# The killer whale (*Orcinus orca*) in the Caribbean Sea: an updated review of its ecology, exploitation, and interactions with fisheries

# La orca (*Orcinus orca*) en el mar Caribe: una revisión actualizada de su ecología, explotación e interacciones con pesquerías

# L'orque (*Orcinus orca*) dans la mer des Caraïbes : état des lieux actualisé de son écologie, de son exploitation et de ses interactions avec les pêcheries

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**ABSTRACT**

The killer whale (*Orcinus orca*) is a cosmopolitan marine cetacean distributed worldwide. Extensive studies have described their ecology and behavior across multiple polar and temperate regions. Conversely, limited information on their distribution, ecological roles and abundance has been documented from tropical and subtropical regions. Here, we build on previous work to update information on the spatial-temporal distribution, exploitation, and natural history of killer whales in the Caribbean Sea. We also document new records on their interaction with human activities. We collected 356 records from the literature, biodiversity information systems, internet (social networks and video hosting websites), and citizen-based initiatives. Records included sightings (87.1%), intentional captures (10.9%), bycatch (0.3%), and strandings (1.7%). The origin of the records included research projects/activities (46.4%), citizen-based initiatives (40.2%), logbooks from the 19th century whaling industry (2.2%), intentional takes (10.9%), and bycatch (0.3%). Records were distributed in the Eastern Caribbean (36.6%), the Greater Antilles (23.3%), the southern Caribbean (20.8%), the Bahamas (12.6%) and Central America (6.7%). Killer whales were recorded all year round, but most records were reported in the warmer months. Our dataset confirms the regular and widespread occurrence of killer whales throughout the Caribbean Sea. Low densities and limited predictability of their occurrence hinders dedicated research on this species. This study supports the growing importance of opportunistic observations by citizen-scientists to document the occurrence and ecology of this species in the Caribbean.

KEYWORDS: Western tropical Atlantic, occurrence, feeding ecology, exploitation, bycatch

## INTRODUCTION

Cetacean diversity of the Caribbean Sea is relatively high, including at least 31 species recorded (Ward and Moscrop, 1999; Ward et al., 2001; Debrot et al., 2013; Lucke et al., 2014). However, knowledge on these species in the region is limited, and for most species, their occurrence, distribution, and movement patterns remain poorly understood (Ward et al., 2001; Luksenburg, 2014; Lucke et al., 2014). This lack of information is largely due to the paucity of systematic surveys in the region, despite more extensive efforts in recent years (2012-2022), mainly in the Eastern Caribbean (Gandilhon et al., 2012; Mannocci et al., 2013; Debrot et al., 2013; Geelhoed et al., 2014; Van Canneyt et al., 2018) and the Greater Antilles (Stevick et al., 2018; MacKay et al., 2019). The paucity of data is due to the limited capacity of most states from the region to carry out dedicated research that is time consuming and costly.

During the last decade, the increased quality and availability of digital cameras and mobile phones with high-resolution cameras has led to an increase of new image data through "citizen-based science" (Andrachuk et al., 2019; García-Soto et al., 2021). The growing documentation of opportunistic sightings of wildlife species by non-specialists, coupled with increased data sharing on social networks and video-hosting websites (e.g., www.youtube.com), has created a major source of potentially valuable information for cetacean biologists and conservationists. In cetaceans, for example, citizen-based initiatives have contributed to improve the knowledge on ecology, distribution and densities of these species in British Columbia in Canada (Harvey et al., 2018), the strait of Sicily in Italy (Alessi et al., 2019), and Chile (García-Cegarra et al., 2021). In the Caribbean Sea, citizen-science data were used to model habitat preferences of pantropical spotted dolphins (*Stenella attenuata,* Barragán-Barrera et al., 2019; Courtain et al., 2022) and the migratory movements of humpback whales (*Megaptera novaeangliae*; Stevick et al., 2018).

The killer whale (*Orcinus orca*) is a cosmopolitan cetacean distributed worldwide (Jefferson et al., 2015) capable of extensive movements. Satellite telemetry and photo-identification methods suggest that some individuals can travel over 8,000 km between ocean basins (Guerrero-Ruiz et al., 2005; Matthews et al, 2011; Durban and Pitman, 2012). Most research on the biology and ecology of killer whales has been carried out in polar and temperate waters across the globe,

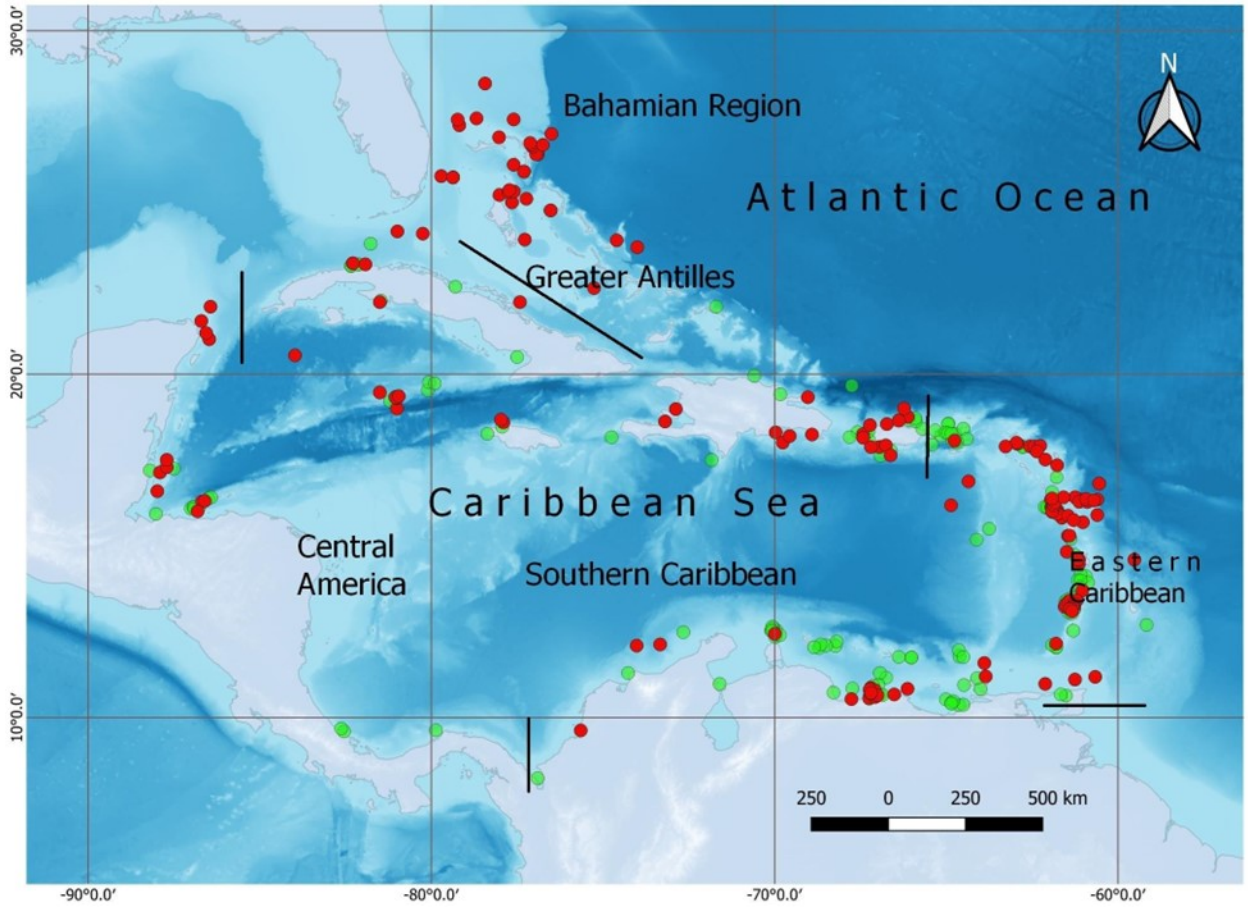


**Figure 1.** Spatial distribution of killer whale records in the Caribbean Sea. Green dots: records published in Bolaños Jiménez et al. 2014 (*n* = 176, 1866-2012); red dots: new records (*n* = 180, 1851-2022). Black lines indicate separation among ecoregions

whereas information on their behavior, occurrence, and natural history is generally lacking in tropical and subtropical regions (Bolaños-Jiménez et al., 2014).

Until 2014, most of the information of the occurrence and exploitation of killer whales in the Caribbean Sea was scarce and limited to whaling records from the southeastern Caribbean, particularly in St. Vincent and the Grenadines (Caldwell and Caldwell, 1971; Caldwell et al., 1975; Price, 1985). Additional records came from a review of the sightings and takes by the former "American pelagic" whaling fleet that operated in the north Atlantic (1851-1894; Reeves and Mitchell, 1988) and a literature review of records collected in the central-western Atlantic by Katona et al. (1988).

Over the past two decades, there has been an increase in published reports on killer whales from tropical and subtropical regions (Bolaños-Jiménez et al., 2014; Pitman et al., 2015; Rankin et al., 2013; Testino et al., 2019; Weir et al., 2010; Whitt et al., 2015; Denkinger et al., 2020; Vargas-Bravo et al., 2020; Kiszka et al., 2021; Iñiguez et al. 2021; Terrapon et al., 2021; Castro Azofeifa, 2021). For most published studies, sample sizes are small, and most records are based upon opportunistic records. However, the recent description of a previously unidentified tropical ecotype of the killer whale in the Eastern Tropical Pacific (Vargas-Bravo et al., 2020) highlights the need to assess the ecology, population identity, and behavior of killer whales in low latitudes.

Previous reviews on the spatial-temporal distribution, diet, and morphology of killer whales in the Caribbean Sea (Bolaños-Jiménez et al., 2009; 2014) were based on the combination of a literature review, field data, citizen-based contributions, and access to databases of research teams working in the study area. Here, we build on previous knowledge of this species in the Caribbean Sea using up-to-date information on observations, captures, and fisheries interactions of killer whales in this region.

## METHODOLOGY

The region of interest for this review is the Caribbean Sea (Fig. 1), that was further divided into five ecoregions (Spalding et al., 2007; Bolaños-Jiménez et al., 2014): the Bahamian region, the Greater Antilles, the eastern Caribbean, the southern Caribbean, and Central America. Following Jefferson et al. (2009) and Bolaños-Jiménez et al. (2014), information on killer whale occurrence in the

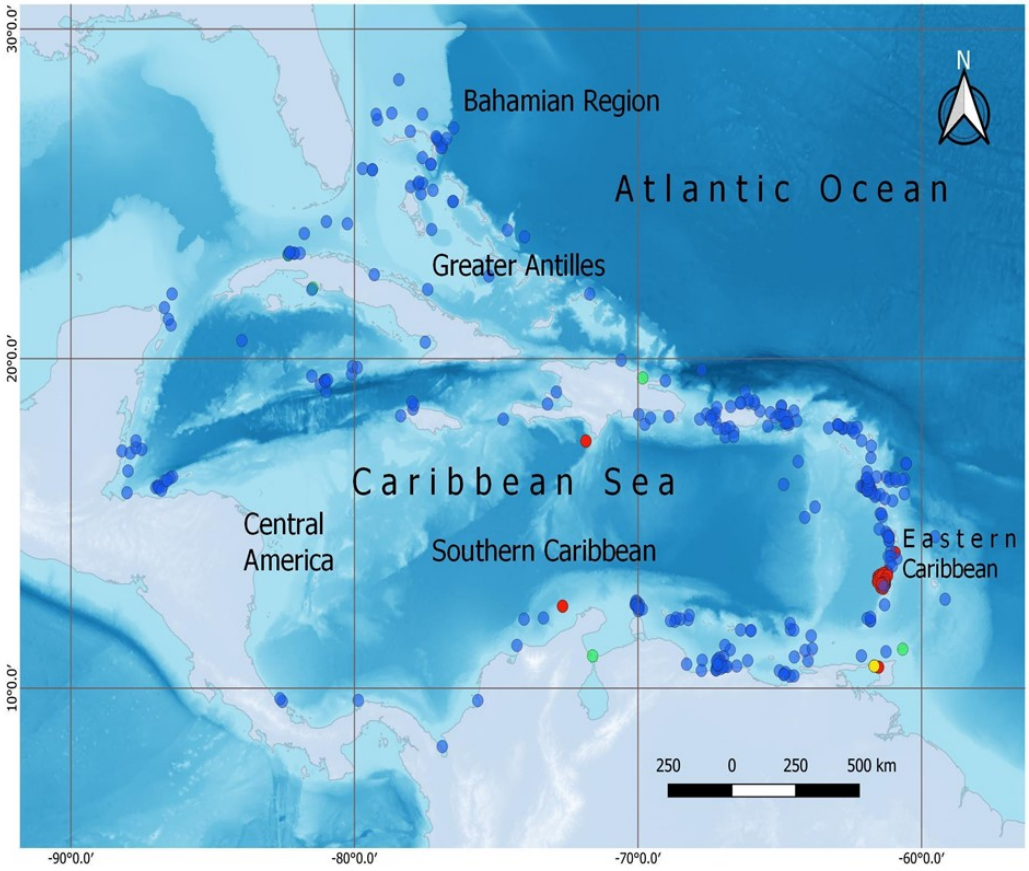


**Figure 2**. Killer whale records in the Caribbean Sea by record type. Blue dots: sightings; red dots: intentional capture; yellow dots: bycatch; green dots: strandings.

study area was gathered and validated by reviewing the literature and biodiversity information systems (for example OBIS SEAMAP, www.obsenmer.org, www.observation.org), as well as from reports submitted directly to the authors and collaborators by interested parties (experienced observers, local NGOs), posts in social media, video-hosting websites, and citizen-based initiatives. The records were classified as sightings, strandings, intentional captures, and bycatch. The records were also classified based on their origin in takes, mention in logbooks from whaling ships operating in the nineteenth century in the North Atlantic and Caribbean, sightings from dedicated surveys or collected opportunistically by experienced observers, and citizen-science initiatives. Records provided by the public through citizen-based initiatives, or any multimedia material uploaded to video-hosting websites or shared in social media were assigned to the category "citizen-based initiatives". Sightings from dedicated surveys and literature reviews were considered as originated by "scientific research/activities".

All confirmed records that counted on the date and GPS coordinates were added to the database. In those cases, in which GPS coordinates were not provided but the observers indicated the distance to the coast and/or a reference point, we estimated approximate coordinates, added them to the database and plotted the records (Katona et al., 1988; Jefferson et al., 2009). For those captures reported in St. Vincent and the Grenadines, we assigned coordinates based on the existing knowledge of the known fishing grounds of the Barrouallie fleet, as described by Fielding (2010, fig. 4.7). The coordinates were entered into the freely available geographical information system QGIS v. 3.22 (QGIS.ORG, 2022) to visualize the spatial distribution of records. Other information for each record included the source and origin of the record, group size and composition (e.g., presence of calves, females or juveniles) and links to social media. The identification of each record was evaluated, and coded with one of two confirmation codes (modified from Jefferson et al., 2009):

**(1) Confirmed**: Records that included videos, photographs or the explicit description of diagnostic characters, and/or validation by another knowledgeable cetologist.

**(2) Rejected**: Records lacking availability of diagnostic characters and that were of doubtful accuracy. These records were not included in the analysis.

We also conducted a regular, manual search of pictures and videos of species on the internet, social media, video-hosting websites and online biodiversity information systems (v.gr. OBIS SEAMAP, www.observation.org, www.obsenmer.org). All the new records included in this

review were reviewed and validated by the lead author (JBJ) before being added to the dataset. Any published information on the occurrence, ecology and exploitation of killer whales in the Caribbean region was also compiled. Whenever possible, interactions with other species (i.e., sea turtles, fish, other cetaceans) were documented. Interactions with boats and fishing gear were also recorded. We defined "interaction" as any approach to, or swimming at the sides, of the whales to either a recreational boat, a fishing boat, nets or fishing lines.

RESULTS

We compiled 356 records of killer whales in the Caribbean Sea from May 1851 to January 2022. Of these, 176 records were previously published in Bolaños-Jiménez et al. (2014), and 180 are new records (Fig. 1). Records included intentional captures (10.9%), bycatch: 0.3%), sightings (87.1%), and strandings (1.7%; Fig. 2). Intentional captures included two by whaling ships off Isla Beata, Dominican Republic, on May 28th, 1866, and St. Lucia on April 30th, 1884, respectively (Reeves and Mitchell, 1988). A female was bycaught in a net in the Gulf of Paria, Trinidad and Tobago in 1987 (Ottley et al., 1988; Bolaños-Jiménez et al., 2014). The origin of the records included intentional takes (n = 39, 10.9%), bycatch (n = 1, 0.3%), sightings from experienced observers, summarized in scientific accounts (n = 165, 46.4%), citizen-science initiatives (n = 143, 40.2%), and (sighting) records in logbooks of whaling ships operating in the second half of the 19th century (n = 8, 2.2%; Fig. 3).

**Spatial and temporal distribution**

Reports of killer whales were distributed in the Eastern Caribbean (36.6%, the Greater Antilles (23.3%), and the southern Caribbean (20.8%), with only 12.6% and 6.7% for the Bahamian region and the western Caribbean, respectively (Fig. 1). Most of the records were from the French West Indies (19.4%), Venezuela (13.5%), the Bahamian region (12.6%), St. Vincent and the Grenadines (10.4%) and Puerto Rico (8.1%; Table 1).

Killer whales were reported every month of the year (Fig. 4), with the most records in August (n = 37) and April (n = 35), and the lowest in September (n = 12) and February (n = 15). Differences in the median of records compared by month were not significant (Kruskal-Wallis, $H_c = 17.1$, $p = 0.11$).

**Group size**

Estimates of minimum group size ranged from 1 to 25 individuals (Mean = 4.1; SD = 3.7; Mode = 1, Fig. 5) and most of the groups (94%) had between 1–10 individuals. Solitary individuals were recorded in 28.5% of the cases.

**Feeding ecology**

Information on the feeding ecology of killer whales in the WCR remains scattered. However, a recent study combined the use of stable carbon and nitrogen isotope ($\delta^{13}C$ and $\delta^{15}N$, respectively) analysis in killer whale's muscle tissues collected in St Vincent and the Grenadines and whaler's perceptions (Kiszka et al. 2021). Bayesian stable isotope mixing models suggest that the diet of killer whales sampled in St Vincent and the Grenadines is dominated by odontocete cetaceans (60.4%) including sperm whales, *Physeter macrocephalus*, short-finned pilot whales, *Globicephala macrorhynchus*, and smaller delphinids. Other prey such as large pelagic sharks and teleosts are probably consumed, but in smaller proportions. Whaler's traditional knowledge from St Vincent and the Grenadines confirmed that odontocetes are the main prey of killer whales in this region (Kiszka et al. 2021). The potential consumption of odontocete cetaceans such as sperm whales and short-finned pilot whales has also been reported opportunistically through observational evidence in the region (Bolaños-Jiménez et al., 2014). Also, on 22 March 2019, a potential occurrence of predation of killer whales on sperm whales was also observed off St. Vincent and the Grenadines. While recording sounds of sperm whales, a research team from

**Table 1.** Number and percentage of killer whale records in the Caribbean Sea ordered by country or territory

| Country/territory | Number of Records | % |
|---|---|---|
| French West Indies | 69 | 19.4 |
| Venezuela | 48 | 13.5 |
| Bahamas | 45 | 12.6 |
| St. Vincent and the Grenadines | 37 | 10.4 |
| Puerto Rico | 29 | 8.1 |
| Dutch West Indies | 17 | 4.8 |
| Cuba | 14 | 3.9 |
| Cayman Islands | 11 | 3.1 |
| Honduras | 11 | 3.1 |
| U.S. Virgin Islands | 10 | 2.8 |
| Dominican Republic | 9 | 2.5 |
| St. Lucia | 8 | 2.2 |
| Belize | 6 | 1.7 |
| Colombia | 6 | 1.7 |
| Antigua and Barbuda | 5 | 1.4 |
| Dominica | 5 | 1.4 |
| Grenada | 4 | 1.1 |
| Jamaica | 4 | 1.1 |
| Mexico | 4 | 1.1 |
| Trinidad and Tobago | 4 | 1.1 |
| Haiti | 3 | 0.8 |
| British Virgin Islands | 2 | 0.6 |
| Costa Rica | 2 | 0.6 |
| Barbados | 1 | 0.3 |
| Panamá | 1 | 0.3 |
| Turks and Caicos | 1 | 0.3 |

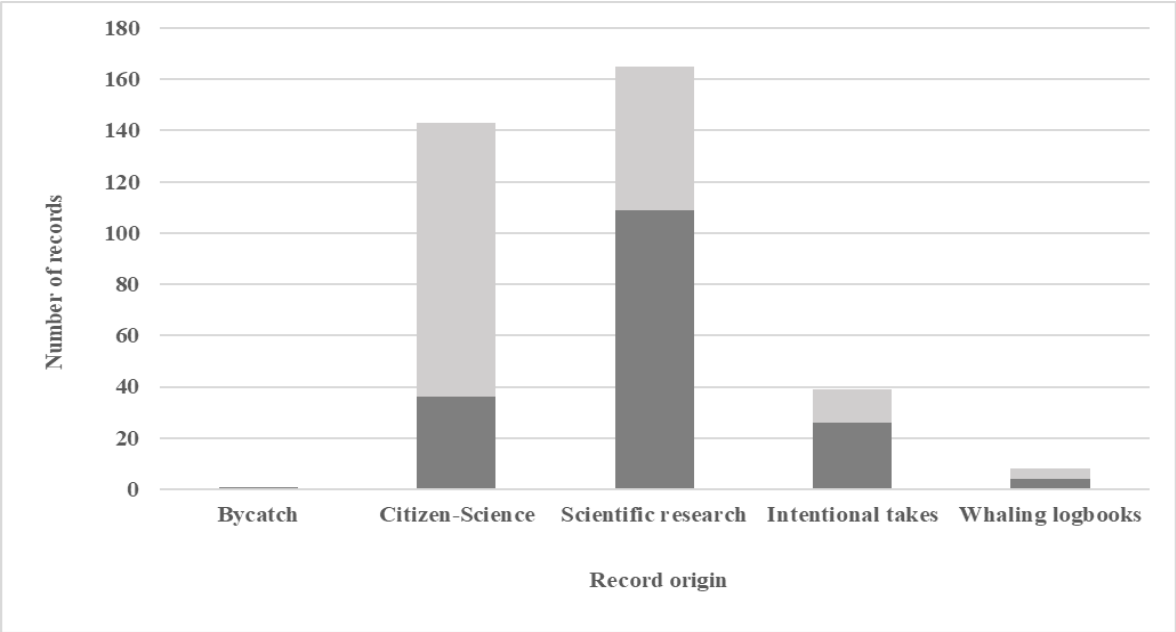


**Figure 3.** Number of killer whale records in the Caribbean Sea by record origin. Dark gray: records in Bolaños-Jiménez et al. (2014, n = 176); light gray: new records (n = 180).

Dalhousie University found a pod of killer whales of which a male had a chunk of dark meat in its mouth. At the same time, a thick oil film was seen on the water, but no samples were obtained so the species identification was not confirmed (F. Vachon, Dalhousie University, pers. comm.). Killer whales have also been observed catching and consuming pygmy sperm whales (*Kogia breviceps*). Potential predatory events have also been observed on Bryde's whales (*Balaenoptera edeni*; Bermúdez-Villapol and Sayegh, 2005), and leatherback sea turtles (*Dermochelys coriacea*; Oviedo et al., 2008).

**Exploitation and fisheries interactions**

We documented 39 cases of intentional captures of killer whales from May 1866 to March 2022. The first captures of killer whales in the Caribbean Sea were traced back to the 19th Century, when American whaling ships killed whales in the Dominican Republic in 1866, and in St. Lucia in 1884, respectively (Reeves and Mitchell, 1988). An additional capture was documented in 1986 along the Caribbean coast of Colombia, which represents the only case in which depredation on bait and fish catches was confirmed, and a killer whale was killed in retaliation (Álvarez-León, 2002; Bolaños-Jiménez et al., 2014). A case of an entanglement of a young female in a gillnet was documented in the Gulf of Paria, Trinidad and Tobago, on June 10th, 1987 (Ottley et al., 1987).

In the Caribbean, killer whales are only known to be directly targeted by humans at St Vincent and the Grenadines. Until 2014, the St. Vincent captures were the main source of killer whale records in the region (Caldwell and Caldwell, 1971; Caldwell et al., 1975; Bolaños-Jiménez et al., 2014). Recent research conducted in St. Vincent indicates that between 1947 and 2020, more than 109 killer whales were taken in this unregulated operation (Fielding and Kiszka 2021).

Interactions with human activities were documented on 83 occasions (23.3%), including intentional captures (10.9%), incidental captures (or bycatch; 0.3%). Killer whales were also observed approaching boats (7.9%), and to fishing gear (4.2%). Interactions (predatory and non-predatory) with other species included cetaceans (4.2%), fish (1.1%) and sea turtles (0.3%).

## DISCUSSION

This review provides an update on available information on killer whales in the Caribbean Sea. With a number of records that more than doubled in comparison with the first review published by Bolaños-Jiménez et al. (2014), this work provides more details on the species´ ecology, natural history, exploitation and interaction with fisheries.

The proportion of records provided from citizen-science initiatives (including posts in social networks) increased remarkably from 20% in the dataset published by Bolaños-Jiménez et al. (2014) to 60% when combining past and new records added here such that, currently, the total contribution from citizens (40.2%) almost equals the contribution from scientific activities (46.4%), emphasizing the importance of involvement of citizens in scientific research for marine megafauna (García-Soto et al., 2021).

Our results confirm that killer whales are widely distributed in the Caribbean Sea and occur year-round but in low densities such that it is not feasible to predict their presence at a local level, which is consistent with previous findings (Reeves and Mitchell, 1988, Bolaños-Jiménez et al., 2009, 2014). No seasonal trends in occurrence could be found in our dataset, confirming that killer whales are present in the study area all year round.

Katona et al. (1988) hypothesized a northward

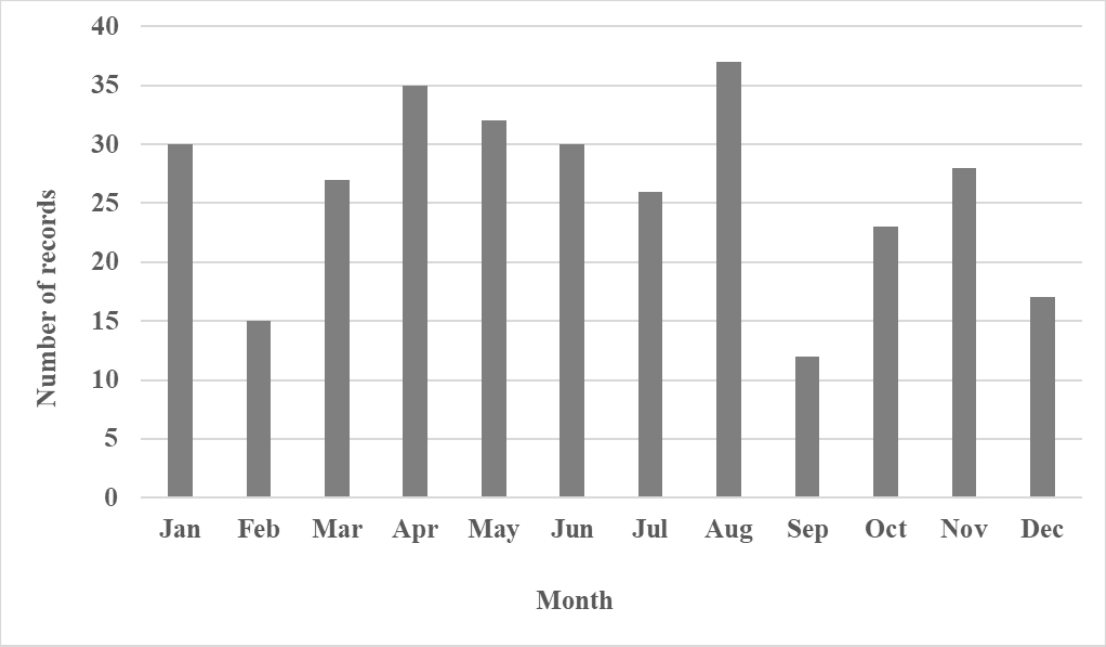


**Figure 4**. Monthly distribution of killer whale records in the Caribbean Sea between 1851 and 2022 (n = 312).

migration from the Caribbean into the latitude of Cape Cod Bay and Massachusetts (42° N) bay beginning in May or June, but we were not able to find any evidence. On the other side Reeves and Mitchell (1988) hypothesized that in the Caribbean Sea: 1) One or more "stocks" of killer whales could summer either in the Arctic or the tropics, 2) other stocks or populations that are non-migratory might occur on a year-round basis, or 3) other unknown patterns of distribution in the Caribbean might occur. As recent research found that individual killer whales can travel more than 8,000 km and explore different ocean basins (i.e., Guerrero-Ruiz et al., 2005; Matthews et al, 2011; Durban and Pitman, 2012), we cannot confirm or exclude that the killer whale population that uses the waters of the Caribbean Sea is composed of a combination of non-migratory individuals and/or individuals traveling from other parts of the Atlantic. Additional methods (e.g., population genetics, satellite telemetry, photo-identification) would help to better understand the movements and population identity of killer whales in the Atlantic (Reeves and Mitchell, 1988).

The highest number of records in the French West Indies is mainly related to the existence of solid citizen-science initiatives in this region, rather than a higher occurrence of killer whales. It is not clear from our data if the scarcity of records in other regions (e.g., Central America) reflects true low densities or a lower observation effort. Recent reviews on the occurrence of minke (*Balaenoptera acutorostrata*, Bolaños-Jiménez et al., 2021) and false killer whales (*Pseudorca crassidens*, Alvarado-Hofmeister, 2021) in the Caribbean Sea also identified scarcity of records in central American waters, emphasizing the need for an increased research effort in that ecoregion.

Minimum group sizes in the Caribbean (mean = 4.1, SD = 3.7, n = 316) were similar to group sizes of killer whales in other tropical regions including Hawaii, Perú and Mexico, lower than west Africa, and greater than the Pacific coast of Costa Rica (see Table 2).

In their earlier review, Katona et al. (1988) speculated that killer whale movements in the Northwest Atlantic are linked to changes or movements in local abundances of prey populations, mainly baleen whales. They also suggested that baleen whales wintering in the Caribbean Sea might be consumed by killer whales but that odontocetes could also be an important part of their diet, particularly after the large whales migrate back to their feeding grounds. This is consistent with recent research that used both stable isotopes and traditional ecological knowledge of local whalers in St. Vincent that confirmed that, at least in the eastern Caribbean, the diet of the killer whales is dominated by odontocetes, including sperm whales, short-finned pilot whales, other smaller delphinids and, to a lesser extent, by teleosts and large pelagic elasmobranchs (Kiszka et al. 2021). These results confirm previous findings that the diet of the killer whales of the Caribbean Sea is broad (Katona et al., 1988; Bolaños-Jiménez et al., 2014), thus contributing to the growing perception that killer whales in tropical regions are probably generalist feeders (Baird et al., 2006; Weir et al., 2010).

The exploitation of killer whales and other cetaceans in St. Vincent and the Grenadines is by far the most important threat to cetaceans all along the study area. From 1947 to 2021, at least 13,856 small cetaceans including 109 are killer whales have been captured in this ongoing, unregulated operation and these numbers are with no doubt an underestimation (Fielding and Kiszka,

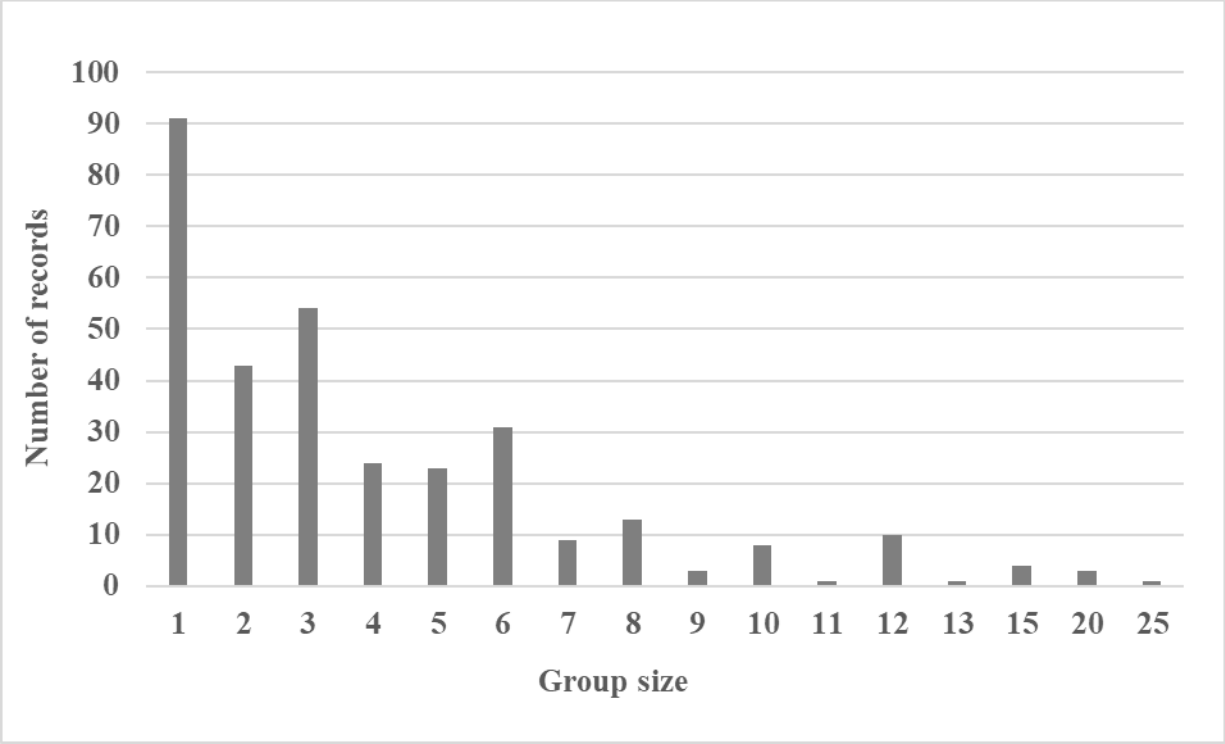


**Figure 5.** Group size frequency of killer whales in the Caribbean Sea between 1851 and 2022 (*n* = 319).

2021). This is in direct contradiction with the provisions of the SPAW Protocol (CEP-UNEP, 1990), of which St. Vincent and the Grenadines is a signatory. Monitoring of killer whale (and other small cetaceans) catches will be critical in the future, particularly to quantify the magnitude and potential impacts of whaling on these species.

Limited study and their probable low densities limit our ability to predict if and where killer whales regularly occur in most Caribbean ecoregions. More detailed, systematic surveys are necessary to document the offshore distribution, relative abundance, population structure, habitat preference and prey preference of killer whales in the Caribbean region. Future work should also include more detailed efforts to document the potential presence of tropical ecotype(s) in the Caribbean Sea and, if such an ecotype exists, to describe its behavioral ecology.

the fragmented nature of the regulatory and policy regime for managing derelict fishing gear nationally, highlights the need for the establishment of effective mechanisms for cross-sectoral cooperation and collaboration which may not currently exist within these states and territories. Legislative review and reform is urgently needed to effectively manage the challenge of abandoned, lost and discarded fishing gear within the small-scale fisheries of the OECS and Barbados.

KEYWORDS: Derelict Fishing Gear, Small Scale Fisheries, Eastern Caribbean, Legal Review, Gap Assessment

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**Table 2**. Group size, Standard deviation and sample size of killer whales in tropical regions used for parameter comparison between the Caribbean Sea and other tropical regions.

| Region | Reference | Average group size | S.D. | Sample size |
|---|---|---|---|---|
| Caribbean Sea | This work | 4.1 | 3.7 | 319 |
| Hawaii | Baird et al. 2006 | 4.2 | 2.1 | 21 |
| Perú | Testino et al. 2019 | 4.3 | 3.5 | 25 |
| Perú | García Godos 2004 | 4.5 | 2.9 | 13 |
| Mexico (Eastern Tropical Pacific) | Vargas-Bravo et al. 2020 | 4.6 | 2.4 | 16 |
| West Africa | Weir et al. 2010 | 5.6 | 3.5 | 32 |
| Pacific coast of Costa Rica | Castro Azofeifa 2021 | 3.4 | 2.6 | 31 |

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## LITERATURE CITED

Alessi, J, F. Bruccoleri, V. Cafaro. 2019. How citizens can encourage scientific research: The case study of bottlenose dolphins monitoring. *Ocean & Coastal Management* **167**:9–19. https://doi.org/10.1016/j.ocecoaman.2018.09.018

Alvarado-Hofmeister, W.A. 2021. Distribución espacio-temporal de la falsa orca *Pseudorca crassidens* (Owen, 1846) en el Gran Caribe. Tesis de Licenciatura, Universidad de Carabobo, Valencia, Estado Carabobo, Venezuela. 52 pp.

Álvarez-León R. 2002. Capturas comerciales con palangre en la zona económica exclusiva frente a la Guajira, Caribe de Colombia. *Revista de Biología Tropical* **50**: 227–231.

Andrachuk, M., M. Marschke,C. Hings, D. Armitage. 2019. Smartphone technologies supporting community -based environmental monitoring and implementation: a systematic scoping review. Biological Conservation, **237:** 430-442.

Baird, R.W., D.J. McSweeney, C. Bane, J. Barlow, D.R. Salden, L.K. Antoine… D.L. Webster. 2006. Killer whales in Hawaiian waters: Information on population identity and feeding habits. *Pacific Science* **60** (4): 523–530.

Barragán-Barrera, D.C., K.B do Amaral, P.A Chávez-Carreño., N. Farías-Curtidor, R. Lancheros-Neva, Botero-Acosta, N., P. Bueno, I.B. Moreno, J. Bolaños-Jiménez, L. Bouveret, D.N. Castelblanco-Martínez, J.A. Luksenburg, J. Mellinger, R. Mesa-Gutiérrez, B. de Montgolfier, E.A. Ramos, V. Ridoux, D.M. Palacios. 2019. Ecological niche modeling of three species of Stenella dolphins in the Caribbean basin, with application to the Seaflower Biosphere Reserve. *Frontiers in Marine Science* **6**:10. https://doi.org/10.3389/fmars.2019.00010.

Bermúdez-Villapol, L., A. Sayegh. (2005) Informe técnico de varamientos de cetáceos en el Estado Nueva Esparta, Venezuela, período 2000–2004. Informe Técnico Depositado en la Dirección Estadal Ambiental del Estado Nueva Esparta y en la Oficina Nacional de Diversidad Biológica, MARN. 69 pp.

Bolaños-Jiménez, J., D. Fertl and M. Iñíguez. 2009. A note on killer whale (*Orcinus orca*) occurrence in Venezuelan waters, 1982-2008. *Latin American Journal of Aquatic Mammals* **7**(1-2):75-79.

Bolaños-Jiménez, J., A. Mignucci-Giannoni, J. Blumenthal, A. Bogomolni, J.J. Casas, A. Henríquez, M. Iñíguez-Bessega, J. Khan, N. Landrau-Giovannetti, C. Rinaldi, R. Rinaldi, G. Rodríguez-Ferrer, L. Sutty, N. Ward, and J.A. Luksenburg. 2014. Distribution, feeding habits and morphology of killer whales *Orcinus orca* in the Caribbean Sea. *Mammal Review* **44** (3-4): 177–189. ISSN 0305-1838.

Bolaños-Jiménez J., E. Morteo, L- Bouveret, A. Henriquez, J.A. Luksenburg, C. Delfín-Alfonso, N. Lara, A. Mignucci-Giannoni. 2021. On the spatial-temporal distribution of the minke whales (*Balaenoptera acutorostrata* and *B. bonaerensis*) in the Wider Caribbean Region and adjacent western tropical North Atlantic. International Whaling

Commission. SC/68C/NH/01

Caldwell, D.K., M.C. Caldwell. 1975. Dolphin and small whale fisheries of the Caribbean and West Indies: occurrence, history, and catch statistics – with special reference to the Lesser Antillean Island of St. Vincent. *Journal of the Fisheries Research Board of Canada* **32**: 1105–1110.

Caldwell, D.K., M.C. Caldwell, W.F. Rathjen, J.R. Sullivan. 1971. Cetaceans from the Lesser Antillean island of St. Vincent. Fishery Bulletin **67**(2): 303-312.

Castro-Azofeifa, C. 2021. Avistamientos de Orcinus orca (Linnaeus, 1758) (Cetartiodactyla: Odontoceti: Delphinidae) en el Pacífico costarricense (1990-2020). *Revista de Ciencias Marinas y Costeras* **13** (2): 29-47.

CEP-UNEP (Caribbean Environment Programme, United Nations Environment Programme). 1990. International Protocol Concerning Specially Protected Areas and Wildlife in the Wider Caribbean Region. Available at: https://www.unep.org/cep/what-we-do/specially-protected-areas-and-wildlife-spaw

Courtain, B., C. Millon, A. Feunteun, M. Safi, N. Duporge, J. Bolaños-Jiménez, D.C. Barragán-Barrera, L. Bouveret, and B. de Montgolfier. 2022. Insights on the residency status and inter-island movement patterns of pantropical spotted dolphins *Stenella attenuata* in the Agoa Sanctuary, Eastern Caribbean. *Latin American Journal of Aquatic Mammals* **17**(1) https://doi.org/10.5597/lajam00277.

A.O. Debrot, N. Esteban, T. Bervoets, P.C. Hoetjes and M. Scheidat. 2013. Marine Mammals of the north-eastern Caribbean Windward Dutch Islands: Saba, St. Eustatius, St. Maarten, and the Saba Bank. *Caribbean Journal of Sciences* **47**: 159-172.

Denkinger, J., D. Alarcon, B. Espinosa, L. Fowler, C. Manning, J. Oña, and D.M. Palacios. 2020. Social structure of killer whales (*Orcinus orca*) in a variable low-latitude environment, the Galápagos Archipelago. *Marine Mammal Science* **36**:774–785.

Durban, J.W. and R.L. Pitman. 2012. Antarctic killer whales make rapid, round-trip movements to subtropical waters: evidence for physiological maintenance migrations? *Biology Letters* **8** :274–277. https://doi.org/10.1098/rsbl.2011.0875

Fielding, R. 2010. *Artisanal Whaling in the Atlantic: A comparative study of culture, conflict, and conservation in St. Vincent and the Faroe Islands*. PhD thesis, Louisiana State University, Louisiana, USA. 446 pp.

Fielding, R., and J.J. Kiszka. 2021. Artisanal and aboriginal subsistence whaling in Saint Vincent and the Grenadines (Eastern Caribbean): history, catch characteristics, and needs for research and management. Frontiers in Marine Science 8:668597. doi: 10.3389/fmars.2021.668597

Gandilhon, N. 2012. *Contribution au recensement des cétacés dans l'archipel de Guadeloupe*. Thèse de doctorat, Université des Antilles et de la Guyane, Guadeloupe. 335 pp + annexes (83 pp).

García-Cegarra, A.M., F. Toro, V. Gonzalez-Borasca. 2021. Citizen science as a tool to assess cetacean diversity in the Atacama desert coast. *Ocean and Coastal Management*, **213**: 105858

García-Godos, I. 2004. Killer whale (*Orcinus orca*) occurrence off Perú, 1995-2003. Latin American Journal of Aquatic Mammals 3(2): 177-180.

Garcia-Soto C., J.J.C., Seys, O. Zielinski, J.A. Busch, S.I. Luna, J.C. Baez., C. Domegan C., Dubsky K., Kotynska-Zielinska I, Loubat P, Malfatti F, Mannaerts G, McHugh P, Monestiez P, van der Meeren G.I. and Gorsky G .2021). Marine Citizen Science: Current State in Europe and New Technological Developments. F*rontiers in Marine Science* **8**:621472. doi: 10.3389/fmars.2021.621472

Geelhoed, S.C.V, N. Janinhoff, J.P., Verdaat, R.S.A. van Bemmelen, and M. Scheidat. 2014. Aerial surveys of marine mammals and other fauna around Aruba, Curaçao and Bonaire, November 2013. Report number C012/14 IMARES - Institute for Marine Resources and Ecosystem Studies, 2500 EK The Hague, The Netherlands.

Guerrero-Ruiz, M., I. García-Godos, and J.R. Urbán. R. 2005. Photographic match of a killer whale (*Orcinus orca*) between Peruvian and Mexican waters. *Aquatic Mammals*, **31**(4), 438–441. https://doi.org/10.1578/AM.31.4.2005.438

Harvey, G.K.A., T.A. Nelson, P.C. Paquet, C.J. Ferster, and C.H. Fox, 2018. Comparing citizen science reports and systematic surveys of marine mammal distributions and densities. *Biological Conservation*, **226**: 92-100. https://doi.org/10.1016/j.biocon.2018.07.024

Iñíguez-Bessega, M., S. Fisher, S. Millward, L. Mitchell, and C. Cassani. 2021. Small cetacean takes in Barrouallie, Saint Vincent and the Grenadines (2014-2020). International Whaling Commission. SC/68C/SM10.

Jefferson, T.A., D. Fertl, J. Bolaños-Jiménez, and. A.N. Zerbini. 2009. Distribution of common dolphins (*Delphinus* spp.) in the western Atlantic Ocean: a critical re-examination. *Marine Biology* **156**: 1109-1124.

Jefferson, T.A., M.A. Webber and R.L. Pitman. 2015. *Marine Mammals of the World: A Comprehensive Guide to their Identification* 2nd ed., Academic Press, San Diego.

Katona, S.K., J.A. Beard, P.E Girton, and F. Wenzel. 1988. Killer whales (*Orcinus orca*) from the Bay of Fundy to the equator, including the Gulf of Mexico. *Rit Fiskideildar* **11**: 205–224.

Kiszka, J.J., M. Caputo, P. Méndez-Fernandez, and R. Fielding. 2021. Feeding ecology of elusive Caribbean killer whales inferred from Bayesian stable isotope mixing models and whalers' Ecological Knowledge. Frontiers in Marine Science 8:648421. doi: 10.3389/fmars.2021.648421

Lucke, K., M. Scheidat, S. Geelhoed, A.O. Debrot, N. Ward, L. Hatch, D. Wiley, C. McDonald, J. Reynolds, P. Hoetjes, J. Bolaños-Jiménez, H. Souan, G. Vandersarren, N. Gandhilon. 2014. Marine mammals in the Wider Caribbean – Current research and

priorities for future studies. Report C007/14, IMARES (Institute for Marine Resources and Ecosystem Studies), Wageningen UR, The Netherlands. 38 pp.

Luksenburg, J.A. 2014. The cetaceans of Aruba, southern Caribbean. *Journal of the Marine Biological Association of the United Kingdom* **94 (**6):1161 – 1174.

MacKay, M.M., C.E. Bacon, L.Bouveret, S. Fossette, S., and P.T. Stevick. 2019. Humpback Whale (*Megaptera novaeangliae*) Intra/Inter-Seasonal Exchanges Between Puerto Rico and the Southeastern Caribbean. *Animal Behavior and Cognitio*n, **6** (2):98–104.

Mannocci, L., P. Monestiez, J. Bolaños-Jiménez, G. Dorémus, S. Jeremie, S. Laran, R. Rinaldi, Van Canneyt, O., Ridoux V. 2013. Megavertebrate communities from two contrasting ecosystems in the western tropical Atlantic. *Journal of Marine Systems* **111-112**: 208-222

Matthews, C.J.D., S.P. Luque, S.D. Petersen, R.D. Andrews, and S.H. Ferguson. 2011. Satellite tracking of a killer whale (*Orcinus orca*) in the eastern Canadian Arctic documents ice avoidance and rapid, long-distance movement into the North Atlantic. Polar Biology, **34**: 1091–1096. https://doi.org/10.1007/s00300-010-0958-x

Ottley, T., C. Henry, A. Khan, A. Siung-Chang, and M. Sturm, M. 1988. Incidents involving whales in Trinidad waters during 1987. *The Living World – Journal of the Trinidad and Tobago Field Naturalists' Club 1987–88*: p. 47.

Oviedo, L., M.A. Esteves, E. Alfe, R. Acevedo-Galindo, and J. Bolaños-Jiménez. 2008. Interaction between killer whales (*Orcinus orca*) and a leatherback turtle (*Dermochelys coriacea*) off northeastern Venezuela. *JMBA2 6156 – Marine Biodiversity Records*. Available from: http://www.mba.ac.uk/jmba/pdf/6156.pdf.

Pitman, R. L., J.A. Totterdell, H. Fearnbach, L.T. Ballance, J.W. Durban, and H. Kemps. 2015. Whale killers: Prevalence and ecological implications of killer whale predation on humpback whale calves off Western Australia. *Marine Mammal Science* **31** (2): 629–657.

Price, W.S. 1985. Whaling in the Caribbean: historical perspective and update. Report of the International Whaling Commission **35**: 413–420.

QGIS.org. 2022. QGIS Geographic Information System. QGIS Association. http://www.qgis.org

Rankin, S., F. Archer, and J. Barlow. 2013. Vocal activity of tropical dolphins is inhibited by the presence of killer whales, *Orcinus orca*. *Marine Mammal Science* **29** (4): 679–690.

Reeves R.R., and E. Mitchell. 1988. Killer whale sightings and takes by American pelagic whalers in the North Atlantic. *Rit Fiskideildar* **11**: 7–23.

Spalding, M.D., H.E. Fox, G.R. Allen, N. Davidson, Z.A. Ferdaña, M.A.X. Finlayson, B.S. Halpern, M.A. Jorge, A.L. Lombana, S.A. Lourie, and K.D. Martin, 2007. Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. *BioScience* **57** (7):573-583.

Stevick, P. T., L. Bouveret, N. Gandilhon, C. Rinaldi, R. Rinaldi, F. Broms, …Wenzel. 2018. Migratory destinations and timing of humpback whales in the southeastern Caribbean differ from those off the Dominican Republic. *Journal of Cetacean Research and Management*, **18**:127–133

Terrapon, M., J.J. Kiszka, and J. Wagner. 2021. Observations of Killer Whale (*Orcinus orca*) feeding behavior in the tropical waters of the northern Mozambique Channel Island of Mayotte, Southwest Indian Ocean. *Aquatic Mammals* **47**(2): 196-205.

Testino, J. P., A. Petit, B. Alcorta, A.S. Pacheco, S. Silva, J. Alfaro-Shigueto… A. González-Pestana. 2019. Killer whale (*Orcinus orca*) occurrence and interactions with marine mammals off Peru. *Pacific Science* **73** (2) 261–273.

Van Canneyt O., G. Dorémus, S. Laran, V. Ridoux, and P. Watremez. 2018. Distribution et abondance de la mégafaune marine aux Antilles et en Guyane. Rapport de campagne Remmoa -II Antilles / Guyane - 2017. Observatoire Pelagis (UMS 3462, Université de La Rochelle / CNRS) and Agence française pour la Biodiversité. 65 pp.

Vargas-Bravo, M.H., F.R. Elorriaga-Verplancken, A. Olivos-Ortiz, B. Morales-Guerrero, M.A. Liñán-Cabello, and C.D. Ortega-Ortiz. 2020. Ecological aspects of killer whales from the Mexican Central Pacific coast: Revealing a new ecotype in the Eastern Tropical Pacific. *Marine Mammal Science* **37** (2): 1–16.

Ward, N. and A. Moscrop. 1999. Marine mammals of the Wider Caribbean Region: a review of their conservation status. Paper presented at the Fourth Meeting of the Interim Scientific and Technical Advisory Committee (ISTAC) to the Protocol Concerning Specially Protected Areas and Species (SPAW) in the Wider Caribbean Region. Havana, Cuba, 3-6 August 1999. UNEP, 25 pp.

Ward, N., A. Moscrop and C. Carlson. 2001. Elements for the development of a marine mammal action plan for the Wider Caribbean Region: a review of marine mammal distribution. First Meeting of the Contracting Parties (COP) to the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) in the Wider Caribbean Region, Havana, Cuba, 24-25 (September 2001). UNEP, 77 pp.

Weir, C.R., T. Collins, I. Carvalho, and H. Rosenbaum. 2010. Killer whales (*Orcinus orca*) in Angolan and Gulf of Guinea waters, tropical West Africa. *Journal of the Marine Biological Association of the United Kingdom* **90** (8): 1601-1611.

Whitt, A.D., M.A. Baran, M. Bryson and L.E. Rendell. 2015. First report of killer whales harassing sperm whales in the Gulf of Mexico. *Aquatic Mammals* **41** (3): 252–255.