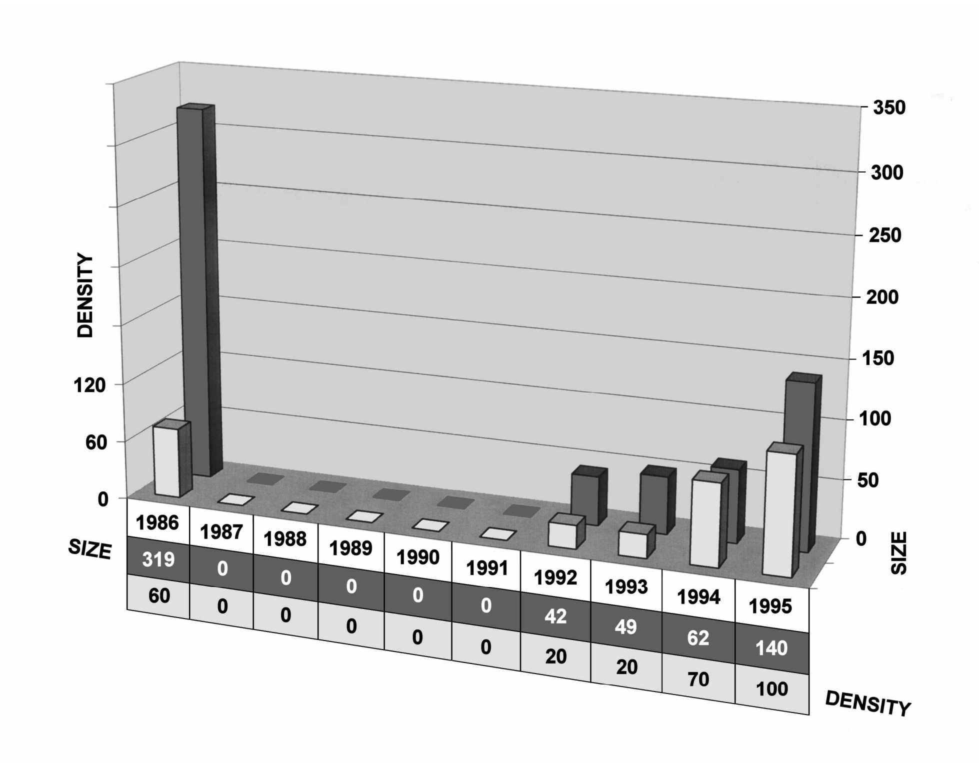


Figure 10: *Spongia officinalis*. Trend of population extinction (1987) and recolonisation (1992) in the lagoon Stagnone di Marsala (N. Sicily). The body size of specimens and the population density are indicated by mean covered area (cm^2) and mean specimens n°/100 m^2, respectively. Source: Modified from Rizzello *et al*., 1997.

Extinction. Disappearance of entire populations occurred in areas that have been especially affected by climate change, for instance in the western Mediterranean. At the end of the summer of 1999, an extreme sea water warming event stressed many species of sponges and sea fans, resulting in “local extinctions” in the Mediterranean Sea. During this catastrophic epidemic not only *S. officinalis* was affected; other massive sponge species were also decimated in a wide geographic area along the coasts of Liguria, Provence, Tuscany, Corsica and Sardinia (Pronzato, 1999; Cerrano *et al.*, 2000; Pérez *et al.*, 2000; Pronzato *et al.*, 2000a, b; Manconi *et al.*, 2001; Peres & Capo, 2001).

So-called “sponge-disease” became a common event in the subsequent years, and sponge fishermen and traders have been in a state of constant apprehension on that account. A further alarm was recently reported from North Africa (Egidio Bellini Spugnificio, Cogozzo di Viadana, Mantova, Italy, pers. com.) and western Sardinia (R. Manconi, pers. obs.) where bath sponges were observed to be suffering and dying, although not massively, in the autumn and winter of 2006–7.

One of the most studied populations of *S. officinalis* of the Mediterranean was certainly that of the Portofino Promontory (Ligurian Sea), particularly along the submerged cliffs below the lighthouse. The first reports date back more than 50 years (Sarà, 1958, 1964, 1966). In the summer of 1986, *S. officinalis* showed a very high density of over 100 specimens/100 m^2 at 12-25 m of depth (Gaino *et al.*, 1992). In the summer of 1987, ca. 60% of specimens were affected by the sponge disease, and this value decreased to 5% in 1988 and 20% in 1989. Notwithstanding the persistent disease, in 1995, the Ligurian population density was still similar (ca. 40-50 specimens/100 m^2) to that of other Mediterranean areas such as Ustica Island in the Tyrrhenian Sea (Pronzato *et al.*, 1998a; Gaino *et al.*, 1999).

This event was the beginning of the end. In 1999, the heaviest epidemics also hit the population of the Portofino Promontory (Cerrano *et al.*, 2000; Pronzato *et al.*, 2000a, b), leading to the complete disappearance of *S. officinalis*. Ten years after that event, *S. officinalis* is still not reappearing. At the present time we have to confirm its possible extinction for this Ligurian locality. Other mass mortality events were reported more recently (Pérez & Capo, 2001; Garrabou *et al.*, 2009). Peres & Vacelet (2014, in press) evidence high mortality rates in a protected marine area as a result of sponge disease. The commercial species previously recorded in Port-Cros, *S. lamella* and *H. communis*, totally disappeared, and only scattered individuals of *S. officinalis* survived in 2009–10. This last species had been really common ca. 10 years previously (Pérez & Capo, 2001; Pérez & Vacelet, 2013).

Over-fishing and sponge disease are not only a Mediterranean phenomenon (Webster, 2007). The first sponge mass mortality was reported for the West Indies in 1938–39 (Galstoff, 1942; Vicente, 1989). As a result of several successive feral events, the species *Hippospongia gossypina* became locally extinct from the coasts of Florida, while other commercial sponge species are disappearing from Cuban waters (Alcolado, 1994; Alcolado *et al.*, 2004).

In this case too, the progressive decline seems to be related to a synergy between over-fishing and disease; in fact the industrial sponge fishery, carried out in even more out-of-control fashion than in the Mediterranean, started in 1841. From that moment the sponge banks in the Caribbean Sea and Mexican Gulf were doomed (Maldura, 1931, 1938; Storr, 1964; Stevely *et al.*, 1978; Alcolado, 1994; Stevely & Sweat, 2000a, b).

Summarising, multiple factors have contributed to the decline of *S. officinalis*. Three potential, non-exclusive factors are climate shifts, habitat alteration, and high levels of predation by humans. These impacts may have been important in association with other stressors at local to basin scale.

As the potential for recovery of sponge beds, repopulation in the wild can occur by sexual propagules from natural populations from marginal areas. Indeed dispersal of *S. officinalis* in the wild occurs almost exclusively by means of larvae (*parenchymellae*). Reproductive strategies of this species are mainly based on sexual modes by internal fertilisation and viviparity i.e. by brooding larvae up to almost complete maturation. Parenchymellas are released from June to July, asynchronously (with a few days of de-phasing) either at the individual or the population level (Baldacconi *et al.*, 2007). Up to 523 larvae/48 h for a sponge specimen were counted (Baldacconi *et al.*, 2007). However lecithotrophic larvae have limited swimming capabilities, and both predators and environmental injuries can drastically reduce their potential for settlement and their dispersal power (Maldonado, 2006).

Domestication of *Spongia officinalis*

The domestication of sponges started in 1785, with the in situ experiments of Filippo Cavolini in the Bay of Naples. Buccich and Schmidt performed their first attempt at sponge (*S. officinalis*) cultivation between 1863 and 1872, when the Austrian Government financially supported sponge farming experiments along the coast of Hwar Island (Croatia). As a result, they obtained specimens of ca. 30 cm in diameter in 3 years, with a mortality rate of 10 %, using sponge fragments fixed onto wood boxes (Rathburn, 1887; Moore, 1910).

Although Radcliffe (1938) strongly suggested a general necessity of sponge farming, a long period of inactivity occurred after the promising experiments performed between the end of the 19th century and the beginning of the 20th century (Moore, 1910). More recently, Wilkinson & Vacelet (1978) tested sponge transplantation to locations with differing conditions of light and current, and Verdenal & Vacelet (1990) established a plant for sponge farming in the Gulf of Lions to study relationships between growth and mortality rates and environmental factors. These experiments have played an important role in promoting a revival of sponge farming in the western Mediterranean (Gaino *et al.*, 1994; Pronzato *et al.*, 1998b, 1999, 2000, 2006; Manconi *et al.*, 1999, 2004; Pronzato, 1999; Scalera-Liaci *et al.*, 1999; Van Treeck *et al.*, 2003; Corriero *et al.*, 2004; Ferretti *et al.*, 2006a, b; Baldacconi *et al.*, 2010; Çelik *et al.*, 2011; Ledda *et al.*, 2012, Padiglia *et al.*, 2018).

Sponge farming is a simple and eco-sustainable solution that exploits the natural intrinsic capacity of sponges to perform a clonal proliferation simply by body fragmentation. Sponge culture technologies are easy and not expensive (Pronzato *et al.*, 2006, 2013; Manconi *et al.*, 2008), and this activity is possible, in shallow water, in combination with all other mariculture approaches e.g. fish farming in floating cages (Manconi *et al.*, 1999). Moreover sponges are very efficient natural water cleaners; they can filter an enormous water volume, performing very high cleaning rates (Reiswig, 1974, 1975; Ledda *et al.*, 2012). Sponges feed normally on bacteria, organic suspended particles, and dissolved organic matter; as a consequence a combination between sponge farming and sources of organic pollution (e.g. drainages) can mitigate environmental damages in coastal areas (Manconi *et al.*, 1999; Pronzato, 2003; Baldacconi *et al.*, 2010).

Three or four days after transplantation sponge fragments regenerate their outer layer; after one week they restore pigmentation on the dermal membrane surface;

and after a short time they show a tendency to assume the growth form typical of the cultured species. Mortality, usually lower than 10%, occurs during the first days, when frequent checking and cleaning of the plant is necessary (Pronzato, 1999; Pronzato *et al.*, 1998b, 1999, 2000a, b).

Sponge mariculture could offer a way to avoid the risk of local population extinction resulting from the effects of harvesting on already stressed natural sponge populations, whose density in the Mediterranean as a whole is quite unknown. The production of larvae from farmed specimens and the reduction of harvesting effort could contribute both to the repopulation and to the conservation of target species in stressed areas (Pronzato, 2003).

Humans were able, in less than 15,000 years, to domesticate several animal species ranging from terrestrial invertebrates (*Apis mellifera* L., 1758) to large mammals (*Elephas maximus* L., 1758), and many marine species have not escaped this fate.

The domestication of animals, despite its evident advantages, hides many pitfalls: first of all, the dangerous drastic reduction in genetic diversity of breeding species. Another, no less important factor of damage to natural biodiversity is the extinction of wild populations of the reared species. See for example the cases of the aurochs (*Bos taurus primigenius* Bojanus, 1827) and the horse (*Equus caballus* L., 1758), although the trend in the marine environment could be different from the terrestrial one.

Now, in the moment of greatest risk of extinction of the wild Mediterranean populations of *S. officinalis,* mariculture techniques for this endangered species are on the increase. We could end up in a situation as has happened for San Marzano tomatoes, Dalmatian dogs and Lipizzaner horses. Namely that domesticated species and varieties survive their wild ancestors.

Concluding remarks: The end of the story?

It seems impossible to imagine that such an important historical, cultural and biological heritage as that of the bath sponge can be permanently lost due to human carelessness. Tens of millions of specimens of *S. officinalis* have usefully served humanity since the appearance of the first Mediterranean civilisations. Tens of thousands of fishermen have risked and lost their lives to take possession of this legendary marine Golden Fleece.

Now this may all come to an end. The dramatic warning signals are unmistakably there (as evidenced in the present paper). But there is nobody doing anything, and there are no cries of alarm. The present fishermen and sponge traders continue their work as if nothing had happened, and as if, ineluctably, the end of this history has already been written.

Incredibly, today’s animal welfare and environmentalist groups are not concerned with this issue, because bath sponges and sponges in general are not charismatic animal species.

It seems that what we have here is a striking and highly dangerous case of global disinformation, closely related to what might be called “submerged science”.

A story has to be written first, and then read and told; but if only a few people read, write and tell it, then the microcosm of which the tale is told is likely to go unnoticed to all others, even in this age of global communication that we inhabit.

A branch of science exists as long as there are scientists who cultivate it; the larger the numbers of scientists who practise a discipline, the larger are the chances of success and resonance of the science in question. On the other hand, the fewer the number of researchers, the greater is the risk that the scientific discipline is “buried alive”, because of a lack of critical mass.

The case of *S. officinalis* falls into the latter category. The over-fishing and disease have been reported on several occasions, but those voices have remained isolated and enclosed in narrow academic circles. They have not resulted in any concrete political action of safeguarding at the international level. No long-lasting management programmes have been planned. The lack of “visibility” for the catastrophic events that are taking place across our sea-beds will not help to raise awareness of who should manage properly the exploitation and protection of marine ecosystems. Strangely, it seems that the concept of “natural disaster” does not extend to underwater environments.

The story of *Spongia officinalis*, the sponge by definition, is likely to end on the sly, with the world being unaware of the disappearance of its wild varieties. It could happen that only the “domestic” variety will remain: pampered, protected and nourished in closed sponge gardens. Far from all environmental dangers. Only to serve the needs of humans. But, perhaps, we still have time to write a different ending. Is anyone able to write it? Regardless of the eventual outcome, this story had to be told, so that no one can say, “I did not know! Because no one informed me!”

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Table I

Genus *Spongia*. Annotated list of the valid species generally accepted by the scientific community. The geographic range is drawn from the unpublished manuscript register (71 volumes) of Pulitzer-Finali (1995) and the World Porifera Database (Van Soest *et al.*, 2018). Capital letters refer to the Realms listed in Table II (see also Fig. 2). Here we consider only the subgenus *Spongia (Spongia)*. Depending on the authors cited, the number of species can rise to around sixty. Consequently the following list should be approached with caution.

[**Note**: In the e-version of this chapter the links are clickable]

1. *Spongia agaricina* Pallas, 1766 (Philippines, Torres Strait) (F)
2. *Spongia anclotea* de Laubenfels & Storr, 1958 (Florida) (D)
3. *Spongia arabica* Keller, 1889 (Red Sea) (E)
4. *Spongia australis* Bergquist, 1995 (New Caledonia) (F)

5. *Spongia bailyi* (Lendenfeld, 1886) (West Australia) (F)

6. *Spongia barbara* Duchassaing & Michelotti, 1864 (West Indies, West Panama, Gulf of Mexico, Bahamas, Cuba) (B-D-H)

7. *Spongia bibulus* Rao, 1941 (India, Ceylon) (E)

8. *Spongia brunnea* Lévi, 1969 (Atlantic South Africa) (J)

9. *Spongia cerebralis* Thiele, 1905 (Chile, Juan Fernandez, North Patagonia, Argentina) (H-I)

10. *Spongia ceylonensis* Dendy, 1905 (South India, Ceylon, South Chinese Sea) (E-F)

11. *Spongia conifera* (Lendenfeld, 1886) (Ceylon, India, Torres Strait, Australia) (E-F)

12. *Spongia distans* (Schulze, 1900) (Indonesia, Ambon Bay, Banda Sea) (F)

13. *Spongia graminea* Hyatt, 1877 (Florida, North Mexico Gulf, South Carolina) (B-D)

14. *Spongia hispida* Lamarck, 1814 (Australia, Japan, South Chile, Bass Strait, Banda Sea, Hawaii, Indonesia, Manning-Hawkesbury, Mascarene Islands, South India, Sri Lanka, South-East Madagascar, Torres Strait, New Zealand) (C-E-F-G-I-K)

15. *Spongia illawarra* (Whitelegge, 1901) (South-East and South-West Australia) (K)

16. *Spongia irregularis* (Lendenfeld, 1889) (Mauritius, Northern and Central Red Sea, Ambon Island, Molucche, India, Australia, Hawaii, Mascarene Islands, Mauritius, Surigao Strait, Philippines) (E-F-G)

17. *Spongia lamella* (Schulze, 1879) (Mediterranean Sea, Portugal) (B)

18. *Spongia lesleighae* Helmy, El Serehy, Mohamed & Van Soest, 2004 (North Red Sea) (E)

19. *Spongia lignea* Hyatt, 1877 (South-East West Australia, West Indies, Bermuda, Hawaii, Pacific Costa Rica, Pacific Colombia) (D-G-H)

20. *Spongia magellanica* Thiele, 1905 (Antarctic, Chile, Argentina) (I-L)

21. *Spongia matamata* de Laubenfels, 1954 (Micronesia-Marshall) (G)

22. *Spongia mollissima* (Schulze, 1879) (Mediterranean Sea) (B)

23. *Spongia nicholsoni* Hyatt, 1877 (South-East Australia) (K)

24. *Spongia nitens* (Schmidt, 1862) (Mediterranean Sea, Cabo Verde, Portugal) (B)

25. *Spongia obliqua* Duchassaing & Michelotti, 1864 (Florida, North Gulf of Mexico, Curaçao, St. Thomas, Bahamas, Cuba, Bermuda, British Virgin Islands) (B-D)

26. *Spongia obscura* Hyatt, 1877 (West Indies, Florida, Gulf of Mexico, North Carolina, Curaçao, Cuba, Bahamas) (B-D)

27. *Spongia oceania* de Laubenfels, 1950 (Hawaii) (G)

28. *Spongia officinalis* Linnaeus, 1759 (Mediterranean Sea, Azores, Canaries, Madeira, New Guinea, Western-Central Indo-Pacific, West Indies, Puerto Rico, Australia, South Africa, Norway, Puerto Cabello, Sulawesi, Antarctic, Biscay, North Atlantic, Ceylon, Mauritius, Red Sea, Congo, West Africa, South-West Bahia) (A-D-E-F-J-L)

29. *Spongia osculata* (Lendenfeld, 1889) (Freemantle, West Australia,) (K)

30. *Spongia osculosa* (Lendenfeld, 1889) (Bermuda) (D)

31. *Spongia pertusa* Hyatt, 1877 (Bahamas, Florida, Greater Antilles, Curaçao, Fernando de Noronha, Atoll das Rocas, Brasil) (D)

32. *Spongia solitaria* Hyatt, 1877 (Bahamas, Curaçao, South Caribbean) (D)

33. *Spongia spinosa* (Lendenfeld, 1888) (Manning-Hawkesbury South-East Australia) (K)

34. *Spongia sterea* de Laubenfels & Storr, 1958 (Florida, North Gulf of Mexico) (B)

35. *Spongia sweeti* (Kirkpatrick, 1900) (Clipperton Island, Eastern Pacific) (H)

36. *Spongia tampa* de Laubenfels & Storr, 1958 (Florida) (B)

37. *Spongia tenuiramosa* (Dendy, 1905) (Sri Lanka) (E)

38. *Spongia tubulifera* Lamarck, 1814 (Bermuda, Florida, Bahamas, Gulf of Mexico, Curaçao, Cuba, Greater Antilles, British Virgin Islands) (B-D)

39. *Spongia violacea* Lévi, 1969 (Atlantic South Africa) (J)

40. *Spongia virgultosa* (Schmidt, 1868) (Mediterranean Sea, Portugal, Azores, Canaries Madeira, West Indies, Chile, Brasil, Hanga Piko Easter Island, Japan, Australia) (B-C-D-F-I-K)

41. *Spongia zimocca* Schmidt, 1862 (Mediterranean Sea, Red Sea, Australia, Singapore, Bahamas) (B-D-E-F-K)

Table II

Genus *Spongia*. Species distribution referred to the Costal Marine Realms *sensu* Spalding *et al.* (2007). Numbers indicates the species listed in Table I. See also Fig. 2.

A	Arctic
B	Temperate Northern Atlantic (13 species) 6, 13, 17, 22, 24, 25, 26, 28, 34, 36, 38, 40, 41
C	Temperate Northern Pacific (2 species) 14, 40
D	Tropical Atlantic (13 species) 2, 6, 13, 19, 25, 26, 28, 30, 31, 32, 38, 40, 41
E	Western Indo-Pacific (10 species) 3, 7, 10, 11, 14, 16, 18, 28, 37, 41
F	Central Indo-Pacific (11 species) 1, 4, 5, 10, 11, 12, 14, 16, 28, 40, 41
G	Eastern Indo-Pacific (5 species) 14, 16, 19, 21, 27
H	Tropical Eastern Pacific (3 species) 6, 19, 35
I	Temperate South America (4 species) 9, 14, 20, 40
J	Temperate Southern Africa (3 species) 8, 28, 39
K	Temperate Australasia (8 species) 14, 15, 19, 23, 29, 33, 40, 41
L	Southern Ocean (2 species) 20, 28

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