High concentrations of European Storm Petrel (*Hydrobates pelagicus* ssp. *melitensis*) at tuna farms in the Western Mediterranean Sea

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Offshore fish farms are attracting points for several species of seabirds. In 2015, high concentrations of European storm petrels (*Hydrobates pelagicus*, Linnaeus 1758) were spotted nearby an offshore fish farm devoted to fattening of bluefin tuna (*Thunnus thynnus*, Linnaeus 1758), located 2.5 miles off l'Ametlla de Mar in Sant Jordi Gulf (Catalonia, NE Iberian Peninsula). During 6 years, censuses at the tuna cages were undertaken to study storm petrel abundances, as well as their autoecology, phenology, behavior and interaction with other seabirds. Storm petrel numbers peaked in spring and summer, accounting for more than 100 individuals, with their maximum recorded in May. It must be noted the great density registered in 2020 with 455 individuals observed, which represent the highest number ever recorded in Catalonia. These figures are extraordinary at Catalonian coasts, where references of big flocks of this species are scarce. Important aggregations of storm petrel associated with tuna farms were previously described in Malta and in the Southeast of the Iberian Peninsula. However, these farms are located relatively near their breeding colonies whilst in the case of individuals studied in l'Ametlla de Mar the nearest colonies known are Columbretes and Balearic Islands, which are much further from the fish farm than in the formerly mentioned cases. Our results point to offshore fish farms as a predictable feeding ground for *H. p. melitensis*. More research is needed to improve the knowledge on the main feeding areas of this endemic Mediterranean subspecies as a main tool for its management and conservation.

Keywords: *Seabirds; Procelaridae; Storm petrel; Aquaculture; Tuna fattening.*

ELEVADES CONCENTRACIONS D'OCELLS DE TEMPESTA (*Hydrobates pelagicus* ssp. *melitensis)* A INSTAL.LACIONS AQÜÍCOLES D'ENGREIX DE TONYINA A LA MEDITERRÀNIA OCCIDENTAL. Les instal·lacions aqüícoles a mar obert presenten condicions que atrauen diverses espècies d'ocells marins. L'any 2015 es van detectar agregacions d'ocells de tempesta (*Hydrobates pelagicus*, Linnaeus 1758) al voltant de les instal·lacions aqüícoles destinades a l'engreix de tonyina roja (*Thunnus thynnus*, Linnaeus 1758), situades a 2,5 milles de la costa de l'Ametlla de Mar, al golf de Sant Jordi (Catalunya, NE Península Ibèrica). Durant 6 anys s'han realitzat censos i s'ha estudiat aspectes de l'autoecologia de l'espècie, com la fenologia, el comportament i les interaccions amb altres aus marines. La primavera i estiu es detecten agregacions que superen el centenar d'exemplars, amb màxims al mes de maig. Destaquen els 455 individus observats l'any 2020, l'agrupació més nombrosa registrada a Catalunya coneguda pels autors. Les xifres obtingudes són excepcionals a la costa Catalana, on són molt escasses les citacions de grans grups. A Malta i al sud-est de la Península Ibèrica s'han descrit concentracions d'ocells de tempesta en instal·lacions aqüícoles de tonyina, sempre pròximes a colònies de reproducció. En el cas de l'Ametlla de Mar les colònies de

reproducció conegudes estan molt allunyades, les més pròximes a les illes Columbrets o les Balears. Les dades aportades mostren la importància que poden tenir les instal·lacions aqüícoles com a punt d'alimentació predictible per a la subespècie *melitensis* de l'ocell de tempesta. Cal seguir avançant en el coneixement de les principals àrees d'alimentació d'aquesta subespècie endèmica del Mediterrani, com a eina fonamental per la seva gestió i conservació.
Paraules clau: *Aus marines; Procelaridae; Ocell de tempesta; Aqüicultura; Engreix de tonyina.*

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Introduction

European storm petrels (*Hydrobates pelagicus*, Linnaeus 1758), pertaining to the family Procellariidae (petrels), are small marine birds with pelagic habits (Sanz-Aguilar *et al*., 2019). Two different subspecies were described with base on their morphometric characteristics, genetic signatures and vocalizations: the British storm petrel (*H. p. pelagicus*, Linnaeus 1758) in the European Atlantic coasts and the Mediterranean storm petrel (*H. p. melitensis*, Schembri 1843) in the Mediterranean Sea (Cagnon *et al*., 2004; Flood *et al*., 2011). There are around half million pairs of British storm petrels (Brooke, 2004) while the Mediterranean subspecies has an estimated European population of only 13.000-17.000 pairs (Birdlife International, 2015), with their largest colonies in Filfla (Malta), Marettimo (Sicilia) and s'Espartar (Ibiza) (Sanz-Aguilar *et al*., 2019). They usually nest in caves, cavities, crevices, or holes under vegetation located on islands and isles to avoid the presence of mammal predators, which are their main threat during the breeding season (de León *et al*., 2006; Ratcliffe *et al*., 1998; Scott, 1970).

The diet of storm petrels is varied and comprises mainly zooplankton and small fish and cephalopods, which are captured by dipping their beak in the water surface (Sanz-Aguilar *et al*., 2019). Likewise other petrels, scavenging is also a common form of feeding for storm petrels, which can detect smells of dead fish and fish-oil slicks from long distances (Howell, 2012). They can even feed near groups of dolphins and tuna when chasing. Schools of fish are pursued to the surface by their marine predators, allowing birds to feed on smaller fish and on left-over scraps (Howell, 2012).

In the Mediterranean area, storm petrels visit their breeding colonies at the end of March. The laying period lasts 3 months and extends from mid-April to mid-July with most laying occurrences between mid-May and mid-June (Mínguez, 1994). It was shown that this period can vary greatly in different years, differing in up to one-month delay the years with the earliest breeding occurrences and ones with the latest (Ramírez *et al*., 2016). Environmental conditions in the breeding or wintering areas, as well as in their feeding grounds are thought to be the main factors that determine the initiation of the breeding season (Sanz-Aguilar, 2011). Breeding season is a critical period for these birds, not only for the bulk energy that egg laying and chick rearing represent but also because storm petrels must initiate moulting at the time of incubation which will slowly continue during migration and winter

(Bolton and Thomas, 2001). Therefore, during this critical period they must feed intensively to fulfil their own and their chick energy requirements.

In order to protect this and other endangered species of seabirds, the creation of marine important bird areas (IBAs) was proposed in several European Union coastal countries, as an extension of the already well established terrestrial IBAs, in the framework of the Nature 2000 network 92/43/CEE (Council of the European Communities, 1992) and the Birds Directive 79/409/EEC (Council of the European Communities, 1979). The marine IBA ES409 (Ebro Delta- Columbretes) is the biggest of the Spanish state and comprises one of the most important feeding areas for numerous species during their breeding seasons. Columbretes Island is the only spot inside the IBA holding reproductive colonies of Mediterranean storm petrels with 30-55 pairs (Sanz-Aguilar *et al*., 2019). The Ebro Delta-Columbretes shelf is also one of the Spanish-Mediterranean sectors with the highest densities of storm petrels during their breeding season, showing preferences for areas ranging 200-1000 m depth (Bécares *et al*., 2011).

The marine IBA is also an area of high productivity where an important fishing and aquaculture industry was established. Among these sectors, bluefin tuna (*Thunnus thynnus*, Linnaeus 1758) fattening was the one which has experienced the most rapid development during the last decades, having an important economic impact in villages such as l'Ametlla de Mar (Tarragona, Spain). The main aquaculture company in l'Ametlla de Mar, Balfegó group S.L., installed their offshore bluefin tuna fattening cages in the early 2000s.

Offshore mariculture infrastructures may perform as gathering points for marine wildlife. On the one hand, supplies of pelleted feeds and farmed fishes themselves would represent a regular source of food for wild fish, marine mammals and seabirds (Borg, 2012; Dempster *et al*., 2004; Fernandez-Jover *et al*., 2009; Güçlüsoy and Savas, 2003). Also, organic waste and excrements may create a productive area on the fish farm surrounds, which could support marine food webs, with increased importance in oligotrophic seas (Machias *et al*., 2004). On the other hand, floating cages were suggested to act as fish aggregating devices (FADs), which are used from ancient times for fishing purposes (Fonteneau *et al*., 2000; Gooding and Magnuson, 1967). FADs do not only attract fish, but also pelagic seabirds seem to be interested in drifting objects (Arcos *et al*., 2000; Jaquemet *et al*., 2004). Altogether, offshore fish farms appear to be a suitable feeding ground for certain species of pelagic seabirds such as the Mediterranean storm petrel which was recently reported to concentrate nearby fattening cages of bluefin tuna in the Mediterranean Sea (Aguado-Giménez *et al*., 2016; Borg, 2012).

Likewise, these other fish farms, Balfegó's cages gather a diverse number of seabirds, especially during the fish feeding tasks. In 2015, the authors observed large aggregations of storm petrels at these tuna cages, which were apparently associated with the presence of these facilities. Considering the importance of this area for Mediterranean populations of storm petrels, further investigations were performed with the aim of verifying the relationship between the fish farm and the seabird occurrence.

This work envisaged the study of storm petrel abundances and behaviour, associated with an offshore fattening bluefin tuna farm located within the limits

of a Mediterranean marine IBA (NE Iberian Peninsula).

Material and Methods

Study area

Geographical and environmental features

Sant Jordi Gulf is located in Catalonian coast (NE Iberian Peninsula) and is delimited by Cape Tortosa (40°44' N, 0°52'E) to the South and Cape Salou (40°58' N, 0°53'E) to the North, with a distance of around 23 nautical miles (~43 km) between these bounds (Fig. 1).

The area is highly influenced by the Ebro River. This zone is characterized by a wide continental shelf and nutrient enrichment as a result of the river sediment inputs. The front caused by the Ligurian-Provençal current at the northern face of the continental shelf (in Gulf of Sant Jordi) together with seasonal strong winds favour local upwelling and high marine productivity. For this reason, a stable artisanal fleet operates in the area.

The study area is also included within the boundary of the IBA Ebro Delta-Columbretes, which extends 140 km along the coastline with their limits between Castelló de la Plana with Columbretes Islands, to the South (39º54'26''N, 0º00'43''W) and Cape Salou to the North (41º07'54''N, 1º23'37''W). The marine area has 10314 km^2 of total surface, which comprises the whole continental shelf and part of the continental slope, reaching depths of 1000 m (Arcos, 2009) (Fig. 1).

Location and description of the studied bluefin tuna farm

Balfegó bluefin tuna farm's cages are located 2,5-3 miles offshore the coastal village of L'Ametlla de Mar (A: 40º 51,5´N 00º 51,0 ´E; B:40º 51,95´N 00º 51,17´E; C:40º 51,57´N 00º 51,5´E; D: 40º 51,9´N 00º 51,61´E) (Fig. 1). The company first settled their activity in 2004, with 6 cages occupying 300.000 m^2 and a total capacity of 1250 tonnes. In 2014, their total capacity was increased to 2500 tonnes by doubling the number of cages. The production of bluefin tuna was estimated in 4.000 tonnes for the year 2019. The offshore infrastructures are composed of two polygonal zones holding 2 circular cages with 50 m of diameter and 4 cages with 25 m of diameter, all of them with 25 m depth. An average of 600 individuals per cage, weighing around 200 kg can be stabled, although not the totality of cages is used at the same time. The tuna fattening cycle usually starts in July with the restock of new individuals caught in their catching grounds, in the Balearic Sea. The captured specimens are fed small pelagic fish, mostly sardine (*Sardina pilchardus*, Walbaum 1792) and Atlantic mackerel (*Scomber scombrus*, Linnaeus 1758) twice a day. A quantity of around 40 tonnes of frozen baitfish is provided to the tuna fish daily. The feeding system is a submerged net attached to a floating squared frame, which is positioned into the cage, and where a block of frozen fish is placed. As fish thaw, it is released into the cages and is rapidly ingested by the farmed fish. The bluefin tuna individuals are fattened for a maximum of one year, and afterwards slaughtered. Then, the cage is prepared for the reception of new individuals and the initiation of a new cycle (Balfegó, *personal communication*; ICCAT, 2020; Industrias Pesqueras, 2020; IPac, 2013).

Storm petrel sights

Storm petrel censuses started in 2015 and were initially undertaken during the touristic boat trips that the same company organizes in spring and summer to bring visitors to the tuna fish cages (*Tuna Tour*).

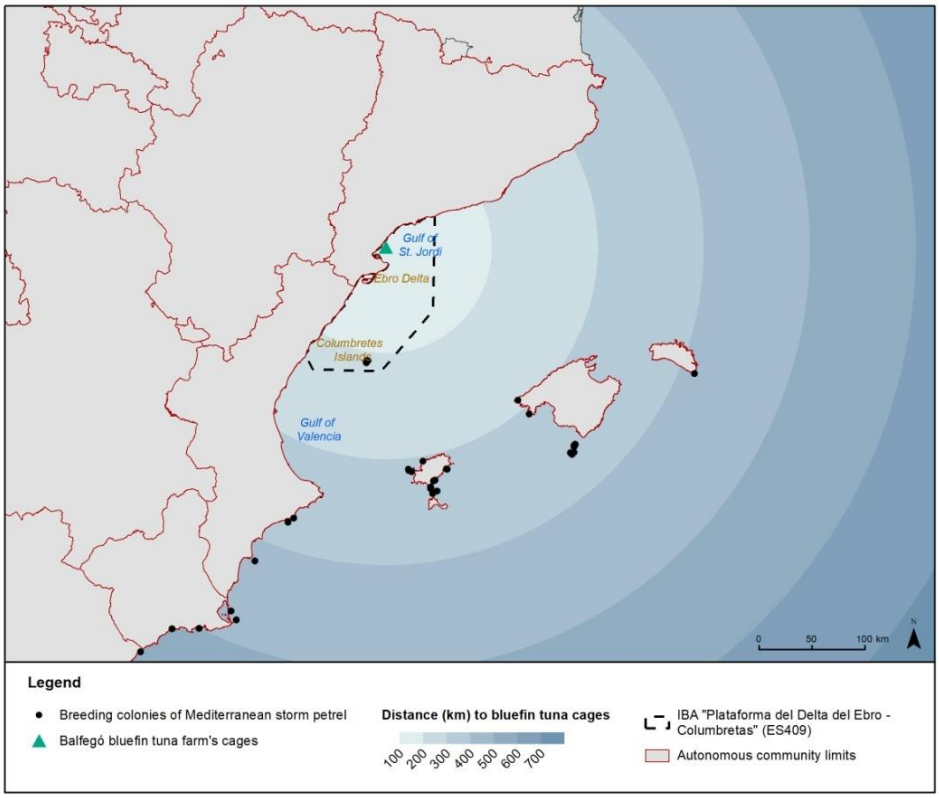

Fig. 1. Map displaying the location of the IBA 'Plataforma Delta del Ebro' (dashed line), bluefin tuna cages (triangle), Mediterranean storm petrel colonies (dots) and distance between them.
Fig. 1. *Distribució de la IBA "Plataforma Delta de l'Ebre" (línia discontínua), les gàbies de tonyina (triangle), les colònies d'ocell de tempesta de la Mediterrània (punts) i la distancia entre elles.*

From 2017 to 2019 the censuses were carried out from fishing boats, working in the area or in passage. In 2020, the counts were performed from land between April and June and later on from the company's multipurpose workboat during feeding or maintenance tasks (Table 1).

Although the number of samplings varied between different years, they always overlapped with the reproductive season of Mediterranean storm petrels (April-September).

The counting method was the same for any census type (with the exclusion of those performed from the coastline) and was based on the 360º scan around the ship (Tasker *et al*., 1984). Counts were carried out by one or two experienced observers simultaneously from different boats, when possible. The observer, equipped with binoculars (Swarovsky, Zeiss and Opticron 10x42) and camera (Nikon D610 with Nikkor 28-300mm 3,5-5,6f or Sigma170-500mm 6.3f, and Panasonic DMC-FZ200 25-600mm f2,8) counted all birds on sight in 360º rotating in the opposite direction of bird flight to avoid biases. Bird numbers were recorded every 30 minutes within 2-4

hours. For each sighting event, the census with the largest number of individuals observed simultaneously was recorded. The censuses performed from the coastline were completed from a second-floor flat on the sea-front, by scrutinizing the fish farm offshore facilities from side to side with a terrestrial telescope (Swarovsky 20-60x80mm and Vortex 20-60x85mm).

Relevant data such as feeding behaviour, interaction with conspecifics and other seabird species and wing moulting were also registered. Since the quick fly of storm petrels does not allow for the observation of subtle details to ageing each bird in the field, those individuals observed at short distance were photographed or filmed for the study of their moult. The photographs were afterwards scrutinized to determine the age and moulting stage of aimed birds.

Year	**Month**	**Census type**			
		Tuna tour boat	*Multipurpose boat*	*Fishing boat*	*Land*
2015	May	2	-	-	-
2016	July	1	-	-	-
2017	April	1	-	-	-
2017	June	1	-	-	-
2017	July	-	-	2	-
2018	June	1	-	-	-
2018	August	2	-	-	-
2018	September	1	-	-	-
2019	May	1	-	-	-
2019	August	1	-	-	-
2019	September	1	-	-	-
2019	October	1	-	-	-
2020	April	-	-	-	5
2020	May	-	-	-	9
2020	June	-	2	-	-
2020	July	-	2	-	-
2020	August	-	2	-	-
2020	September	-	1	-	-
Total		**13**	**7**	**2**	**14**

Table 1. Storm petrel censuses performed in Balfegó bluefin tuna offshore cages along 6 years.
Taula 1. *Censos d'ocells de tempesta realitzats en les gàbies de tonyina vermella de Balfegó en mar oberta al llarg de 6 anys.*

Results

Storm petrel census results

From the 36 censuses performed between 2015 and 2020 there were several peaks of densities, mainly at the end of April and May, coincident with the pre-laying period (Fig. 2). These figures decreased during June and July except for the year 2020, when the number of individuals recorded in each census was always above 100 exemplars.

The maximum number of storm petrels registered accounted for 455 individuals on the 16th of May, 2020.

Behaviour

Throughout feeding works at the tuna cages, storm petrels were observed foraging on oleaginous patches on the water and collecting small portions of whitish floating leftovers around and inside the cages. The feeding movements were similar to those described by Flood & Fisher (2011), consisting in different traveling and foraging actions (batting, foot pattering, hang-gliding and dives to collect the food). They were also spotted frequently near sport-fishing boats, not far from the tuna cages. Aggregations of wild bluefin tuna around the cages result very appealing for anglers, who usually go fishing there. One of the methods used by these fishers is throwing grinded fish as chum. The aim of

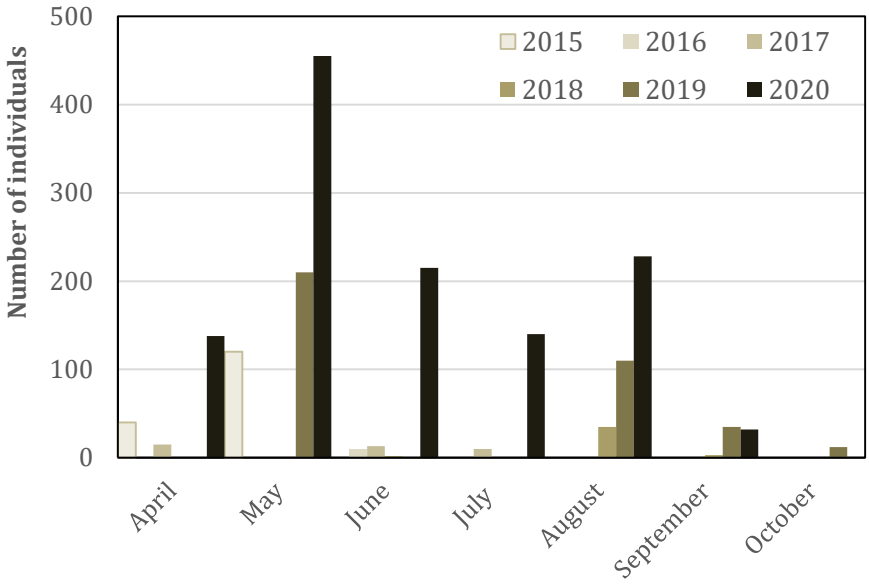

Fig. 2. Number of Mediterranean storm petrels registered per month during the study. For each month, only the maximum number observed is represented in the graph.
Fig. 2. *Número d'ocells de tempesta registrats al mes durant l'estudi. Per a cada mes, només es representa al gràfic el número màxim observat.*

this bite is to attract small fish, so that their predators follow them to the surface. Several storm petrels feed on the chum, especially in summer, when the number of anglers increases.

Some specimens were seen resting on the water and interacting with other species. Despite storm petrels are believed to avoid yellow-legged gulls (*Larus michahellis*, Naumann 1840), several individuals were observed feeding near them. Only one case of yellow-legged gull attack was registered. This attack occurred early in the morning, before the feed supply. Two cases involving great skua (*Catharacta skua*, Linnaeus 1758) and storm petrels were also recorded. The first one was a very quick harassment which ended when a yellow-legged gull chased the off the skua. In the second encounter, the harassed storm petrel avoided the attack by diving into the sea.

Moult

Storm petrels have a complete annual moult: in adults, primaries moult starts during the 2nd half of incubation or later, while non-breeders start to moult earlier. Second and third year individuals start 3-4 weeks earlier than in adults (Bolton and Thomas, 2001; Demongin, 2016). The specimens photographed in April and May had already completed their moult. The first storm petrel with primary active moult was detected on the 29th of June. The number of individuals in active moult and the extension of moult increases with time along July. In August, most registered individuals (photographed, filmed or closely observed) presented primary active moult, thus ruling out first-year individuals. In September, the state of moult was advanced, with the most advanced moult specimens displaying up to eight primary moulted feathers. However, individuals moulting the two most external primary feathers were not detected. The same month, only a few first-year storm petrels were observed.

Associated species

A number of species other than storm petrels profited from the availability of food in and around the tuna cages. Some of them even used the emerged cage walls as roosts. . Among them, it is worthy to mention slender-billed gull (*Larus genei*, Brème 1839), Mediterranean shag (*Phalacrocorax aristotelis desmarestii*, Linnaeus 1761), Sandwich tern (*Sterna sandvicensis*, Latham 1787), common tern (*Sterna hirundo*, Linnaeus 1758) and black tern (*Chlidonias niger*, Linnaeus 1758), as well as several endangered species such as Balearic shearwater (*Puffinus mauretanicus*, Acerbi 1827) and Audouin's gull (*Larus audouinii*, Payraudeau 1826).

As expected, generalist species such as yellow-legged gulls are abundant at these facilities. Marine mammals also get close to tuna cages, including bottlenose dolphins (*Tursiops truncatus*, Montagu 1821).

Discussion

Storm petrel abundances

The number of birds presented here are exceptional off the Catalonian coast, where storm petrel concentrations of more than 100 individuals had not been previously described. The authors themselves had never detected such high concentrations along more than 40 trips performed at different points of the Tarragona coast, where maximums recorded accounted for 30 simultaneously observed individuals.

Monthly variation

Previous studies reported storm petrel aggregations at bluefin tuna cages in the

Mediterranean. Borg (2012) reported the maximum number of individuals in July and August with a decrease in autumn, in a tuna farm in Malta. Numbers of individuals reached 100-120 in August 2011. A similar pattern was observed in offshore farms in Murcia, where storm petrel sights increased in August and sharply decreased in September (Aguado-Giménez *et al*., 2016). Densities in this area were estimated to be 297 individuals per km^2 for some transects, in late August (Aguado-Giménez *et al*., 2016). The range of our scope at the fish farm was about 1 km^2, allowing a rough comparison of numbers with those of Aguado-Giménez and collaborators (2016). Our results are in agreement with these studies with numerous flocks registered in late summer. However, in our study the maximum number of storm petrels occurred at the end of April-May, concomitantly with the pre-breeding season (Mínguez, 1994). This increment was followed by a drop in June-July and a peak again in August, which declines in September. The annual maximums detected in L'Ametlla de Mar in spring, and not observed in the other referred studies, may be due to the fact that in l'Ametlla de Mar farming activity is maintained all year round, while for tuna farms located in Malta and Iberian SE their productive cycle starts in July, after a 4-6-month fallow period (Borg, 2012; Marin *et al*., 2007).

Except for the year 2020, very low densities of storm petrels were observed in our study during egg-laying, incubation and chick rearing periods which take place in June-July (Mínguez, 1994). At this time, a maximum of 13 individuals were observed in 2017. In August, the rise of storm petrel sights was concomitant with the end of the breeding and intensive moult period, for most individuals.

Despite individual and interannual variabilities (Ramírez *et al*., 2016; Sanz-Aguilar, 2011) these monthly patterns in storm petrel abundances were observed along the 6 year studied period and are probably related to the need of energy provisions prior to breeding and migratory seasons.

Interannual variability

Our results show an increase in storm petrel numbers along the time. For instance, figures for August in 2018, 2019 and 2020 represent 35, 134 and 228 storm petrels, respectively. Interannual variability of breeding storm petrel abundances may be influenced by several factors, including food availability and environmental conditions (Ramírez *et al*., 2016; Sanz-Aguilar, 2011). Also, an elevated number of nest desertions may cause many individuals to leave their colonies to search for places with high food availability. In the case of L'Ametlla de Mar it would be possible that storm petrels could have learnt the location of this predictable food source in previous years and repeat their visits yearly.

Despite the differences in census methodology within the study period, our observations revealed figures similar to those reported in previous studies (Aguado-Giménez *et al*., 2016; Borg, 2012) except for the year 2020, when outstanding numbers were recorded. In 2020, the maximum number recorded attained 455 individuals in May, for a census performed from the nearest coastline, thus, this figure may be underestimated. Individuals present along June and July in the same year were 215 and 140, respectively, significantly higher than in previous years, in which the maximum was only 13 individuals.

The large aggregations observed in censuses performed in 2020 suggest that

year was exceptional and factors other than the provision of fish in tuna cages may be behind these elevated numbers. As a matter of fact, storm Gloria, which occurred at the beginning of the same year, impacted severely in the area, causing serious damages in several offshore fish farms along the Levantine coasts, among them Balfego's tuna cages. For this reason, at the time of 2020's censuses, Balfego's cages were emptied and thus feeding tasks were not undertaken until June (Balfego, *personal communication*). Escapes and fatalities of fish were reported by several aquaculture companies and fishermen operating in the area. It is well-known the scavenging behaviour of storm petrels and their appeal for fish-oil slicks smells (Howell, 2012). Therefore, it could be plausible that dead fish and decomposing carcasses together with the presence of cages acting as FADs still worked as an attractive spot for wild fauna, including storm petrels.

Storm petrels are considered to feed mainly on zooplankton and ichthyoplankton of oceanic and littoral composition, during breeding season, foraging in the most abundant prey (Albores-Barajas *et al*., 2011; D'Elbee and Hemery, 1998). Interestingly, it has been suggested that the contribution of baitfish wastes to storm petrel diet could be lower than expected, since they may feed also on the abundant plankton around fish cages (Aguado-Giménez *et al*., 2016). In 2020, sediment inputs from the Ebro River and Delta increased during the storm, which could create a zone of high productivity in the Gulf of Sant Jordi. The fallow period could also favour the plankton bloom, by the reduction of deleterious ammonia inputs (Marin *et al*., 2007), decrease of water turbidity and remineralization of organic matter, leading to inorganic nutrients available for microalgae.

Nearby Storm petrel colonies

The aquaculture parks studied in the region of Murcia comprised several bluefin tuna, European seabass (*Dicentrarchus labrax*, Linnaeus 1758) and gilthead seabream (*Sparus aurata*, Linnaeus 1758) farms. They were located at 4.65 and 0.7 km offshore and were intersected with four storm petrel breeding colonies. However, storm petrels were only observed in the furthest park. The distance between this aquaculture park and the nearest colony in Grosa isle is about 12 km. Most marked individuals in Grosa were identified foraging in the tuna farm (Aguado-Giménez *et al*., 2016). The area investigated in Malta was located about 30 km from the main breeding colony (Filfla) (Borg, 2012). In our study area the distance between tuna farms and the continental coast is similar (2,5 miles, 4,6 km) but, on the contrary, the distance between tuna farms and the nearest colonies is much larger. The nearest known colonies in Columbretes Islands are about 107 km away from Balfego's offshore infrastructures. The second closest known colonies are settled in the Balearic Islands of Ibiza, Mallorca (200 km away) and Menorca (270 km). Benidorm Island holds, as well, a small breeding colony of Mediterranean storm petrel located about 300 km away from L'Ametlla de Mar. Trips of up to 468 km from the reproduction to the feeding areas were reported for Mediterranean storm petrels (Rotger *et al*., 2020a). Thus, Balfegó's cages could gather individuals not only from the closest colonies in Columbretes but also from Balearic Island and the Spanish Levantine coasts. GPS-tagged reproductive individuals in Benidorm islet

were seen to undertake foraging trips which lasted between 1 and 4.5 days with a total distance travelled ranging between 303 and 1726 km. They were seen to move mainly southwest, towards Alborán Sea (Rotger *et al*., 2020b). In Balearic Island, individuals from na Pobra (Cabrera) performed trips which lasted between 2 and 4 days and a distance travelled ranging between 415.95 and 1308.59 km. Individuals from S'Espartar showed trips duration between 2.75 and 5 days and travelled between 762.35 and 1411.83 km. Individuals from Balearic Islands showed higher variability and also included areas near Algeria, Balearic Islands and the Ebro Delta (Rotger *et al*., 2020a).

Moult

Storm petrels adults have a complete annual moult (Bolton and Thomas, 2001). In adults, primaries moult starts during the 2nd half of incubation or much later while non-breeding individuals start to moult earlier. They moult slowly during 7 to 8 months, and continue during migration and winter. Second and third year individuals start 3-4 weeks earlier than in adults (Demongin, 2016). First sign of body moult in juveniles occurs in December-January (Flood *et al*., 2011). In the region of Murcia, an individual with initial moult was found on the 2nd of June, and on the 1st of August moult had started for 99% of individuals (Sallent *et al*., 2015). Similar moult timing was found in Malta (Sultana *et al*., 2011). The primary moult is regular, while the moult of the secondaries and tail is slower and irregular. Birds usually start moulting their secondaries from three places but not simultaneously and by mid-September most birds are also in active secondary and tail moult (Sultana *et al*., 2011).

The moult period observed in the present study is in agreement with those described for the Mediterranean (Sallent *et al*., 2015; Sultana *et al*., 2011). Most individuals photographed in August presented an active moult of primaries. Taking into account the number of individuals registered in August, with 228 specimens in 2020, seems plausible that this area has great importance in this crucial time of the annual cycle of this species. The fact that the individuals with the most advanced moult reached the 8th primary suggests that they end the moult during the end of autumn/winter somewhere else. On the opposite, l'Ametlla de Mar seems not to be an important zone for post-juvenile dispersion since a very low number of first-year individuals were observed.

Importance of offshore aquaculture systems for storm petrel and other marine bird conservation

Our results suggest this farming activity provides predictable foraging areas for storm petrels allowing them for energy and time saving in their most critical periods. Energy costs associated to egg formation have been suggested for several bird species (Williams, 2005) including petrels (Hedd *et al*., 2014; Mallory *et al*., 2008). During the pre-laying exodus, female Balearic shearwaters were shown to feed on different prey and spend more time feeding than males (Guilford *et al*., 2012). Pre-laying exodus was described in Wilson's storm petrel (*Oceanites oceanicus*, Kuhl 1820), as well (Beck and Brown, 1972).This differential trophic behaviour is probably related to higher or distinct nutritional requirements for egg development (Gatt *et al*., 2019; Navarro *et al*., 2009). The same could be true for storm petrels. Along the breeding season, parents

are subjected to extreme fasting during incubation and afterwards they must nourish their chicks and themselves. The fledging time is also a decisive period for survival of juveniles. Subsequently, storm petrels must abandon their colonies and leave for the high seas. Therefore, having a reliable source of food during these crucial months may increase survival and reproductive success of the Mediterranean storm petrel populations.

Besides, other key-stone species such as Balearic shearwater, Audouin's gull, slender-billed gull, Mediterranean shag, common tern, Sandwich tern, and Black tern, as well as bottlenose dolphin present in the IBA may take advantage of the farming activities and structures. Tuna cages, contrarily to other aquaculture installations, lack a protective net covering the structure, which are responsible for important bird mortalities. Several of the seabird species that were observed making use of the cages or close to the facility are species that are considered to meet the IBA criteria set by European regulations (Arcos, 2009; Ministerio de Agricultura Alimentación y Medio Ambiente, 2014), for their importance at the regional, EU or global level. This is the case of great skua, common tern and little tern (*Sternula albifrons* Pallas 1764), for instance. Among the observed species, some of them are also included in the list of endangered or threatened species or own a special protection status by the Barcelona convention (SPA/BD Protocol, 1995), such as storm petrel, Scopolis' shearwater (*Calonectris diomedea*, Scopoli 1769), Yelkouan shearwater (*Puffinus yelkouan*, Acerbi 1827), Mediterranean shag, slender-billed gull, Sandwich tern, Balearic shearwater and Audouin's gull. These two formers have special relevance for their interest and concerns in conservation at a global level. As a matter of fact, Balearic shearwater is regarded as the most threatened seabird species in Europe and is included as critically endangered in the IUCN red list, accounting for 19.000 mature individuals (BirdLife International, 2018) with only 3000 pairs (Arcos 2017). The population trend is negative, with an estimated annual decline of 14%, largely influenced by low adult survival (0.81) (Arcos *et al*., 2017). This species, endemic from the Western Mediterranean, only nests in Balearic Islands representing the unique reproductive population in the entire world (Arcos and Oro, 2004, 2003). Flocks of 1000-2000 individuals could be observed regularly in winter (beyond the study period) from the coast of L'Ametlla de Mar, with concentrations that reach 4.800 in front of the Ebro Delta (Bigas and Curcó, 2018) highlighting the importance that these waters may have for this Mediterranean endemism. Similarly, Ebro Delta holds some of the most representative colonies of Audouin's gulls in the world and flocks of thousands of individuals were commonly observed near tuna cages especially in June-July. Audouin's gulls are known to profit fishing by-catches (Bécares *et al*., 2016). Since trawlers closures typically occur during these months in the nearby ports the food supply available in the tuna cages may be an important resource for Audouin's gulls and for their chicks from the nearest colonies. On the other hand, generalist species, such as the yellow-legged gull, are always present in significant numbers at the cages. Therefore, it would be important to assess the effect of aquaculture activities on their population as well as their competition with other species.

Our observations suggest that tuna cages in l'Ametlla de Mar do not have a negative impact for seabirds, most likely, acting as a supplementary and sustainable

food source as well as a hotspot for Mediterranean endemic seabirds. Nevertheless, the potential benefit obtained from bluefin tuna farms by storm petrels and other endangered pelagic seabirds breeding in the IBA Ebro Delta-Columbretes should be assessed and investigated further.

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