Harnessing the Power of Social Media to Obtain Biodiversity Data About Cetaceans in a Poorly Monitored Area

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The study and conservation of cetaceans benefit from systematic studies and non-systematic records about sightings and strandings. However, iEcology (internet ecology) was critical for numerous ecological studies and should be in the toolkit of cetacean ecologists. We hypothesize that iEcology is irreplaceable to obtain diversity data about cetaceans in poorly monitored regions that coincide with touristic destinations, where whale-watching companies go out to sea regularly and post their sightings on social media. Our study assessed the advantages and disadvantages of iEcology while obtaining the first broadscale and long-term assessment about cetaceans' diversity off the Algarve, a European tourist destination with numerous whale-watching companies. We retrieved 1,299 time-referenced records about 15 species posted on Facebook and Instagram between 2011 and 2020. Data collected from Biodiversity4All, an online citizen science biodiversity database, disclosed georeferenced records about nine species made between 2008 and 2020, however, the number of records was 15.8 times lower than social media posts. We obtained information about 16 species, two of which were never mentioned in the scientific literature [*Balaenoptera musculus*, *Balaenoptera edeni* (record made in 2021)] and five species were only mentioned in the gray literature. Previous assessments were restricted in time, published in the gray literature, and only reported six and 11 species. So, social media was essential to obtain the first broadscale and long-term assessment of cetaceans' diversity off the Algarve. The main advantages of iEcology were the possibility to obtain data collected over one decade and its low cost. The main disadvantages are the impossibility to obtain georeferenced records from social media, the difficulty to estimate the number of individuals in large groups, and the presence of rare species can be inflated if multiple whale-watching companies report the same individual(s) while they migrate along the coast. Nonetheless, these disadvantages can be mitigated. Overall, we endorse the use of iEcology to increase the ecological knowledge about cetaceans which might be the only tool to study them in numerous regions across the world. The contributions of whale-watching companies are invaluable, so we recommend the implementation of a standardized cetacean observation log as a relevant source of data for conservation.

Keywords: iEcology, social media, biodiversity, cetaceans, whale watching, Algarve, Portugal

INTRODUCTION

Social media has progressively changed how humans interact in the digital landscape, while morphing societies at a fast pace leaving no aspect untouched, including science (Aichner et al., 2021). Social media has evolved over the past decades (Aichner et al., 2021) and is now defined as internet-based applications with user-generated content maintained by the social media service provider which facilitate the development of online networks between individuals or group users (Obar and Wildman, 2015). The most used social media platforms in the world, like Facebook or Instagram, provide generalist platforms for people to interact with acquaintances and others around common interests, or for organizations to convey their messages or sell their products. On the other hand, specialized platforms focus on specific subjects, including biodiversity (e.g., iNaturalist, GBIF- Global Biodiversity Information Facility), therefore being extremely effective in reaching their potential audience despite having a smaller overall audience.

The ever-growing digital data originated from social media and specialized biodiversity platforms have given rise to iEcology (internet ecology) which is expected to become more and more prevalent (Jarić et al., 2020). This new discipline has been defined as an "approach that uses diverse online data sources and methods to generate insights about species distribution over space and time, interactions and dynamics of organisms and their environment, and anthropogenic impacts" (Jarić et al., 2020). iEcology has advantages and disadvantages. Two of the main advantages are it's low-cost for users and the broad geographic scope of the ecological insights that can be obtained (Jarić et al., 2020; Encarnação et al., 2021a,b). On the other hand, species misidentification, focus on charismatic or rare species, and non-random collection of data are some of the disadvantages that iEcologists need to be aware of Jarić et al. (2020). While the posts of general social media platforms can focus on charismatic or rare species, this tends to dilute partially when analyzing data from biodiversity platforms where naturalists or professional ecologists share their observations. One of the most prolific biodiversity platforms is iNaturalist, a biodiversity social media platform with over one million naturalists and scientists registered, where georeferenced photographs of all sorts of species are posted and species identifications are validated by peers (iNaturalist, 2021).

Social media can provide timely information about numerous topics, from public health (Lopreite et al., 2021) to non-indigenous (Azzurro and Tiralongo, 2020) and invasive species (Daume, 2016; Encarnação et al., 2021a), or it can be mined to obtain retrospective ecological assessments (Toivonen et al., 2019). Traditionally, the study and conservation of cetaceans have benefited from systematic records using a multitude of tools aboard scientific ships/aircraft and ships of opportunity (Hammond et al., 2013; Alves et al., 2018; Correia et al., 2021) and from non-systematic records about sightings and strandings (Evans and Hammond, 2004; Li et al., 2021). Nowadays, iEcology is another tool that should be included in the toolkit of cetacean ecologists while being perfected. Some successful examples include the photo-identification of *Tursiops truncatus* in the Irish coast (Gibson et al., 2020) and obtaining estimates of changes in population density of *Delphinus delphis* based on stranded specimens (Robbins et al., 2020). Also, social media records about the presence/absence of cetaceans in the central Tyrrhenian Sea between 2008 and 2017 led to the recommendation of conservation policies (Pace et al., 2019), while in Kenya, a combination of multiple methodologies (dedicated surveys, opportunistic sightings, citizen science) successfully retrieved information about marine mammals over 9 years (Mwango'mbe et al., 2021). Therefore, we hypothesize that iEcology can become particularly useful to study cetaceans in touristic areas, where cetacean watching companies (hereafter referred to as whale-watching) go out to sea regularly and post their sightings on social media. The Algarve, a major European touristic area located in southern Portugal, is the ideal area to test this hypothesis because of the numerous whale-watching companies that exist (Claro, 2009; Sequeira et al., 2009) and the small number of formal scientific studies that have been undertaken in the region.
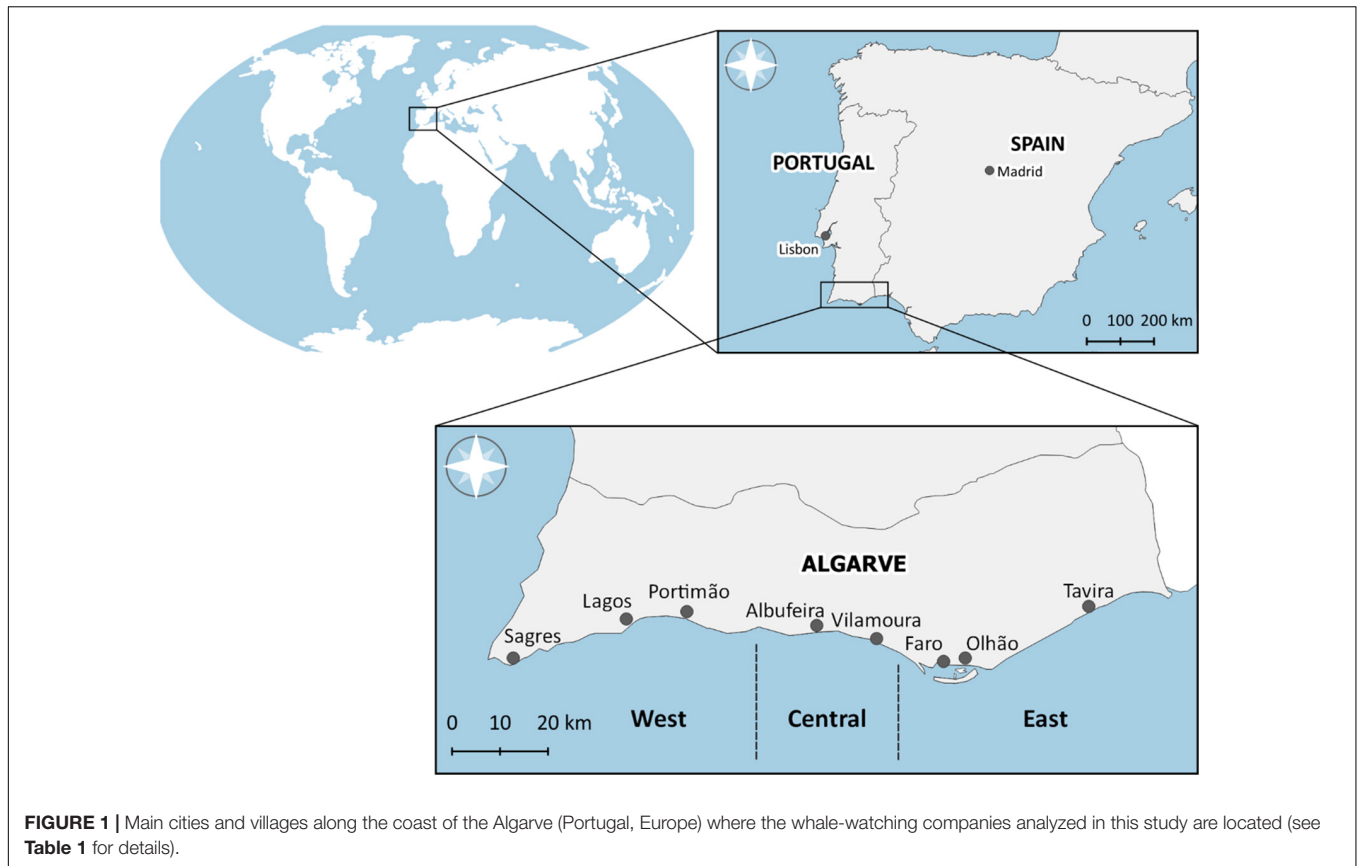
In the Algarve, a long-term monitoring program has never been implemented which is crucial for any robust conservation program. So far, the two most comprehensive studies made about the abundance and distribution of cetaceans in the Algarve are only published as gray literature (Castro, 2010; Laborde et al., 2019). One study registered the presence of six species along a ∼30 km coast stretch in the western Algarve during a little over 8 months (Castro, 2010), while the other study reported the presence of 11 species along the entire region during 6-month periods over 10 years (Laborde et al., 2019). Existing knowledge is mostly published as gray literature, while peer-reviewed publications are scarce and have focused on strandings (Silva and Sequeira, 2003; Sousa and Brito, 2012), aspects of population connectivity (Alves et al., 2019; Dinis et al., 2021) the population ecology of *Delphinus delphis* (Moura et al., 2012; Castro et al., 2020), and *Orcinus orca* (Esteban et al., 2013) description of opportunistic observations (Martin and Walker, 1997; Báez et al., 2007), interaction with fisheries (Goetz et al., 2015; Marçalo et al., 2015), diet (Marçalo et al., 2018, 2021) or diet/trophic ecology (Giménez et al., 2017), behavioral responses to drones (Castro et al., 2021), and epidemiology (Bento et al., 2016).

So, our main goal was to use the social media posts of whale-watching companies located in the Algarve to test our hypothesis and obtain the first broadscale and long-term assessment about cetaceans' biodiversity off the Algarve. We also have three complementary objectives: (i) enumerate the advantages and disadvantages of iEcology to study cetaceans; (ii) compare data from general social media platforms (Facebook, Instagram) and Biodiversity4All to understand if data from these two major sources complement each other; and (iii) propose a methodology to improve and increase the data collected by whale-watching companies.

MATERIALS AND METHODS

Study Area and Whale-Watching

The Algarve is the southern region of Portugal (Europe) and its southern coast extends for 155 km. The eastern area is mostly a sandy coast, only interrupted by the Ria Formosa lagoon and its barrier islands, while the central and western areas are characterized by limestone and sandstone rocky shores

FIGURE 1 | Main cities and villages along the coast of the Algarve (Portugal, Europe) where the whale-watching companies analyzed in this study are located (see **Table 1** for details).

along with pocket sandy beaches and cliffs toward western areas (Moura et al., 2006). The continental platform is wider to the east of Cape Santa Maria (Faro) (>40 km) and with a gentle slope, while it narrows down toward Cape Saint Vincent (Sagres) (<15 km). Here, the slope is steep, and depths of 100 m can be reached within 10 km from the coast (Relvas and Barton, 2002).

The Algarve is the center of the whale-watching industry in Portugal's mainland (Sequeira et al., 2009), an industry that began to operate in 1999 in the Sado estuary (30 km south of Lisbon). The Algarve's whale-watching industry is highly seasonal, with most of the activity occurring from late spring to early fall, nonetheless, some companies operate year-round. In 2018, 35 whale-watching permits were authorized to touristic operators in the Algarve which used 83 boats. A code of best practices to safeguard the wellbeing of cetaceans during the approach and observation of cetaceans is stipulated in decree-law 9/2006 (Governo de Portugal, 2006). This decree-law includes guidelines on the distance that must be kept between the boat and animals during approximation (over 30 m if cetaceans do not actively approach the boat), distance and number of boats allowed near an individual or group of individuals during observation (no more than three boats within a radius of 100 m from cetaceans), duration of the observation (less than 30 min when closer than 100 m), and procedures to perform when cetaceans exhibit stress behaviors (boats must move at least 300 m away from cetaceans) (Governo de Portugal, 2006). Although it is difficult to verify if the law is being implemented to its full extent by the whale-watching

companies, a study already published in 2009 mentions that 66% of customers believed that the regulations were implemented during their trip (Claro, 2009). However, a study done in the region observed that *Tursiops truncatus* exhibits stress reactions to the presence of boats, particularly as the number of boats increases (MacEwan et al., 2016).

Social Media Data

Facebook and Instagram are the social media platforms most used in Portugal, including by whale-watching companies in the Algarve. First, we collected data about which of these companies used Facebook and Instagram to post information about the species they encountered during tours. Those companies that only posted promotional material without time-referenced posts were not considered in our analysis. This has left us with 15 companies that made time-referenced social media posts of cetaceans observed off the Algarve (**Figure 1** and **Table 1**). Then, we retrieved information from every single social media post (photographs and videos) and excluded from the analysis the promotional posts that were not time-referenced. We collected information about the species, date of observation, the minimum number of individuals, and the area where the observation was made in the Algarve (west, central, east). The species identification mentioned in the post description was always confirmed by us.

We calculated the Qualitative Commonness Index (QC Index, %) to assess how common each species was. The QC Index is the ratio between the number of records of species i (S_{i_n}) and the

Whale-watching companies	Location and area of the Algarve	First post on social media	Number of posts
Cape Cruiser	Sagres—west	June 2012	171
Days of Adventure	Lagos—west	August 2012	60
Dolphins Driven	Albufeira—central	July 2011	68
Ecomarine	Faro—east	June 2017	33
Mar Ilimitado	Sagres—west	May 2016	198
Ocean Quest Algarve	Vilamoura—central	April 2018	40
Ocean Vibes	Faro—east	August 2019	49
Ocean4you	Tavira—east	July 2016	10
Passeios Ria Formosa	Olhão—east	February 2014	33
Rota das Ilhas Boat	Olhão—east	June 2018	28
Sabino Tours	Olhão—east	August 2015	27
Sea Dolphins	Portimão—west	March 2018	34
Sealife Dolphin Watching	Lagos—west	June 2016	135
SeaXplorer	Sagres—west	April 2016	222
Wild Watch Algarve	Portimão—west	May 2013	191

number of records of the species with most social media posts (S_{n_max}) (Equation 1).

$$QC\ Index = \frac{S_{i\_n}}{S_{n\_max}} \times 100 \quad (1)$$

Species were classified into four categories, rare ([0–5%], uncommon ([5–50%]), common ([50–80%], and frequent ([80–100%]). We also estimated the minimum number of individuals present in a social media post when the exact number of individuals from a given species was impossible to determine from a photograph or video. This strategy was mainly used to estimate the minimum number of the most common dolphin species in the Algarve, *Delphinus delphis,* and *Tursiops truncatus*.

Citizen Science Data

All data about the cetaceans observed off the Algarve coast available on Biodiversity4All (2021) was retrieved and comprised of all records made between 2008 and 2020. This is a citizen science biodiversity platform available in Portuguese and synchronized with sibling platforms under the iNaturalist.org consortium. Each record contains a photo, date of observation, and is georeferenced. Data were analyzed according to the year of observation, species, and location.

RESULTS

Social Media

A total of 1403 records were retrieved from observations made by 15 whale-watching companies from 2011 to 2020. The majority of social media posts were time-referenced (92.2%, $n = 1,299$), made reference to a single species (83.7%, $n = 1,180$) (**Figure 2A**), and ranged from 1 post in 2011 to 306 posts in 2018 (**Figure 2B**). Facebook was the platform where most posts were made (51.6%, $n = 670$), but its preponderance decreased along time from 100% in 2011 ($n = 1$) and 2012 ($n = 12$) to 34.7% ($n = 114$) in 2018 as the number of posts on Instagram increased ($n_{max} = 215$ (65.4%) in 2018) (**Figure 2B**).
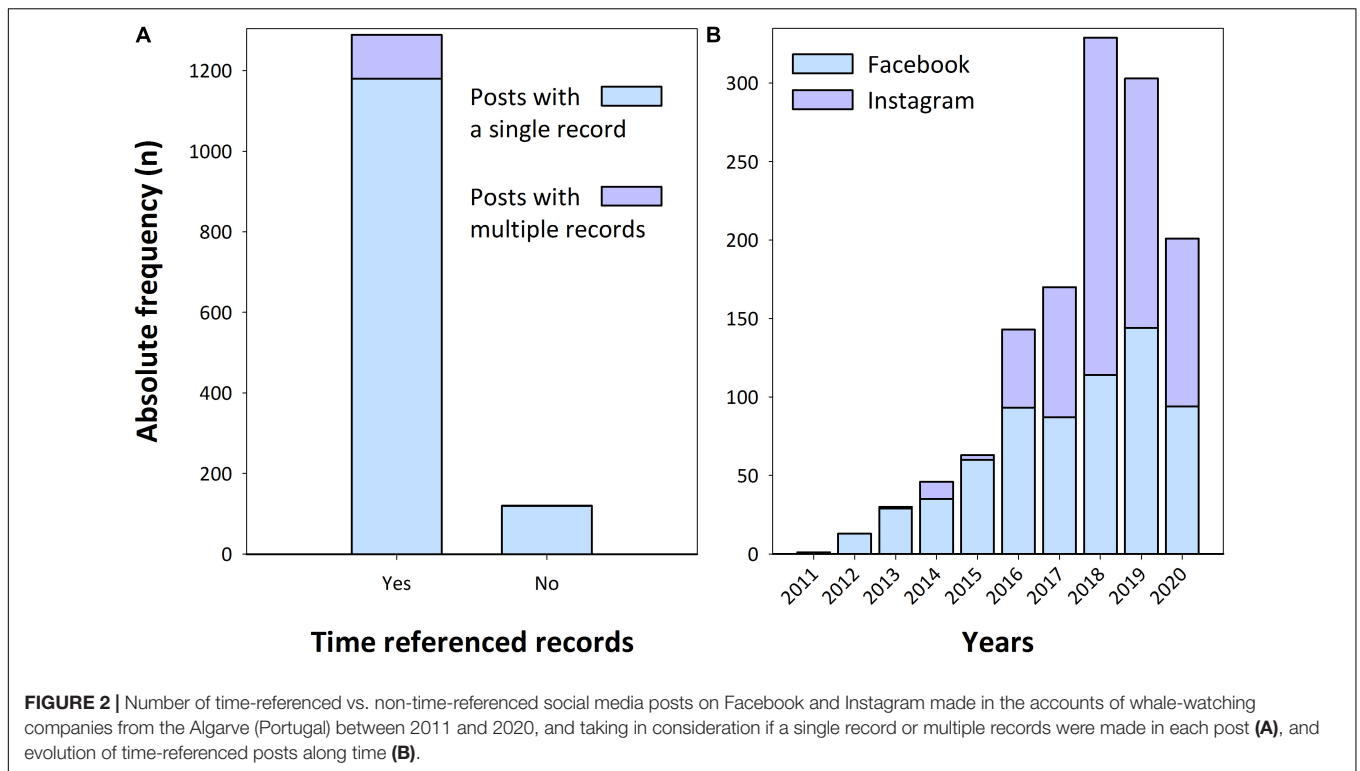
The number of posts peaked in 2018 (25.3%, $n = 329$) (**Figures 2B**, **3A**) and most observations were made in the western region of the Algarve (77.8%, $n = 1,011$) (**Figure 3**) and during the main touristic season (June through September) (65.2%, $n = 847$) (**Figure 3B**). The number of social media posts was lower in the central (8.3%, $n = 108$) and eastern Algarve (13.9%, $n = 180$) during the winter and early spring (December-April, 11.8%, $n = 153$). A total of 15 cetacean species were registered along the Algarve coast: nine odontocetes and five mysticetes, one of which was only mentioned in a promotional post made by Cape Cruiser (western Algarve) in 2014 without being time-referenced—sperm whale *Physeter macrocephalus*. The three most common species on social media posts were *Delphinus delphis* (43.8%, $n = 569$), *Tursiops truncatus* (29.6%, $n = 384$), and *Orcinus orca* (5.1%, $n = 66$) (**Figure 3C**). When analyzing the relative frequency of *Delphinus delphis* and *Tursiops truncatus* in each area of the Algarve, their contribution varied between 42.6–49.4% and 26.3–49.1%, respectively (**Figure 3D**). Unsurprisingly, odontocetes were the most common group depicted in social media posts (90.4%, $n = 1,174$; mysticetes- 9.6%, $n = 125$) (**Figure 3E**).

According to the QC Index categories defined for this work, *Delphinus delphis* was classified as frequent while *Tursiops truncatus* was classified as common, although both were observed year-round. Five species were classified as uncommon (*Balaenoptera acutorostrata*, *Balaenoptera physalus*, *Grampus griseus*, *Orcinus orca*, *Stenella coeruleoalba*) with the relative number of records ranging from 9.5 to 11.6% of the total, while seven species were rare (*Balaenoptera borealis*, *Balaenoptera musculus*, *Globicephala macrorhynchus*, *Globicephala melas*, *Megaptera novaeangliae*, *Phocoena phocoena*, *Pseudorca crassidens*) with the number of records ranging from 0.2 to 3.2% of the total (**Figure 3C**).

The highest means (± standard error; median, n) of the minimum number of individuals registered in each record were 14.1 ± 2.2 (median = 4, $n = 569$) for *Delphinus delphis*, 12.9 ± 4.8 (median = 2, $n = 65$) for *Stenella coeruleoalba*, and 4.6 ± 0.4 (median = 3, $n = 384$) for *Tursiops truncatus* (**Figure 4**). The maximum sum of the minimum number of individuals registered on social media posts in a month was 33 individuals for *Delphinus delphis* (August 2019) and 19 individuals for *Tursiops truncatus* (August 2019 and July 2020) (**Figure 5**). The rarest species, with only one individual reported between 2011 and 2020 were *Balaenoptera borealis*, *Balaenoptera musculus*, *Globicephala macrorhynchus*, and *Pseudorca crassidens* (**Figure 5**).

Citizen Science Data

A total of 82 observations of nine species of cetaceans were registered on Biodiversity4All. Three observations corresponded

FIGURE 2 | Number of time-referenced vs. non-time-referenced social media posts on Facebook and Instagram made in the accounts of whale-watching companies from the Algarve (Portugal) between 2011 and 2020, and taking in consideration if a single record or multiple records were made in each post **(A)**, and evolution of time-referenced posts along time **(B)**.

to stranded individuals—*Balaenoptera acutorostrata* (Altura on Jan 27, 2020), *Delphinus delphis* (Olhão on July 7, 2020, and Faro on July 14, 2020) (**Figure 6A**). The number of observations peaked in 2020 ($n = 28$, 34.1%) (**Figure 6B**) and most records were made in August ($n = 18$, 22.0%) and October ($n = 19$, 23.2%) (**Figure 6C**). Most observations registered were of *Tursiops truncatus* ($n = 32$, 39.0%) and *Delphinus delphis* ($n = 28$, 34.1%) (**Figures 6D,E**). Six species of odontocetes were registered and were also the most common group of cetaceans observed ($n = 76$, 92.7%), while only three species of mysticetes were registered ($n = 6$, 7.3%) (**Figure 6F**). Regarding the minimum number of individuals registered in each record, 95.1% of the records (78 out of 82) varied between 1 and 14 individuals. Larger groups of individuals belonged to three species *Stenella coeruleoalba* (estimate of 1,500 individuals, July 2020, off Faro), *Delphinus delphis* (estimate of 1,000 and 400 individuals, September 2020 and October 2019, both off Faro), and *Tursiops truncatus* (estimate of 150 individuals, August 2019, off Olhão) (**Figure 7**).

DISCUSSION

This study proved the value of iEcology in obtaining fundamental data about cetaceans in a poorly studied region, i.e., spatial and temporal information, presence/absence of species. In the following sections, we provide details that support the value of iEcology to cetacean research, mention its caveats, and recommend a strategy to maximize the information acquired by whale-watching companies during cruises and how it could benefit research and conservation.

Diversity of Cetaceans Off the Algarve

We successfully retrieved spatial and temporal information from the social media of whale-watching companies about 15 cetacean species present or migrating along the coast of the Algarve. The fact that the Algarve is a touristic area certainly contributed to this success. For example, a nationwide approach to monitor marine mammals in Kenya, which used other methodologies (dedicated surveys, opportunistic sightings, citizen science) gathered 792 records over 9 years (2011–2019) (Mwango'mbe et al., 2021). In Italy, 1274 records obtained from Facebook and YouTube during 10 years (2008–2017) disclosed information about the presence/absence of species and habitat selection along a 370 km stretch of the coast in the Tyrrhenian Sea (Pace et al., 2019). In an identical period, the Algarve's whale-watching companies published 1299 time-referenced records on social media during 10 years (1098 records from 2011 to 2019) and along a coastline approximately one-third the size of the Kenyan coast (Mwango'mbe et al., 2021) and part of the examined Tyrrhenian Sea coast (Pace et al., 2019).

Among the records of 15 species that were retrieved from social media between 2011 and 2020, four species were never described in the scientific literature for the Algarve (*Balaenoptera borealis*, *Balaenoptera musculus*, *Megaptera novaeangliae*, *Pseudorca crassidens*) (**Table 2**). Another species that was never mentioned in the scientific literature was *Balaenoptera edeni* which was reported on social media by a whale-watching company on August 23, 2021 (Ocean Vibes Algarve, 2021). Although this record was not made during the temporal scope of this study, we included this species in the list of cetacean species of the Algarve due to its uniqueness and therefore raising
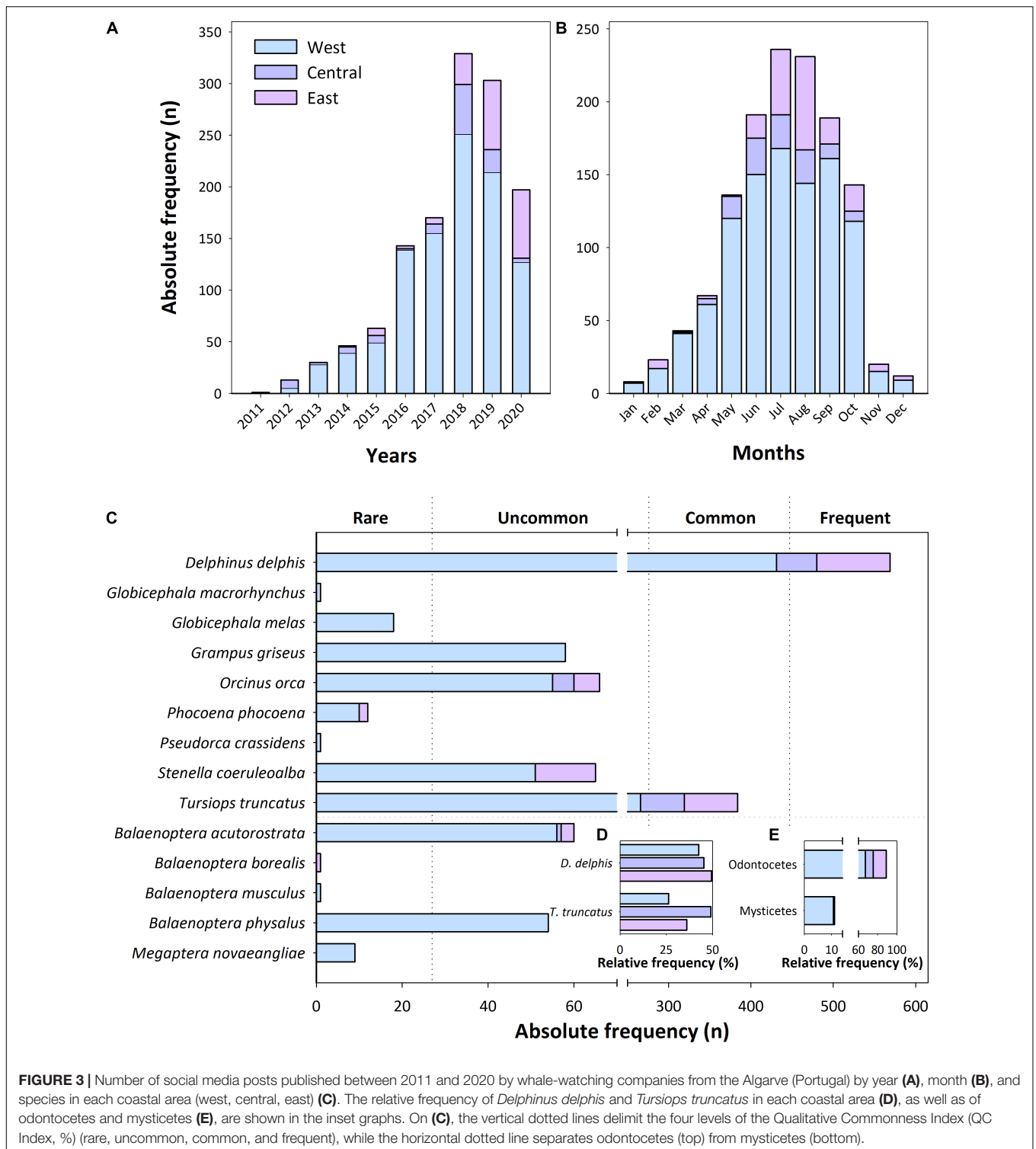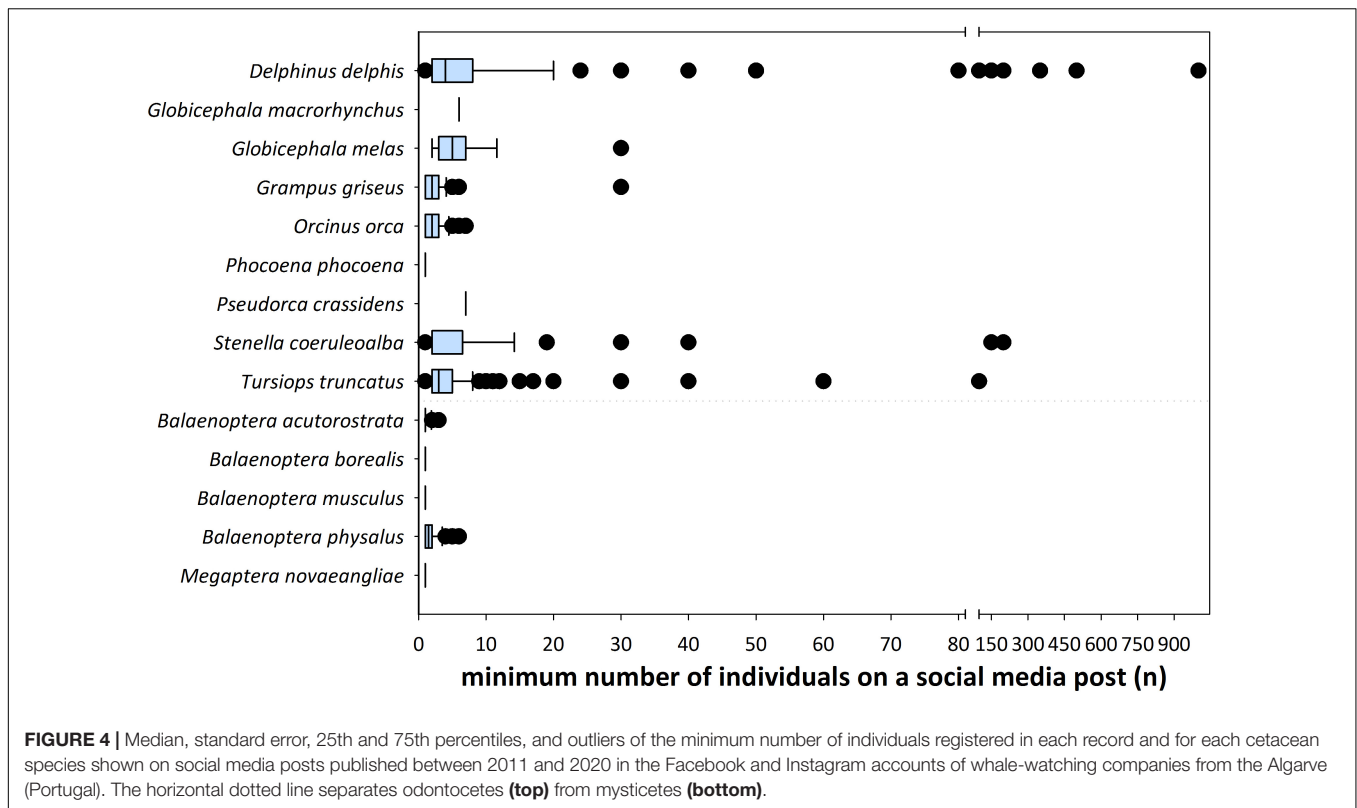
FIGURE 3 | Number of social media posts published between 2011 and 2020 by whale-watching companies from the Algarve (Portugal) by year **(A)**, month **(B)**, and species in each coastal area (west, central, east) **(C)**. The relative frequency of *Delphinus delphis* and *Tursiops truncatus* in each coastal area **(D)**, as well as of odontocetes and mysticetes **(E)**, are shown in the inset graphs. On **(C)**, the vertical dotted lines delimit the four levels of the Qualitative Commonness Index (QC Index, %) (rare, uncommon, common, and frequent), while the horizontal dotted line separates odontocetes (top) from mysticetes (bottom).

the number of species to have ever been observed in the region to 24 (**Table 2**). The record of *Balaenoptera edeni* in 2021—beyond the 10-year scope of our study—shows the importance of continuously monitoring social media in such a poorly monitored region. The three most comprehensive studies made

about the abundance and distribution of cetaceans in the Algarve are only published as gray literature and registered fewer species. One study registered the presence of six species between Sagres and Lagos during a little over 8 months (February 14–October 26, 2009; 412 h; 9599 km)—*Balaenoptera acutorostrata*, *Delphinus*

FIGURE 4 | Median, standard error, 25th and 75th percentiles, and outliers of the minimum number of individuals registered in each record and for each cetacean species shown on social media posts published between 2011 and 2020 in the Facebook and Instagram accounts of whale-watching companies from the Algarve (Portugal). The horizontal dotted line separates odontocetes **(top)** from mysticetes **(bottom)**.

delphis, *Grampus griseus*, *Megaptera novaeangliae*, *Phocoena phocoena*, *Tursiops truncatus* (Castro, 2010). A second study covered the entire region and reported 11 species (*Balaenoptera acutorostrata*, *Balaenoptera borealis*, *Balaenoptera physalus*, *Delphinus delphis*, *Globicephala melas*, *Grampus griseus*, *Megaptera novaeangliae*, *Orcinus orca*, *Phocoena phocoena*, *Stenella coeruleoalba*, *Tursiops truncatus*) between May and October of 2010, until 2019 (Laborde et al., 2019).

Despite that seven species were reported for the Algarve and are missing from the list of species recorded by whale-watching companies on social media (**Table 2**), these species are extremely rare. Six species have only been mentioned in the gray literature, refer exclusively to stranded individuals, and concerning records made between 1978 and 2017 (*Kogia breviceps*- 3 individuals, *Kogia simus*- 2 individuals, *Mesoplodon bidens*- 1 individual, *Mesoplodon europaeus*- 1 individual, *Mesoplodon mirus*- 5 individuals, *Ziphius cavirostris*- 2 individuals) (Sabino-Marques, 2005; Carvalho, 2018; Carvalho et al., 2019, **Table 2**). The other species, *Eubalaena glacialis*, was only mentioned in one peer-reviewed publication describing the sighting of one adult and a calf which made from land in February 1995 (Martin and Walker, 1997). Although the record of *Physeter macrocephalus* reported in our study was not time-referenced, we decided to keep it in the list of species registered by whale-watching companies because there is only one reference about this species in peer-reviewed articles mentioning a mass stranding of 10 individuals in 1784 in Olhos de Água (4 km to the east of Albufeira) (Sousa and Brito, 2012).

In the Algarve, the citizen science biodiversity platform (Biodiversity4All) did not complement the records from social media (Facebook and Instagram), yet its greatest advantage is that provides georeferenced records. The number of records on Biodiversity4All (82 records) was 15.8 times lower than social media posts (1299 posts) and only gathered information of nine species, but both datasets revealed the same trend in terms of proportions between odontocetes and mysticetes. The use of online biodiversity platforms should not be abandoned because its relevance is uneven around the world (iNaturalist, 2021) and increases if a citizen science project requests the upload of records into a platform (Encarnação et al., 2021b; Rodriguez et al., 2021). So, the solution is to continue promoting citizen science as a whole and incentivize people to share their sightings about cetaceans on online biodiversity platforms. Despite the few records made in the Algarve and available on Biodiversity4All, these could still improve the information shown on the Atlas of marine mammals in Portugal (Moura et al., 2019), including for the most common species (*Delphinus delphis*, *Tursiops truncatus*) or if records overlap with existing locations (*Grampus griseus*). This is so because continued monitoring of occurrence and abundance is an important component of management and conservation, and these platforms provide a unique opportunity for this information to continue to be collected, especially given that the government or other organizations are unlikely to be able to conduct periodic monitoring surveys. For the other seven species, Biodiversity4All would provide the first record of a species in the Atlas for the Algarve (*Balaenoptera physalus*) or
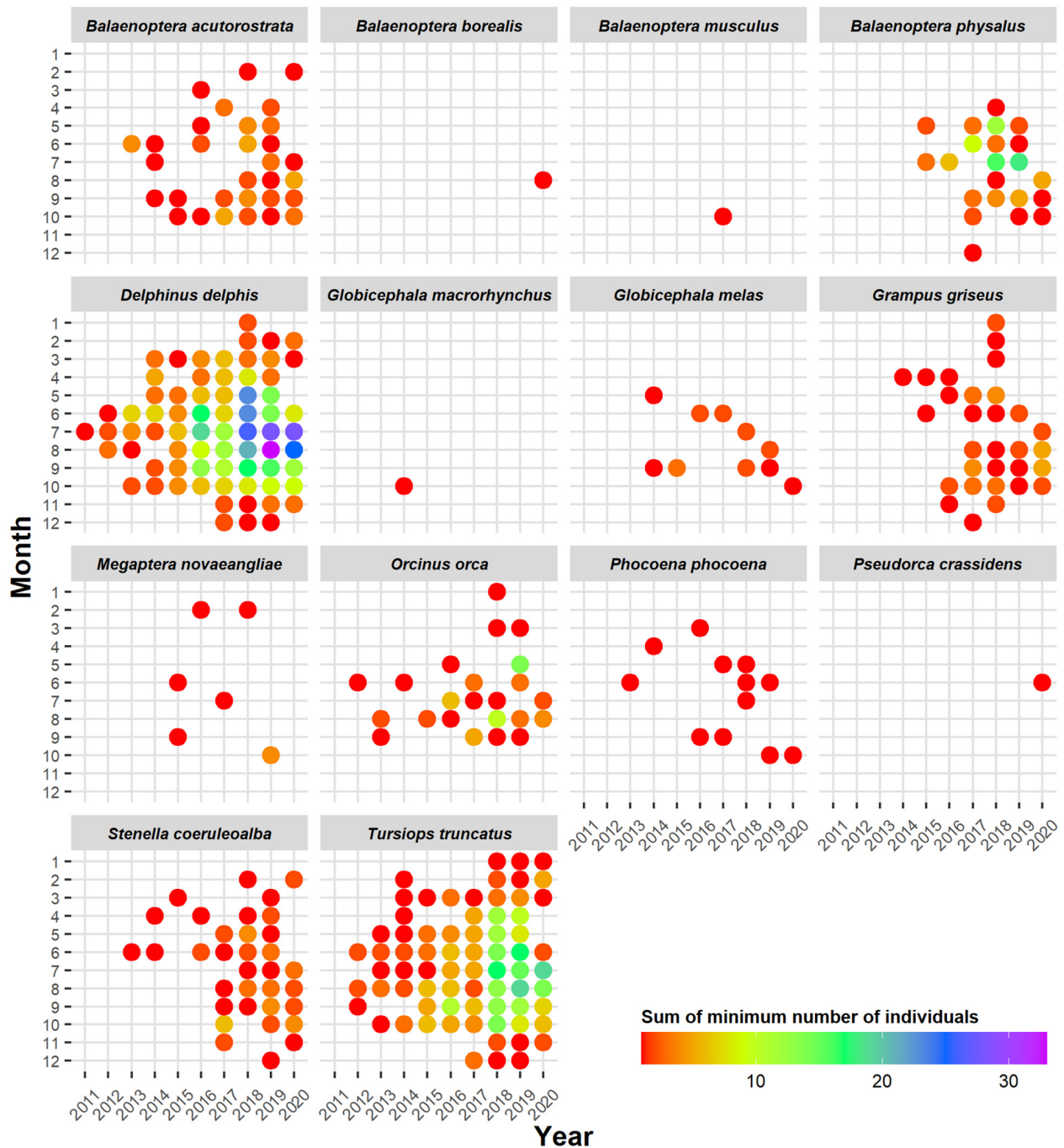
FIGURE 5 | Monthly sum of the minimum number of individuals of each cetacean species shown on social media posts published between 2011 and 2020 in the Facebook and Instagram accounts of whale-watching companies from the Algarve (Portugal).

would increase the low number of records in the Algarve, which vary from four records for *Balaenoptera physalus* and *Stenella coeruleoalba* to nine records for *Balaenoptera acutorostrata*.

The whale-watching industry is highly seasonal, so it was unsurprising that 86.7% of records made on social media were made during 6 months—between May and October. Despite

the industry's seasonality, some companies operate year-round, so we gathered records made every single month of the year in the 2 years before the COVID-19 pandemic (2018, 2019). Most species were observed in every season except for the rarest species—*Balaenoptera borealis*, *Balaenoptera musculus*, *Megaptera novaeangliae*, and *Pseudorca crassidens* (see **Figure 5**
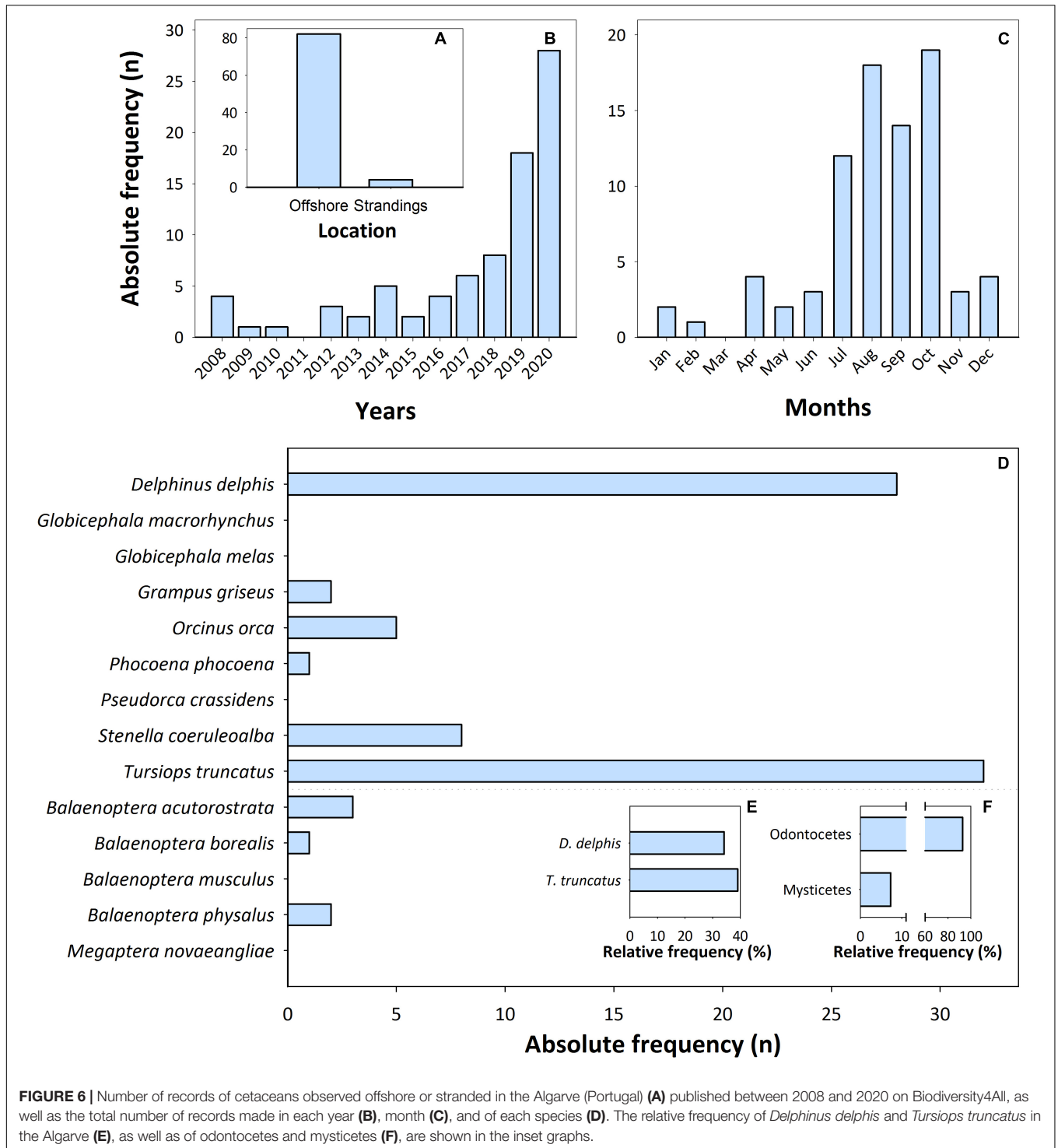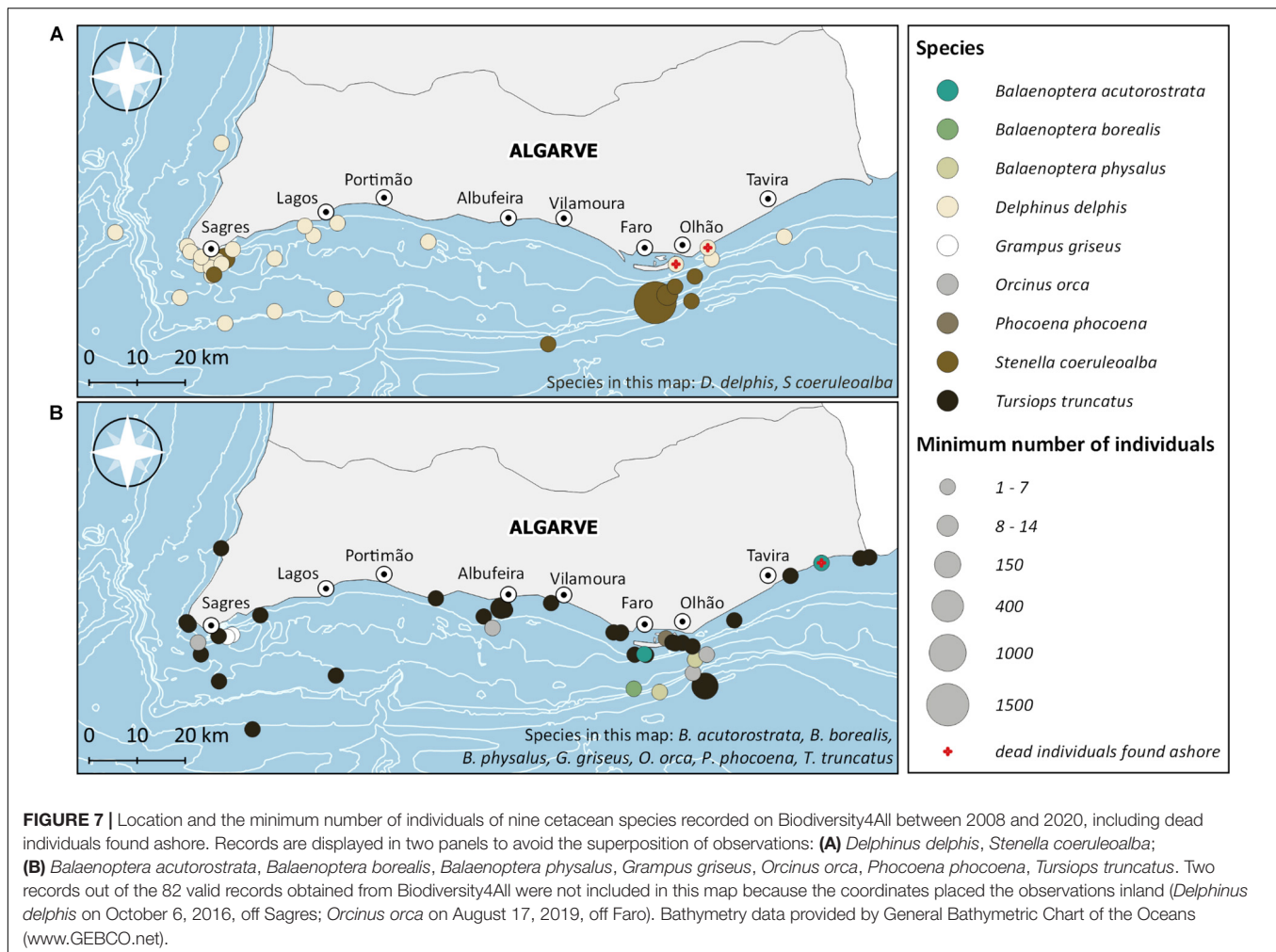
FIGURE 6 | Number of records of cetaceans observed offshore or stranded in the Algarve (Portugal) (A) published between 2008 and 2020 on Biodiversity4All, as well as the total number of records made in each year (B), month (C), and of each species (D). The relative frequency of *Delphinus delphis* and *Tursiops truncatus* in the Algarve (E), as well as of odontocetes and mysticetes (F), are shown in the inset graphs.

for details). The identification of seasonality patterns of presence or abundance is still impossible to disentangle because the observation effort is unknown. Because of this, one of the major concerns about iEcology is the over-representation of emblematic or rare species. This can certainly be the case with cetaceans since rare dolphins or whales attract more attention and clients

for whale-watching companies. Although we cannot evaluate this aspect with accuracy, we estimate that odontocetes are slightly underrepresented in our study. A field study with a total effort of 3,768 h, made onboard the boats of whale-watching companies off the Algarve, registered 97.0% of odontocetes (May-October 2010, 2011, 2012) (Castro et al., 2013b), while they represent

FIGURE 7 | Location and the minimum number of individuals of nine cetacean species recorded on Biodiversity4All between 2008 and 2020, including dead individuals found ashore. Records are displayed in two panels to avoid the superposition of observations: **(A)** *Delphinus delphis*, *Stenella coeruleoalba*; **(B)** *Balaenoptera acutorostrata*, *Balaenoptera borealis*, *Balaenoptera physalus*, *Grampus griseus*, *Orcinus orca*, *Phocoena phocoena*, *Tursiops truncatus*. Two records out of the 82 valid records obtained from Biodiversity4All were not included in this map because the coordinates placed the observations inland (*Delphinus delphis* on October 6, 2016, off Sagres; *Orcinus orca* on August 17, 2019, off Faro). Bathymetry data provided by General Bathymetric Chart of the Oceans (www.GEBCO.net).

90.4% of the records on social media. Whales are indeed far rarer off the Algarve, so any sighting of mysticetes is more likely to be announced on social media.

Despite the caveats (unknown observation effort, putative misrepresentation of rare species, low spatial resolution), this study clearly showed how useful the social media of whale-watching companies can become to reveal the diversity of cetaceans in touristic areas. We obtained the longest time series of occurrences so far in the Algarve. In coming years, with more and more frequent reports in social media posted by whale watching companies, as already shown in 2018 and 2019 (before the COVID-19 pandemic), progress in social media data-mining, and increased awareness about citizen science, it may be possible to extract long-term trends or changes in abundance as crude indicators of ecological trends.

Advantages and Disadvantages of iEcology to Study Cetaceans

The use of generalist social media can play an important role in conservation science if the research questions and interpretation of data acknowledge the limitations of this approach (Aravind, 2013; Di Minin et al., 2015). In the case of the Algarve, data from

a biodiversity platform did not enrich the information already obtained with the social media platforms. This is likely to be different in other regions of the world where both data sources add significant value to the general dataset, or that social media is far less relevant.

This work revealed that the greatest advantages of iEcology to study cetaceans is the possibility to obtain numerous records made throughout a long period [1381 records—1299 records on Facebook and Instagram since 2011, and 82 records on Biodiversity4All since 2008] and even georeferenced [only with Biodiversity4All], besides its low cost. We identified three disadvantages. First, it is impossible to obtain the precise location where the observations reported on Facebook and Instagram were made—although this can be minimized since whale-watching companies operate along a restricted stretch of the coast (up to 10 miles from the coast) and in the vicinity of the port where they are based. Currently, EXIF data (Exchangeable Image File Format) is removed from photos posted on Facebook and Instagram before they are published so it is impossible to obtain georeferenced information if that was included in the photograph. Second, it is difficult to estimate the number of individuals of large groups of dolphins—mainly *Delphinus delphis* and *Tursiops truncatus* off the Algarve. In this region,

TABLE 2 | List of the 24 cetacean species that have ever been registered in the Algarve.

Cetaceans of the Algarve	Conservation status	This study	Peer reviewed	Gray literature
Balaenoptera acutorostrata Lacépède, 1804 Common minke whale	LC[1,2]	✓	Q	D, E, F, G, I, T, U
Balaenoptera borealis Lesson, 1828 Sei whale	EN[1,2]	✓	–	F, I, T, U
Balaenoptera edeni Olsen, 1913 Bryde's whale	LC[1]	✓	–	–
Balaenoptera musculus Linnaeus, 1758 Blue whale	EN[1,2]	✓	–	–
Balaenoptera physalus Linnaeus, 1758 Fin whale	VU[1,3]/NT[2]	✓	AF	F, I, S, U, AE
Delphinus delphis Linnaeus, 1758 Short-beaked common dolphin	LC[1]/DD[2]/EN[3]	✓	J, K, Q, Y, Z, AC, AG	E, F, G, H, I, O, S, U,AF
Eubalaena glacialis Müller, 1776 North Atlantic right whale	CR[1,2]	–	AB	–
Globicephala macrorhynchus Gray, 1846 Short-finned pilot whale	LC[1]	✓	B	–
Globicephala melas Traill, 1809 Long-finned pilot whale	LC[1]/DD[3]	✓	Q	F, U, AF
Grampus griseus G. Cuvier, 1812 Risso's dolphin	LC[1]/DD[2,3]	✓	Q	E, F, G, I, R, U, AD, AF, AI
Kogia breviceps de Blainville, 1838 Pygmy sperm whale	DD	–	–	E, AF
Kogia sima Owen, 1866 Dwarf sperm whale	LC[1]/NA[2]	–	–	E, AF
Megaptera novaeangliae Borowski, 1781 Humpback whale	LC[1,2]	✓	–	E, G, T, U
Mesoplodon bidens Sowerby, 1804 Sowerby's beaked whale	LC[1]/DD[2]	–	–	F
Mesoplodon europaeus Gervais, 1855 Gervais' beaked whale	LC[1]/DD[2]	–	–	E
Mesoplodon mirus True, 1913 True's beaked whale	LC[1]/DD[2]	–	–	E, F
Mesoplodon spp. beaked whale	–	–	–	F, AF
Orcinus orca Linnaeus, 1758 Killer whale	DD[1,2]/CR[4]	✓	N, Q	U, AE
Phocoena phocoena Owen, 1846 Harbour porpoise	LC[1]/VU[2]	✓	Q	C, E, F, G, I, U, AF
Physeter macrocephalus Linnaeus, 1758 Sperm whale	VU[1,2]/EN[3]	✓	Q, AH	B, C, V
Pseudorca crassidens Owen, 1846 False killer whale	NT[1]/NA[2]	✓	–	E, F, AF
Stenella coeruleoalba Meyen, 1833 Striped dolphin	LC[1]/DD[2]/VU[3]	✓	Q, AA	E, F, U, AF
Tursiops truncatus Montagu, 1821 Common bottlenose dolphin	LC[1]/VU[3]	✓	K, M, P, Q	A, E, F, G, I, L, U, V, W, X, AF, AJ
Ziphius cavirostris Cuvier, 1823 Cuvier's beaked whale	LC[1]/DD[2,3]	–	–	E, F, AF

Here, we mention if these species were reported by this study, peer-reviewed articles (14 articles), and/or mentioned in the gray literature (22 studies). The conservation status of each species (IUCN Red List, 2021) and the geographical scope of the assessment are shown [1- global, 2- Europe, 3- Mediterranean Sea, 4- Strait of Gibraltar subpopulation, NA, not applicable; DD, data deficient; LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered; CR, critically endangered]. References: A- Almeida (2017), B- Alves et al. (2019), C- Borges and Magalhães (2016), D- Castelo and Magalhães (2016), E- Carvalho (2018), F- Carvalho et al. (2019), G- Castro (2010), H- Castro et al. (2013a), I- Castro et al. (2013b), J- Castro et al. (2020), K- Castro et al. (2021), L- Cid et al. (2013), M- Dinis et al. (2021), N- Esteban et al. (2013), O- Galego et al. (2014), P- Giménez et al. (2017), Q- Goetz et al. (2015), R- Laborde et al. (2011), S- Laborde et al. (2012), T- Laborde et al. (2015), U- Laborde et al. (2019), V- MacEwan et al. (2016), W- Magalhães (2016), X- Magalhães and Claro (2013), Y- Marçalo et al. (2015), Z- Marçalo et al. (2018), AA- Marçalo et al. (2021), AB- Martin and Walker (1997), AC- Moura et al. (2012), AD- Poças and Magalhães (2019), AE- Pereira et al. (2012), AF- Sabino-Marques (2005), AG- Silva and Sequeira (2003), AH- Sousa and Brito (2012), AI- Stekke et al. (2011), AJ- Vieira (2017).

groups of *Delphinus delphis*, including newborns and calves, can reach up to 1,000 individuals and averaging 31.0 ± 51.6 individuals (Moura et al., 2012; Castro et al., 2020), however, the average of the minimum number of individuals we retrieved from social media was two times lower—14.1 ± 53.5 individuals. This is less problematic for most species because they were present in small groups, or the posts often mentioned the number of individuals observed. The third disadvantage concerns rare or uncommon species because multiple whale-watching companies along the coast can post photographs/videos of the same individual(s), therefore artificially inflating the presence of the species in a given region.

Overall, when taking into consideration the advantages of iEcology and if the disadvantages are carefully assessed and disclosed, social media posts from whale-watching companies can reveal critical information about cetaceans in poorly monitored regions of the world. Eventually, iEcology data from these regions can lead to the proposal and implementation of conservation plans (Pace et al., 2019) and other studies (e.g., photo-identification) (Gibson et al., 2020), or more importantly, providing valuable information for the inventory of the global conservation status of cetaceans by the International Union for Conservation of Nature (IUCN).

Developing the Cetacean Observation Log as a Conservation Tool

Social media can complement and, in some situations, compensate for the lack of field studies (Toivonen et al., 2019; Jarić et al., 2020; Al Mabruk et al., 2021), particularly when the goal is to record the absence/presence of species. However, social media data may be very volatile and ephemerous because a social media platform may close, an account can be eliminated if a whale-watching company closes, or relevant posts for ecologists can be deleted at the company's discretion. This weakness could be partially alleviated if whale-watching companies also posted their daily encounters on their websites (e.g., Monterey Whale Watching—montereywhalewatching.com/category/daily sightings) or by making their data available for the scientific community on more robust platforms or data repositories.

We have shown that the social media of whale-watching companies from the Algarve provided quality information

that cannot be neglected by cetacean scientists, NGOs, and national and international environmental agencies. Several whale-watching companies have already contributed to many scientific studies and play a determinant educational role, however, there are unexplored opportunities for environmental agencies and academia to collaborate with them and obtain standardized data. We are convinced that whale-watching companies would likely be willing to contribute with more detailed information if that would be requested by national environmental agencies. We propose the creation of an official standardized cetacean observation log for whale-watching companies to register the observations made in each trip, the equivalent—in concept—to the information that fishing boats need to register about their fishing activities. The cetacean observation log could be uploaded on a public biodiversity database—once validated—to provide timely information to scientists, NGOs, and environmental agencies similarly to national official fishing stats. The information that could be included in the log of each trip would be the length of each trip, coordinates of where each species was observed, time, number (or estimate) of individuals observed, presence/absence of newborns or calves and how many, behavior (e.g., traveling, preying, playing, type of interaction with other species), the direction of swimming (i.e., to the east, west, south, north), and conditions of the sea and wind (Beaufort wind force scale, Douglas sea scale). The Algarve has shown to be the ideal region to test the applicability of a standardized cetacean observation log as a source of information for conservation policies which could then be adopted by other countries in the European Union and around the world.

CONCLUSION

The social media posts of whale-watching companies located in the Algarve were essential to obtain the first broadscale and long-term assessment of cetaceans' diversity off the Algarve. Social media platforms (Facebook, Instagram) provided substantially more information than a citizen science biodiversity platform (Biodiversity4All), and data from the latter did not complement the information already retrieved from social media. However, this reflects the particular context of where this study was made and not a pattern that is mirrored in other regions of the world. The main advantage of iEcology to study the cetaceans off the Algarve was the possibility to obtain data collected over one decade, besides its low cost. The main disadvantages of data retrieved from social media are the impossibility to obtain a precise location where the observations were made, difficulty to estimate the number of individuals of large groups of individuals, and the likelihood of inflating the presence of rare species if multiple whale-watching companies post photographs/videos of the same individual(s) while they migrate along the coast. Nonetheless, these disadvantages can be mitigated. Overall,

iEcology can be useful to increase the ecological knowledge about cetaceans in regions of the world where scientific data is scarce or inexistent. The creation and implementation of a cetacean observation log filled by whale-watching companies would provide critical information for conservation policies. So, scientists and environmental agencies should proactively pursue collaborations with whale-watching companies to implement this strategy around the world.

DATA AVAILABILITY STATEMENT

The datasets presented in this article will be made available upon request and full disclosure of its use. Reuse of data and incorporation into other datasets is possible upon agreement. Requests to access the datasets should be directed to the corresponding author.

ETHICS STATEMENT

Ethical review and approval was not required for the animal study because this study obtained data from social media posts (Facebook, Instagram) published by whale watching companies and others available on Biodiversity4All, a citizen science biodiversity database.

AUTHOR CONTRIBUTIONS

PM conceptualized the study, obtained the funding, coordinated data collection, revised the data, analyzed the data, and wrote the article. LA collected the data and revised the article. ED conceptualized the study, obtained the funding, and revised the article. All authors contributed to the article and approved the submitted version.

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