Abundance and distribution of common dolphins, *Delphinus* spp., off northeastern Venezuela: implications for conservation and management

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ABSTRACT

The northeastern coast of Venezuela hosts a high diversity of megafauna correlated with high productivity due to coastal upwelling. This area is characterized by the largest fisheries in Venezuela, mostly supported by a great abundance of small pelagic species. The current status of cetacean populations off northeastern Venezuela is uncertain, mainly because research efforts have been very sparse. There are still many information gaps related to cetacean biology that are necessary to establish a solid baseline that can be used for management and decision-making. Common dolphins (*Delphinus* spp.) are widely distributed over the entire northeastern basin, including waters off Araya and Paria Peninsula and around Margarita, Coche and Cubagua islands. Areas of higher densities for *Delphinus* spp. are located on the northeastern coast, which coincides with the focal location of sardine fisheries and the most active upwelling in the area. Management should consider the areas of major productivity along this coast as potential critical habitat for the species. Further data collection is recommended, studies of trophic ecology and continuity of behavioral sampling paired with systematic line-transect estimations of abundance.

KEYWORDS: ATLANTIC OCEAN; SOUTH AMERICA; CARIBBEAN SEA; DISTRIBUTION; ABUNDANCE ESTIMATE; NORTHERN HEMISPHERE; ECOSYSTEM; HABITAT.

INTRODUCTION

Evaluation of the status of dolphins of the genus *Delphinus* has been strongly recommended by the Scientific Committee of the International Whaling Commission (IWC, 2007, p. 306). According to Jefferson *et al*. (2009), the Venezuelan stock "is an isolated, coastal population of *D. capensis* that occurs over the continental shelf in central/northeastern Venezuela. Its abundance is unknown, but its status is of concern due to past and current threats." The taxonomic identity of the Venezuelan stock of common dolphins is currently unresolved (Jefferson *et al*., *2009*); it could constitute a unique morphotype of *Delphinus (*Esteves and Oviedo 2007a). We refer to the common dolphin form addressed in this report as *Delphinus* spp., under the premise that the taxonomic identity will be elucidated in the future.

In this study, we evaluate *Delphinus* spp. abundance, distribution, behavior and habitat use with data collected between 1997 and 2008. Determination of critical habitat is the keystone to designation of any special management status in any specific locations of the cetacean habitat (Lusseau and Higham, 2004; Hoyt, 2005). Our ultimate goal is to determine what portions of the marine habitats of the northeastern coast of Venezuela represent key areas in the distribution and abundance of *Delphinus* spp.

MATERIALS AND METHODS

Study area

The Caribbean portion of the Venezuela' EEZ, and particularly the northeastern coast hosts a great diversity of megafauna correlated with increased productivity due to coastal upwelling. This area is characterized by occurrence of big Spanish sardine schools (*Sardinella aurita*) among other species of importance for commercial fisheries (Guzman *et al*., 1999; Cárdenas and Achury, 2000; Mendoza *et al*., 2003). Within the region bounded by the 100-m isobath inside the Cariaco Basin, the upwelling seasonal plume usually covers a surface area that ranges between 0 and 1000 km^2 from August to October ; the plume typically extends over an area greater than 12.000 km^2 during March (Müller-Karger *et al*., 2004).. The study area was subdivided at a major scale into four sections of the five subdivisions as proposed by Acevedo *et al.* (2007) (Figure 1). Overall, the four sections comprise approximately 35% (>5,700 km^2) of shelf habitat and 65% (>10,500 km^2) of oceanic environment off the shelf break:

The continental shelf break on the north coast of Margarita Island and La Blanquilla Island (approximate area 6,752 km^2): This portion is a transition zone between the neritic and pelagic habitats. Lesser upwelling centers are present in the northern coast of Margarita Island, including Macanao Peninsula. Although fishermen use the area, it has the lowest level of disturbance and resulting change due to anthropogenic activities. It is quite important to point out that this location is currently considered for oil industry exploration and development activities in the near future (Oviedo, 2005; Martín *et al*., 2006).

Margarita Island's eastern coast and Margarita-Los Testigos submarine platform (approximate area 3,898 km^2): The continental shelf here is wide and relatively even, with both mud and mud-sand bottom. The latter features mostly constitute a key shallow neritic habitat, also influenced by the upwelling off Carupano's coast (central Paria Peninsula). This zone has a traditional use of marine resources by people.Coastal population densities have been increasing in recent years; there are also significant land-based sources of pollution associated with port development and tourism (Oviedo, 2005).

The northern coast of Araya Peninsula, including Margarita, Coche and Cubagua islands (approximate area 1812 km^2): This region has complex submarine topography due to the presence of Margarita, Coche and Cubagua islands. An area of upwelling is located off north Araya Peninsula; intensity of upwelling is highly influenced by the seasonal variations associated to the annual cycles of trade winds. The most important anthropogenic impacts here are fisheries, chemical and acoustic pollution, and commercial shipping traffic.

The Cariaco Basin, southwest of Margarita and Cumaná, including the Cariaco Gulf (approximate area 3889 km^2): Although one portion of this area has National Park status (The Mochima National Park), the human impact on the marine portion of the ecosystem is intense here. The threats include fisheries, chemical and acoustic pollution, development of oil and gas production facilities, commercial shipping traffic and unregulated dolphinwatching activities (Oviedo, 2005; Bolaños-Jiménez *et al*., 2007; Jefferson *et al*., 2009).

Dolphin Sightings and Data Analysis

Opportunistic collection of cetacean encounters (sightings) off northeastern Venezuela has been carried out aboard several vessels since 1997 by the authors. This has resulted in an extensive database of both published and non-published records for more than 10 species. The species include wintering humpback whales (Silva *et al*., 2006; Acevedo *et al*., 2007, 2008), as well as *Balaenoptera edeni* (Oviedo and Silva, 2001; Oviedo and Silva, 2005; Acevedo *et al.,* 2007), *Balaenoptera physalus* (Lira *et al*., 1995; Acevedo *et al.,* 2007; Bolaños-Jiménez and Villarroel-Marín, 2008), *Physeter macrocephalus*, *Tursiops truncatus* (Oviedo *et al.*, 2005; Oviedo and Silva 2005), *Stenella frontalis*, *Stenella attenuata* (Rangel, 2007; Rangel and Cobarrubia-Russo,

2008), *Stenella coeruleoalba*, *Feresa attenuata*, *Grampus griseus*, *S. guianensis* (Esteves and Oviedo, 2007b; Oviedo and Esteves, 2008) and *Delphinus* spp.

Sightings records on common dolphins from 1997 - 2006 (*n*= 146) were pooled together with observations from Araya Peninsula area, where information have been collected from systematic surveys during 2007 - 2008 (n= 38). All records (*n*= 184) were analyzed through descriptive statistic and integrated into a Geographical Information System (ArcGIS 9.2). Observations included information on date, time, group size, sea state (Beaufort scale), geographic coordinates, behavior (at initial encounter according to the standard definitions on behavioral states in Mann, 1999; Mann, 2000), and effort-corrected (days invested during searches) relative abundance and sighting indices (Abundance Per Unit of Effort APUE and Sighting Per Unit of Effort SPUE, respectively).

Arbitrary classes of APUE were established by a cluster analysis (group average, square Euclidean) and tested for statistical differences by Kruskal Wallis test, concurring with the non parametric distribution of the sample (Zar, 1996). Using ArcGIS 9.2, distribution maps were constructed using the effort corrected APUE and geographical coordinates as input parameters, interpolated in a 1.8 × 1.8 km grid using a Gaussian Kriging Interpolation to generate thematic maps. Relative abundance was also plotted, according to the clumping resulted from the cluster analysis.

RESULTS

Total field effort was 153 days. Systematic surveys comprised 76 of those days: 12 in coastal habitat plus 64 surveys distributed in shelf and transitional habitat. The most frequently encountered odontocete species overall were common and the Atlantic spotted dolphin (50% and 15%, respectively).

Relative abundance of common dolphins is represented in five arbitrary classes of APUE: (1) very high (3.54 dolphins, CI 95%: 2.14 - 4.95); (2) high (0.76 dolphins, CI 95%: 0.59 - 0.95); (3) medium (0.38 dolphins, CI 95%: 0.32 - 0.46); (4) low (0.26 dolphins, CI 95%: 0.25 - 0.27); and (5) very low (0.14 dolphins, CI 95%: 0.11 - 0.17). Differences amongst the estimates were statistically significant (Kruskal Wallis, X^2:41.46 *DF:* 4, p <0.05). Spatial distribution of the common dolphin's APUE reflects a major abundance in the neritic habitat between the southern coast of Margarita Island and central Paria Peninsula and north of Araya Peninsula, with important concentrations of common dolphins along the Islands of the Mochima NP, and within the eastern portion of the Cariaco Basin (Figures 2 and 3).

The distribution according to the density of occurrence of common dolphin is shown in Figure 4. Approximately 63% (*n*=2094) of all the individuals recorded occurred within shelf waters. The distribution pattern in this important habitat of very high density would concur with the distribution of APUE mentioned before, including the transitional habitat off the northwestern coast off Araya Peninsula. High density would equally cover deep oceanic-like areas, such as the Cariaco Basin. The lowest density would be localized at the shelf break off the northern coast of Margarita Island. However, density would progressively increase in oceanic depths off the western coast of La Blanquilla Island. Seasonality in APUE spatial pattern was not statistically significant (Kruskal Wallis, X^2:0.04 *DF*: 1, p >0.05).

DISCUSSION

Distribution and abundance

The spatial pattern of the abundance estimates provides a good insight of the wide distribution of *Delphinus* spp. off the northeastern coast of Venezuela. Common dolphin inhabits any major marine habitat here, from shelf waters to transitional areas, and even oceanic habitats, such the Cariaco Basin (Rangel *et al*., 2005; Acevedo-Galindo, 2007). Information drawn from the APUE estimates indicates an uneven distribution of common dolphin abundance. The latter is an indication of a differential pattern of habitat use. Although levels of occurrence differ quantitatively and spatially, the trend of dominance and representativeness of the species over the region's cetacean diversity prevails. Common dolphin importance as the main component of the cetacean fauna in the northeast coast basin has been previously documented, even at proportions over 50% of the total cetaceans sighted (Naveira 1996, Acevedo-Galindo 2001, 2007; Molero, 2004; Quevedo, 2004; Orlando, 2005; Bolaños-Jiménez and Villarroel-Marín, 2005, Bolaños-Jiménez *et al*., 2006; Rangel, 2007; Molero *et al.*, 2008; Rangel and Cobarrubia - Russo, 2008).

Common dolphins (*Delphinus* spp) might be a key predator for the main fishery resource of the northeast coast basin: Spanish sardines. At this point of the research progress, we can only suggest the relevance of *S. aurita* in the diet of common dolphins, firstly according with observations of foraging events plus anecdotic accounts of stomach content of stranded dolphins, and secondly through the only quantitative diet assessment done to two stranded specimens by Naveira (1996). Foraging habits are determinant in the distribution of the species in the rich environment of the study area.

The density pattern within shelf habitat would reflect the close spatial relation between predator-preys; particularly with Spanish sardines, specifically on the sectors referred by Freon *et al.* (1997) as key fishing grounds. The latter also coincide with the location of the most important coastal upwelling area off the coast of Central Paria Peninsula and Araya Peninsula, similar to the documented occurrence of *Delphinus delphis* as an indicator species of upwelling modified waters in the Eastern Tropical Pacific (Ballance *et al*., 2006, Fernández *et al*., 2007, Fernández and Oviedo, 2009). Since density distribution would locally emulate that of its potential prey (Forcada, 2002), and consequently overlap with areas of coastal up-welling, the latter trend comprises discrete areas limited by boundaries, which defines a system diverging by physical and biological features.

The increasing density trend in oceanic waters, such as the deep waters of the Cariaco Basin and beyond the shelf break west of La Blanquilla Island, could also be interpreted in terms of prey distribution, particularly on the occurrence of mesopelagic prey species as myctophids. There is strong possibility that myctophids might play a relevant role as prey items, probably more in the case of common dolphins occurring in oceanic-like environments, such as the Cariaco Trench. The elements considered above could imply the possible migration to diversified foraging ground, similar to the local migratory movement considered by Stockin *et al.* (2008) with common dolphins in New Zealand Waters.

Records close to Farallón Centinela (Crescini pers. comm. Figure 1), and even those from the central Venezuelan coast (Cobarrubia and Bolaños-Jiménez, 2007) would be closely associated to the upwelling off Cabo Codera, which itself has a particular temporal and intensity pattern, when compared to the coastal upwelling in Northeastern Venezuela (Lorensoni, 2000). Nevertheless it is the westernmost boundary of the Cariaco Basin, where the narrow Centinela Channel connects the basin to the Caribbean Sea (see figure 1 in Müller-Karger *et al*., 2004). The influence of Cabo Codera´s upwelling might turns into a gradient of productivity influencing the central coast. This might explain the recent documented records of *Delphinus* spp. of Cobarrubia and Bolaños-Jiménez (2007), and even the potentially extralimital record of Ramírez-Carroz and González-Fernandez (2004), off the Venezuela's Gulf (possibly associated with lesser coastal

upwelling off the west coast, such as the one in Paraguaná Peninsula). Density and level of occurrence of common dolphin in these areas would not be as concentrated as in Northeastern Venezuela, where the most intense coastal upwelling is localized. Consequently, the delimitation of a Venezuelan stock, as suggested by Jeffersson *et al.* (2009) would be supported and bounded, by a gradient of coastal upwelling influence concentrated in the Cariaco Basin.

Seasonality could have a non significant influence in the spatial distribution of common dolphin in the northeastern coast of Venezuela, where the species seems to be present year-round (Naveira, 1996, Acevedo, 2007). Additionally, the effect of the Orinoco river influx during rainy season, could potentially balance the difference in productivity between dry (upwelling) and the rainy seasons (see figure 1 in Müller-Karger *et al*. 2004), supporting the presence year-round of predators as common dolphin due to prey availability.

Management and conservation

An issue of concern is the declining trend of the Spanish sardine stock that resulted in 0 catch in 2005, according to landing statistics of the Venezuelan Fishery Administration Agency (INSOPESCA). The affectation of common dolphins in a possible trophic cascade scenario was suggested before (Oviedo, 2005). The actual sardine fishery situation seemed to accelerate the need of understanding the predator-prey interrelationship between *S. aurita* and common dolphins in the study area.

Focal upwelling localized within shelf habitat, particularly in central Paria Peninsula and adjacent waters can be identified as the potential critical habitat for long beaked common dolphin. A trend of regionalization is reflected in the distribution and abundance of *Delphinus* spp. in the northeast coast of Venezuela. According to Pauly and Zeller (2003), the latter will serve as a base-line to assess ecosystem health and evaluate management scenarios.

Based on the considerations above, If the relevance of *S. aurita* in the diet of long-beaked common dolphin is confirmed by research in progress, *Delphinus* spp. will serve not only as an indicator-species for upwelling modified waters, but as an effective mean to monitoring sardine stock and ecosystem stability. Added to the latter, the fact that critical habitats for the species, as proposed in this report, are the key centers of primary productivity, therefore they should be considered as candidate areas for MPA status, due to the applications of these locations for the complex trophodynamic of the maritime environment of the northeastern coast of Venezuela.

We acknowledge the potential effects of the heterogeneity of sampling protocols and distribution of field efforts, even though there is a solid representation of search efforts in every of the four sections assessed, the uneven investment in search efforts might produce biased results.

ACKNOWLEDGEMENTS

Lenin Oviedo's data gathering was supported by funds from the *Whale and Dolphin Conservation Society* (WDCS), *The Rufford Project Conservation Fund*, and *Cetacean Society International* (CSI). Logistic support to Jaime Bolaños-Jiménez was provided by Marino Diaz and the boat crew of Aventura Marina. in Puerto la Cruz. Oceanographic data was provided by the Cariaco Project of Estación de Investigaciones Marinas de Margarita (EDIMAR - FLASA) and the University of South Florida (USF) ; many thanks to Professors Irene Astor and Ramón Varela. Fisheries statistics were provided by INSOPESCA - Gobierno Bolivariano de Venezuela (www.insopesca.gob.ve). We thank PDVSA -- the Venezuelan Oil Company -- for authorizing the use of data collected aboard the oceanographic cruises for the Plataforma Deltana Project (LBAPD). We are also grateful to the Captain and the crew of the R.V. *Hermano Ginés* and Fundación la Salle de Ciencias Naturales (FLASA).

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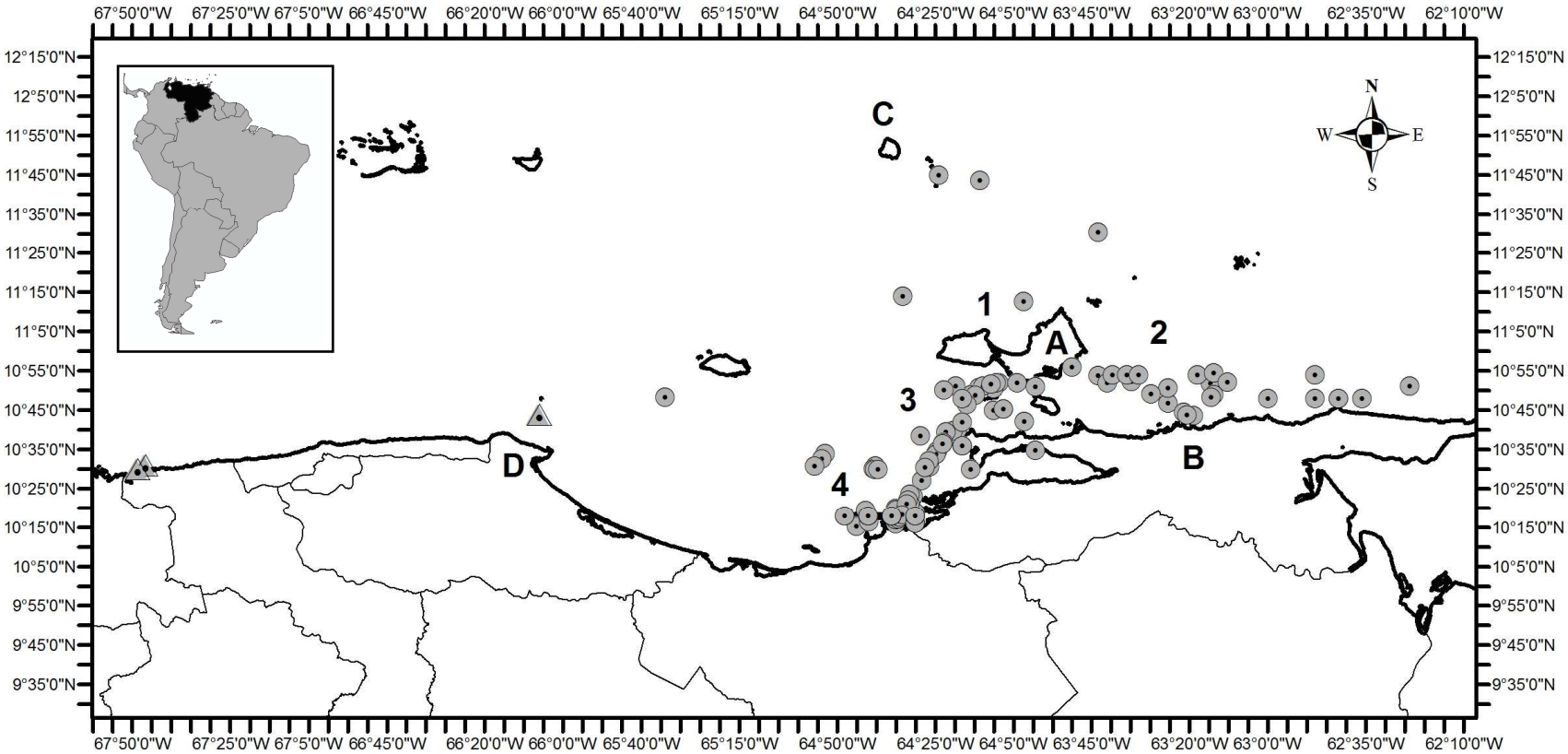

Figure 1. Study area in northeastern Venezuela following Acevedo *et al.* (2007): 1) shelf edge on the north coast of Margarita Island (A) and La Blanquilla Island (C); 2) Margarita Island's east coast and Margarita-Los Testigos submarine platform, including central Paria Peninsula (B); 3) north coast of Araya Peninsula, including Coche and Cubagua islands; and 4) Cariaco Basin southwest of Margarita and Cumaná, including the Cariaco Gulf. Records of *Delphinus* are represented by circles; records from the central coast around the area of influence of Cabo Codera' upwelling (D), are denoted by a triangle, including those reported in Cobarrubia and Bolaños Jiménez (2007).

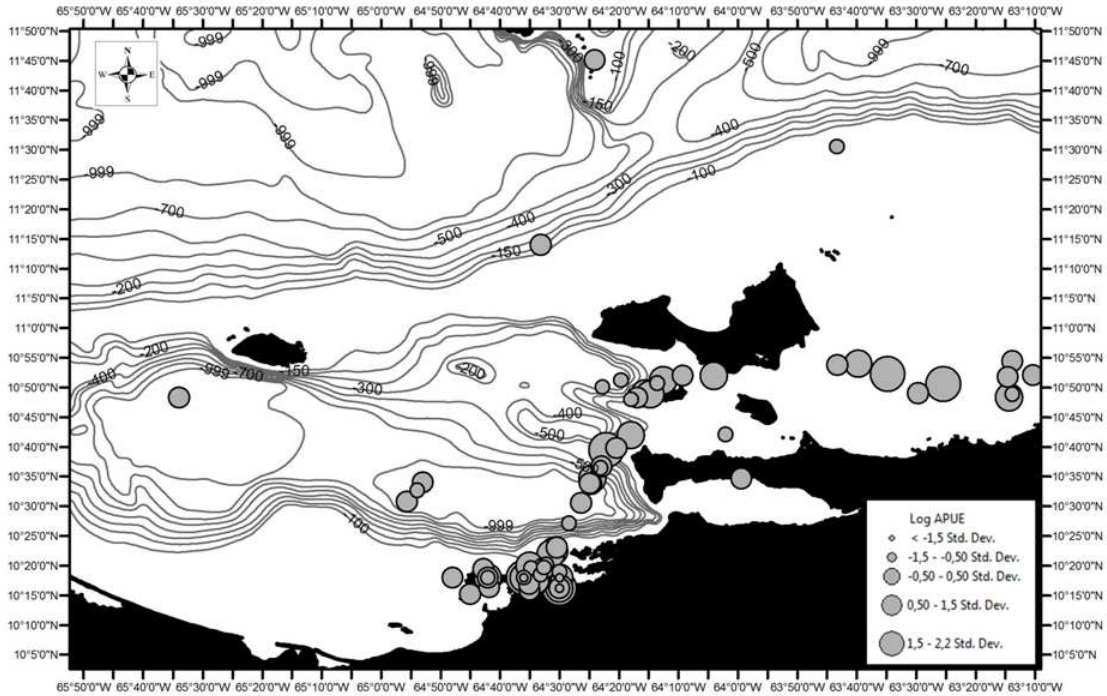

Figure 2. Distribution of effort corrected APUE during initial sightings of *Delphinus* in the study area during the dry season.

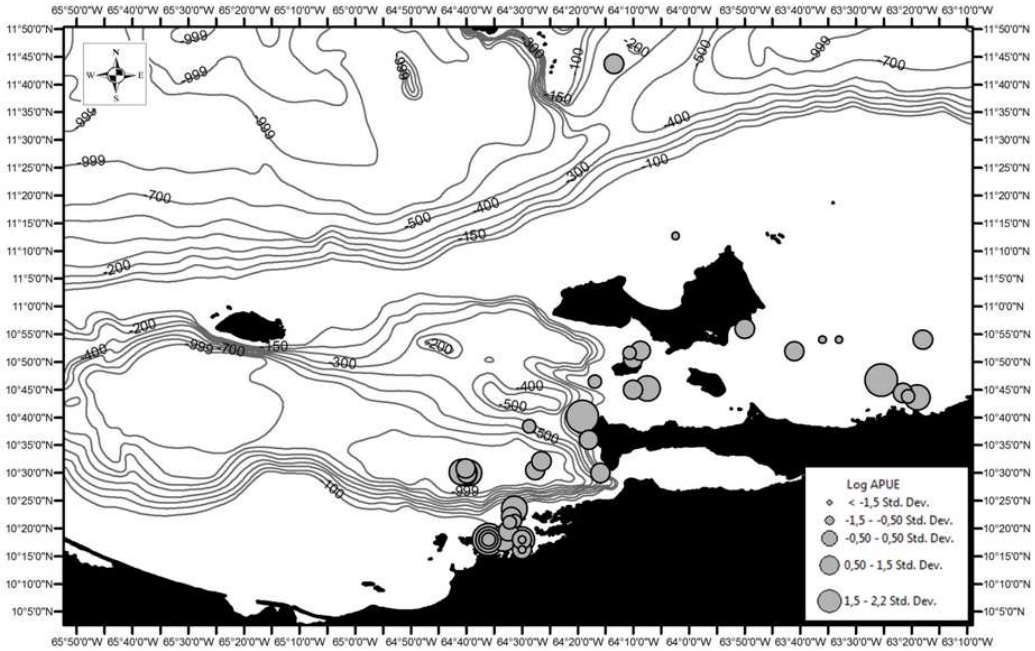

Figure 3. Distribution of effort corrected APUE during initial sightings of *Delphinus* in the study area during the rainy Season.

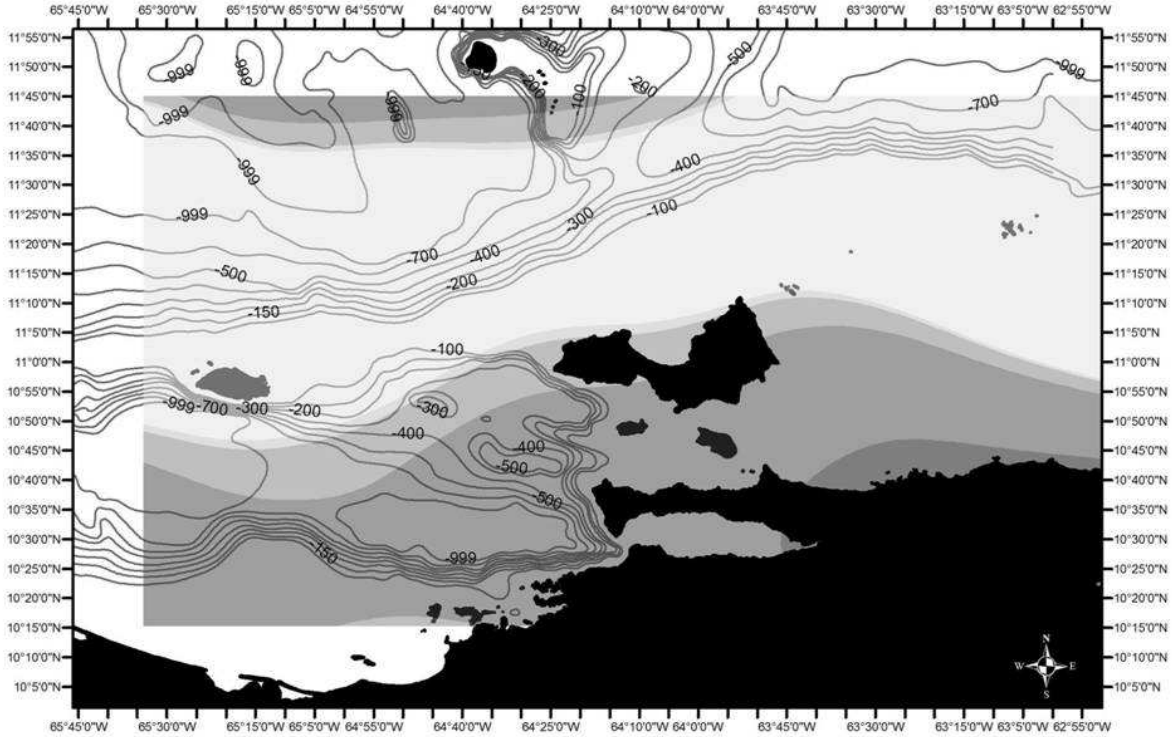

Figure 4. Density of *Delphinus* spp (generated from effort corrected APUE) off the northeast coast of Venezuela. Density scales from low (light gray) to high (dark gray).