Title
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MASTER THESIS TIMELINE

TASK	2010							2011					
	J	J	A	S	O	N	D	J	F	M	A	M	J
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Literature review													
Study approach													
Methodology design													
Conformation of the advisory committee													
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Develop the master thesis													
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Abstract

The reality in Drake Bay was not different to hundreds of beaches where marine turtle trade was considered as an income source. In 2004, the depredation and loss of nests reached 85% of total nesting. The olive ridley population of Drake Bay was endangered. Therefore, the protection and recuperation of this population became essential.
The Corcovado Foundation arrived to Drake Bay in response to the environmental concerns of several community members in 2005. In Corcovado Foundation Sea Turtle Conservation Program's five years of work, the integration of the community in conservation efforts is the major achievement. This Costa Rican organization has implemented a model of community-based conservation trough the local association ACOTPRO (Marine Turtle Conservation Association, El Progreso).
Currently, community overwhelmingly endorses, supports and respects the conservation program, which becomes a socioeconomic alternative to neighboring communities.
The first overarching goal of this study is to analyze economic aspects of marine turtle uses and the socioeconomic impact of this particular conservation program on surrounding communities. Additionally, this study aims to demonstrate that the economic alternative, which the Corcovado Foundation offers to the communities, is a social reality and a way to preserve the sea turtle population in Drake Bay.

On the other hand, when we working with hatcheries in sea turtle conservation projects, it is necessary compare incubation conditions of nests relocated to the hatchery against natural conditions of in-situ nests on the beach in order to measure the efficiency of the hatchery.
For this purpose, we studied thermal profiles within nest of *Lepidochelys olivacea* in Drake Bay, Costa Rica, during nesting season 2010. We used dataloggers placed both in nests relocated to the hatchery and in-situ nests on the beach. These dataloggers were programmed to record temperatures in the study nests (N=15), and their respective controls, at 1-hour intervals during the incubation period. The parameters monitored were; olive ridley's incubation temperatures, clutch sizes and hatching successes. Our objectives were compare incubation conditions between the hatchery and the beach, and study possible variations on the thermal profiles among zones and over time.
We conclude that the hatchery works in similar way than the thermal conditions on the beach. In addition, we estimate that Drake Bay might exhibit a male bias in the total hatchling production during olive ridley nesting season 2010.
The results indicate that the location of oviposition doesn't have effect on the research parameters. However, the incubation temperatures within study nests were affected by timing of oviposition, decreasing from nests laid in August to October. As a consequence, the expected proportion of males increased over time.
By monitoring nest conditions, both on the beach and in the hatchery, projects will be better suited to incorporate temperature data into management decisions.

SOCIOECONOMIC IMPACT OF THE CORCOVADO FOUNDATION CONSERVATION PROGRAM IN DRAKE BAY

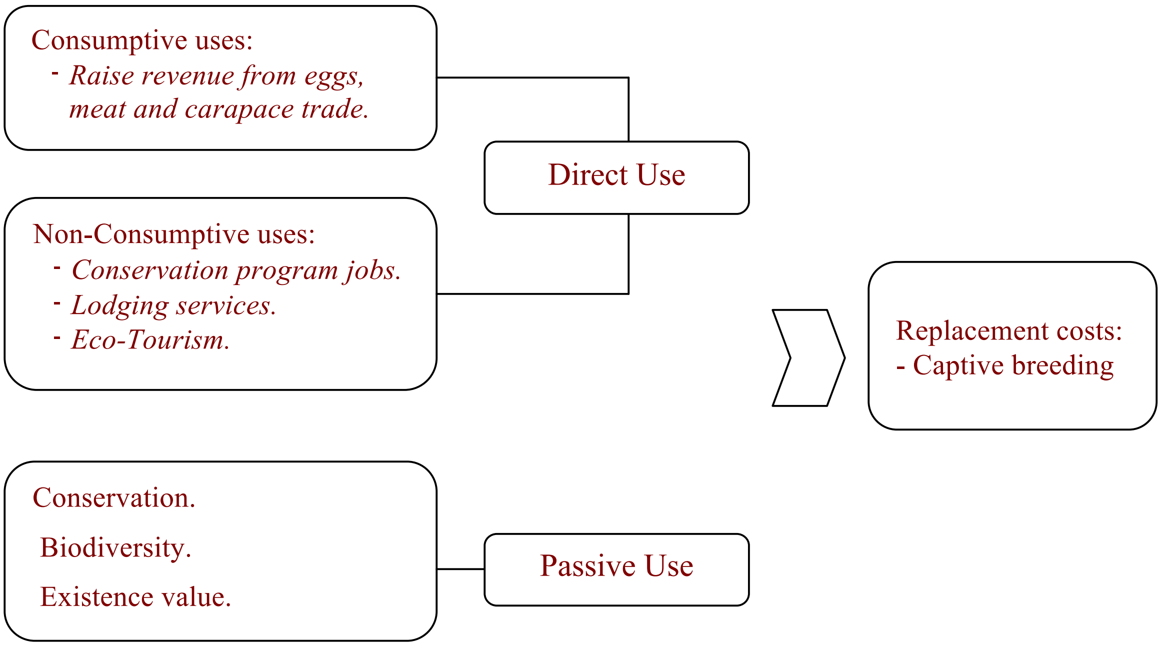
Introduction

Sea turtles are a highly migratory species that inhabit tropical and subtropical regions. They have been an open-access resource of food and sustenance for coastal communities for thousands of years. Human activities, noticeably overexploitation, fisheries by-catch and habitat destruction, are causing dramatic sea turtle declines (Seminoff 2002, Spotila*et al.*2000). Today, six of the world's seven species of sea turtle are listed on The IUCN Red List of Threatened Species(UICN 2010).

Their economic uses of sea turtles are an expression of utilitarian value, reflecting traditional idea of material benefit derived from exploiting nature to satisfy various human needs and desires. In addition, non-consumptive uses that generate economic revenue capitalize on other dispositions that make sea turtles attractive to tourists and scientists, such as the naturalistic, scientific and aesthetic values.
Although the goods and services provided by sea turtles are valued by societies around the world, they are predominantly located in tropical and subtropical areas. Their distribution extends principally through countries with developing economies (IUCN 2010, OECD 2000). For five of the seven species of sea turtle, 78%-91% of countries where they occur are countries with developing economies. Two thirds of countries with developing economies have sea turtles; 61% of developing countries have at least two species and a third of developing countries have three or more species. Therefore, the future of sea turtle populations and their potential to generate benefits to human societies depend mainly on management decisions and policies implemented in countries with developing economies. Ecologists and economists to a large extent agree that methods combining biological and economic information can help us to identify strategies to reverse biodiversity and ecosystem loss.

Economic aspects of Sea Turtle uses

The aim of this section is to examine theoretically the different uses and economic aspects related to sea turtles.
The framework of sea turtle use and conservation are described in the table below.



<u>DIRECT USE</u>

SEA TURTLE CONSUMPTIVE USE

Sea turtles have been used for eggs, meat, carapace, oil, leather or other products since at least 5000 BC (Frazier 2003). Mesoamerican Mayas and other Amerindians had consumptive uses of sea turtles in common (Frazier 2003, Wing & Wing 2001). During colonial times, sea turtle utilization increased for use as food by ships' crews and for export to European countries (Jackson 1997, Parsons 1962, 1972).
Today, intentional capture of sea turtles for consumptive use continues in tropical and subtropical regions. In several cases, overexploitation has caused drastic declines in sea turtle populations (Jackson 1997, 2001, Jackson et al.2001, Seminoff 2002). Sea turtles are easily caught when they are emerging to nest on sandy beaches, and their eggs are collected by locals or concession holders. In addition, sea turtles are also caught using nets, harpoons or traps in feeding grounds and during their migrations. Direct beneficiaries from consumptive use include egg collectors, poachers, fishermen and intermediaries from communities close to the nesting beaches or grassing areas. Often traders are involved in aggregating value and transporting sea turtle products before final sale in towns and cities located further away. It is likely that the intermediaries receive the greatest share of the gross revenue.

Conversely, changes in sea turtle abundance have consequences for consumptive use. Smaller sea turtle populations can sustain less consumptive use and hence will generate less gross revenue from sea turtles. In the light of these trends, policies of sustainable consumptive use of sea turtles are not easy to enforce. And sometimes, these would conflict with other goals such as non-consumptive uses value.

SEA TURTLE NON-CONSUMPTIVE USE

Non-consumptive use of sea turtles is mainly eco-tourism and eco-friendly activities related to sea turtles. These types of activities are relatively recent phenomena in tropical and subtropical countries. Although, they are an important income source in some areas, usually non-consumptive use of sea turtles, such as being a tourism attraction, is not sufficiently developed due to the lack of an appropriate network to carry out these activities.

Other aspects of non-consumptive uses of sea turtles are the conservation activities made by scientists and volunteers. The revealed preference of volunteers may be measured by how much they are willing to pay for enjoy of this existence value (sea turtles). These are the costs paid by volunteers for being involved in the conservation program including travel costs, material costs, etc. Some of these payments made by volunteers become incomes for local communities, finally.

PASSIVE USE

Sea turtles are to a large extent a public good (note: they are rival and exclusionary when we talk in terms of consumptive uses). The turtles represent a benefit as existence value to the global community, who enjoy them. This value is represented in part by the willingness of the global community to pay to protect them. Thus, global existence values are at least as high as the costs paid for the worldwide conservation of sea turtles.
Sea turtles have a wide range of passive use values. These include option, intrinsic, ethical (Naess 1989, Rolston 1994), existence and bequest values. In order to maintain the intrinsic values of sea turtles, their roles in ecosystem functioning, and to maximize total sustainable social value of turtles (non-use values), sea turtles populations need to be protected and restored to higher levels.

REMPLACEMENT COST

Sea turtles are keystone species in coastal and oceanic marine ecosystems. They also function as biological transporters of nutrients from marine to terrestrial ecosystems with benefits to numerous species of fauna and flora (Bouchard & Bjorndal 2000).
Decline of sea turtles has adverse ecological impacts with subsequent economic effects on human societies (Jackson 2001, Jackson et al. 2001).

The complex ecological interactions between turtles and the ecosystems they inhabit make it difficult to quantify completely the value of the ecological services provided by sea turtles. Even so, rough estimates serve to demonstrate that conservation of sea turtles in the wild is a much less costly strategy than captive breeding to maintain the flow of sea turtle goods and services.

Drake Bay

Drake Bay is located on the Pacific coast of Costa Rica, 12 miles to the north of Corcovado National Park on the Osa Peninsula, 8° 42′ N, 83° 40′ W. Drake Bay is a remote area within Puntarenas Province, Osa Canton, which is usually isolated for most of the wet season (September to November), being only possible to get to the zone by plane or boat. There are three main communities in the area; the main town is "Agujitas" (approx. 1,000 inhabitants) followed by "El Progresso" (approx. 250 inhabitants) and "Los Angeles" (approx. 180 inhabitants)(INEC, 2010). Primary sector (agriculture and livestock) is the main source of income for communities, which reaches 52.60% of labor occupancy. The human development index estimated for this area is 0.67% and the poverty rate is 40.4%(PNUD Costa Rica). The poverty rate in this area had led to locals to over-exploit their natural resources reaching unsustainable levels.

Project objectives and strategies

The Corcovado Foundation Sea Turtle Conservation Project arises from the need to work in the protection and preservation of sea turtles and their nesting beaches in Drake Bay. Until 5 years ago, the reality in Drake Bay was not different to hundreds of beaches where sea turtle trade was considered as an income source. In the previous years to the implementation of this conservation program, the depredation and loss of nests in the area reached 85% of total nesting (Sanchez *et al.*, 2006). The olive ridley population, the main species in this area, declined dramatically in Drake Bay to the point it was endangered. Therefore, the protection and recuperation of this population became essential due to its biological and ecological value.

The project strategy was the creation of a viable socioeconomic alternative to consumption of sea turtles for the local communities, while promoting environmental conservation activities at the same time. The Corcovado Foundation aims to sensitize local communities about the importance of protecting and preserving sea turtles, and linking this protection with the opportunity to increase their incomes directly from the work into the conservation project and/or indirectly from the development of the ecotourism activity in the area. In this way, it would achieve a reduction of the consumptive use of the sea turtles in Drake Bay through the preservation of this natural resource.

The foundation established a framework with the following objectives and strategies;

- Sensitize local communities about the importance of sea turtle conservation for future generations.
- Reduce the poaching of turtle eggs and the misuse of natural resources in communities, involving also locals in a sea turtle conservation project.
- Provide communities with training to develop their own local eco-tourism industry, which is based in the conservation and preservation of their natural resources.
- Implement models of community-based conservation, taking locals an important role in the management of their own natural resources.

The Corcovado Foundation Sea Turtle Conservation Program; *"A socioeconomic alternative"*

The NGO Corcovado Foundation has conducted a sea turtle conservation project on Drake Bay since 2005, under research permit INV-HOUNDS-011-06 issued by the Ministry of Environment of Costa Rica, Osa Conservation Area. An important point during all these years has been the balance that needs to be achieved between conservation objectives and local socio-economic development. A conservation initiative focused only on the biological aspects of the ecosystem will become an ongoing struggle, as conflicts arise continuously with the local population. Conservation should take into account local communities and their needs should be considered a key priority of any environmental conservation project. This policy led to Corcovado Foundation become in the first organization that gets to implement a sea turtle conservation project in the area.

The conservation efforts are undertaken on Drake Beach and the camp base is located in the town "El Progreso". Corcovado Foundation has set up a project with standardized methods to facilitate their incorporation into regional initiatives and give an accurate view of the reality of this nesting population. Every year, an international team of a research coordinator, research assistants, volunteers and locals conducts the fieldwork.
The fieldwork extends from June to December, coinciding with the olive ridley nesting season (Melero *et al*., 2008, 2009, 2010). Drake Beach receives an average of 150 sea turtle nesting events per season. The predominant species is the olive ridley turtle (*Lepidochelys olivacea*) with 98% of the total of nesting sea turtle events on this beach.

ECONOMIC ASPECTS.

In this study we calculated the incomes for the communities from different uses of sea turtles during 2010 season in order to evaluate if the Corcovado Foundation (CF) conservation project represent a real sustainable economic alternative.

For consumptive uses we estimated two different scenarios;
In the first one, we calculate the current income that the illegal trade generates through the sale of eggs. This estimation is based in the total poached eggs during 2010 season and the final selling price per unit in the illegal market. During the 2010 season, poaching levels reached 10.5% of total nests, generating a maximum income of **$1,496** in the Drake Bay area. We estimate that at least 70% of this harvest was for personal consumption. This amount might represent a sustainable level of harvest value, although the goal of the CF conservation program is eliminate the poaching in this area.

CONSUMPTIVE USE	
Poached nests	17
% poaching nests/total nests	10.5%
Poached eggs	1,870
Price per eggs (illegal market)	$0.80
[1]**Total**	**$1,496**
Meat trade	Non- existent
Carapace trade (craft use)	Non- existent
TOTAL	**$1,496**

Table 1. Direct incomes for the locals from the consumptive uses of sea turtles. 2010 CF season report.

[1] This is the maximum value calculated for the total poached eggs. It is estimate that 70% approx. of these are for personal consume finally.

In the second scenario, we estimated the potential income if the conservation program had not been implemented. Taking into account that poaching was around 85% of total nests in prior years to the implementation of the CF conservation program, this potential income would reach $11,016 during the 2010 season. In addition, this amount represents a non-sustainable level of harvest value. In fact, removal of sea turtle nests by consumptive uses reduces survivorship rates and reproductive output of populations, generating less gross revenue from the harvest of sea turtles.

If use exceeds sustainable levels, the exploited populations begin to decline. It is reasonable to assume that the consumptive uses during the last decade (an average of 85% poached nests in the previous seasons to implementation of the CF conservation program) (Sanchez et al., 2006) play an important role in the negative population trends of the olive ridley in Drake Bay.

CONSUMPTIVE USE (potential)	
Poached nests	132
% poaching nests/total nests	85%
Poached eggs	13,200
Price per eggs (illegal market)	$0.80
[2]Total	**$11,016**
Meat trade	Non- existent
Carapace trade (craft use)	Non- existent
TOTAL	**$11,016**

Table 2. 2010 potential incomes (without implementation of conservation policies) for the locals from the consumptive uses of sea turtles.

[2] This is the maximum value calculated for the total poached eggs. It is estimate that 70% approx. of these are for personal consume finally.

Corcovado Foundation through its conservation program has encouraged non-consumptive uses of sea turtles through the conservation of these, and has established an economic alternative for locals, which is based in the preservation of natural resources. As a result of that, members of the communities created ACOTPRO (Sea Turtle Conservation Association, "El Porgreso") in 2008. This is an important initiative due to this association is led entirely by community members and work in collaboration with CF.

ACOTPRO and Corcovado Foundation have established a conservation network of the olive ridley population in Drake Bay. The principal aims of the association are to coordinate and manage all conservation efforts done by locals. Several job positions have been created within the communities in the last 2 years. Corcovado Foundation forms the ACOTPRO employees in the sea turtle biological and conservation issues. The association is highly involved with the CF conservation project; each employee donates the same numbers of paid turns as no-paid turns. Also, these same employees participated voluntary in the construction of the hatchery at the beginning of the season.
This non-consumptive use becomes direct incomes for locals. The total benefit from conservation activities generated by CF project wages was **$8,896** during the 2010 season. This amount represents a lower bound on the non-consumptive use, since the value of protecting sea turtles exceeds the cost.

NON-CONSUMPTIVE USE (direct income)	
ACOTPRO (Sea Turtle Conservation Association "El Progreso")	
Employees in the project (rangers/guards)	17
• Paid turns per week	28
• Unpaid turns per person/week	28
• Turn salary	$16
[3]Total	$448 (per week)
TOTAL	**$8,896**

Table 3. Direct incomes for the communities from the non-consumptive uses of sea turtles. 2010 CF season report.

[3] This is the average value per week. At the beginning and the end of the season the turns are reduced, contrarily these turns increase at the peak of the season or when there aren't enough volunteers to carry out the fieldwork. Turns are distributed equally between the employees during the season.

The Corcovado Foundation sea turtle conservation project also generates indirect incomes for the communities, from the main needs to the project maintenance to different purchases of the volunteers' daily life. Additionally, the benefits from the incipient eco-tourism activities carried out by locals are increasing each year.

The Sea Turtle Festival is held as culmination of these initiatives. Every year, this festival brings together entire families from neighboring communities. This event represents a unique chance to creating an awareness of cooperation and conservation of natural resources within communities of the area. In 2010, the Sea Turtle Festival brought together more than 200 people, generating a net benefit of $1,600 to ACOTPRO from handcraft, food and other purchases sold during the event.

We estimated that indirect incomes generated by CF conservation program reached a total of **$18,188** during 2010.This amount was distributed widely among a huge portion of community members.

NON-CONSUMPTIVE USE (indirect incomes)	
Main needs for the project	
• Houses rented (x2)(volunteer logging)	$1,440 - $1,800
Total	**$3,240**
• Cooker camp base (x1)	$120 (per week)
Total	**$2,160**
• Food	$3,600
• Perishables	$450
• Materials	$600
• Laundry services	$108
• Repairs [4](bikes)	$180
Total	**$4,938**
Volunteers	
• Mean purchases per volunteer in the communities	$114
• Volunteers during 2010 season	50
Total	**$5,700**
Eco-tourism (ACOTPRO guides)	
• "Nature" tours (x18)	$450
• "Sea Turtles" tours [5](x5)	$100
Total	**$550**
Sea Turtle Festival **Total**	**$1,600**
TOTAL	**$18,188**

Table 4. Indirect incomes for communities generated for the conservation activities.2010 CF season report.
[4] CF provides bikes for volunteers to go to fieldwork or free-use.
[5]Sea Turtles tours were unusually low during 2010 season. An average of 14 tours were demanded in the previous seasons.

The direct and indirect incomes from non-consumptive use reached **$27,084** in 2010 season. The total social value of protecting turtles in Drake Bay far exceeds the consumption value of sea turtles, inclusive when they are not protected.

SOCIAL ACHIEVEMENTS.

The major social achievement of Corcovado Foundation is the integration of the community in conservation efforts. The ultimate goal of CF is for the community to make decisions and manage their own natural resources. In 2008, this goal was partially realized with the creation of ACOTPRO (Sea Turtle Conservation Association, "El Progreso").

On the other hand, community benefits are not only measures in economic terms. Corcovado Foundation has developed several initiatives such as;
Eco-Tourism courses; in 2007, the Corcovado Foundation began to develop a creative strategy to promote the conservation of sea turtles in the Drake Bay area. This is a program that promotes the development of eco-tourism as an economic activity within the area of influence. The aim of these courses is to make locals understand the importance of sea turtles and the whole natural heritage as a natural resource, which could be used as eco-tourism attraction using the correct management.
At the moment, tourism had been a large source of income in the area (ICT, 2010). But, basically only a few owners control these businesses and mostly of them are foreign people. Despite that, tourism offers temporary jobs for the locals during the high season. By offering tourism training to locals, is expected that communities play a role more active in the management of their own natural resources, in this particular case, in the eco-tourism activities, while increasing their income.
Environmental education programs; focused on working with local schools. Periodically, at least once a week, international volunteers visited the schools in El Progreso, Los Angeles and Agujitas. They taught to students the importance of conserving sea turtles and how to join actively to this process. Also, recycle workshop were carried out with the participants.
English lessons; volunteers taught weekly English lessons in the schools with the participation of a considerable amount of adults. With the aim of provide a foreign language education to the students and a better and equality integration of locals in the eco-tourism incipient industry.

Conclusions

The Corcovado Foundation Sea Turtle Conservation Project represents an economic alternative for communities at Drake Bay. Furthermore, since much of the costs of sea turtle protection end up as income to locals, the locals are themselves better off with the conservation program than with their former consumption of sea turtles activity. The results of the 2010 season show clearly the great difference between the potential incomes for locals from consumptive uses of sea turtles ($1,496) against the incomes from involving in the conservation program ($8,896) plus the spread indirect incomes generated by these non-consumptive activities ($18,188). These incomes from non-consumptive activities represent the opportunity cost of harvesting sea turtle eggs for locals.

If users can earn more money from conserving sea turtles or activities related with the sea turtle conservation, consumptive use may become the less attractive economic alternative. In the light of these trends, Costa Rica has recognized the potential negative impact of consumptive use on sea turtle populations. National legislation, protective of endangered species, prohibits the take of sea turtles and domestic trade in their products. (Law Nº 8325, Legislative Assembly of Costa Rica, 2002 and Law Nº 7906, Inter-American Convention for the Protection and Conservation of Sea turtles, 1999). Still, illegal consumptive use of sea turtles continues in many zones.

Additionally, since sea turtles are to a large extent a public good, the existence values of these are likely to be much higher than the benefits generated by the CF conservation program, which can be measured by costs paid by the foundation for the protection of olive ridley in Drake Bay. Thus, the true benefits are likely to be much higher, even though some people are not paying for them (i.e. being free riders on the efforts of local communities and the costs paid by CF).

In Corcovado Foundation's five years of work, the integration of the community in conservation efforts is the major social achievement. Currently, community overwhelmingly endorses, supports and respects the conservation project. This achievement becomes a socioeconomic alternative to neighboring communities, which have shown interest in becoming a part of the restoration and conservation of sea turtle colonies and other natural resources.

Proof of that has been the consolidation of the association ACOTPRO (Sea Turtle Conservation Association, "El Porgreso").
Many of members of this local association were poachers or turtle fishers before to work to Corcovado Foundation's program in initiatives for the conservation of sea turtles. The conservation work represents for them an economic alternative during the nesting season, which is shared with agriculture and livestock during the rest of the year.

The current results are encouraging due to it is taking an important step to restore the olive ridley population in Drake Bay. In 2005, when Corcovado Foundation initiated conservation efforts in Drake Beach, approximately 85% of all sea turtles eggs deposited on the beach were illegally collected. In 2010, only 10.5% of olive ridley nests were illegally taken.

To conclude, the overall global trend has been one of dramatic decline of all sea turtle populations. The current levels of consumptive use, fisheries by-catch and habitat degradation mean that global sea turtle populations will continue to decline if there is no change in human induced mortality. Continued sea turtle decline will have negative economic consequences, particularly for coastal communities in developing countries. People that use sea turtles for meat, carapace, eggs and other products will see their income from consumptive use reduced. The current risk of extinction is a threat to the long-term economic benefits provided by sea turtles. Loss of the sea turtle ecological functions will impact economic sectors that depend on healthy marine and coastal ecosystems.

Creation of local economic incentives, such as the Corcovado Foundation performs in Drake Bay, is crucial to eliminate consumptive uses and promote both non-consumptive uses and other economic alternatives, which don’t harm natural resources.

TEMPERATURE MONITORING AS A TOLL FOR HATCHERIES MANAGEMENT

Introduction

As in many oviparous reptiles, sex of hatchlings in sea turtles is determined by the temperature during incubation, a phenomenon termed temperature-dependent sex determination (TSD) (Standora and Spotila, 1985; Pieau *et al*., 1995; Godley *et al*, 2001). Embryo development occurs within a transitional range of temperature (TRT), which includes the pivotal temperature (PT) at which a 1:1 sex ratio is produced (Mrosovsky, 1991; Wibbels 2003). Sex of hatchlings is determined during the middle third of incubation (Mrosovsky and Yntema, 1980, Merchant-Larios, 1997). The temperature at which sex ratio is 1:1 is called the pivotal temperature, where more females are produce at higher temperature and more males at lower temperatures (Yntema and Mrosovsky, 1980; Spotila *et al.*, 1987). Nest temperatures are influenced not only by sand temperature and moisture levels, but also by metabolic heat generated by the embryos during the incubation period (Broderick *et al.*, 2001).

The olive ridley sea turtle (*Lepidochelys olivacea*) has a circumtropical distribution, with nesting occurring throughout tropical waters. This sea turtle species exhibits unique nesting behavior known as arribada, in which hundreds of nesting females nest simultaneously at some beaches. In addition, other females nest solitary at other beaches. Each clutch contains approximately 100 eggs (Pritchard and Plotkin, 1995). Incubation takes approximately 60 days and the average hatchling success is approximately 80% (Plotkin, 2007). The PT described for this species in the Pacific coast of Costa Rica is 30.5 ºC and the TRT is between 27 ºC and 32 ºC (MacCoy 1983, Wibbels 1998). Olive ridley sea turtle is listed as Vulnerable (VU A2bd) on the IUCN Red List of Threatened Species (2010).

Due to the increasing natural and anthropogenic threats in terrestrial nesting habitats during the last decades, hatcheries have become a useful tool for the protection of eggs and hatchlings. However, artificial incubation techniques at hatcheries, and the change in physical, chemical and biological conditions of the nests might influence incubation conditions and consequently embryo development (Ackerman, 1981; Marcovaldi and Laurent, 1996). Some researchers have questioned the potential long-term effects of biased sex ratios at hatcheries (Ackerman, 1980; Lutcavage *et al.*, 1997). Also, egg movements during the relocation or delayed egg relocations may affect the survival rates of clutches (Limpus, 1979). Special consideration should also be given to potential contamination produced by a previous season eggshells into hatcheries (Talbert *et al*., 1980). Increased infestation of eggs by insects has also been observed in relocated nests in comparison with natural nests (Andrade *et al*., 1992). On the other hand, several studies have shown in some cases hatching success rate was higher in relocated nest within hatcheries than in situ nests on the beach (Limpus, 1979; Wyneken *et al*., 1998). Also, hatcheries have become an efficient solution to protect egg clutches and hatchlings on beaches with high rate of poaching (Witherington, 2003).

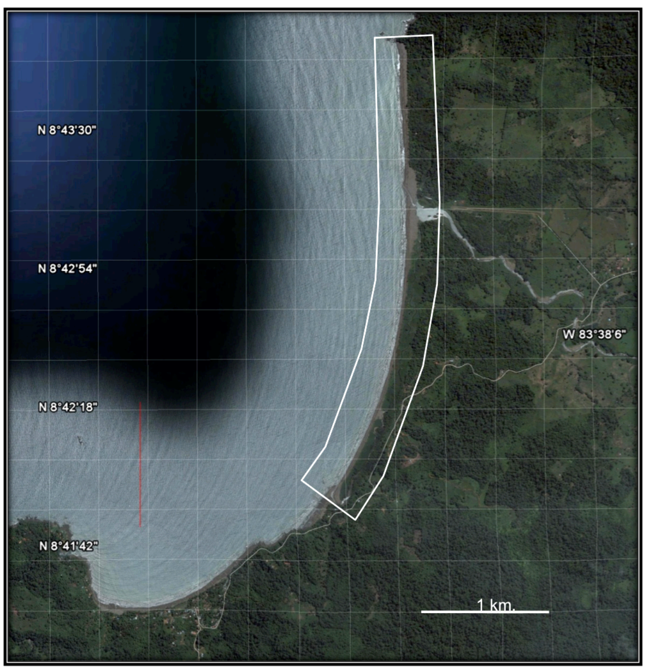
Monitoring nest conditions in hatcheries provide a method to estimate conservation programs' efficiency, allowing improved conservation strategies (Eckert and Eckert, 1990).

The main goal of this research is to establish a monitoring study on olive ridley nests, both on the beach and in the hatchery, with the aim of evaluating management effectiveness of the conservation project that Corcovado Foundation performs over this species in Drake Bay, Costa Rica. We investigate different parameters such as incubation period and temperatures, hatchling sex ratios, emergence and hatch successes in order to evaluate the work that the Corcovado Foundation's hatchery is performing on Drake beach in terms of hatchling production and simulation of natural conditions (Eckert and Eckert, 1990; Abella *et al.,* 2007).

Methods

Study area

This study was conducted from July to December 2010 on Drake Beach (8º42'N, 83º39'W), located in Drake Bay, Osa Peninsula, in southern Pacific Costa Rica. This beach is a natural nesting beach mainly for olive ridley sea turtles, *Lepidochelys olivacea*, with an average of 150 nesting events annually (Melero *et al*., 2010).



Drake Bay. Google Earth©

Drake Beach is a dark sand beach, which contains a river mouth (Drake river). From the river mouth, the beach 2.3 km to south and 1.5 km to north. The average beach slope is 16% and the beach width varies from 18 to 50 meters during the season due to erosion and soil deposition. Above this area, there is a plain, where grasses and coconut palms grow interspersed by several oil palm plantations.

Corcovado Foundation owns with a protected hatchery with capacity for 100 nests, which are monitored continuously. The hatchery is divided in two equal areas; a sunny open area and a shady area (enclosed with a 70% shade-cloth roof). The hatchery is located on the same beach as the natural nesting area 30 meters from the high tide mark in order to minimize any differences in sand characteristics and environmental conditions with the in situ nests. The hatchery is relocated annually in the surrounding area to prevent the destructive effects of previous seasons' decaying eggshells (Talbert *et al*., 1980).

Field methods

The Corcovado Foundation Sea Turtle Conservation Project conducts annually a monitoring study on olive ridley nesting activity on Drake Beach from July to December (Sánchez *et al*., 2006, 2007; Melero *et al*., 2008, 2009). Each nest is either relocated to the hatchery or left untouched (*in situ*) based on the location of the nest. The determination was based on such factors as possibilities of poaching, depredation, root invasions, and erosion. All relocated clutches were handled with care and placed into the hatchery within 3 h. of being laid in order to minimize any movement-induced mortality (Limpus *et al*., 1979).

In order to investigate variations on the thermal profiles among hatchery treatments and in situ conditions, we monitored the thermal conditions of 15 nests selected randomly from the three study treatments (sunny hatchery, shady hatchery, and in situ).

To monitor incubation temperatures, data-loggers (HOBO Pendant Temperature UA-001-08/64; resolution 0.10 ºC, accuracy ±0.47 ºC) were placed in nests and temperature recorded every 1-hour during incubation periods. The dimension of the loggers (5.8 x 3.3 x 2.3 cm) is not expected to interfere with either incubation or the movement of the hatchlings out of the egg chamber.
Each logger was placed in a nest at the center of the clutch immediately after eggs were laid or relocated. Additionally, for each in situ nest, a logger was placed 70 cm from the study nest at the same depth as the center of the clutch. Six loggers were placed as controls into the hatchery. These temperature measurements outside of nests were used to study thermal profiles of the beach during the study period.

Zone / Month	August	September	October
Sunny hatchery	1 nest + 1 control	2 nests + 1 control	2 nests + 1 control
Shady hatchery	1 nest + 1 control	2 nests + 1 control	2 nests + 1 control
Beach	1 nest + 1 control	2 nests + 2 controls	2 nests + 2 controls

Table 1. Distribution of data-loggers.

These data allowed us to determinate the duration of the incubation period and incubation temperatures of the study nests. We estimated the sex ratio of the study clutches using the indirect method based on mean temperature on the middle third of incubation period (Mrosovsky and Yntema, 1980, Merchant-Larios, 1997). The pivotal temperature for the species has been reported as 30.5 ºC for Playa Nancite, Pacific coast of Costa Rica (Wibbels 1998), where more females are produced above the PT reaching 100% at 32 ºC. Mean temperatures during the same period below 30.5 ºC produce a greater proportion of male hatchlings reaching 100% at 27 ºC (MacCoy 1983, Wibbels 1998). We assumed this linear function to estimate the sex ratio of study nests.

Four days after the primary emergence of hatchlings (the first group of hatchling that emerge from a nest), data-loggers were retrieved and the study nests content were excavated in order to determine hatching and emergence success. Hatching and emergence success were calculated for each nest as the proportions of hatched eggs and the number of emerged hatchlings, respectively, relative to the total number of eggs. For this purpose the eggshells were counted representing the amount of live hatchlings emerged from the clutch. If more than 50% of the eggshell remained it was considered as the eggshell of one hatchling. Remaining eggshell pieces were puzzled together to the approximate size of an egg and registered. The eggs without emerging evidence were opened and separated into eggs with embryos, eggs without development and eggs with signs of depredation or infection (Chacon *et al*., 2007).

Since the hatchery was monitored 24h daily, we used an additional method to estimate the hatch and emergence success in the hatchery. We placed cages over the nests, days before the predicted emergence date, in order to contain the emerging hatchlings. This allowed us to directly count the number of live hatchlings of each nest. This number was compared with the corresponding amount of previously relocated eggs in order to determinate hatch and emergence success. In the hatchery case, both methods (egg shells counted or hatchlings counted against laid eggs) to calculate hatch and emergence successes were checked with each other; where discrepancies occurred, the more reliable calculation was preferred, in this case was the direct method to count the live hatchlings.

We used all these parameters to evaluate and estimate the efficiency of the Corcovado Foundation's hatchery management in terms of; egg relocation strategies, sunny-shadow nests distribution, hatchling production and nesting conditions in comparison with natural conditions on the beach.

Results and Discussions

Results (a)

One hundred and sixty two olive ridley nests were laid during the 2010 nesting season on Drake Beach. Of these, 91 nests (56.17% of total nests) were relocated to the shady area (n=45) and the sunny area (n=46) of the Corcovado Foundation hatchery. In addition, 3 nests were lost by erosions and 17 nests (10.5%) were poached.
The nesting activity was concentrated during; August (n=33), September (n=51) and October (n=37) (Fig. 1).

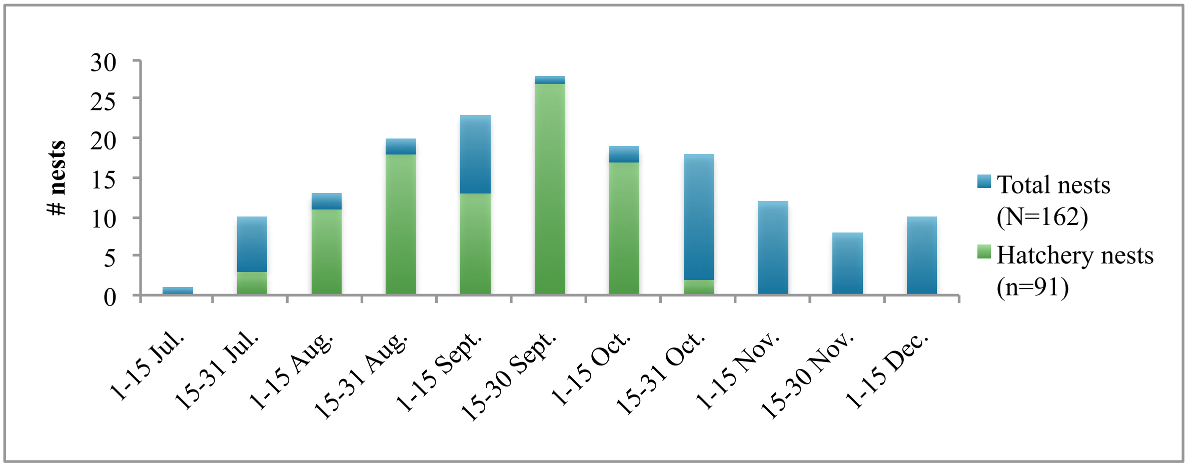


Fig. 1. Nesting activity on Drake Beach during season 2010.

We analyzed the sand temperature profiles through controls placed in the three study areas. We lost three beach nests laid in August (n=1) and October (n=2) and their respective controls by erosions and poaching. In addition, the first couple of data loggers in the controls placed into the hatchery were not recovered. Therefore, we have only the sand temperature data after August.

These controls showed that sand temperatures in the three study zones (sunny hatchery, shady hatchery and beach) follow similar trends during the monitored period from September to mid December (Fig. 2). However, these trends exhibited different temperature ranges among the treatments (Table 2).

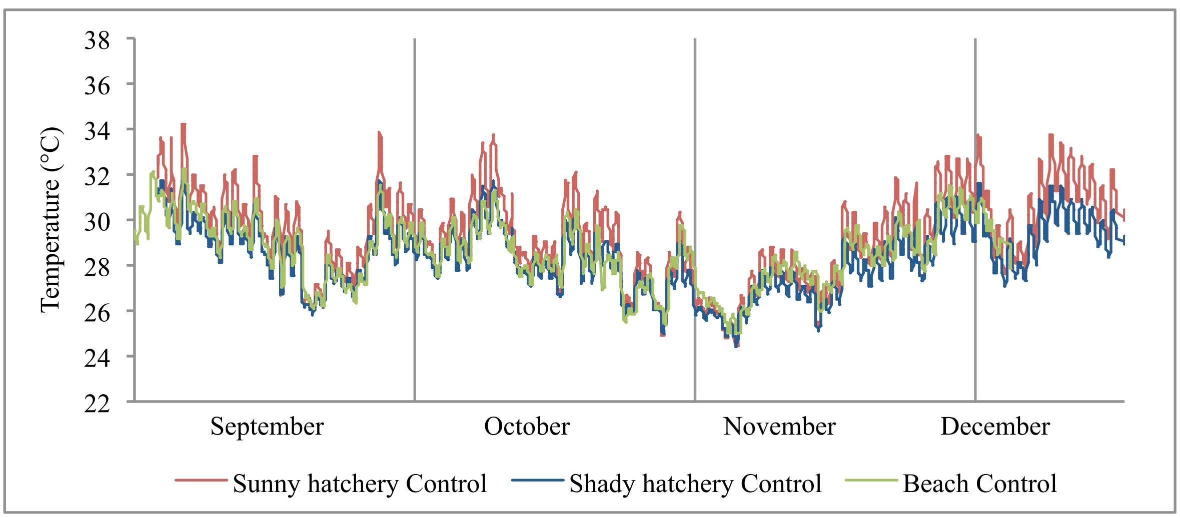


Fig. 2. Means of sand temperatures recorded by the controls in the three study zones.

Zone	Mean temp(C°) ± SD	Max temp(C°)	Min temp(C°)
Sunny hatchery	29.31 ±1.97	34.22	24.45
Beach	28.56 ±1.47	32.25	25.02
Shady hatchery	28.27 ±1.53	31.72	24.41

Table 2. Sand temperature ranges from September to mid December 2010.

Discussion (a)
Meteorological factors, mainly rainfalls, affect thermal conditions of the nesting beach. Mean air temperatures are cooler from mid September to November, coinciding with the peak of the wet season (Fig. 3) (Annex 1).

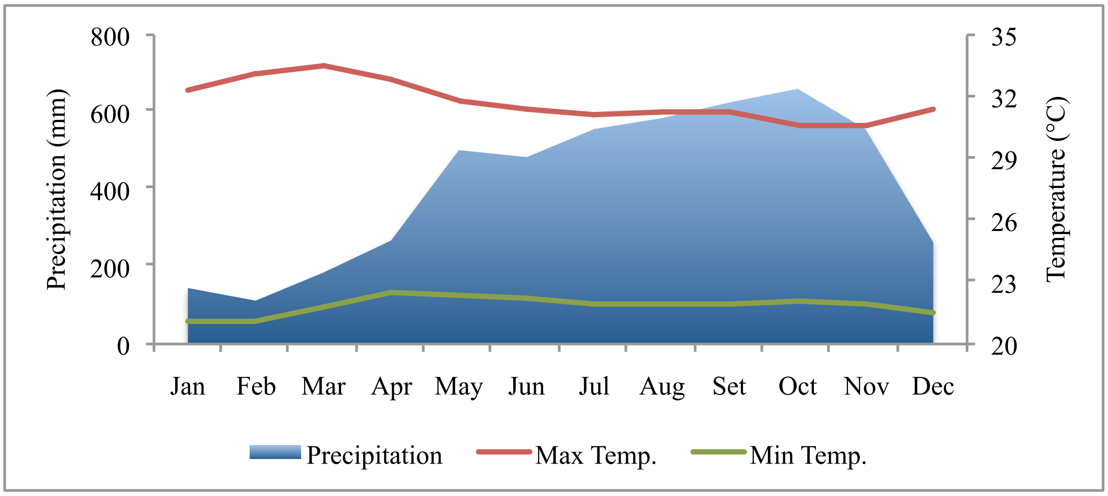


Fig. 3. Precipitation and monthly average air temperatures. Data from National Meteorological Institute, Costa Rica: IMN meteorological station 24, Rio Claro, Golfito, Costa Rica.

Results (b)
The thermal profiles of study nests showed the mean temperatures during the middle third of incubation were significantly different among months (August through October), where the means decreased over the time period. (Fig. 4)(Annex 2). (Kruskal-Wallis; Chi square = 9.231, d.f. = 2, $P = 0.010$) (Annex 6).
We suffered a loss of nests from the beach in August and October, and consequently we also lost the respective data. Thus, we analyzed only data from nests laid in September in order to search significant differences between mean temperatures during the middle third of incubation among zones. We found no significant differences for the study means temperatures during the middle third of incubation among the study zones during September (Annex 7).

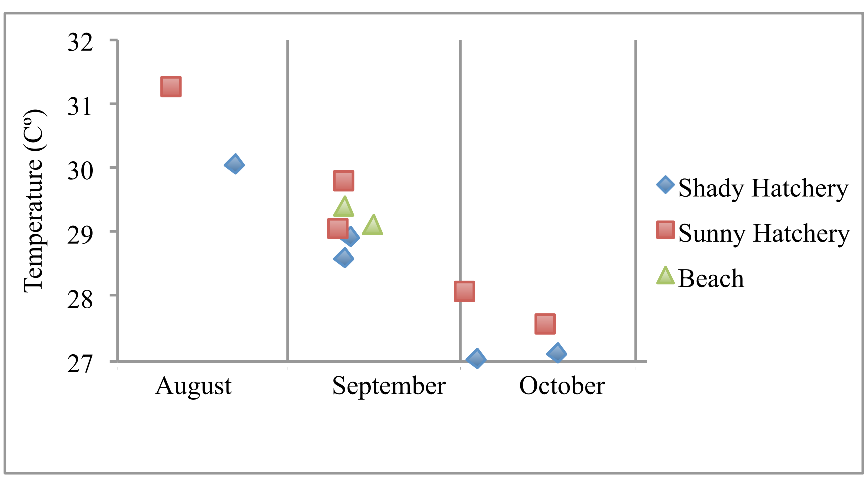


Fig. 4. Mean temperature during the middle third of nests laid on the date indicated.

Sex ratio of study nests was estimated using the indirect method based on mean temperature on the middle third of incubation period (Mrosovsky and Yntema, 1980, Merchant-Larios, 1997). Taking on account PT (30.5ºC) and TRT (27ºC-32ºC) for olive ridley in the Pacific coast of Costa Rica (Wibbels 1998), we assumed a linear function to estimate the sex ratio within this temperature range.
As expected from the decline in the average temperature from August to October (Fig 4), the expected proportion of males increased over time (Figure 5). We observe that sex ratio of clutches of study nests also varied seasonally, increasing the hatchling male production in nests laid form August to October (Fig. 5) (Annex 3). We analyzed the estimated sex ratios from nests laid in September in order to search significant differences among zones. We found no significant differences for sex ratio among the study zones during September (Annex 7).

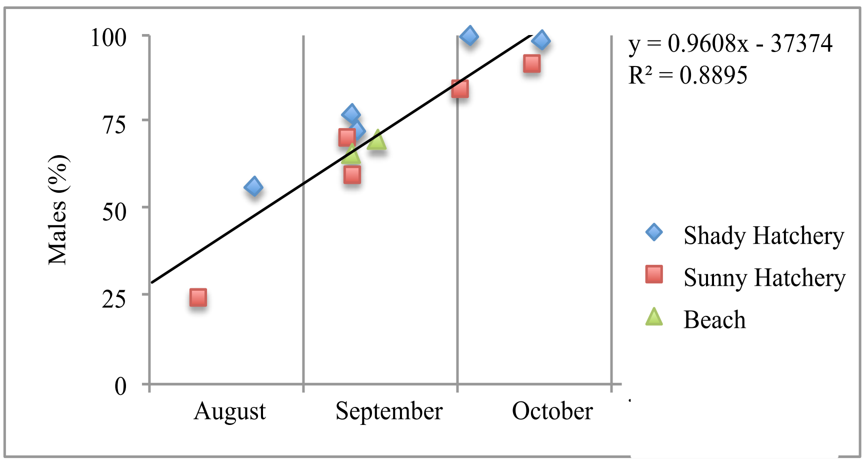


Fig. 5. % hatchling males of nests laid on the date indicated.

The incubation periods and hatch successes of the study nests also were analyzed. Kruskal-Wallis results showed that no significant differences for these parameters over time (Fig. 6,7) (Annexes 4,5) (Annexes 6). We analyzed these parameters from nests laid in September in order to search significant differences among zones. Also, we found no significant differences for incubation periods and hatch successes among the study zones during September.(Annex 7).

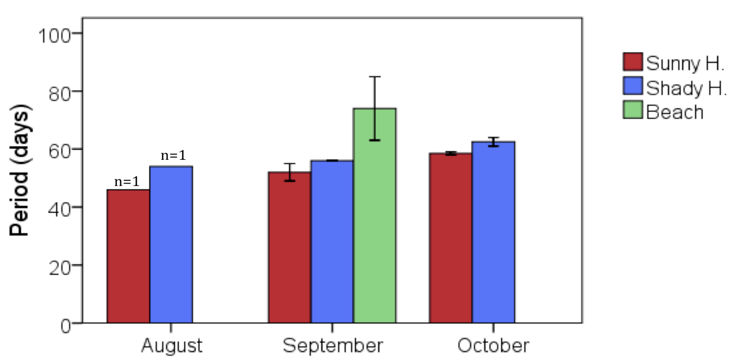


Fig. 6. Mean incubation times (days) of nests laid on the date indicated.

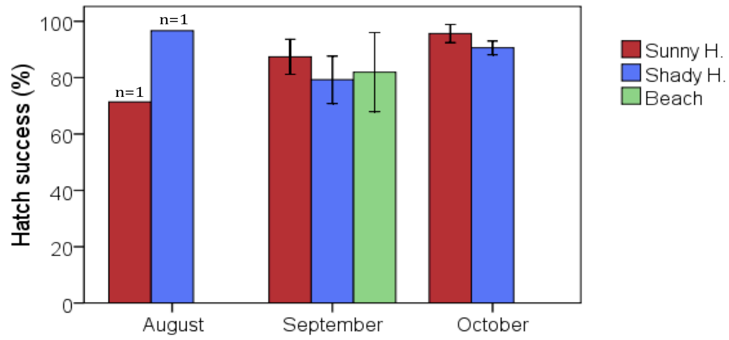


Fig. 7. Mean hatch success (%) of nest laid on the date indicated.

Discussion (b)

The mean temperatures during the middle third of incubation were affected only by timing of oviposition. These mean temperatures decreased from study nests laid in August to October. As a consequence, the expected proportion of males increased over time. We did not observe any effect produced by location of oviposition on means temperatures during the middle third of incubation in study nests (Annex 6).

Incubation periods and hatch successes were not affected by timing and location of oviposition (Annex 6). Because of lack of data, we assumed that there was no difference in incubation periods and hatch success among months.

I assumed that the samples represent the thermal trends of the nests laid between August and October. I argued that at least 89.26% of nests laid from August to October produced clutches with more than 50% males. This means that a male bias occurred in at least 66,67% of the total nests of the 2010 season (Fig. 8). Therefore, we estimate that Drake Beach exhibited a male-biased in the hatchling production during the olive ridley nesting season 2010.

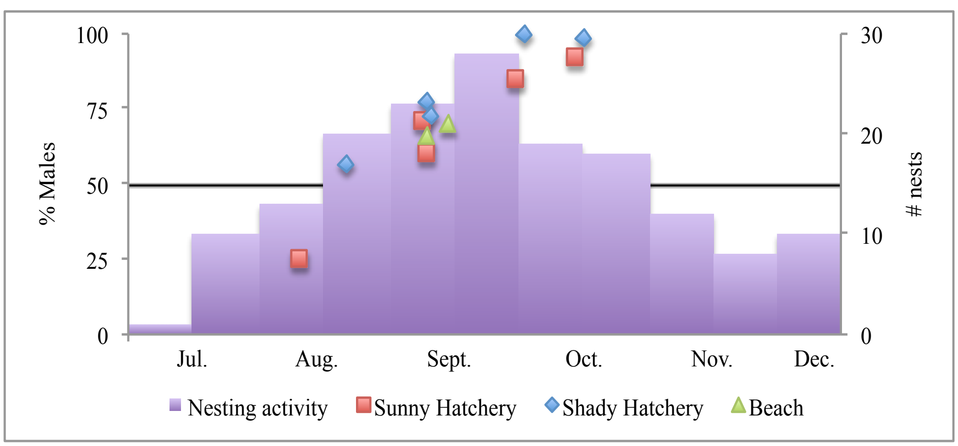


Fig. 8. Olive ridley nesting activity on Drake Beach (2010) and sample size sex ratio estimation.

Conclusions

The implementation of the Corcovado Foundation sea turtle conservation program achieved a reduction of poaching events (85% in previous years to the program) through the relocation of nests to the hatchery. But, we witnessed that poaching continues on this beach, reaching 10.5% of total nests during the 2010 season. Therefore the conservation strategy used by Corcovado Foundation to protect nests through the relocation of these to the hatchery is justified and it should continue in Drake Bay.

Rainfall might be the most influential factor to the nest temperature profiles over the season. Additionally, mean air temperatures are slightly cooler from mid September to November (peak months of the wet season). These factors affect directly the thermal nest conditions and, as a consequence, the sex ratio of hatchling, producing more male during cooler months.

Sand temperatures of the three different study zones recorded by controls follow similar trends. Therefore, we assumed that the whole hatchery works in similar way than the thermal conditions on the beach.
We estimate that Drake Beach might exhibit a male bias in at least 66,67% of the total nests of the 2010 season.

These conclusions are based in the data available. The study was designed to sample 10% of the total nests. However, due to unexpected poaching and erosion of the nesting beach only 7.5% were sampled. Additionally, I did not have any data from nests laid in July, November and December. The results from this study might not represent the hatchling productions of olive ridley at Drake Beach.

Recommendations

Recommendation: Due to annual variability, meteorological conditions should be monitored each year through a meteorological station placed in the study area in order to obtain more accurate weather data (meteorological data from external stations sometimes are not available or these stations are far away).
The thermal conditions of sea turtle nests are affected by several factors (Baker-Gallegos, 2009). Add studies of these different factors such as beach characteristics, sand composition, moisture within nests, Albedo effect and insolation rate would help to understand better what factors affect this thermal environment.

Recommendation; Olive ridleys pivotal temperature and TRT might vary inter-specifically. Therefore an exhaustive study of these parameters should be carried out on Drake Beach. This would allow calculating accurately the function needed to estimate the hatchling sex ratios of nests laid in Drake Bay.
Sample sizes should be increased so that the sufficient sample size would result even if some nests and temperature loggers were lost due to poaching and erosions.

Annexes

Month	Minimum air temperatures (°C)	Maximum air temperatures (°C)	Total precipitation (mm)	Rainfall days
January	21.1	32.3	144.9	11
February	21.3	33.1	112.2	8
March	21.9	33.5	184.9	13
April	22.5	32.9	267.9	17
May	22.4	31.8	501.7	24
June	22.2	31.4	483.5	23
July	22	31.2	556.3	23
August	22	31.3	584.5	25
September	22	31.3	625.3	26
October	22.1	30.7	660.2	26
November	22	30.6	556.1	26
December	21.6	31.4	263.3	17

Annex 1. Average climate data 2010; Station 24, Rio Claro, Golfito, Costa Rica.
National Meteorological Institute, Costa Rica: IMN meteorological.

Date/Mean Tº middle third (Cº) ± SE	Sunny hatchery	Shady hatchery	Beach
August	31.254 ± 0.06	30.053 ± 0.02	
September	29.047 ± 0.06	28.596 ± 0.06	29.397 ± 0.04
	29.790 ± 0.08	28.925 ± 0.05	29.111 ± 0.03
October	28.071 ± 0.07	27.028 ± 0.05	
	27.564 ± 0.07	27.115 ± 0.05	

Annex 2. Mean temperature during the middle third of incubation period of study nests.

Date/Males%	Sunny hatchery	Shady hatchery	Beach
August	24.87	56.38	
September	70.75	77.20	65.77
	60.04	72.50	69.83
October	84.70	99.59	
	91.94	98.35	

Annex 3. % hatchling males of study nests.

Date/Incubation period (days)	Sunny hatchery	Shady hatchery	Beach
August	46	54	
September	49	56	84
	55	56	60
October	58	64	
	59	61	

Annex 4. Incubation periods of study nests.

Date/Hatch success (%)	Sunny hatchery	Shady hatchery	Beach
August	71.43	96.70	
September	93.62	70.84	67.96
	81.19	87.70	96.00
October	92.39	88.14	
	98.89	93.04	

Annex 5. Hatch successes of study nests.

Test Statistics [a,b]

	Mean Temperature Middle Third	% Males	Incubation Period (days)	Hatch success (%)
Chi-square	9.231	9.231	5.069	1.801
df	2	2	2	2
Asymp. Sig.	.010	.010	.079	.406

a. Kruskal Wallis Test

b. Grouping Variable: Aug:Sept:Oct

Annex 6. Statistical test for research parameters over study time (Aug:Sept:Oct).

Test Statisticsa,b

	Mean Temperature Middle Third	% Males	Incubation Period (days)	Hatch success (%)
Chi-Square	3.429	3.429	4.706	.286
df	2	2	2	2
Asymp. Sig.	.180	.180	.095	.867

a. Kruskal Wallis Test

b. Grouping Variable: Sunny hatchery:Shady hatchery:Beach

Annex 7. Statistical test for research parameters among different study zones for September 2010 (Sunny hatchery:Shady hatchery:Beach).

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