Mass mortality event of the sponges *Ircinia variabilis* (Schmidt, 1862) and *Sarcotragus fasciculatus* (Pallas, 1766) (Porifera, Demospongia) in the southern Spanish coast

Evento de mortalidad masiva de las esponjas *Ircinia variabilis* (Schmidt, 1862) y *Sarcotragus fasciculatus* (Pallas, 1766) (Porifera, Demospongia) en la costa del sur de España

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Episodes of mass mortality of certain benthic invertebrates in the Mediterranean Sea following positive thermal anomalies are being increasingly reported in the literature in recent decades (Cerrano *et al*., 2000; Perez *et al*., 2000; CIESM, 2008; Rivetti *et al*., 2014), although it is quite possible that they are more frequent than usually reported. As pointed out by Cerrano *et al.* (2000), this is because when these mortality events occur, affected groups lacking economic or touristic importance, scarcely charismatic or with relatively small size often go unnoticed despite the key roles that these organisms may play in their ecosystems. In fact, mortality events themselves are often not detected nor recorded. However, the characterization of these pronounced episodes of declining wildlife throughout the years allows, among other things, a reliable assessment of some effects of global climate change on the marine environment.

Naturally occurring cyclical or episodic local mortalities can have a beneficial effect on the maintenance of biodiversity or on the persistence of a mosaic of different successional stages (Riegl, 1999; Cerrano *et al*., 2000). Fluctuations or pulses in populations are part of the natural dynamics of ecological systems (Templado, 2014). Sometimes high mortality events can lead to episodes of high recruitment that result in the recovery of populations and ultimately regulate their dynamics and structure. Nonetheless, when the occurrence rate of these events (or its intensity or magnitude) is directly or indirectly increased by human action, the consequences can be catastrophic. Also, when other causes of destruction, alteration or pollution of habitats are added their effects can be synergistic, resulting in natural disasters and sharp declines in biodiversity. In fact, it is often difficult to decouple the effects of one or another factor acting on living communities or even understand each link in the chain of events that cause episodes of mortality. For example, abnormally high temperatures can promote significant increases in populations of pathogenic organisms (fungi, protists, bacteria, etc.) or increase its virulence, as well as make the hosts most vulnerable when subjected to stressful situations. High temperatures also contribute to the stratification of the shallow water column and to decrease the concentration of dissolved oxygen (hypoxia). In addition, abnormally high temperatures can affect the functioning of food webs, cause community changes related to species tolerances (first eliminating the most sensitive species and, sometimes, increasing those more thermophilic), or favour the arrival and settlement of alien taxa (tropicalisation) that could displace native species (Francour *et al*., 1994; Cerrano *et al*., 2000; Perez *et al*., 2000; CIESM, 2008; Templado, 2014).

In relation to the above referred fact of mass mortalities of marine organisms related to abnormally high temperatures, it is outstanding two major well-documented multispecies mass mortality events that impacted the NW Mediterranean after the summer heat waves of 1999 and 2003 (Cerrano *et al*., 2000; Perez *et al*., 2000; Garrabou *et al*., 2009; Coma *et al*., 2009; Crisci *et al*., 2011). They affected many long-lived filter-feeders structural invertebrates (mainly Porifera and Cnidaria) over several hundred kilometres of coastline. In the case of sponges, 13 species were affected, including the demosponge *Ircinia variabilis* (Schmidt, 1862) (Lejeusne *et al*. 2010). This same phenomenon occurred in late summer 2008 and 2009 in different parts of the western Mediterranean (Cebrian *et al*., 2011) focusing mainly on *Ircinia fasciculata* (Esper, 1794) [currently *Sarcotragus fasciculatus* (Pallas, 1766)] and to a lesser degree on *Sarcotragus spinosulus* Schmidt, 1862. In the same period, a study monitoring the population of *Ircinia* sp. at the Granada coast (Punta de la Mona) (southern Spain) and in Chafarinas Islands (North African coast) was carried out. In that study it was detected that populations of *Ircinia* sp. were affected by a disease process although only a small part of them died, while the remaining individuals recovered total or partially (Maldonado *et al*., 2010). Afterwards, the effects of a new heat wave in 2015 on the marine benthic invertebrates have been reported by Rubio-Portillo *et al*. (2016) in the Tabarca Marine Protected Area (SE Spain).

More recently, in late summer 2016, a new mass mortality episode of *I. variabilis* and *S. fasciculatus* [see Pronzato *et al*. (2004) and van Soest (2008, 2010) for the taxonomic status of these species] has been detected in the

Granada coast. On September 1st, after a very long period of easterly winds, some cases of diseased sponges (fig. 1) were detected in Punta de la Mona, La Herradura Bay (Granada). On September 4th, also in Punta de la Mona, a large proportion of individuals showed pustules on its surface. In order to assess the effect of this episode of disease, eight transects were carried out, seven in the coast of Granada and one in Malaga. Transect length ranged from 205 to 1980 m. Data (length, depth, date, etc.) of these transects and obtained results are presented in Table I. Percentages of diseased individuals ranged from 7.2% to 81%, while percentages of dead individuals ranged from 0% to 92.8%. In two of the transects no individual was healthy.

In the absence of records of temperature of seawater in the study area, data from the buoy of Malaga (the closest area where data are available) in the page of the Spanish Government *Puertos del Estado* (http://www.puertos.es/es-es/oceanografia/Paginas/portus.aspx) were considered. According to those data registered at 15 m depth between August 7th and September 13th,

Fig. 1.—Two infected individuals of *S. fasciculatus*. The individual on the left showed part of the body with necrosis and the remaining part with pustules. The individual on the right was dead.
Fig. 1.—Dos individuos de *S. fasciculatus* infectados. El individuo de la izquierda presentaba parte del cuerpo con necrosis y la parte restante con pústulas. El individuo de la derecha estaba muerto.

Table. 1.—Data on transects carried out during the study and obtained results regarding number and percentages of healthy, diseased and dead sponges individuals.
Tabla. 1.—Datos sobre los transectos efectuados durante el estudio y resultados obtenidos con ellos respecto al número y porcentaje de individuos de esponjas saludables, enfermos y muertos.

Transect	*Date (dd-mm-yy)*	*Site*	*Submarine scooter*	*Start coordinates*	*Final coordinates*	*Transect length (m)*	*Depth (m)*	*Healthy N (%)*	*Diseased N (%)*	*Dead N (%)*
A	13-09-16	Punta de la Mona	Yes	36°43´11.15´´N 3° 43´35.45´´W	36° 43´26.93´´N 3° 43´33.63´´W	890	8-15	0	21 (7.2)	269 (92.8)
B	16-09-16	Cantarriján	No	36°44´15.60´´N 3°46´39.52W	36°44´17.31´´N 3°46´44.80´W	205	5-9	19 (18.1)	85 (81.0)	1 (1.0)
C	17-09-16	La Costera	No	36°44´31.53´´N 3°38´16.89´´W	36°44´30.40´´N 3°38´08.28´´W	229	5-10	167 (75.9)	51 (23.2)	2 (0.9)
D	19-09-16	La Huerta	No	36°43´51.00´´N 3°46´16.81´W	36°43´55.92´´N 3°46´24.64´W	320	5-15	0	43 (53.8)	37 (46.3)
E	26-09-16	Cerro Gordo	Yes	36°43´46.54´´N 3°45´55.13´´W	36°43´51.77´´N 3°46´17.37´´W	720	10-15	2 (33.3)	4 (66.7)	0
F	28-09-16	La Huerta-Cantarriján	Yes	36°43´56.66´´N 3°46´24.59´´W	36°44´03.98´´N 3°46´25.64´´W	417	5-10	59 (34.1)	61 (35.3)	53 (30.6)
G	29-09-16	Los Gigantes	Yes	36°43´10.78´´N 36°44´04.59´´W	36°43´28.38´´N 36°44´13.46´´W	844	8-15	3 (3.9)	7 (9.1)	67 (87.0)
H	03-10-16	La Costera-II	Yes	36°44´36.90´´ N 3°38´41.74´´W	36°44´30.88´´N 3°37´29.33´´W	1980	6-12	569 (86.9)	70 (10.7)	16 (2.4)

temperature practically remained above 25° C, a continuous abnormally high value for this area. The comparison of the values of 2016 with the averages of the values obtained since 2010 (year from which data are available) indicates, for example, an increase of more than 1.5° C in the average values in the month of August 2016 (25.9° C in 2016 compared to the average of 23.4° C). This increase in average temperature was not due to exceptionally high maximum temperatures (in fact the maximum temperature recorded in 2016 was lower than the average maximum temperature), but because of the absence of low values, so that the minimum temperature recorded in August 2016 (23.4° C) was four degrees higher than the average minimum temperature of that month (19.3° C) and almost equal to the average temperature for August (24.4° C). As reported by Maldonado *et al.* (2010), the epidemic outbreaks at the end of summer and beginning of autumn in our study area can be arguably favoured by abnormally high seawater temperatures in August.

From the obtained results, it can be seen as the disease episode affects the entire coastline, but in a variable way. Mortalities seem to be affected by the topography of the coast. Thus, the more protected areas, such as the Bay of La Herradura (Punta de la Mona, transect A in Table I), hinder the arrival of deep cold water and, consequently, the thermocline reaches greater depth. In these areas, percentages of dead and diseased individuals were higher (Table I). Contrary, in more open waters (as La Costera, transect C in Table I, where the thermocline was located around 9 m depth the day that the transect was made, and temperature changed from 26° C in surface to 20° C at that depth) percentage of healthy individuals were considerably higher (Table I). The influence of the coast topography and thermocline position on the degree of mortality during mass mortality events has been previously discussed for Mediterranean populations of *Corallium rubrum* (Linnaeus, 1758) by Garrabou *et al*. (2001).

When comparing the present data in Punta de la Mona (transect A, Table I) with those obtained by Maldonado *et al*. (2010) in the same place in 2008-2009 (fig. 2), it can be concluded that the recent disease episode has been more aggressive, with high percentages of dead or diseased individuals and no healthy ones. This result also indicates that these episodes do not immunize the population against future infections (in the case that the infectious agent is the same in different times). Another aspect to consider is the speed with which death sometimes occurs. Individuals that were apparently healthy in September 4th 2016 were dead nine days later (fig. 2).

Future studies integrating the knowledge of these recurrent mortality events in different taxa from different Mediterranean areas will be needed to understand the changes that are taking place in this marine ecosystem in the current frame of climate change.

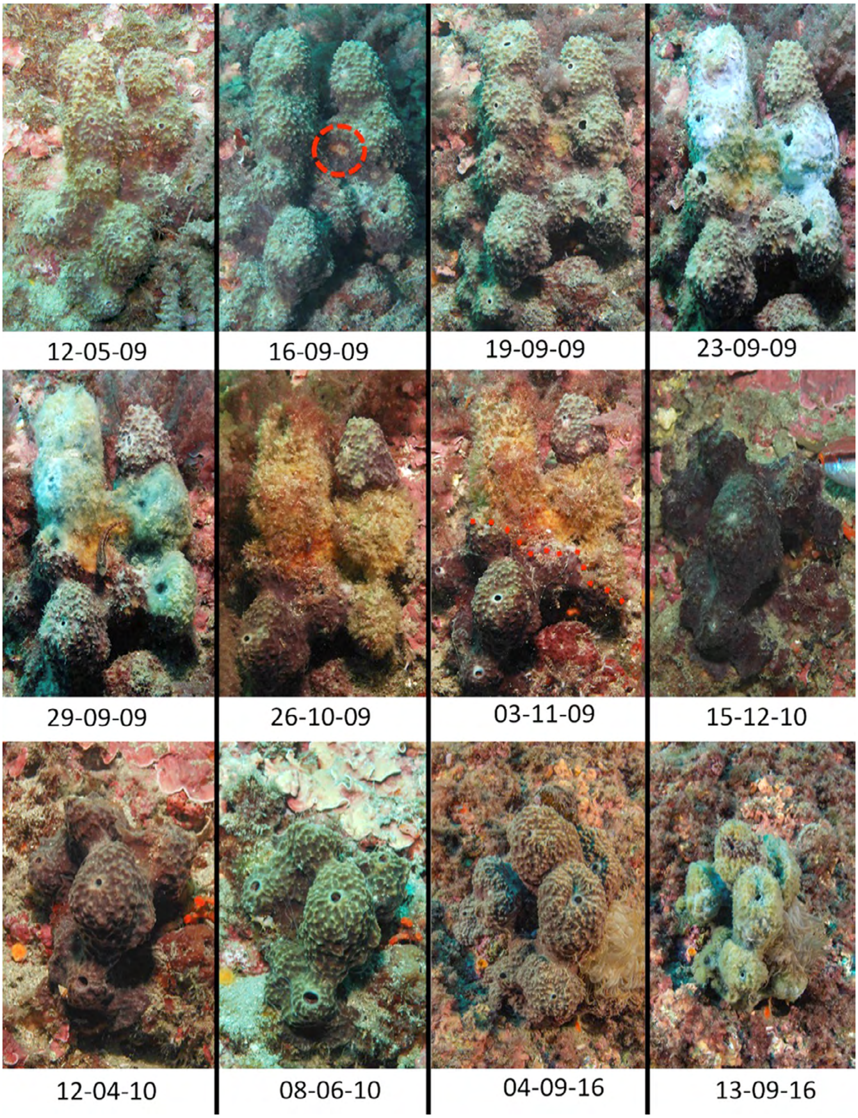

Fig. 2.—Sequence of disease stages in a *S. fasciculatus* individual from May 2009 to September 2010. It can be observed a first disease process in 2009 which caused the loss of more than 2/3 of its volume, and a second process in 2016 which caused its dead. The red circle indicates the appearance of the first pustule and the red point line indicatesthe place where necrosis and fragmentation began.

Fig. 2.—Secuencia de estados de enfermedad en un individuo de *S. fasciculatus* desde mayo de 2009 a septiembre de 2010. Se puede observar un primer proceso infectivo en 2009 que causó la pérdida de más de 2/3 de su volumen y un segundo proceso en 2016 que causó su muerte. El círculo rojo indica la primera aparición de una pústula y la línea roja indica el lugar donde comenzó la necrosis y la fragmentación.

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