Withdrawal behaviour of the red sea pen *Pennatula rubra* (Cnidaria: Pennatulacea)

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**Abstract**

Aggregations of sea pens are important soft-bottom communities providing a three-dimensional complexity from which several associated species can benefit. The red sea pen *Pennatula rubra* is one of the Mediterranean coastal field-forming sea pens able to establish dense aggregations on the sandy/muddy bottoms of the infra- and circumlittoral zones. This species was first described at the end of the 17th century, but since then little information has been published about its biology, ecology and biogeography. Even less is known about its behaviour, its reactions after disturbance and its possible escape strategies. Several species of pennatulaceans can withdraw partially or completely into the sediment, usually in a fast (i.e. a few seconds) process of polyp closure and expulsion of part of the water contained within the colony. The present study reports and discusses the withdrawal behaviour of *P. rubra* after disturbance. This behaviour has never been documented before in this species. It proved to be a slow process requiring between 210 and 340 seconds (3 min 30 sec to 5 min 40 sec) for the complete withdrawal. Moreover, a soft bioluminescence was observed in two undisturbed colonies in the study area, while two other colonies were found to be out of the sediment, inflating themselves with seawater and getting carried by currents as a sort of dispersal behaviour.

**Keywords:** Sea pens, ROV, megaepibenthic communities, soft bottoms, Mediterranean Sea

**Introduction**

Sea pens are a specialised and morphologically distinct group of octocorals (Class Anthozoa, Subclass Octocorallia) adapted to live on soft sediments thanks to an anchoring muscular peduncle (Bayer 1956; Williams 2011). These animals are often found in moderately high-energy environments and may form locally dense aggregations, known as facies or fields (Pérès & Picard 1964; Gage & Tyler 1991) and belonging to the so-called animal forests (Rossi 2013; Rossi et al. 2017). Examples of sea pens forming fields (Aguilar et al. 2009; Mastrototaro et al. 2013; Kenchington et al. 2014; Porporato et al. 2014; Chimienti et al. 2015), structuring flat, low-relief soft-bottom habitats and acting as nurseries for fish (Pirtle 2005; Baillon et al. 2012) highlight their role in benthic ecosystems (Ruiz-Pico et al. 2017).

Pennatulacean fields alter water current flow, retaining nutrients near the seafloor (Birkeland 1974; Tissot et al. 2006; Kenchington et al. 2011), and provide refuge for planktonic and benthic invertebrates (Birkeland 1974; Porporato et al. 2011, 2012) which may be preyed on by fish (Krieger 1993). Williams (1999) provided extensive bibliographic sources regarding pennatulacean biology, ecology and behaviour.

The red sea pen *Pennatula rubra* (Ellis, 1761) is an emblematic pennatulacean species in the Mediterranean Sea. This species was mentioned already by Linnaeus (1758) who distinguished it from the congeneric *Pennatula phosphorea* Linnaeus, 1758. He wrote: “*Penna (Rubra) pinnis falciformibus, tentaculis in pinnarum facie concava densissime dispositis*” about *P. rubra* and “*Penna (Rosea) pinnis falciformibus, tentaculis in pinnarum facie concava laxe dispositis*” about *P. phosphorea*.
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*dispositis* about *P. phosphorea*, referring to the number of autozooids on the polyp leaves. Bohadsch (1761) observed some colonies collected by fishermen off Naples and reiterated the concept of “polyps placed in one row within half a line of one another” for *P. phosphorea* and “placed in a double row and as near as they can be together” for this red sea pen, suggesting that this latter could be a different species, which he called *Penna rubra* following Linnaeus (1758). The work of Bohadsch (1761) was subsequently suppressed by the International Commission on Zoological Nomenclature for nomenclatural purposes (Williams 1999). Ellis (1763) gave a copy of Bohadsch’s figures and descriptions, analysed a colony from the Mediterranean Sea and re-established the name *Penna rubra*. In a letter to the Honorable Coote Molesworth, Ellis (1763) underlined the orientation of the autozooids in *P. rubra* and its differences from *P. phosphorea*, as recently shown by Chimienti et al. (2015). Ellis (1763) also assumed that *P. rubra* can move in the water using its polyp leaves as fins. However, no particular behaviour of this species has been documented in its natural environment to date and no information about its defence/escape strategies is known (e.g. movement, withdrawal, bioluminescence). Light bioluminescence has been observed after electric stimulation of *P. rubra* in an aquarium (Panceri 1871; Titchack 1966), but no evidence of its bioluminescent behaviour in nature has been published thus far.

In the present study, withdrawal behaviour of *P. rubra* observed in the field after disturbance is described and discussed for the first time. Pennatulacean withdrawal behaviour already fascinated Charles R. Darwin, in Patagonia, who described the rather striking ability of an intertidal species of the genus *Virgularia* to quickly withdraw itself into the seabed when disturbed (Darwin 1845). In fact, several species of sea pens can withdraw partially or completely into the sediment by the closure of the polyps and the expulsion of part of the water contained within the colony (Hoare & Wilson 1977). Withdrawal behaviour has been well documented in laboratory studies of several different sea pen species (e.g. Mori 1960; Pavans de Ceccatty et al. 1963; Pavans de Ceccatty & Buisson 1965; Imafuku 1976, 1980; Hoare & Wilson 1977; Dickinson 1978), while the only *in situ* observations of this behaviour were reported by Birkeland (1974) for *Ptilosarcus gurneyi* (Gray, 1860), Langton et al. (1990) for *Pennatula aculeata* Daniellsen, 1860 and Ambroso et al. (2013) for *Virgularia mirabilis* (Müller, 1776). In particular, withdrawal behaviour was only observed in 12% of the colonies of *P. aculeata* observed by Langton et al. (1990), but without any appreciable disturbance. However, the reasons for withdrawal behaviour in pennatulaceans are not well understood. For some species it has been explained by light conditions and metabolic factors, as in *Cavernularia obesa* and *Veretillum cynomorium* (Mori 1960; Buisson 1964; Imafuku 1976, 1980) or tidal-based rhythms, as in *V. mirabilis* (Wilson 1975). Predation and disturbance are usually mentioned as possible causes, even if no evidence is reported in the literature.

**Materials and methods**

The field of *P. rubra* here studied is located off Punta Alice (southern Italy) in the Ionian Sea (39°35.13’N, 16°52.16’E), between 60 and 70 m depth (Chimienti et al. 2015). A survey was carried out during November 2015 using the remotely operated vehicle (ROV) *Pollux III*, during the cruise Marine Strategy 2015, onboard the R/V *Minerva Uno*. The ROV was equipped with a low-definition Charge Coupled Device (CCD) video camera for navigation and a high-definition video camera (Sony HDR-HC7, 2304 × 1296 pixels) for the detailed observation of the colonies. The ROV also hosted a depth sensor, a compass, a grabber arm and three laser beams providing a 20-cm scale for dimensional measurements. The ROV survey was performed during the daytime, from UTC 9:48 a.m. to 12:19 p.m., with 2 hours and 30 minutes of video recording on the seabed at a constant depth of 64–65 m.

Ten different colonies of *P. rubra* were randomly selected for the behavioral observations after a mechanical disturbance. Each colony was gently touched every 15 seconds with the ROV arm, or just by opening and closing the arm’s fingers in the proximity of the colony. The three fingers on the arm were completely covered with cotton in order to have a softer touch and to not damage the polyps. The time of complete withdrawal was measured for each colony, and the values of the mean and standard deviation were calculated. The ROV’s headlights were periodically turned off before and during the disturbance in order to observe eventual bioluminescent behaviour of *P. rubra*. More observations were randomly carried out within the *P. rubra* field to assess whether there is any bioluminescence in undisturbed colonies or any particular behaviour. Moreover, the associated megafauna observed was identified at the lowest possible taxonomic level.

**Results**

All the colonies of *P. rubra* disturbed with the ROV arm started to withdraw into the substratum. This behaviour was performed with the backward and
forward bending of the colony, one or several times, for the expulsion of the seawater through the siphonozooids. Afterwards, when the colony was already partially withdrawn and considerably smaller than before, it returned to the erect position and withdrew completely into the hole (Figure 1). Contracted colonies can be more than three times smaller than extended ones, thus fitting completely in their holes after water expulsion. Five main phases of the withdrawal behaviour were distinguished: (1) erect colony, not disturbed; (2) backward bending; (3) forward bending; (4) erect and contracted colony; (5) colony withdrawn. This proved to be a quite slow process, taking between 210 and 340 seconds (3 min 30 sec–5 min 40 sec) for the complete withdrawal, with a mean time of 290 ± 47 seconds. Figure 2 shows the sequence of a colony which took 256 seconds (4 min 16 sec) to completely withdraw into the sediment.

Two of the 10 colonies disturbed became inaccessible to the ROV arm during one of the forward bending phases and it was not possible to disturb them again. In these two cases the withdrawal behaviour stopped when the disturbance ended and the colonies remained bent forward and only partially withdrawn.

None of the disturbed colonies showed a bioluminescent behaviour during the disturbance and the withdrawal, whereas light bioluminescence was observed in two undisturbed colonies (Figure 3(a)). Some detailed observations of other undisturbed colonies highlighted the presence of eggs at the base of the polyp leaves of several colonies of this broadcast-spawning species (Figure 3(b)).

Two colonies of P. rubra were found out of the mud, inflating themselves with seawater and getting carried by currents (Figure 3(c)).

In terms of the associated megafauna, a few specimens of Polychaeta belonging to the genus Sabella and the fishes Cepola macrophthalmalma (Linnaeus, 1758), Lesueurigobius suerii (Risso, 1810) and Serranus hepatus (Linnaeus, 1758) as well as some

Figure 1. Withdrawal behaviour of Pennatula rubra. (a) Still photographs of the different moments of the withdrawal, and (b) schematic representation of the five main phases distinguished: (1) erected colony, not disturbed; (2) backward bending; (3) forward bending; (4) erected and contracted colony; (5) colony withdrawn. Scale bars = 2 cm.
unidentified Gobidae were observed in the area nearby (Figure 4). In particular, *S. hepatus* usually showed a hiding behaviour behind the colonies of *P. rubra*. Gobidae and *C. macropthalma* often took shelter in the holes of the bioturbated mud, the latter by entering vertically (Figure 4). The burrowing ability of the red band-fish *C. macropthalma* has been studied in the North Atlantic by Atkinson and Pullin (1996).

Several marks of commercial trawl fishing were also observed (Figure 3(d)), and four trawling fishery boats were working around the area during the survey.

**Discussion**

The present study confirms that *P. rubra* is a pivoting species able to completely withdraw into sediments, but not able to actively move on the seabed as hypothesised by Ellis (1763). Withdrawal was found to be the only reaction to disturbance, and it can be complete after a prolonged disturbance or not complete if the disturbance ends before the slow time needed to expel water and withdraw. This slow process is different from the fast one observed in other species, such as *V. mirabilis*, which are able to withdraw in a few seconds (Ambroso et al. 2013). This could be due to the fact that *Virgularia* species, despite occurring as deep as the bathyal zone, can settle in very shallow environments under tidal influence, thus developing a fast withdrawal response. On the contrary, no *Pennatula* species living in such shallow waters are known to date.

Two healthy and completely extended colonies were observed out of the mud (Figure 3(c)), but it was not possible to assess whether their dislodgement was accidental (e.g. due to trawling impacts in the area) or to the

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**Figure 2. Example of the withdrawal behaviour of a colony of Pennatula rubra.** In 256 seconds, the colony passes from (a) the erect position, when not disturbed, to (b) the backward bending, (c) the forward bending, (d) the erected and contracted colony, partially withdrawn, and (e) the entire colony withdrawal into the hole until (f) the complete retraction of the colony under the seabed. White arrows indicate the colony (a–d) and the hole (e–f). Scale bars = 5 cm.
ROV survey) or natural (e.g. due to predation or as an escape strategy). We hypothesise that this current-carried behaviour may represent the only possible displacement strategy for *P. rubra* and that in this way a colony can slowly and randomly move from one place to another. This possible dispersal behaviour of detachment from the substratum and conveyance by benthic currents to a different geographical area has also been surmised for the so-called rockpens (sea pens that attach to rocky surfaces), by Williams and Alderslade (2011).

*Pennatula rubra* showed a slight, rare bioluminescence during daytime (Figure 3(a)), while it was not possible to observe this behaviour during night time because ROV night dives were not allowed. Before our observation, the bioluminescent behaviour of *P. rubra* had only been observed by Panceri (1871) and by Titschack (1966) in an aquarium, in total darkness and under experimental conditions (i.e. under electric stimulation in a controlled environment).

Despite sea pen fields representing important habitats for associated species (Ruiz-Pico et al. 2017), the ROV survey revealed only a few demersal fish species (Figure 4). The function of *P. rubra* colonies as shelter for small fishes such as *S. hepatus* was frequently observed in the area. Further targeted studies are likely to reveal an associated community, which could benefit from the presence of *P. rubra* fields.

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Geolocation information

The study area is located off Punta Alice, southern Italy, in the Ionian Sea: 39°35.13′N, 16°52.16′E.

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