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In situ long term observation of Dendrophyllia ramea (Linnaeus, 1758)

Eva Salvati (eva.salvati@szn.it)
Stazione Zoologica Anton Dhorn
Claudio Provenzani
Global Underwater Explorers
Andrea D’Ambrosi
BigBlueXplorers Association
Elena Romano
ISPRA, Institute for Environmental Protection and Research
William Santero
Blueresearch Srls
Simonepietro Canese
Stazione Zoologica Anton Dhorn

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Abstract

An interesting site for the wider population of the coral *Dendrophyllia ramea* has been identified south-east of Syracuse (Sicilia Channel, Ionian Sea) at 75 water depth. *Dendrophyllia ramea* is a poorly known arborescent scleractinian coral, classified as ‘Vulnerable’ according to the Mediterranean IUCN Red List, listed in the Barcelona Convention (Annex B). To increase the knowledge about the ecology of the species, long-term in situ observations were carried out on two colonies using a specific homemade underwater recording system. *D. ramea*, in analogy with other Anthozoans of different environments, also showed a circadian rhythm of partial opening and closing of the polyps despite being strongly influenced by the intensity of the current. These aspects, of great interest to the ecology of this protected species, will be investigated with the aid of current meters to obtain a quantitative estimate of the intensity of the current. This project gave great results in terms of innovative research as well as the added value of trained GUE divers in these data collection activities, which are otherwise difficult to obtain.

Introduction

In recent times the exploration of large deep-sea areas has put light on rich communities with a strong tree dimensional development formed mainly by cnidarian and porifera; these communities represent a true hot spot of biodiversity, with an important role in structuring deep-sea communities. At depth below the thermocline, the environment became more stable, but the evening of life continues to respond to several factors still to be understood.

Dendrophyllia ramea (Linnaeus, 1758) is a large scleractinian characterized by an orange-yellow arborescent skeleton with huge white polyps and forming large patches in very few areas in which colonies grow up to 1 m in height. Together with *D. cornigera*, it is the largest Mediterranean colonial Dendrophylliidae corals. According to [1], the two species differ in geographical, and depth distribution and are not ecologically equivalent. In particular, *D. ramea* seems to be a shallower species mainly developing in the circalittoral zone. *Dendrophyllia ramea*, present in the southern Mediterranean Sea and Atlantic waters, is of particular conservation interest (IUCN Red List, Annex B of Barcelona Convention), even if its segregated distribution has not favored the acquisition of useful data for the understanding of the ecology of this species. The increase of oceanographic campaigns associated with surveys and image acquisitions using ROV (Remote Operated Vehicle) has confirmed a scarce diffusion of this species.

The start of technical diving allowed to discover and observe this species at different sites, highlighting how these large colonies have been impacted by fishing activities [2].

These corals often concentrate on ridges where strong currents enhance food accessibility [3, 4], making the capture rates dependent on water flow [5, 6], which is a primary factor affecting the feeding success of passive suspension feeders [7, 8, 9].

Data related to the ecology and biology of *D. ramea* are very scarce due to the few sites where it was recorded, often at different depths and substrates, even if it could be deduced something from the studies carried out on other deep corals [10]. Their physiology has been much less studied than tropical species, owing to difficulty accessing their habitats and maintaining them for laboratory studies, but an 18-months experiment carried out on this species demonstrated that it can increase its growth rates between 12°C (0.021 ± 0.007% day^{-1}) and 24°C (0.211 ± 0.026% day^{-1}) forming also new polyps, which suggested efficient thermal acclimatization [11]. *In situ* investigations, isotopes and lipid signature analyses, and experiments performed under laboratory conditions have shown that they can feed on a wide range of food sources, including detritus, phytoplankton, and different size spectrum zooplankton [12]. Specific laboratory experiments on the rhythms were carried out, which highlighted that despite the measures are more accurate and complex in controlled conditions, there is an overestimation of filtration rate, probably correlated to the food concentration, current speed, or light [13]. Food particles are captured and stuffed into the tentacles' mouths or trapped in mucus and then sucked into the mouth. In particular, the *D. cornigera* shows constant capture rates of mesozooplankton over a wide range of flow speeds (up to 10 cm s^{-1}) [6] because it does not form as far as it is currently known a true reef structure and has polyps directly exposed to flow. In addition, the large size of its polyps gives them a sufficient tentacle surface exposed to water flow even if they are partially deformed by high flow speed [11].

The coral motion may play an essential role in feeding, competition, reproduction, and thus survival and fitness. Therefore, characterizing coral behavior through motion analysis could aid the understanding of basic biological and physical coral functions and, at the same time, their performance, physiology, and health in a changing environment in terms of light conditions, temperature, pH, and other environmental variables [14].

It has long been agreed that the functions of living beings are regulated by circadian clocks, a molecular network that translates predictable environmental signals into organismal responses, including behavior and physiology [15–18].

Corals are ecologically important marine organisms that have worldwide distribution. Studying their rhythmic regulation of behavior would provide knowledge about the physiology of this key animal group [19].

Although the factors influencing patterns of expansion and contraction of polyps and tentacles for tropical anthozoans have been well described, there is still little information for temperate species.

The driving factors that regulate the contraction and expansion of tentacles and polyps in tropical corals are mostly light, current, and food availability. The stimuli that regulate the opening and closing of polyps in tempered corals are probably different. The alternating movement of contraction and release of the polyps guarantees food capture, both by adhesion and direct capture, the removal of sediment, and the protection of soft tissues from predators. An interesting study [20] describes the retiming behavior of 9 species of temperate corals highlighting how both light and current are fundamental elements in regulating the rhythm even in non-symbiotic corals. Most of the species contract during the day and expand at night, although intense currents favor the opening of the polyps even during daylight hours. The present work describes the analysis of the polyps' movement of two large colonies of *D. ramea*, placed off Syracuse (Sicily, Italy), observed by video, which allowed considerations about their circadian rhythm.

Methods

Study area

At the site, known as Apollo Bank (lat 36°54.786'N, long 15°11.648'E), local technical divers identified a widespread coral *D. ramea* population between 75 and 85 meters in depth. It is located on the northern border of the Malta Escarpment, representing the dominant morphological feature linking the deep Ionian basin to the east with the Hyblean carbonate platform to the west (Fig. 1).

It is a 250 km-long underwater cliff that extends southwards from the eastern coast of Sicily towards the eastern coast of the Maltese islands and beyond [21]. From a sedimentological point of view, concerning its morphological and lithological characteristics and the absence of tributary watercourses, the seabed mainly comprises hard rocky bottoms [22]. The study area is influenced by a coastal current that heads south to the confluence of Capo Passero, where it impacts the front determined by the meanders of the superficial Atlantic current that enters the Sicilian Channel. The flow is generally very active, ensuring a good transport of suspended material and, above all, a quick change of coastal waters to benefit the quality of the marine environment in the area [23].

The site is characterized by mainly soft sediment (fine sands/mud) with small rocky outcrops that, from 50 m, gently break up to a vertical step towards the open sea at 75 m. The base, which forms a cliff, is about 83 m deep. The colonies are arranged in no particular order, mainly anchored on a rocky substrate, sometimes even embedded in the muddy sediment.

Assembly of the instruments

A very cheap camera of relatively small dimensions for allowing a diver to bring at the bottom was specifically built by Blueresearch (http://www.blueresearch.eu/). The system was composed of two Delrin™ housing connected by a wet pluggable sea cable; one housing hosts a Mobius ActionCam (full HD resolution 1920x1280) with a battery pack and controller. The other housing hosts a 6-watt led lamp with its battery pack (Fig. 2). The control board is built around an Arduino Pro Mini board and a DS3231 RTC module. The time-lapse camera was set to record a five-second video every hour (w-video). Camera was fixed to a custom-made stainless-steel tripod that kept cameras and lights. In addition, the camera was equipped with HOBO U24-002-C – conductivity/salinity data logger (https://www.hobodataloggers.com.au*)* for recording temperature and salinity every hour.

Site selection and positioning of the instruments

Considering the logistic difficulty of the site, the support of specially trained divers has been necessary, in particular divers from Global Underwater Explorers, which identified the best area for the positioning of an underwater camera fixed on a tripod based on the presence of the *D. ramea* colonies and the physical characteristics of the seabed to guarantee long-term stability [24].

The positioning of the tripod was carried out in June 2018. Rebreather and open circuit divers brought and placed the camera and sensors at 75 m water depth at 95° compass direction in front of 2 colonies (named A and B) about 20 cm wide and 30 cm high each, one of which was on the top of a rock boulder (A) and the second closest to the seabed (B) (Table 1).

Table 1
Details related to deployment

Depth (m)	Deploy date	Retrieval data	End acquisition	Id colonies	N° polyps	days	Number of analyzed videos
75	16/06/2018	28/10/2018	05/09/2018	A - B	60–66	83	1943

Once it was positioned pointing directly to colonies at a one-meter distance, the tripod was made heavier by adding extra weight, and the whole system was fixed to the bottom through safety lines and ties (Fig. 3). The divers also placed a 10m x 10m grid close to the tripod, within which they surveyed the additional colonies present, documenting them photographically. Finally, the divers checked the functionality and the correct alignment of the camera before ascending. All the activities have been documented by video.

The SINAPSI system was used to georeference the divers’ path and position the individual observed colonies on an experimental basis. SINAPSI is a special navigation system integrated into a Diver Propulsion Vehicle (DPV), specifically a SUEX DPV, that makes it possible to receive and process underwater navigation data; in particular, it maintains constant orientation while diving, records the route, and allows to fix every target with a related georeferenced position.

The survey carried out by SINAPSI allowed the divers to take the position of each colony along the path followed; once on the surface, the data were downloaded and reported on the map allowing a georeferencing of each colony on the seabed. In addition, all the colonies were photographically documented.

The removal phase was performed four months later (October 2018) using the same divers. The camera was recovered using a lifting balloon, assisted by divers in the initial phase, to ensure a gradual and slow detachment from the sea bottom and avoid any damage or flooding of the camera.

Data analysis

The video and photo data collected by divers during the activities were analyzed to provide a preliminary characterization of the area around the colonies to be recorded. Furthermore, the substrate typology and the number of colonies within the grid were evaluated with the relative distance.

Each polyp was counted and classified into two categories: open or closed. The movement and velocity of the suspended matter were used as a proxy of water flow and related direction. The presence of other mobile animals such as fishes, crustaceans, and echinoderms was also documented. Also data related to temperature and salinity was considered.

The data relating to the flow's direction have been processed using the Kiviat diagram, a graphical method for showing data on multiple variables in a two-dimensional graph of three or more variables, represented on axes with the same origin. It is a graphic consisting of a sequence of rays that originate from a center and form equal angles; each ray represents one of the variables. The distance from the center of the point marked on the ray is proportional to the variable's value with respect to the maximum achievable value.

Results

The analyzed video highlighted an extensive area characterized by a sandy-silty bottom with rocky outcrops varying in size from pebbles (20–40 cm) to blocks that rises to a few meters. On the particularly muddy seabed, an extensive hydroid covering, coralline red algae, encrusting and submassive porifers (*Axinella* sp.), tunicates (*Halocynthia papillosa*), bryozoans (*Retepora* sp.), echinoderms (*Hacelia attenuata*, *Peltaster placenta*, and Cidaridae), and polychaetes (*Protula* sp. have been observed. The site is particularly rich in colonies of *Corallium rubrum*, which mainly populate cracks or small vertical walls. Additionally, numerous lost fishing gears (ropes and lines) were observed.

The *D. ramea* colonies are anchored on the rock blocks, seemingly without a preference for size. Overall, seven large colonies (> 25 polyps), six small/medium-sized, and three single corallites were counted within the grid with an estimated density of 0.16 colonies m^{-2}. The largest colonies show a planar growth while the smaller ones have a massive one. The former showed an opening/closing phase differentiated according to the side of exposure, i.e., a closure of the polyps on one side with a corresponding opening of the polyps on the opposite one; on the contrary, the smaller ones did not show a preference for exposure (Fig. 4).

The survey carried out by SINAPSI allowed the georeference of all the colonies present on the seabed; the results highlight that the colonies are mainly aligned in a direction perpendicular to the axis of the canyon (Fig. 5).

The opening/closing polyps analysis was carried out on A and B colonies, with approximately the same number of polyps (60 in the first and 66 in the second).

Counting for each colony the total daily hours in which the polyps were closed, it emerged that a similar trend, with colony B closing on average two hours earlier, except for two-time intervals (25-27.7.2018 and 8.8.2018) in which colony A has a significantly higher number of hours of closure than colony B (Fig. 6).

Further analysis of the frequency during the opening/closing day of the polyps showed a prevalence of closure during the day with a slight phase shift of colony B, which tends to close 2 hours earlier than A (Fig. 7). The two colonies close at least once a day, and colony A remains closed on average for 3.5 hours while colony B 2 hours.

The average water temperature recorded in the survey period was 15.3°C (14.7–16.7°C) without evident fluctuations (Fig. 8). However, from the comparison between the opening/closing data of the polyps and the temperature trend, there does not seem to be a close relationship between them.

The flow mainly resulted coming from the fourth quadrant and secondly from the second quadrant. By dividing the 24 hours into the four main parts of the day (morning, afternoon, evening, and night), changes in the flow throughout the day were found (Fig. 9). The main direction of the flow is SE regardless of the period while, at night, they alternate with currents from E and N. In the morning and the afternoon, the currents from the SE alternate mainly currents from the N and N, while in the evening, the currents from the SE alternate (mainly) with those from the NW, N, and E.

The video analysis allowed the identification of nine species of fishes (*Anthias anthias*, *Diplodus vulgaris*, *Diplodus sargus*, *Murena helena*, *Pagrus pagrus*, *Phycis phycis*, *Scorpaenodes arenai*, *Symphodus cabrilla*, *Zeus faber*), and four species of crustaceans, including *Palinurus elephas* and *Scyllarides latus* which move around the two colonies of *D. ramea*. Except for *D. vulgaris*, *S. cabrilla*, and *A. anthias*, which did not seem to link their presence to particular time slots, the other species are observable during low light hours, from 17:20 to 06:20 (Fig. 10).

Two curious phenomena were observed: the presence for six continuous days of a specimen of *Peltaster placenta* and a high density of fish that moved very fast, limited to 1 hour (from 1:20 to 2:20 of 7th July 2018). Given the speed of the movement, it was difficult to identify the species observed; it could be *Centracanthus cirrus*.

Discussion

From the position of the different colonies observed during the surveys, it is evident that these prefer areas close to the break of the slope of the escarpment with a prevailing water flow coming from greater depths. The flow analysis shows how these colonies find themselves well in areas with a strong current, being the area mainly beaten by currents with a southward direction, and how, especially for large ones, they modify their morphology in a planar growth perpendicular to the dominant flow.

Dendrophyllia ramea, like many Anthozoans, is a filter feeder that captures food during the expansion of the tentacles and alternates periods of expansion and feeding with periods of contraction and hypothetical inactivity [25]. As early as Parker [26] argued that the current is a stimulus for expansion; by increasing the absorption of oxygen due to the morphological changes of the polyp, to ensure a satisfactory amount of energy, the expansion of the polyp in the presence of sustained currents would compensate the energy expenditure with a greater quantity of filtered water that carries food per unit of time. In many anthozoans of temperate waters and non-symbiotic tropical ones, a circadian rhythm has been observed with polyps opening at night and contracting during the day [20]. In our study, the circadian rhythm of the colonies manifests itself not with the total closure of all polyps but with an increase in the frequency of contracted polyps during the day; from 08:00 to 20:00, the percentage frequency of contracted polyps rises by 15%. The continuous water movement recorded during the observation period suggested a positive energy balance despite the high percentage of opened polyps over the 24 hours. Moreover, this is evidenced by the fact that during the sporadic events of strong diurnal current recorded in the period, the colony appears as if it were at night, sometimes with the polyps completely open; while in moments of absence of electricity at night, closing is sometimes brought forward by an hour.

The hypothesis that the current may be, for some cnidarians, a stimulus for the opening of the polyps can be supported by an old study [27], in which the extroflexion of the tentacles of an anemone was noted due to the deformation of the body wall induced by the current and to the stimulation of sensory cells concentrated in the parietal region of the mesentery. Furthermore, if the colony has a higher percentage of polyps closed during the day, it is interesting to know that the single polyp is closed only for a few hours (3h 30’). Finally, it would be important to understand what regulates the closing time of the single polyp, if the colony has an effective utility in the closing part of the polyps during the day or if it is only genetic inheritance. Should the contraction of the polyp be interpreted as an energy-saving, or does it have a precise physiological function ascribable to “recovery”?

Among the functions attributable to the contraction of polyps in non-symbiotic cnidarians, in addition to feeding strategy and sediment removal, there is protection against predators [20]. There have never been any interactions or predatory activities by the fish species observed around the two colonies, and the greater diversity of ichthyofauna around the colonies is concentrated at night. Even with the echinoderma *Peltaster placenta*, no interactions or evident predatory activities were observed despite the same individual having been in proximity to one of the two colonies for six consecutive days and is known in the literature as a predatory activity of this asteroid on the black coral *Parantipathes larix* [28].

It is commonly known that some species can switch between passive and active mode, depending on the varying environmental conditions [13]; nevertheless, in this study, the polyp's behavior was constant. In 3 hours of recording, no movements attributable to active feeding were ever observed, although it was possible to recognize macrozooplankton (Euphausiacea or Mysida) in the vicinity of the individual polyps; this could lead to the hypothesis that the main diet of this species is particulate organic matter (POM), in analogy with what [29] observed for the black coral (*Anthipatella subpinnata*), a Mediterranean mesophotic species that lives in similar environmental conditions.

Although it is not possible to advance hypotheses on the reproductive modalities of this species, due to the lack of knowledge of their biology and ecology, no releases or morphological changes have been observed in the individual polyps. This could be in accordance with what was observed for the congener *D. cornigera*, studied in the same period (spring-autumn) by other authors [30], which did not detect any larvae inside the polyps or evident reproduction phenomena. The authors observed how the number of oocytes decreased from May to October, pointing out spawning events and how their sizes revealed two different size classes in August and October (see indicating several potential spawning periods, as already observed in other cold-water corals as *Lophelia pertusa* [31], one of them probably after October.

This study made it possible to observe, thanks to a data collection for a significant interval of time, how *D. ramea*, in analogy with other Anthozoans of different environments, also shows a circadian rhythm of partial opening and closing of the polyps despite being strongly influenced by the intensity of the current. These aspects, of great interest to the ecology of this protected species, will be investigated with the aid of current meters to obtain a quantitative estimate of the intensity of the current.

Declarations

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Author contributions statement

E.S., S.C., conceived the research, C.P., A.D., and E.R. provided the operative support for the execution, and E.S., E.R., and S.C. analyzed, described and discussed the results. All authors contributed to the original paper and reviewed the manuscript.

Data availability statement

The datasets used and/or analyzed during the current study will be available from the corresponding author on reasonable request.

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Figures

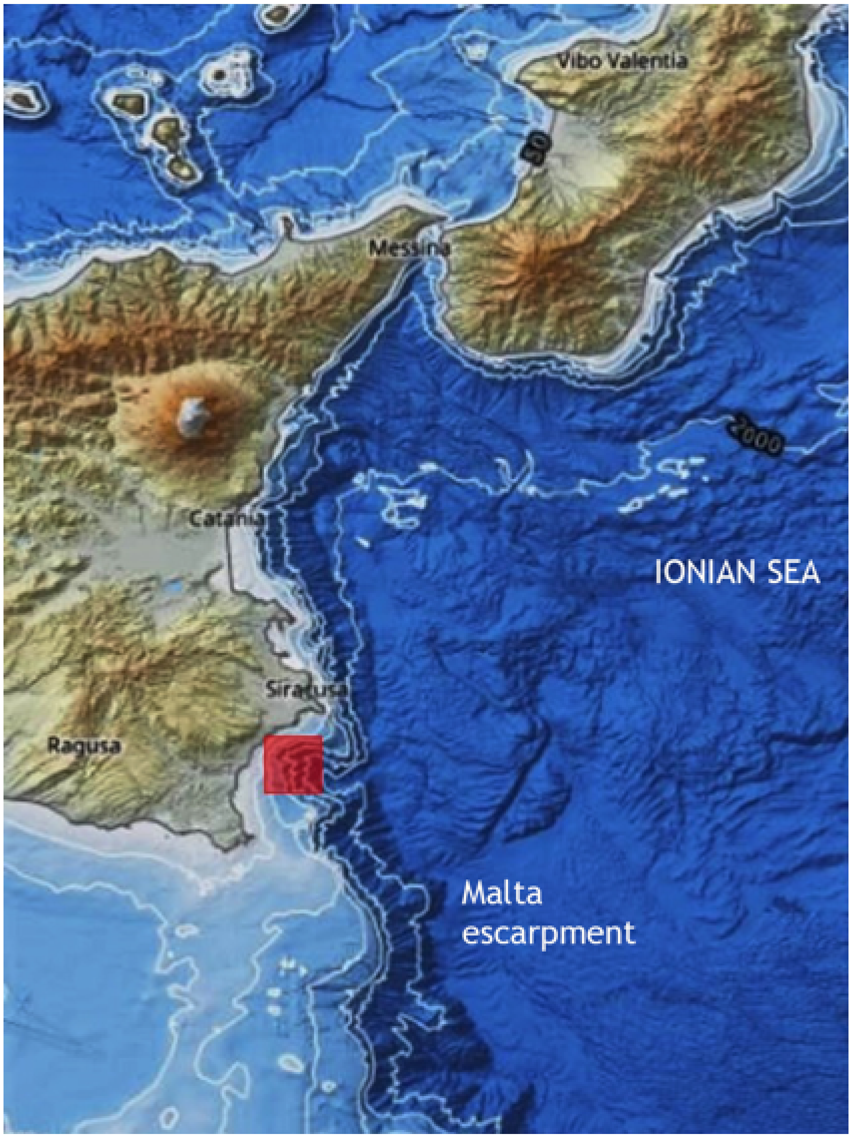

Figure 1

The study area (red box) is located on the Malta Escarpment border. From the EMODNET website (https://www.emodnet-bathymetry.eu/)

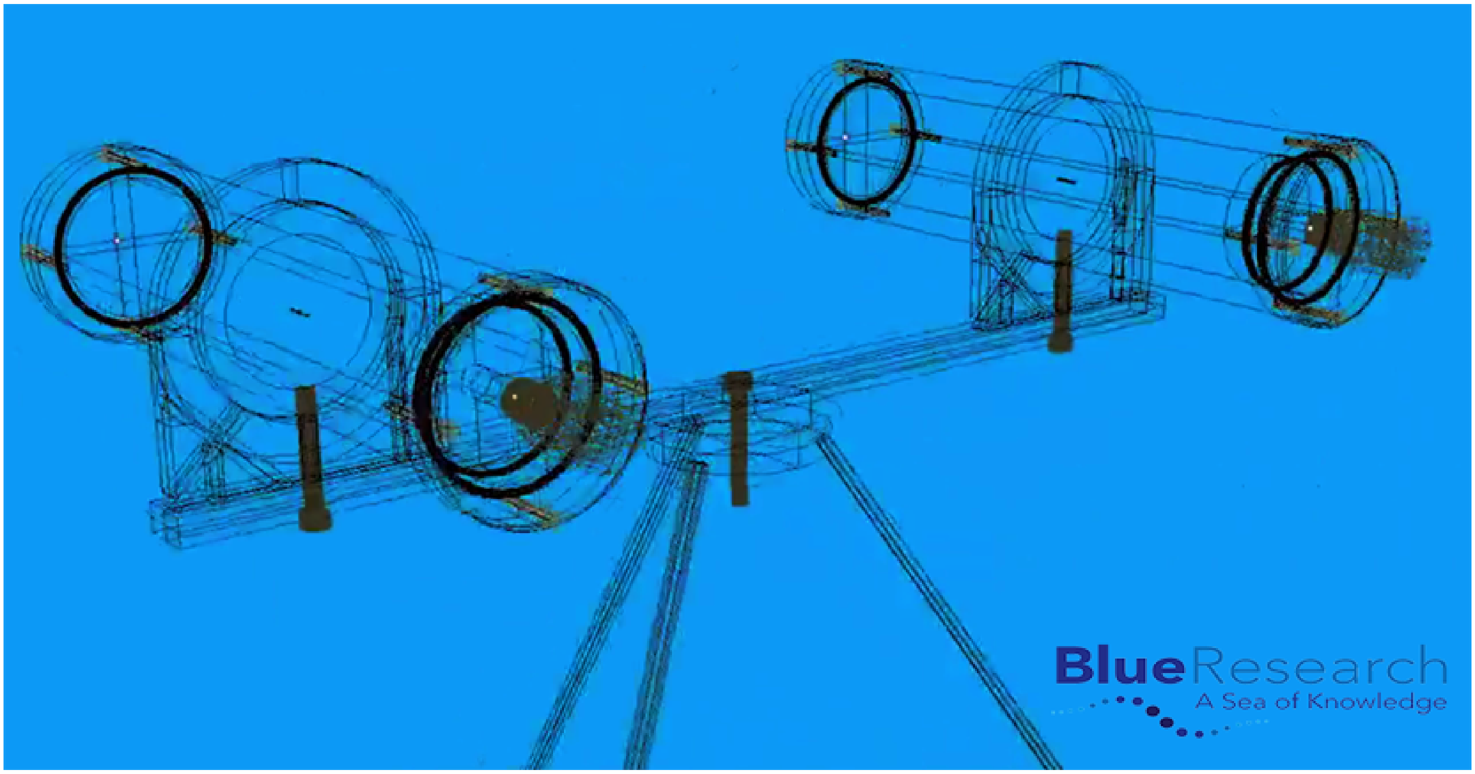

Figure 2

Scheme of time-lapse camera

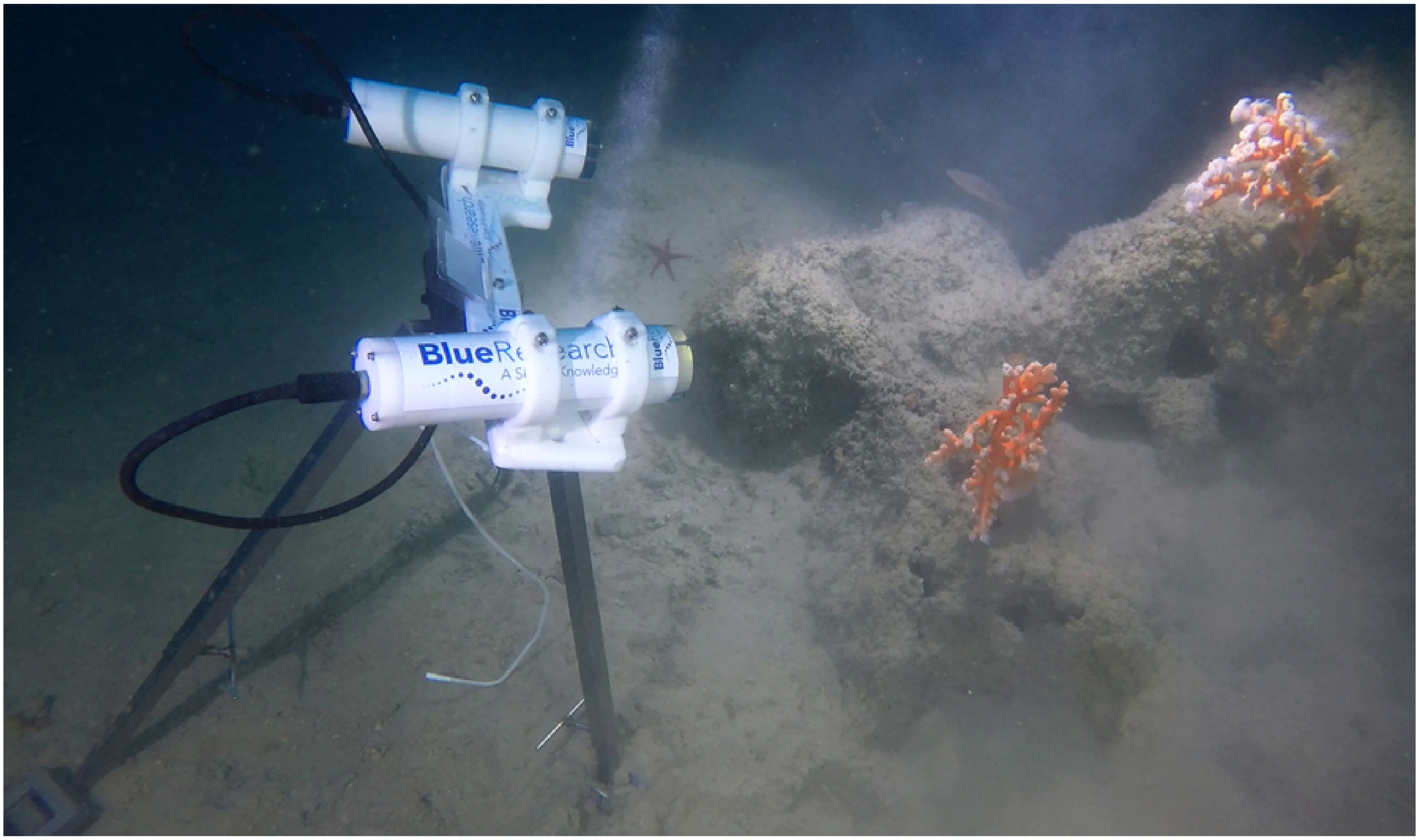

Figure 3

Place the tripod in front of colonies of *Dendrophyllia ramea (courtesy of Claudio Provenzani)*.

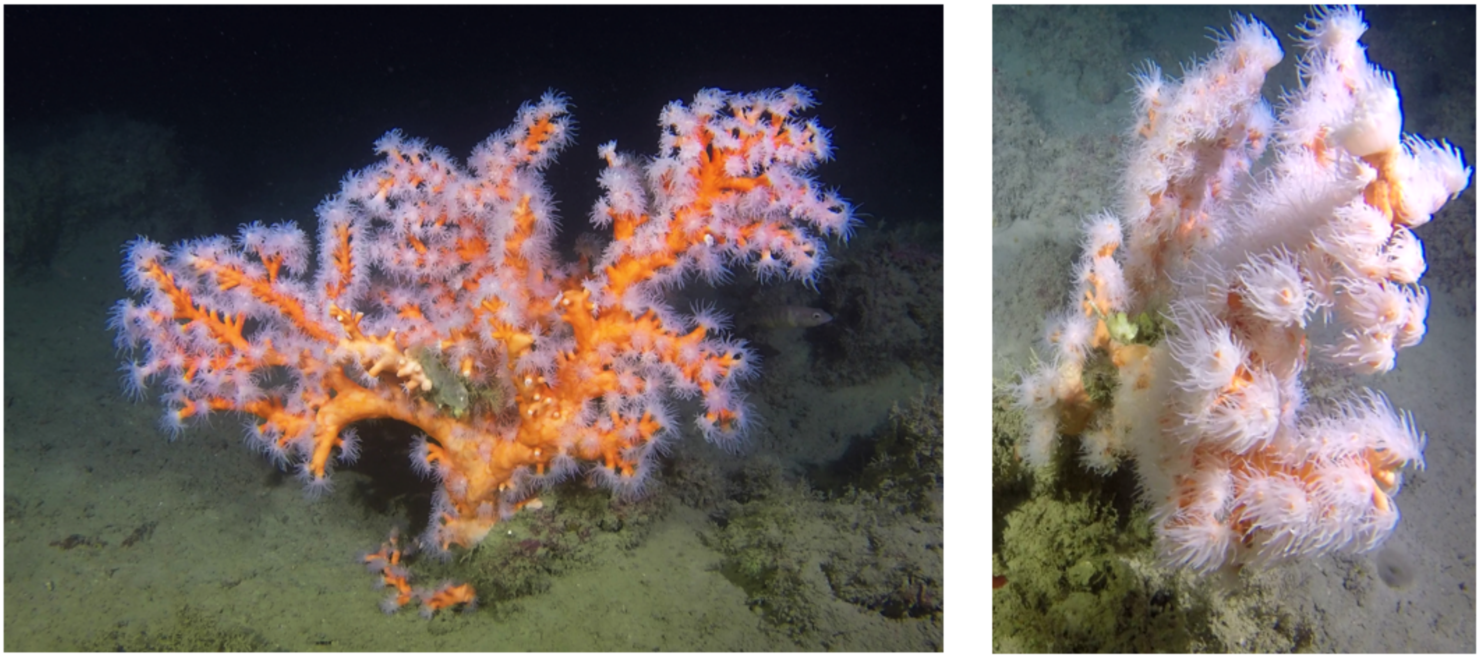

Figure 4

Planar growth on the left and massive one on the right *(courtesy of Claudio Provenzani)*

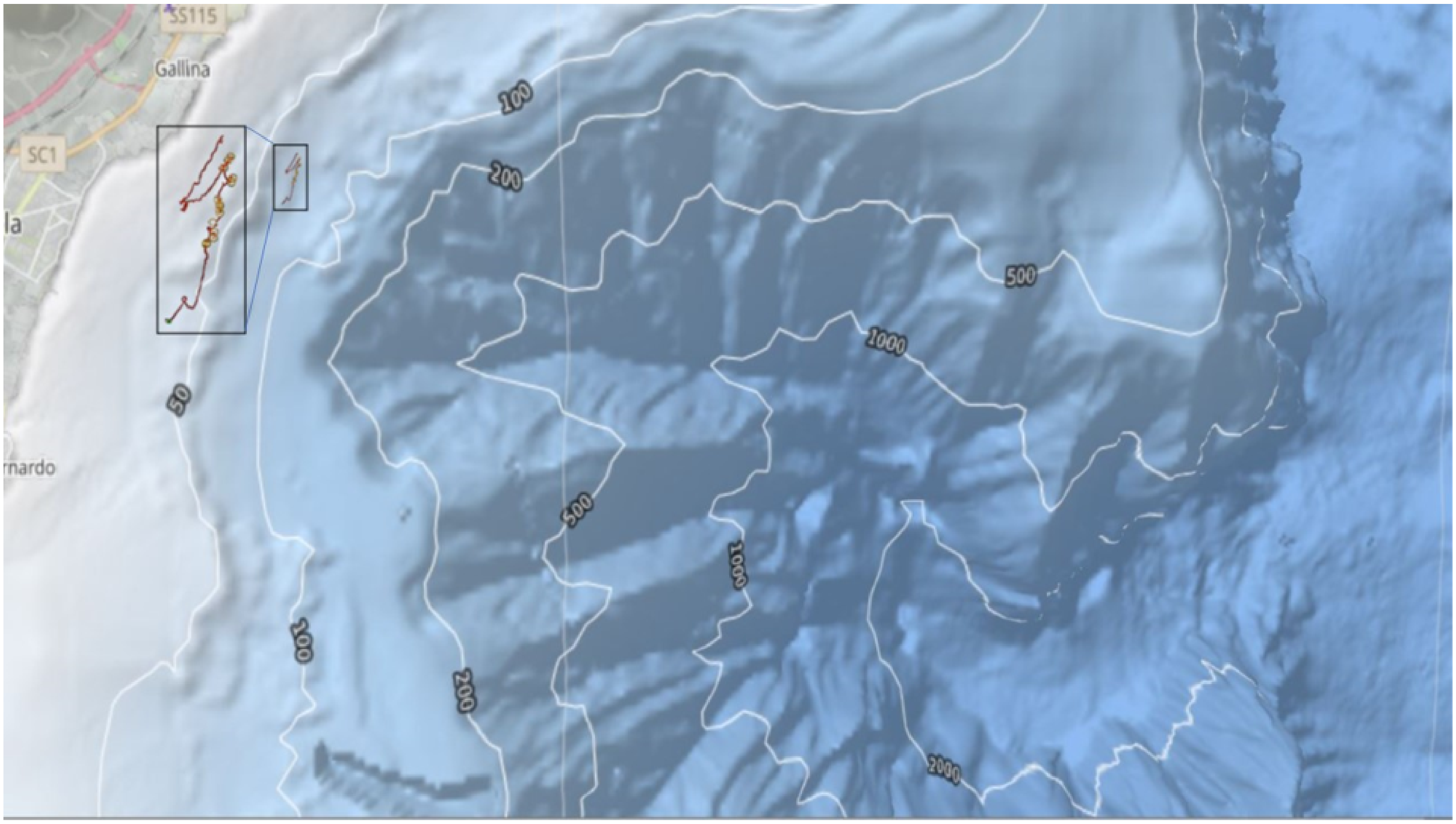

Figure 5

The survey by SINAPSI system. In the box is the detailed positioning of each colony.

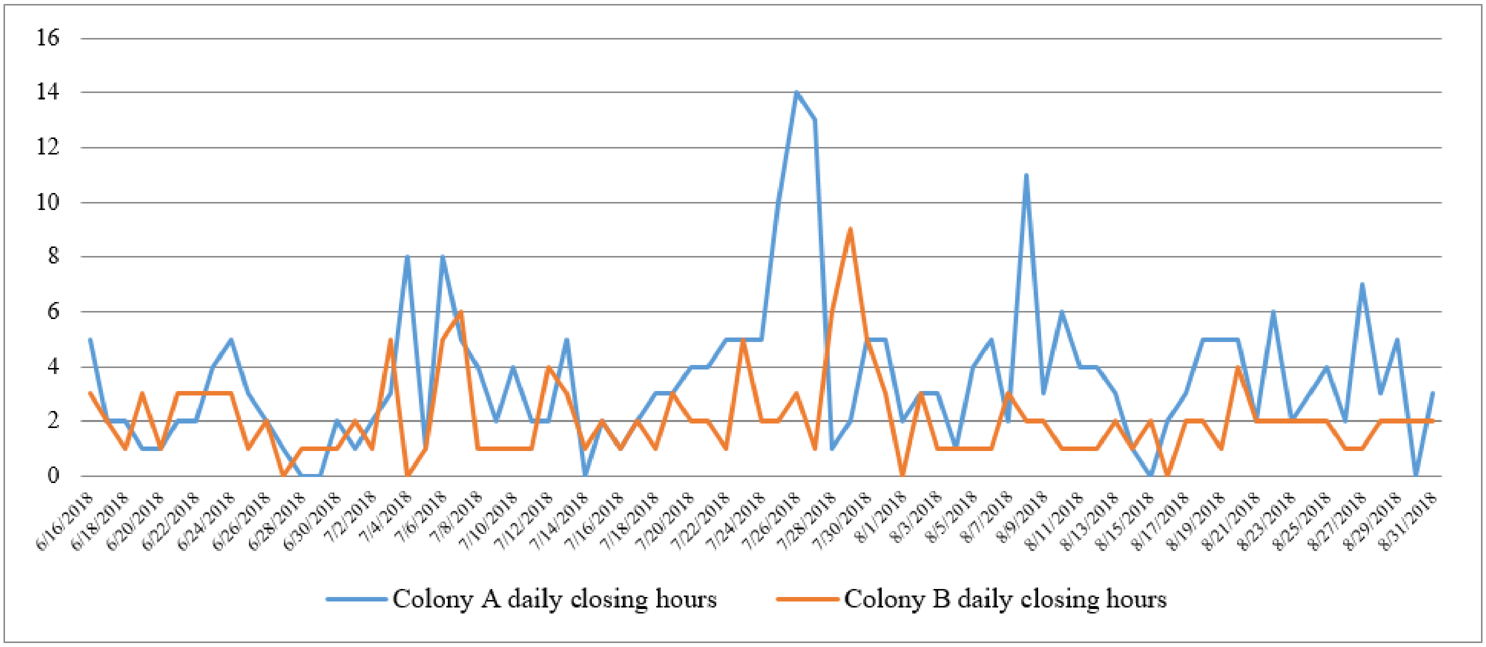

Figure 6

Closing polyp’s activity from 16th June 2018 to 31st August 2018.

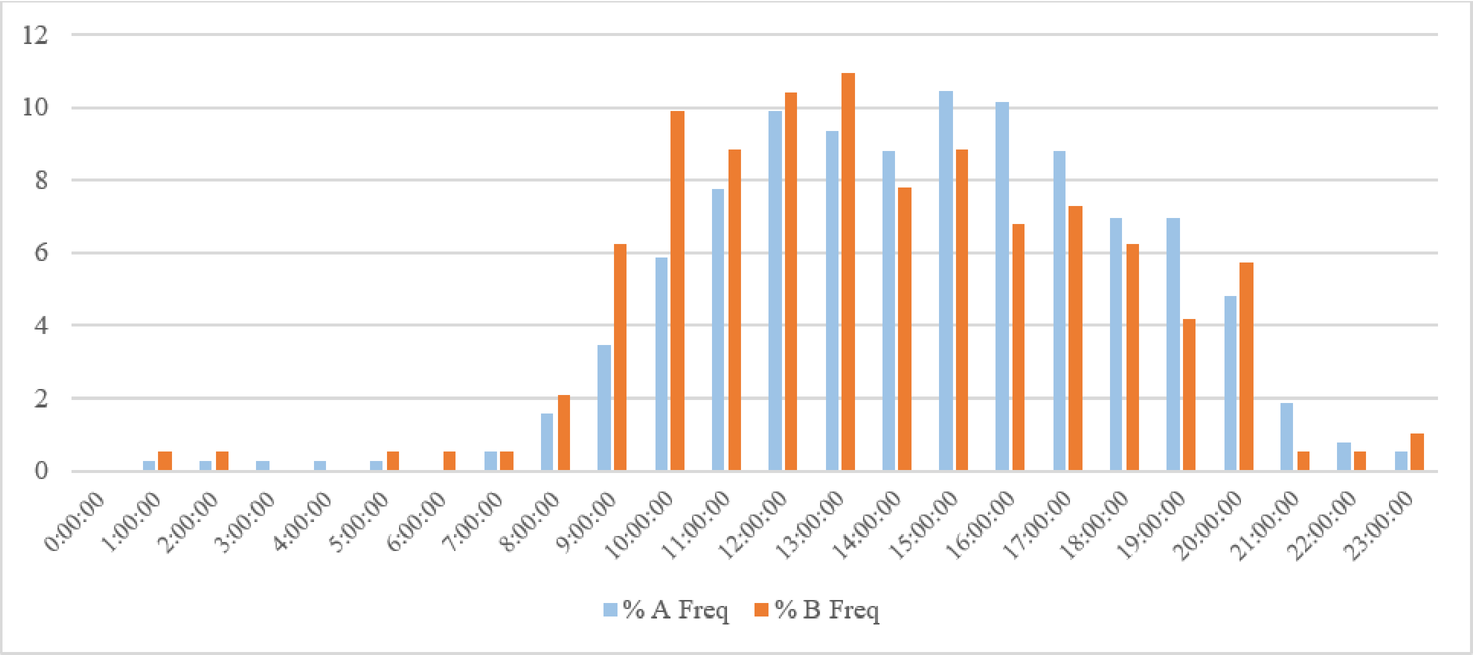

Figure 7

Frequency of closing polyps in the two colonies over the day.

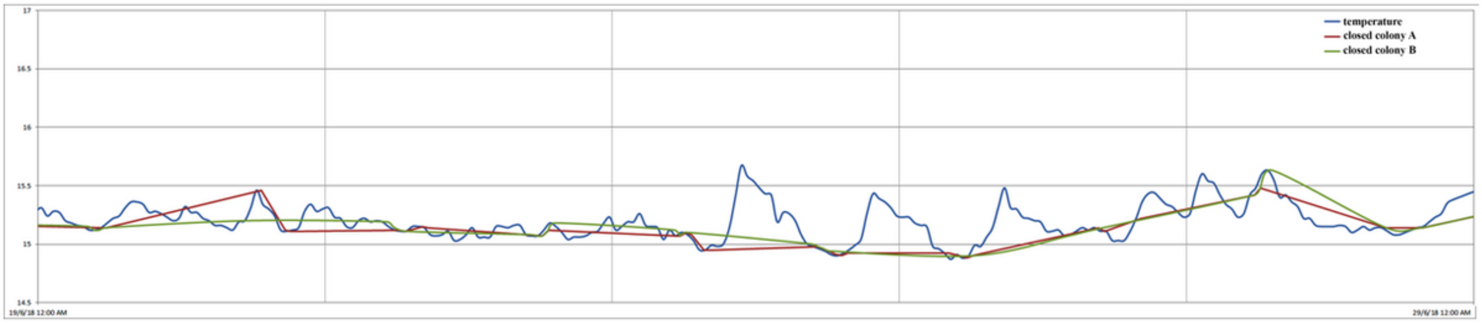

Figure 8

The trend of the water temperature during the observation period of the colonies.

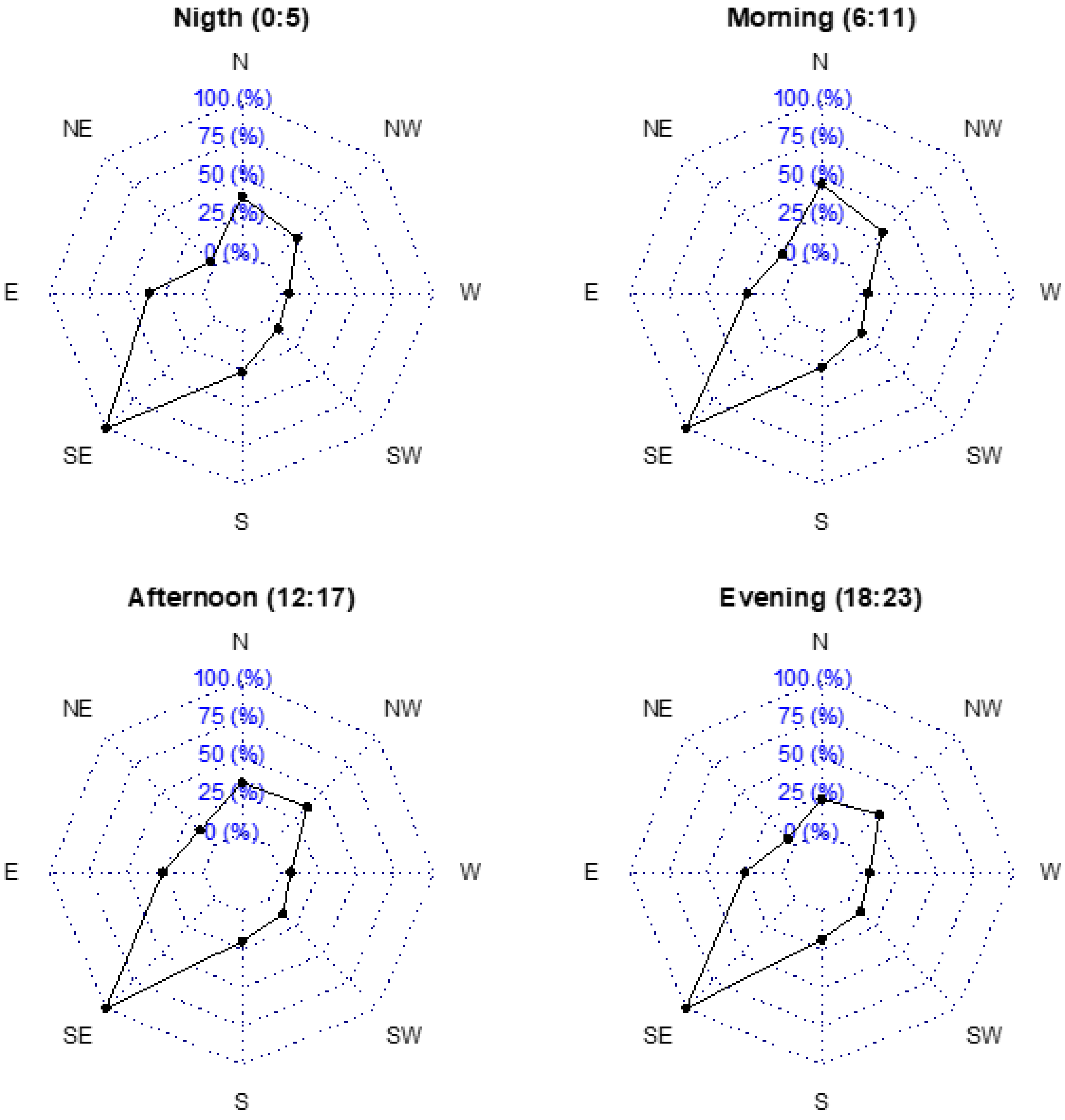

Figure 9

Rad chart of flow directions.

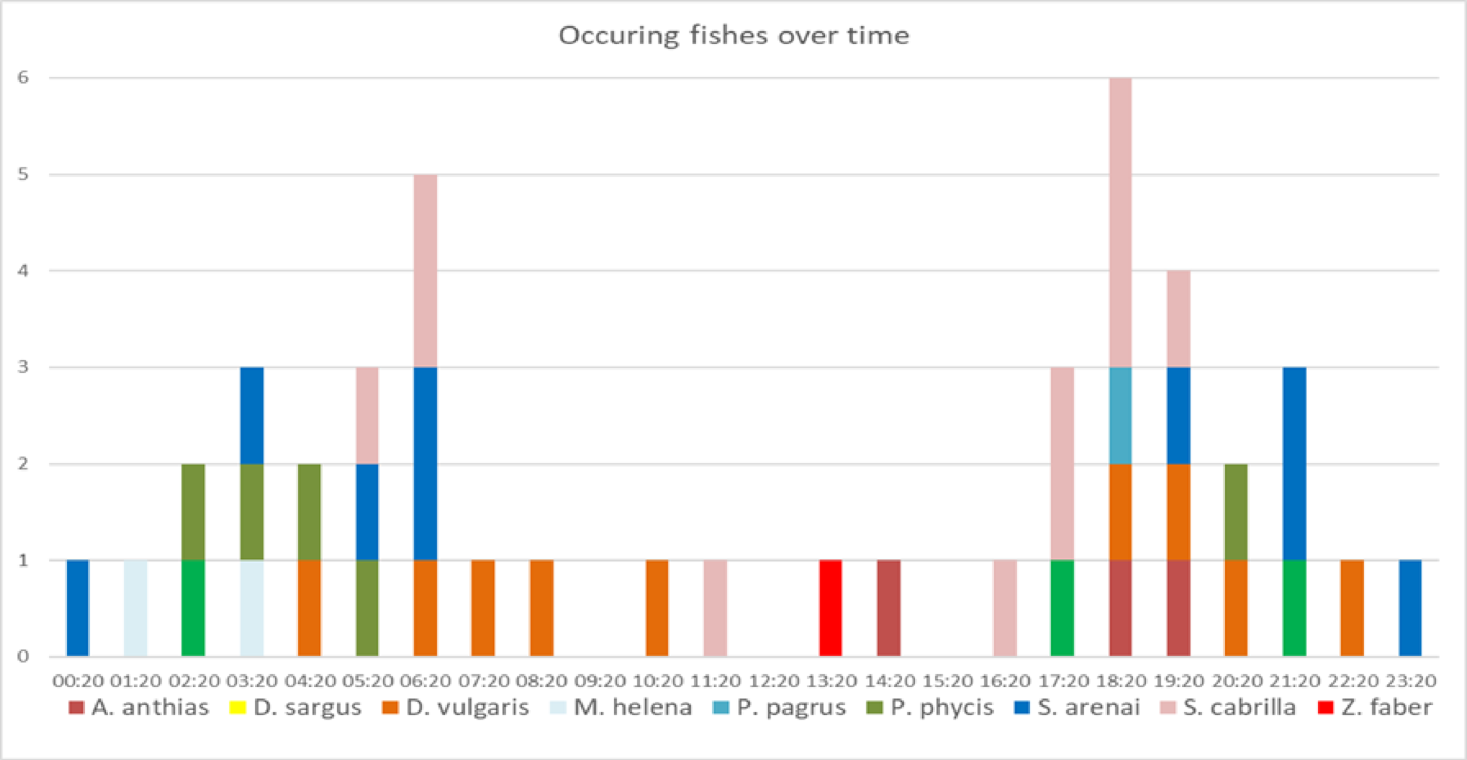

Figure 10

The occurrence of fish species over 24 h