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Marine mammals of Mexico: Richness patterns, protected areas, and conservation trends

Mariana Muzquiz-Villalobos*,[1], Sandra Pompa-Mansilla[2]

Instituto de Ecología, UNAM, Circuito Exterior S/N anexo Jardín Botánico Exterior, Ciudad Universitaria, Ciudad de México, Mexico

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ABSTRACT

Mexico registers about 60% of the total of marine mammals worldwide. However, species listed under a risk category show that, globally, Mexico faces big marine mammal conservation challenges. Thus, it becomes essential to successfully apply the existing knowledge into interdisciplinary conservation programs. We generated a presence/absence species richness map containing all 47 marine mammal species recorded in Mexico's Exclusive Economic Zone. After selecting nine oceanographic variables influencing marine mammal species richness, the top three factors influencing such richness were sea surface temperature and dissolved oxygen grouped in component #1, and salinity composed component #2. We also identified the species that are protected within a Marine Protected Area (MPA) category and its representation in management programs of these areas. Currently, 98% of marine mammal species distributed in Mexican waters are protected within an MPA; nevertheless, around 12% of them are not listed in management programs. Three priority sites in the Pacific Ocean and one for the Gulf of Mexico were identified to promote their conservation. Considering the sentinel and umbrella attributes of marine mammals, the information presented here will not only benefit their populations, but will also contribute to address marine species and ecosystems threats and improve the effectiveness of conservation plans.

1. Introduction

Resolving threats to widely distributed marine megafauna requires knowledge of the geographic distributions of both, the threats and the population unit(s) of interest (Wallace et al., 2010; Schipper et al., 2008). In Mexico, the knowledge of the distribution of marine mammals, their patterns of species richness and their current threats are known in general terms.

Of the 129 species currently recognized worldwide (Wilson and Reeder, 2005), between 45 and 49 different species have been recorded in the Mexican Economic Exclusive Zone (EEZ) (about 60% of all species recorded in the world) (Salinas and Ladrón de Guevara, 1993; Torres et al., 1995) belonging to the orders Cetacea (between 37 and 41 species), Carnivora (7 species) and Sirenia (1 species) (Medrano-González et al., 2007; González, 2006). It is known that at least 60% of these species are in a risk or threatened category following the International Union for Conservation of Nature criteria (IUCN, 2013). Despite this, the spatial dynamics of just a few species have been studied to understand the ecological variables that determine their presence/absence in Mexico. Moreover, fewer studies address the topic of the application of public policies in conservation actions for this group.

On the other hand, understanding the variables and threats influencing the presence of marine mammals in Mexican waters is necessary to implement successful conservation and management strategies. For most marine mammals, the distribution patterns seem to be primarily defined by three variables: water temperature, depth, and factors that affect the distribution and abundance of their prey (such as seabed topography, ocean currents and primary productivity), although other factors, such as predator avoidance, impact of human activities, and reproductive requirements, may also influence the distribution of some species to a lesser extent (MacLeod, 2009). Many organisms are thought to react to changes in their environment by changing their distribution to stay within the environmental envelope represented by their ecological niche; whence understanding the niche these species occupy becomes important for species conservation itself (Wiens and Graham, 2005).

Marine mammals also play an important role in the ecological dynamics of marine and freshwater ecosystems (Pompa et al., 2011) and

* Corresponding author.
E-mail address: lucero.mz.v@gmail.com (M. Muzquiz-Villalobos).
[1] Present Address: Centro de Investigaciones Biológicas del Noroeste. Av. Instituto Politécnico Nacional 195, Playa Palo de Santa Rita Sur; La Paz, B.C.S. México; C.P. 23096.
[2] Present Address: Fuego Verde S.C. Constitución #207-2 Col. Centro; Mazatlán, Sinaloa; México. CP. 82000.

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are potential indicator species, such that their protection should also ensure the health of other key components of the marine ecosystem (Hooker and Gerber, 2004). In response to such suggestions, researchers have explored empirical associations between diversity and several physical or biological variables, and tested specific hypotheses about the ecological mechanisms determining distribution and diversity patterns (Redfern et al., 2006). Recently, cetacean habitat distribution models have been developed to define the boundaries of marine protected areas (MPAs; Cañadas et al., 2005). To this day, it is recognized that MPAs provide the broader coastal and marine areas with several goods and services, including conservation of biodiversity; protection of critical habitats; increased productivity of fisheries through stock regeneration; increased knowledge of the marine environment; a refuge for, and protection of, genetic diversity, protection of cultural heritage and diversity; and local development through tourism and recreation (Cicin-Sain and Belfiore, 2005; Watson et al., 2014).

Following these guidelines the Mexican federal agency responsible for the management of all protected areas, including MPAs, (the National Commission of Protected Areas or CONANP for its Spanish acronym) has developed different strategies to conserve the most representative ecosystems of Mexico and its biodiversity, through the Protected Natural Areas and other conservation modalities, which include, management programs, action programs focused on endangered species, conservation programs for sustainable development, etc. These programs are formulated based on existing knowledge; however, this information is often incomplete, not easy to access, or not applied in full. Furthermore, research and educational programs for MPAs often do not focus on linkages between the MPA and adjacent coastal and marine areas, or exploit the opportunities that MPAs can provide as benchmarks of the state of coastal and marine environments. Therefore, a successful integration of the existing knowledge on marine mammals and ocean and local human dynamics can serve as a powerful tool for assessing areas of high relative species diversity within MPAs, and for determining which factors influence their distribution (Redfern et al., 2006). In turn, the identification of these key areas provides a focus for conservation action and appropriate management in different zones within MPAs (Bailey and Thompson, 2009).

This work aims to identify the oceanographic variables that play a fundamental role in places with high concentration of species richness of marine mammals. To achieve the objective, a thorough analysis of oceanographic variables and their influence on the species distributed on Mexican waters using principal component analysis. Oceanographic variables were analyzed to identify, predict, and determine priority sites for conservation. This paper also includes a discussion of gaps and omissions in conservation strategies for marine mammals within the Mexican Marine Protected Areas system and analyzes how the results could be used as a conservation decision making tool regarding these species and their marine ecosystems.

2. Methods

2.1. Study area

Mexico's Exclusive Economic Zone (EEZ) covers 3,149,920 km^2 (Contreras and Castañeda, 2004; De la Lanza-Espino, 1991). The Mexican EEZ covers the Mexican Pacific region, including the Gulf of Tehuantepec, and Gulf of California, and the Atlantic region, including the Gulf of Mexico and the Caribbean Sea. The Pacific EZZ covers more than 2.3 million km^2 of marine extension. EEZ starts at the lowest low tide mark and extends 200 nautical miles off the coast. In the Pacific region the coast has 7828 km in length, including the offshore Guadalupe Islands, off the northwest area of Baja California and the Revillagigedo Islands (INEGI, 2002). The Gulf of California is an evaporation basin (Roden, 1964) of approximately 1000 km long and on average 150 km wide. The tropical eastern Pacific is located between Cabo Corrientes (20° N and 105° 41 ′W) and Costa Rica (10° N and 84° 15′ W). Its main feature is that the sea surface temperature there is always equal to or hotter than 28 °C; it is the less studied zone in terms of primary productivity (Trasviña-Castro et al., 1999). The Gulf of Tehuantepec, *ca.* 125,000 km^2, is located in the southern part of the Mexican Pacific between Oaxaca and Chiapas states. It is delimited to the west by Puerto Angel, Oaxaca, and east by the Suchiate river in Chiapas, between the coordinates 96° 7 ′and 92° 14′W, 14° 30′ and 16° 13′N. In general, due to the presence of important physical and ecological processes, continental freshwater inputs, the presence of upwellings and ecological dynamics of large lake systems, the Gulf of Tehuantepec is recognized as an ecological marine macro region (CONABIO, 2008).

The Atlantic EZZ covers 1,507,639 km^2 and is located in a transition zone between tropical and subtropical climate, between 18° and 30° N and 82° and 98° W. It is a semi-enclosed basin that communicates with the Atlantic Ocean and the Caribbean Sea to the Strait Florida and the Yucatan Channel restpectively (Monreal-Gómez and Salas de León, 1997).

2.2. Species richness data acquisition

Marine mammal species richness data reported for Mexico were obtained from Pompa et al. (2011). We followed Reeves et al. (2002) and Wilson and Reeder (2005) for the basic taxonomic arrangement. The lack of better distributional data precludes more sophisticated analysis to predict ranges of the majority of marine mammal species on very large scales (Kaschner et al., 2006). Any comprehensive consideration of the distribution of cetaceans is hampered by the uneven sighting effort; range maps therefore must be interpreted with caution. The data were analyzed in a Geographic Information System (GIS). A total of 290 cells (1° x 1° resolution) were created and each cell contained the information on the presence or absence of each marine mammal species in a given cell in the EEZ of Mexico.

2.3. Oceanographic data acquisition

We selected the sea surface values of the following 9 oceanographic variables that could influence the species richness of marine mammals in Mexico: sea surface temperature (SST), salinity concentration (Practical Salinity Scale, PSU), phosphate concentration (P), nitrate concentration (N), silicate concentration (Si), dissolved oxygen (O_2), dissolved oxygen saturation (O_2^S), bathymetry and chlorophyll fluorescence line height (FLH). These variables were selected as they are considered to be key abiotic factors controlling the ocean primary production (Harrison and Cota, 1991; Sigman and Hain, 2012) and this in turn influences potentially on prey richness and abundance for marine mammals (Berta et al., 2006; Prado, 2009; Whitehead et al., 2010).

Data were gathered from the *World Ocean Atlas 2009* (WOA09) series. The WOA09 series include analysis for sea surface temperature (Locarnini et al., 2010), salinity (Antonov et al., 2010), dissolved oxygen, dissolved oxygen saturation (Garcia et al., 2010a), and dissolved inorganic nutrients (phosphates, nitrates and silicates) (Garcia et al., 2010b). We selected monthly climatologies, which were calculated using data collected in a given month regardless of the day of the month in which the observation of that variable was made. Climatologies are the average of five decadal climatologies for the following periods: 1955–1964, 1965–1974, 1975–1984, 1985–1994, and 1995–2006, while dissolved oxygen and dissolved oxygen saturation and nutrients climatologies use all available data regardless of year of observation.

Chlorophyll fluorescence line height (FLH) data were collected from the Satellite-based Ocean Monitoring System (SATMO) developed by the National Commission for the Knowledge and Use of Biodiversity (CONABIO for its Spanish acronym). The real-time values of the phytoplankton chlorophyll fluorescence emission line height (FLH, mW

cm^{-2} μm^{-1} sr^{-1}) are obtained as the intensity of upwelled radiance in Moderate Resolution Imaging Spectroradiometer (MODIS) band 14 (676.7 nm) above the baseline created from bands 13 (665.1 nm) and 15 (746.3 nm). The climatologies used in this work were monthly averages from 2002 until 2012 in a resolution of 1 km × 1 km. The averages of all the environmental factors were computed to match the GIS species presence/absence data, which was aggregated into grid cells of 1° x 1°. This data processing were conducted using ArcGIS (ESRI, 2011).

2.4. Data processing and statistical analyses

The oceanographic variables were added to the GIS species presence/absence data to create a single database that included the data for each month of the year.

A Pearson's R correlation coefficient was used to test if a linear correlation existed between each marine mammal species and each of the nine oceanographic variables as to identify a correlation between oceanographic variables Results were significant when $P < 0.05$ unless otherwise stated.

After the correlation was tested, a Principal Component Analysis (PCA) was conducted to determine the components that were influencing the species richness of marine mammals in Mexico. All these analyzes were performed using Statistica © 7.0 software (StatSoft, Inc. 1984–2004).

2.5. Assesment of marine mammal's protection within marine protected areas

The boundary polygons for the 32 Marine Protected Areas were downloaded from the Mexican National Commission of Natural Protected Areas (CONANP) website (http://sig.conanp.gob.mx/website/pagsig/) and overlaid with the species richness GIS previously created. We identified the species currently recorded in the MPAs and calculated the species' total distribution area within the EEZ and the percentage of their EEZ distribution covered within the MPA polygon.

3. Results

3.1. Species richness

In terms of species richness, a total of 290 of 1ºx1º resolution cells for the EEZ of Mexico were analyzed; 213 belonging to the Pacific Ocean and 77 to the Atlantic Ocean. A total of 47 species were recorded belonging to 3 orders, 11 families and 31 genera. We obtained an average richness of 26 species with a maximum of 36 and a minimum of 23. The area with the highest species richness was located at the northeast Pacific with up to 36 species, followed by some cells in the Gulf of California with 31 species, third are the cells located at Tropical Pacific with a total of 28 species and the cells in the Gulf of Mexico with 27 species (Fig. 1).

3.2. Statistical analysis

The Pearson's R correlation test showed an expected strong negative correlation ($r = -0.93$, $P < 0.05$) between the concentration of dissolved oxygen and the SST. We also found that the percentage of oxygen saturation was positively correlated with dissolved oxygen, as we anticipated, given the strong dependence of dissolved oxygen concentration on temperature (Weiss, 1970). Also, all the species, with the exception of *Delphinus delphis*, *Mesoplodon peruvianus* and *Phocoena sinus*, showed a strong correlation with the SST factor. Finally, all the species excepting *P. sinus* showed a strong correlation with the salinity factor.

In the principal component analysis, we evaluated the eigenvalues and retained only those components that showed eigenvalues greater than 1.00 (Kaiser, 1960). The first two components (PC1 and PC2) explained 57.97% of the total variance for the 12 months of the year. PC1 explained 38.20% of the total variance for the same months (Fig. 2). The most important oceanographic variables on the PC1 axis were dissolved oxygen on the negative side and temperature on the positive side. PC2 explained an average of 16.79% of the total variance for the 12 months (Fig. 2); the most important feature on the PC2 was the salinity. Each component had different marine mammals species associated. In some cases, a third component formed by the nitrate concentration and silicates concentration in different scenarios was found (PC3).

For PC1 the presence of *Feresa attenuata, Lagenodelphis hosei, Peponocephala electra, Stenella attenuata and Stenella longitrostris* were influenced positively by the SST and negatively by the dissolved oxygen factor (Fig. 3).

The presence of *Arctocephalus townsendii, Berardius bairdii, Eubalaena japonica, Lagenorhynchus obliquidens, Lissodelphis borealis, Mesoplodon carlhubbsi, Mesoplodon ginkgodens, and Mesoplodon perrini* were affected negatively by the SST factor, and positively by dissolved oxygen factor (Fig. 3).

For the second component (PC2) the presence of *Mesoplodon europaeus, Stenella frontalis* and *Stenella clymene* are favored by high salinity concentration; on the negative side of PC2, we found the presence of *M. peruvianus* and *D. delphis* (Fig. 3), which are adversely affected by the salinity component.

For all the 12 months, the species *Balaenoptera edeni, Callorhinus ursinus, Delphinus capensis, Enhydra lutris, Mesoplodon stejnegeri, Mirounga angustirostris, Orcinus orca, Phocoenoides dalli, P. sinus, Phoca vitulina, Trichechus manatus* and *Zalophus californianus* had no significant values in any of the two components.

Note that *Balaenoptera acutorostrata, B. borealis, B. musculus, B. physalus, Globicephala macrorhynchus, Grampus griseus, Kogia breviceps, Kogia sima, Megaptera novaeangliae, Mesoplodon densirostris, Physeter macrocephalus, Pseudorca crassidens, Steno bredanensis, Stenella coeruleoalba, Tursiops truncatus y Ziphius cavirostris* were not included in the analysis as they show wide distributions and showed no variance in the data.

3.3. Marine mammals protection within marine protected areas

At least 98% of the 47 species of marine mammals that are distributed throughout the year in Mexican waters are protected within at least one MPA along its distribution range. 62% of these species are considered by IUCN under a risk category and 92% are under any of the risk categories established under Mexican regulations (NOM-059-SEMARNAT-2010; DOF, 30-12-2010).

In terms of representation, 16 MPA located in the Mexican Pacific Ocean protect 42 species of marine mammals (98% of total registered for that ocean), only Dall's porpoise (*P. dalli*) is currently not protected in any MPA in the Pacific. For the Atlantic Ocean, 16 MPA protect 26 species (96%); only the orca (*O. orca*) is not represented in an MPA (Table 1).

The MPAs that protect a greater number of species in the Pacific Ocean were El Vizcaino Biosphere Reserve (BR) (36 species), followed by Guadalupe Island (BR) (32 species) and the Area of Protection of Flora and Fauna (APFF) Cabo San Lucas (29 species). In the Atlantic Ocean, all existing MPAs protect 26 species each.

The average oceanic Mexican MPA coverage is 1500 km^2, however seven MPA's (22% of total) range below 100 km^2 (Table 1).

The average percentage of protection provided by an MPA to any marine mammal species is about 2.31% (approximately 28.056 km^2, ranging from 0.05% to 29.74%) of their total geographical distribution range in the Mexican EEZ (Table 1) meaning that for many species, the size and configuration of existing protected areas, leaves most of their remaining range outside the reserve network (Dickman et al., 2013).

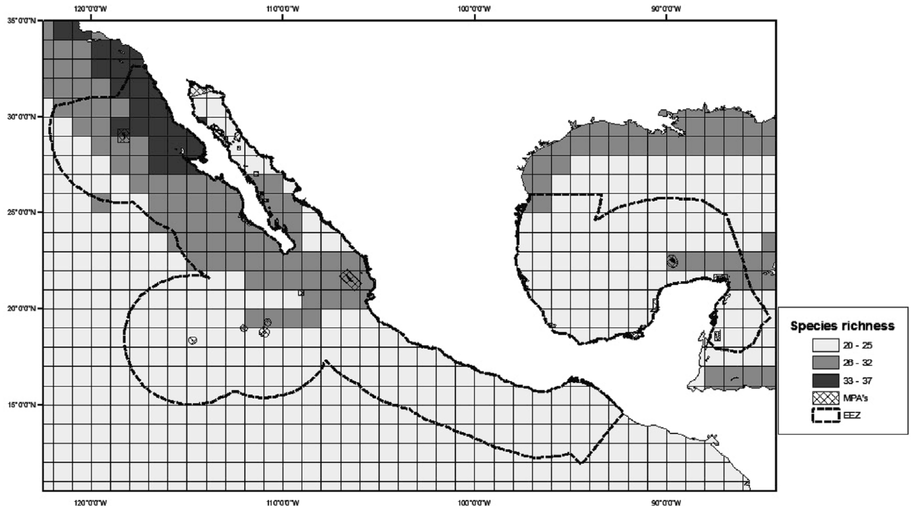

Fig. 1. Marine mammal species richness map and the Marine Protected Areas within the Exclusive Economic Zone of Mexico.

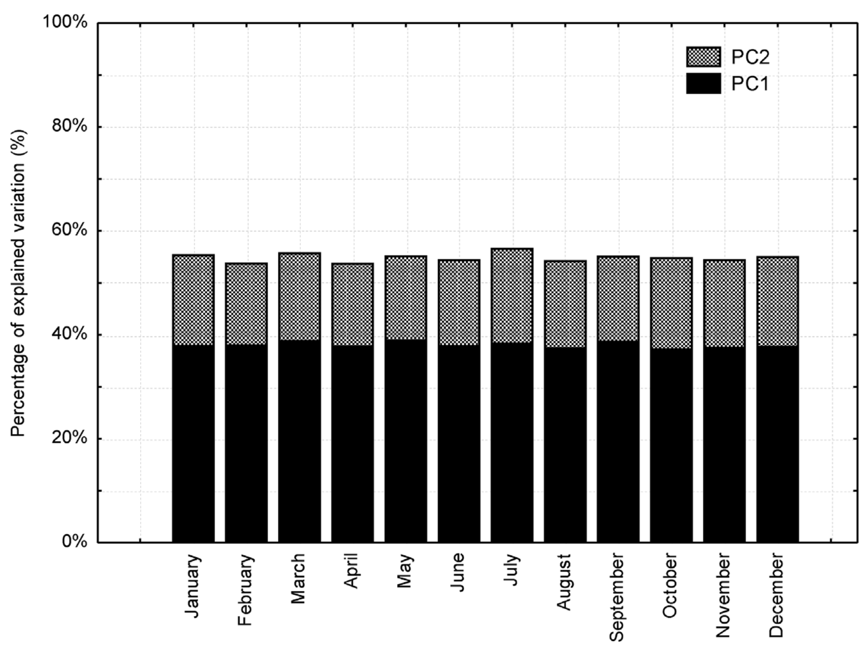

Fig. 2. Percentage of monthly variance explained by each Principal Component (PC1 and PC2).

In theory every protected area must have a management plan developed by CONANP together with the people that inhabit the protected area. Results showed that for the Gulf of Mexico, only 12 of the 16 MPA enacted have a management program. Among the different management plans, we found listed the presence of only 23 of the 27 species of marine mammals reported on this paper for this ocean (85% of total). A more optimistic scenario occurs at the Pacific Ocean where 15 of the 16 AMP enacted have a management program; in those programs we can find 38 of the 43 species recorded for this ocean (88% of the total). Currently, the only AMP that has listed on its management plan all the species that distribute in the area is the Espiritu Santo Archipelago, but at least 12% of the marine mammals present in Mexican waters are not included in any protection-conservation management strategy.

It is through subsidiary programs directed to the local people that inhabit the protected areas that CONANP implements conservation strategies. Within subsidy programs implemented by CONANP, six species of marine mammals are considered under the Conservation Program Species at Risk (PROCER): Guadalupe fur seal, fin whale, porpoise, manatee, humpback and blue whales. Of these 6 species, four species already have an Action Program for the Conservation of Endangered Species (PACE) (vaquita, manatee, humpback and blue whale). The vaquita is the species that has received the greatest benefit during 2011–2015. Within the Biological Monitoring Program in protected areas (PROMOBI), the only marine mammal listed is the California sea lion; this program aims the monitoring of populations and the health state of breeding colonies that inhabit at the Gulf of California. The Conservation Program for Sustainable Development (PROCODES) has a single record in 2013 for monitoring marine mammals at the Islands of the Gulf of California. In all, five years of action of these three programs, have invested a total of $3,900,000.00 US dollars focused on 10 natural protected areas and 7 species (16% of all species recorded in Mexican waters) concentrated mainly in areas of the Pacific Northwest and the Gulf of California. Vaquita has received 82% of the investment and is to receive 4 million US dollars in 2017. The manatee in the Gulf of Mexico, stopped receiving financial support after 2013.

Based on our results we have identified four priority regions essential for the conservation of marine mammals in Mexico: 1) the

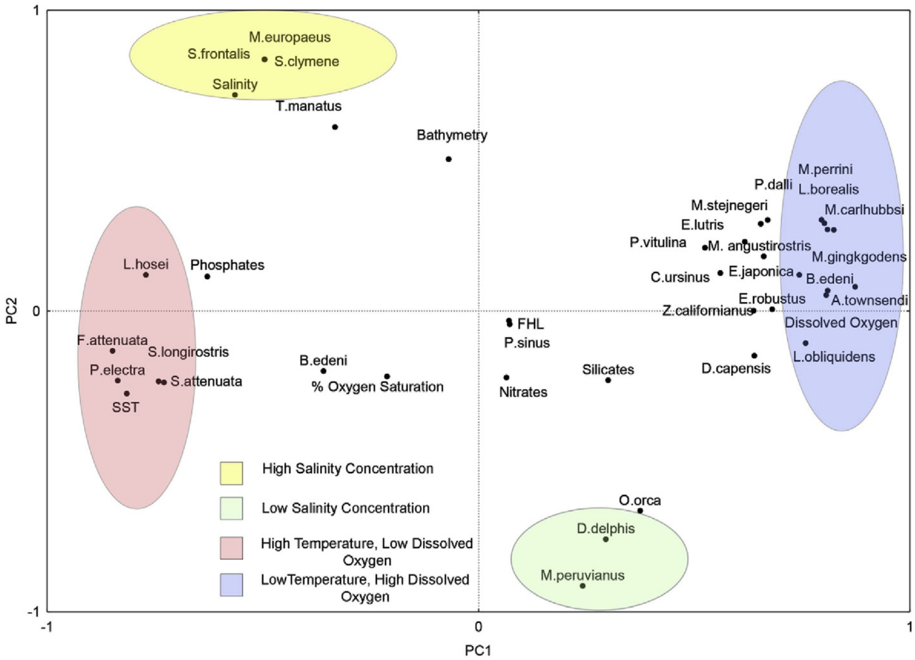

Fig. 3. Principal component analysis showing Principal Component 1 (Sea surface temperature and dissolved oxygen and species associated) and Principal Component 2 (Salinity concentration and species associated).

Northern Gulf of Mexico, 2) the Northeast Pacific, 3) Gulf of California and, 4) the Southeast Pacific; this based on both species richness and the current conservation status in the different MPAs.

4. Discussion

Mexico EEZ exhibits complex oceanographic dynamics both seasonally and interannually; this variability in turn produces different effects on the distribution of marine mammals.

The EEZs of Mexico can be divided in two regions based on two oceanographic variables (temperature and dissolved oxygen) according to the PCA, one region of warm or tropical waters with lower concentrations of dissolved oxygen, and another region of temperate waters with higher concentrations of dissolved oxygen. These factors determine the presence of different species of marine mammals in both regions.

The five marine mammal species that we can find on the positive side of the PC1 have a pan-tropical and tropical distribution whose boundaries are between 40°N and 40°S, associated with equatorial waters and warm currents which allow the expansion of its distribution beyond the tropics (Jefferson et al., 1993; Perryman et al., 1994; Taylor et al., 2008). Their trophic spectrum is comprised mainly by cephalopods, lantern fish and shrimp among others, so we observe that they feed from both cosmopolitan species, and species restricted to tropical or subtropical waters (Wang et al., 2012; Robertson and Chivers, 1997; Dolar et al., 2003). In counterpart, the species present on the negative side of the PC1, share an affinity for cold and temperate waters, so that the masses of cold water carried by the California Current in the majority of the year to the North Pacific and Gulf of California promote their distribution regardless of the taxonomic level than the case. The animals that conform the diet of these marine mammals (cephalopods, benthopelagic fish and crustaceans; Mead et al., 1982; Chou et al., 1995; Brownell et al., 1999; Dalebout et al., 2002; Walker et al., 2002; Aurioles-Gamboa and Camacho-Rios, 2007) are distributed in temperate and cold waters (mostly) starting from the Baja California Peninsula and into the Gulf of Alaska, factor that may explain the limits on the distribution of these mammals.

It should be noted that, associated to the negative side of this component, for the month of May we also recorded a significant value for the species *Eschrichtius robustus*; although most literature reports that the gray whale is no longer distributed in Mexican waters at this time of the year (Guerrero-Ruiz et al., 2006), the species was not dismissed as part of the component due to historical records that confirm the presence of this species during the month of May (Urbán et al., 2003).

Regarding PC2, it is reported that salinity in the Atlantic Ocean is higher than salinity at the same latitude in the Pacific Ocean (Marshall and Plumb, 2007). This component divides then Mexico in two regions: Pacific and Atlantic. This difference causes that species belonging to the same families (Ziphiidae and Delphinidae) distribute in waters with different salinity concentrations, this probably caused by adaptations to different salinity or given by the presence of prey which have different salinity requirements for their development (Koslow and Allen, 2011; Lopes et al., 2012; Perrin et al., 1981; Osnes-Erie, 1999; Schwartz et al., 1992).

We conclude that for the species *C. ursinus, E. lutris, M. stejnegeri, M. angustirostris, P. dalli, P. vitulina, and P. sinus*, the number of cases analyzed may be the cause why we do no report significant values for any of the components above listed; given its restricted distribution within the EEZ of Mexico and scale addressed in this analysis we may not be representing the total variability of the physical variables of its distribution range and the components obtained are unable to explain further the presence of these species in Mexican waters.

Something similar can be addressed for the manatee, a species known to prefer shallow (less than 3 m deep) as well as coastal lagoons and estuaries, followed by coastal waters protected by reefs, and to a lesser degree the cays (Morales-Vela, 2000). In this study, the oceanographic variables include very few near shore values, that could not be holding the total variability manatee habitat, this causes that PC1 and PC2 are not able to explain the total variance.

Special cases like *D. capensis, Z. californianus, and E. robustus* whose distribution ranges include environmental variability from the temperate-cold Northweast Pacific region and the warm-temperate zone of the Gulf of California transition, showed no significant variance in the temperature-dissolved oxygen component; this produced by the mixture of zones with different temperature gradients. On counterpart, we

Table 1
Total distribution range in the EEZ of México and percent coverage provided by all the Mexican MPA for each marine mammal species.

Species	Total Range in the EEZ (km2)	Total range (km^2) protected by any AMP	% Coverage
Arctocephalus townsendi	552,634.18	10,168.42	1.84
Balaenoptera acutorostrata	3,133,869.68	48,598.08	1.55
Balaenoptera borealis	3,133,871.24	48,598.08	1.55
Balaenoptera edeni	3,091,948.46	48,598.08	1.57
Balaenoptera physalus	3,133,869.68	48,598.08	1.55
Banalenoptera musculus	3,133,871.24	48,598.08	1.55
Berardius bairdii	603,202.47	7216.19	1.2
Callorhinus ursinus	185,700.52	85.27	0.05
Delphinus capensis	881,854.88	27,613.43	3.13
Delphinus delphis	2,023,380.79	34,274.97	1.69
Enhydra lutris	95,681.13	1748.57	1.83
Eschrichtius robustus	516,881.94	15,759.70	3.05
Eubalaena japonica	304,557.31	5976.61	1.96
Feresa attenuata	2,175,846.93	24,860.47	1.14
Globicephala macrorhynchus	3,133,869.68	48,598.08	1.55
Grampus griseus	31,33,869.68	48,598.08	1.55
Kogia breviceps	3,133,869.68	48,598.08	1.55
Kogia sima	3,133,869.68	48,598.08	1.55
Lagenodelphis hosei	1,916,382.04	19,537.52	1.02
Lagenorhynchus obliquidens	1,005,495.15	16,740.59	1.66
Lissodelphis borealis	228,087.64	5734.36	2.51
Megaptera novaeangliae	3,133,869.68	48,598.08	1.55
Mesoplodon carlhubbsi	250,452.96	6300.90	2.52
Mesoplodon densirostris	3,133,869.68	48,598.08	1.55
Mesoplodon europaeus	820,925.49	14,199.56	1.73
Mesoplodon gingkgodens	223,776.47	7044.48	3.15
Mesoplodon perrini	304,565.26	5982.15	1.96
Mesoplodon peruvianus	2,134,982.29	32,434.35	1.52
Mesoplodon stejnegeri	140,256.01	769.49	0.55
Mirounga angustirostris	168,443.55	3713.92	2.2
Orcinus orca	2,508,165.09	34,398.52	1.37
Peponocephala electra	2,575,071.66	28,745.27	1.12
Phoca vitulina	71,216.05	668.37	0.94
Phocoena sinus	18,462.45	5491.5	29.74
Phocoenoides dalli	87,575.60	0	0
Physeter macrocephalus	3,133,869.68	48,598.08	1.55
Pseudorca crassidens	3,133,869.68	48,598.08	1.55
Stenella attenuata	2,816,089.26	43,814.29	1.56
Stenella clymene	820,925.49	14,199.56	1.73
Stenella coeruleoalba	3,133,869.68	48,598.08	1.55
Stenella frontalis	820,925.49	14,199.56	1.73
Stenella longirostris	2,816,089.26	43,814.29	1.56
Steno bredanensis	3,133,869.68	48,598.08	1.55
Trichechus manatus	306,900.00	14,009.61	4.56
Tursiops truncatus	3,133,869.68	48,598.08	1.55
Zalophus californianus	544,958.73	22,056.22	4.05
Ziphius cavirostris	3,133,869.68	48,598.08	1.55

can observe high values (without being statistically significant) in the PC3 considered a nutrients component (nitrates and silicates concentration) that show a higher concentration in the Gulf of California, zone dominated by the presence of upwellings on both coasts.

B. edeni was another species that showed no significant values in any of the components. This can be explained by its wide distribution that covers almost the entire Mexican EEZ except for a small portion of approximately 41,900 km^2 in the north Pacific, this means that its distribution covers temperate-cold areas and temperate-warm zones so variance cannot be explained only in relation to changes in salinity concentration or temperature-dissolved oxygen gradients.

Finally, for *O. orca*, a cosmopolitan species with records for both the Pacific Ocean and the Gulf of Mexico, the absence of significant values for this species in the main components could be related to their feeding habits; according to Baird (2002), this species in tropical and oceanic areas are less prone to present prey specializations, which does not restrict its range to areas with certain values of temperature or salinity.

The results presented here can be used to make interpolations or modeling the variation that can occur in the species distribution range, depending on distinct factors, such as s changes in the SST. Given the strong correlation showed between some variables (e.g, SST and dissolved oxygen concentration), we recommended for future studies the incorporation of analysis using the product of the interaction between different variables, including human dimension variables (Decker et al., 2012) as this that could reveal different patterns beyond those mentioned in this work.

4.1. Management implications

The average geographic distribution of marine mammals in the world is 52 million km^2 (Pompa et al., 2011) and 1.7 million km^2 for the marine mammal species in Mexico, so in relation to the average coverage of MPAs of Mexico (1500 km^2) this is hardly representative (approximately 0.08%) of the average range of the species. The protection of marine mammals must identify their habitats and its threats to develop better conservation strategies. This protection becomes more effective when broader initiatives are included unlike when efforts are set only to protect a single species (Clayton and Myers, 2015; Rosales-Nanduca et al., 2011; Guerrero-Ruiz et al., 2006). Based on our results we have identified four areas that are critical to the conservation of marine mammals in Mexico.

The Northern Gulf of Mexico is a high species richness area for marine mammals and supports a high biological activity for many other species. However, no MPA has been designated for this area (Wilkinson et al., 2009). Moreover, the Gulf of Mexico is an area that lists on average 4 marine mammal species in their MPA's management plans from an average of 26 species that are distributed here. It is noteworthy that the total financial support managed by CONANP for marine mammals in the Gulf of Mexico has been invested in the manatee only. Therefore, we recommend that both, efforts and investment in conservation, in this area generate and utilize knowledge about the ecology of the species in order to identify and address possible threats to populations of a larger number of species of marine mammals present here.

In the Southeast Pacific, there is only one AMP designated which polygon consists exclusively of coastal areas. The open water area, characterized by the presence of upwelling and high productivity, is outside the polygon, leaving unprotected the marine mammals that are distributed beyond the coastal zone. The Mexican Pacific Southeast hosts between 18 and 23 species of marine mammals, among which are *T. truncatus, S. attenuata, S. longirostris, F. attenuata, G. griseus, G. macrorhynchus,* and *M. novaeangliae*. In addition to records of *O. orca, P. macrocephalus,* and *Z. cavirostris*. Some of these species have tropical affinities, so they are influenced by the SST (SST equal to or greater at 28 °C) (Trasviña-Castro et al., 1999). This component may be limiting their presence in areas further north of our country (Gulf of California, Pacific Northwest), where most of the AMP is concentrated. At the end of this study, this area lacked institutional support for the conservation of marine mammals, hence we propose the possibility of allocating budget to existing conservation programs focused exclusively on the MPA's in the North Pacific, even when it comes to the same species, this in order to help eliminate existing gaps in knowledge of the marine mammals are distributed here.

The Northeast Pacific has the highest species richness of marine mammals in Mexico and is ranked second in diversity of species worldwide (Pompa et al., 2011). It is also recognized as one of the key sites for breeding, calving, transit and migration of these mammals, as well as being a fundamental part of the distribution of many species of cold and temperate affinities, influenced by the component temperature and dissolved oxygen in our analysis. The variation of any of these conditions in this area of convergence of currents could have consequences in the distribution ranges of these species (Kaschner et al., 2011). In this area, we can also find 3 species (*M. stejnegeri, P. vitulina,* and *C. ursinus*), which have the lowest distribution range percentage under protection, this may be influenced by the fact that this area has designated only two MPA.

The Gulf of California is the second area with higher species richness in Mexico (31 species), and it is also recognized as key site for breeding, calving, transit and migration for many species. However, we found that MPA's like Cabo San Lucas Natural Monument (NM) and Cabo Pulmo National Park (NP) have a marine surface of less than 100 km^2; this last one records 28 species of marine mammals present and only includes 3 species within their management plan. For these reason, previous works propose for this region an expansion or union of different MPA polygons such as Cabo Pulmo and Cabo San Lucas or even the creation of a corridor between Bahia de Loreto Marine Park and the Espiritu Santo Archipelago (CONANP, 2009).

This last two areas (The Gulf of California and Northeast Pacific), concentrate most the budget projected to the conservation of marine mammals in Mexico (98%). These regions, despite present high species richness, allocate conservation programs for only 4 species. We recommend evaluating whether existing programs are currently accomplishing the objectives proposed. Likewise, we consider appropriate to diversify programs for the incorporation of more species or habitats in new projects or the inclusion of other species of marine mammals within existing projects, since in some cases the objectives can be shared by more than one species. Therefore, include other marine mammals increase the possibility of identifying possible changes in its distribution or abnormalities and changes in oceanographic conditions for these regions.

We do not explicitly consider whether the designation of MPAs is the most appropriate solution to the problems facing the marine mammals in México. Clearly, the conservation of these species requires the development of appropriate and effective conservation strategies that include habitat conservation, environmental education of the species and attention to its threats. However, the designation of new MPA as well as the extension or creation of corridors between MPAs in the regions here highlighted may represent one-step in this process. Moreover, without the appropriate implementation of management plans that aim to reduce the species'/ecosystem's threats, development of environmental education schemes, and proper funding designation, MPAs only represent 'paper parks' that provide a false impression of conservation success (Cañadas et al., 2005; Duffus and Dearden, 1995). We suggest that management programs be developed in those MPAs that lack this document, and make sure they include specific management measures for the conservation of marine mammals. Those MPAs that have a published management program need to make sure it includes specific management measures for the conservation of these mammals, especially aiming at human activities with greater impact such as whale-watching tourism and fisheries. Finally, encouraging the education and participation of local people in the marine mammals' conservation and threat management strategy will be key to a successful outcome.

Our recommendations and results aim to help minimize existing gaps in the knowledge of marine mammals in Mexico and look to provide scientific basis that reflects in effective management strategies.

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