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Bryde's Whale (*Balaenoptera edeni brydei,* Artiodactyla: Balaenopteridae) aggregation area in the Gulf of Chiriqui, Panama

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ABSTRACT

Introduction: Even though they occur worldwide in tropical and subtropical waters, Bryde's whales (*Balaenoptera edeni*) are one of the most enigmatic of all the balaenopterid species. Previous research has reported the presence of Bryde's whales off the Pacific coast of Panama, but little is known about their behaviors, abundance, and distribution in these waters.

Objective: We report on an area in the Gulf of Chiriqui, Panama, where Bryde's whales have regularly been sighted.

Methods: We conducted small-boat surveys for marine mammals in the Gulf of Chiriqui between 2001 and 2022, during both the austral (26 300 km) and boreal (4 700 km) winter seasons.

Results: We made 25 sightings of 33 Bryde's whales. Sightings were made in nine of the years surveyed, and most were in the austral winter season (92 %). Most sightings were of one animal (80 %), and one sighting was of a mother-calf-escort trio. The aggregation area appears near the Contreras Islands, where most sightings (84 %) were made. We have photo-identified 14 individual whales using the dorsal fin. One individual has been sighted over two years (2014 and 2015), while the remaining have been documented only once. No photographic matches have been made to other areas.

Conclusions: The persistent use of this aggregation area could indicate it is used for foraging, and the presence of a calf may indicate the area is also used for reproduction. The one inter-annual resight suggests this area may be used repeatedly by some of the same animals. Further research is needed off Panama to better understand this population of Bryde's whales, its conservation status, and its relationship to the broader eastern tropical Pacific populations. Expanding the marine protected areas in the Gulf of Chiriqui may be warranted in order to protect this aggregation area.

Key words: Central America; baleen whales; eastern tropical Pacific; occurrence; photo-identification.

RESUMEN

Área de Agregación de la Ballena de Bryde (*Balaenoptera edeni brydei)* en el Golfo de Chiriquí, Panamá

Introducción: Aunque la ballena de Bryde (*Balaenoptera edeni*) tiene una distribución global en aguas tropicales y subtropicales, la especie es una de las más enigmaticas entre los balaenoptéridos. Observaciones previas han reportado la presencia de ballenas de Bryde en la costa del Pacífico de Panamá, pero sabemos poco acerca de su comportamiento, abundancia, y distribución en estas aguas.

Objetivo: Reportamos un área en el golfo de Chiriquí, Panamá, donde la ballena de Bryde ha sido avistada frecuentemente.

Métodos: Realizamos muestreos para mamíferos marinos desde embarcaciones pequeñas en el golfo de Chiriquí entre el 2001 y el 2022, tanto durante el invierno austral (26 300 km) como el boreal (4 700 km).
Resultados: Registramos 25 avistamientos de 33 ballenas de Bryde. Los avistamientos ocurrieron en nueve de los años muestreados, la mayoría en el invierno austral (92 %). La mayoría de avistamientos fueron de un animal (80 %), y un avistamiento fue de un trío madre-cría-escolta. El área de agregación ocurre cerca de las islas Contreras, donde la mayoría de los avistamientos (84 %) fueron registrados. Foto-identificamos 14 individuos usando la aleta dorsal. Un individuo fué avistado en dos años (2014 y 2015), mientras que el resto solamente ha sido documentado una vez. No se han registrado recapturas fotográficas con otras áreas.
Conclusiones: El uso repetido de ésta área de agregación podría indicar que es usada para alimentación, y la presencia de un trío madre-cría-escolta también sugiere actividad reproductiva. El único re-avistamiento interannual sugiere que el área es usada por algunos de los mismos animales. Se necesita más investigación en aguas panameñas para entender mejor esta población de ballena de Bryde, su estatus de conservación, y su relación con otras poblaciones del Pacífico tropical oriental. Una expansión de las áreas marinas protegidas en el golfo de Chiriquí puede ser necesaria para proteger esta población.

Palabras clave: Centroamérica; ballenas de barbas; Pacífico tropical oriental; ocurrencia; foto-identificación.

INTRODUCTION

Bryde's whales (*Balaenoptera edeni* Anderson, 1878) are one of the most enigmatic of all the balaentopterid species, despite having a worldwide distribution in tropical and subtropical waters, including in the Pacific, Atlantic, and Indian Oceans (Kato & Perrin, 2018). Much remains unclear about this species, including its taxonomy, distribution, and migration. Currently there are two subspecies recognized; *B. edeni edeni* is smaller and typically found in coastal waters, and *B. edeni brydei* is larger and globally distributed (Kato & Perrin, 2018; Kershaw et al., 2013,). Both subspecies have been found in the Indian and Pacific oceans, and *B. edeni brydei* also has been found in the Caribbean (Luksenburg et al., 2015). Unlike other baleen whale species, Bryde's whales do not make long annual migrations between cold-water feeding areas and warm-water breeding areas, but remain in tropical and subtropical waters year-round. However, some populations have shown evidence of large-scale movement within this range, while others appear to be resident (Best, 2001; Kato & Perrin, 2018; Lagerquist et al., 2017; Murase et al., 2015). Bryde's whales are considered opportunistic feeders and can feed on small pelagic schooling fish or zooplankton. Different populations tend to show a preference for one type of prey depending on geographic location (Constantine et al., 2018; Kato & Perrin, 2018).

Between 1986 and 2005, large-scale visual surveys in offshore waters of the eastern tropical Pacific (ETP) documented Bryde's whales between 30°N and 15°S (Hamilton et al., 2009). Additionally, an acoustic study in the ETP between 1999 and 2001 detected Bryde's whale calls at seven different offshore stations between 12° N and 8° S (Heimlich et al., 2005). Across the broader eastern Pacific, other reports of Bryde's whales include off southern California (Kerosky et al., 2012; Smultea et al., 2012), Mexico (Salvadeo et al., 2011; Tershy, 1992; Viloria- Gómora et al., 2021), Nicaragua (De Weerdt et al., 2021), Costa Rica (May-Collado et al., 2018), Colombia (Palacios et al., 2012), Ecuador, including the Galapagos Islands (Alava et al., 2013; Biggs et al., 2017; Castro et al., 2017; Palacios & Forney, 2008), Peru (Clarke & Aguayo, 1965; Ramirez, 1986; Valdivia et al., 1981), and Chile (Clarke & Aguayo, 1965; Gallardo et al., 1983; Pastene et al., 2015). Bryde's whales have been previously reported in Panama (May-Collado et al., 2018; Rasmussen & Palacios, 2013), but little information is available from the Gulf of Chiriqui.

This study reports on Bryde's whales sighted in the Gulf of Chiriqui from long-term, small-boat surveys between 2001-2022.

MATERIALS AND METHODS

Study site: The Gulf of Chiriqui lies in the western part of Panama and is bordered by the Azuero Peninsula to the east, and Punta Burica to the west (7°18' - 8°18' N & 82°54' - 81°36' W; Fig. 1). This gulf is characterized by generally shallow waters (< 300 m) and many island groups. Monthly sea surface temperature ranges between 25 – 29 °C (Randall et al., 2020). However, like the rest of the ETP, the gulf is subject to the anomalous effects from the regional El Nino-Southern Oscillation (ENSO) phenomenon, which results in warmer sea surface temperatures (Podestá & Glynn 2001; Randall et al., 2020; Wang & Fiedler, 2006;). Two protected areas have been established by the government of Panama (Fig 1a): Coiba National Park and its Special Zone of Marine Protection, which is also a UNESCO World Heritage Site and includes Coiba Island and the Contreras Islands (https://whc.unesco.org/en/list/1138/), and the Gulf of Chiriqui National Marine Park, which includes the Paridas Islands. The gulf is also well-known for its use as a breeding area by two different populations of humpback whale, *Megaptera novaeangliae* (Borowski, 1781), one migrating from feeding areas in the Southern

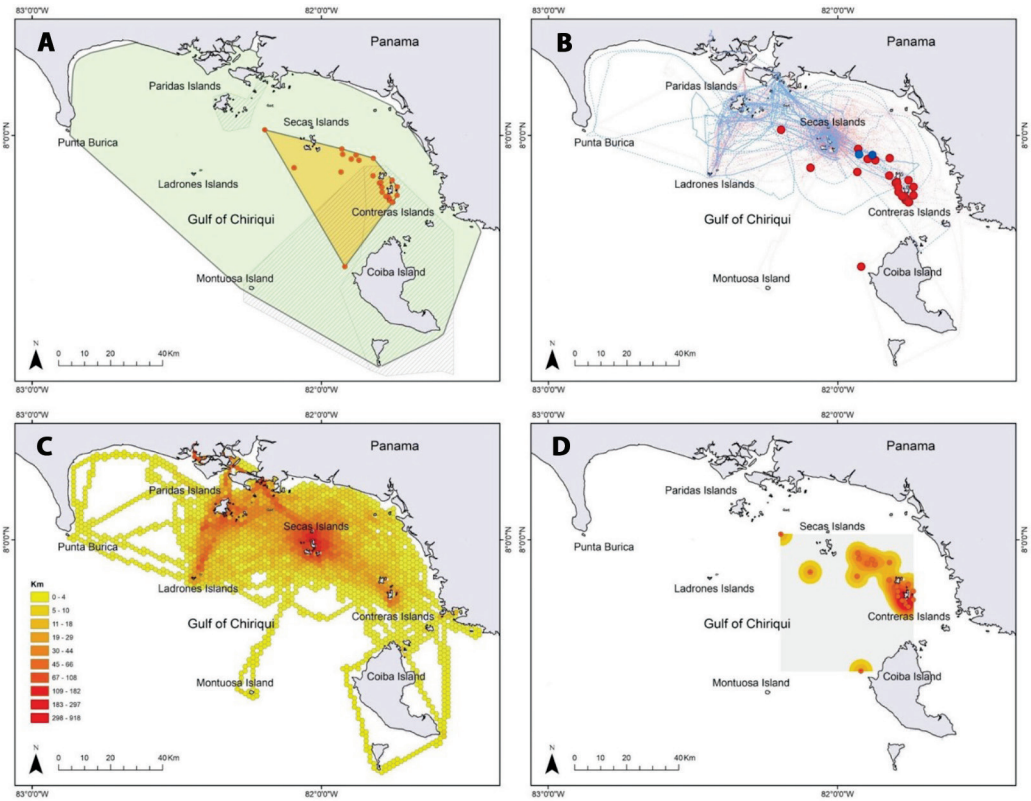

Fig. 1. A. Minimum convex polygons (MCP) for both survey area (green) and sighting locations (orange), red circles indicate sighting locations for all Bryde's whale sightings. The hatched overlays represent marine protected areas, including Gulf of Chiriqui National Marine Park at the Paridas Islands, and Coiba National Park (right side of Coiba hatched overlay) and its Special Zone of Marine Protection (left side of overlay). **B.** Survey effort tracklines and Bryde's whale sighting locations for two seasons (blue for boreal winter and red for austral winter). **C.** Gridded representation of the survey effort in the Gulf of Chiriqui using a honeycomb grid with 1-km edges. **D.** Kernel density distribution for Bryde's whale sightings.

Hemisphere, and one migrating from feeding areas in the Northern Hemisphere (Rasmussen et al., 2007).

Boat surveys: Visual surveys were conducted from a small boat in the Gulf of Chiriqui between 2001 and 2022, in both the boreal winter (January-March) and austral winter (July-September), to correspond with the breeding seasons of the two humpback whale populations that use this area (Rasmussen et al., 2007). Humpback whales were the primary species targeted, but all marine mammal species encountered were documented. Data collected included time, GPS location, number of animals in the sighting, and behaviors. Surveys were non-systematic in design and conducted in waters less than 200 m depth, near coastlines, island groups, and rocky outcroppings, which are the preferred humpback whale breeding habitat (Clapham & Mead, 1999; Rasmussen & Palacios, 2013). When Bryde's whales were encountered, identification photographs of the right and left sides of the dorsal fin were taken with a Nikon SLR camera equipped with a telephoto lens.

Data analyses: Given the extensive and non-uniform survey effort, the survey tracklines were gridded for visual interpretation using honeycomb cells with 1-km edges with the XtoolsPro software (https://xtools.pro/) for ArcMap v. 10.8.2 (Esri, Redlands, CA). Kernel density analysis of the sighting locations was conducted with ArcMap to characterize the concentration of Bryde's whale sightings. The total survey area and the area used by the Bryde's whales were estimated using minimum convex polygon analysis (MCP) in ArcMap.

RESULTS

We surveyed a total of 31 000 km over 334 days. Most effort (26 300 km and 294 days) was in the austral winter between 2002 and 2019 (with the exception of 2005 and 2016, when no effort took place) (Fig. 1b). The remaining effort (4 700 km and 40 days) was in the boreal winters of 2001-2003, 2018, and 2022 (Fig. 1b). Surveys covered most of the gulf, with the greatest concentration near the island groups of Secas, Paridas, Ladrones, and Contreras (Fig. 1b and c).

Between 2004 and 2022 we made 25 sightings of 33 Bryde's whales. Most sightings (n = 23, 92 %) were in August and September, and two sightings (8 %) were in February (Fig. 1b). Whales were sighted in nine separate years (2004, 2007, 2009, 2013-2015, 2018, 2019, 2022), with the most sightings in one year (nine) occurring in 2014. Most sightings were of single whales (n = 20, 80 %), three sightings were of two whales (12 %), and one sighting was of four whales (4 %). One sighting (4 %) in September 2004 included a mother-calf-escort trio.

Encounter rates (whales seen per 100 km surveyed) were calculated for both the austral and boreal seasons to give an index of relative abundance. Bryde's whales were seen at a rate of 0.09 whales/100 km in the austral winter, and 0.04 whales/100 km in the boreal winter. For comparison, humpback whales were documented during these same surveys at a rate of 13.79 whales/100 km in the austral winter and 0.41 whales/100 km in the boreal winter.

All sightings were near the Contreras and Secas island groups, and one near Coiba Island (Fig. 1b). All sightings were made in depths of less than 200 m. Distances to shore ranged between 1 and 16.1 km (mean = 5.0 km, median = 2.5 km, SD = 4.3 km).

The kernel density analysis of the sighting locations revealed the highest concentration of sightings around the southern Contreras Islands, and extending to the northwest towards the Secas Islands (Fig. 1d). The total survey area, as delineated by a MCP, was estimated at 11 800 km^2, while the MCP of the area of Bryde's whale sightings was estimated at 1 200 km^2, or 10 % of the survey area (Fig. 1a).

Of the 25 sightings of Bryde's whales, most (n = 17, 68 %) were under 20 minutes in duration, either because the whales were difficult to follow or due to bad weather. The longest period we followed a single whale was 1 hour 25 minutes. Most whales exhibited an erratic

surfacing pattern, in which the direction of travel changed between each surface series, and sometimes within a surface series. Five sightings included close approaches by the whales to the boat.

We photographed dorsal fins of 19 whales, of which 14 were of good quality for identification purposes. Of the 14, six had distinctive nicks or shape, and eight were nondescript. One individual (identification #009) was sighted over two years on 6 September 2014 and again on 5 September 2015. The estimated distance between the two sighting locations was 12 km. The remaining 13 whales were identified only once.

DISCUSSION

In the Gulf of Chiriqui, Bryde's whales are seen at a much lower rate (0.09 whales/100 km in the austral winter and 0.04/100 km in the boreal winter) than humpback whales (13.79/100 km in the austral winter and 0.41/100 km in the boreal winter). The results of the kernel density estimate as well as the MCP of the aggregation area both also indicate that despite the extensive survey effort, Bryde's whales are more likely to be found near the Contreras and Secas island groups than anywhere else in the Gulf of Chiriqui, regardless of the season or year. Such a persistent aggregation area suggests this may be a localized area of elevated productivity where Bryde's whales are foraging. The Contreras Islands are historically known by local fishers to be one of the most productive areas in the Gulf of Chiriqui, including small schooling fish (L. Bernal, personal communication, 6 May 2022), although this area is currently protected and no fishing is allowed within the National Park boundaries (see Fig. 1a). Examples of Bryde's whale feeding areas described less than 10 km to shore include in the Galapagos Islands, Ecuador (Biggs et al., 2017), the Beibu Gulf, China (Chen et al., 2019), and the Gulf of California, Mexico (Tershy, 1992). Further study is needed specifically in the Contreras and Secas Islands to assess the oceanographic and bathymetric conditions that may lead to a localized area of high productivity (Wingfield et al., 2011).

The September sighting of a mother-calf-escort trio in Chiriqui could indicate that in addition to this being a feeding area, it may also be an area used for reproduction. Mother-calf pairs have been seen in an area associated with foraging in the Galapagos Islands (Biggs et al., 2017), suggesting it is an area where both foraging and breeding behaviors both occur. Further study would also address the extent to which Bryde's whales are using Chiriqui for reproductive purposes in addition to foraging.

The seasonality of Bryde's whales in this area is somewhat unclear. This study reports sightings in February, August and September, but there are also anecdotal reports from residents and naturalists in Chiriqui from November and December (L. Klein, V. Wilson, personal communication, 19 April 2022). Between 2013-2021 seven strandings of Bryde's whales were reported off Panama in February, March, April, August and December, although none of these were in Chiriqui (L. Trejos-Lasso, personal communication, 29 April 2022). A current study in Chiriqui using continuously sampling bottom-mounted hydrophones could add information on the seasonality of Bryde's whales in the area (L. May-Collado, personal communication, 4 May, 2022).

While the re-encounter of one of our photo-identified whales to the same area a year later could suggest that the same animals may be using this area year after year, further study is necessary to determine the extent of site fidelity. Other studies have reported varying degrees of site fidelity for this species (Athayde et al. 2020; Figueiredo et al. 2014, Lodi et al. 2015, Tezanos-Pinto et al. 2017,). There is no information on whether this population is strictly coastal or may also move to offshore areas. Different populations of Bryde's whales have shown a variety of seasonal movement patterns. Two distinct populations of Bryde's whales in South Africa are an example of this, with one, the Southeast Atlantic population, migrating between the equator and 34° S, while the South

African coastal population is resident year-round (Best, 2001; Constantine et al., 2018).

A previous study compared our photo-identification catalog to 51 individually identified Bryde's whales from Ecuador (both the continent and the Galapagos) and Peru, and found no matches (Castro et al., 2017). Further comparisons among regional photo-ID catalogs as well as satellite tagging could yield more information about the movements of these whales.

The taxonomy of this population and how it relates to other Bryde's whale populations in the ETP is also worthy of investigation. Genetic sampling will help determine the taxonomic status as well as help to resolve some of the uncertainty of this species on a global level (Constantine et al., 2018). A previous genetic study determined that Bryde's whales off Brazil, Chile, and Peru were the *B. brydei* form (Pastene et al., 2015). Further genetic sampling is needed not only off Panama, but in other areas of the ETP as well.

While the Gulf of Chiriqui does contain some marine protected areas (MPAs), extending some of these MPAs to better include the Bryde's whale aggregation area we have identified here may be warranted. The gulf is an important breeding area for humpback whales from the southeast Pacific (Rasmussen & Palacios, 2013) and is also used by humpback whales from the Central America Distinct Population Segment, which is currently listed as endangered by the USA government (Rasmussen et al., 2011, Rasmussen & Palacios, 2020; National and Oceanic Atmospheric Administration, 2016). In comparison with humpback whales, Bryde's whales are seen far less frequently in the Gulf of Chiriqui, yet they have been consistently sighted since 2004 and are concentrated in a relatively small area of the gulf. Globally, the conservation status of Bryde's whales is considered of "Least Concern" by the IUCN (Cooke & Brownell, 2018). However, the restricted distribution and low encounter rates in the Gulf of Chiriqui suggests that either this is a small and localized population, or that this habitat supports a small number of visiting individuals. This population could be particularly vulnerable due to its restricted distribution within the gulf, although this restricted distribution is well-suited for conservation purposes as it lends itself to a clear designation of a protected area. While some of the Bryde's whale aggregation area (as determined by the MCP analysis) is within the Coiba National Park MPA, some if it is outside the protected zone (Fig. 1a). Therefore, it may be advisable to expand this MPA to include all of the area where Bryde's whales are sighted. Connecting it with the Gulf of Chiriqui Marine Park in the Paridas Islands would create a continuous protected corridor which could benefit not only Bryde's whales, but other marine species as well.

Ethical statement: the authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgements section. A signed document has been filed in the journal archives.

Author Contribution: KR collected data in the field, conceptualized and conducted data analysis, and drafted the manuscript. DMP collected data in the field, conceptualized and assisted with data analysis, and contributed to the manuscript.

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