The utilization distribution of humpback whales in Golfo Dulce, Costa Rica

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ABSTRACT

Humpback whales (Megaptera novaeangliae) aggregate in winter breeding and calving grounds along continental margins, coastal islands, or archipelagos located in tropical waters. Migration to these breeding sites requires a long journey from northern feeding areas in temperate and circumpolar latitudes. The humpback whales habitat preference is generally restricted to coastal areas, and their tendency to concentrate in specific locations to reproduce exposes them to anthropogenic threats such as fishing, coastal development, water pollution, and marine traffic. There has been an increasing interest for coastal development projects that intent to capitalize the natural attributes of Golfo Dulce, in the southern Pacific coast of Costa Rica, potentially threatening the stability of the ecosystem and creating habitat disruption for the wintering population of humpback whales in the area. This contributions focalize in important ecological aspect related with areas use, particularly behavioral elements associated with the spatial aggregation of competitive groups, mother – calf pairs and vocalizing humpback whales. We identify areas with significant aggregation of mother- calf pairs that can be categorized as critical nursing areas, producing key baseline information to promote effective conservation and management strategies such as Marine Spatial Planning.

INTRODUCTION

The tropical waters of Costa Rica are a suitable breeding and calving grounds for humpback whales, promoting the arrival of migrant whales from the Northeast and Southeast Pacific populations. The genetic and cultural exchange could be possible if an overlap occurs between populations (Acevedo & Smultea 1995, Oviedo *et al* 2008). Nevertheless, the arrival in different seasons is more frequent; the northern population migrates to the wintering grounds between December and April, whereas those from austral zones make their journey from June to October (Clapham 2002). The northern population of the American stock feed in the summer and falls off coast of California, and migrates to the Mexican waters during the winter (Baker *et al* 1994). However some authors suggest that the southernmost record of northern population is the Isla del Caño and Golfo Dulce in the Pacific of Costa Rica (Acevedo & Smultea 1995). On the other hand, the migration route of the southern population has two important

wintering grounds in Central American waters: Las Perlas Archipielago off the coast of Panama, and the Pacific coastline of Costa Rica, being The Caño Island, Drake Bay and Golfo Dulce, areas of greater concentration of sightings for this species (May-Collado *et al*, 2005). First records of southern Pacific humpback whales in Costa Rica, documented by Acevedo-Gutiérrez & Smultea (1995) are focused on humpback whales occurrence in Golfo Dulce, but not dealing with the spatial distribution and habitat use. It is important to determine the habitat use of cetaceans species to understand their relevance in the ecosystem, as integral part of local the marine implications in resources management and conservation of marine predators. There has been recently an increase interest for developing projects in Golfo Dulce, with important economic implications on the local coastal communities, such as Tuna Feed Lots and luxury Marinas, likely to result in a highly negative environmental pressure, especially over the cetacean's populations (Oviedo *et al* 2009). This contributions focalize in important ecological aspect related with areas use, particularly behavioral elements associated with the spatial aggregation of competitive groups, mother – calf pairs and vocalizing humpback whales. We identify areas with significant aggregation of mother- calf pairs that can be categorized as critical nursing areas, producing key baseline information to promote effective conservation and management strategies such as Marine Spatial Planning.

MATERIALS AND METHODS

Study Area: Golfo Dulce is a fjord-like embayment situated between 8°33'N and 83°14'W, with a 50 Km long and 10-15 Km wide. The climate is humid tropical with a rainy season that extends from May to November, having an average of monthly precipitation of about 100-700 mm. The main input of fresh water comes from the rivers Coto, Tigre, Esquinas and Rincon that have a direct influence in the circulation patterns of this strongly stratified estuary. A sill area is localized to 20 Km from the mouth, dividing the gulf in two regions with different physical and oceanographic features: the inner and the outer basin. The maximum depth of the inner basin is approximately 215 m with an anoxic layer in the deeper zone (Brenes & Leon 1988). However, the sill has shallow depths reaching 60 m at the deepest point, preventing the free exchange with the adjacent coastal water masses. Additionally, the tidal range varies of 2-4 m in a lunar month cycle (Svendsen *et al* 2006).

Data Collection: The surveys were made between 2006-2012, from a 7 m fiberglass vessel with outboard engine of 115 HP, within the gulf and the surroundings areas of Osa Peninsula. For each sighting, date, time, size and group composition, was registered and up-dated every ten min, along with GPS position and the behavioral state of the subjects of the encounter (single whales, mother and calf pair, triads or competitive groups). The boat was positioned 100 m away of the group or individual in beginning of the observations, and the localization of the animals was equated to that of the the vessel. After initial encounter, the protocols of photo-identification and the underwater recordings were undertaken, using a combination of a hydrophone, tape recorder and underwater camera.

Data Analysis: The spatial data were processed to evaluate the distribution of the whales according to the zones established in this study: inner basin and the sill area. We calculated an index of relative density (Sightings per Unit of Effort-SPUE) and deploy a Spline method to obtain a surface of humpback whales encounters. Utilization distribution was evaluated using a the *Average Near Neighbor Ratio*, combined with a Kernel Estimate, two main contours where defined in the kernel, a 95% volume contours that included all sightings defining the extension of the Home Range within the study area and a 50% volume contour that aggregates all encounters that define a core area of distribution. Temporal autocorrelation was avoided in the analysis; nevertheless we acknowledge spatial autocorrelation as intrinsic of our research topic.

RESULTS

Sightings and Group Composition: During the encounters made between 2006 and 2012, there were 68 sightings with an average of 2.2 individuals per sighting. The group size showed variations among 2 to 6 individuals; single whales were also common. In total 149 individuals were observed; 112 adults, 1 juvenile and 36 calves. The group composition shows a greater quantity of only adults groups with 34 records (53%), followed by mother-calf pair with 24 (37.5%) and the triads were rare. In all records only two competitive groups was seen in this location (figure 1). The competitive groups were composed of three to five males trying to have access to a female with a calf.

Spatial distribution: Although the home range cover almost all the area of the estuary, we noticed a general trend towards a more frequent use of the western coast in its middle part at the sill, representing a core area for all encounters including mother-calf pairs, such pattern of clustered aggregation is supported by the average nearest neighbor index (Observed Mean Distance / Expected Mean Distance = 0.74, Z Score = -4.15 standard deviations, $p< 0.01$). However, when only encounters of mother and calf pairs are considered, aggregations seemed to be rather random (Observed Mean Distance / Expected Mean Distance = 0.98, Z Score = -0.23 standard deviations, $p> 0.05$). Therefore, this pattern of spatial distribution does not show a clear difference in the segregation of different groups. Nevertheless, graphically there seemed to be a slight change in the distribution of mother calf pairs related to the general pattern of distribution of this specie (Fig. 2), the main difference was found into the core area that present a uniform arrangement in the kernel representation for mother and calves pairs, while in the spline interpolation surface, the overall distribution seemed patchy due to some low values of SPUE (Fig. 3).

DISCUSSION

The data present in this paper is evidence that Golfo Dulce constitutes an important wintering ground on the Pacific Central American coasts and the habitat use in this estuary would be governed by the physical and oceanographic features, which has been documented in previous studies (Oviedo & Solis 2008, Martínez-Fernández 2011). Despite the fact that the spline interpolation method is deterministic and the resultant surface mainly represent the variation bounded to physical process (Webster & Oliver 2007), we consider feasible to weigh against oceanographic data, with special attention to the map of currents proposed by Zhang-Lei (2002). Qualitatively, the

bathymetry, temperature and possibly currents regime can have an important role in the distribution of these cetaceans in Golfo Dulce. We observe a coincidence among the low probabilities and the zones of eddie formation reported by several authors (Zhang-Lei 2002, Quirós 2003, Svendsen 2006) and the current probability of encounter illustrate in the interpolation model. This information suggests that humpback whales actively avoid the areas of turbulent mixing and would possible concord with movements in the direction of the currents to prevent energy losses.

The distribution patterns of the vocalizations and its relationship with the social organization or group composition (proportions between adults and mother-calf pair in the groups), suggests that the bay's waters are used mostly by singing adults. Because the songs are used in the mating systems of the whales, this could be an indication that mating occurs within the estuary, and this idea may be supported by the presence of competitive groups over the sill, characterized by depths less than 60 m, Then, according with Whitehead and Moore (1982), we can define the sill of the gulf as reproductive areas for humpback whales.

The mothers with calves seek out the warm and shallow waters over the western region of the sill and the relative quite water in southeast end of the inner basin. In the innermost part of the estuary Zhang-Lei (2002) and Svendsen (2006), reported currents lesser than 0.5 m/s and the highest temperature, around 29,7° C, which will supply suitable conditions to nursing whales groups, however, there were relative scant encounters over this area. We inferred from this data that the sill area is the zone of greatest importance for *M. novaeangliae.* Here is possible a temporal overlap among females with calves and competitive males, the latter concord with the observations of Oviedo & Solis (2008) elsewhere in the Osa peninsula surroundings.

The habitat use of *M. novaeangliae* in Golfo Dulce is not differential in the estuary. The general pattern shows a preference by the western side of the sill, where the core area of distribution is located. The sill area is very dynamic, a key location with overlap between different classes of groups, allowing the social interactions. The depths and the dynamics of the currents over the sill define this area possibly as breeding area and potentially as a competition zone. We acknowledge the influence of spatial autocorrelation in the analysis undertaken, but we rationalized it as part of the very nature of the subjects being evaluated.

This key spatial distribution criterion should be take in account to establish guidelines on the appropriate management of the resources in this important coastal-marine habitat of Costa Rica, considering the pressing need of create connectivity between different marine protected areas to maximize the protection efficiency of the species and resources, using an ecosystem approach.

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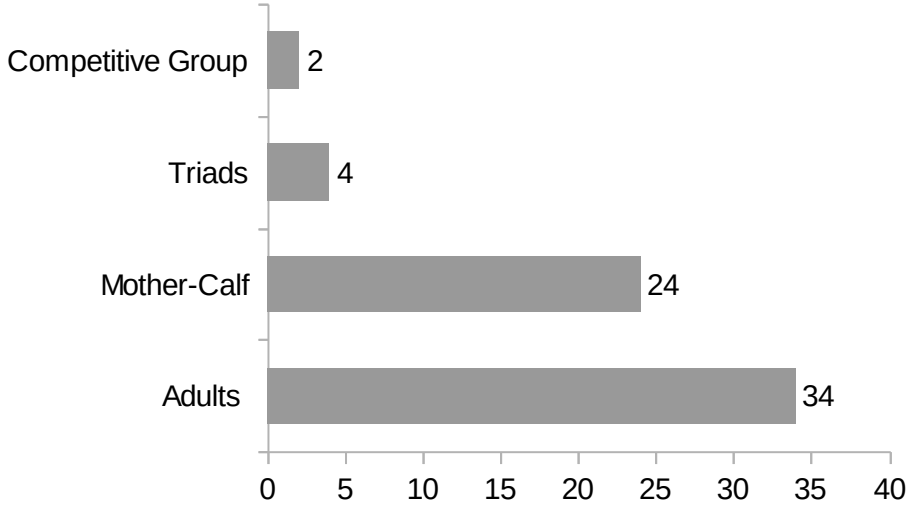

Figure 1.Proportions between group classes of Humpback whales in Golfo Dulce. The numbers shows the quantity of occurrence of different groups.

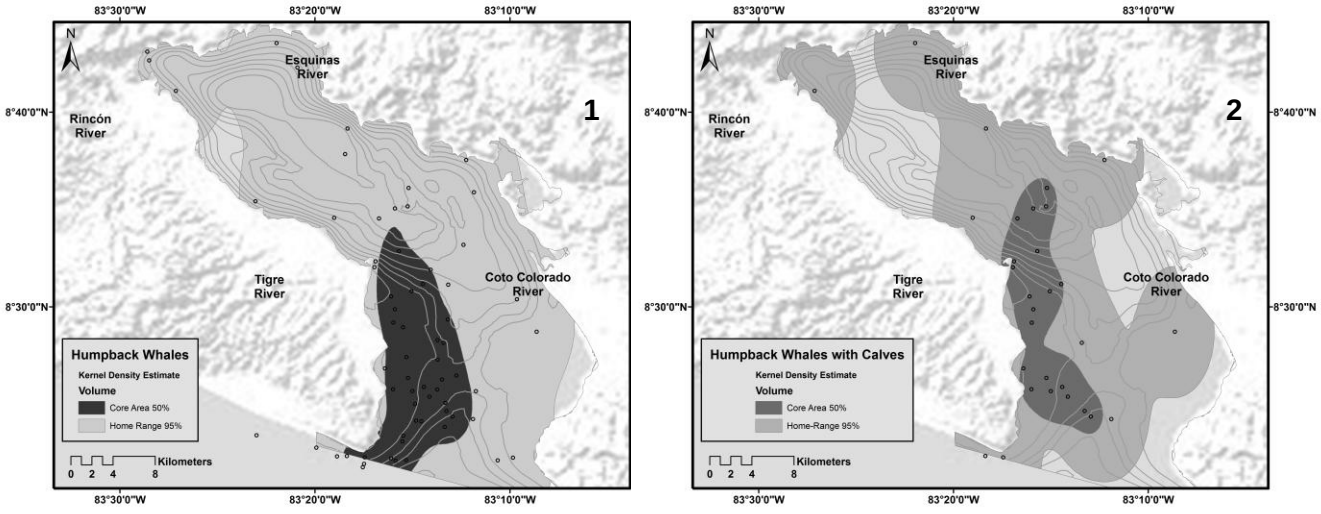

Figure 2. Kernel estimate of home range and core areas of the humpback whales in Golfo Dulce: All encounters (1) and mother-calf (2) distributions.

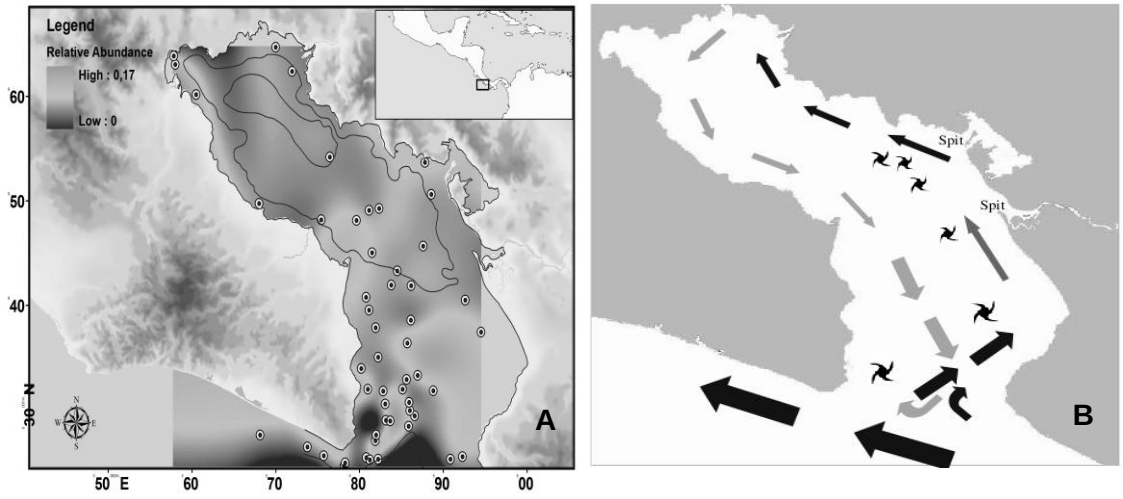

Figure 3. Comparison between whales' distribution and tidal current direction-eddies formation. A) Position of the encounters and the relative abundance of humpback whales computed using the SPUE and the contours indicate the isobaths of 100 and 200 meters; B) The tide current dominant direction and eddies formation (Zhang-Lei 2002).