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Increases in Hawksbill Turtle (*Eretmochelys imbricata*) Nestings in the Yucatán Peninsula, Mexico, 1977–1996: Data in Support of Successful Conservation?

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ABSTRACT. – We analyzed the long-term trends in number of hawksbill nests for the 20-year time series derived from Federal, State, and Municipal Government Agencies, academic institutions, and NGO programs in the Yucatán Peninsula, Mexico. We found that the steady improvement in monitoring effort (mainly increased beach coverage) occurring over 1977–92 is the major explanation for the gradual increases in nestings reported for that interval. However, we consider that the consistent trend for annual increases in hawksbill nestings since 1993 (average annual increase of 270 nests/year for 1992–96) is indicative of real population increments since beach coverage had peaked (123 km of nesting beaches in Campeche, 106 km in Yucatán, and 39 km in Northern Quintana Roo) and monitoring effort was sustained over seasons. The pooled total of 4522 protected nests reported for the 1996 nesting season (equivalent to about 940–2200 nesting females, assuming an average of from 2.1 to 4.8 nests per female per season), implies that the Yucatán Peninsula hawksbill nesting population (conservatively estimated at 1900–4300 individuals) is the largest in the Western Atlantic and one of the largest on a global scale. We suggest that the major causes (in order of importance) for the recorded annual increases in nesting activity after 1993 are: 1) increased survival rates of juveniles, subadults, and adults brought about by regional conservation measures, and 2) increased recruitment into the breeding stock from turtles hatched at protected beaches in the Peninsula (assuming times to maturity extrapolated from growth recorded in local tagging studies). While the nesting increments suggest that conservation measures have been successful, long-term recovery of the population will still require that efforts be sustained. In this light, current trends of downscaling and under-funding of conservation fieldwork, and modification and degradation of critical habitats in the region, still pose serious threats both to regional monitoring and conservation programs and to the future stability of hawksbill populations in the Yucatán Peninsula.

KEY WORDS. – Reptilia; Testudines; Cheloniidae; *Eretmochelys imbricata*; sea turtle; conservation; status; nesting density; migration; breeding population size; Yucatán Peninsula; Mexico

Concern about the decline of hawksbill turtles (*Eretmochelys imbricata*) worldwide (Groombridge and Luxmoore, 1989; Meylan, 1989; Eckert, 1995) has prompted increasing attention over the condition of individual populations of the species throughout its global range (Meylan and Donnelly, 1999). While the Mexican hawksbill population is considered to be one of the largest in the world (Meylan, 1989; Groombridge and Luxmoore, 1989; Meylan, 1999a; Meylan and Donnelly, 1999) some data are already outdated. Data sources for recent approximations of total population sizes for the Yucatán stock (e.g., Meylan, 1989) came from estimates of 500–562 nestings reported for 1981–82 surveys in the Gulf of Mexico (including Tamaulipas and Veracruz) and 88 from the Mexican Caribbean (Márquez, 1984a, 1984b), a pooled annual total of 684–942 nests (compiled from various sources by Groombridge and Luxmoore, 1989), and an approximation of 800–1000 annual nestings between Isla del Carmen (Campeche) and Isla Holbox (Quintana Roo) made by Byles (cited in Eckert, 1995).

Estimates of both population sizes and fishing pressure can sometimes be derived from fishery statistics. Hawksbills, as well as other sea turtles, were captured and used since pre-Hispanic times by Yucatán natives (Parsons, 1972). Traditional utilization by coastal communities, however, increased from the 1950s onwards after outboard motors and nylon nets were introduced and the commercial demand for both food and by-products grew as human presence increased in the area (Fuentes, 1967; Márquez, 1976). Handicrafts made from hawksbill shell (tortoiseshell, or *carey* as it is referred to in Mexico) were very popular in the southeastern part of the country and by the 1970s most of these products aimed at internal trade came from Yucatán hawksbills (Groombridge and Luxmoore, 1989). Open exploitation continued until regulatory measures were implemented in the middle and late 1970s (Márquez, 1976, 1984a, 1984b). All sizes of turtles were utilized: stuffed juveniles or subadults for souvenirs; scutes to be crafted into luxury items; eggs, oil, hide, and meat for mostly local, human consumption.

The magnitude of the historical hawksbill harvest in Mexico is difficult to estimate because official figures are generally imprecise and often reflect market forces rather than true population densities. Available official fishery statistics show high fluctuations. No production figures are available for some years (1948–52, 1957–63); more than 1 ton of shell was recorded in some years (1954–55, 1968); and a remarkable peak value of 4.87 tons of shell was recorded in 1973 that, if we use a conversion of 1.5 kg of shell per individual, corresponds to approximately 3000 individuals (Montoya, 1967; Márquez, 1976; Groombridge and Luxmoore, 1989; Garduño, 1998). The total registered official take in Mexico over this period of time was 12.73 tons of shell, equivalent to approximately 8500 individuals, which we consider to be an underestimate. No information is available from 1976 onwards when hawksbill fishing became illegal (Márquez, 1978).

Information on hawksbill nestings in Yucatán has been collected over the last two decades, and some of it has been partially published by regional workshops since 1988 (Abundes, 1989; Aguirre, 1990; Miranda and Vázquez, 1990; Frazier, 1993; Frazier et al., 1993). A large part of the results, though, have not been published, or remained within technical reports with small circulation, and have not been subjected to an integral analysis for the whole Peninsula providing a comprehensive view of population trends.

MATERIALS AND METHODS

Habitats. — Hawksbills nest in a wide range of coastal ecosystems of the Yucatán Peninsula, many of which are long beaches that are shared with the green turtle, *Chelonia mydas*. In the State of Yucatán many of the sites are typical fine to coarse calcareous sand, but devoid of extensive shrub vegetation. The hawksbills prefer open spaces or those with scarce vegetation (Garduño-Andrade, 1999). In Campeche, on the other hand, the nesting habitats are very diverse. Besides nesting on sandy substrates on exposed oceanfront beaches, they also nest on sheltered estuarine beaches of Términos Lagoon and on small islets in the Campeche Bank. In this area, various substrates are used for nesting, ranging from typical marine sands, to pebbles or shell debris, or clay river deposits brought into the small beaches around river mouths in the interior margins of Términos Lagoon, where the habitat is of a transitional estuarine type (see Guzmán et al., 1995; Márquez et al., 1987). In this last zone, nesting even occurs in sandy patches within the mangrove forest (*Rhizophora mangle*; Guzmán et al., 1993).

The major current affecting the area originates in Central America and flows south to north, running parallel to the Quintana Roo coast in a channel with depths > 1000 m. It collides against the Campeche Bank, only 150 m deep, creating an upwelling rich in nutrients that generates a year-round zone of high biological productivity sustaining extensive food chains (Merino, 1992). The prevalent current conditions (NOAA, 1985) can transport hatchlings born in the Peninsula into the Gulf of Mexico on loop currents that, according to the model of Collard and Ogren (1990), could carry them for several months (maybe years) of pelagic existence until they become adapted to near-shore benthic life.

There are also important hawksbill foraging areas in coastal waters near nesting beaches (e.g., Términos Lagoon in Campeche, seagrass beds throughout the Campeche Bank, the Yalahau Lagoon, Quintana Roo, and coral reefs off both Yucatán and Quintana Roo; Guzmán et al., 1995; R. Herrera, *pers. comm.*)

Sources of Information. — We obtained data primarily from annual technical reports and a few published accounts generated by hawksbill conservation programs operating over the last two decades in the Yucatán Peninsula.

Campeche: Chacahito, Isla del Carmen, Isla Aguada, Sabancuy, Chenkan, Punta Xen, Seybaplaya, San Lorenzo, and Isla Arenas (Barrios, 1990; Barrios and Canul, 1993; Barrios et al., 1995; Escanero and Gómez, 1988, 1989a, 1989b; Escanero and Vigilante, 1991; Escanero et al., 1993; Garduño, 1983a, 1983b; Guzmán et al., 1993, 1994, 1995, 1996; Guzmán and Garduño, in prep.; Márquez et al., 1987).

Yucatán: Celestún (Durán, 1990; Durán et al., 1991; Rodríguez et al., 1993; Acosta et al., 1995), Sisal (Miranda et al., 1993), Dzilam de Bravo (R. Miranda, *pers. comm.*), Río Lagartos-Coloradas (Carrasco, 1988; Carrasco et al., 1993; Castañeda, 1987, 1990; García, 1990; Iglesias and Lope, 1990; Garduño and Lope, 1991, 1992, 1994, 1995, 1996; Garduño and Márquez, 1994; Garduño et al., 1993; Garduño, 1998; Garduño-Andrade, 1999). El Cuyo (Aguirre and García, 1987, 1988; Licona, 1994; Rodríguez and Zambrano, 1991, 1992, 1993; Vázquez, 1993; Campos et al., 1995).

Quintana Roo: Isla Holbox (Durán, 1989, 1992; Gil et al., 1993; García, 1990; Miranda et al., 1995), Isla Contoy (Durán, 1985; Duran et al., 1984; Juárez et al., 1997), Isla Cancún (Gil, 1988), Mahahual (González, 1995; González et al., 1994, 1995).

The major hawksbill nesting activity in the Yucatán occurs from April to September and conservation camps that are associated with the most important nesting beaches are set up during this period of the year. Four of the hawksbill monitoring programs were characterized by extended observation periods. We used these against which to compare pooled state results for trend analysis. Thus, data from Isla Aguada (1977–96) was used to analyze Campeche results, data from Las Coloradas and El Cuyo (1979–96) for Yucatán, and Isla Holbox (1988–96) for Quintana Roo.

Extent of nesting activity has been typically monitored by surveys performed during the hawksbill nesting season by nightly patrols on all terrain motorcycles (ATC). Prior to 1990, patrolling was carried out on foot, by boat, or on terrestrial vehicles. At some sites, monitoring was performed during the daytime (but not every day). In all programs the major goal has been nest protection, commonly achieved by translocating eggs to beach hatcheries.

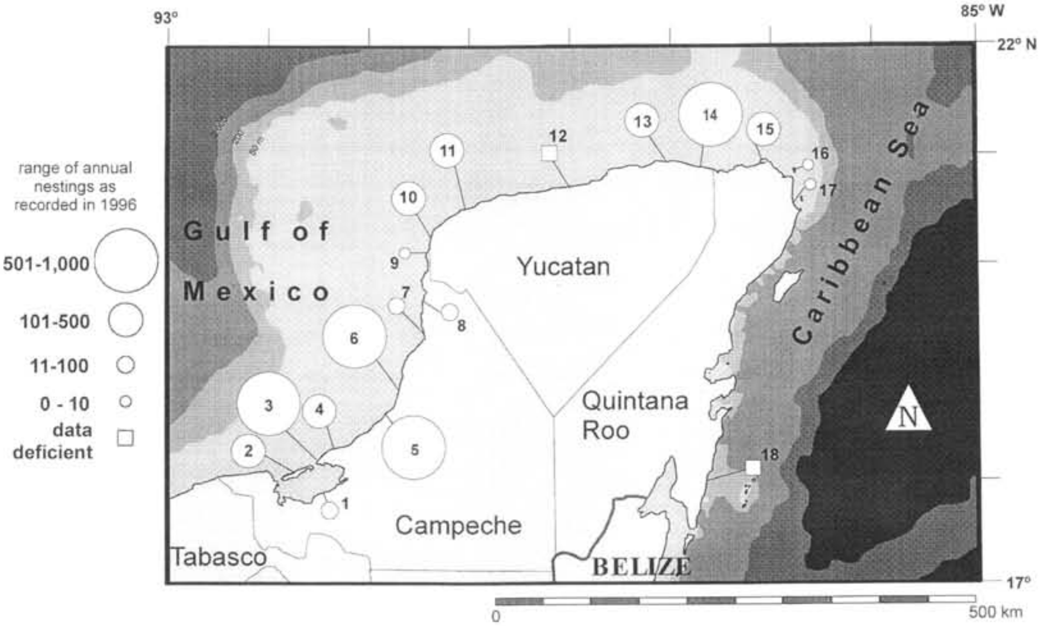

Figure 1. Surveyed hawksbill nesting beaches in the Yucatán Peninsula and their relative nesting abundance. Size of circles represent range of nest numbers recorded in 1996 beach surveys. Lengths of beaches covered in conservation work indicated in parentheses: *Campeche*: 1. Chacahito (8 km), 2. Isla del Carmen (35 km), 3. Isla Aguada (28 km), 4. Sabancuy (26 km), 5. Chenkan (25 km), 6. Punta Xen (30 km), 7. Seybaplaya (25 km), 8. San Lorenzo (1 km), 9. Isla Arenas (8 km); nesting also occurs on about 28 km of beaches in Laguna de Términos and the Campeche keys (Cayo Arcas, Cayo Isla Arenas, Isla Triángulos, not shown). *Yucatán*: 10. Celestún (20 km), 11. Sisal (35 km), 12. Dzilam de Bravo (ca. 10–15 km), 13. Río Lagartos–Coloradas (22 km), 14. El Cuyo (31 km). *Quintana Roo*: 15. Isla Holbox (24 km), 16. Isla Contoy (5 km), 17. Isla Cancún (10 km), 18. Mahahual (125 km).

Some registered nests, however, were left undisturbed in their original location for *in situ* incubation. From 1992 onwards, most nests at Celestún, Las Coloradas, El Cuyo, and Holbox were left *in situ* and the few that were moved to beach hatcheries were those with high risk of being lost due to poaching, predation, or flooding. Statistics from these four beaches incorporated data for protected nests as well as nests lost to any of these factors.

Estimates of Nesting Densities and Breeding Stock. — In general, we considered that estimates of beach coverage could be taken as indicators of variations in monitoring capacity as fieldwork in the area progressed. Nonetheless, to offset the effect that variations in beach coverage would have on numbers of nests reported, some of our analyses on nesting effort were carried out using density values (nests/km) instead of nest numbers. As is common in conservation programs involving a wide variety of institutions, temporal variations in the monitoring effort (from year to year and from study site to study site) have occurred, particularly in the pre-1992 period. Yet, since most sites monitored the beaches during the height of the nesting season (May–September), the effect of differing monitoring periods between sites was not considered to have a significant impact on the nesting density results that we analyzed and was therefore not corrected for.

As in other studies (e.g., Meylan, 1989), we used the number of hawksbill nests recorded each season as an index of annual breeding population size. In order to estimate the number of nesters from the available data, information on nesting behavior from intensive tag-recapture studies was also used. Thus, the number of females nesting in any particular year was derived by dividing the nest counts by the average number of nests laid by individual hawksbills each season, as reported by various Caribbean studies: 2.1 (Garduño, 1998), 3.1 (Guzmán et al, 1996), 3.0–4.8 (Hoyle and Richardson, 1993).

RESULTS

The full extent of hawksbill nesting beaches in the Yucatán Peninsula (Fig. 1) is approximately 500 km. Of the 214 km that occur in Campeche, 186 km have been surveyed, but the main nesting sites cover a total of 123 km, which have been monitored since 1993. In Yucatán, major nesting beaches extend a total of 121 km, with major attention directed to the State and Federally protected areas near the two extremes of the coastline (a total of 106 km). Along the central zone of this state (about 150 km) there are extensive town developments and vacation homes where, nonetheless, locals regularly report hawksbill nesting events. In Quintana Roo, we obtained information from a maximum of 164 km of nesting beaches, although most data came from Holbox, Isla Contoy, and Cancún (39 km) in the northern part of the state. Since only occasional hawksbill nesting is reported further to the south (Zurita et al., 1993) and on the beaches of Sian Ka'an and the area around Mahahual (a total of 125 km; González et al., 1995), we did not include data from these beaches in the analysis.

As reported previously (Márquez, 1984a, 1984b; Meylan, 1989), the largest reports of nests came from Campeche beaches (57% of the pooled results from the Peninsula; see Fig. 1). Density values (nests/km) varied between beaches. Average nesting densities for individual beaches (Table 1) ranged from 0.8–64 nests/km (mean = 16.7) for the last season reported (1996). San Lorenzo, Campeche (1 km long, the shortest beach in the survey) had unusually high densities: 110 nests/km in 1995 and 64 nests/km in 1996. Also, there were specific sections of monitored nesting beaches where the density was considerably higher than average. For example, for the 1995 season at El Cuyo, Campos et al. (1995) reported the highest densities (40–45 nests/km) at sites 3–7 km from the village.

Trends in Hawksbill Nesting Reports 1977–96

We discerned four phases in the development of sea turtle conservation work in the Yucatán Peninsula.

1) During 1977–86, initial conservation programs were established and overall efficiency and experience was gained gradually. The earliest sea turtle conservation projects were initiated in Quintana Roo around 1964, although the primary focus was on green (*C. mydas*) and loggerhead (*Caretta caretta*) turtles (Fuentes, 1967). Efforts were later extended to Campeche and Yucatán in 1977, where the main hawksbill nesting beaches were found to occur. As far as the hawksbill nesting sites are concerned, the coverage was extended from 25 to 100 km (4 beaches) during this period.

2) From 1986 to 1990 conservation monitoring was intensified and the number of government and NGO centers increased. By 1990 a total of 8 beaches were protected (174 km), new conservation centers were introduced by the Ministry of Ecology, more field biologists were incorporated and, as motorized transport (ATC) was introduced into some of the beach monitoring programs, greater coverage efficiency was attained. Other factors that also converged during this period included a total ban on all sea turtle exploitation in Mexico (in 1990) and greater national and international public interest in sea turtle conservation, which focused both attention and important resources into conservation work. Environmental law enforcement also became more effective during this time, in no small measure through the long-term stay of conservationists on nesting beaches which deterred nest poaching and take of nesting females.

3) By 1990–92 (Fig. 2a) increases in the annual number of protected nests were reported. However, since the increases were highly correlated to increases in beach coverage (r = 0.96) it is probably the latter that had an over-riding influence on the number of nests registered. This is reflected by the lack of change in the nest densities over this same period (Fig. 2b; density = 0.175*year - 343.35; $r^2 = 0.58$; t-value for regression coefficient = 1.19, $p > .05$) The precision of the annual nest counts for the years prior to 1991 should be viewed with caution since the surveillance capacity, efficiency, and periods of monitoring were very variable among conservation programs (e.g., the time and periodicity of patrols, the quality of personnel involved, their experience, transport availability). In many cases the deficiencies will have lead to underestimates of number of nests, and we consider this to be the case for data at least through 1991. Nonetheless, improvements in conservation capacity and expertise led to greater constancy in effort, particularly after 1991 when most centers received motorized vehicles and their surveillance encompassed a large part of the nesting season and the beach sections with the highest nesting densities.

4) By the final interval, 1992–96, the region's conservation programs were covering the most important hawksbill nesting sites (227–267 km overall). The annual number of nests and nesting densities reported increased considerably (Fig. 2) with greater annual increments than in previous

Table 1. Hawksbill nesting densities recorded for the 1996 season at beaches of the Yucatán peninsula (see Fig. 1 for extent of protection work on each beach). Data sources: [1] Miranda (1997), [2] Juárez (1997), [3] Juárez et al. (1997), [4] Jurado (1997). Information from all other beaches were provided by the authors.

State	Beach	Number of protected nests	Nesting density (nests/km)
Campeche	Chacahito	62	7.8
	Chenkan	505	20.2
	Isla Aguada	557	20.0
	Isla Arenas	6	0.8
	Isla del Carmen	181	5.2
	Punta Xen	955	31.8
	Sabancuy	480	18.8
	San Lorenzo	64	64.0
Yucatán	Celestún	337	16.9
	El Cuyo	659	21.3
	Río Lagartos	247	11.5
	Sisal[1]	126	4.2
Quintana Roo	Isla Cancún[2]	13	1.3
	Isla Contoy[3]	49	9.8
	Isla Holbox	403	16.8
	Mahahual[4]	6	< 0.01

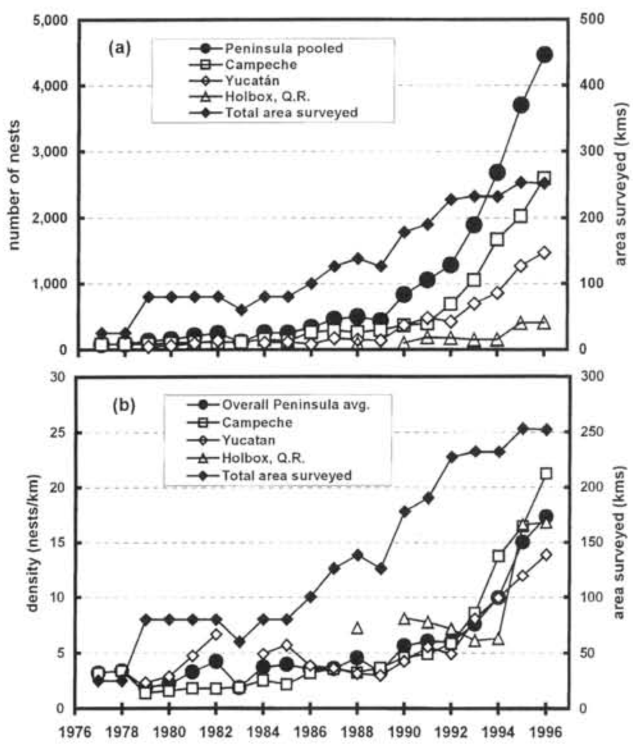

Figure 2. Number of hawksbill nests protected (**a**) and their densities (**b**) reported for the three states in the Yucatán Peninsula 1977–96. Total surveyed area is also indicated.

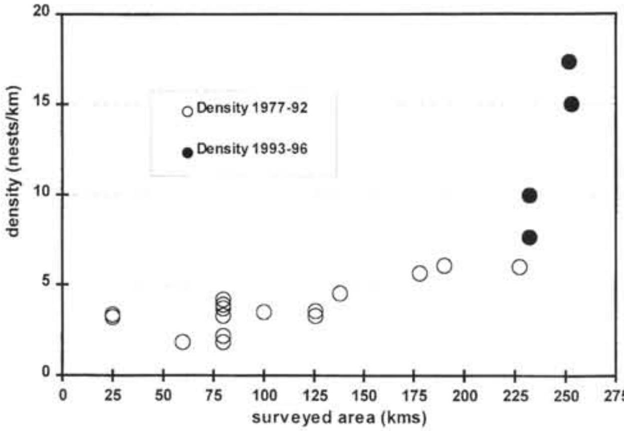

Figure 3. Changes in hawksbill nesting densities associated with the increase in surveyed area in protected beaches 1977–96.

periods (density = 3.00*year - 5978; $r^2 = 0.96$; t-value for regression coefficient = 9.32, $p < .01$) and independently of changes in beach coverage (Fig. 3). We suggest that the conservation actions have yielded real increases in the size of the breeding populations over the time period under study. A peak in the number of protected nests was reached in 1996 with 2590 reported for Campeche, 1467 for Yucatán and 465 for Quintana Roo, giving a pooled total of 4522 nests for the Peninsula. This is equivalent to a 56-fold increment relative to the number of nests protected in 1977 while the survey area increased only 7-fold (Fig. 2).

A case that illustrates the effects of increasing monitoring efficiency is El Cuyo, Yucatán, where 67 nests were reported in 1990 (Vázquez, 1993), clearly an underestimate caused by the lack of equipment and facilities. On the other hand, we assume that the increases in nesting density reported from 1991–93 when 200–300 nest were recorded (Rodríguez and Zambrano, 1991, 1992, 1993) to 1994–95 when over 500 nests were reported (Campos et al., 1995) are real, since surveillance effort was similar over that time span.

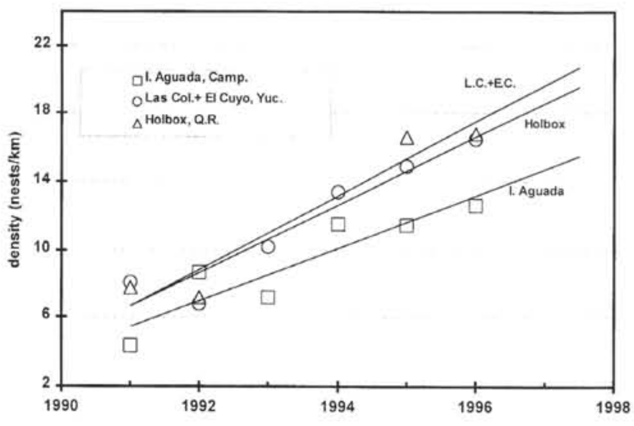

Figure 4. Hawksbill nesting densities at Isla Aguada, Campeche; Las Coloradas and El Cuyo, Yucatan; and Holbox, Quintana Roo; for the period 1991–96. Data from Las Coloradas and El Cuyo were combined since they are contiguous beaches. Data for Holbox for the 1993 and 1994 seasons were not included since there was irregular coverage. All regression slopes are positive ($p < .05$) and none differ significantly from each other ($p < .05$).

We analyzed the general trends in the nesting densities from pooled data for each state (Fig. 2b) and from four individual beaches where efficiency and coverage were constant and intense, at least from 1991 onwards (Isla Aguada, Campeche; Las Coloradas and El Cuyo, Yucatán; and Holbox, Quintana Roo; Fig. 4). Regression lines for individual beaches (Fig. 4) were positive and significant, reflecting real increases in reproductive output. We derived an average annual increase of 270 nests/year for 1992–96. Nest densities of more than 10–15 nests/km per season have been observed since 1995.

Number of Breeding Females

We derived estimates of number of nesting females per season at monitored beaches from nest counts (see Materials and Methods) using three different estimates of fecundity. This produced estimates for the Peninsula that ranged from 172–393 for 1990, to 942–2153 for 1996 (Table 2).

Calculation of between-season increases in number of breeders has to take into account that tagging studies have shown that hawksbills remigrate with a common periodicity of two to three years (Corliss et al., 1990; Hillis, 1994a, 1994b). In Las Coloradas, Yucatán, available data indicated 1% of studied nesters return at 1-year intervals, 65% every 2 years, 19% every 3 years, and 15% at > 3 years (Garduño, 1998); in Campeche the results are almost identical (Guzmán et al., 1995). This implies that interpretations derived from changes in inter-annual nesting activity would have to bear in mind the presence of different "cohorts" (these are apparent in the fluctuations in the nesting records from Isla Aguada; see Fig. 4). For the sake of simplicity, we adopted the most common 2-year remigration interval to derive an average annual increase of about 370–850 females per season between alternating years (1993–95 and 1994–96). Clearly, this figure is an approximation since it does not take into account that some females return to nest after three or more years.

Furthermore, since multi-annual remigration behavior entails that only a portion of the female breeding stock nests in any given year, we derived a *conservative* approximation of the full size of the female breeding stock by multiplying the estimated number of females nesting in the last season

Table 2. Number of reproductive females estimated from total regional annual nest counts and different estimates of fecundity — nests/female/season ([1] Garduño, in prep.; [2] Guzmán, *pers. comm.*; [3] Hoyle and Richardson, 1987).

Year	Total protected nests	Equiv. number of nesting females extrapolated from 2.1[1]	3.1[2,3] nests/female/yr	4.8[3]
1990	826	393	266	172
1991	1053	501	340	219
1992	1282	610	414	267
1993	1891	900	610	394
1994	2777	1322	896	579
1995	3697	1760	1193	770
1996	4522	2153	1459	942

reported (1996) by the most common remigration period (two years) to obtain 1900–4300 individuals for the Yucatán Peninsula.

DISCUSSION

In all, the beach coverage and resources that have been directed towards sea turtle conservation in the Yucatán are some of the highest for the Caribbean. Nonetheless, the increases in the numbers of hawksbill nests in the Yucatán had several causes, of which we consider the following to be the most significant:

(1) *Increased survival of juveniles, pre-adult, and adult phases brought about by conservation measures applied both in Mexico and in the region.*

Increases in these stages would have a profound and rapid positive impact on population dynamics as has been shown by mathematical modeling (e.g., Crouse et al., 1987). Various conservation measures have been effective in reducing mortality of these stages. Although the catch (direct or incidental) of sea turtles has not been totally eradicated in Mexico, it has been effectively reduced to a minimum through the various bans focused on the hawksbill since the mid-1970s and the total ban for all species established in 1990. Stiff penalties on the sale of hawksbills have discouraged exploitation by fishermen and tradesmen as well as the utilization by traditional artisans. Finally, the use of *carey* in articles for personal apparel (combs, hair grips, bracelets, rings) has been significantly reduced and replaced by plastics which are cheaper. Increased public awareness campaigns have also influenced both local and foreign buyers, diminishing the demand for hawksbill products.

In addition to new law-enforcement agencies brought in over the last decade, the mere presence of conservation programs on nesting beaches has made illegal take and commercialization of sea turtles much more difficult. A measure of the success for these measures are the number of hawksbill nesting sites that are now protected, and the consequent reduction in poached nests and take of turtles of all sizes. Furthermore, increasing numbers of juveniles in foraging sites in waters of the Peninsula can also be viewed as evidence of a resulting increased survival in pre-adult stages (Guzmán et al., 1993; Barrios et al., 1995; Guzmán, in prep.).

Mitigation measures implemented in other countries of the region may also have contributed if the population is shared. For example, there may have been a significant impact on the region's hawksbill populations by the changes in management of hawksbill harvesting in Cuban waters over the last 30 years (Carrillo et al., 1999). The take of around 4700 hawksbills per year of > 65 cm size-classes occurring in Cuba until 1991 was significantly reduced over the period 1992–95 to about 500 per year (Republic of Cuba, 1997; Carrillo et al., 1999). Migratory links between Yucatán and some Cuban habitats have been deduced both from the presence of Yucatán haplotypes in specific Cuban foraging areas subjected to historical harvests (Espinosa et al., 1998; Carrillo et al., 1999) and from the recovery in Cuban waters of a juvenile tagged previously in Yucatán (Garduño, 1998) The question remaining is what proportion of turtles breeding in Yucatán could have been affected by the Cuban harvest? While the limited amount of tagging and genetic data available do not provide sufficient information to evaluate possible impacts, we suggest they would be minor compared to the contributions afforded by local conservation measures in Mexico. Further precision will require additional tagging of juveniles and adults, as well as a more extensive genetic characterization of Yucatán populations and their relationships to regional stocks. Both of these investigations are currently being pursued.

Impacts from management practices in other international connections must also be studied from the same perspectives because the dispersal of hawksbills occurs in various directions and distances, even if in small proportions (Meylan, 1999b). Thus, post-hatchlings emerging from Yucatán beaches are believed to reach into coastal habitats of the USA (NMFS/USFWS, 1993), tagged juveniles have been recovered as far away as Nicaragua (Garduño, 1998), and some satellite-tagged females have been tracked from Yucatán nesting sites into international waters of the Caribbean (Byles and Swimmer, 1994). Similar behavior is observed in hawksbills in other areas of the Caribbean. For example, turtles of U.S. Virgin Islands origin have been recovered in eastern Puerto Rico, the British Virgin Islands, St. Martin, and St. Lucia (Boulon, 1989).

Another aspect that could be linked to increases in the survival rates of hawksbills is the reduction in many predator populations over the last decades. In general, elasmobranchs, serranids, lutjanids, and other groups that commonly prey on sea turtles of various sizes (but mostly smaller ones) have become greatly depleted in Yucatán waters (Bonfil, 1994; Pauly et al., 1998).

(2) *Increased recruitment into the reproductive stock resulting from hatchlings produced by local conservation programs.*

Times to sexual maturity in sea turtles are subject to controversy because of large differences in estimates obtained for the same species in different regions. For example, around 20 years for age-at-maturity are suggested from studies of Caribbean hawksbills (in the U.S. Virgin Islands and Puerto Rico: Boulon, 1983, 1994; Diez and van Dam, in prep.) which stands in contrast to the 30–40 years calculated for the Australian population in the Southern Great Barrier Reef (Limpus, 1992).

Preliminary studies of growth rates for juveniles in the feeding grounds off Las Coloradas, Yucatán, suggest they are high (on average 7.4 cm/yr for 24-65 cm SCL individuals), and extrapolations suggest hawksbills can reach 80 cm SCL (the smallest nesting size found on a Yucatán beach) in about 14 years and 90 cms SCL (average size) in about 24 years (Garduño, 1998). If we accept these growth rates, it would follow that some of the turtles that are recruiting today could have originated as hatchlings released by the earliest conservation programs. Yet, the contribution of this source of relatively increased hatchling production in areas free of poaching is impossible to quantify.

The increasing abundance of post-hatchlings and juveniles, noticeable over the last few years in monitored shallow feeding areas near the entrance and interior of Términos Lagoon (Guzmán et al., 1993; Barrios et al., 1995; Guzmán, in prep.), supports the concept of escalating recruitment into the population associated with increasing numbers of hatchlings released by the conservation camps. This is also reflected in the broad spectrum of juvenile size classes observed in Río Lagartos, Las Coloradas (20–65 cm; P. Castañeda, unpubl. data) that implies the presence of a wide range of ages in the population structure, and the increases observed in the proportion of nesters falling within smaller size-classes on Campeche beaches (Guzmán et al., 1993).

Reduction in egg consumption and availability in local communities, to a large extent brought about by increased beach monitoring and stronger law-enforcement plus impacts on habits through educational campaigns, will have also contributed significantly to increased hatchling survival over the last 19 years.

Management Implications

The observed increases in the hawskbill breeding population of the Yucatán Peninsula could not have been possible without the long-term management programs that involved a large group of interested parties (government, academic, NGOs, local communities) and focused not only on the nesting beaches but also on law-enforcement and public awareness campaigns. That these conservation measures, sustained over extended periods and applied to a large portion of the breeding population, can lead to encouraging increases in sea turtle populations is also found for other turtle species in Mexico: *Lepidochelys kempii* in Tamaulipas (Márquez et al., 1996a), *L. olivacea* in major Pacific beaches (Márquez et al., 1996b), and *C. mydas* in the Gulf of Mexico and Yucatán areas (Zurita et al., 1993; Guzmán et al., 1995).

The concurrent monitoring and data integration from the conservation projects has also been fundamental because only with robust information can population trends be identified and conservation strategies assessed. Our study was only possible with the level of stability, continuity, and monitoring coverage available particularly over the last 6–8 years. It now contributes a new and more complete baseline for future analyses of hawksbill breeding population trends both in the Yucatán and elsewhere in the Caribbean region.

Unless this conservation and monitoring capacity is maintained and supported, the long-term stability of hawksbill populations in the Yucatán Peninsula will still be threatened. It is very discouraging to note that some critical habitats are quickly being degraded or placed at risk. Increasingly, the development of tourist resorts of various dimensions, vacation homes, coastal roads, and other developments are transforming nesting beaches and increasing the destruction of reef environments, critical to the survival of hawksbills. Further, we consider that species-orientated conservation practices, though successful thus far, must become integrated into ecosystem or coastal-zone management in order that these threats be assessed and addressed appropriately. The true dimensions of impact that incidental catch by coastal fishing gear (e.g., gill nets) have on the hawksbill populations (particularly the juvenile stages) must also be assessed and addressed. On a regional scale, because hawksbill populations partake in extensive migratory routes through more than one country, close and careful collaboration between the scientific and management institutions of the range states will also be necessary to assume the shared responsibilities of a common resource. These should lead to a concrete regional management plan that incorporates recovery criteria and goals as well as priority actions in order that the effective and long-term sustainability of the species is guaranteed.

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