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Intensive beach management as an improved sea turtle conservation strategy in Mexico

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Abstract

We evaluate the role of intensive beach management, meaning intense patrolling and nest reburial to a central hatchery, as a strategy for improving the success of sea turtle conservation at nesting sites in Mexico. We report the results of an experimental program at Playa Cuixmala, Jalisco, western Mexico. Sea turtle conservation efforts in Mexico have, in general, poor results because of lack of funds, which leads to insufficient beach protection and severe negative effects of nest removal on hatching success and sex ratios. Alternative strategies are needed to optimize limited resources. We predicted that intensive beach management, which included intense patrolling and careful nest reburial, could be an effective way to maximize nest survival and hatchling release under limited financial and human resources. The results of our 9-year study were very positive. Survival rate increased several fold during the study period. Hatching success and sex ratios were not significantly different between in-situ and removed nests. Survival in removed nests was, however, much higher that in-situ nests, because of predation and beach erosion. In total, the small (3 km length) Playa Cuixmala became the second most productive sea turtle nesting beach in the region because of these concentrated efforts. Intense beach management can be an important technique for sea turtle conservation, and can be properly applied to small beaches or the most productive sections of large beaches.

Keywords: Beach management for sea turtles; Beach protection; Sea turtles; Nest translocation; *Lepidochelys olivacea*; Nest predation; Beach erosion; Conservation strategy; Enclosed hatchery; Sex–temperature determination

Debate over the optimum methods for conserving dwindling populations of endangered sea turtles has been a concern of the conservation community for decades. Conservation of sea turtles include management of nesting beaches, nest translocation to protected hatcheries, head starting, reduction or elimination of natural predators, and protection against poaching and fishing (Bjorndal, 1995; Ehrenfeld, 1995). The protection of nesting beaches and nests is considered part of a broader sea turtle conservation strategy, where mortality factors at other stages of the life cycle have to be addressed (Frazer, 1992; Spotila et al., 2000).

The protection of nesting beaches and the nest translocation to enclosed hatcheries has been widely implemented (INP, 1990; Pritchard et al., 1993; Cornelius, 1995; Chan and Liew, 1995; Pritchard, 1995; Tow and Moll, 1995). Nest translocation is an important conservation tool on beaches where natural hatching is low or non-existent due to poaching, predation, or erosion. There is controversy, however, about the utility of nest translocation and nest removal to hatcheries versus in-situ protection because managed nests may experience lower hatching success and altered sex ratios (Limpus et al., 1979; Mrosovsky and Yntema, 1980; Parmenter, 1980; Blanck and Sawyer, 1981; Morreale et al., 1982; Dutton et al., 1985; Eckert and Eckert, 1990; Márquez, 1990; Cornelius et al., 1991; Pritchard et al., 1993; Bjorndal, 1995; Chan and Liew, 1995; Ehrenfeld, 1995; Pritchard, 1995).

The main strategies for sea turtle conservation in Mexico includes a complete ban on exploitation of sea

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turtles and their eggs, and the protection of nesting beaches (SEPESCA, 1991). Management has mainly focused on nest protection in centralized beach hatcheries (Kilma and McVey, 1995; INP, 1990; SEPESCA, 1990b). Recurrent problems related to lack of funds include insufficient beach protection and inadequate management of nest removal to hatcheries have resulted in poor overall success of the conservation programs (SEMARNAT, 1996; Pritchard, 1995).

The objective of this study was to evaluate the potential of intensive beach management as an improved strategy for sea turtle conservation in Mexico. By intensive beach management we mean both intensive beach patrolling and adequate nest reburial, to avoid both natural and human-induced nests losses, and negative effects of nest management on sex ratios and hatching success. To carry out this study we selected Playa Cuixmala, a small beach (<3 km length) in the Jalisco coast, western Mexico. We report here the results of nine annual breeding seasons of Olive ridley (*Lepidochelys olivacea)*.

In our work we test the following postulates:

1. Concentrating on intensive beach management is an efficient conservation strategy to maximize nest protection under limited financial and human resources.
2. Natural and human-caused nest losses can be effectively reduced by nest removal to an enclosed hatchery.
3. Careful management of nest removal and hatcheries minimizes their negative effects on hatching success and sex ratios.

1. Study site

Playa Cuixmala (19°22′–19°21′ lat N and 105°00′–104°59′ long W) is located along the southern coast of Jalisco, 140 km south of Puerto Vallarta, and is part of the Chamela-Cuixmala Biosphere Reserve (Ceballos and Garcia, 1995). It is 3 km long, with marked monthly variations in width (30 to 70 m), especially during the rainy season. The physical and biotic characteristics of the area are described elsewhere (Bullock, 1986; García and Ceballos, 1994). The climate is tropical, hot, humid, and characterized by well-defined dry and rainy seasons. Annual mean temperature is 24.9 °C and mean annual rainfall is 788 mm, concentrated between July to October; the dry season can last 8 months, from November to June (Bullock, 1986).

Human activities have profoundly impacted sea turtle populations along the Jalisco coast. Large “arribadas”, including groups from 20,000 to 30,000 of *Lepidochely olivacea* females, were recorded on Mismaloya Beach (70 km north of Cuixmala) as late as 1970 (Casas-Andreu, 1978; Cliffton et al., 1995; SEPESCA, 1990a). Playa Cuixmala has been officially protected as a sea turtle nesting sanctuary by a presidential decree since 1986 (SEPESCA, 1986). Prior to 1988, poaching was a common activity. Beach area is highly variable, with beach erosion caused by high tides during hurricanes and tropical storms (from July to October), when beach area can be reduced up to 70% in a single storm (e.g. September 1987). Nest loss by beach erosion is high because the hurricane season coincides with the sea turtle nesting season (Casas-Andreu, 1978; Bullock, 1986).

2. Methods

Data for this study were collected from July 1988 to March 1997, comprising nine annual breeding seasons (July–March). All the activities were carried out by the staff of the Cuixmala Ecological Foundation, an organization responsible for the protection of Cuixmala beach. Before the breeding season started, guards were trained and the hatchery built. The beach was protected against human poaching by controlling its two points of accesses. Beach patrols were conducted at 3-h intervals from 22:00 to 07:00 to find tracks of nesting females that lead to the nests, or to locate the nesting females. Due to regular patrols, the small beach length, and the ability to rapidly transport the removed nests to the hatchery, time between oviposition and reburial was no longer than 3 h.

After nests were found, they were collected, numbered, clutch size recorded, and transported in clean plastic bags to the enclosed hatchery by foot. The enclosed hatchery was located in a well-drained area free of vegetation and shades. The hatchery was moved each year around the area to avoid accumulation of bacteria and other kinds of contamination. The enclosed hatchery was 10 × 35 m and was constructed of 2.5-m high wooden posts, and woven wire mesh, as well as a 1.5-m high mosquito mesh. The wooden posts and the woven and mosquito mesh were buried 0.5 m to avoid predators such crabs and coatis.

In order to control hatchlings emergence, mosquito mesh tubes were placed around each nest close to hatching. Hatchlings were counted and released immediately to the sea by putting them on the beach to allow them to move along the sand. Two days after the natural emergence of hatchlings, nests were completely opened to count the hatched, non-hatched, and infected eggs, and the dead and live hatchlings inside the nest.

We evaluated human poaching by counting the number of poached nests compared to all of the nests recorded in the beach. To evaluate the importance of the intensive protection of our small beach we compared our data with information from all protected beaches along the Jalisco coast (SEPESCA, 1992, 1993;

SEMARNAP, 1996). For comparisons between beaches, results were standardized by calculating the average number of nests protected per linear kilometer, due to variability in beach length. An index of relative importance of beaches in relation to nest protection was determined by dividing the number of nests protected by the linear kilometers of each beach. For the purpose of comparison, nest data was presented by calendar year instead of breeding season, in accordance with government reporting procedures for the other beaches.

We experimentally evaluated the natural causes of nest loss by comparing survival of translocated (i.e. hatchery) and in-situ nests. Experiments were performed in August 1990, July 1991, and October 1994. The removed nests were carried to a hatchery as described above, and the in-situ nests were left exposed to beach erosion and predation. Nests found in the field were alternately allocated to each condition. At the end of each experiment we recorded the number of surviving and destroyed (i.e. nests lost to predation or beach erosion) nests. The number of nests allocated to hatchery and in-situ conditions in the experiments were 32 in 1990, 80 in 1991, and 18 in 1994. In all experiments, we evaluated the effect of nest removal to the enclosed hatchery on hatching success. Hatching success was calculated by dividing the number of hatched eggs by the total number of eggs found in each nest.

We compared nestling sex ratios from removed versus in-situ nests in the 1994 experiment. In *Lepidochelys olivacea,* sex ratios are female and male biased at temperatures between 32 and 34 °C and between 26 and 28 °C, respectively. The threshold temperature, where a balanced sex ratio is produced is around 30 °C (McCoy et al., 1983). We monitored the temperature inside all nests during the incubation period twice a day (06:00 and 14:00 h), to determine if incubation temperatures differed in the removed and in-situ nests. Thermocouples (Bailey Instruments, model BAT-12, with 0.1 °C of resolution) were used to monitor nests' temperature (see Benabib, 1984; Mrosovsky, 1995). Based on the recorded temperature profiles, we predicted expected sex ratios. Twenty hatchlings from each nest were selected randomly for sex determination in the laboratory using the techniques of Humanson (1979) and Merchant-Larios et al. (1989). Sample size was 20 turtles from each nest, and was similar to, or larger than, sample sizes in other field studies on temperature–sex determination (Benabib, 1984, Mrosovsky et al., 1984). The sex of 283 and 247 turtles from 17 transplanted and 14 in-situ nests was determined.

3. Results

Our study comprised 72 months of fieldwork and 8640 daily beach surveys, and represents the longest study of *Lepidochelys olivacea* nesting in Mexico. Altogether, there were 2418 nests protected and 141,548 hatchlings released in Cuixmala from July 1988 to March 1997. The frequency of laid nests during the breeding season (July–March) showed a peak (73% from total recorded nests) from August to October (Fig. 1). Mean number of nests laid per month in the 3 km study site for the 72 months was 33.3 (S.D. = 36.9), with the highest and lowest values in September (mean = 81, S.D. = 40) and March (mean = 2, S.D. = 2), respectively.

3.1. Intensive beach management

How efficient were our efforts to reduce natural and human-induced mortality of nesting sea turtles and nests at Cuixmala beach? Not surprisingly, intense beach management, which included patrolling and nest reburial, was an effective way to reduce nests losses in Cuixmala. Altogether, the outcome of such efforts was the release of 141,548 hatchlings. The number of protected nests showed an impressive recovery from 20 nests in 1989 to 456 in 1996, with an annual average of 300 (S.D. = 127 nests) and a total of 2418 nests (Fig. 2).

The effectiveness of our program was the combined reduction of mortality caused by poaching and natural factors such as the destruction of nests by beach erosion and predators. Poaching was completely halted. During the 1987–1988 and 1988–1989 breeding seasons when Cuixmala beach was not strictly protected, most nests ($>90\%$) were poached. In contrast, during the following 8 years, when beach protection was enforced, only two nests were poached in 1990.

Our work also eliminated nest losses by predation or beach erosion among the nests in the hatchery. In contrast, only an average 56% (range 44–70%) of the in-situ nests survived because of beach erosion and predation by coatis (*Nasua narica*; Fig. 3). Nest survival in the hatchery was statistically higher than in-situ nests ($T = 5.02$, df = 4, $P < 0.05$). If no management had been done from 1989 to 1997, the total number of surviving nests in Cuixmala could have been 1450 as a maximum, when considering no poaching and a 56% average nest survival rate. Adding the effects of poaching and natural causes of nest destruction, it is likely that only 213 nests (10%) and 14,155 hatchlings would have survived during the study period.

3.2. Effects of nest translocation

An important part of the success of our program was the translocation of nest to a hatchery to avoid nests losses by beach erosion and predation. Our results clearly indicate that our nest reburial technique had few negative effects on hatching success and sex ratios (Figs. 3 and 4). Hatching success was, on average,

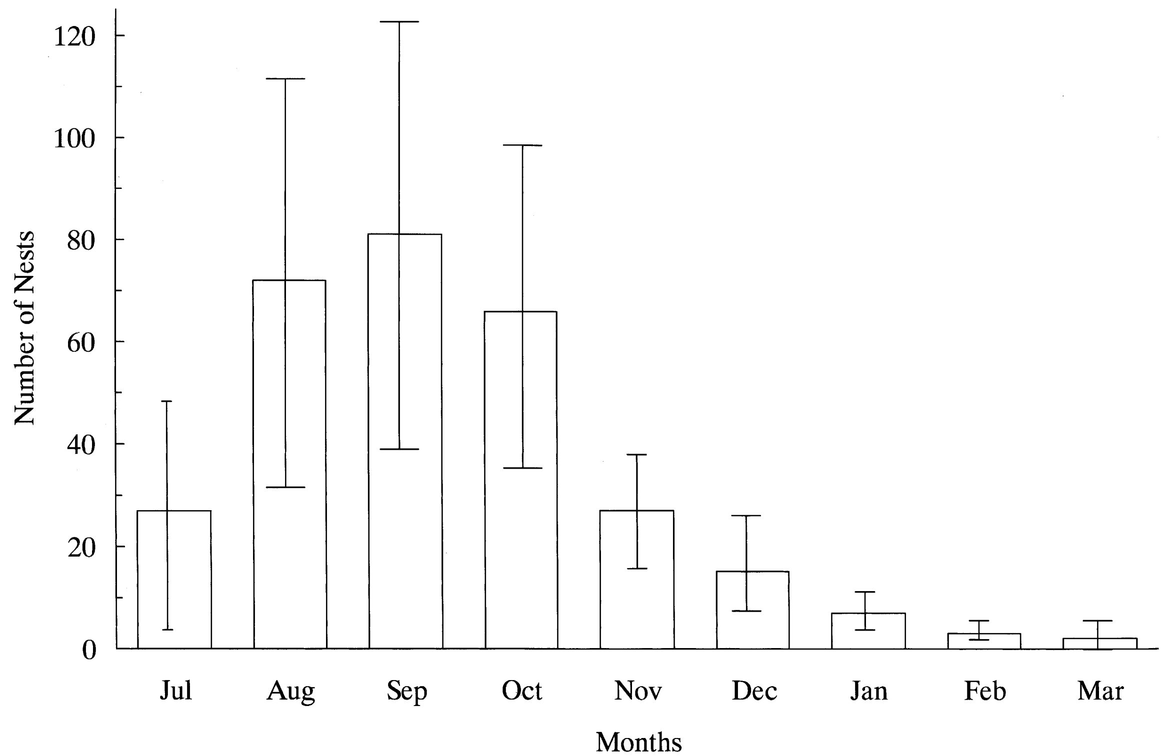

Fig. 1. Annual nesting pattern of Olive ridleys (*Lepidochelys olivacea*) at Cuixmala beach, Jalisco, Mexico, from 1988 to 1997. A total of 2418 nests were counted, averaging 33.3 (S.D. 36.9) nests per month.

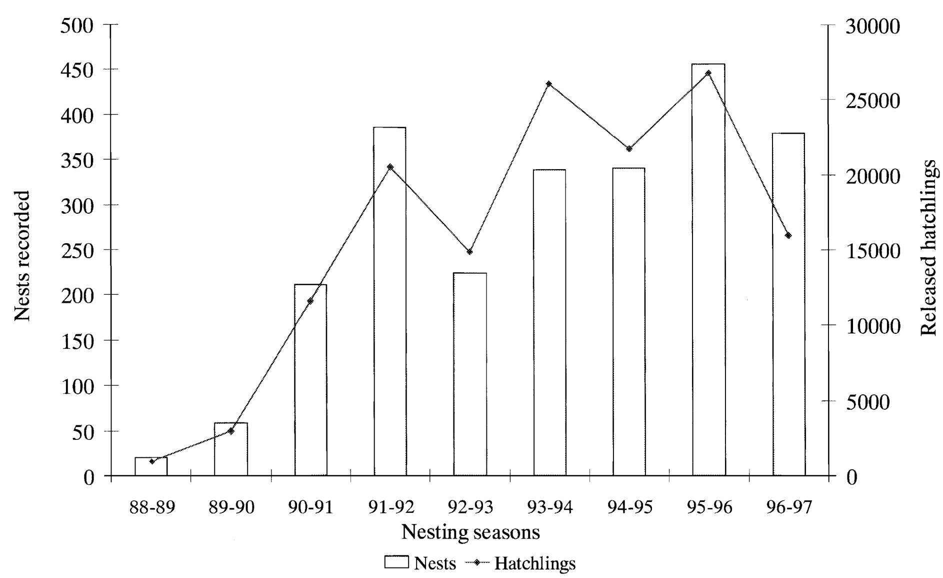

Fig. 2. Recorded nests (bars) and released hatchlings (line) of Olive ridleys (*Lepidochelys olivacea*) at Cuixmala beach, Jalisco, Mexico, from 1988 to 1997.

higher in the in-situ (66%) than in hatchery (59%) nests, but this difference was not statistically significant ($T = 1.75$, df = 211, $P > 0.05$). Hatching success varied among experiments, and was higher in the in-situ nests in 1991 and 1994, but lower in 1990. In the 1991 experiment, differences between in-situ and translocated nest were statistically significant ($T = 3.53$, df = 137, $P < 0.05$), but in the 1990 and 1994 experiments, no significant differences were found ($T = 1.14$, df = 46, $P > 0.05$ and $T = 1.48$, df = 24, $P > 0.05$, respectively).

The hatchery and in-situ nests experienced similar temperatures during the three week sensitive temperature period for sex determination ($T = 0.9$, df = 30, $P > 0.05$). The average temperature for such period was

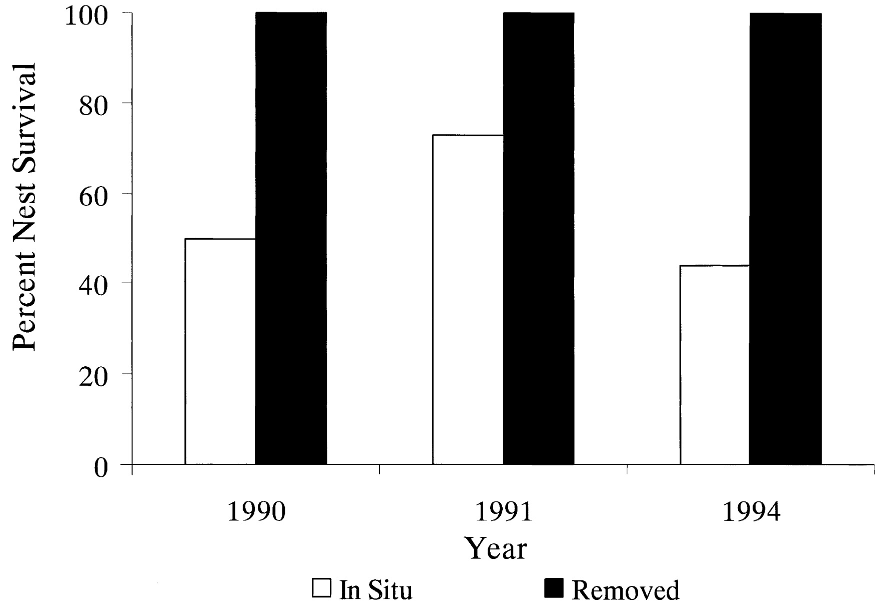

Fig. 3. Percent of survival in in-situ (open bars) and removed (black bars) nests at Cuixmala beach, in 1990, 1991, and 1994.

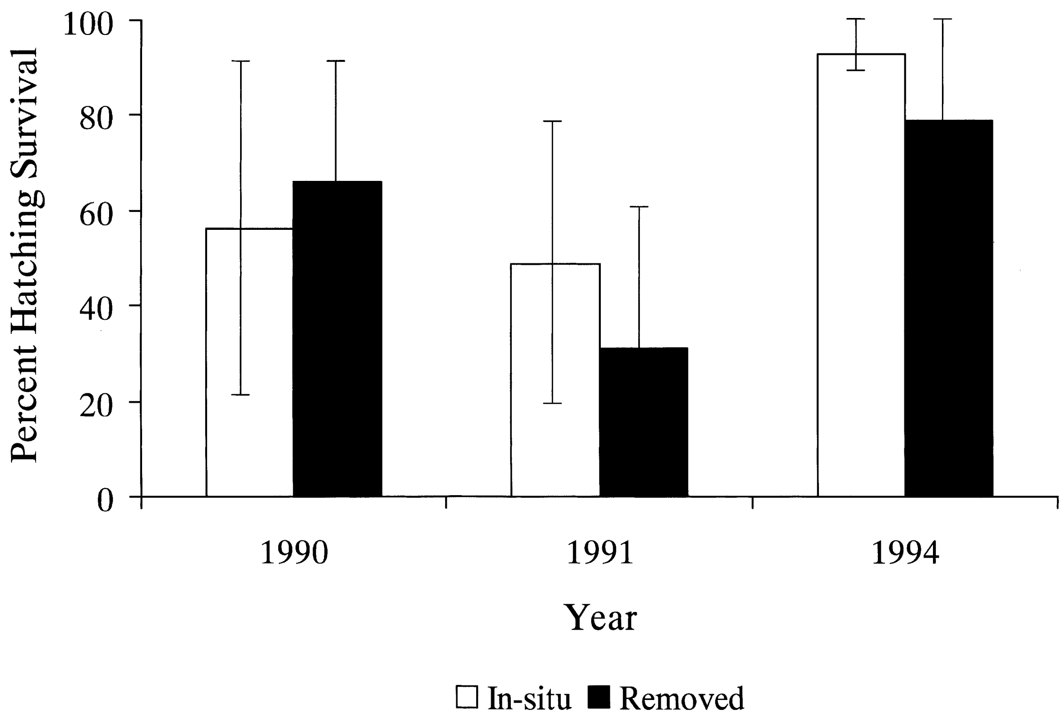

Fig. 4. Hatchling success in-situ (open bars) and removed (black bars) at Cuixmala beach in 1990, 1991, and 1994.

30.5 °C ($N = 266$, S.D. = 0.62) for in-situ nests and 30.6 °C for hatchery nets ($N = 380$, S.D. = 0.62). Based on observed temperatures, we expected slightly female biased sex ratios in both conditions. Our results supported our predictions, because sex ratios did not differ statistically between translocated and in-situ nests ($t = 0.74$, d.f.0 29, $P > 0.05$), and were skewed towards females (Table 1).

3.3. Comparison of Cuixmala and other regional beaches

How do our results compare with other protected sea turtle nesting beaches in the same region? Although we hypothesized that intensive protection of a small beach like Cuixmala could have a positive regional contribution to sea turtle conservation, we did not expect the

Table 1
Incubation temperatures and sex ratios in experimental conditions for in-situ and removed nests at Cuixmala beach. Temperatures ± standard deviation

	Hatchery	In situ
Mean temperature at incubation period	30.9 °C ± 1.169	30.4 °C ± 0.989
Mean temperature at sensitive period	30.6 °C ± 0.699	30.5 °C ± 0.761
Sex ratio	1:1.41	1:1.35

magnitude of our results. The productivity of beaches increased throughout the region during this study as a result of sea turtle conservation efforts (Figs. 5 and 6). Nonetheless, the relative contribution of the 3 km Cuixmala beach to the total 50 km of protected beaches along the Jalisco coast increased from 1989 to 1994. The proportion of all successful nests increased from 4 to 16% while the proportion of all hatchlings released increased from 3 to 18% of the regional totals (Fig. 5). During that period, Cuixmala became the most important beach for sea turtle conservation at the state level in relative terms (i.e. number of hatchling released per km of beach) and the second one in absolute terms (i.e. total number of hatchling released).

4. Discussion

The general conservation lessons from our work on sea turtle conservation are related to three issues. (1) We explored the role of what we called *intensive beach management* for sea turtle conservation. (2) We did this because of a need to reduce both human-induced and natural factors causing nest losses and hatching success. (3) Through our work we tested the usefulness of nest reburial to an enclosed hatchery as a conservation strategy. It is important to emphasize, however, that our data is based on a single beach.

A successful sea turtle conservation strategy in the Pacific coast of Mexico must combine mechanisms to reduce human-induced and natural factors causing nests and hatchling losses. We believe that an intensive beach management strategy like the one used in Cuixmala, can be applied to practically any beach, modifying it according to the local conditions, where human-induced and natural factors causing nest and hatchling losses may vary. Our results clearly indicated that intensive beach management was a successful strategy to increase the impact of our sea turtle conservation efforts.

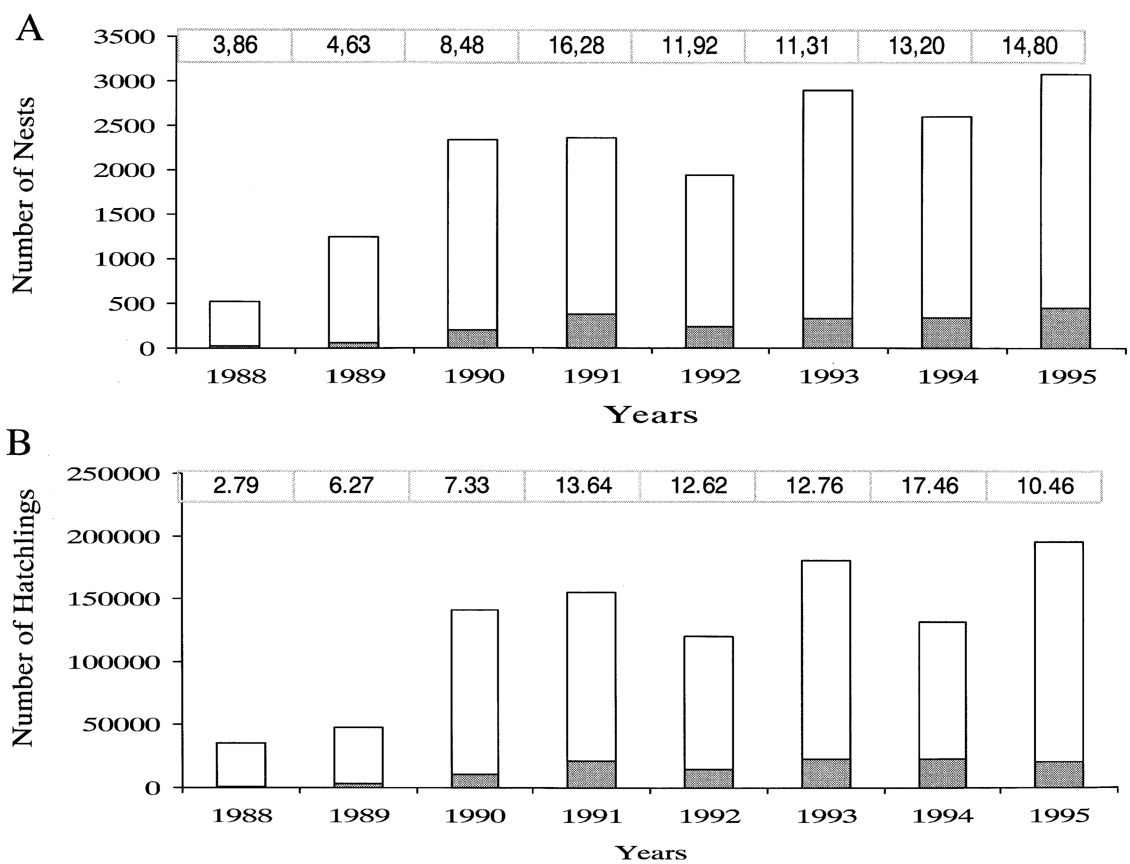

Fig. 5. Total number of nests and hatchlings released on the Jalisco coast (open part of bars) and the relative contribution of Playa Cuixmala (shaded part of bars; valves on top of the bars) from 1988 to 1995.

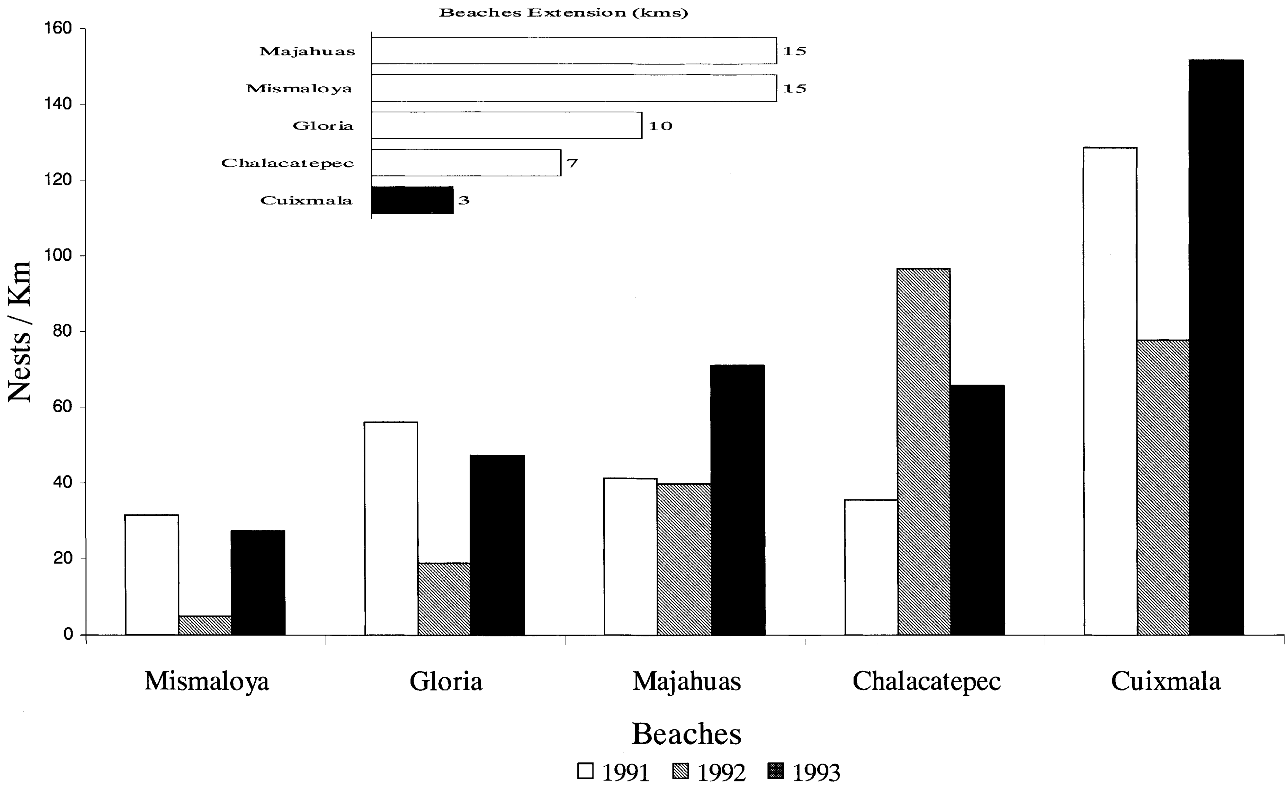

Fig. 6. Relative importance (N/km) of the sea turtle conservation program of Playa Cuixmala in comparison with other protected beaches in the Jalisco coast from 1991, 1992 and 1993.

4.1. Human-induced nests losses

The strict control and patrolling of access to Cuixmala beach together with the constant beach patrolling by the staff of the biosphere reserve, practically eliminated both nest and sea turtle poaching. Our results reinforce current views that beach protection is a priority strategy for sea turtle conservation (Alvarado and Figueroa, 1992; Ratnaswamy and Warren, 1998; Wang and Cheng, 1999).

The effects of poaching can be devastating for sea turtles. Nest poaching has been the main mortality factor for sea turtle populations elsewhere along the Jalisco coast where from 75 to almost 100% of all nests are destroyed in some beaches. People poach turtle nests to get eggs, which are illegally sold for human consumption in local communities. Two examples illustrate the severity of this problem; in Teopa beach (5 km length), located immediately to the north of Cuixmala beach, an average 80% of all nests were poached annually from 1989 to 1994. Similarly, in the 30-km total length of Mismaloya and La Gloria beaches (with the highest nesting activity in the region), 93% of the nests were poached during the 1991 nesting season (SEPESCA, 1992). Despite the fact that Cuixmala beach is the smallest protected beach in the Jalisco coast, it has become one of the most productive beaches in that state (SEPESCA, 1991, 1992; SEMARNAP, 1996).

In Mexico, beach patrolling has been focused on relatively large beaches with high nesting activity. However, the lack of adequate funding and the size of the beaches have precluded the effectiveness of the conservation programs. *Focusing protection and patrolling on small beaches and the most productive portions of large beaches is an important strategy that can be implemented under limited resources to maximize conservation impact.*

4.2. Natural-induced nests losses

Our fieldwork positively indicated that beach erosion and predation were natural causes of severe nest and sea turtle hatchling losses. We used nest reburial to an enclosed hatchery to reduce nests losses. The validity of nest reburial to an enclosed hatchery as a tool for sea turtle conservation has been questioned because in some circumstances it reduces hatchling success and alters sex ratios (Mrosovsky and Yntema, 1980, Morreale et al., 1982, Mrosovsky, 1995). Sea turtle hatching success can be affected by direct and indirect disturbance from humans, climatic conditions, environmental unpredictability (e.g. storms, floods, erosion), fungal and bacterial diseases, and predation (Eckert and Eckert, 1990; Bjorndal, 1995).

Nest reburial to an enclosed hatchery should be used in beaches were natural causes of nest losses are common (Parmenter, 1980; Ehrenfeld, 1995; Grand and Beissinger, 1997). Beach erosion, common at our site, is also a common cause of nest losses in other sites. For example, it has destroyed up to 30% of the nests in Playa Nancite and Ostional, Costa Rica (Cornelius, 1986; Cornelius et al., 1991), and 60% of *Dermochelys coriacea* nests in the Virgin Islands (Eckert, 1987; Eckert and Eckert, 1990). Nest losses by predation were also common in our study. Predation is also a major cause of sea turtle nests losses in many beaches (Fowler, 1979; Cornelius, 1986; Márquez, 1990; Cornelius et al., 1991; Stancyk, 1995). *Our results indicated that the risk of nest losses by environmental factors outweighed any possible disadvantages that might be caused by nest translocation.*

Our study is the first in Mexico to evaluate the effect of nest removal to an enclosed hatchery on sex ratios under natural conditions. Sex determination in sea turtles is temperature-dependent; cold incubation temperatures tend to produce males while warm temperatures tend to produce females (Bull and Vogt, 1979; Bull, 1980; Mrosovsky and Yntema, 1980; Vogt and Bull, 1982; McCoy et al., 1983; Standora and Spotila, 1985; Mrosovsky, 1995). In general, nest removal has resulted in altered sex ratios because the nests are incubated in either Styrofoam boxes or in shaded enclosed hatcheries, drastically changing the humidity and temperature of the incubation period (Morreale et al., 1982; Mrosovsky, 1995). Under such conditions, sex ratios produced are male biased, which can have profound effects on the population dynamics and long-term conservation of the species (Morreale et al., 1982; Dutton et al., 1985; Mrosovsky, 1995). *Our results indicate that of an enclosed hatchery, maintaining environmental conditions as close as possible to the adjacent beach can minimize negative effects on sex ratios.*

5. Conclusions

The long-term conservation of endangered sea turtles in Mexico, as in other regions of the world, depends on their protection at nesting sites and other stages of the life cycle. The evaluation of different conservation strategies at nesting sites is required to promote adequate allocation of financial resources to improve conservation impact. We propose that intensive beach management is a valuable conservation strategy of sea turtle nesting beaches, aimed to reduce both human and natural induced nests losses. Intensive beach management offers hopes for sea turtle conservation in countries like Mexico, and improves our chances to reduce sea turtle extinction probabilities worldwide.

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