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Social structure of the Galapagos sea lion *(Zalophus wollebaeki)* at different beaches on San Cristobal Island, during different seasons and different times of day

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HOJA DE APROBACIÓN DE TESIS

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Dedicatoria

Al habitante insular. A mi Isla, San Cristóbal: brisa, palo santo, atardeceres, fiestas populares, Barrio Frío, La Playa, El Malecón, La Predial, sonrisas, esfuerzos, arte, cultura, conservación, identidad

A las nuevas generaciones de Galapagueños y a mis hermanos menores: María Alejandra, María Romina y Martín Cox, con quienes comparto el orgullo y la alegría por nuestra cultura insular; para prepararnos al más alto nivel y regresar a donde pertenecemos

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Al propósito de considerar al habitante de Galápagos no como la mayor amenaza sino como la herramienta fundamental para la conservación

I dedicate my thesis:

To the local population of the Galapagos Islands; to our young generation committed to contribute to our islands at the highest level

To my family, third generation on San Cristobal; for giving me the privilege of being born and raised on the islands and for encouraging me to have a sense of responsibility toward our natural and cultural legacy

To the challenging pursuit to consider the human presence on Galapagos not as a threat but instead as the most useful tool for conservation

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Resumen

Comprender la estructura social del lobo marino de Galápagos *(Zalophus wollebaeki)* permite evaluar la complejidad de la dinámica de colonias de estos mamíferos gregarios y apoyar a medidas de conservación eficaces. Esta investigación pretendió determinar la presencia promedio de lobos marinos de Galápagos que viven en colonias urbanas de Puerto Baquerízo Moreno en diferentes colonias reproductivas en la Isla San Cristóbal. Las unidades experimentales fueron edad y sexo del lobo marino de Galápagos (macho, hembra, adulto no identificado, juvenil, cachorro).La recolección de datos se llevó a cabo en cuatro playas (Carola, Playa Mann, Playa de los Marinos, La Lobería) durante temporada fría 2011 y caliente 2012, en cuatro diferentes horas del día (06h00-7h00, 11h00-12h00, 15h00-16h00, 20h00-21h00). Durante temporada fría, Carola de noche fue el sitio más frecuentado por adultos no identificados y juveniles, así como Playa de los Marinos en la noche, frecuentada por juveniles, adultos no identificados y hembras. Durante temporada caliente, Playa de los Marinos fue el único sitio de reproducción más frecuentado por hembras, adultos no identificados y machos. Los resultados obtenidos arrojaron una alta dinámica en las cuatro colonias estudiadas, ya que la presencia promedio de individuos varió en cada observación.

Abstract

Understanding the social structure of the Galapagos sea lion *(Zalophus wollebaeki)* helps to assess the complexity of colony dynamics of these gregarious mammals and support effective conservation measurements. This research aimed to shed light onto colony attendance of Galapagos sea lions living in urban colonies on Puerto Baquerizo Moreno by determining the mean presence of Galapagos sea lions at different reproductive colonies on San Cristobal Island. The experimental unit were age and sex of the Galapagos sea lion (male, female, non identified adult, juvenile, pup). The data collection was carried out on four beaches (Carola, Playa Mann, Playa de los Marinos and La Loberia), during the 2011 cold season and the 2012 warm season, at four different times of day (6h00-7h00, 11h00-12h00, 15h00-16h00 and 20h00-21h00). During the cold season, Carola at night was the most frequented site by non identified adults and juveniles, as well as Playa de los Marinos at night, frequented by juveniles, non identified adults and females. During the warm season, Playa de los Marinos at night was the only reproductive site more frequented by females, no identified adults and males. Outcomes revealed the four studied colonies to be highly dynamic since mean presence of individuals varied on every observation.

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1. Introduction

1.1 Background

During the last years, one of the factors most responsible for reducing worldwide pinniped populations is the decrease of fish due to overfishing (Drago, 2010; Costa et al. 2006). Among the pinnipeds, the otariid family is the most vulnerable to human impact since they have a high interaction with the terrestrial ecosystem due to their long nursing periods: this augments their exposure to humans. Additionally, the fact that female otariids have the need to feed around their colonies during nursing makes them more vulnerable to these changes in food availability (Drago, 2010; Páez-Rosas, 2008). In the case of the Galapagos sea lion, commercial fisheries would immediately threaten their resources (Dellinger & Trillmich, 1999).

The most important facts affecting the Galapagos sea lion population *(Zalophus wollebaeki)*, are El Nino events (ENSO): considering the 1982-1983, 1997 -1998 and 2002 events as the last more severe (Alava et al. 2011). These events represent a threat to the Galapagos sea lion populations, since they produce a drastic change in the dynamics of the ecosystem and cause extreme food stress (Páez-Rosas, 2011). These events present conditions which are highly variable by causing shortages and therefore demonstrating how precarious the life of this specie is (Riedmann, 1990). In 1982, sea lion pups died in a 100% and territorial males died in an 80%, thus impacting the chances of reproduction (Trillmich y Ono, 1991). In fact, the Galapagos sea lion population is estimated to be half of what it was thirty years ago with a decrease from 40.000 in the 70's to 16.000 individuals currently (Alava et al. 2011).

This alarming fact has prompted UICN to consider the Galapagos sea lion as species in danger of extinction (Aurioles-Gamboa y Trillmich, 2008).

Other problems related to the conservation of the Galapagos sea lion are the accidents caused by anthropogenic activities. In the colonies of sea lions inhabiting Wreck Bay at Puerto Baquerizo Moreno, on San Cristobal Island, from 2006 until the present, there has been an increase in sea lion health problems, deaths, entanglements, due to various human impacts (Denkinger et al 2010, 2011, 2012). The number of individuals with anomalies -such as injuries, death and diseases- has risen significantly each year. The main causes of injuries and illness are boat engines, different types of fishing nets, hook gear, dog bites, shark attacks (Figure 30) and parasites (Denkinger et al 2010, 2011, 2012). Dogs not only disturb sea lion resting sites Introduced species like rats, dogs and cats also threaten the Galapagos sea lion. Besides causing direct aggressions and disturbances in their resting sites, but also attack and kill pups (Figure 31). Furthermore, introduced species are vectors transmitting pathogen agents (Aurioles- Gamboa y Trillmich, 2008; Salazar, 2002).

Understanding the social structure of the Galapagos sea lion, helps to assess the complexity of the colony dynamics of these gregarious mammals and support effective conservation measurements. This research aims to shed light onto colony attendance of Galapagos sea lions living in urban colonies on San Cristobal in order to improve conservation management (Figure 33 and Figure 34).

1.2 Objective of the Study

Determine the mean presence of the Galapagos sea lion *(Zalophus wollebaeki)* at urban colonies of Puerto Baquerizo Moreno on San Cristobal Island, during two different seasons and four different times of day.

1.3 Hypothesis of the Study

Considering the importance of obtaining the mean presence of Galapagos sea lions in order to comprehend the social structure and evaluate the colony dynamic of these gregarious mammals in urban colonies, the hypothesis stated for this research was that site, season and time of day are factors influencing the mean presence of the Galapagos sea lion (*Zalophus wollebaeki)* in four reproductive colonies on San Cristobal Island, during two different seasons and four different times of day.

1.4 Research questions

The following questions sought to estimate why and how the Galapagos sea lions *(Zalophus wollebaeki)* mean presence varied depending on the three factors (season, site and time of day) at the four reproductive colonies studied on San Cristobal Island.

- Is site a variable in determining the social structure of the Galapagos sea lion *(Zalophus wollebaeki)*? Do topographic traits influence demographic traits in a reproductive colony?

- Is season a variable in determining the social structure of the Galapagos sea lion *(Zalophus wollebaeki)*? How is ocean productivity playing a role in Galapagos sea lion reproductive colonies?

- Is time of day a variable in determining the social structure of the Galapagos sea lion *(Zalophus wollebaeki)*? How is habitat use linked to the Galapagos sea lions reproductive colonies?

2. Theoretical Framework

2.1 Research Context

In order to comprehend the social structure and to evaluate the colony dynamics of Galapagos sea lions in urban colonies this research was focused on the fact that Puerto Baquerizo Moreno on San Cristobal Island, sea lions constantly interact with humans: particularly along the boardwalk or *El Malecon* (Figure 23) and in Playa de los Marinos. These colonies on San Cristobal are some of the largest sea lion colonies in the archipelago after the strong El Niño event in 1997-1998 (Denkinger et al. 2010). These constant interactions with humans (Figure 24 and Figure 32) have to do with the fact that San Cristobal is an inhabited island. As tourism increases, the Galapagos sea lion reproductive colonies on San Cristobal are more and more exposed to humans (Epler, 2007) as opposed to colonies on uninhabited islands where tourism has less of an impact (Figure 22). These uninhabited islands have large reproductive colonies of their own, such as Gardner Bay on Española Island

(Figure 20), which is touristic site regulated by the Galapagos National Park (galapagosnationalpark.org).

The expectations for this research were a long term and integral study. This research seeks to relay the urgent need to study the state of the endemic and vulnerable species in urban colonies on San Cristobal and the rest of the inhabited islands of Galapagos. This is the first research to study the mean presence of Galapagos sea lions observed on Puerto Baquerizo Moreno at different times of day and during both seasons. It is unique in that it is not very often that Galapagos locals develop research on inhabited islands. This is a shame since they offer a tremendously important perspective. ¨It is surprising that a great percentage of research developed in the Galapagos has been disciplinary in a single and basic perspective. There are just a few the researchers focused on the linkage of nature, society and economics of the archipelago¨ (Tapia et al. 2009). ¨It is alarming how there is still a scarcity of information concerning ecological and socio-cultural processes, the ouctomes of which would be essential for decision management and for developing policies leading Galapagos to a more applicable plan for sustainability (Tapia et al. 2009).

The purpose of this research was to determine at four different beaches on San Cristobal Island, during two different seasons, why and how the Galapagos sea lions use their habitat at different times of day, and to find if these three factors (season, site, time of day) are influential for their social structure. For this research a colony was defined as a group of a single alpha reproductive male and its harem of up to 30 females, pups and juveniles (Eibl-Eibesfeldt, 1984). In Puerto Baquerizo Moreno on San Cristobal Island there is more than a single colony on every beach. This research assumed that the three factors (season, site, time of day) influencing the mean presence of Galapagos sea lions on the four reproductive colonies studied on San Cristobal Island were going to vary depending on the following facts: 1) Topographic traits influence demographic traits, 2) Ocean productivity plays a determinant role in social structure of *(Zalophus wollebaeki)* and 3) Habitat use is linked to the Galapagos sea lion social structure.

2.2 Galapagos sea lion *(Zalophus wollebaeki)*: distribution

The genus *Zalophus* occurs as three isolated species: *(Z. japonicus)*, on the coasts of Japan and Korea, *(Z. californianus)*, on the Pacific coast of North America and *(Z. wollebaeki)*, in the Galápagos Islands (Trillmich, 1979). The Galapagos sea lion *(Z. wollebaeki)* is found on all the major islands throughout the Archipelago and as well ason many smaller islands. In contrast to most pinnipeds of temperate zones which aggregate on land mainly during short highly synchronized reproductive periods, the Galapagos sea lions are tropic otariids non-migratory and maintain large colonies throughout the year (Trillmich, 1979).

2.3 Site as a variable: topographic traits influencing reproductive colonies of the Galapagos sea lion

The Galapagos sea lion *(Zalophus wollebaeki)* is a tropic otariid which occupies terrestrial habitats all year around (Wolf et al*.* 2005). As a coastal mammal, it is frequently hauling out on shore and is rarely found more than 16 km out to sea (Nowak, 1999). In the Galápagos, this otariid is basically diurnal, with peaks of activity in the morning and late afternoon (Eibl-Eibesfeldt, 1984). They walk slowly, move at a rapid gallop or stride over smooth surfaces using their front flippers for climbing (Figure 21). Galapagos sea lions are definitely the most agile pinnipeds on land (Riedmann, 1990), but since they are adapted to the marine environment as well, they have a thick layer of blubber and dense fur, which prevent heath loss in water. However, these adaptations can cause overheating in warmer climates. Shade is therefore necessary for thermoregulation, especially for the young ones.

In many sexually dimorphic species, adult sexes tend to segregate socially, spatially, or in habitat use. Studies have being carried out on this Galapagos sea lion *(Zalophus wollebaeki)* regarding to habitat use and sexual segregation, showing thermoregulation and costs of locomotion as the most frequent factors determining habitat use. Concerning the relationship between thermoregulation and terrestrial habitat use, results obtained by Wolf et al. 2005 proved that proximity to the sea, evaporative cooling, availability of tide pools and avoiding the sun were the most important habitat uses for males. Indeed, hyperthermia should be a more acute danger for big males than for any other individuals. This is the reason why Galápagos sea lions choose areas directly adjacent to the sea where there is easy access to relatively calm waters; flat beaches or simple flat surfaces, either sandy or rocky; shade provided by vegetation and/or tide pools to cool down during the hottest part of the day (Wolf et al. 2005; Riedman, 1990; Eibl-Eibesfeldt, 1984). In these areas, sexes and age classes differ in their usage patterns (Wolf et al. 2005).

2.4 Season as a variable: oceanographic productivity influencing reproductive colonies of the Galapagos sea lion

The Galapagos Islands are extremely arid compared to most tropical archipelagos, and they experience two distinct seasons each year: warm and cold. The warm season (typically January to May) presents high sea-air temperatures and clear skies. Littoral and arid lowland regions experience a peak in plant growth during this period. In contrast, the cold season (from June to December) presents lower sea-air temperatures and little precipitation in the lowlands. Sea lions depend strongly on the upwelling around the islands and on the cold Humboldt Current that bring nutrients to the Galápagos waters (Dellinger and Trillmich, 1999; Riedman, 1990). Their diet is based on small pelagic fish and cephalopods (Eibl-Eibesfeldt, 1984).

Sea lions on San Cristobal base 99% of their diet on fish, salemas *(Selar crumenophthalmus)* being their main prey. In the bay there is a high diversity on prey. According to Páez-Rosas, 2008, *(Zalophus wollebaeki)* is a 'plastic specialist', which means it is capable of adjusting its diet according to the most abundant type of prey available. On San Cristobal particularly, *(Zalophus wollebaeki)* showed a coastal (inshore) foraging strategy. As there is low trophic overlap among colonies sharing foraging areas, individuals from the colonies located on the bay of San Cristobal showed high plasticity, meaning that they have a high probability of withstanding possible drastic changes in the environment. Feeding behavior of marine predators depends on the level of competition to which they are exposed. If populations are living in the same or overlapping geographic regions (sympatric), they are usually under inter-specific competition, leading to the development of differing trophic strategies augmenting both nutritional and reproductive efficiency. Studying the distribution patterns of populations of *(Zalophus wollebaeki)* living in the central region, like San Cristobal, the foraging mean was 41.8 ± 20.3 km with divings of 91 ± 35.2 m (Villegas-Amtmann et al. 2008) (Figure 25).

Since the four reproductive colonies (Carola, Playa Mann, Playa de los Marinos, La Loberia) studief for this research are close to each other, a high trophic overlap might be assume, thus turning San Cristobal Island into the perfect scenario to test the trophic overlapping hypothesis. This has to do with the fact that *(Zalophus wollebaeki)* possess the traits need to have this type of adaptation: a) *(Zalophus wollebaeki)* is a predator of high trophic level, b) it is the only pinniped in the zone since its closest relative *(Arctocephalus galapagoensi)* or the Galapagos fur seal lives on the opposite side of the archipelago, 3) the islands present a high diversity of prey but with low relative abundance, which is revealed in the mean size of the sea lion populations (+/-300 individuals) and defines the habitat as marginal for this species (Páez-Rosas, 2008).

Furthermore, Galapagos sea lion have the potential for long-distance dispersal and staying home reflects an animal’s ‘‘choice’’ rather than a constraint by locomotor limitations. Instead, there is limited suitable breeding habitat in close proximity to rich feeding grounds and consequently some pinnipeds aggregate in large colonies reaching impressive numbers and densities (Riedmann, 1990). Its amphibious way of life leads them to forage in a range determined by swimming ability and breeding and resting habitat. The terrestrial habitat of Galapagos sea lion is compared to large marine home ranges but constitutes the centre of breeding activity and social interactions (Wolf and Trillmich, 2007).

2.5 Time of day as a variable: habitat use influencing reproductive colonies of the Galapagos sea lion

Colonially organized animals are considered challenging model organisms. Despite being extensively studied for decades, little is known about factors that affect their individual interaction and decisions which in turn shape processes governing the internal social structure and the relationships among members (Wolf et al. 2007). Social interaction patterns are nonrandom; at a population level, social structure might be influenced by sex and age class, whereas fine-scale site fidelity might explain social structure at the community level (Wolf et al. 2007). The long-term fidelity to a breeding site has been studied, but less is known about fine-scale site fidelity within a breeding colony and its relation to habitat quality (Wolf and Trillmich, 2007). Investigating on-shore site fidelity in a highly social environment by addressing the influence of habitat quality on fine-scale spacing use may be of key importance to further our understanding of how dense animal accumulations may have evolved and are stably maintained (Wolf and Trillmich, 2007). This spatial selection linked to habitat use has to do with the fact that sea lion colonies maintain strong social ties with genetically more similar interaction partners and might influence behavioral decisions, like cooperation and capacity to adjust degree of aggressiveness to habitat use depending on their sex and ages class.

As polygynous species, during reproductive periods, areas most strongly frequented by females are established by males as their territory. Non-successful males move into suboptimal habitats usually with no water access and less than 10 % of males manage to establish the territory (Wolf et al. 2005). Successful bulls obtain harems of up to 30 females (Eibl-Eibesfeldt, 1984), as well as pups and immature individuals of both sexes and varying ages (Orr, 1967). While females nurse their pups and immature individuals (Orr, 1967), bulls protect pups (Figure 27) by preventing sharks from accessing the deep waters and by chasing this sharks away from the pups (Barlow, 1974). Otariid males fast during territory tenure, for a territorial male the main cost might be the permanent presence in its territory and the costs associated with male-male conflict rather than the vocal display itself (Hansjoerg, 2007).

In the Galapagos sea lion colonies, females nucleate the social network, since they show a higher degree of fine-scale site fidelity and they are less aggressive than males. Female Galapagos sea lions are more social at the level of the group, since they tend to associate in close-knit groups, whereas males are more dispersed (Wolf et al. 2005). Females with offspring occupy smaller areas than non-breeding females, which require spatial predictability (Wolf and Trillmich, 2007). According to Insley et al. 2003, females tend to return to the place where they last suckled their pup und usually defend this site. Nursing lasts at least until birth of the next pup (Trillmich, 1981) (Figure 26). That is why up to 23 % of all pups are born while their mother is still nursing the older sibling. Newborns with older siblings are born lighter and suffer increased mortality due to direct aggression or competition with the older sibling (Trillmich and Wolf, 2008). Perinatal period is the time of intensive interaction between mother and pup (Figure 43). That is the time when they rub each other, greet each other with nosing, headshaking and bleating like a sheep -in the case of the pup- and the mother in deeper voice (Eibl-Eibesfeldt, 1984). Galapagos sea lion pups have two activity peaks: suckling and searching for a mother (Majetka, 2010) In order to identify the mother among the rest of females in the colony returning from the daily foraging trips, pups learn to recognize the mother's calls approximately ten days after birth (Trillmich, 1981). Mother-pup communication uses vocal and olfactory cues, as long distance calls and sniffing. After approaching each other the mother sniffs the pup confirming that it is hers (Trillmich, 1981). Mothers nurse only their own pup (Trillmich, 1981). Therefore, no female would be nursing another females pup (Figure 27).

To summarize, in group-living animals social structure constitutes the framework within which foraging, defense, and reproduction take place (Wolf and Trillmich, 2007). Studying fine-scale site fidelity of social structure is complicated by the fact that an individual's particular spatial decisions are linked to habitat quality (Figure 28). According to Pomeroy et al. 2001 in Wolf et al. 2005, it has been shown that habitat quality differs within terrestrial habitat, and this affects the spacing decision of different sex- and age-classes leading to segregation in habitat use. Fine-scale spatial range can induce behavioral population structure (Wolf and Trillmich, 2007). By setting the context for repeated interactions and if persistent across generations, these behavioral population structures, based on spatial decisions leading to segregation in habitat use, confer fitness benefits and therefore, might create a stable social environment, which has the potential to restrain competition and aggression (Wolf et al. 2005). In other word, fine-scale site fidelity may be of key importance to how dense animal accumulations may have evolved and are stably maintained (Wolf et al. 2005). Wolf et al. 2008 analyzed the intricate relationships between social behavior, dispersal strategies and genetic structure through network approaches, demonstrating that indeed, low levels of relatedness and even small differences in relatedness can be relevant for natural selection.

3. **Methodology**

3.1 Study Area

3.1.1 Galapagos Islands: geography and geology

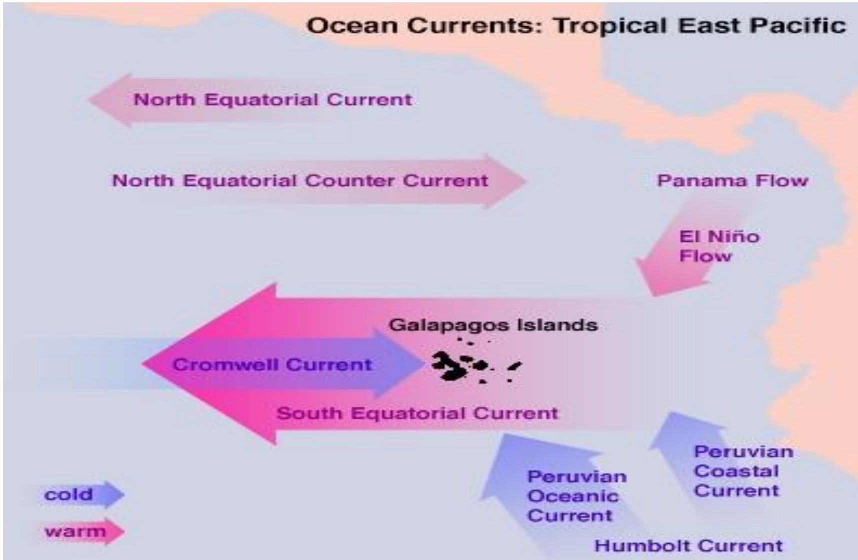
The Galapagos Islands are located 960Km away from Ecuador (Figure 1). The archipelago encompasses 15 principal islands and more than 100 islets and rocks representing almost 800.000km^2, with a total of 97% protected as National Park and 3% designated for use by locals on the four inhabited islands: Santa Cruz, San Cristóbal, Isabela and Floreana (or Santa María). The Galapagos Marine Reserve with 135.000Km^2, is the largest marine reserve in a developing country and among the largest in the world (worldwildlife.org). The islands were formed by underwater volcanic eruptions caused by the displacement of the tectonic Nazca plate, which is located over the hot-spot located northwest of Isabela and Fernandin, the youngest islands. According to its geological age, the Galapagos Islands are relatively young, 4 million years old for the oldest and less than a million for the youngest. Both, short age and oceanic origins are key factors to explain the biological diversity present on the islands (CDF y WWF, 2002).

www.travelecuador.com

Figure 1: Galapagos Islands map: in Ecuador, South America

3.1.2 Galapagos Islands: oceanography, weather and diversity

The Galapagos Islands are influenced by three predominant oceanic currents displaying a remarkable seasonality (Figure 2). The North equatorial current brings warm waters through the Panama Current, while the Peruvian Current brings cold waters through the Humboldt Current. The water temperature oscillates between 14 to 23°C. One of the most important currents is the Equatorial Undercurrent or Cromwell Underwater Current, since it flows eastwards and transports mainly cold waters, rich in nutrients, creating locally intense upwelling zones and providing a vital service to Galapagos species (Palacios, 2002; Feldman, 1985). Despite being an archipelago located on the Equator, the upwelling in the Galapagos Islands produced by the Cromwell equatorial undercurrent is propitious to generate zones of high productivity in the ocean (Figure 3) which benefits two pinniped species: the Galapagos sea lion *(Zalophus wollebaeki)* (Silvertsen, 1953) and the Galapagos fur seal *(Arctocephalus galapagoensis)* (Heller, 1904). During the warm season, the North equatorial current predominates from December to May and the weather is rather typical; with high temperatures and strong rain falls due to the convective air currents, while during the cold season from June to November, the predominant current is the Peruvian current, presenting non typical cold temperatures for these ecosystems, together with short precipitations and slight rain or *garua* (Palacios, 2002; Feldman, 1985).



Yale University, 2009

Figure 2: Oceanographic currents influencing Galapagos and Ecuador

3.1.3 Sea lion urban colonies on San Cristobal Island

San Cristobal Island houses one of the largest reproductive colonies of Galapagos sea lions *(Zallophus wollebaeki)* in Galapagos; which is also the largest sea lion colony exposed to human presence (Denkinger et al. 2010). Studying breeding colonies, their status and their relation to habitat quality is of key importance to further comprehending how dense animal accumulations may have evolved, may be stably maintained (Wolf and Trillmich, 2007) or may be affected by natural and anthropogenic threats.This research was carried out in Puerto Baquerizo Moreno, on San Cristobal Island (Figure 3), the capital of the Galapagos Province and one of the four inhabited islands on the archipelago of the Galapagos. Three of the beaches, Playa de los Marinos, Playa Mann and Carola are located at the bay of Puerto Baquerizo Moreno, called Wreck Bay, in the Western side of San Cristobal Island. The fourth studied beach, La Loberia, is located to 3 nautical miles to the South-Western side of Puerto Baquerizo Moreno (Figure 4).

3bp.blogspot.com Google Earth 2012

Figure 3: Map of San Cristobal Island and satellite map of Puerto Baquerizo Moreno

3.1.4 Sea lion colony at Carola

Carola is a relatively isolated recreational beach adjacent to Wreck Bay consisting of a long sandy beach surrounded by rocky areas (Montero, 2012). Sea lions were observed along the shore over the sand or over the rocks and on the summit of the sand dunes under the bushes used for shade. Sea lions observed in Carola included the individuals from the start of the beach up to the ones laying on the rocks around the lighthouse.

Photo by: Daniela Cox

Figure 4. Sea lion colony in Carola

3.1.5 Sea lion colony at Playa Mann

Playa Mann is a popular recreational beach frequented by residents and visitors, mostly during weekends. It is a small sandy beach with rocky patches at both sides located a few minutes away from the central area of Puerto Baquerizo Moreno. Sea lions on this beach were observed on the rocks, on the sand and under the bushes.

Photo by: Daniela Cox

Figure 5. Sea lion colony in Playa Mann

3.1.6 Sea lion colony at Playa de Los Marinos

Playa de los Marinos is a long beach located in the town center of Puerto Baquerizo Moreno, where sea lions constantly interact with people. Is one of the largest colonies of the archipelago settled after the strong El Niño event in 1997-1998 (Denkinger et al. 2010). This site encompasses two sandy beaches including a brackish lagoon on the back. The individuals considered on this site were observed the sand, on the rocky areas along the beach and over the central park called Plazoleta Municipal. This beach does not have bushes but repairing boats in the shipyard were used as shade for sea lions.

Photo by: Daniela Cox

Figure 6. Sea lion colony in Playa de los Marinos

3.1.7 Sea lion colony at La Loberia

La Loberia is a located 3 nautical miles to the South-Western side of Puerto Baquerizo Moreno (Páez-Rosas, 2008) and is a recreational beach for tourists and residents. It is an intermediate size sandy beach with two long rocky patches aside. Thirty years ago it used to be the beach most crowded of sea lions. The observations on Loberia included the tiny sandy area at the right side located at the entrance of the beach; sea lions were laying on the sand, over the rocks and under the bushes.

Photo by: Daniela Cox

Figure 7. Sea lion colony in La Loberia

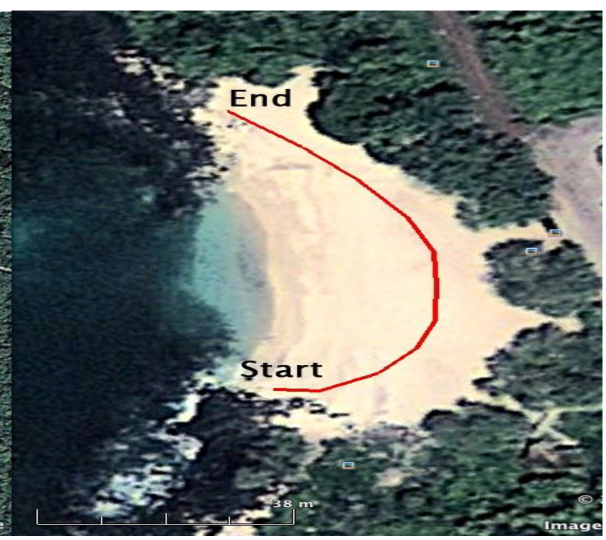
3.2 Data Collection

The experimental unit of this research was the age and sex of the Galapagos sea lion *(Zalophus wollebaeki)*. Data collection was carried out during two different seasons: the cold season during August 2011 and the warm season from January-February 2012. To determine the social structure of the Galapagos sea lion ***(****Zalophus wollebaeki)*, the census or samplings of sea lions observations where developed at four different beaches or urban colonies of Puerto Baquerizo Moreno on San Cristobal Island at four different times of day. Therefore, three factors were considered: group, site and time of day. All of the factors varied according to either season. Group factors included sex and age of the individuals: male, female, non identified adult, juvenile, pup. Site factor encompassed four beaches or reproductive colonies: Carola, Playa Mann, Playa de los Marinos and La Loberia. Time of day factor included: 6h00-7h00, 11h00-12h00, 15h00-16h00 and 20h00-21h00.

3.2.1 Sea lion observations

The samplings were done by direct observation or by binoculars when needed, as the distance toward the individuals was usually two meters. Samplings were carried out during 20 days of census on each season at each of the four sites during the four different times of day. This means that the first day the census were carried out in Playa Mann, the second day in Playa de los Marinos, the third day in Carola and the fourth day in La Loberia in order to obtain the mean presence of the sea lions from the five samplings at four different times during each season. In other words, for both seasons four replications were carried out every day on every reproductive colony identifying every group (male, female, no identified adult, juvenile, pup). Each sampling or census lasted 25 minutes at the short beaches (Playa Mann, La Loberia) (Figure 9 and Figure 11) and one hour at the long ones (Carola, Playa de los Marinos) (Figure 8 and Figure 10); for instance, during the cold season, census on Carola was from 20h00-21h00.

Google Earth 2012



Google Earth 2012

Figure 8. Satellite map of Carola **Figure 9**. Satellite map of Playa Mann

Google Earth 2012

Google Earth 2012

Figure 10. Satellite map of Playa de los Marinos **Figure 11.** Satellite map of La Loberia

The outcome was that it was not possible to make an estimation of the total number of individuals belonging to every single group (male, female, no identified adult, juvenile, pup) in all the sites during both seasons and at different time of day since individuals were not marked nor tracked (distribution was not the topic of research) and, therefore, each individual may been counted multiple times. Nevertheless, an estimation of the mean presence and frequency was obtained since individuals were observed depending on the group, the site, the season and the time of day.

3.2.2 Identification of individuals

Individuals were identified into five age and sex categories: adult males, adult females, non identified adults, juveniles, and pups (Figure 12 to Figure 15) in accordance with Holcomb, 2009 and Riedman, 1990 (See chart below). Adult individuals were considered males when they had a developed front head and crest, robust neck, presence of testicles between hind flippers and visible penis. Males reached a length of 200-250cm and a weight of 200Kg. Adult individuals were considered females when they had tanned fur (Nowak, 1999), a more slender head than males, no crest nor testicles, were nursing and were not barking but grunting to communicate with pups or when they felt disturbed or threatened. Females reached a length of 150-200cm and weight 100kg. Adult individuals were considered non identified adults when it was not possible to identify them as males nor females. This could be because they either layed on the sand among a lot of individuals or exposed only their back side making it difficult to differenciate them. Non identified adults reached a length of 150-200cm and a weight of 100Kg. Young individuals were considered juveniles when they had less fur than pups and in some cases were still nursing. Juveniles reached a length of 150-200cm and a weight of 25-40Kg. Individuals were considered pups when they were younger than two years old, had not undergone molting yet and had fluffier fur. Pups reached a length of 150-200cm and a weight of 5-6Kg. At 4-5 months of age pups undergo their first molt (Trillmich, 1981) At birth they have a brownish-black lanugo coat, which fades to pale brown within three to five months (Aurioles-Gamboa and Trillmich, 2008).

Age group	Traits	Size (cm)	Weight (Kg)
Males	Adult individuals with developed front head and crest, robust neck, presence of testicles between hind flippers and visible penis	200-250	200
Females	Adult individuals with tanned fur, more slender head than males, without crest nor testicles, nursing and not barking but grunting to communicate with pups or feel disturbed or threatened	150-200	100
Non Identified Adults	Adult individuals not possible to identify as male or female	150-200	100
Juveniles	Young individuals with less fur than pups after molting. Some still nursing	100-120	25-40
Pups	Individuals younger than 2 years old, brownish-black lanugo coat which fades to pale brown, have not undergone molting yet	30 - 75	5-6

(Holcomb, 2009; Riedman, 1990)

Photo by: Daniela Cox

Figure 12. Male

Photo by: Daniela Cox

Figure 13. Female

Photo by: David Parra

Figure 14. Juvenile

Photo by: Daniela Cox

Figure 15. Pup

3.2.3 Sources of reference for the sea lion observations

Sources of references used for this research were prior census and observations developed on San Cristobal Island: (Montero, 2012, Fietz, 2012, Denkinger 2010, 2011, 2012), where it more individuals were expected during warm season than during the cold season.

3.2.4 Gear used for the sea lion observations

The gear used were a water proof binocular Minolta Activa 12x50W, an Energizer flash light, a Pelican Stealth Lite2400 submersible flash light, a note book and a pen.

3.3 Statistic Analyses

3.3.1 Frequency and percentage of observed individuals

To obtain the frequency and percentege of observed individuals per group, site, season and time of day, the Chi Square Paired Test was applied using SAS software.

3.3.2 One Way ANOVA: Variability among factors

To confirm variability among the three factors (group, site and time of day) during each season (cold and warm), the coefficient variation was obtaining by applying One Way ANOVA Test using SAS software. The coefficient variation during cold season was 74.20938**,** while during warm season the variation coefficient was 115.0907. Since the obtained values were too high, mean required to be transformed, obtaining a variation coefficient = 35.26180 during cold season and 46.89317 during warm season.

3.3.3 Tukey Range Test: Means significantly different

To find means that are significantly different from each other the Tukey Range Test or Tukey Kramer method was applied, in conjunction with ANOVA Test, using SAS software (Table 11 to Table 16). The Tukey Range Test is a multiple comparison procedure based on a range distribution, which compares the means of every treatment to the means of every other treatment and identifies any difference between two means if it is greater than the expected standard error. Comparing the means of three factors (group, site, time of the day) for all the colonies during each season (cold and warm), variability was measured by the distance among ranges from *A* to *E*; where *A* represented the highest mean values and *E* range represented the least mean values. Variability among means were significant depending on how distributed the ranges were.

3.3.4 Chi Square Test: Dependence or independence among variables

To determine the dependence or independence among the variables (group, season, site, time of day) the Chi Square (X^2) statistic test used was applied to evaluate if there is or is not association among variables from the rows and variables from columns in a contingency table (Table 1 to Table 10). It was requiered to obtain the *significance*, which is the probability of error accepted: 0.05 to accept or reject the hypotheses, where H_0: variables are not associated; they are independent among each other and H_1: variables are dependent among each other. H_0 is the one to test if there is no association among data from the columns and the rows in a contingency table. In order to have an X^2 value of confidence, frequencies or samplings had to be robust.

4. Results

4.1 Obtained data from the sea lion observations

This research considered three factors (season, site, time of day) to obtain the mean presence of the colony composition or group (male, female, no identified adult, juvenile, pup) of *Zalophus wollebaeki* on the four reproductive colonies or sites (Carola, Playa Mann, Playa de los Marinos, La Loberia) studied on San Cristobal Island during both seasons (cold and warm) at different times of day (6h00-7h00, 11h00-12h00, 15h00-16h00, 20h00-21h00). The tested hypothesis was that mean presence of *Zalophus wollebaeki* observed depend on the site, the season and the time of day.

4.1.1 Total mean of sea lions observed per season and site

The total mean of individuals observed per reproductive colony were: 164 individuals in Carola, 124 individuals in Playa de los Marinos, 69 individuals in Playa Mann, 51 individuals in La Loberia during the cold season and 205 individuals in Playa de los Marinos, 45 individuals in La Loberia, 32 individuals in Carola, 19 individuals in Playa Mann during the warm season (Figure 16).

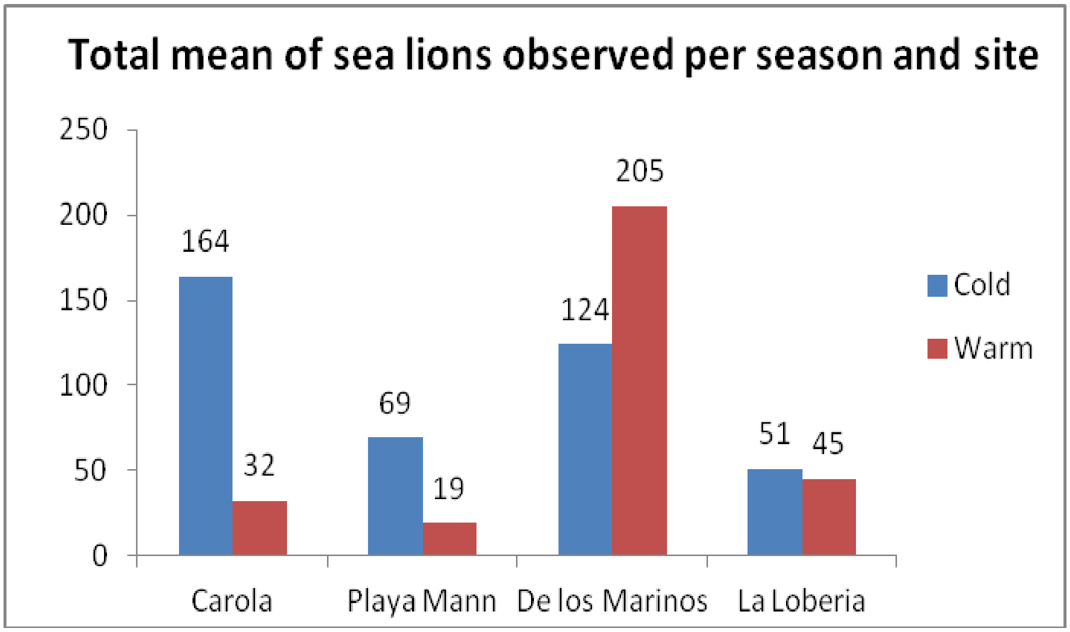


Figure 16. Total mean of sea lions observed per season and site

4.1.2 Total mean of sea lions observed per group, site and season

The total mean of sea lions observed per group, site and season was: non identified adults (121.22 +/- 102.7835), juveniles (133.98 +/- 53.98981), females (80.43 +/- 53.14073), males (58.27 +/- 33.13458), pups (19.24 +/- 19.32425) during the cold season and females (87.25 +/- 74.46878), non identified adults (41.25 +/- 58.73085), males (61.9 +/- 35.16109), juveniles (42.35+-26.41429), pups (68.5 +- 22.08055) during the warm season. The largest groups observed were: non identified adults (56.5 +/- 39.96775) in Carola during the cold season and females (59.65 +/- 41.55944) and males (52.3 +/- 26.10122) in Playa de los Marinos during the warm season (Figure 17).

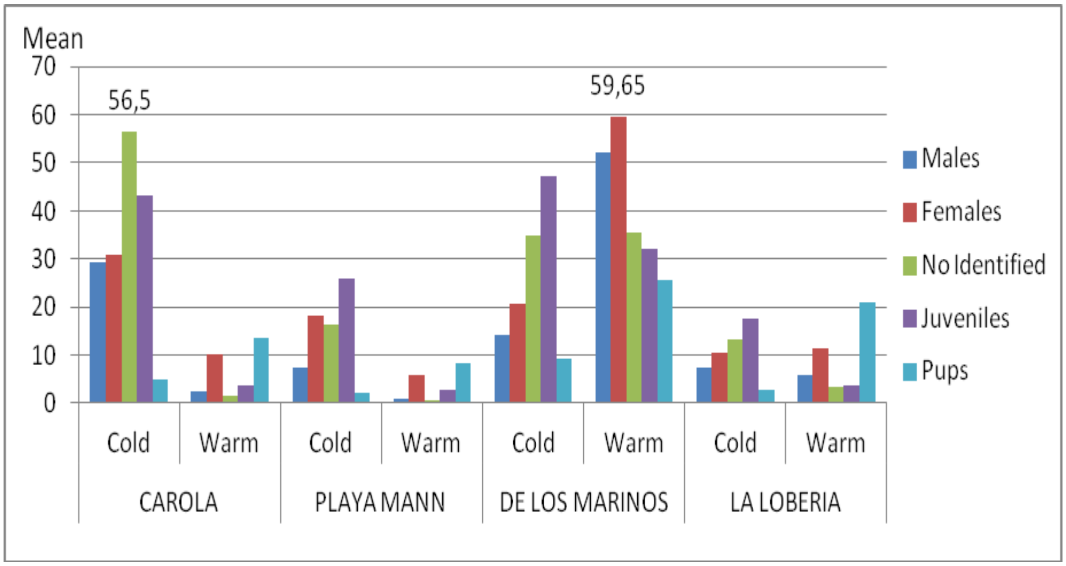


Figure 17. Total mean of sea lions observed per group, site and season

4.1.3 Total mean of sea lions observed per group, season, site and time of day

The more detailed comparison was gathering the three factors by comparing the total mean of individuals observed per season, site and time of day. During the cold season, non identified adults (88.2 +/- 64.48411) in Carola and juveniles (83.2 +/- 23.76342) in Playa de los Marinos presented the largest frequency and mean of individuals observed, both sites at 20h00-21h00 (Figure 18). During the warm season, females (108.4 +/- 50.94409), non identified adults (93.4 +/- 80.58102) and males (79.4 +/- 27.63693) in Playa de los Marinos presented the largest frequency and mean of individuals observed at 20h00-21h00 (Figure 19).

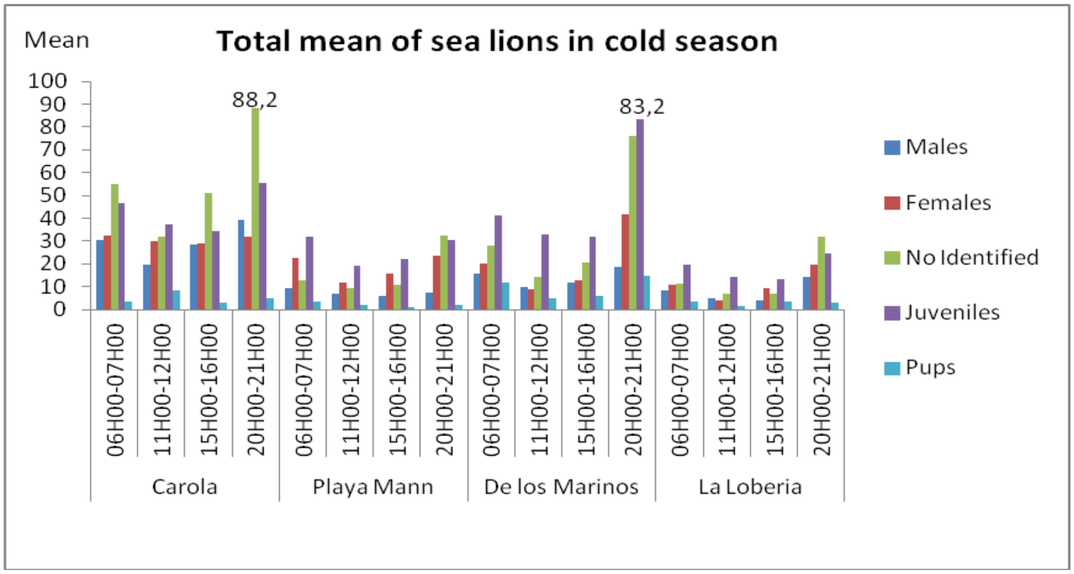


Figure 18. Total mean of sea lions observed per group, site and time of day during the cold season

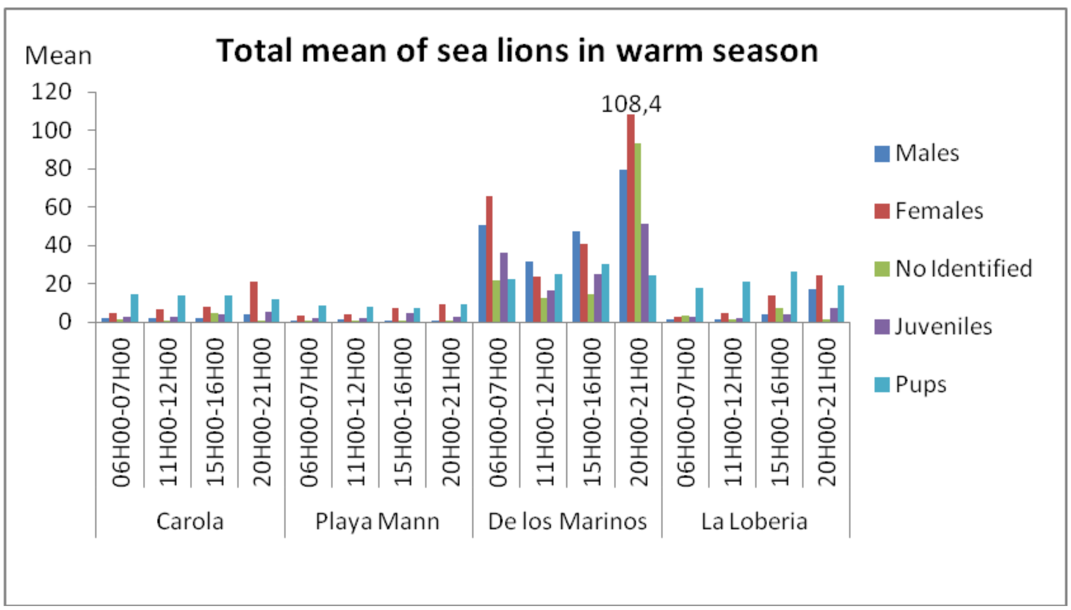


Figure 19. Total mean of sea lions observed per group, site and time of day during the warm season

4.2 Obtained values from the Statistic Analyses

4.2.1 Tukey Range Test

Comparing the means of every factor (group, site, time of day) to identify significantly differences among all the colonies together applying Tukey Range resulted in the following: values for Group in the cold season had high variability among treatments (juveniles, non identified adults, females, males and pups) (Table 11). Instead, values for Site in the cold season were very close among each other especially between Playa Mann and La Loberia (Table 12). The same range of distribution of means was for Time of Day in the cold season between15h00-16h00 and 11h00-12h00 (Table 13). Values for Group in the warm season were close for pups and females, while juveniles approached the value for males and non identified adults (Table 14). For Time of Day in the warm season, Loberia and Carola had similar values (Table 15). Values for Time of Day in the warm season presented almost alike distribution of ranges between 15h00-16h00, 16h00-07h00 and 11h00-12h00 (Table 16).

4.2.2 Chi SquareTest

Considering the variables site (Carola, Playa Mann, Playa de los Marinos, La Loberia) and time of day (06h00-7h00, 11h00-12h00, 15h00-16h00, 20h00-21h00) for every group of sea lions (males, female, non identified adults, juveniles, pups) during each season (cold and warm), where H_0: *variables are not associated; they are independent among each other* and H_1: *variables are dependent among each other*, the obtained outcomes showed that most of the significance were less than 0.05(Significance <.0001, which is a value clearly less than 0.05); therefore, rejecting H_0 and accepting H_1. This conclusion applies as well for juveniles in warm season

(X^2= 23.2003 and Significance= 0.0058, where 0.058 is practically over 0.05), where data suggests but does not conclude about the relation among variables, meaning H_0 was rejected and H_1 was accepted. Similarly for males in the cold season (X^2=16.1126 and Significance=0.0646, where 0.058 is practically over 0.05), rejecting H_0 and accepting H_1. The only exception in this conclusion was for pups in the warm season (X^2= 9.3675 and Significance= 0.404, which is higher than 0.05), accepting H_0: *variables are independent among each other*.

5. Discussion

5.1 Purpose of the Study

This research aimed to shed light on the social structure of the Galapagos sea lions living in urban colonies of Puerto Baquerizo Moreno on San Cristobal Island. To study the social structure of otariids based on fine-scale spatial range and habitat use depending on sex and age usage patterns helps: 1) to assess the social behavioral structure, the colony dynamics and the status of these gregarious mammals and 2) to support the encouragement of research initiatives and the improvement of conservation management alternatives on fragile and complex ecosystems; for instance on inhabited islands like the ones in the Galapagos. Therefore, the foremost aim of this study was to obtain the mean presence of the Galapagos sea lion *(Zallophus wollebaeki)* and the expectation would be to involve the local population into research and science both short and long term; to develop interest and commitment to know the Galapagos from a deeper point of view by learning and understanding our surroundings.

5.2 Analysis of the obtained data during the cold season: Oceanographic productivity

During the cold season, from June to November, the predominant current is the Peruvian current. The Peruvian or Humboldt Current brings together the upwelling produced by the Cromwell equatorial undercurrent, which is propitious to generate zones of high productivity in the ocean (Palacios, 2002; Feldman, 1985). With productivity in the ocean, the breeding season occurs. On San Cristobal Island, breeding season occurs from July to November, with October to November being the peak of pupping season (Fietz, 2012). During this season, Carola at night was the most frequented site by non identified adults and juveniles, as well as Playa de los Marinos at night, frequented by juveniles, non identified adults and females. On the four urban colonies studied during the cold season, which is when breeding occurs, a decrease was observed in the mean presence of male adults. The frequency of individuals descended in the four fundamentally owing to the decrease of males by 60 %; since they abandon the colony during breeding season due to the increase of aggressiveness from territorial males constantly patrolling during the day, blocking the access of other males to the beach, and attacking other males in case they approach their colony (Montero, 2012). Concerning the inter-annual population variation, the Galapagos sea lion *(Zalophus wollebaeki)* follows a different pattern compared to most pinnipeds; which show an annual peak of abundance during breeding season (Jeminson et al. 2001).

5.3 Analysis of the obtained data during the warm season: Social behavior

During the warm season, when is not breeding season anymore, the North equatorial current predominates from December to May with high temperatures and strong rain falls due to the convective air currents (Palacios, 2002; Feldman, 1985). During this season, Playa de los Marinos at night was the only reproductive site more frequented by females, non identified adults and males. As mentioned in Denkinger 2010, 2011, 2012; the estimation of the annual peak attendance in the populations of Galapagos sea lions on San Cristobal Island occurred during the latest time of breeding season. Therefore, the agglomeration of females, non identified adults and males observed at night in Playa de los Marinos might be related to their high degree of social behavior; which leads them to spend most of their life in contact with other individuals (Wolf et al. 2007). Consequently, this fluctuation might be caused by the different behavior patterns between sex existing in pinnipeds; where females show greater philopatry or site fidelity along the entire year owing to their prolonged periods of lactation (Páez-Rosas 2010; Elorriaga-Verplancken, 2004) compared to males, whom increase their foraging journeys previous and during mating season to increase energetic reserves in order to increase their probability of winning when competing for territory (Páez-Rosas, 2008; Trillmich y Wolf, 2007; Riedman, 1990).

5.4 Analysis of the obtained data determined by topographic traits: Habitat use and thermoregulation strategies

Physical characteristics might have been another explanation for the variability in the mean presence of sea lions between the four studied reproductive colonies. On flat sandy areas, as it is the case on Playa Mann, sea lions reduce the energy cost associated with locomotion on land by avoiding steep areas, as that is the case for Carola, Playa Mann and La Loberia. In addition, on flat sandy beaches during the night sea lions are less exposed to the cold wind and the increased density of individuals reduces heat loss (Bentjees, 2006). Playa de los Marinos, more so than the other sites hosts preferential conditions for sea lions. Studies on other species of pinnipeds that inhabit temperate and cold climates described the peak of abundance in resting areas as occurring at noon (Pauli y Terhune, 1987; Jemison et al. 2001). Instead, based on our observations on every site there was a decrease in the number of individuals at that time of day; a possible explanation might be that generally the distribution range of the species of pinnipeds is associated with high latitudes (Riedman, 1990; Costa et al, 2006) where temperatures are significantly lower than in the Galapagos. That is the reason why Galapagos sea lions prefer to spend much of the daylight hours in the sea, in the shade, in the rocky areas near the coast, or over artificial substrates like platforms which are used as adaptation for thermoregulation (Figure 33) (Montero, 2012).

5.5 Analysis of the obtained data determined by human impact

Mean presence variation on sea lion colonies might be derived as well from human impact. During the cold season and the warm season, the high mean presence of sea lions in Playa de los Marinos at night probably occurs to avoid the noise in the area during the day given the high level of interaction between the colonies and the urban sector of Puerto Baquerizo Moreno (Acevedo-Gutierrez, 2011; Guevara, 2011). On San Cristobal Island, sea lions living in such close vicinity to humans are very likely exposed to stress resulting from human-animal interactions. Therefore, their most important activities when ashore (resting and nursing) appear natural compared to other species (Henry and Hammill, 2001; Boren, 2001; Anderson and Harwood 1985). Sea lions indicate a high level of habituation to human presence; this human presence hardly influences their behavior. Since *(Zalophus wollebaki)* is accustomed to people, disturbances in general seem to have smaller impacts than on other species (Kucey 2005, Denkinger et al. in rev.). Indeed, when the reproductive season begins in August, tension in the colony increases and Galapagos sea lions on San Cristobal are so occupied with territorial conflicts, courting females, and mating behavior that they pay less attention to their surroundings and disturbers. This is probably because if they do react, their reactions represent high energy expenditure (Fietz, 2012). This might explain why in Playa Mann, a sea lion reproductive colony constantly frequented by humans, presents fewer individuals of sea lion compared to the rest of the recreational sites -Carola and La Loberia-, which are less frequented by humans. Consequently, it is important to build a sea lion mean presence baseline for conservation management to show that although *(Zalophus wollebaki)* is an animal with a high level of habituation, it is not immune to stressors caused by anthropogenic interactions (Fietz, 2012).

5.6 Contribution and importance of the Study

Potentially, this study might be used as an approximation of the mean presence of males, females, no identified adults, juveniles and pups attending the four most visited sea lion reproductive colonies on San Cristobal Island. The importance of this research is that this is a pioneering, meticulous work on San Cristobal from a student regarding sea lions, with data collected during both seasons (cold and warm) and during different time of day, setting the tone for continuing with the same methodology of the direct observations to obtain the mean presence of sea lions or any other species from Galapagos. Using the results and understanding the purpose of the thesis, will benefit: 1) the colonies of sea lions *(Zallophus wollebaeki),* which are unique species to the world currently considered under threat of extinction (Aurioles-Gamboa y Trillmich, 2008) and 2.) the local students from High Schools and from research centers on San Cristobal to learn more about these gregarious mammals in order to promote awareness and mechanisms to protect the ecology of the specie *(Zallophus wollebaeki)* and its interaction with residents and visitors.

5.7 A different perspective of Science

Galapagos is a complex socio-ecological system made of bonds between the ecosystems and human welfare. The socio-economic system of this archipelago is deeply linked to the marine ecosystems it depends on and interacts directly with in a dynamic way (Tapia et al. 2009). The opinions existing regarding to this field of study (sea lions research-conservation) might change given the fact that along the human history of the Galapagos science and research have been developed mostly by foreigner volunteers and visitors. This is a research from the point of view from a local student of Marine Ecology and this is the beginning of the need for the locals to claim science and for locals to be used as a tool for decision management. Sometimes in Galapagos, there is no common perspective about what, how and what for to conserve Galapagos. Although the actors claim conservation and sustainable development as their main goals, each of them has their own particular perspective about what the archipelago is and what it means to the local population, to mainland Ecuador and to the rest of the world (Tapia et al 2009). Therefore, beyond the research, there is an important meaning with this work; relying on the possibility to rebuild the bridge between science and the population on the Galapagos, making the obtained information more accessible to the local community and seeking to join the gap existing ever since between both.

6. Conclusions

6.1 General Summary

Studying breeding colonies and their relation to habitat quality (Wolf and Trillmich, 2007) is of key importance to further comprehend how dense animal accumulations may have evolved, may be stably maintained or may be affected by natural and anthropogenic threats. Outcomes were high mean values compared to the standard deviation values, meaning that there is a high dynamic of activity in the four studied urban colonies (since one day 5 individuals were counted and the next time 30, for instance). During the cold or breeding season on Puerto Baquerizo Moreno, sea lions are spread in the different beaches or reproductive colonies, while during the warm season once breeding season is over; colonies get disaggregated from each beach in order to aggregate mostly on Playa de los Marinos. The mean presence of Galapagos sea lion *(Zalophus wollebaeki)* was dependent on the site, the season and the time of day in the four urban colonies, during the cold and the warm season and during the four different times of day, accepting the hypothesis of the study.

6.2 The challenge for the Conservation Research

Over the last two decades the Galapagos Islands have displayed their natural uniqueness together with the challenging attempt to consider local inhabitants as fundamental actors developing environmental education, implementing environmental policies or participating on research projects. Therefore, this thesis is an invitation to local students to continue with the sea lion observations to obtain the mean presence on reproductive colonies and therefore to evaluate their ecological status to create a linkage with human impact and establish alternatives of conservation measurements.

6.3 Recommendations

For further research it might be required to carry out observations for longer periods of months during each season and during more than a single year in order to compare data. Further conservation of the biodiversity and of the unique ecosystems in Galapagos will depend enormously on the local inhabitants, local and national institutions and research centers, which have the responsibility to carry out sustainable social-economic practices and sustainable sciences adapted to the fragility of the archipelago.

7. References

Acevedo-Gutiérrez, A. (2011) *Nocturnal Haul-Out Patterns of Harbor Seals (Phoca vitulina) related to Airborne Noise Levels in Bellingham,* Washington, USA. *Aquatic Mammals*, *37*(2), 167-174. doi:10.1578/AM.37.2.2011.167.

Anderson, S. and Harwood, J. (1985) *Time budgets and topography: how energy reserves and terrain determine the breeding behavior of grey seals.* Animal Behavior 33: 1343 –1348.

Alava et al. (2011) *DDT strikes back: Galapagos sea lions face increasing health risks.*

Aurioles-Gamboa, D. and Trillmich, F. (2008) *Zalophus wollebaeki*. IUCN Red List of Threatened Species. Version 2010.

Barlow, G. W. (1974) *A Paternal Role in Galapagos Sea Lions.* Evolution 28:433-476.

Beentjes, M. (2006) *Behavioral thermoregulation of the New Zeland Sea Lions (Phocarcto shookeri).* Society, 22 April, 311-325.

Boren, L.J. (2001) *Assessing the impacts of tourism on New Zealand fur seals* (*Arctocephalus forsteri*). MSc thesis, University of Canterbury, Christchurch, New Zealand.

CDF (Charles Darwin Foundation), and WWF (World Wildlife Fund) 2002). *A Biodiversity vision for the Galápagos Islands*. Unpublished. Charles Darwin Foundation.pp. 141.

Costa, D.P., Weise, M.J. and Arnould, J.P. (2006) *Potential Influences of Whaling on the Status and Trends of Pinniped Populations.* University of California Press, Berkeley.

Dellinger, T. and Trillmich, F. (1999) *Fish prey of the sympatric Galápagos fur seals and sea lions: seasonal variation and niche separation*. 77: 1204–1216.

Denkinger et al. (2010, 2011, 2012) *Proyecto Informe Parque Nacional Galapagos.*

Denkinger et al. (2010) *Human-wildlife conflicts and benefits of Galápagos sea lions on San Cristóbal Island, Galápagos*. GAIAS (Galápagos Institute for the Art and Science), Puerto Baquerizo Moreno, San Cristóbal Island, Galápagos, Ecuador.

Drago, M. (2010) *Dieta y dinámica poblacional del león marino del sur (Otaria flavescens) en Patagonia.* Tesis de Doctorado. Universidad de Barcelona.

Eibl-Eibesfeldt, I. (1984) *The Galápagos Seals Part 1. Natural History of the Galápagos Sea Lion (Zalophus californianus wollebaeki, Sivertsen).* In: Perry R (ed.) Key Environments GALAPAGOS. Pergamon Press, Oxford: 207-223.

Elorriaga-Verplanken, F. (2004) *Incidencia y efectos del enmalle sobre el lobo marino de California (Zalophus californianus*), Lesson, 1828, Los Islotes, B. C. S., México. CICIMAR-IPN.

Epler, B. (2007) *Tourism, the Economy, Population Growth, and Conservation in Galapagos.* Charles Darwin Foundation, Puerto Ayora, Santa Cruz Island, Galapagos Islands, Ecuador: 68 pp.

Farrer, J. y Acevedo-Gutiérrez, A. (2010) *Use of Haul-Out Sites by Harbor Seals(Phocavitulina)* in Bellingham: Implications for Future Development. Northwestern Naturalist, 91(1), 74-79.

Feldman, G.C. (1985) *Satellites, seabirds and seals*. In: Robinson G, del Pino EM (eds.) El Niño en las Islas Galápagos: El Evento de 1982-1983. Fundación Charles Darwin para Islas Galápagos, Quito, Ecuador: 125-130.

Fietz, K. (2012) *General Behavioral Patterns and Human Impact on Behavior of the Galapagos Sea Lion (Zalophus wollebaeki) on San Cristóbal, Galapagos*.

Department of Animal Ecology and Conservation. University of Hamburg, Germany.

GNP (Galapagos National Park) (2013) official webpage

Guevara, N.C. (2011) *Línea base del estado de salud y detección de Leptospira patógena por PCR en lobos marinos de Galápagos (Z. wollebaeki) de la Isla San Cristóbal.* Tesis de Licenciatura. Universidad San Francisco de Quito, Ecuador.

Hansjoerg, P. (2007) *Seasonal Changes of Vocal Rates and their relation to territorial status in male Galapagos Sea lions (Zalophus wollebaeki)*

Henry, E. and Hammill, M.O. (2001) *Impact of small boats on the haulout activity of harbour seals (Phoca vitulina) in Métis Bay, Saint Lawrence Estuary, Québec, Canada.* Aquatic Mammals 27.2: 140 – 148.

Heller, E. (1904) *Mammals of the Galapagos Archipelago, exclusive of the Cetacea.* Proceedings of the Californian Academy of Science 3(3): 233-250

Holcomb, K., Young J.K, and Gerber, L.R. (2009) *The influence of human disturbance on California sea lions during the breeding season.* Animal Conservation 12: 592 – 598.

Insley, S.J., Phillips, A.V. and Charrier, I. (2003) *A review of social recognition in pinnipeds.* Aquatic Mammals 29.2:181-201.

Jemison, L. A., Pendleton, G. W. y Wilson, C. A. (2001) *Harbor seal population trends and factors influencing*. Population (English Edition),*1995* (April 2000), 5370.

Kucey, L. (2005). *Human disturbance and the hauling out behaviour of Steller sea lions* (*Eumetopias jubatus*). Unpublished. The University of British Columbia. 75 pp.

Marjetka, Š. (2010) *Evaluating the impacts of human presence on mother-pup communication in the Galápagos sea lion (Zalophus wollebaeki (Sivertsen 1953).* Departamento de Ciencias da Vida. Facultade de Ciencias e Tecnologia.Universidad de Coimbra.

Montero, I. (2012) *Caracterización y uso de hábitat del lobo marino de Galápagos (Zalophus wollebaeki) en la Bahía Naufragio de la Isla San Cristóbal*. Universidad de Barcelona, España. Facultad de Biología, Universidad de Barcelona

Nowak, R.M. (1999) *Walker's Mammals of the World.* Volume II. 6th edition. John Hopkins University Press, Baltimore, Maryland: 852-855.

Orr, (1967)*The Galapagos Sea Lion.* Journal of Mammalogy, Vol 48: 62-69. Accessed February 02, 2009.

Páez-Rosas, D. (2011) *Ecología trófica de los pinípedos de las Islas Galápagos: análisis espacial y temporal.* Instituto Politécnico Nacional Centro Interdisciplinario de Ciencias Marinas. México.

Páez–Rosas, D. y Aurioles-Gamboa, (2010) *Alimentary niche partitioning in the Galapagos sea lion, Zalophus wollebaeki*. Mar. Biol. 157, 2769–2781

Paez-Rosas, D. (2008) *Diversificacion de dietas en tres colonias de lobos marinos Zalophus wollebaeki, evaluada con análisis de excretas e isotopos estables de C y N.* Instituto Politécnico Nacional Centro Interdisciplinario de Ciencias Marinas. México.

Palacios, D.M. (2002) *Factors influencing the island-mass effect of the Galapagos.* Geophys. Res. Lett. 29, 2134.

Pauli, B. D. and Terhume, J. M. (1987) Tidal and temporal interaction on harbor seals haul-out patterns. Aquatic Mammals 13, 93-95.

Riedman, M. (1990) *The Pinnipeds: Seals, Sea Lions, and Walruses.* University of California Press, Berkely. Los Angeles, 439 pp.

Salazar, S. (2002) Capítulo 15: *Lobo marino y lobo peletero*. In: Danulat E, Edgar GJ (eds.). Reserva Marina de Galápagos. Línea Base de la Biodiversidad. Fundación Charles Darwin/Servicio Parque Nacional Galápagos, Santa Cruz, Galápagos, Ecuador: 267-289.

Silvertsen (1953) *Evaluating the impacts of human presence on mother-pup communication in the Galápagos sea lion (Zalophus wollebaeki (Sivertsen 1953)*

Tapia, W., Ospina, P., Quiroga, D. et al. (2009) *Ciencia para la sostenibilidad de Galápagos*. Parque Nacional Galápagos, Ecuador.

Trillmich, F. and Wolf, B.W. (2008) *Parent-offspring and sibling conflict in Galápagos fur seals and sea lions*. Beh Ecol Sociobiol 62: 363-375.

Trillmich, F. y Ono, K. (1991) *Pinnipeds and El Niño: Responses to Environmental Stress.* Springer-Verlag, Berlin.

Trillmich, F. (1984) *The mating systems of pinnipeds and marine iguanas: convergent evolution of polygyny.*

Trillmich, F. (1981) *Mutual mother-pup recognition in Galápagos fur seals and sea lions: cues used and functional significance*. Behaviour 78: 21-42.

Trillmich, F. (1979) *Noticias de Galápagos*, Estación Científica Charles Darwin, Puerto Ayora – Ecuador, 29: 8-14.

Villegas-Amtmann et al. (2008) *Multiple foraging strategies in a marine apex predator, the Galapagos Sea Lion*. Mar. Ecol. Prog. Ser. 363, 299–309.

Wolf, J. et al. (2008) *Kin in space: social viscosity in a spatially and genetically substructured network*. Institute for Genetics, Evolutionary Genetics, University of Koln. Department of Animal Behaviour, University of Bielefeld, PO Box 10 01 31, 33501 Bielefeld, Germany.

Wolf, J. and Trillmich, F. (2007) *Beyond habitat requirements: individual fine-scale site fidelity in a colony of the Galapagos sea lion (Zalophus wollebaeki) creates conditions for social structuring.* 152: 553-567.

Wolf, J. et al. (2007) *Social structure in a colonial mammal: unraveling hidden structural layers and their foundations by network analysis.* Department of Animal Behavior, University of Bielefeld and Department of Physics, University of Bath.

Wolf, J., Kauermann, G. and Trillmich, F. (2005) *Males in the shade: habitat use and sexual segregation in the Galapagos sea lion (Zalophus californianus wollebaeki)*.

8. Anexxed

Tables A:

a) Frequency and percentage of individuals observed per group, site, time of day during the cold season:

	6h00-7h00	I1h00-12h00	15h00-16h00	20h00-21h00	TOTAL
Carola	151 13.04%	98 8.46%	142 12.26%	197 17.01%	588 50.78%
Playa Mann	46 3.97%	35 3.02%	29 2.50%	38 3.28%	148 12.78%
De los Marinos	79 6.82%	50 4.32%	58 5.01%	94 8.12%	281 24.27%
La Loberia	41 3.54%	24 2.07%	19 1.64%	57 4.92%	141 12.18%
TOTAL	317 27.37%	207 17.88%	248 21.42%	386 33.33%	1158 100.00%

Table 1. Frequency and percentage of males observed per site and time of day during the cold season

	6h00-7h00	11h00-12h00	15h00-16h00	20h00-21h00	TOTAL
Carola	161 10.08%	150 9.39%	145 9.07%	159 9.59%	615 38.49%
Playa Mann	112 7.01%	59 3.69%	78 4.88%	118 7.38%	367 22.97%
De los Marinos	100 6.26%	44 2.75%	64 4.01%	208 13.02%	416 26.03%

La Loberia	55 3.44%	19 1.19%	47 2.94%	79 4.94%	200 12.52%
TOTAL	428 26.78%	272 17.02%	334 20.90%	564 35.29%	1598 100.00%

Table 2. Frequency and percentage of females observed per site and time of day during the cold season

	6h00-7h00	**11h00-12h00**	**15h00-16h00**	**20h00-21h00**	**TOTAL**
Carola	275 11.41%	159 6.59%	255 10.58%	441 18.29%	1130 46.87%
Playa Mann	65 2.70%	47 1.95%	54 2.24%	163 6.76%	329 13.65%
De los Marinos	141 5.85%	72 2.99%	103 4.27%	381 15.80%	697 28.91%
La Loberia	57 2.36%	35 1.45%	35 1.45%	128 5.31%	255 10.58%
TOTAL	538 22.31%	313 12.98%	447 18.54%	1113 46.16%	2411 100.0%

Table 3. Frequency and percentage of no identified individuals observed per site and time of day during the cold season

	6h00-7h00	**11h00-12h00**	**15h00-16h00**	**20h00-21h00**	**TOTAL**
Carola	233 8.75%	186 6.99%	171 6.42%	276 10.37%	866 32.53%
Playa Mann	160 6.01%	95 3.57%	110 4.13%	151 5.67%	516 19.38%
De los Marinos	206 7.74%	164 6.16%	159 5.97%	416 15.63%	945 35.50%

La Loberia	99 3.72%	71 2.67%	66 2.48%	99 3.72%	335 12.58%
TOTAL	698 26.22%	516 19.38%	506 19.01%	942 35.39%	2662 100.00%

Table 4. Frequency and percentage of juveniles observed per site and time of day during the cold season

	6h00-7h00	**11h00-12h00**	**15h00-16h00**	**20h00-21h00**	**TOTAL**
Carola	18 4.71%	42 10.99%	14 3.66%	25 6.54%	99 25.92%
Playa Mann	18 4.71%	9 2.36%	6 1.57%	10 2.62%	43 11.26%
De los Marinos	58 15.18%	24 6.28%	30 7.85%	73 19.11%	185 48.43%
La Loberia	18 4.71%	8 2.09%	18 4.71%	11 2.88%	55 14.40%
TOTAL	112 29.32%	83 21.73%	68 17.80%	119 31.15%	382 100.00%

Table 5. Frequency and percentage of pups observed per site and time of day during the cold season

b) Frequency and percentage of observed individuals per group, site, time of day during the warm season:

	6h00-7h00	**11h00-12h00**	**15h00-16h00**	**20h00-21h00**	**TOTAL**
Carola	11 0.89%	10 0.81%	11 0.89%	20 1.62%	52 4.20%

Playa Mann	4 0.32%	6 0.48%	5 0.40%	5 0.40%	20 1.62%
De los Marinos	254 20.52%	157 12.68%	238 19.22%	397 32.07%	1046 84.49%
La Loberia	7 0.57%	7 0.57%	20 1.62%	86 6.95%	120 9.69%
TOTAL	276 22.29%	180 14.54%	274 22.13%	508 41.03%	1238 100.00%

Table 6. Frequency and percentage of males observed per site and time of day during the warm season

	6h00-7h00	**11h00-12h00**	**15h00-16h00**	**20h00-21h00**	**TOTAL**
Carola	25 1.43%	33 1.89%	40 2.29%	107 6.13%	205 11.75%
Playa Mann	17 0.97%	21 1.20%	35 2.01%	47 2.69%	120 6.88%
De los Marinos	329 18.85%	118 6.76%	204 11.69%	542 31.06%	1193 68.37%
La Loberia	12 0.69%	23 1.32%	70 4.01%	122 6.99%	227 13.01%
TOTAL	383 21.95%	195 11.17%	349 20.00%	818 46.88%	1745 100.00%

Table 7. Frequency and percentage of females observed per site and time of day during the warm season

	6h00-7h00	**11h00-12h00**	**15h00-16h00**	**20h00-21h00**	**TOTAL**

Carola	6 0.73%	2 0.24%	22 2.67%	3 0.36%	33 4.00%
Playa Mann	4 0.48%	3 0.36%	5 0.61%	1 0.12%	13 1.58%
De los Marinos	110 13.33%	63 7.64%	72 8.73%	467 56.61%	712 86.30%
La Loberia	17 2.06%	8 0.97%	35 4.24%	7 0.85%	67 8.12%
TOTAL	137 16.61%	76 9.21%	134 16.24%	478 57.94%	825 100.00%

Table 8. Frequency and percentage of no identified observed per site and time of day during the warm season

	6h00-7h00	**11h00-12h00**	**15h00-16h00**	**20h00-21h00**	**TOTAL**
Carola	13 1.53%	12 1.42%	19 2.24%	28 3.31%	72 8.50%
Playa Mann	10 1.18%	10 1.18%	22 2.60%	14 1.65%	56 6.61%
De los Marinos	181 21.37%	81 9.56%	124 14.64%	257 30.34%	643 75.91%
La Loberia	13 1.53%	9 1.06%	19 2.24%	35 4.13%	76 8.97%
TOTAL	217 25.62%	112 13.22%	184 21.72%	334 39.43%	847 100.00%

Table 9. Frequency and percentage of juveniles observed per site and time of day during the warm season

	6h00-7h00	**11h00-12h00**	**15h00-16h00**	**20h00-21h00**	**TOTAL**

Carola	74 5.40%	68 4.96%	68 4.96%	59 4.31%	269 19.64%
Playa Mann	44 3.21%	41 2.99%	38 2.77%	46 3.36%	169 12.34%
De los Marinos	112 8.18%	126 9.20%	150 10.95%	122 8.91%	510 37.23%
La Loberia	90 6.57%	105 7.66%	131 9.56%	96 7.01%	422 30.80%
TOTAL	320 23.36%	340 24.82%	387 28.25%	323 23.58%	1370 100.00%

Table 10. Frequency and percentage of pups observed per site and time of day during the warm season

Tables B:

One Way ANOVA Test and Tukey Range Test

Range	Transformed Mean	Group	Real Mean
A	5.5973	Juveniles	33.696203
B	4.8546	No Identified	30.518987
C	4.1943	Females	20.227848
D	3.4944	Males	14.658228
E	1.7772	Pups	4.835443

Table 11. Tukey Range Test – Comparison of transformed mean for Group during the cold season for all the colonies

Range	Transformed Mean	Site	Real Mean
A	5.1885	Carola	32.9800000

B	4.5529	De los Marinos	25.2400000
C	3.3083	Playa Mann	14.0300000
C	2.8266	La Loberia	10.378947

Table 12. Tukey Range Test – Comparison of transformed mean for Site during the cold season for all the colonies

Range	Transformed Mean	Time of Day	Real Mean
A	5.0378	20H00-21H00	32..884211
B	4.1094	06H00-07H00	20.9300000
C	3.5432	15H00-16H00	16.0300000
C	3.2965	11H00-12H00	13.9100000

Table 13. Tukey Range Test – Comparison of transformed mean for Time of Day during the cold season for all the colonies

Range	Transformed Mean	Time of Day	Real Mean
A	4.0046	Pups	17.1250000
A	3.7880	Females	21.8125000
B	2.8767	Males	15.4750000
B C	2.5206	Juveniles	10.5875000
C	2.0026	No Identified	10.3125000

Table 14. Tukey Range Test – Comparison of transformed mean for Group during the warm season for all the colonies

Range	Transformed Mean	Site	Real Mean
A	5.9797	De los Marinos	32.9800000
B	2.5733	La Loberia	25.2400000
B	2.0897	Carola	14.0300000
C	1.5112	Playa Mann	10.378947

Table 15. Tukey Range Test – Comparison of transformed mean for Site during the warm season for all the colonies

Range	Transformed Mean	Time of Day	Real Mean
A	3.8134	20h00-21h00	24.6100000
B	3.1048	15h00-16h00	13.2800000
B C	2.8103	06h00-07h00	13.3300000
C	2.4253	1100-12h00	9.03000000

Table 16. Tukey Range Test – Comparison of transformed mean for Time of Day during the warm season for all the colonies

Figures

Pinnipeds in Galapagos

Photo by: Daniela Cox

Figure 20. Females on Gardner Bay, Espanola Island

Pinnipeds on San Cristobal

Photo by Daniela Cox

Figure 21. Wreck Bay at Puerto Baquerizo Moreno, San Cristobal Island

Photo by: Daniela Cox

Figure 22. Boardwalk of Puerto Baquerizo Moreno on San Cristobal Island

Photo by: Daniela Cox

Figure 23. Typical scene along the boardwalk on San Cristobal Island

Habitat and Distribution

Photo by: Daniela Cox

Figure 24. Pup standing in a busy day in Playa Mann, San Cristobal Island

Diving and Foraging

Photo by: Daniela Cox

Figure 25. Juvenile diving nearby Elizabeth Bay, Isabela Island

Nursing

Photo by: Daniela Cox

Figure 26. Mother nursing its pup on Egas Port, Santiago Island

Behavioral Traits

Photo by: Daniela Cox

Figure 27. Mother nursing its own pup and chasing away other female's pup

Social Structure

Photo by: Daniela Cox

Figure 28. Male and pups at the boardwalk of Puerto Baquerizo Moreno

Site Fidelity

Photo by: Daniela Cox

Figure 29. Sea lion colony on Santa Fe Island

Natural Threats

Photo by: Daniela Cox

Figure 30. Juvenile injured by a shark attack on Gardner Bay, Espanola Island

Human Impact

Photo by: Daniela Cox

Figure 31. Juvenile disturbed by an abandoned dog in Playa de los Marinos

Photo by: Daniela Cox

Figure 32. Juvenile resting on the sidewalk of Puerto Baquerizo Moreno

Conservation Management

Photo by: Daniela Cox

Figure 33. Sea lions platform in front of Playa Mann in Wreck Bay

Photo by: Alejandra Cox

Figure 34. Local kid showing his T-shirt from the socio-environmental campaign *"My Buddy Sea Lion",* San Cristobal Island