

# Patterns of prey biomass consumption by small odontocetes in the northeastern coast of Venezuela

Lenin Oviedo<sup>1,2</sup>

1) Proyecto Golfo de la Ballena, Biotropica, Caracas Venezuela. 2) Proyecto Delphinus, Isla de Margarita, Venezuela.

## ABSTRACT

Trophic relationships are conditioned by population dynamics of interacting species in the community (species present, connections between them in the web, and interaction strengths), and on the consequences of these species interactions for ecosystem processes such as productivity and nutrient flux. Odontocete predators use a wide range of prey items; they are adapted to feeding at different depths, base on the fact that increased water depth is likely to offer more niches to be exploited by marine life. The aim of this report is to assess the patterns of prey consumption by small odontocetes in the study area, using a spatial predictive model and incorporate natural predatory patterns into a potential management scheme of strategic food sources, for both human and marine predators. Using the geo-statistical analysis tool of ArcGIS 9.2, a model of prey consumption density was predicted for species with a SPUE > 0.15. The model was constructed using the biomass consumption estimates, effort corrected APUE and geographical coordinates as input parameters, interpolated on a  $1.8 \times 1.8$  km grid using a Gaussian Kriging Interpolation to generate thematic maps. The biomass consumption emphasized the differential in habitat use by species. The latter tendency primarily sustains the dominancy of common dolphins in the whole assessed area, with a major level of consumption within shelf waters. The trends in predicted prey biomass removal distribution by odontocetes particularly suggest the stratification of niches primarily in shelf waters, with a prey biomass that would be constitute basically by demersal fish and small pelagic (including *Sardinella aurita*), and into transition-oceanic depths where most of the predatory pattern would rely in pelagic - mesopelagic squids and myctophids. Overall the spatial tendencies in regionalization presented in this contribution will serve as a base-line to assess ecosystem health and evaluate management scenarios.

KEYWORDS: ATLANTIC OCEAN; SOUTH AMERICA; DISTRIBUTION; FOOD/PREY; NORTHERN HEMISPHERE; CARIBBEAN SEA; MODELLING, ECOSYSTEM, HABITAT.

## INTRODUCTION

The understandings of food webs entail a detailed perception of factors in the interface of community and ecosystem ecology. Trophic relationships are conditioned by population dynamics of interacting species in the community (species present, connections between them in the web, and interaction strengths) and on the consequences of these species interactions for ecosystem processes such as productivity and nutrient flux (Begon *et al.*, 2006).

Food consumption is a response inherent to the relationship established by an organism and the ecosystem' attributes it inhabits. Spatial distribution is associated by the specialized or generalized pattern of food consumption of predators and other consumers. Cetaceans' distribution is generally related to the presence/absence of their prey (Forcada, 2002). Due to the relatively high energy requirements, cetaceans would occur primarily in locations with high potential prey occurrence. Odontocete predators use a wide

range of prey items, they can be distributed over wide ranges, and change their distribution seasonally, influenced by the availability of their prey. Different species are adapted to feeding at different depths (Cañadas *et al.*, 2002, Weir *et al.*, 2001; Davis *et al.*, 1998), based on the fact that increased water depth is likely to offer more niches to be exploited by marine life. Therefore, the complexity of the cetacean habitat is an indirect environmental attribute with implications for foraging success, for instance steep sea floor slopes, such as those typically associated with continental shelf-breaks provides upwelling opportunities by forcing nutrient-rich deep-water currents to the surface, thus promoting a potentially rich foraging environment (Hui, 1985, 1979).

This report is a preliminary approach that examines the patterns of spatial distribution of biomass' consumption by small odontocete cetaceans in the marine ecosystem off the northeastern coast of Venezuela. The waters off the northeastern coast of Venezuela, is a key area in terms of biodiversity in the Greater Caribbean eco-region, prey abundance is particularly characterized by the local occurrence of small pelagic such as sardines associated with habitat productivity. There have been a documented decrease in the wind force since 2004, resulting in a weak upwelling that has affected the larval energy intake of the cetacean' potential prey, Spanish sardines (*Sardinella aurita*). Consequently, the Spanish sardine fishery has equally decrease since 2003, reaching a critical point in 2005.

Prey depletion has been an influential factor for cetacean population decreased (particularly common dolphins) in locations within the Mediterranean basin (Bearzi *et al.*, 2008), identifying a degradation of the food web, where the current situation of exploitation of marine resources could lead to additional species loss (Coll *et al.*, 2008). The aim of this report is to assess the patterns of prey consumption by small odontocetes in the study area, using a spatial predictive model. The ultimate goal of this contribution is to incorporate natural predatory patterns into a potential management scheme of a strategic food source, for both human and marine predators.

## **MATERIALS AND METHODS**

### **Study area**

The study area has been subdivided at a major scale into four sections of the five subdivisions proposed by Acevedo *et al.* (2007) as important areas of conservation for mysticete cetaceans (Figure 1). Overall the four sections comprise approximately 37% (>5,700 Km<sup>2</sup>) of shelf habitat and 63% (>10,500 Km<sup>2</sup>) of oceanic environment off the shelf break.

### **Small Odontocetes' Sightings and Data Analysis**

Opportunistic and systematic data collection on cetacean encounters (sightings) off northeastern Venezuela has been carried out since 1997, resulting in an database with records of more than 10 species: *Megaptera novaeangliae*, *Balaenoptera edeni*, *Balaenoptera physalus*, *Physeter macrocephalus*, *Tursiops truncatus*, *Stenella coeruleoalba*, *Stenella frontalis*, *Stenella attenuata*, *Grampus griseus*, *Sotalia guianensis* and *Delphinus* sp.

Sightings records on five species (Table 1) of small odontocetes from 1997 - 2008 (n= 96) were selected. All records were analyzed through descriptive statistic and integrated into a Geographical Information System (ArcGIS 9.2). Observations yield information on date, time, group size, detectability conditions (wind force by Beaufort scale), geographic coordinates, and effort corrected (days invested during searches) abundance and sighting indices (APUE and SPUE respectively).

Additionally, an inference of biomass consumption was done using the species' biomass estimations (maximum weight) reported by Trites and Pauly (1998), and updated with Barlow *et al.* (2008). Then following the approach of Read and Brownstein (2003), the estimates were incorporated to the expression:  $IB$  (*Ingested Biomass*) =  $0,123M^{0,80}$ . Subsequently, the ingested biomass was extrapolated to the density calculated through the APUE, using the approximate total area extension of NE Venezuela (30.000 km<sup>2</sup>), over a time frame of a year.

Using the geo-statistical analysis tool of ArcGIS 9.2, a model of prey biomass consumption density was predicted for species with a SPUE > 0.15. The model was constructed using the biomass consumption estimates, effort corrected APUE and geographical coordinates as input parameters, interpolated on a 1.8 × 1.8 km grid using a Gaussian Kriging Interpolation to generate thematic maps. Biomass consumption by species was also plotted, clumped by classes of the standard deviation. Confidence intervals of total biomass consumption by species were obtained through a non-parametric bootstrap. Statistical differences between species' biomass consumption estimates were established by Kruskal Wallis test, concurring with the non parametric distribution of the sample (Zar, 1996).

## RESULTS

### Odontocete occurrence

From all the odontocetes species observed off the northeastern coast of Venezuela during 1997 - 2008 (table 1), the majority of the encounters corresponded with the local form of common dolphin, second only by Atlantic spotted dolphins. The dominance of *Delphinus* sp. encounters was particularly reflected in both, the sighting (SPUE) and the relative abundance (APUE) indices.

### Predicted biomass consumption distribution

The biomass consumption of all five species is presented in table 1 and illustrated in figure 2. It emphasized the differential in habitat use by species. The latter tendency, which was supported statistically (Kruskal Wallis, X<sup>2</sup>: 14.84 DF: 3, p <0.05), primarily sustained the dominancy of common dolphins in the whole assessed area, with a major level of consumption within shelf waters. The prey biomass consumption pattern of *S. guianensis* would remain confined to coastal waters, in contrast with *Stenella* dolphins that would remove the prey biomass located at the shelf edge and off transitional waters, towards major depths. Common bottlenose dolphin prey biomass intake would be considerable at mid-shelf waters, not closer to the continental coastline, but to Island archipelagos within the shelf ecosystem.

The predicted distributions of the biomass consumption pattern would comply with the trend described above (Figures 3, 4 and 5); biomass removal would be majorly concentrated in shelf waters for common dolphins, covering also deep waters of the Cariaco Basin, the highest level on consumption would be localized in two key areas: 1) the waters between the south-eastern coast of Margarita Island and the continental coast of central Paria Peninsula, 2) the western side of the Araya Peninsula. Atlantic spotted dolphins would concentrate the prey biomass removal by predation to deep waters of the north-eastern portion of the shelf edge, and the western side of Margarita Island toward the Cariaco Basin. The model also showed that spotted dolphins' consumption level would increase progressively from the shelf edge to deep waters south-west of La Blanquilla Island. Bottlenose dolphins would increase the level of prey removal from the eastern coast of Margarita Island, and around deep waters off the shelf toward the central coast of Venezuela.

## DISCUSSION

The predicted distribution of odontocetes' biomass consumption, based on the relative abundance of toothed cetacean off the northeastern coast of Venezuela, primarily highlight a clear evidence that predators are not evenly distributed throughout the environment of the study area; and second, the location of predatory pattern's spatial arrangement would concentrate in discrete areas, giving insight of habitat use and resources partitioning.

The predatory pattern predicted for *Delphinus* sp. and the prey biomass removal within shelf habitat would represent the close spatial relation between predator- preys; particularly with the potential local prey of common dolphins, Spanish sardines, specifically on the sectors referred by Freon *et al.* (1997) as key fishing grounds (areas numbered 2 and 6, in their figure 1). Consequently, common dolphin prey biomass consumptions would also coincide with the location of the most important coastal upwelling area off the coast of Central Paria Peninsula and Araya Peninsula. The occurrence of *Delphinus* sp. has been linked with areas of high productivity, as a result the species has been use as an indicator of upwelling modified waters in the Eastern Tropical Pacific (Balance *et al.*, 2006, Fernández *et al.*, 2007). Since predators' biomass consumption distribution would locally emulate that of its potential prey, and in this specific case, overlap with areas of coastal up-welling, the spatial arrangements of common dolphins' predatory patterns includes discrete areas limited by boundaries, which defines a system diverging by physical and biological features.

The trends in predicted prey biomass removal distribution by odontocetes particularly suggest the stratification of niches primarily in shelf waters, with a prey biomass that would be constitute basically by demersal fish and small pelagic (including *S. aurita*), and into transitional-oceanic depths where most of the predatory pattern would potentially rely in pelagic - mesopelagic squids and myctophids.

Provided that the spatial distribution of a given predators is conditioned by the specialized or generalized pattern of food consumption, and associated with the spatial arrangement of its prey (Forcada, 2002), the distribution of top predators' biomass consumption would be an indirect indication of prey location and abundance.

In general this approach combining elements of spatial and trophic ecology, has established clear patterns of habitat and resources partitioning, plus trends in occurrence' dominancy in coastal and shelf areas of an important portion of the Venezuela's EEZ. However the information presented here is conditioned by two important limitations: 1) the estimations of relative abundance are based on a major data set derived of a non-systematic research effort, and 2) the information on diets is not an empirical approach but a theoretical one based on Pauly *et al.* (1998), that would not yield important local particularities.

Prey biomass consumption distribution assumes that predators' spatial arrangement would match that of their prey. However, prey abundance by itself should not be considered as a unique proxy of habitat use, the abundance of cetacean predators will also play a direct role, or an indirect pressure through the seascape of fear (Wirsing *et al.* 2008), to comply with, in the elucidation of both the spatial and foraging pattern of cetacean species.

According to Pauly and Zeller (2003), the spatial trend in regionalization, as the one presented in this report represents a key base-line to assess ecosystem health and evaluate management scenarios.

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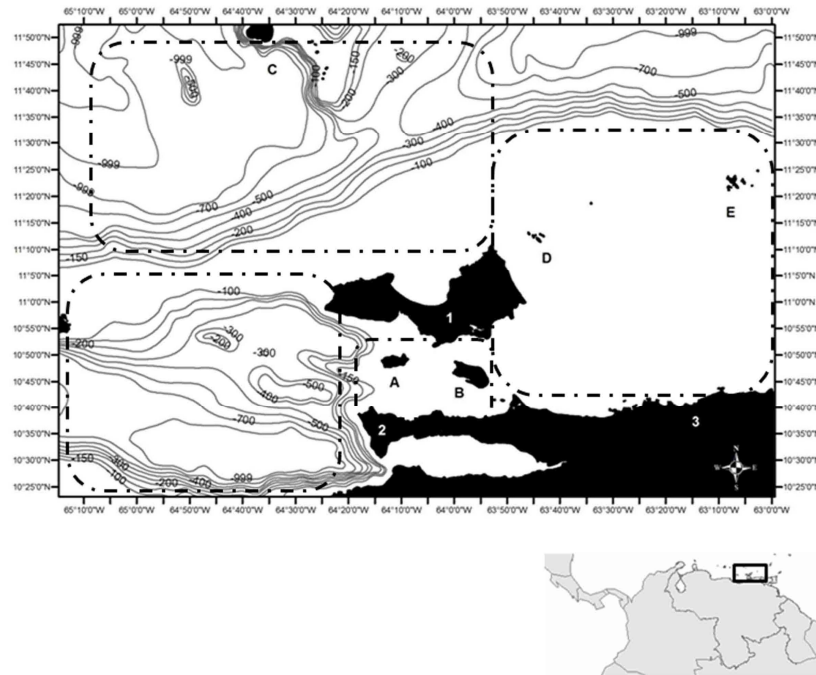
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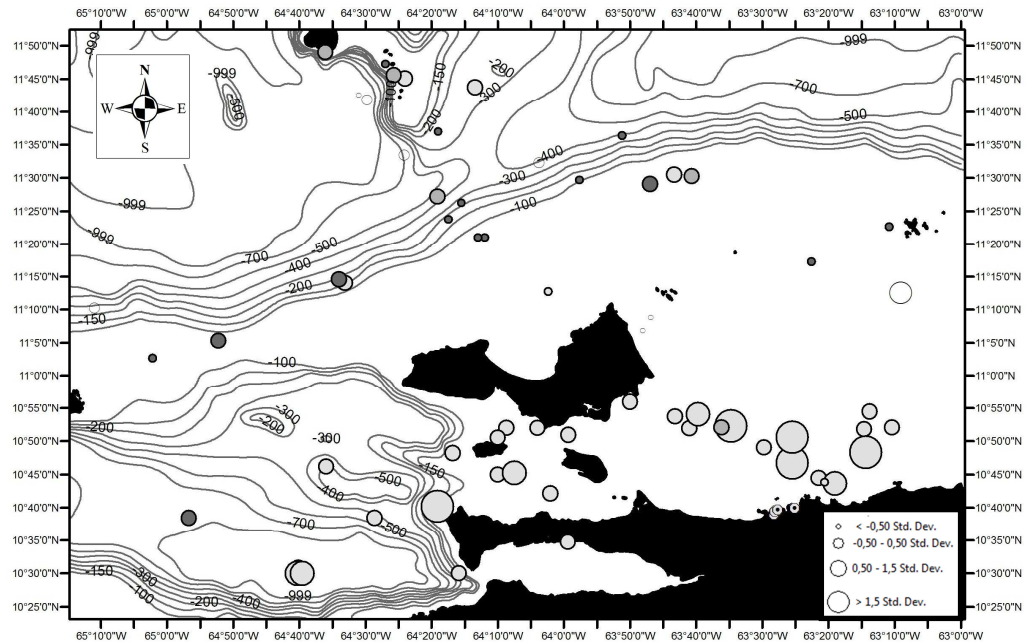
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**Table 1.** Odontocetes cetacean's records (1997 - 2008) incorporated in the analysis: Sighting per unit of effort (SPUE), Abundance per unit of effort (APUE), Biomass ( Kg), according to Trites and Pauly (1998), and \*Barlow *et al.* (2008), Total Prey Biomass Consumption (PBC) in Ton/Km<sup>2</sup>/Year.

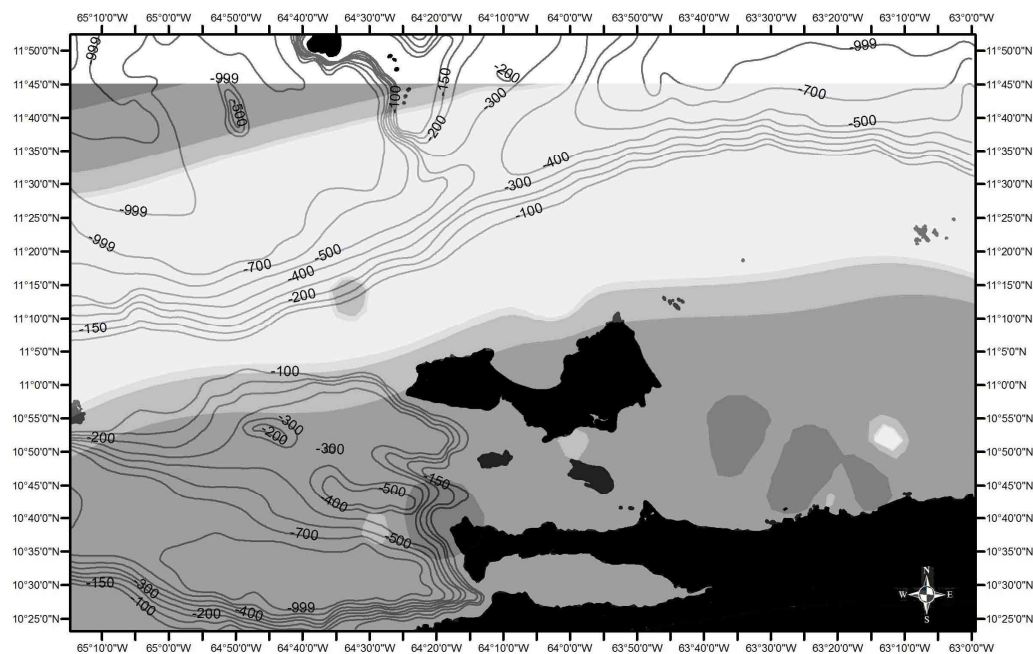
Common name	Scientific name	SPUE	APUE	Biomass	PBC
Common dolphin	<i>Delphinus sp</i>	0.59	17.78	80*	9734.82
Atlantic spotted dolphins	<i>Stenella frontalis</i>	0.28	4.84	67.50	5301.40
Common bottlenose dolphin	<i>Tursiops truncatus</i>	0.16	1.56	203	1709.27
Guiana dolphin	<i>Sotalia guianensis</i>	0.10	2.87	38.60	3138.11
Pantropical spotted dolphin	<i>Stenella attenuata</i>	0.06	0.74	71,70	814.57



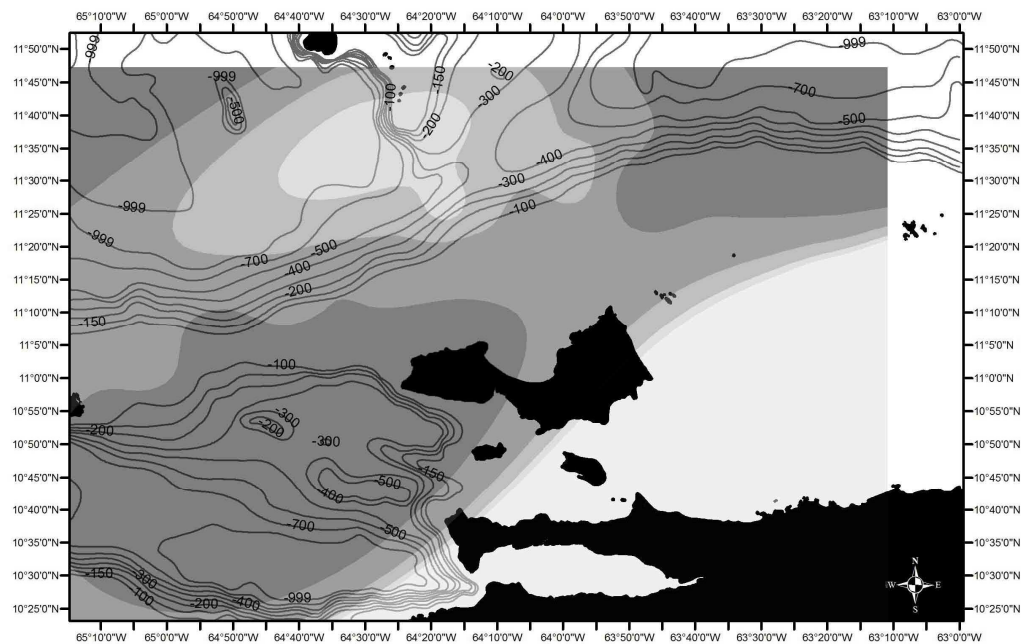
**Figure 1.** Study Area in Northeastern Venezuela, divided according to Acevedo *et al.* (2007): Margarita Island (1), Araya Peninsula (2), Central Paria Peninsula (3), Cubagua Island (A), Coche Island (B), La Blanquilla Island (C), Los Frailes Archipelago (D), Los Testigos Archipelago (E).



**Figure 2.** Prey biomass consumption levels by species: Filled circles correspond with common dolphin (light gray), Pantropical spotted dolphins (medium light gray), and Atlantic spotted dolphin (dark gray), small gray filled circles with concentric dot represent Guiana dolphins, and blank unfilled circles common bottlenose dolphins. Circle size is proportional to the level of biomass consumption.

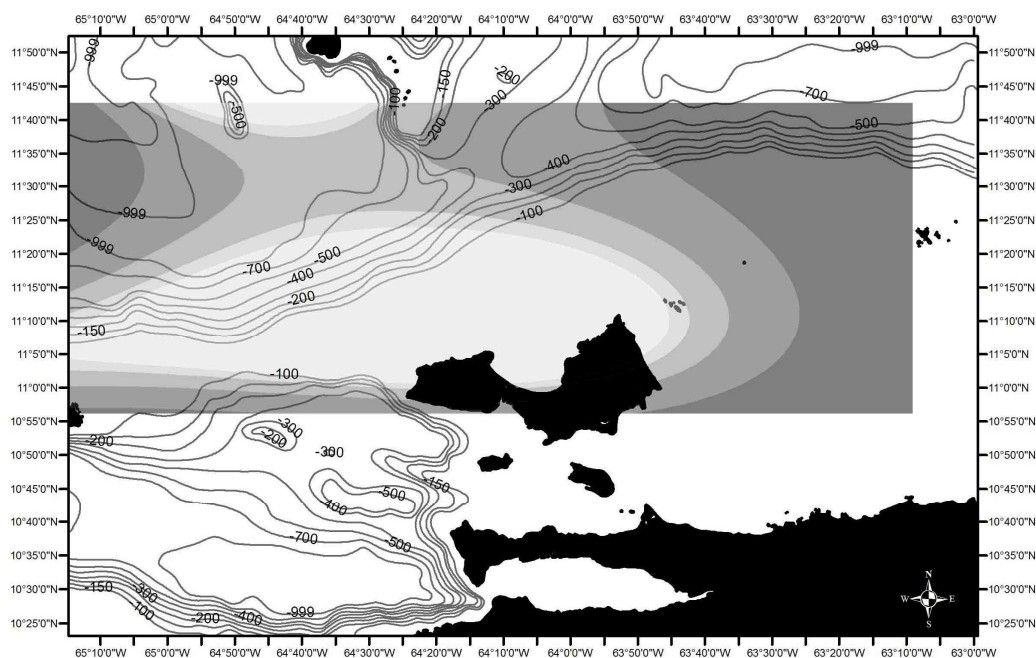


**Figure 3.** Prey biomass consumption by common dolphin (*Delphinus* sp), levels on consumption are represented by light gray to the lowest, and dark gray to the highest level of biomass removal.



**Figure 4.** Prey biomass consumption by Atlantic spotted dolphin (*S. frontalis*), levels on consumption are represented by light gray to the lowest, and dark gray to the highest level of biomass removal.





**Figure 5.** Prey biomass consumption by common bottlenose dolphin (*T. truncatus*), levels on consumption are represented by light gray to the lowest, and dark gray to the highest level of biomass removal.