Sea cucumber: a new candidate species for aquaculture in Mediterranean Sea

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Abstract

Sea cumbers are now a global product known by the Chinese as “beche-de-mer”, “trepang” o “haisom” and are almost unexploited resources in the Mediterranean region. In the Mediterranean region they are currently harvested and exported in Turkey and are the most expensive seafood in Catalonia and Balearic islands. Considered a delicacy in many Asian countries, there is also growing interest in their medicinal value. Several studies have demonstrated the potential antimicrobial, antioxidant and anticancer properties of sea cumber extracts. Sea cumbers extracts have also found a place in cosmetics. Successful utilization of sea cumbers in the Mediterranean will require continued refinement of aquaculture techniques and development of industrial processes for enhancing the scale of production. In this context it is clear that the future of sea cucumber farming has interesting lucrative potential in the Mediterranean and turning sea cucumbers into aquaculture value-added products could have tremendous economic benefits in this region.

Key words: sea cucumber, sea cucumber farming, echinoderms, trepang,

Status of sea cucumber farming

Sea cucumbers are a traditional staple food in China, where they are both harvested from natural stocks and farmed (Chen J., 2003.). The ease of international transport has broadened the variety of foods in the global marketplace and sea cucumber trade is flourishing globally (Vannuccini S., 2004). The status and importance of the worldwide sea cucumber fishery and aquaculture trade (Fig. 1) has been extensively reported in several FAO reports during this last decade (Lovatelli et al., 2004; Purcell S.W., 2010; Toral-Granda et al., 2008). Although sea cucumber farming is not a traditional activity outside of China and far Eastern countries, a great number of coastal communities have developed sea cucumber fisheries and aquaculture for export as an integrative economic source. Sea cucumber farming is not currently an active fishery or aquaculture industry in the Mediterranean. Asian consumers, however, are residents and restaurant patrons throughout Europe. In addition, the varied uses for sea cucumber extracts as pharmaceutical, nutraceutical and cosmetic ingredients have expanded. The time appears right to consider farming sea cucumbers as a commercial enterprise in the Mediterranean to support growing consumer and commercial interests in sea cucumber products and diversification of Mediterranean aquaculture productions. In this review we provide a foundation for exploring sea cucumber farming in the Mediterranean.

Natural History of Sea Cucumbers

Sea cucumbers are a class (Holothuroidea) of Echinoderms. There are 500 species of sea cucumber in the world and 47 in the Mediterranean sea; some of which are edible (Aymin, 2008; Chakly et al., 2004; Montserrat et al., 2010). As members of the benthic marine invertebrate community they play an integral role in sustaining the health of marine ecosystems (Purcell S.W., 2010). Sea cucumbers are benthic scavengers that remove organic particles from the sea floor as well as plankton and the eggs and larvae of other species (e.g. small crustaceans) from the water column

(Hamel and Mercier,1998). They also serve as an important source of food for many fish, and large invertebrates (mainly Echinoderms). The majority of species are dioecious, but some undergo gender reversal and a number of different reproductive strategies are displayed (Sewall A., 1998). While fertilization for many species occurs in the water column, others use an internal fertilization strategy and retain the developing larvae in brood pouches until the developed juveniles are released onto the sea floor (Tortonese A., 1965).

Cultural History and Status of Sea Cucumber Fisheries

Eating sea cucumber is a Chinese custom in coastal areas that can be traced back to the Ming Dynasty (1368–1644 BC) (Chen J., 2003). Sea cucumbers are now a global commodity known as "beche-de-mer", "trepang" o "haisom" (FAO, 1990). Trepang is considered a luxury by the Chinese and Japanese, as well as other cultures throughout the Indo-Pacific region. In China, sea cucumbers are traditionally prepared first by boiling, followed by drying in sun, then roasting over a fire (Huizeng F., 2001; Zhong et al., 2007). Local preparation customs vary and sea cucumbers are prepared in many different ways based on local custom and regionally distinct preparation practices (Ferdouse F., 2004)

Commercial Fishing of Sea Cucumbers

The sea cucumber fishery produces approximately 80,000 tonnes of raw sea cucumber each year in the South Pacific and Asia for processing into beche-de-mer. Harvesting is mostly focused on about thirty species, and simple traditional techniques are used to harvest sea cumbers from the benthic community. The fishery systems used vary geographically (Conand C., 2004). In China, the largest producer is Lianonig province, where the production was about 200,000 tonnes in 2004 (Chen, 2004).

In the northern hemisphere, the sea cucumber fishery is mainly supported by four countries: Canada, the United States (Bradbury A., 1994), the Russian Federation and Iceland. Their harvests focus on four main species (*Parastichopus californicus, P. parvimensis, Cucumaria frondosa* and *C. japonica*), but the collective list of species harvested is lengthy (Table 1) (Akamine J., 2004). In the northern Atlantic, a limited fishery for the sea cucumber *Stichopus tremulus* has originated in Norway (Therkildsen et al., 2006). Montserrat and co-workers (2010) recently discussed the great interest in the royal sea cucumber (*Sthicopus regalis*) in Spain, were this sea cucumber is considered a delicacy in haute cuisine. The royal sea cucumber is currently the most valued seafood in the Catalan market, reaching up to 130 €/kg. European consumption of sea cucumber is mainly focused on high quality dried and prepared seafood, which are popular among people of Chinese origin. In 2003 Spain, France, Germany and Belgium comprised the bulk of the Western European sea cumber trade and processing of sea cucumber products had reached 17,000 tons with a value of almost 47 Mln US$ (Ferdouse F., 2004). In Italy, initial attempts to interest consumers in sea cumber products met with limited success (Sella E., 1940; Tortonese E., 1965). However since the second world war sea cucumbers have been consumed as a delicacy in Apulia, Italy and other regions in Southern Italy. Turkey is the only Mediterranean country actively harvesting and exporting sea cucumbers to Asia, and predominately Singapore, Hong Kong and Japan (Aydin, 2008; Cakly et al., 2004). The most common sea cucumber species in Mediterranean sea are *Holoturia tubulosa, H. forskalii* and *H. poli* (Ocana and Sanchez Tocino, 2005).

Over- exploitation Risks

Natural populations of sea cucumbers and other echinoderms (e.g. sea urchin) have been often over harvested (Panagiotis P.A., 2009). With the exception of some temperate areas of the northern hemisphere, sea cucumber populations are under intense exploitation throughout the world (Conand and Byrne, 1993; Kinch et al., 2008a; Mmbaga et al., 2004; Uthicke, 2004). International fishery

statistics reported by FAO since 1992 and document a general decline of natural populations of sea cucumber worldwide, with the exception of some tropical fisheries. The FAO has proposed a Plan of Action to control the fishery and stabilize natural populations and the international harvest. In response, harvest restrictions have been introduced in some countries (Conand C., 2004). In the Indo-Pacific region many species are now extinct (Sitwell, 1993). In response, countries such as Papua New Guinea have adopted management plans to slow the decline of natural stocks (Kinch et al., 2008b; Polon, 2004; Tuwo, 2004). Exploitation of natural populations in Indo-China prompted dramatic declines in sea cucumbers. During 1998 Egypt started harvesting of sea cucumber on Red sea coasts for exportation toward Hong Kong and Singapore. In the successive years the fishery expanded dramatically, leading to rapid overexploitation (Gabr et al., 2004). In Turkey, a 2002 regulation was established prohibiting sea cucumber fishing during the reproduction period (Aydin, 2008). Harvests and exportation rapidly increased from 20 tons of sea cucumber in 2002 toward 77 tons in 2007 (Tab. 2). In this context, sea cucumber farming provides an alternative source of product and supports efforts to preserve natural populations.

Sea cumber farming

Sea cucumbers have been farmed in China since the middle of the 1980s and successively in Malaysia, Korea and Japan (Akamine J., 2004). In the Asian and Pacific regions sea cucumber farms have many typologies, ranging from extensive, to industrial. The bulk of the production has been exported primarily to supply the Asian market, with China and Hong Kong the main export destination. China is the world largest sea cucumber producer and sea cucumber farming is a key part of its aquaculture industry (Chen J., 2004). Dalian is a major production area in northern China for trepang and its production reached 25,000 tons in 2007, accounting for nearly 50 percent of China's total output (Chen J. 2008). During the period 1983–1990, a strong increase in the demand for trepang heightened interest in sea cucumber farming (Morgan et al., 1999). A Chinese Ministry

of Agriculture government commitment to encourage the industry's success led to the development of hatcheries and improved techniques for the culture of *Apostichopus japonicus*. As demand for sea cucumber products has increased, the culture of new species has been considered (Conand C., 2004), including temperate species, which are slowly gaining popularity in the marketplace. Sea cucumbers are now reared in Tanzania, Papua New Guinea, in the Northern Territory and northwestern Australia, Seychelles islands, Galapagos, in Solomon islands and in the islands of the South China Sea, Cuba, Madagascar, Egypt, Philippines (Gamboa et al., 2004), Malaysia, Indonesia and Japan (Conand C., 2008). The ports of Hong Kong, Singapore and Taiwan are the primary markets from which processed sea cucumbers are exported from producing countries (Ferdouse F., 2004). But a definitive quantification of sea cucumber product market yield and value is still complicated by the limited availability of trade and import/export data (Baine M., 2004; Vannuccini et al., 2004). High sea cucumber prices (e.g. 370 USD /kg in China)(Chen J., 2003) have strongly stimulated the development of sea cucumber farming, and in particular the culture of *Apostichopus japonicus*; a highly regarded species (Ferdouse F., 2004). Recently, Chinese capital investment has been attracted into this sector of aquaculture and academic institutes are now actively engaged in enhancing sea cucumber farming techniques. Indeed, some investment interests have moved away from shrimp culture and have embraced sea cucumber farming as a viable commercial enterprise.

Sea Cucumber Culture Techniques

There are more than 134 edible sea cucumber species along the Coast of China that are of commercial interest (Chang Y., 2008). *Apostichopus japonicus* is the primary species under cultivation, but more than 30 species (23 Holothuriidae; 6 Stichopodidae), with different commercial value have been exploited. In northern China, sea cucumbers reach market size between 10-18 months. Documented survival of cultured species has varied widely between 10-90 % (Yaqing et al., 2004). The optimal cultured density of sea cucumbers is 100-150, 000 animal per

hectare. In experimental farming, juveniles were stocked in early spring, with a density of 100 - 150,000 individuals per hectare. The yield reached 4000 to 7000 kg ha-1 in the following year (Yaqing et al., 2004). Common features of species selected for aquaculture include: abundance growth in shallow waters; large size of the animals; thickness and stiffness of the tegument, which facilitate processing techniques. Three main culture methods have been used successfully by sea cumber farmers: pond culture, pen culture and bottom culture (Chen J., 2003; Xilin S., 2004). In view of its lower investment and higher return, bottom culture accounts for 75 % of total area of culture in China. Lower investment intensive bottom culture techniques would be a prudent choice of for initial efforts to farm sea cucumber in the Mediterranean sea

Potential use for pharmacology and other applications

Sea cucumbers are also consumed for their beneficial effects on human health (Chen J., 2008; Kuznetsova T.A. et al., 1982; Poh-Sze C., 2004.). Several studies in the last two decades have demonstrated that the biological activities of sea cucumber extracts promote wound healing and exhibit antimicrobial, antioxidant and anticancer properties (Fredalina et al., 1999; Haug et al., 2002; Qui et al., 2007; Tian et al., 2005). Sea cucumbers are healthy foods. They are rich in protein, and low in fat; the majority of which is polyunsaturated. eicosapentaenoic acid (EPA). It is the predominant fatty acid in *Cucumaria frondosa* and represents approximately 50 % of the total fatty acids in *Stichopus chloronotus* (Fredalina et al., 1999; Zhong et al., 2007)). Suggested tissue repair promoting properties of sea cucumbers have been associated with its high EPA content. In general, marine invertebrates living in shallow waters are naturally protected against oxidative stress caused by their exposure to high levels of solar UV radiation (Hawa et al., 1999; Zhong et al., 2007). For this reason sea cucumbers could serve as a extraordinary source of antioxidants. Among Atlantic species, *Cucumaria frondosa* is rich in triterpene oligoglycosides, cucumariosides and some antioxidant compounds (Aminin et al., 2001; Mamelona et al., 2007; Zhong et al., 2007). Several

studies have demonstrated that metiltetradecanoic acid found in sea cucumber is an inhibitor of lipoxigenase enzyme, and may have anti-cancer and antinflammatory characteristics. Sea cucumbers are also rich in mucopolysaccarides and particularly in condroitin sulphate. Recently several compounds extracted from sea cucumbers have been used as a source of chondroitin sulphate, for commercial products such as ArthriSea® and SeaCUMAX® (Chen J., 2004) Dietery glucosaminoglycan (GUGA) are already used in dog nutrition (Henrotin et al., 2005). Vanadium is present in sea cucumber emolymph and there is no clear evidence of its function, but may have promising biomedical applications. In 2007, a pharmaceutic company, PLoS Pathogens, found that sea cucumber could have anti-malarial properties. Extracts from sea cucumbers have also been demonstrated to have anti-viral inhibitory activity and an anti HIV therapy has been recently patented. Pharmaceutical companies are also incorporating sea cucumber extracts into cosmetic products as an alternative to the use of vertebrate animal products in cosmetics. Although sea cumber-associated products may have marked value to human health additional controlled clinical trials are needed to validate it therapeutic and preventive health benefits.

Integrated productions

Sea cucumber as well as other detritivorous or microphagous invertebrates populations often naturally increase near fish farms. Integrated farming of fish and sea cucumbers could functionally help mitigate the environmental impact of large scale productive of some culture marine fish species (Bartley and Bell, 2008; Bell et al., 2008; Purcell and Kirby, 2006). Several studies have investigated polyculture with shrimp (Yaqing et al., 2004), mussels (Slater et al., 2007) and oysters (Paltzat et al., 2008) and bioremediation applications (Bell et al., 2007; Michio et al., 2003). In one study, the quality of California sea cucumbers reared inside floating net pens used to rear salmon in Alaska was significantly greater than that of sea cucumbers occurring in the wild (Ahlgren, 1998). Integrated aquaculture techniques have been applied to sea cucumber production in China where

Apostichopus japonicus has been successfully reared, without artificial feeding, on reefs placed in aquaculture ponds (Paltzat et al., 2008; Yaqing et al., 2004). As bottom dwellers, sea cucumbers, could be effectively used as bioindicators for surveying metal contamination in the marine ecosystem (Warnau et al., 2006)

Conclusion - Toward sustainable sea cucumber farming and fishing in the Mediterranean

The great natural abundance of sea cucumbers in the Mediterranean offers great potential for the development of sea cucumber aquaculture in the Mediterranean region. If natural stocks can be protected, sea cumber farming could support both the international consumer seafood market and the product needs of the pharmaceutical and cosmetic industry. The demonstrated economic value of sea cucumber enterprises in Turkey and in southern Spain reflect the potential value to coastal areas in the Mediterranean if sea cucumber farming can be adapted to local conditions. However, the overall potential success of sea cumber aquaculture will be dependent on each farmer's ability to produce high quality products that are competitive with Asiatic products (Asha and Muthiah, 2008; Xiyin et al., 2004; Morgan, 1999).

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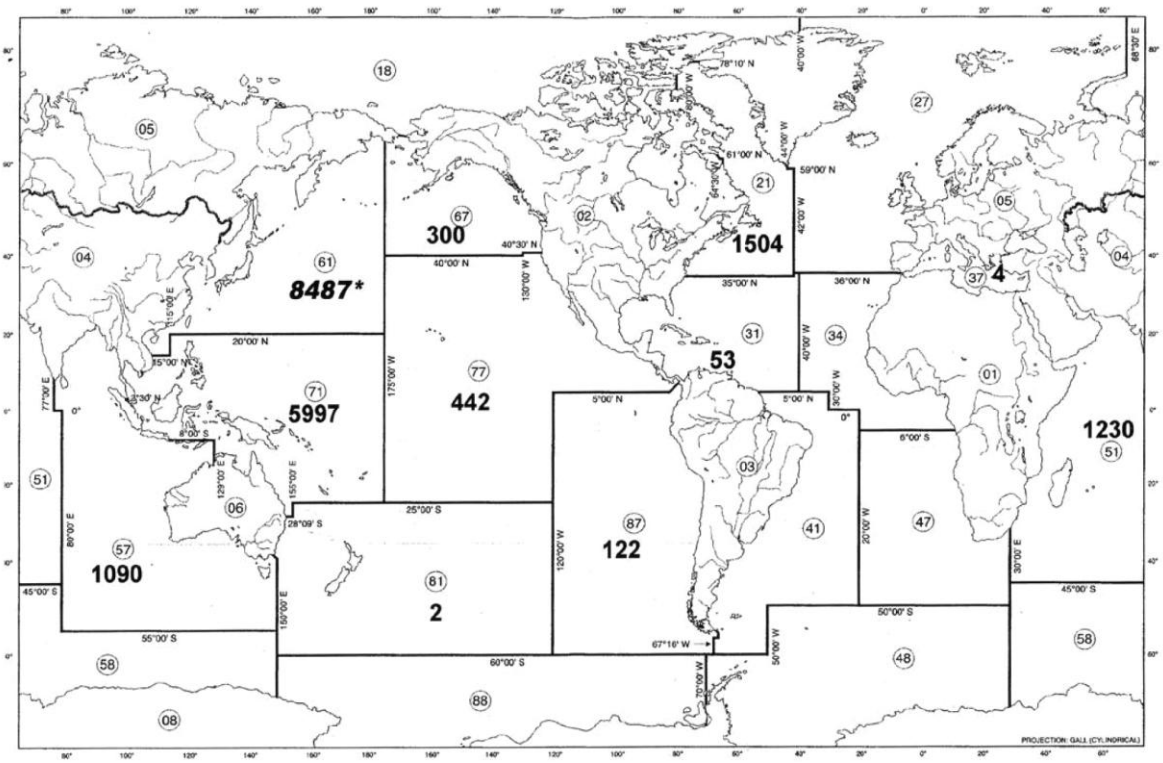

Figure 1. Sea cucumber captures in 2001, in bold, according to FAO zones (tonnes) (give due credit to FAO. Conand C., 2004)

Table 1. Commercial species of sea cucumber (Echinodermata: Holothuroidea) found in the North Atlantic, North Pacific and Mediterranean sea (from Hamel et al., 2008, modified)

Species	**Common name**
Cucumaria frondosa (Gunnerus 1767*)*	Sea pumpkin; Orange–footed sea cucumber.
Cucumaria japonica (Sempre 1868)	Japanese sea cucumber
Parastichopus parvimensis (Clark 1913)	Warty sea cucumber
Parastichopus californicus (Deichmann1937; Stimpson 1857)	Giant red sea cucumber; Californian sea cucumber.
Actinopyga mauritiana	Redfish; shoes trepang
Holothuria fuscogilva	White teat-fish
Actinopyga lecanora	Stone trepang; sea cucumber
*Holothuria nobilis***	Black teat-fish
Actinopyga echinites	
Holothuria moebii	
Actinopyga miliaris	Black trepang
Holothuria cinerascens	
Bohadschia argus	Tiger-fish; spotted fish
Holothuria arenicola	
Bohadschia marmorata	White-fish
*Apostichopus japonicus**	Thorn trepang
Holothuria atra	Black trepang
Stichopus chloronotus	Square trepang
Holothuria edulis	Stichopus horrens
Holothuria fuscocinerea	Stone trepang
Stichopus variegatus	Yellow meat
Holoturia leucospilota	Black trepang, black dog
Holothuria leucospilota	Black trepang, black dog
*Thelenota ananas***	Plum-flower trepang
Holothuria pervicax	Tiger spotted trepang
Thelenota anax	Plum-flower trepang
*Holothuria scabra***	Sandy-fish; white-fish
Acaudina leucoprocta	Perfume trepang
Holoturia tubulosa	Mediterranean tubular sea cucumber
Holoturia poli	Mediterranean white spot sea cucumber

* Highest commercial value
** High commercial value
*** from Chen et al., 2003, modified

Table 2. Total production and processing methods of sea cucumber in Turkey until 2007 (from Aydin M, 2008, modified)

Year	Total production (kg)	Processing method
1996	19,868	Frozen
1997	37,665	Frozen
2002	172	Flour
2003	10,843	Dried and flour
2004	5,421	Dried
2005	53,293	Dried and frozen
2006	24,200	Frozen and dried
2007	77,238	Frozen, dried and salted

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