Trends of the Nesting Activity of the "Arribadas" of the Olive Ridley (*Lepidochelys olivacea*, Eschscholtz 1829), in the Ostional National Wildlife Refuge (1971-2003)

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Abstract. The nesting activity of the olive ridley sea turtle, *Lepidochelys olivacea*, was monitored at seven zones on Ostional and Nosara beaches, Ostional Wildlife Refuge, Costa Rica. A number of 257 "*arribadas*" were recorded throughout the years 1971–2003. One zone, the Mayor Nesting Beach (MNB), had more nesting activity; averaging eleven "*arribadas*" per year, while the others had only one or two in recent years. July and August had the highest frequency of *arribadas* at the MNB, with no statistical significance. In other zones, *arribadas* occur from July to December. From December to July, the average length of the *arribadas* was four days, contrasting with six in the other months. The size of the "*arribada*" (the number of females that enter the beach) in the MNB showed up and down events, with peaks in 1987, 1994, 2002 and 2003.

1 Introduction

The olive ridley, *Lepidochelys olivacea*, is regarded as the most abundant marine turtle in the world [1, 2]. Several hundreds of females crowd onto nesting beaches almost simultaneously to lay eggs, a phenomenon known as an *arribada* [3]. It is defined as the nesting synchronized of 100 or more sea turtles in one kilometer and in one night [4]. Each *arribaba* lasts several days. Large *arribadas* of *L. olivacea* take place in Surinam [5], México [6], Costa Rica [7] and India [8]. Smaller *arribadas* happen in Nicaragua [9] and Panamá [10].

The *arribadas* of olive ridleys are a recent discovery by zoologists. In 1963 the first one was described in Eilanti, Surinam [5]. In Costa Rica, the two massive nesting beaches are Nancite in the Santa Rosa National Park and Ostional in the Ostional National Wildlife Refuge. These *arribadas* were first described in the beginning of the 1970's [7], but the local people of Ostional report that the *arribadas* first appeared ten years before [4]. At the start of the seventies and the eighties *arribadas* were discovered in India, in the Orissa region [8].

Publish accounts of *arribadas* are rare [8, 11, 12]. However, the very phenomenon of *arribadas* seems to be endangered. Three out four nesting beaches in México disappeared due to over exploitation for meat and leather before scientists began to study them [3]. In the same way the Surinam *arribadas* disappeared in 1972, just five years after a study was begun on them [5]. These facts make information from other *arribada* beaches very important to understand and conserve one of the most impressive phenomena of massive reproduction in the animal kingdom. This paper presents information on the *arribadas* from the Ostional National Wildlife Refuge between 1971 and 2003. For this study we collected data on population size, duration of *arribadas*, spatial distribution and frequency.

2 Material and Methods

2.1 Study Site

The Ostional National Wildlife Refuge (ONWR) is confined to a small area in the Guanacaste province of Costa Rica (from 85° 43' 50" W, 10° 01' 00" N to 85° 40' 40" W, 09° 54' 30" N), corresponding to the marine-terrestrial zones of Ostional, Nosara, Peladas and Guiones beaches. A thin area of 200 m wide and 19 km long comprises it (Fig. 1). The ONWR belong to the life zone of the basal humid rain forest transition to dry forest [13]. The dry season lasts from December to April and the rest of the year is wet season. The annual mean precipitation is 2,100 mm, the annual mean temperature is 27.5 C ranged between 22 and 33 C [14].

The study took place on the Ostional and Nosara beaches, across two transects for a total of 7 km (Fig. 1). Both sites were marked with numbered posts every 50 meters (140 posts in total), beginning in the north zone (Rayo creek) and ending in the Nosara river mouth. The beaches were divided into seven zones in relation to the estuary incidence (Fig. 1). These zones are (the numbers between the parenthesis indicates the sectors included) Rayo 1 (1-17), Rayo 2 (18-29), Rayo 3 (30-39) and Rayo 4 (40-59): the Mayor Nesting Beach, MNB (60-78); in Nosara Beach, Nosara 1 (79-125) and Nosara 2 (126-140).

Throughout the beaches there are changes in the size of the berm or sand dune, in its inclination and the flora present. Also, there are several estuaries and mouths of streams and rivers [4] (Fig. 1). Rayo 1 is very sloped, the berm is short and it is cover with shrubs and beach grasses. There are three small estuaries: in sector 1, between sectors 8 and 10 and, between sectors 16 and 17. Rayo 2 and 3 do not have vegetation on the berm. At the edge of the beach there are almond trees (*Terminalia catappa*), majagua (*Hibiscus tiliaceus*), columnar cactus (*Stenocereus aragonii*) and beach grasses (*Ipomoea* spp). Abruptly the berm opens in sector 25 to a width of more than 20 meters. In the wet season the mouth of the estuaries creates gradients more than 2 m high in the sectors 29 to 32 and 41 to 47 (Biscoyol estuary). In Rayo 4 the vegetation is dominated by the spiny succulent *Bromelia pingui*, which is used by the people for building fences. The town of Ostional stretches from sectors 45 to 59. Again the people use spiny succulent fences, but they planted coconuts and almond trees too. A small estuary opens in the sector 58. There are no streetlights in the town and the house lights are hidden from the beach.

The Ostional estuary opens in sector 60, marking the start of the MNB, which ends with the Las Cocineras reef in the sector 78 (Fig. 1). A big mangrove swamp occurs here, composed predominantly of red mangrove (*Rhizophora mangle*) and black mangrove (*Avicennia germinans*). The beach has a low slope in this zone and the berm is wide, close to 30 meters in average, generally without vegetation. This zone has been well described previously [4, 15, 16].

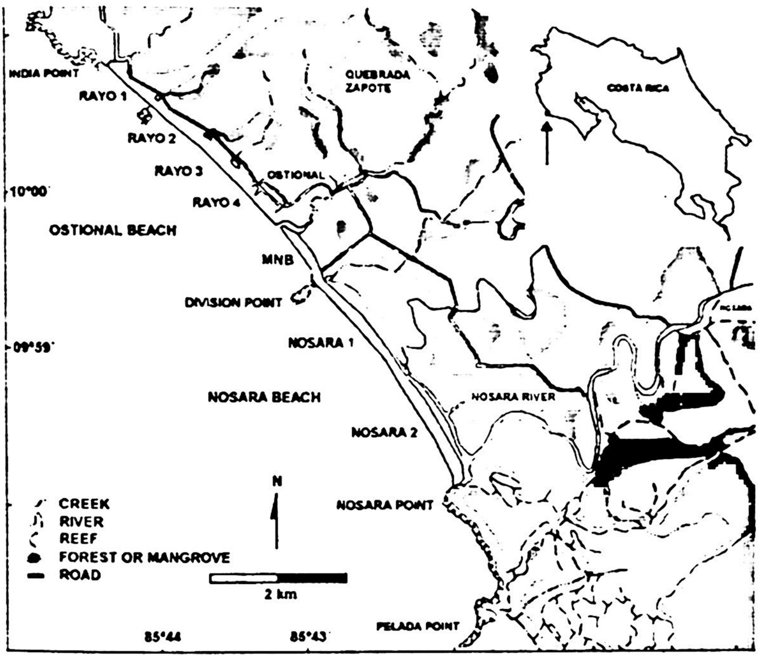

Fig. 1. Ostional National Wildlife Refuge map, showing the Ostional and Nosara beaches, and the zones established within them for data collection: Rayo 1-4, Major Nesting Beach (MNB) and Nosara 1 and 2

The last estuary opens in sectors 79 and 80 (Escondido estuary). Nosara Beach starts here. This beach is distinguished by having high slope and berm and is covered with vegetation, including spiny succulents, majagua and beach grasses. Much debris also is found here, including logs, tree branches and garbage from the Nosara River, making it hard to cross this part of beach. Mangrove vegetation occurs between sectors 95 and 140 because the Montaña River runs parallel and close to the beach (Fig. 1).

2.1 Data Collection

Only *arribadas* bigger than one thousand turtles are analyzed in this paper (with the exception of the July 1988 *arribada* with 800 turtles), as a result of the low number of years than those arribadas were monitored.

The frequency of the arribadas was measured as the total number of massive nesting events occurring per year and zones. By means of Kolmogov-Smirnov goodness of fit test we compared these frequencies by year for each zone. Using two-way ANOVA test we evaluated the variation in mean of *arribada* frequency by zone and by year, and then with least squared differences (LSD) test the statistical significance of this differences were analyzed. The trend in this variable throughout the study period was evaluated by mean of correlations. Using chi squared independent tests we compared the total number of *arribadas* by month, by year, and by zone.

The length of the *arribadas* is the number of days that the phenomenon occurred, no matter how many times the females nested in each day. By means of two-way ANOVA tests and LSD tests we evaluated the mean by year and month, in the same way described above for the *arribada* frequencies. Also, the trends in the length throughout the year were analyzed by means of correlation tests. The duration of the *arribadas* between the zones was compared with ANOVA test, LSD and tables of contingences.

Several methods were utilized to estimate the *arribada* size during the study period. From 1971 to 1981 the number of sea turtles were estimated by sight, no matter if the females made a nest or not. From 1982 to 1997 the number of nesting females were estimated by mean of the sampled of three quadrates of 300 square meters put in the berm and using the Cornelius and Robinson equation [17]. During 1998 we utilized the Valverde and Gates method, based on the instantaneous counting index [18]. This method estimated the actual number of nesting females. From 1999 to 2003 we utilized the instantaneous counting index modified by the authors (G. Chaves and R. Morera, unpublished data) to estimate the number of females entering the beach for the period of *arribadas* regardless of whether they nested. Under our modified method, a line transect of 15 by 890 m was established in the MNB in front of the beach, in the zone where the ocean waves soaked the sand. The numbers of sea turtles entering the beach, the initial and final sample time were recorded.

The transect was sampled every ten minutes in the MNB, only when many volunteers were present in Ostional we were able to collect data in the zones Rayo 2 to 4.

To estimate *arribada* size we used the following equation:

$$T = n*H/(4.2*c) \quad (1)$$

Where

T = Total of sea turtles estimated during the sampled time.

n = Sum of turtles sampled.
H = Period sampled (minutes).
c = Total of samples and
4.2 = Constant that represents the average of time that sea turtles remain in the sampled area.

It was not feasible to sample during all the *arribadas* each day. For this reason the next correction was applied:

$$C = m^{*}s. \quad (2)$$

Where
C = Total of sea turtles estimated during the sampled period.
m =Mean number of sea turtles per minute during the sampled period and
s = Total time per day that the *arribada* occurred (minutes).

The estimation was done for each day separately and the total size of *arribadas* was the sum of the estimations for each day.

The *arribada* size estimates were averaged among years only when the estimate was obtained by the same method. By means of two-way ANOVA and LSD test we compared these means for the Cornelius and Robinson estimates and the Chaves and Morera estimates independently. the rest of the estimation methods had few data to evaluate. The trend in *arribada* size throughout time was analyzed by means of a correlation test for each of the two methods.

The *arribada* size was also averaged by month for either method. Only the data from 1980 to 2003 were evaluated. because there was not enough data collected in the seventies. By means of two-way ANOVA and LSD test we compared the means among months. The *arribada* size between zones Rayo 2 and 4 and the MNB was estimated in 1988. 1999 and 2000. The former was estimated by sight and the others with the Chaves and Morera method. and for this reason these data sets were analyzed separately with two-way ANOVA and LSD tests.

3 Results

We recorded 257 *arribadas* between 1981 and 2003 in the MNB. There were no significant differences in the number of massive nesting events yearly in the MNB (Table 1). They tended to vary from 7 to 16 with a mean of 11.17 ± 2.29 (Fig. 2a). Commonly one *arribada* occurred every month. with an inter-nesting period of 30.72 ± 15.48 days. Peaks were presented in 1991 and 1997 with 16 and 15 *arribadas* respectively. with a drop in 2001 to only 7 *arribadas*.

Few *arribadas* occurred in Rayo 1 (0.13 ± 0.34 arribadas per year) and Nosara 2 (0.26 ± 0.75). with only 3 and 6 arribadas recorded throughout the monitoring period. Rayo 1 reported arribadas in 1985. 2002 and 2003 (Fig. 2b). while Nosara 2 only in the last four years (Fig. 2g).

Rayo 2 (1.35 ± 1.97 arribadas per year). Rayo 3 (1.65 ± 2.21). Rayo 4 (2.00 ± 2.45) and Nosara 1 (1.09 ± 1.98) accounted for 25 to 46 *arribadas* from 1981 to 2003. whereas in the eighties no more than 2 *arribadas* occurred in these zones. Since

1998 there were 3 to 8 arribadas per year (Fig. 2c-f), with significant differences among the years. There was a positive relationship among zones in the number of *arribadas* throughout the study period (Table 1).

Table 1. Results of the Kolmogorov-Smimov (KS) goodness of fit test and Pearson's correlations of the annual *arribadas* frequencies by zone of the Ostional and Nosara beaches between 1981 and 2003, in the Ostional National Wildlife Refuge. The degrees of freedom are 1 and 22 and the n = 24 for the correlation test

	Kolmogorov-Smimov Test			Correlation Test		
ZONE	KS	n	P	r	F	P
MNB	0.04	256	1.00	0.13	0.36	0.56
Rayo 1	0.58	3	<0.01	0.27	1.77	0.20
Rayo 2	0.58	39	<0.01	0.67	18.38	<0.01
Rayo 3	0.51	37	<0.01	0.64	15.28	<0.01
Rayo 4	0.44	47	<0.01	0.59	11.97	<0.01
Nosara 1	0.71	24	<0.01	0.62	13.71	<0.01
Nosara 2	0.83	6	<0.01	0.45	5.72	<0.01

The recorded number of synchronized massive nesting events per month that occurred in the MNB demonstrated a peak in July and August (Fig. 3a), although not significant (X^2 = 10.09 df = 11, P = 0.52), this means that the *arribadas* have a monthly period throughout the year, but sometimes this period is reduced to every two weeks or increased more than two months. On the other hand, the other zones showed arribadas predominantly between July and December (Fig. 3 b-g). The distribution of the recorded number of *arribadas* per month between those zones was homogeneous (X^2 = 16.91 df = 35, P = 0.996) that indicated that the phenomenon was synchronized in all zones at least during the wet season.

Among years, the average of the arribada duration showed a peak in 1991 (7.44 ± 10.84 days), and among other years it varied between 4 and 6 days (Fig. 4a), with statistical differences between them (F= 4.44, df = 22/267, P << 0.00). This variable tended to have up and down changes throughout the study period (Fig. 4a). For this reason there was no correlation between the time and the duration of arribadas (r = 0.38, F = 3.61, df= 1/21, P = 0.07).

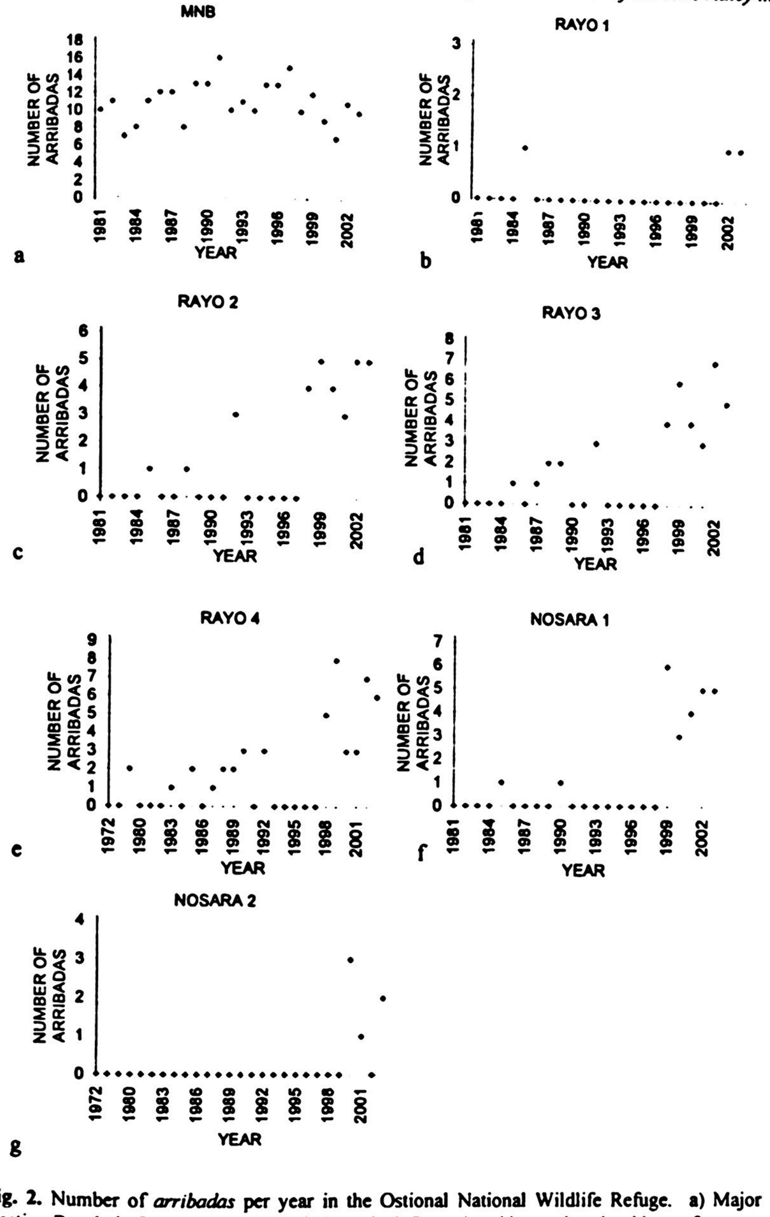

Fig. 2. Number of *arribadas* per year in the Ostional National Wildlife Refuge. a) Major Nesting Beach, b) Rayo 1, c) Rayo 2, d) Rayo 3, d) Rayo 4, e) Nosara 1 and g) Nosara 2

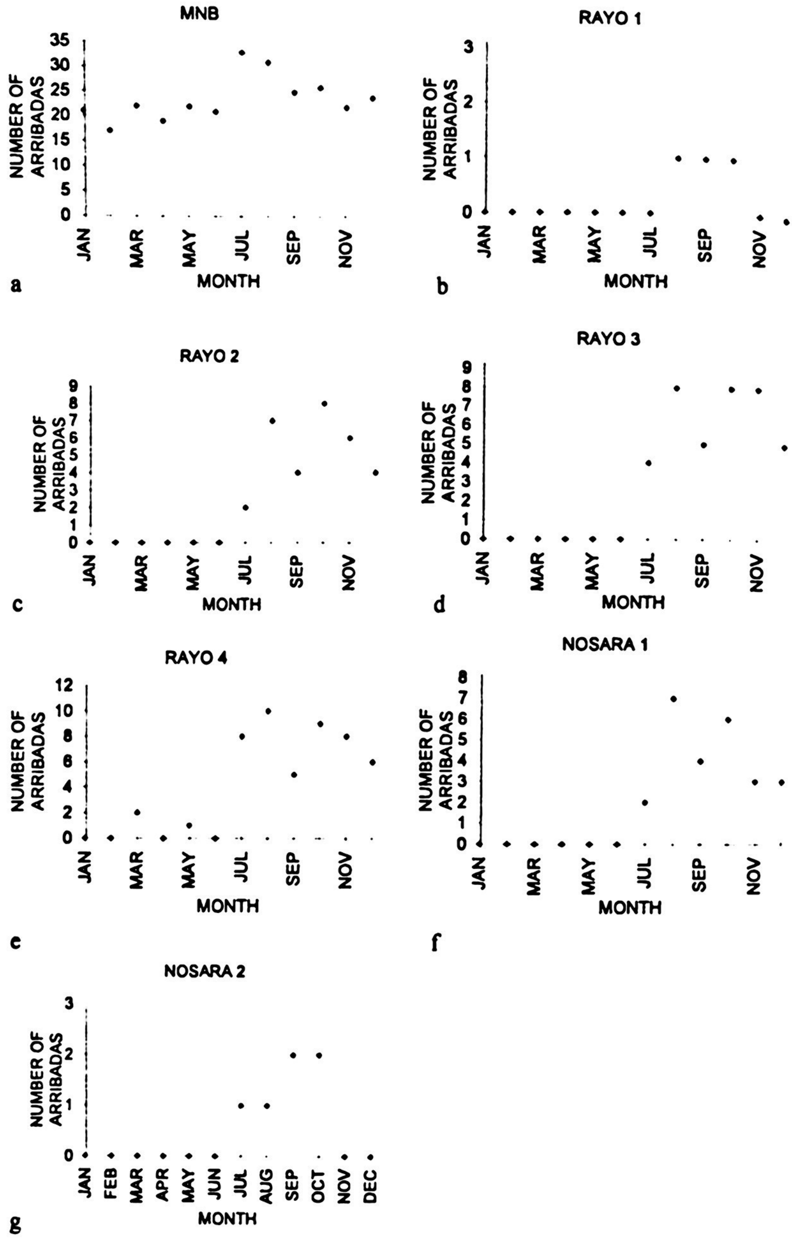

Fig. 3. Cumulated of the number of *arribadas* in each zone of the Ostional National Wildlife Refuge. between 1975 and 2003. a) Major Nesting Beach. b) Rayo 1. c) Rayo 2. d) Rayo 3. d) Rayo 4. e) Nosara 1 and g) Nosara 2

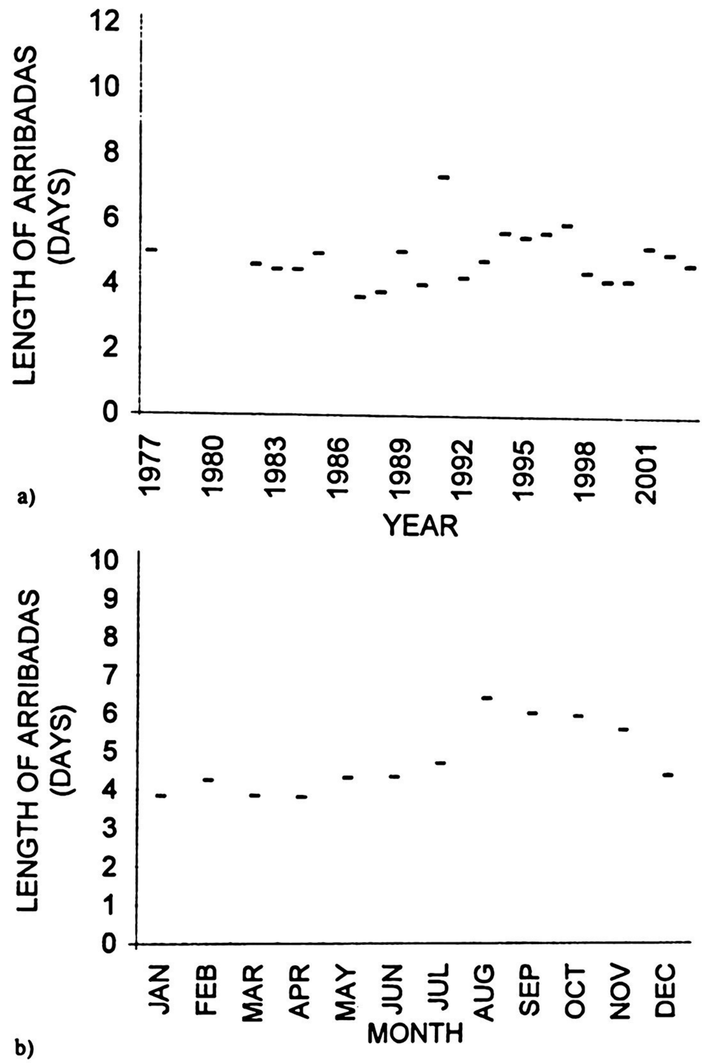

Fig. 4. Annual (a) and monthly (b) average and standard deviation of the duration of *arribadas* in the Major Nesting Beach of the Ostional National Wildlife Refuge during 1977 to 2003. For the years 1978 to 1981 and 1986 there were no data

Within years, there were significant differences among months of *arribada* duration (F = 6.30, df 11/261, P < 0.00). Two periods with similar variance were found (Fig. 4b). From December to July occurred the lower mean (4.20 ± 0.33 days), and in the rest of the year the larger mean duration (6.04 ± 0.33).

Since 1980 to 2003 the annual average *arribadas* size in the MNB varied between 33,000 and 130,000 sea turtles (Fig. 5). There were several up and down movements in mean *arribadas* size throughout the monitoring period and the differences between them had statistical significance (F =2.35, df = 12/87, P = 0.01). There were no correlations between this variable and the time (r = 0.36, F = 1.97, df = 1/11, P = 0.18). Between 1982 and 1987 there was tend to increase, but the mean dropped suddenly in 1988. In 1994 the mean increased, but decrease again between 1995 and 1997 (Fig. 5).

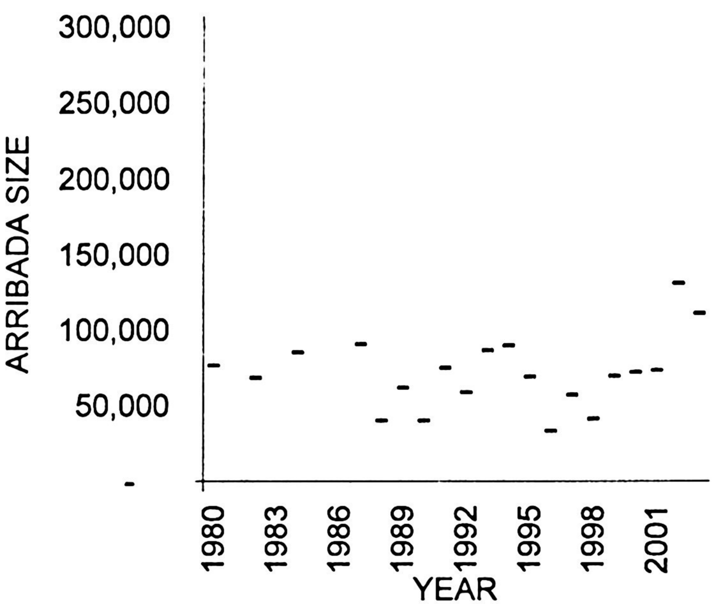

Fig. 5. Average and standard deviation of the number of sea turtles per *arribadas* and year in the Major Nesting Beach of the Ostional National Wildlife Refuge during 1980 to 2003. There were no data for 1981, 1985 and 1986. In 1988 another method was used. Between 1980 and 1987 was used the Cornelius and Robinson methodology [19]. To 1998 some arribadas were estimates with the Valverde and Gates method [18] and other with the first method and for this reason it was no included. Between 1999 and 2003 the Chaves and Morera method described in this paper were used.

During 1982 to 1997 there was high variation in the monthly size average of the massive nesting (Fig. 6a) with statistical differences between them (F = 6.88, df = 11/87, P < 0.01). Two groups of similar variance were found. Between December and July the average was smaller (58.872.02 ± 24.231.31) than to the rest of the year (13,6748.29 ± 24.324.98).

From 1999 to 2003 the annual mean *arribada* size demonstrated that the first three years had lower means than in the 2002 and 2003, but the differences were not significant (F = 1.20, df = 4/43, P = 0.32) (Fig. 5). The monthly mean *arribada* sizes between 1999 and 2003 (Fig. 6b) show no statistical differences (F = 5.53, df = 11/43, P < 0.01). However, two groups of significant variance were produced again. Between December and August the arribadas size average was lower (78,161.05 ± 70,771.29) than in the rest of the year (214,118.73 ± 11,259.72, Fig. 6b)

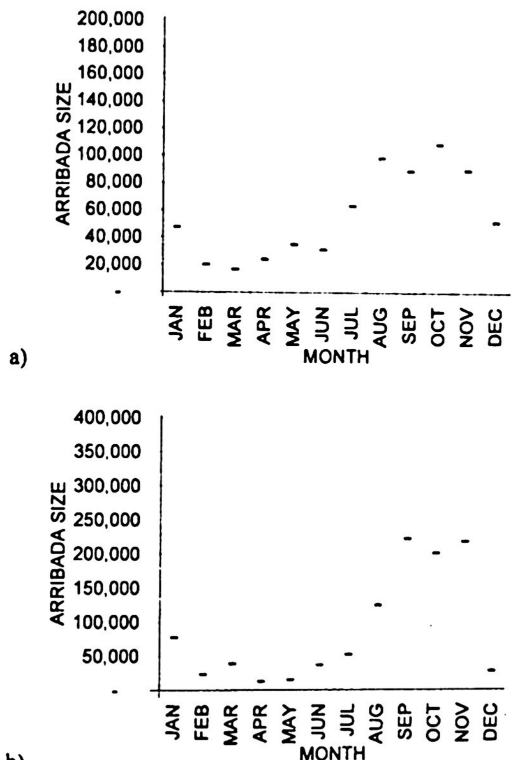

Fig. 6. The annual average and standard deviation of the *arribadas* size in the Major Nesting Beach of the Ostional National Wildlife Refuge. a) 1980 to 1997, b) 1998 to 2003

Comparing the *arribadas* size among the zones of the beach in 1999 and 2000, we found that the MNB had lower numbers of turtles, while the Rayo 3 had more (Fig. 7), however the differences were not significant (F = 0.14, df = 1/3, P = 0.72). For the November 1988 *arribada*, we estimated 11300 females in the MNB, while in the Rayo 4, 3 and 2 we estimated 100.000, 70.000 and 50.000 turtles, respectively. Those results remained the same relationship between the MNB and the others zones found in 1999 and 2000.

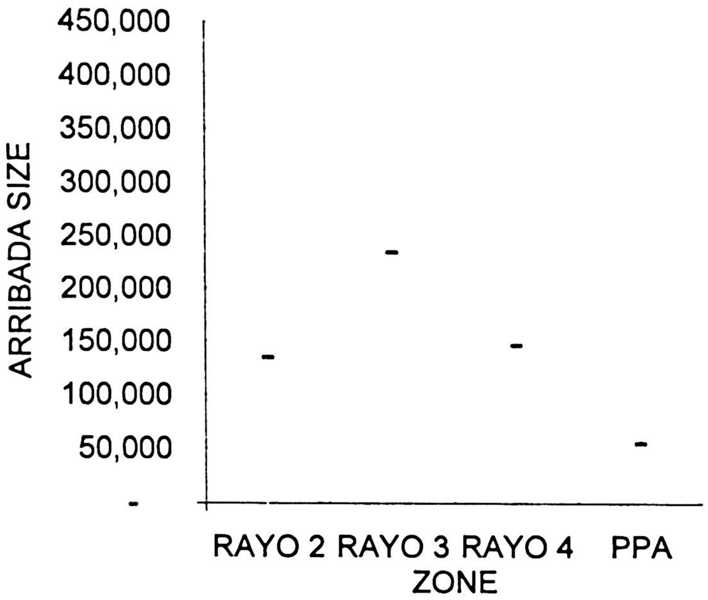

Fig. 7. Average and standard deviation of the number of sea turtles per *arribada* in the Rayo 1 to 4 and the Major Nesting Beach of the Ostional National Wildlife Refuge, for the August and November 1999 and November 2000 *arribadas*

4 Discussion

The olive ridley has an average inter-nesting time of 17 to 30 days in the solitary populations and 45 in others arribadas populations [20]. In Ostional this period is close to monthly, similar to the solitary populations. Locals in Ostional told us that between 1970 and 1974 there were more frequent *arribadas*, with two weeks inter-nesting intervals. Dr. Douglas Robinson, principal of the former Sea Turtles Program of the Universidad de Costa Rica, noted the same about the behavior of the arribadas in the same time [4]. Only in 1991 and 1997 several *arribadas* occurred every two weeks.

The synchronized massive nesting activity of the ridleys in Ostional refuge occurs throughout year, with peaks between July and August. This pattern is new in this beach, because in the seventies the true *arribadas* occurred between August and February, and between March and July only some hundreds of turtles were present during some days each month [11]. In the beginning of the eighties the arribadas started in April and ended in December [21]. On Nancite Beach a similar condition was occurring in the seventies, with *arribada* periods between August and December [11]. In India were reported only one or two arribadas every year [8]. In Escobilla, Mexico, until 1990 the *arribadas* happened nearly all year round, from May or June to February [22]. In Suriname the nesting season occur between February and August, with a peak in May or June [5]. In the American Pacific the nesting season begins in July and ends in February for the solitary ridleys populations, and reaches its peak in September or October [1]. The yearly nesting activity in Ostional is unusual, because there are high mortality rates of the eggs between March and June due to the high temperatures on the beach [23] and for this reason natural selection against this behavior should be strong and would tend to be eliminated.

The average length of the *arribadas* in Ostional is 4.78 ± 1.02 days. However, the total time throughout the year for 11 arribadas is 47.56 ± 22.51 days, seven fold than in India with only two *arribadas* and 7.37 ± 9.03 days based on the data in the table 3 of Shanker et al. 2003.

The most important finding in Ostional was the amplification of the *arribada* area, and the new zones showed bigger *arribada* sizes that the MNB, however they only occurred during the wet season. This behavior contrasts with the trends in other *arribada* beaches in the world where the tendencies are towards decline and extinction [3, 12, 24]. For example in Orissa, India, three important beaches lacked massive nesting activity in 1997 and 1998 [8]. In Gahirmatha Beach, India, a cyclone left only 4 km available for *arribadas* [25], and there were no *arribadas* in 1997 [24]. However, the causes for this increase in Ostional are not clear and are paradoxical because it is the only *arribada* beach with a management program that include eggs harvest since 1987 [17, 26, 27].

Concerning the *arribada* sizes in the MNB we found that between 1980 and 1997 turtle numbers showed the typical up and down fluctuation that is common in many animals populations [28]. The factors that explain these changes are unknown but some possible causes include the fact that only a small part of the female population nests each season, variation in the physical condition of turtles, variation in food supply, and geography position in relation to the nesting beach, etc. [20]. The mortality of young and adult individuals by incidental and direct fishing activities can play an important roll, too [29].

The size of the *arribadas* in the last four years show increases never seen before mainly in relation to the increase of the nesting area. For example the October *arribadas* in 1999 and 2000 had an estimated 772,576 and 1,235,459 females for the zones MNB and Rayo's zones but not including the Rayo 1 and the Nosara zones. These estimates are bigger than those reported from India [8], however the methods used to estimated the *arribadas* are different.

This increase in *arribadas* size contrasts with the situation in other *arribada* beaches. For example in Suriname the massive nesting events changed from 2450 females in 1967 to less than 1000 turtles since 1973 and this tendency continued into the nineties [5]. In Gahirmatha, India, is reported 694.500 sea turtles yearly in the eighties, followed by a decline to 339.500 in the period 1993-1994, and 290.000 females in the 1995-1996 period, without signs of recovery at the present [30]. In Rushikulya, India, since 1995 -1996 there were more than 60.000 females yearly, but in 1997-1998 period it declined to 8.500 sea turtles [30]. In Escobilla, Mexico the number of nests produced annually tended to decline between 1973 and 1988, with a peak in 1975 (295.000 nests). However in 1994 a sudden increase to 718.800 nests occurred [22]. In Nancite Beach, Costa Rica, the decline appeared in the beginning of the eighties [4], and continued in the nineties [12]. At the same time this beach is among the most protected beaches in the world, because there are no human populations close to it and, it is inside the Santa Rosa National Park [3].

Some researchers have the opinion that the increase in the *arribadas* in Ostional can be explained by migration of closer populations, like Nancite Beach (Didiher Chacón, personal communication) that underwent a decline in the nineties [12]. However the tagging program performed at both beaches in the seventies and eighties show that only 56 out 7.000 recaptures corresponded to interchanges between the beaches [31]. Also, only one solitary ridley had found during the *arribadas* in eight years of research [31]. This means that the migrations between beaches are low, and there is no evidence that this behavior changed recently.

On the other hand, it is possible that the combination of strict monitoring of egg harvesting and the application of protection practices, such as keeping out predators of eggs and hatchlings, cleaning the beach every month, and, lastly, the absence of direct fishing (although the incidental fishing can play some roll at this time) probably are producing positive effects in the population trends. Similar tendencies are present with the same species in Escobilla Beach [22], and in Rancho Nuevo with the Kempi ridley (*Lepidochelys kempii*) [32].

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Part II

Environmental Information Systems