The critical foraging habitats of bottlenose and coastal pantropical spotted dolphins in Golfo Dulce, Costa Rica

Oviedo, L[1,2]., Herra-Miranda, D[1]., Pacheco-Polanco, J.D[1]., Márquez-Artavia, A[1]., Quirós-Pereira, W[3]., Hernández, M.G.S[1] and Figgener, C[1]

1. Cetaceos Golfo Dulce, Rincon de Osa, Golfo Dulce-Costa Rica
2. Cetacean Ecology Lab, The Swire Institute of Marine Science, The University of Hong Kong
3. International Student Volunteers (ISV), Costa Rica

ABSTRACT

The identification of critical habitats for cetaceans is the foundation in the design and implementation of Marine Spatial Planning, including the creation of Marine Protected Areas, associated with local cetacean fauna. Golfo Dulce is a tropical fjord-like embayment located in the southern Pacific coast of Costa Rica; it is among the best preserved marine habitats in the Osa Peninsula ecosystem. Baseline data on cetacean occurrence have been gathered in this region since 2005, focusing primarily on two sympatric populations of coastal delphinids, the pantropical spotted dolphin (*Stenella attenuata graffmani*) and bottlenose dolphin (*Tursiops truncatus*). The current study investigates the underlying behavioral mechanisms that govern patterns of niche differentiation and the resulting conservation implications. We focus on the foraging areas/habitats of high conservation importance due to the role they play in the day-to-day needs of the two dolphin species in their year-round presence in the inner basin of Golfo Dulce.

INTRODUCTION

The identification of critical habitats for cetaceans is the foundation in the design and implementation of *Marine Protected Areas* associated with local cetacean fauna. The conceptual framework of this study is based on the habitat structure, including the intrinsic physical attributes, the eco-dynamic processes and the resources it provides, to promote the continuity of key survival activities involved in sustaining a healthy population grow (Gowans *et al.* 2008). Cetaceans' behavioral patterns are linked to habitat characteristics, eliciting a dynamic response that would ultimately influence population structure.

Golfo Dulce is a tropical fjord-like embayment located in the southern Pacific coast of Costa Rica; it is among the best preserved marine habitats in the Osa Peninsula ecosystem. It also represents an ideal potential location to several development projects seeking to capitalize the benefits of its physical and scenic characteristics relevant for the tourist industry. For instance, two major marinas are planned to be located adjacent to the two major coastal settlements, where the most important productive activities are related with tourism, focusing either in eco-tourism or sport fishing.

The understanding of ecological processes and characteristic of the whole coastal marine ecosystem of Golfo Dulce has increased notably, but integral baseline information is yet to be consolidated to sustain decision making. Unfortunately, environmental risk prevention by adhering to the precautionary principle is not always considered to mitigate pervasive negative effects derived from coastal development, recently “exploratory fishing licenses” have been implemented to exploit the local population of ballyhoo “*Hemiramphus* sp” a key resource of the foraging habitat for spotted and bottlenose dolphin populations inhabiting Golfo Dulce, as well as a priced bait for sport-fishing, even though there is not a reliable quantification of small pelagic biomass in the inner basin. Another example was the plan to establish Tuna Feed Lots facility, at the entrance of Golfo Dulce, without considering the potentiality for cetacean habitat displacement and the risk posed by antipredator gear to induce incidental catch through entanglement (Oviedo *et al.* 2009).

The current study investigates the underlying behavioral mechanisms that govern patterns of niche differentiation and the resulting conservation implications. We focus on the foraging areas/habitats of high conservation importance due to the role they play in the day-to-day needs of the two dolphin species in their year-round presence in the inner basin of Golfo Dulce.

MATERIALS AND METHODS

Study Area: Golfo Dulce (8º 30’ N, 83º16’W) is embayment characterized by a deep inner basin (>215 m of maximum depth) and a shallow sill of 70 m at the Gulf’s mouth (Wolff *et al.* 1996, Quesada - Alpizar 2006), with a total surface area close to 750 Km^2 (Fig 1). As described in Oviedo (2007); water circulation is restricted alike to true fjords and there is a slow deep water renewal by occasional intrusion of dense subsurface waters. Productivity in Golfo Dulce is most likely subsidized by riparian discharge to the inner basin, particularly by contributions of four major continental water sources: Esquinas, Rincón, Tigre and Coto Colorado Rivers, along with some other minor creeks.

Dolphin surveys and behaviour sampling: Dolphin surveys have been carried out using as research platform a 9 m boat, powered by a 115 HP engine, from March 2005 to February 2012, covering two season, Rainy (June –October) and Dry (November – May). The surveys have expanded to cover the outer sill area and beyond the Gulf’s entrance towards the transition to oceanic waters. A representative coverage of the study area has been achieved by allocating an alternated search effort between sectors (inner basin, outer area, transitional-oceanic) within a season.

Detectability conditions were constantly monitored by means of environmental stations, periodically registered every half an hour, as in Gowans and Whitehead (1995), they allow the collection of parameters such as sea surface temperature (through hand- held field thermometer), wind stress over the surface (Beaufort scale), visibility and boat location (GPS reading).

Observation were recorded by experienced observers, once a dolphin group was located and slowly approached, data was gathered on geographical location, group size and composition, along with behavior at first encounter and lagged behavior at approximately 5-10 min after the encounter. Research boat disturbance and its corresponding effects on sampling were mitigated through appropriate boat navigation at all times, a time slot to allow habituation with the boat of even more than 30 min from the onset and corresponding recording of behavior at initial encounter was used, cued by signs of dolphins carrying on their activities without minding the boat presence. Behavioral states were recorded using a standardized behavioral key based on Scheneider (1999), summarized in the definitions stated in table 1, following a similar approach to Garcia and Dawson (2003) in the ethological assessment of pantropical spotted dolphins in Panama.

Field work during 2007, 2008, 2011 and 2012 were specifically directed to collect behavior data through continuous scanning methodology (Mann, 1999, 2000) on pantropical spotted dolphin in a seasonal basis: the months of July - August 2007, 2011 for the rainy season, and January 2008, 2012 for the dry term. Systematic boat sampling followed a predetermine survey route, bounded to known areas of spotted dolphins encounters, particularly associated with river mouths. Once dolphins were spotted the boats would slow to an approach speed (~5 kn) at about 500 m, and progressively and slowly parallel the focal group. Once the boat was within approximately 100 m of the animals, the start time and location for the encounter were recorded using a hand-held Garmin GPS etrex Legend, equating the boat position to that of the dolphin's group. Scan sampling was only started at signs of dolphin' groups habituation with the boat as explained above.

Dolphin group is defined as in Karczmarski *et al.* (2005), where spatially aggregated individuals are engaged in similar activities, in a time scale that prevents significant changes in group membership. Behavior scan sampling consisted of group-follow protocol: observations were undertaken using two minutes scans (left to right), with a five minute intervals to provided independence (Altman, 1974; Mann, 1999), during the 2 min scans slot a proportion of the behaviors observed were registered allocating the major portion to the dominant one. In order to generate behavior data spatially associated with a discrete geographical location, at the beginning and end of each two minutes scan, a GPS reading was taken. An important methodological convention adopted during scan sampling, was the decision to remain with the larger group, at occasion where any dolphin group being sampled split. Observations ended when the weather deteriorated and the limiting Beaufort level (>2) for detectability was reached, the focal school was lost, or the day ended.

Behavior analysis: Ethological analysis was based on the insights derived from the behavior sampling, quantified and presented as two different types of activity budget; that detailed the proportion of time invested observing the five behavioral states detailed in table 1, during the rainy and dry seasons:

a) An activity budget that includes all records of behavior at first encounter (2005 – 2012) considering the latter an undisturbed expression of area use.

b) An activity budget with a subset of data derived from the scan sampling (2007-2012), including only group-follows were the prevalent detectability condition were corresponding with a wind stress on the surface of less than three. In this activity budget each two min scan was transformed into an effort corrected observation coefficient (the temporal duration of each observed behavioral state within a time frame of two min), that ranged from 0 to 1, being

1 a pure bout of a defined behavioral state, any value less than one, implied a mixed behavior bout, where there would be a dominant behavior. Dominancy was established at any value equal or above to 0.5.

Spatial analysis

To evaluate the case of dolphins' critical habitat, two complementary analytical approaches were used: (a) assessment of relative densities and identification of frequently used areas by means of the near neighbor index and kernel density maps, and (b) identification of predominant behaviors and their spatiotemporal environmental correlates. Records of behavior at first sighting (for both species of dolphins) and continuous scan sampling (spotted dolphins) were combined with spatial data to model and map the likelihood of behavior occurrence across a spatiotemporal scale. All the spatial analysis was done through ArcGIS 9.2

RESULTS

Baseline data on cetacean occurrence have been gathered in this region since the early 90s, focusing primarily on two sympatric populations of coastal delphinids, the pantropical spotted dolphin (*Stenella attenuata graffmani*) and bottlenose dolphin (T*ursiops truncatus*), as well as the wintering populations (northeast and southeast Pacific) of humpback whales. Cetacean surveys (n=403) correspond with 1600 hours (37,100 Km) searching the study area. Field observations account for 503 cetaceans records of 7 species of delphinids (*S. attenuata*, *T. truncatus* and *P. crassidens* within the inner basin, *S. longirostris*, *Steno bredanesis*, *Globicephala macrorhynchus* and *Lagenodelphis hosei* at the transition to oceanic waters) and one mystecete, *Megaptera novaeangliae*. From all cetaceans sightings, 47% (n=238) of all encounters correspond with the coastal form of bottlenose dolphins and almost 32% (n=161) of the encounters involved pantropical spotted dolphins.

The encounter rates of both species did not differ with season (Mann Whitney U Test: $U=3.52X10^3$, $p > 0.05$ and $U=1.2X10^3$, $p > 0.05$ for bottlenose and spotted dolphins, respectively). The non random clumped pattern of aggregation indicates a strong affinity to inshore areas for bottlenose dolphins (NNI= 0.51, Z score= -12.22, $p < 0.01$) and offshore/oceanic-like habitats for spotted dolphins (NNI= 0.72, Z score= -5.43, $p < 0.01$). The relative sighting densities of spotted dolphins increased in the east and centre of the inner basin (Fig. 1); while the same approach for bottlenose dolphins identified the mouths of Esquinas and Tigre Rives as the most important inshore areas for this species.

For both species, foraging was the most frequently seen behavior (Fig. 2) and generally occurred in well defined locations. For spotted dolphins it was primarily in the deepest part of the inner basin, while for bottlenose dolphins the mouths of Esquinas and Tigre rivers represent their primary foraging ground, according with the Kernel density estimate on sightings with foraging as initial behavior (Fig. 3) Group-follow scan-sampling conducted for spotted dolphins provide further evidence for the differentiation of their Primary Key Areas (Probability of occurrence: 0.76 – 1) and Secondary Important Areas (Probability of occurrence: 0.50 – 0.75), based on the level of occurrence of foraging bouts (Fig. 4).

DISCUSSION

Behavior observations are dynamic responses, perfectly suitable as proxy of habitat use, along with the integration of spatial information; such information would describe the location of those ecological responses. Foraging is the dominant behavioral state within the activity budgets, and fundamental in the habitat use of both dolphin species in the study area (Oviedo 2007, 2008). The important occurrence of foraging bouts defines the inner basin of Golfo Dulce as a critical habitat for energy intake.

Other reports of the same species along the Pacific coast of Central America, account for similar observations associated to habitat use; as in Papagayo Gulf (north Pacific coast of Costa Rica), where a majority of foraging records of *S. attenuata* offer indications of foraging areas (May-Collado *et al.* 2005, May -Collado and Morales 2005) and Bahia Honda (Panama), where pantropical spotted dolphins engaged in feeding as the most frequent behavior (Garcia and Dawson, 2003). On the contrary, results presented here showed a relevant difference with previous assessment of *S. attenuata* in Golfo Dulce; over 50% of foraging occurrence is extensively greater than the 6 % reported in 1996-1997 (Cubero-Pardo 1998a,b). Conversely, the same published data set could not establish an association of dolphins' activities and areas with particular environmental conditions within Golfo Dulce (Cubero Pardo 2007a), furthermore, the latter was justified based on environmental homogeneity in the study area.

There is interplay between travelling and foraging dolphin groups throughout the observations in Golfo Dulce, travel is the second most important behavioral state during the rainy season, and the major activity recorded during the dry season. Such pattern is to be expected if following dolphin groups that engaged in prey capture and consumption, the latter has been commonly documented elsewhere (Neumann 2001, Garrafo *et al.* 2007, Stockin *et al.* 2008). Stockin *et al.* (2008) argues that dissimilarity between the occurrences of dolphins traveling; accessing locations of prey aggregations with dolphins foraging, is associated with the availability of key prey species and an important level of primary productivity. Seasonal and geographical patterns of prey abundance, among other intrinsic factors, influence marine mammals' foraging behavior and it is a direct consequence of the spatial and seasonal pattern of primary productivity (Berta *et al*. 2006). As with common dolphin in the Hauraki Gulf, New Zealand (Stockin *et al*. 2008), the typical physiographic of an enclosed embayment might play a key role in prey aggregation and availability, which would be reflected in the increase of foraging over traveling.

Dolphins' foraging bouts in Golfo Dulce are an indication of prey availability and primary productivity. Records during first encounter and group follow have been consequent with the observation of highly abundant schooling fish in dense aggregations. Remarkably, the most common prey items have been flying fish (exocoetidae) and Ballyhoo (*Hemiramphus* sp). Therefore, such observations opposed the perception of Golfo Dulce as a low productivity environment (Wolff et al. 1996, Cubero Pardo 2007b). Prey availability supporting a predator population such as pantropical spotted and bottlenose dolphins, might be supported by rather riparian input to primary productivity than by upwelling processes, a factor scantly considered in previous evaluation in Golfo Dulce (Quesada-Alpizar and Cortez 2006, Cubero Pardo 2007b).

The location of dolphins' foraging bouts in Golfo Dulce produces non random clustered spatial patterns that would reflect the attraction of individuals to a particular part of their environment (Begon *et al*. 2006). The latter allowed the categorization of *critical areas* where the probability of occurrence of foraging was over a fixed threshold (0.75). Likewise, *important areas* would be determined by a probability threshold between 0.50 - 0.75. As explained in Lusseau and Higham (2004), these thresholds were arbitrarily set, but they are based on the activity budget of the studied dolphin' population, therefore, they are biologically meaningful.

The identification of critical areas and most frequently used habitats can be highly informative in the development and implementation of management strategies to safeguard the ecological and behavioral needs of top predators such as cetaceans. In Golfo Dulce, the drainage of Tigre and Esquinas River should be designated as candidate Marine Protected Areas for bottlenose dolphins; while the central-east inner basin of the gulf should receive a similar status for spotted dolphins as the focal conservation species, with the thresholds of Primary Key Areas and Secondary Important Areas as the basis for the establishment of core and buffer zone structure. In a broader scale of conservation planning, the proposed protected areas should follow the structure of a biosphere reserve; a combination of several management approaches within a protected area where either one or multiple fully protected core areas (IUCN "Nature Reserve" or "Wilderness Area") are supported by complementary conservation categories outside those core locations, where the needs of coastal human communities are considered within a framework of sustainable use and ecosystem management.

Both dolphin species represent an important resource generating revenues for a small fleet of local dolphin-watch operators. The establishment of conservation zoning should be accompanied by the establishment of a license system, a management strategy that would reconcile relevant control tools with sustainable use to grant the local tour operators access to locations of high dolphin encounter rates yet outside of the critical core areas of primary importance to the animals.

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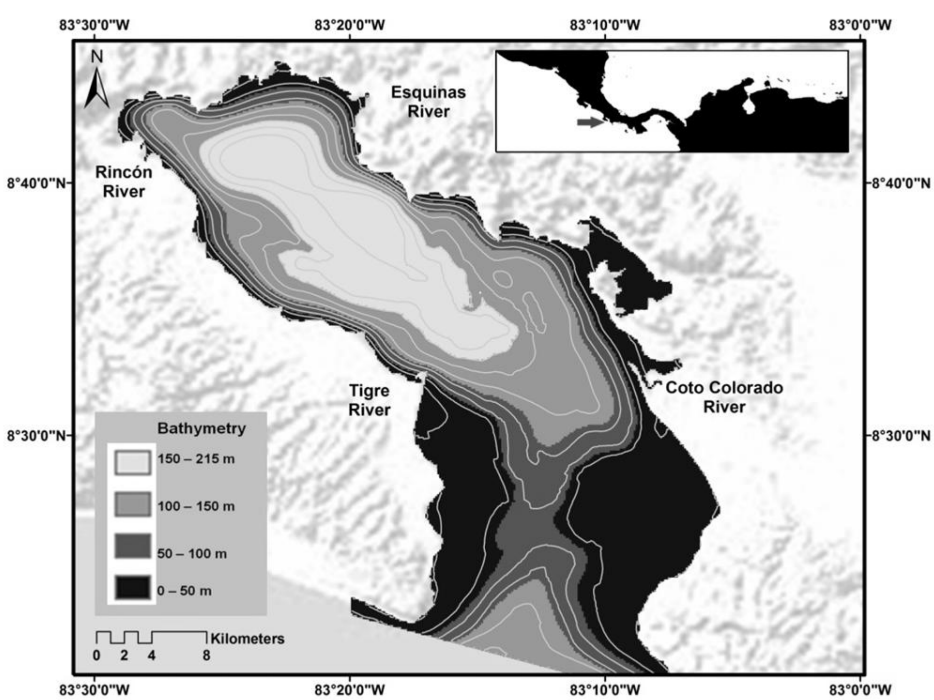

Figure 1. Study area: Golfo Dulce map with bathymetric details

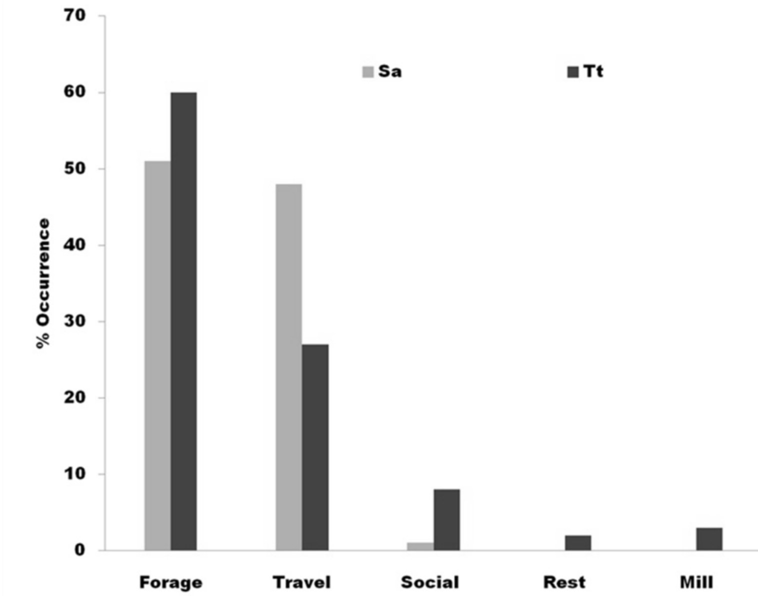

Figure 2. Activity budget of bottlenose (Tt) and spotted dolphins (Sa) in Golfo Dulce, Costa Rica.

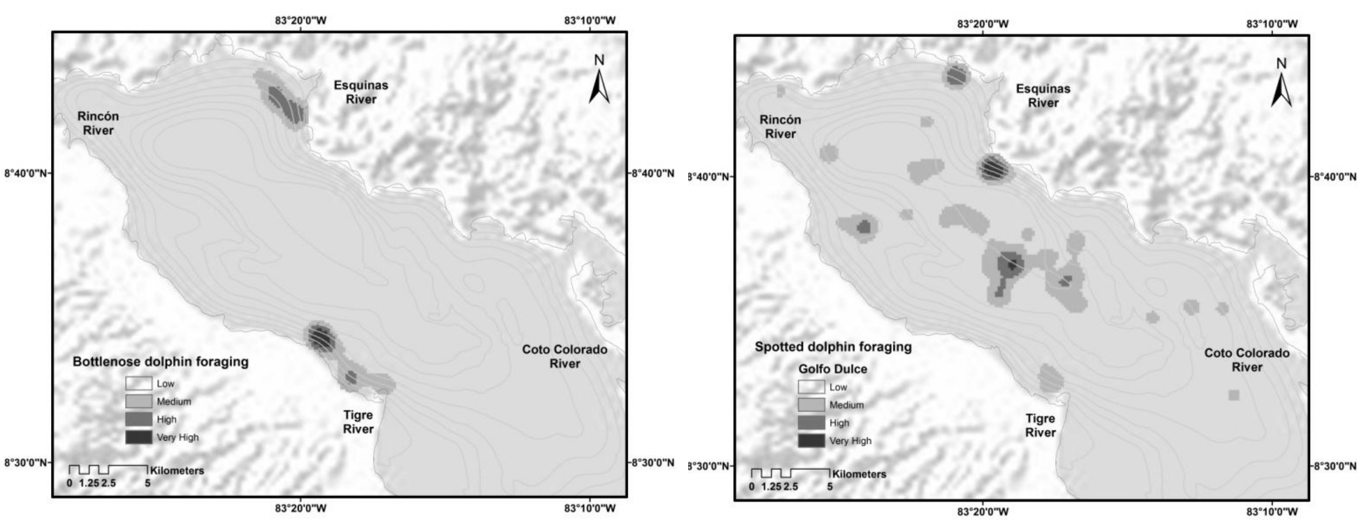

Figure 3. Kernel density estimates for bottlenose (Tt) and spotted (Sa) dolphin sightings collected between 2005 and 2012 where initial behavior was foraging, in Golfo Dulce, Costa Rica.

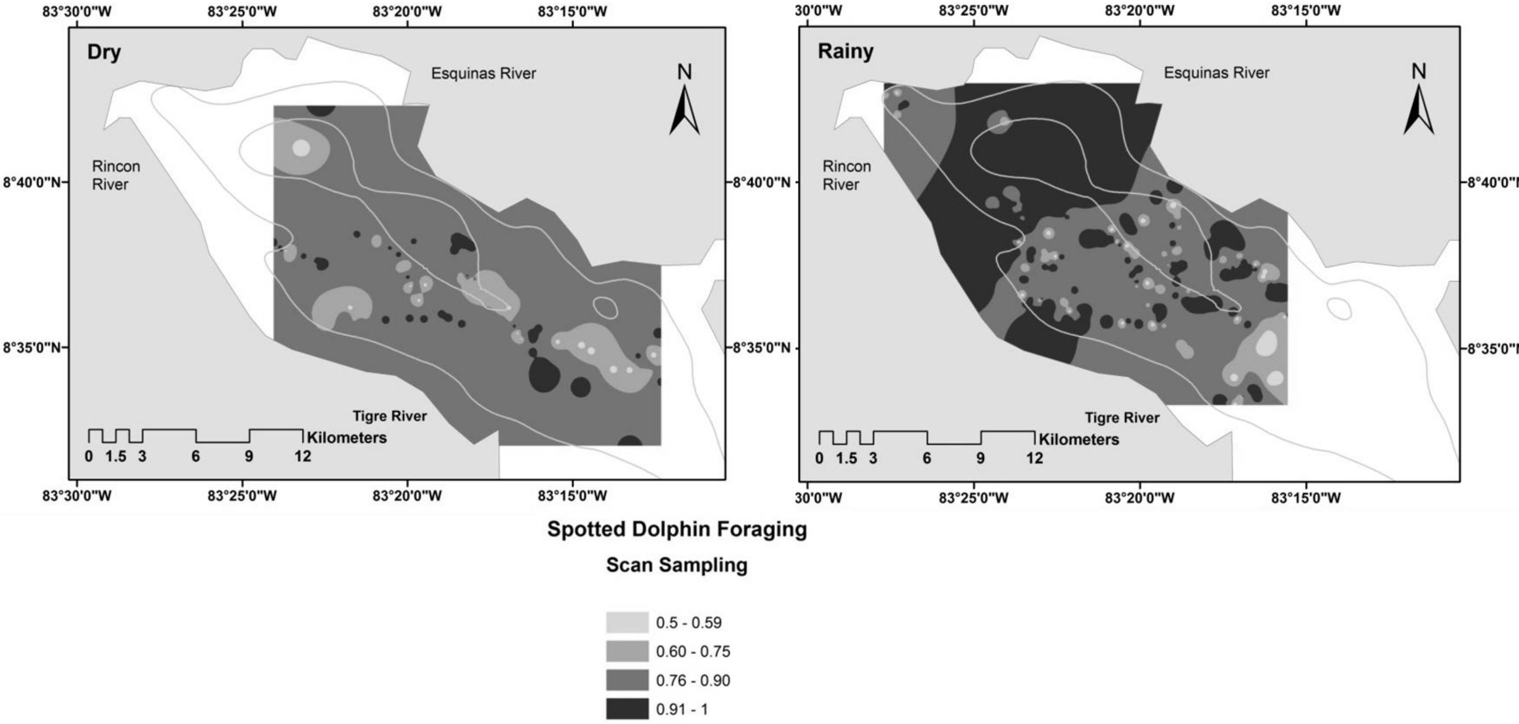

Figure 4. Spatial location of areas of potential foraging incidence for pantropical spotted dolphins in Golfo Dulce's inner basin, color range indicates probability of occurrence