The Mediterranean Storm-petrel, Bluefin Tuna fish-farms and the storm Gloria: the 'perfect storm'

Pere Josa[1]*, Jaume Solé[1] & Lucía Soliño[1]

In 2021 we published a six-year study (2015–2020) of the occurrence of the Mediterranean Storm-petrel *Hydrobates pelagicus* spp. *melitensis* around a Mediterranean Bluefin Tuna *Thunnus thynnus* fish-farm, where high concentrations took place during spring and summer. Great abundances of storm-petrels were recorded in 2020, with more than 100 individuals registered throughout April–August, whereas in previous years only a few individuals had been detected in June–July. These figures suggest either an increasing trend of storm-petrel occurrence in the area (i.e. by learning) or an exceptional episode, probably related to storm Gloria in January 2020. Here, we present the results of censuses undertaken in 2021–2022 whose numbers were lower than those registered in 2020 in May–July. This supports the idea that the events occurring in southern Catalonia after storm Gloria created the 'perfect storm' for storm-petrels in this area.

Key words: Mediterranean Storm-petrel, *Hydrobates pelagicus* spp. *melitensis*, pelagic seabirds, aquaculture, tempest Gloria, primary productivity.

[1]BIOSCICAT - Societat Catalana de Ciències per la Conservació de la Biodiversitat. Rambla Nova, 21, 43003 Tarragona, Spain. email: bioscicat@bioscicat.org

*Corresponding author: perejosa82@gmail.com

Received: 01.09.23; Accepted: 26.11.23 / Edited by J.M.Arcos

The European Storm-petrel *Hydrobates pelagicus* is the smallest seabird in Europe. It belongs to the family Hydrobatidae (northern storm-petrels), a group of marine birds with pelagic habits and a great capacity for movement that only return to land to breed (Sanz-Aguilar *et al.* 2019). The Mediterranean subspecies *Hydrobates pelagicus* spp. *melitensis* has an estimated population of only 13,000–17,000 pairs (BirdLife International 2015), with its largest colonies on Filfla (Malta) and Marettimo (Sicily). The Mediterranean Spanish population has been estimated at about 2,000–3,500 pairs, with its most important colonies on S'Espartar (Ibiza, Balearic Islands) and Benidorm Island (Alicante, E Iberia), and smaller nesting clusters on other isles in the Balearic archipelago and along the eastern Iberian coast (Sanz-Aguilar *et al.* 2019). The species is included in the *EU Birds Directive* (Annex I) and *Bern Convention* (Annex II) and is listed on the Spanish Catalogue of Protected Species. Its declining population led to it being classified as Vulnerable on the *Spanish Red List of Birds* (Sanz-Aguilar & Lago 2021) and, based on the most up-to-date information, it is classified as Endangered in the *Catalogue of Threatened Fauna of Catalonia*.

In the Mediterranean area, storm-petrels start visiting their breeding colonies at the end of March, with most laying taking place between mid-May and mid-June (Mínguez 1994). The onset of breeding differs by up to one month between years (Ramírez *et al.* 2016), as does migration phenology, presumably due to environmental conditions and food availability in breeding or wintering areas (Sanz-Aguilar 2011, Militão *et al.* 2022). Indeed, the most critical period of its life cycle may be the breeding season, which involves periods of high energetic costs during egg-laying and chick-rearing, but

also during moulting since storm-petrels initiate their moults when incubating (Bolton & Thomas 2001, Militão *et al.* 2022). Moult continues slowly during migration and winter, thus still requiring significant energy supplies (Bolton & Thomas 2001, Militão *et al.* 2022).

Offshore fish-farms are predictable food sources for several species of seabirds (King *et al.* 2010, Bath *et al.* 2023) including the pelagic storm-petrels. These small birds have been previously seen clustering around the floating cages of Bluefin Tuna *Thunnus thynnus* fish-farms (hereafter, tuna farms) in Malta and along the eastern Iberian coast (Borg 2012, Aguado-Giménez *et al.* 2016, Josa *et al.* 2021). Similar observations made at different sites imply that this is not a coincidence. Offshore aquaculture facilities in tuna farms consist of floating cages enclosing the farmed fish inside a submerged net. Unlike other fish-farming facilities, tuna cages lack the upper protective net that prevents seabird predation. The food provided to the tuna includes pelagic fish, which are usually supplied as a frozen block that is consumed as it melts into the water. This nutrient supply attracts seabirds and fish that feed on leftovers. Despite the potential negative impact of eutrophication on marine benthic communities, the nutrients in the fish and seabird waste could to some extent contribute to the phytoplankton and zooplankton blooms in the area, thereby creating a site of high productivity in the largely oligotrophic Mediterranean Sea (e.g. Machias *et al.* 2004, Skejić *et al.* 2011). Furthermore, the floating cages act as fish aggregating devices (FADs) under which small fish gather to take shelter.

Storm-petrels appear to feed mainly on zooplankton, ichthyoplankton and small pelagic fish (D'Elbee & Hemery 1998, Albores-Barajas *et al.* 2011, Aguado-Giménez *et al.* 2016, Watanuki & Thiebot 2018), although they can also benefit from floating decomposing dead fish and marine mammals (Howell 2012). As in other procellariforms, their highly developed olfactory sense enables them to detect productive feeding patches on the bare ocean surface at distances of several hundred kilometres (Grubb 1972, Hutchison & Wenzel 1980, Rotger *et al.* 2020, Militão *et al.* 2022).

In 2015, large aggregations of storm-petrels were detected around a tuna aquaculture facility in NE Spain. Opportunistic censuses were performed in 2015–2017 and more regularly from 2018 onwards (Josa *et al.* 2021). Peaks of storm-petrel abundances occurred at the end of April and in May coinciding with the pre-laying period; however, numbers then decreased in June and July, with a second peak in August, coinciding with chick-rearing and the onset of moult, and prior to postnuptial migration (Militão *et al.* 2022). However, in 2020 the number of individuals recorded in each census in April–August was unusually high, with more than 100 individuals recorded on each occasion compared to just a few individuals detected in June–July in previous years (Josa *et al.* 2021). These large and sustained numbers of storm-petrels observed in spring of 2020 compared to previous years could be due to several causes. As we hypothesised in our previous work, this apparent positive trend in the occurrence of storm-petrels in the area may be due to (1) the fact that birds have learnt the location of this predictable food source and thus a growing number of individuals over the time would be expected to be present in the coming years; or (2) the aftermath of a singular meteorological event i.e. storm Gloria, which occurred at the beginning of 2020 and created atypically favourable conditions for storm-petrels. In this case, once normal conditions returned after the storm, a decrease in storm-petrel numbers

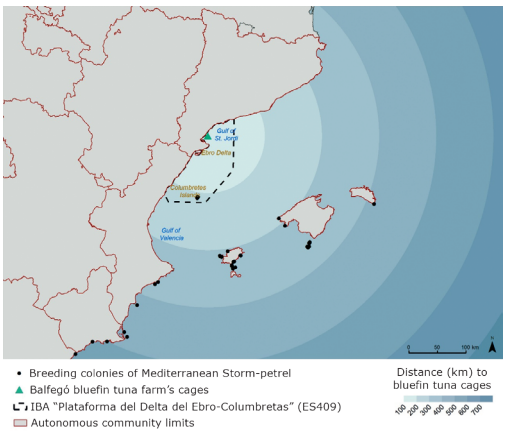

Figure 1. Map showing the location of the IBA Plataforma marina del Delta del Ebro- Columbretes (dashed line), Bluefin Tuna cages (triangle), Mediterranean Storm-petrel colonies (dots) and the distances between them.
Distribució de la IBA "Plataforma marina del Delta de l'Ebre- Columbretes" (línia discontínua), les gàbies de tonyina (triangle), les colònies d'ocell de tempesta de la Mediterrània (punts) i la distància entre elles.

to the figures observed prior to 2020 would be expected. The objective of our research was to discriminate between these alternative hypotheses by conducting a series of censuses in the two years after storm Gloria (2021 and 2022).

Material and methods

Study area and description of the fish-farm facilities

The tuna farm Balfegó is located in the Sant Jordi Gulf 2.5–3 miles offshore of the coastal village of L'Ametlla de Mar (Tarragona, S Catalonia, NE Iberian Peninsula; Fig.1). The area is characterised by a wide continental shelf and nutrient enrichment due to inputs of sediments from the river Ebro (Arcos 2009). The front caused by the Ligurian-Provençal current at the northern face of the continental shelf in the Gulf of Sant Jordi and strong seasonal winds favour local upwelling and relatively high marine productivity. This area lies within the Important Bird Area (IBA) and Special Protected Areas for Birds Ebro Delta-Columbretes (ES0000512).

The company Balfegó installed the first six floating cages in 2004, a number that had

Table 1. Number and type of storm-petrel censuses performed at the Balfegó Bluefin Tuna offshore cages in 2017–2022.
Nombre i tipus de censos d'ocells de tempesta realitzats en les gàbies de tonyina vermella de Balfegó a mar oberta entre 2017 i 2022.

Year	Month	Census type					Days of counting per month
		Tuna tour boat	Industrial boat	Fishing boat	Land	Recreational boat	
2017	April	1	-	-	-	-	1
2017	June	1	-	-	-	-	1
2017	July	-	-	2	-	-	2
2018	June	1	-	-	-	-	1
2018	August	2	-	-	-	-	2
2018	September	1	-	-	-	-	1
2019	May	1	-	-	-	-	1
2019	August	1	-	-	-	-	1
2019	September	1	-	-	-	-	1
2019	October	1	-	-	-	-	1
2020	April	-	-	-	5	-	5
2020	May	-	-	-	9	-	9
2020	June	-	2	-	-	-	2
2020	July	-	2	-	-	-	2
2020	August	-	2	-	-	-	2
2020	September	-	1	-	-	-	1
2021	April	-	2	-	-	-	2
2021	June	1	-	-	-	-	1
2021	July	1	-	-	-	-	1
2021	August	1	-	-	-	-	1
2021	September	1	-	-	-	1	2
2021	October	1	-	-	-	-	1
2022	April	1	-	-	-	-	1
2022	May	1	-	-	-	2	3
2022	June	1	-	-	-	-	1
2022	July	-	-	1	-	-	1
2022	August	3	-	-	-	-	3
2022	September	1	-	-	-	2	3
2022	October	1	-	-	-	-	1
Total							**54**

doubled by 2014 (some remain empty part of the year), in an area approximately 2-km long and 0.5-km wide (A: 40° 51,5´N 00° 51,0 ´E; B: 40° 51,95´N 00° 51,17´E; C: 40° 51,57´N 00° 51,5´E; D: 40° 51,9´N 00° 51,61´E). All the circular cages have diameters of either 50, 60 or 120 m and are placed at a depth of 25 m, each holding an average of 600 tuna individuals weighing around 200 kg each (Josa *et al.* 2021). Reared tuna are fed with small pelagic fish, mostly Gilt Sardine *Sardinella aurita* and Atlantic Mackerel *Scomber scombrus* twice a day. A quantity of around 40 tons of frozen baitfish is provided to the tuna daily (OceanSnell 2020). The feeding system consists of a submerged net attached to a square floating frame in the cage, on which a block of frozen fish is placed. As the fish thaws, it is released into the cages for the farmed fish to feed on (OceanSnell 2020, Balfegó pers. com., personal observations).

Storm-petrel surveys

In July 2017 counts were performed on board fishing vessels working in the area or on passage. After 2018, a collaboration with the fish-farm company allowed for a more systematic survey on board either the *Tuna Tour* vessel or the company's multipurpose workboat used during feeding and maintenance operations. In 2020 due to the COVID pandemic, the counts had to be performed from land in April and May from a building on the sea front at around 12 m above the sea level (Josa *et al.* 2021). Subsequently (June 2020–September 2022), the survey of storm-petrels in the fish-farm was conducted always either on board the multipurpose workboat, on the *Tuna Tour* or on recreational boats (Table 1).

The *Tuna Tour* has two decks and counts can be conducted from the upper decks within the perimeter of the tuna farm. The company operates three different multipurpose workboats, one of which has an elevated bridge that is equivalent to the second deck on the *Tuna Tour*. The other two vessels have lower bridges. Balfego's vessels operate inside the perimeter area delimiting the cages, while, from the lower fishing and recreational boats, counts were carried out at the edge of this perimeter area. The duration and schedule of the censuses varied depending on the type of boat and the purpose of the visit. The census method was performed as described in Josa *et al.* (2021). Briefly, the observer equipped with binoculars (Swarovsky, Zeiss and Opticron 10x42) counted all birds in sight, including both those inside the facility perimeter and those outside, by rotating 360° in the opposite direction to birds' flight direction to avoid biases (Tasker *et al.* 1984). The number of storm-petrels was recorded every 30 minutes and on each occasion the census with the largest number of individuals observed simultaneously by one observer was recorded. Other species present, behaviour, interactions and additional relevant observations were also noted. Censuses were only carried out in calm seas (0–2 degree on the Douglas sea scale) since

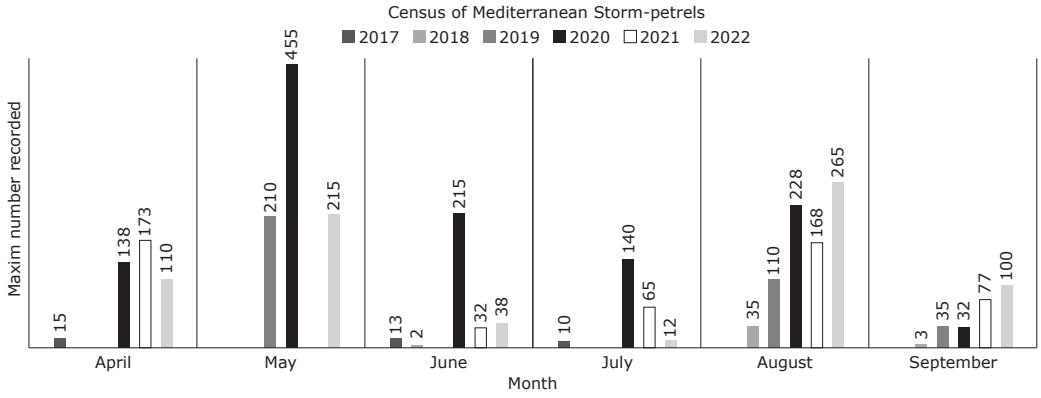

Figure 2. Maximum number of Mediterranean Storm-petrels registered per month in the study period (April–September) in 2017–2022. The absence of columns in the graph indicates a lack of data for that month and year. *Nombre màxim d'ocells de tempesta mediterrani registrats per mes en el període d'estudi (abril-setembre) entre 2017 i 2022. L'absència de columnes al gràfic indica l'absència de dades per al mes i any corresponent.*

even small waves can mean that some birds are not counted.

The censuses from the coastline were performed from a flat-roofed building at about 12 m above the sea level by scrutinising the offshore fish-farm facilities from one side with terrestrial telescopes (Swarovsky 20–60 x80 mm and Vortex 20–60 x85 mm). All specimens detected were counted, the vast majority near the tuna cages. The land-based counts were carried out under calm sea conditions in the afternoon, since in the morning the cages are backlit by the low sun, which hinders observations. In these land-based counts, specimens located near the land were detected but some located within the farm furthest from the land may not have been detected. Thus, these censuses may have underestimated storm-petrel numbers and so in June and July 2020 additional census from land were performed. These censuses were compared with onboard counts performed on the same day and resulted in considerably lower figures registered from land (*i.e.* 135 *vs.* 64 and 140 *vs.* 62).

Results

Result of censuses of storm-petrels 2020–2022

The censuses performed during 2021 and 2022 showed similar values to those observed before 2020, thus suggesting that the unusual peaks observed in May–July 2020 were truly exceptional (Fig. 2). The highest count in that year (455 birds in May) more than doubled any other count in either preceding or subsequent years. On the other hand, counts at the end of the season in September were higher in 2021 and 2022 than in preceding years.

Behaviour

Storm-petrels were habitually observed foraging on the water, collecting small portions of floating leftovers from around and inside the cages. They were also spotted frequently near sport-fishing boats not far from the tuna cages. Aggregations of wild Bluefin Tuna around the cages appeal to anglers who dump ground fish into the water. This bait attracts small fish whose predators follow them to the surface. Several storm-petrels feed on the ground bait, especially in summer, when the number of anglers increases.

Discussion

In our previous study (Josa *et al.* 2021) we hypothesised that the increasing number of storm-petrels detected over the years might be because of (1) a rise in the number of birds recurrently visiting this new feeding ground due to behavioural acquisition/learning or (2) favourable conditions for food provision caused by the storm Gloria that struck at the beginning of 2020. Although these two assumptions may not be mutually exclusive, the results from censuses performed in 2021 and 2022 suggest that storm Gloria triggered an unprecedented situation that was advantageous for these seabirds.

2020–2022 censuses

In 2020 due to the COVID pandemic, counts had to be performed from land in April and May. From mid-June to mid-July, however, counts were carried out from land and at sea, thereby allowing for a comparison of the two methods during this period. The maximum number of individuals observed simultaneously from land in April and May was 65 and 43 individuals, respectively, while the maximum counts at sea in the same period were 140 and 110 individuals, respectively. On the two occasions on which both census methods were performed on the same day there was a difference of 48.1% and 44.3% between counts from land and at sea. These records suggest that land counts may be underestimates since the nearest part of the tuna farm to the land lies at the limit of storm-petrel detection and excellent light conditions and flat seas are required to be able to spot them with the telescope. Storm-petrels in the tuna farm located furthest away from the coast almost certainly remain undetected, so the results obtained in April and May 2020 would probably have been higher if the censuses had been carried out at sea. On the other hand, the greater number of monthly counts conducted from the coast could produce a peak effect (i.e. there was a better chance of recording large concentrations of storm-petrels as the number of counts performed was higher).

The on-board censuses differed depending on the type of vessel, its route and activity. The second deck of the *Tuna Tour* may have allowed us to detect more storm-petrels than from the other boats, although this effect would probably be more important under rough sea conditions (excluded from the study). The censuses carried out from the multipurpose boats and *Tuna Tour* are comparable. The greatest difference in the on-board censuses probably occurred with censuses performed from recreational boats since, due to their lower height, the detectability of distant individuals is poorer. In terms of the type of activity, industrial boats can attract birds when conducting feeding tasks (Borg 2012), although the same specimens would be detectable from other vessels since they were usually in sight. Despite these slight differences between types of vessel, the fact that the censuses were always carried out on flat seas by experienced observers probably minimised any potential bias and allowed equivalent counts to be performed. On the other hand, the counts performed from land in April and May 2020 probably underestimated counts compared to the on-board censuses.

As none of the census methods enabled us to count all storm-petrels present in the area, the maximum number observed simultaneously for each day was taken as the minimum number of storm-petrels present at a given time that were detectable from a single point. It would be very interesting in future projects to make comparisons between the different methods and even trial the use of new technologies.

As previously noted, the main difference between the most recent surveys and the 2020 censuses occurred in May–July. In that year aggregations of 455, 215 and 140 storm-petrels were present at the fish farm during these months, whereas the numbers registered in 2021 and 2022 were in the range of 215–12 individuals. Smaller differences were observed in the censuses performed in April and August. In September, the number of storm-petrels recorded in 2021 and 2022 doubled and tripled, respectively, the counts from 2019 and 2020. Militão *et al.* (2022) studied the onset of the breeding and migration seasons in Mediterranean storm-petrels and concluded that the initiation of post-breeding migration is more variable than the date of arrival at colonies. These differences in synchrony may explain the interannual differences observed in September and could indicate that birds increasingly use this area for energy provision prior to migration and moulting (Militão *et al.* 2022).

Feeding behaviour

Several studies agree that, although storm-petrels feed preferentially on zooplankton, ichthyoplankton and small fish, they also opportunistically exploit other abundantly available resources (Thomas *et al.* 2006, Medeiros 2010, Albores-Barajas *et al.* 2011, Howell 2012, Aguado-Giménez *et al.* 2016). As previously reported, tuna fish-farms are predictable food sources and hence attract birds of this species (Borg 2012, Aguado-Giménez *et al.* 2016, Josa *et al.* 2021). Additionally, floating cages are thought to act as fish aggregating devices (FADs) (Gooding & Magnuson 1967, Fonteneau *et al.* 2000) and pelagic seabirds often show an interest in floating objects, probably because of their potential for attracting small fish (Arcos *et al.* 2000, Jaquemet *et al.* 2004). The presence of tuna both inside and outside the facilities may also be an attractant. Around the fish-farm, wild tuna are abundant and rapidly catch the food that falls outside the cages. Local people say that in the past fishermen used to set their gear for tuna wherever storm-petrels were feeding and, indeed, storm-petrels have been reported feeding near groups of dolphins and tuna chasing small fish and on left-over scraps on the surface (Howell 2012). Storm-petrels are also spotted frequently near anglers when they use methods such as 'chumming', which consists of throwing ground-up fish or 'chum' into the sea to feed small fish and attract large predators like tuna. Occasionally, storm-petrels are seen following fishing boats, which reflects their great learning capacity and adaptability.

Effects of storm Gloria on food provision

Besides the large number of birds observed around tuna fish-farms during the study, our findings suggest that in spring 2020 the conditions in the area during the laying period were particularly attractive for storm-petrels. These conditions could be related to the effects of storm Gloria and a series of events linked to this extreme phenomenon. Between 19 and 24

January 2020 the extreme weather conditions brought by storm Gloria seriously affected the eastern coast of the Iberian Peninsula. Along this coast, the wind velocity averaged 15 m/s, with gusts of wind reaching 36 m/s and abundant rain (maximum values of more than 400 l/m^2). At sea, strong currents exceeding 0.8 m/s and rough seas with maximum significant wave heights of about 8 m impeded fishing activities and damaged coastal and offshore infrastructures (Berdalet *et al.* 2020). The increase of sea level was notable – over 0.6 m – and led to coastal retreat that was very significant in the Ebro delta (Berdalet *et al.* 2020). Along the Catalan coast sediment inputs from rivers to the continental shelf also dramatically increased, thereby enhancing nutrient concentrations that gave rise to phytoplankton blooms about two weeks after the storm (Berdalet *et al.* 2020, Peters *et al.* 2020). Furthermore, the Catalan current over the continental shelf was intensified from NE to SW along the coast due to the strong winds (Berdalet *et al.* 2020), which would have carried more sediments and nutrients towards the Gulf of Sant Jordi.

Phytoplankton blooms trigger a series of trophic cascades that result in boosts in zooplankton and pelagic fish numbers. Previous studies have demonstrated that storm-petrels may rely on cycles of phytoplankton productivity during breeding and moult periods (Ramirez *et al.* 2016, Militão *et al.* 2022). Indeed, Ramirez *et al.* (2016) observed that chick-rearing was concomitant with the maximum abundance of ichthyoplankton that occurred 110 days after the peak of marine productivity. This temporal scale agrees with our observations, since the peak in storm-petrel numbers (May, June and July) occurred about 3–4 months after the peaks in chlorophyll-a (Chl-a) in 2020 (February and March) according to data on Chl-a concentrations in southern Catalonia obtained from the Global Fishing Watch platform (Global Fishing Watch 2023). The peaks in Chl-a concentrations for 2020 were also higher than in previous and subsequent years in the area around the tuna fish-farm (in a polygon of 22.5 km^2) (Global Fishing Watch 2023). In this area, the average Chl-a concentrations for the period 1 January–1 April was 0.81 mg/m^3 in 2017, 1.29 mg/m^3 in 2018, 1.42 mg/m^3 in 2019, 2.52 mg/m^3 in 2020 and 0.68 mg/m^3 in 2021, and 1.05 mg/m^3 in 2022 for 1–31 January (no information is available after this date for this year). In this area in 2020 there were peaks of Chl-a of 9.14 mg/m^3 on 15 February and 5.05 mg/m^{3}on 13 March. In previous and following years, Chl-a peaks were also observed in March but were considerably lower (in a range of about 1–3 mg/m^3) except in 2019 when a peak of 4.23 mg/m^3 was recorded on 5 March.

The storm also seriously damaged Balfego's offshore infrastructures and it is estimated that more than 3000 tuna individuals escaped from the cages (non-official data). As a result, thousands of tunas died or were injured and in the days after the storm hundreds of dead tunas were washed ashore on the coast from L'Ametlla de Mar to La Rápita (around 30 km further south) (Berdalet *et al.* 2020). Dead tunas were not only found along the shoreline but also in trawler hauls, which spoiled catches. This situation lasted into the summer (Industrias Pesqueras 2020) and possibly significantly altered the ecosystem. Like other petrels, storm-petrels also commonly scavenge as they can detect the smell of dead fish and fish-oil slicks at great distances (Howell, 2012). The thousands of putrid fish in the area during these months might have attracted storm-petrels to opportunistically feed on this resource. The tuna cages were empty from February to June 2020 due to the escape of specimens after the storm (OceanSnell 2020) and the maximum number of storm-petrels was counted in May and June 2020 with empty cages and no daily supply of food for the tunas. The high availability of spoiled fish and the peaks in phytoplankton and the following trophic cascades, all triggered by storm Gloria, might have provided an exceptional quantity of food for storm-petrels in 2020 that probably lasted until summer, which would explain the high number of birds counted in May–July. Thus, together these events caused what could be called a 'perfect storm' for storm-petrels.

Future prospects

This and previous studies show the great capacity of storm-petrels to adapt and exploit new feeding resources. Nonetheless, further research about the effects of fish-farm resources on storm-petrels still need to be contemplated. Studying the origin of these birds would also be of great

interest. It is known that Mediterranean storm-petrels perform trips of several hundreds of kilometres from their breeding colonies to their feeding grounds and individuals tagged in the Balearic Islands are known to feed near the Ebro delta and beyond (Rotger *et al.* 2020). Moreover, moult is an energetically demanding process that overlaps with reproduction and even migration (Militão *et al.* 2022), so fish-farms represent a predictable food supply for birds needing to fulfil their energy requirements during breeding, moulting and prior to migration. Militão *et al.* (2022) have demonstrated that Mediterranean storm-petrels synchronise their migration and breeding seasons with productivity abundance cycles in the Mediterranean and Atlantic Ocean. Thus, how the existence of a stable food source such as fish-farms alters migratory patterns, especially under a scenario of global warming, undoubtedly warrants further research.

Acknowledgements

Thanks are due to the staff at Balfegó for their help, in particular to Begonya Mèlich and the boat crew for all their kindness during on-board storm-petrel censuses. We would also like to thank Elisabeth Casanova (Xarter Eli) for the sea-watching trips that provided interesting observations of storm-petrels. We are also grateful to Vicente Tamarit for his assistance in the field and David Bigas for his valuable comments about the Mediterranean Storm-petrel in the area. We thank Cory's Investigación y Conservación de la Biodiversidad and Picampall for their support.

Resum

Ocell de tempesta, granges de tonyina i borrasca Glòria: la "tempesta perfecta"

L'any 2021 vam publicar un estudi realitzat durant sis anys (2014–2020) sobre la presència de l'ocell de tempesta *Hydrobates pelagicus* spp. *melitensis* en una granja de tonyina roja *Thunnus thynnus* a la Mediterrània, on descrivíem concentracions elevades d'aquest ocell durant la primavera i l'estiu. El 2020 es va registrar gran abundància d'ocells de tempesta, sempre amb més de 100 individus entre abril i agost, mentre que en anys previs les observacions en els mesos de juny i juliol eren de només uns pocs exemplars. Aquestes altes xifres podrien suggerir una tendència creixent de l'aparició d'ocell de tempesta a la zona (*i.e.* per aprenentatge) o un episodi excepcional probablement relacionat amb la borrasca Gloria, que va passar a principis del mateix any. Aquí presentem els resultats dels censos realitzats el 2021 i 2022. Les noves dades mostren xifres inferiors a les registrades el 2020, entre maig i juliol, suggerint així que els fets que es van produir a la Catalunya sud després que la borrasca Glòria van crear "la tempesta perfecta" per als ocells de tempesta en aquest zona.

Resumen

Paíño mediterráneo, granjas de atún y borrasca Gloria: la "tormenta perfecta"

En 2021 publicamos un estudio llevado a cabo durante seis años (2015–2020) sobre la presencia del paíño mediterráneo *Hydrobates pelagicus* spp. *melitensis* en una piscifactoría de atún rojo *Thunnus thynnus* en el Mediterráneo, describiendo altas concentraciones de esta ave durante la primavera y el verano. En 2020 se registraron en esta zona abundancias excepcionales de paíños, con mínimos de 100 individuos entre abril y agosto, mientras que en años previos las observaciones en los meses de junio y julio eran de apenas unos pocos individuos. Estas elevadas cifras podrían sugerir una tendencia a un incremento de la presencia de paíños en la zona (*i.e.* por aprendizaje) o un episodio excepcional probablemente relacionado con la tormenta Gloria, que tuvo lugar a principios de ese mismo año. Aquí, presentamos los resultados de los censos realizados en 2021 y 2022. Los nuevos resultados arrojan cifras inferiores a las registradas en 2020 entre mayo y julio, lo que sugiere que los hechos ocurridos en el sur de Cataluña después de la tormenta Gloria crearon "la tormenta perfecta" para los paíños en esta área.

References

Aguado-Giménez, F., Sallent-Sánchez, A., Eguía-Martínez, S., Martínez-Ródenas, J., Hernández-Llorente, M.D., Palanca-Maresca, C., Molina-Pardo, J.L., López-Pastor, B., García-Castellanos, F.A., Ballester-Moltó, M., Ballesteros-Pelegrín, G., García-García, B. & Barberá, G.G. 2016. Aggregation of European storm-petrel (*Hydrobates pelagicus* ssp. *melitensis*) around cage fish farms. Do they benefit from the farmś resources? *Mar. Environ. Res.* 122: 46–58. https://doi.org/https://doi.org/10.1016/j.marenvres.2016.09.006

Albores-Barajas, Y. V, Riccato, F., Fiorin, R., Massa, B., Torricelli, P. & Soldatini, C. 2011. Diet and diving behaviour of European Storm Petrels *Hydrobates pelagicus* in the Mediterranean (ssp. melitensis). *Bird Study* 58: 208–212. https://doi.org/10.1080/00063657.2011.560244

Arcos, J.M. 2009. Áreas importantes para la conservación de las aves marinas en España. Madrid: Sociedad Española de Ornitología (SEO/BirdLife).

Bath, G.E., Price, C.A., Riley, K.L. & Morris Jr, J.A. 2023. A global review of protected species interactions with marine aquaculture. *Rev. Aquac.* 15: 1686–1719. https://doi.org/https://doi.org/10.1111/raq.12811

Berdalet, E., Marrasé, C. & Pelegrí, J.L. 2020. *Resumen sobre la formación y consecuencias de la borrasca Gloria (19-24 enero 2020).* Barcelona: Institut de Ciències del Mar, CSIC. 38 pp. DOI: 10.20350/digitalCSIC/12496.

BirdLife International. 2015. *European red list of birds*. Luxembourg: Office for Official Publications of the European Communities. http://datazone.birdlife.org/info/euroredlist

Bolton, M. & Thomas, R. 2001. Moult and ageing of storm petrels hydrobates pelagicus. *Ring. Migr.* 20: 193–201. https://doi.org/10.1080/03078698.2001.9674244

Borg, J.J. 2012. Tuna farms - a seasonal supplementary food source for storm petrels *Hydrobates pelagicus melitensis*. *Avocetta* 36: 91–94.

D'Elbee, J. & Hemery, G. 1998. Diet and foraging behaviour of the British Storm Petrel *Hydrobates pelagicus* in the Bay of Biscay during summer. *Ardea* 86: 1–10.

Fonteneau, A., Pallares, P. & Pianet, R. 2000. *A worldwide review of purse seine fisheries on FADs.* Pêche thonière et dispositifs de concentration de poissons, Caribbean-Martinique, 15-19 Oct 1999. https://archimer.ifremer.fr/doc/00042/15278/

Global Fishing Watch. 2023. www.globalfishingwatch.org. Accessed on 18 August 2023.

Gooding, R.M. & Magnuson, J.J. 1967. Ecological significance of a drifting object to pelagic fishes. *Pacific Sci.* 21: 486–497.

Grubb, T.C. 1972. Smell and foraging in shearwaters and petrels. *Nature* 237: 404–405. https://doi.org/10.1038/237404a0

Howell, S.N.G. 2012. *Petrels, albatrosses, and storm-petrels of North America: a photographic guide*. Princeton: Princeton University Press.

Hutchison, L. V & Wenzel, B.M. 1980. Olfactory guidance in foraging by Procellariiforms. *Condor* 82: 314–319. https://doi.org/10.2307/1367400

Industrias Pesqueras. 2021. Acuerdo entre Balfegó, cofradías de pescadores y Mapfre sobre la indemnización por el temporal Gloria. *23/04/2021*. https://industriaspesqueras.com/noticia-65628-sec-Sector Pesquero

Josa, P., Soliño, L. & Solé, J. 2021. High concentrations of European Storm Petrel (H*ydrobates pelagicus* ssp. *melitensis*) at tuna farms in the Western Mediterranean Sea. *Boll. Soc. Hist. Nat. Balears* 64: 23–37.

King, D.T., Blackwell, B.F., Dorr, B.S. & Belant, J.L. 2010. Effects of aquaculture on migration and movement patterns of double-crested cormorants. *Human-Wildlife Interact.* 4: 77–86. http://www.jstor.org/stable/24864505

Machias, A., Karakassis, I., Labropoulou, M., Somarakis, S., Papadopoulou, K.N. & Papaconstantinou, C. 2004. Changes in wild fish assemblages after the establishment of a fish farming zone in an oligotrophic marine ecosystem. *Estuar. Coast. Shelf Sci.* 60: 771–779.

Militão, T., Sanz-Aguilar, A., Rotger, A. & Ramos, R. 2022. Non-breeding distribution and at-sea activity patterns of the smallest European seabird, the European Storm Petrel (*Hydrobates pelagicus*). *Ibis (Lond. 1859).* 164: 1160–1179. https://doi.org/https://doi.org/10.1111/ibi.13068

Mínguez, E. 1994. Censo, cronología de puesta y éxito reproductor del paíño común (*Hydrobates pelagicus*) en la Isla de Benidorm (Alicante E de España). *Ardeola* 41: 3–11.

OceanSnell Marina Consultoría Ambiental. 2020. *Estudio de Impacto Ambiental para tramitación ordinaria del proyecto de ampliación de la concesión y producción de Balfegó Tuna, S.L. para el engorde de Atún Rojo (Thunnus thynnus) en el T.M. de L´Ametlla de Mar (Tarragona)*.

Peters, F., Arin, L., Cros, L. & Sala M, M. 2020. Marine production spikes owing to heavy storm Gloria in a NW Mediterranenan coastal site with a decreasing Chlrophyll trend. P. 104 in: *Abstracts volume VII International Symposium on Marine Sciences. July 1-3.* Barcelona.

Ramírez, F., Afán, I., Tavecchia, G., Catalán, I.A., Oro, D. & Sanz-Aguilar, A. 2016. Oceanographic drivers and mistiming processes shape breeding success in a seabird. *Proc. R. Soc. B Biol. Sci.* 283: 20152287. https://doi.org/10.1098/rspb.2015.2287

Rotger, A., Sola, A., Tavecchia, G. & Sanz-Aguilar, A. 2020. Foraging far from home: Gps-tracking of Mediterranean Storm-Petrels *Hydrobates pelagicus melitensis* reveals long-distance foraging movements. *Ardeola* 68: 3–16. https://doi.org/10.13157/arla.68.1.2021.ra1

Sanz-Aguilar, A. & Lago, P. 2021. Paíño Europeo, *Hydrobates pelagicus*. Pp. 466–472 in: N. López-Jiménez (ed.), *Libro Rojo de las aves de España*. Madrid: SEO BirdLife.

Sanz-Aguilar, A., Zuberogoitia, Í., Sallent, Á., Picorelli, V., Navedo, J. & Garaita, R. 2019. Paíño europeo–Hydrobates pelagicus Linnaeus, 1758. In López, P., Martín, J. & González-Solís, J. (eds.): *Enciclopedia Virtual de los Vertebrados Españoles*. Madrid: CSIC-Museo Nacional de Ciencias Naturales. http://www.vertebradosibericos.org

Skejić, S., Marasović, I., Vidjak, O., Kušpilić, G., Ninčević Gladan, Ž., Šestanović, S. & Bojanić, N. 2011. Effects of cage fish farming on phytoplankton community structure, biomass and primary production in an aquaculture area in the middle Adriatic Sea. *Aquaculture Research* 42: 1393-1405. https://doi.org/10.1111/j.1365-2109.2010.02733.x

Tasker, M.L., Jones, P.H., Dixon, T.I.M. & Blake, B.F. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. *Auk* 101: 567–577.

Thomas, R.J., Medeiros, R.J. & Pollard, A.L. 2006. Evidence for nocturnal inter-tidal foraging by European Storm-petrels *Hydrobates pelagicus* during migration. *Atl. Seabirds* 8: 87–96.

Watanuki, Y. & Thiebot, J.-B. 2018. Factors affecting the importance of myctophids in the diet of the world's seabirds. *Mar. Biol.* 165: 79. https://doi.org/10.1007/s00227-018-3334-y