Less information are available about sea cucumbers fisheries in the Mediterranean Sea, in particular for *Holothuria tubulosa* Gmelin, 1788, *Holothuria mammata* Grube, 1840, *Holothuria sanctori* Delle Chiaje, 1823, *Holothuria forskali* Delle Chiaje, 1823, *Parastichopus regalis* Cuvier, 1817, and *Holothuria arguinensis* Koehler & Vaney, 1906 (Çakly *et al.*, 2004; Antoniadou and Vafidis, 2011; Sicuro and Levine 2011; Gonzàlez-Wangüemert and Borrero-Perez, 2012; Mezali and Thandar 2014; Gonzalez-Wangüemert *et al.*, 2014a, 2015). Presently, more than half of global sea cucumber fisheries are considered depleted or overexploited to the extent that governments (including the Italian Government) have banned their harvesting (Anderson *et al.*, 2011; González-Wangüemert *et al.*, 2014, 2018). With the 38% of sea cucumber fisheries currently unregulated and an unknown level of illegal catches, this fishery is considered unsustainable and far from being adequately managed (Anderson *et al.*, 2011; Choo, 2008; Toral-Granda, 2008).

The unregulated exploitation of sea cucumbers is a rising concern for their conservation, with 16 species worldwide now classified as "vulnerable" or "endangered", according to the IUCN Red list (Conand *et al.*, 2014, Ramírez-González *et al.*, 2020). Concern also raises because most of the harvested sea cucumbers are deposit-feeders, thus playing an ecological key role due to their feeding behaviour (Uthicke, 2001; Roberts *et al.*, 2000), their decline could have severe consequences on sedimentary biogeochemistry and benthic ecosystem functioning.

Here we reviewed the available information about the ecological role of sea cucumbers, with a focus on the Mediterranean *H. tubulosa*, their breeding, fishery management issues, main gaps of knowledge and future perspectives for their use as remediation of eutrophicated sediments.

LIFE HISTORY AND POPULATION DYNAMICS OF SEA CUCUMBERS

The increasing interest towards sea cucumbers and their use for food, medical and habitat remediation purposes, stimulated exploration about their reproductive cycle and population dynamics, both crucial aspects for the assessment of wild stocks and their eventual management.

Almost all sea cucumbers are broadcast spawners with external fertilization that present an annual or bi-annual maturation season (Mercier and Hamel, 2009; Mohsen and Yang, 2021). With a few exceptions of hermaphrodite species, they are generally gonochoric that leak in sexual dimorphisms (Smiley *et al.*, 1991; Mercier and Hamel, 2009). The life cycle of sea cucumbers is characterised by one or more planktonic larval stages starting with a feeding auricularia (early, mid and late), a non-feeding doliolaria, substrate (Strathmann, 1975; Ito and Kitamura, 1997; Yanagisawa, 1998).

Doliolaria actively explore the surrounding environment to identify the best place to settle and made the last metamorphosis into the pentactula. If the conditions are not suitable for settlement, the larvae will keep swimming for several days (Mercier *et al.*, 2000). The pentactula lose the ability to swim but can continue to explore the surrounding environment with the buccal podia, moving by small jumps (Mercier *et al.*, 2000). Although rarely, Evans and Palmer (2003) reported the ability of the pentactula larvae of *Parastichopus californicus* Stimpson, 1857, to clone, forming a bud that, after separation, will normally develop into an auricularia larvae.

The pentactula larvae will start to feed and grow, becoming a juvenile in a variable time lag (Mercier *et al.*, 2000; Agudo, 2006; Mercier and Hamel, 2009; Rakaj *et al.*, 2018, 2019). Information about the mechanisms of settlement, physiology and cue that can stimulate the larvae to settle are poorly explored and understood, so far. Studies conducted in mesocosm investigated the success of the larval settlement, which can strongly depend on the larval nutrition state and the capacity to accumulate lipids (Peters-Didier and Sewell, 2019). In the late auricularia stage of *H. scabra*, the development of the hyaline spheres indicates an adequate feeding, and their size is a reliable indicator for subsequent performance (Duy *et al.*, 2016). The settlement and the last metamorphosis, as for other echinoderms, represents a survivorship bottleneck that can lead to high mortality rates. The early juvenile stage (<5 mm length) is also vulnerable and a critical phase with substantial mortality rates (Agudo, 2006; Rakaj *et al.*, 2018).

The holothurians recruitment has been studied mainly on historically exploited species, and information about post-settlers and juveniles in the field is scarcely recorded in the literature and, even, referred to sporadic occasions. For instance, the recruitment of *H. scabra* has been found to occur on a monthly time scale on seagrasses, with adult specimens mainly observed in sandy sediments and juveniles in organic matter (OM) enriched muddy sediments (Mercier *et al.*, 2000). The lack of other information about holothurians recruitment can also be ascribed to the potential misidentification of the species because they can have a considerably different morphology when compared with that of adults. Besides this, juveniles might occupy different habitats and can be obscured from the researchers' view because of their cryptic behaviour (Shiell, 2004). *H. scabra* juveniles can also be affected by predation-mediated mortality by fish belonging to the Balistidae, Labridae, Lethrinidae and Nemipteridae families (Dance *et al.*, 2003), sea stars, and crustaceans (Kinch *et al.*, 2008).