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SISTEMA DE ESTUDIOS DE POSGRADO

TENDENCIA POBLACIONAL Y ÉXITO DE ECLOSIÓN DE
LAS ANIDACIONES MASIVAS DE TORTUGAS LORA (*Lepidochelys
olivacea* ESCHSCHOLTZ 1829) EN EL REFUGIO NACIONAL DE
VIDA SILVESTRE DE OSTIONAL, GUANACASTE

Tesis sometida a la consideración de la Comisión del Programa de Estudios de
Posgrado en Biología para optar al grado de Magister Scientiae en Biología

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Dedicatoria

Este trabajo está dedicado a la memoria del Dr. Douglas Robinson

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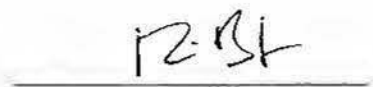
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Resumen General

La tortuga lora, *Lepidochelys olivacea*, es considerada la más abundante de las tortugas marinas en el mundo (Márquez 1996, Pritchard 1997). Algunas veces cientos de hembras se agrupan sobre una playa casi simultáneamente a anidar (Carr 1992), un fenómeno conocido como flota en Costa Rica y como arribada en México, este último nombre es con el cual se conoce en la literatura científica (Carr 1992) y que en el resto del documento se usará para designar el fenómeno. La arribada es definida (Cornelius et al. 1991) como la sincronización de 100 o más tortugas para anidar en un kilómetro de playa por noche. Las arribadas pueden durar por varios días. Se han registrado grandes arribadas de *L. olivacea* en varias playas de México (Márquez et al. 1976), Costa Rica (Richard y Hughes 1972) y la India (Shanker et al. 2003). También es posible encontrar pequeñas arribadas en Nicaragua (Ruiz 1994) y Panamá (Cornelius 1982).

Los zoólogos descubrieron la arribada sólo hasta mediados del siglo veinte (Carr 1992). La primera fue descubierta en 1963 en Eilanti, Surinam (Reichart 1993). En Costa Rica, las dos playas de anidación masiva se encuentran en la provincia de Guanacaste. Una de ellas localizada en Nancite dentro del Parque Nacional Santa Rosa y la otra en Ostional, dentro del refugio nacional de vida silvestre del mismo nombre. Ambas fueron descubiertas simultáneamente en 1970 durante recorridos aéreos (Richard y Hughes 1972), pero los habitantes de Ostional, que viven en la región desde hace más de 100 años (Chavarría 2002), indican que a finales de los años sesenta empezó el fenómeno en forma súbita (Cornelius et al. 1991). A mediados de los setentas las arribadas fueron descubiertas también en la India, en la región de Orissa (Shanker et al. 2003).

La importancia del conocimiento del tamaño y tendencias de las poblaciones de tortugas marinas es fundamental para formular las políticas de manejo adecuadas para su conservación. (Eckert 2000). A pesar de lo impresionante que es el fenómeno arribada, son raras las publicaciones sobre ellas (Richard y Hughes 1972, Hughes 1976, Cornelius et al. 1991, Márquez et al. 1996a, Márquez et al. 1996b, Valverde et al. 1998), y más extraños aún son los que incluyen monitoreos a largo plazo (Márquez et al. 1996a, Márquez et al. 1996b, Valverde et al. 1998). Existe sin embargo mucha información en reportes no publicados. La mayoría de estas publicaciones sugieren que las poblaciones de arribada están en declinación (Pritchard 1997). Las tortugas han dejado de anidar masivamente en tres de las cuatro playas de arribada en México (Carr 1992). La arribada de Surinam desapareció casi por completo para 1972, a tan sólo cinco años después de ser descubierta (Reichart 1993). La India tampoco está exenta de problemas, pues todas sus arribadas han sufrido un severo decline en los últimos años (Shanker et al. 2003), debido la pesca incidental (Behera 2000) provocada por el incremento de la mecanización de la pesquería (Kocherry 2000). En Costa Rica la población de Nancite empezó a declinar al inicio de los años ochenta (Valverde et al. 1998), por razones aún desconocidas.

Ostional es la única playa de anidación masiva que está sometida a un manejo a través del uso sustentable de los huevos de la tortuga lora (Cornelius et al. 1991) y desde que se descubrió ha sido considerada como una de las mayores del mundo (Carr 1992). La población ha sido monitoreada desde 1970 y un total de 294 arribadas han sido registradas hasta el 2006, aunque sólo 25 se pudieron estudiar en los años setentas por problemas de transporte principalmente, dado que la zona era muy poco accesible. El número de arribadas por año tiende a variar entre 7 a 16, para un promedio de 10.87 ± 2.22 eventos y no presenta una tendencia a crecer o a disminuir a

través del tiempo. Sin embargo la frecuencia de arribadas en las áreas fuera de la Playa Principal de Anidación (PPA) si han tendido a incrementarse a través de los años.

Comúnmente ocurre una arribada cada mes con un periodo entre anidaciones de 30.87 ± 14.72 días. El promedio en la estación seca fue mayor que en la estación lluviosa (estación seca 37.08 ± 14.02 , estación lluviosa 28.62 ± 14.36 días). El intervalo de tiempo entre arribadas disminuyó paulatinamente a partir del año 2000. En los meses de julio y agosto es muy frecuente que ocurran dos arribadas cada mes y durante el periodo de estudio fue frecuente que al menos en un mes de cada año no ocurriera del todo la arribada, sin embargo no hay ninguna tendencia a que esto ocurra en un mes en particular.

Antes de 1985 las arribadas se producían esporádicamente fuera de la PPA, pero en los últimos 20 años se ha dado una tendencia a aumentar la frecuencia de ellas en esas áreas, aunque ocurren principalmente durante la estación lluviosa. Son las zonas más próximas a la PPA las que mantienen una mayor frecuencia de arribadas, mientras que en los extremos de la playa Ostional y Nosara ocurren una o dos anidaciones masivas al año.

Las arribadas duran entre uno a catorce días. Durante los primeros seis meses el promedio de duración de las arribadas fue más corto (3.50 ± 0.18 días) que en el resto del año (5.45 ± 2.37 días), siendo las de agosto a noviembre las de mayor duración (6.25 ± 0.13 días). En la PPA las arribadas tienden a durar más días que en el resto de la playa (5.45 ± 2.37 días), y en los extremos de la playa duran menos de 3 días normalmente. También se encontró que la duración de las arribadas tendió a incrementar a lo largo del periodo de estudio

En cuanto al tamaño de las arribadas, en los años setentas se estimaban arribadas de varias decenas de miles de tortugas, suficientemente grandes como para promover la pesca industrial de tortugas en México y Ecuador, zonas de alimentación de las colonias de anidación costarricenses (Cornelius 1983). El tamaño de las arribadas varió entre 40,000 y 111,000 tortugas entre 1981 a 1997, sin embargo en la estación seca llegaron a sumar solamente 4000 animales. El promedio anual de tortugas por arribada varió mucho, pero no se observa una tendencia a incrementar o a disminuir durante este periodo. Entre 1999 y 2006 el tamaño de las arribadas sufrió cambios aún más drásticos que en los años anteriores, pero aún así no hay una tendencia definida en estos cambios. A partir de la experiencia de campo, creemos que durante el año 2002 se presentaron las mayores arribadas en la historia de Ostional, en donde el número de tortugas por arribada superaba fácilmente varios cientos de miles (hasta 700,000 hembras en cuatro kilómetros). El número de hembras que trataban de anidar era de tal magnitud que muchas de ellas se internaron tierra adentro varios cientos de metros, en donde trataron de anidar en los jardines de las casas, plaza de fútbol e inclusive el bar. Muchas de ellas murieron atrapadas en la vegetación, a pesar de los esfuerzos para rescatarlas por parte de la comunidad de Ostional.

Del monitoreo de la población anidadora de tortugas lora en Ostional se puede concluir que ha aumentado debido a que el área usada por ellas durante los eventos de anidación masiva ha crecido; se ha incrementado la frecuencia de las arribadas y reducido el intervalo de días entre anidaciones, por último el número de tortugas que llegan a la PPA no ha mostrado un declive nunca y más bien es en años recientes que se han obtenido los números más altos de tortugas. La estabilidad de esta población se ha conseguido a pesar de que la alta densidad de tortugas produce gran mortalidad

de nidos, debido a que muchas de ellas anidan en el mismo lugar destruyendo los nidos previamente depositados.

Los estudios del efecto de la densidad en la regulación de las poblaciones de tortugas marinas son muy escasos (Miller 1997). Esto es debido a que la mayoría de las poblaciones se componen de unos pocos cientos de tortugas por temporada (Heppell et al. 2003), a pesar que históricamente se sabe que muchas especies mantenían grandes poblaciones (Hildebrand 1982, Ross 1982, Carrillo et al. 1999, Huxley 1999, Meylan 1999, Chaloupka 2001). Hoy en día sólo en el género *Lepidochelys* (Carr 1992) y *Chelonia* (Bjorndal et al. 1999) es que se presentan poblaciones de varios cientos de miles de tortugas. Algunas poblaciones de *Dermochelys coriacea* (Girondot y Fretey 1996) y *Caretta caretta* (Ross y Barwani 1982) pueden alcanzar algunas decenas de miles.

Durante una arribada entre el 20 al 40% de las tortugas destruyen otro nido mientras anidan (Cornelius et al. 1991). Dado que en Ostional las arribadas ocurren con una frecuencia mensual, y en algunas ocasiones quincenalmente (Cornelius et al. 1991), la posibilidad de que un nido sufra el impacto de otra arribada es grande. Evaluando esta situación para 202 arribadas, se encontró que el 80% de ellas fueron impactadas por al menos una arribada. La gran destrucción de nidos provocada por las tortugas anidando en el mismo sitio de la playa, reduce el número de nidos hasta un 30% durante el periodo de incubación. Los nidos que son parcialmente destruidos por otras tortugas presentan problemas de supervivencia, debido a que algunos de sus huevos se pueden cambiar de posición y afectar al embrión o se pueden quebrar.

La destrucción parcial de los nidos por parte de otras tortugas produce que las cámaras de nidos se unan, de forma tal que el número total de huevos que se incuban en un mismo sitio de la playa se incrementa. El incremento en la masa de huevos

hace que se reduzca el intercambio gaseoso y se incremente la temperatura (Ackerman 1980). Al ocurrir esto se incrementa el periodo de incubación, exponiendo a los nidos por más tiempo a factores adversos, como la depredación, erosión y otras arribadas. En Ostional se encontró que el 23.91% de los nidos en las arribadas estaban traslapados. Pero aún los nidos no traslapados tenían un 13.67% de huevos destruidos, probablemente por depredación. Los nidos traslapados ocurrieron principalmente en la zona media de la playa. El traslape de nidos redujo el número de huevos con desarrollo embrionario significativamente, y durante el periodo de eclosión también presentaron una tendencia a reducir el éxito de eclosión.

Se han registrado densidades de entre 7 a 14 nidos por metro cuadrado en Ostional (Cornelius y Robinson 1983), siendo el espacio para incubar afectado por la densidad. Estos nidos además de producir una mayor atracción para depredadores, tienden a sufrir mayor mortalidad dado que el embrión se puede desprender por gravedad o por traumatismo (Ewert 1979), rompiéndose sus vasos sanguíneos. Por otra parte se ha observado que los huevos afectados tienden a incrementar la mortalidad al resto de la nidada (Hill 1971). Durante el estudio de 76 arribadas entre 1998 hasta el 2006 se encontró que la densidad de nidos en Ostional fluctúa entre 0 y 14 nidos, con una densidad pico en octubre y noviembre (2 nidos/m²). A través de la playa, la zona central de la PPA presentó la mayor densidad de nidos (1.19 nidos/m²). El área de la playa cercana al estero Ostional y la zona baja de la berma presentaron las más bajas densidades de nidos.

El porcentaje de huevos con desarrollo embrionario varió entre un 80% al 40% y tendió a disminuir en la medida que aumentaba la densidad de nidos en la playa. El porcentaje de éxito de eclosión (> 30%) tendió a incrementarse hasta una densidad de cuatro nidos, luego de la cual se redujo paulatinamente. Sin embargo la variación no

fue estadísticamente significativa. La falta de significancia se puede deber a la gran destrucción de nidos que ocurre durante el periodo de incubación, la cual reduce la densidad de nidos al momento de la eclosión, y no permite evaluar adecuadamente el efecto de la densidad. Los huecos cuyos nidos tenían la menor viabilidad fueron aquellos en donde se presentaban más de cuatro nidos agrupados, sin embargo al momento de la eclosión no se encontró ningún hueco con más de tres nidos.

La gran destrucción de nidos durante las anidaciones masivas, produce una gran cantidad de residuos de huevos (llamados aquí nidos viejos), los cuales se acumulan bajo la arena por varios meses (Cornelius et al. 1991, Márquez 1996) . Mientras anidan las tortugas tratan de eliminar la mayor cantidad de desechos presentes en el hoyo excavado (Ehrenfeld 1979), sin embargo cuando las densidades de desechos son muy grandes es probable que haya un efecto sobre el desarrollo de los huevos. Es probable que estos desechos puedan afectar las condiciones físicas de la playa (Bjorndal y Jackson 2003), además de incrementar los problemas con patógenos (Mo et al. 1995), y de atraer depredadores (Brown y Macdonald 1995). La densidad de nidos viejos en Ostional varió entre 0 a 24 nidos, pero normalmente se presentaron densidades menores de 10 nidos viejos. A través del año la mayor densidad de nidos viejos (2.77 ± 3.86 a 8.14 ± 3.02) ocurre durante los meses de enero a agosto. Sufriendo una drástica reducción durante las grandes arribadas de la estación lluviosa. La mayor densidad de nidos viejos se presenta en la zona central de la PPA, mientras que en el área cercana al estero y en la parte baja de la berma ocurren las menores densidades. El éxito de eclosión tendió a reducirse en relación con el aumento de la densidad de nidos viejos, sin embargo el porcentaje de huevos en desarrollo mostró una variación irregular con respecto a la densidad de desechos. En este caso es muy probable que la presencia de nidos viejos no afecte inmediatamente

el desarrollo de los embriones, al igual que ocurre con otros factores como la alta temperatura y la desecación, los cuales permiten que algunos huevos vivan solo la primera semana de vida (Chaves 1986). Sin embargo durante la incubación estos residuos depositados en la parte baja del nido, pueden provocar que la dilución de la sal de la playa se reduzca debido a la dificultad de circular el agua en la arena contaminada (Foley et al. 2006). Altos niveles de salinidad reducen la habilidad de los huevos de absorber agua y reducen la humedad en la cámara de huevos (Miller 1985).

Al bajo éxito de eclosión de las anidaciones masivas ha sido atribuido el declive de algunas poblaciones (Cornelius et al. 1991, Márquez 1996, Girondot et al. 2002). Sin embargo en Ostional, porcentajes de emergencia de crías menores al 10%, representan varios cientos de miles de crías por arribada (Cornelius et al. 1991). Esto representa más de un millón de crías al año. La estabilidad de la arribada en Ostional, y su expansión a las zonas aledañas a la playa principal de anidación, puede indicar que este número de crías producidas es suficiente para mantener la población actual

En las áreas cercanas al estero y en la parte baja de la playa, se observa una baja densidad de nidos y desechos de huevos al tiempo que se incrementa la viabilidad de los huevos, lo que indica que las áreas más expuestas a la erosión por el río y por el oleaje favorecen la producción de crías. Estas áreas son efectivamente más utilizadas por la tortuga lora para anidar (Loveridge 1946, Márquez 1996). Durante los últimos ocho años solamente una arribada no ha utilizado el área cerca de los esteros para anidar, el 76% de los días que ocurre la arribada, la anidación está ubicada en esta zona. Las arribadas además tienden a iniciar en el área cercana al estero. Deraniyagala (Loveridge 1946) ha sugerido que la presencia de grano fino y la dilución de la sal por la influencia del agua del estero es un factor que hace que la tortuga lora seleccione estas zonas para anidar. Cornelius et al. (1991) proponían que el continuo

lavado que sufre la arena cerca de los esteros y en la parte baja de la playa, hace que se reduzca la cantidad de patógenos (hongos y bacterias), por lo que se incremente el éxito de eclosión de los nidos incubados ahí. Los resultados de esta investigación indican además que la reducción en el número de nidos trasladados y en general la reducción en la densidad de nidos y desechos de huevos, permite una mayor viabilidad de los huevos sobrevivientes a la erosión.

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Apéndice 1

En formato de artículo científico para ser sometido a la Revista Ecology

Trends of Mass Nesting Events ("arribadas") of the Olive Ridley (*Lepidochelys olivacea*, Eschscholtz 1829) in the Ostional National Wildlife Refuge, Costa Rica (1970-2006)

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Abstract. The nesting activity of the olive ridley sea turtle, *Lepidochelys olivacea*, was semi-continuously monitored at seven sites on Ostional and Nosara beaches, Ostional Wildlife Refuge, Costa Rica for 36 years. A total of 294 mass nesting events or arribadas were recorded between 1970 and 2006. The average size varied during the dry season between 1,000 to 50,000 turtles and from 40,000 to 200,000 turtles in the wet season. The turtles used the Main Nesting Beach (MNB) more intensively through the study period, averaging eleven arribadas per year. Arribada frequency and size have increase over the years. They were greatest in the rainy

season and two events per month are now common during this time. The most important changes in the nesting behavior of the mass nest events took place after the middles of the eighties. First, the arribadas started to occur in times other than the regular nesting season, becoming in a year-round nesting population; second, they gradually expanded from the MNB to the other sites, and now cover all the seven kilometers of the beach, at least during the wet season. In spite of the size increase, the arribada in the MNB exhibited great fluctuations through the study period. They never have declined, as has occurred in all the other mass nesting sites around the world.

Keywords: Reptilia, Testudinata, *Lepidochelys olivacea*, arribada, nesting activity, Costa Rica

Introduction

The olive ridley, *Lepidochelys olivacea*, is regarded as the most abundant marine turtle in the world (Márquez 1996, Pritchard 1997). Sometimes hundreds of females crowd onto a nesting beach almost simultaneously to lay eggs (Carr 1992), a phenomenon known in Costa Rica as “flota” (fleet of turtles) and in Mexico as an “arribada” (the Spanish word for arrival) and in the rest of this paper we will use this name because it is the most common name in the scientific literature. An arribada is defined (Cornelius et al. 1991) as the synchronized nesting of 100 or more sea turtles in one kilometer of the beach and in one night. An arribada can last several days. Large arribadas of *L. olivacea* take place in México (Márquez et al. 1976), Costa Rica

(Richard and Hughes 1972) and India (Shanker et al. 2003). Smaller arribadas occur in Nicaragua (Ruiz 1994) and Panamá (Cornelius 1982).

Zoologists only recently discovered the arribadas of olive ridleys (Carr 1992). The first one was described in 1963 in Eilanti, Surinam (Reichart 1993). In Costa Rica, the two massive nesting beaches are Nancite in the Santa Rosa National Park and Ostional in the Ostional National Wildlife Refuge. Arribadas at these sites were first described in the early 1970's (Richard and Hughes 1972), but inhabitants of Ostional report that the first occurred ten years before (Cornelius et al. 1991). In the middle seventies, arribadas were discovered in India, in the Orissa region (Shanker et al. 2003). There are no reports at all of arribadas before the twentieth-century (Carr 1992).

The importance of the knowledge of the size and trends of the populations is fundamental in the formulation of management policies to conserve any sea turtles species (Eckert 2000). In spite of their importance, published accounts of arribadas are rare (Richard and Hughes 1972, Hughes 1976, Cornelius et al. 1991, Marquez-M. et al. 1996a, Marquez-M. et al. 1996b, Valverde et al. 1998), and longtime monitoring data are even more uncommon (Marquez-M. et al. 1996a, Marquez-M. et al. 1996b, Valverde et al. 1998). Most information is found in unpublished reports. Most publications suggest that the arribadas may be endangered (Pritchard 1997). Turtles ceased nesting in three out of four beaches in México, apparently due to over-exploitation for meat and leather (Carr 1992). The Surinam arribadas also disappeared in 1972, just five years after a study was begun on them (Reichart 1993). In India most of the mass nesting beaches underwent severe declines in recent years (Shanker et al. 2003), perhaps due to the incidental catch (Behera 2000) provoked by the increment of

mechanization of the fisheries (Kocherry 2000). The population of Nancite beach in Costa Rica declined in the beginning of the eighties and never recovered again (Valverde et al. 1998), for unknown reasons.

Ostional is the only mass-nesting beach involved in a project of sustainable use of arribada eggs (Cornelius et al. 1991) and since its discovery it was considered one of the greatest ridley populations in the world. This population had been monitored since 1970. This paper presents data on population size, duration, spatial distribution and frequency on the arribadas of the Ostional National Wildlife Refuge between 1970 and 2006.

Material and Methods

Study Site

The Ostional National Wildlife Refuge (ONWR) is confined to a small area in the Guanacaste province of Costa Rica, a thin strip of coastline approximately 200 m wide and 19 km long (Figure 1). The ONWR is in both the Holdridge lowland humid rain forest and lowland humid rain forest transition to dry forest life zones (Bolaños and Watson 1993). The dry season lasts from December to April; the rest of the year is rainy. The annual mean precipitation is 2,100 mm, the annual mean temperature is 27.5 °C, and the mean monthly maxima and minima ranges between 22 and 33 °C (Barrantes et al. 1985).

The present study took place on the Ostional and Nosara beaches along a 7 km transect (Figure 1). Numbered posts were placed every 50 meters (a sector), beginning in the north zone (Rayo creek) and ending at the Nosara river mouth. The beaches

were divided into seven zones named according to the nearest estuary. These zones are (the numbers in parentheses indicate the sectors included) Rayo 1 (1-17), Rayo 2 (18-29), Rayo 3 (30-39) and Rayo 4 (40-59); the Main Nesting Beach, MNB (60-78); Nosara Beach 1 (79-125) and Nosara Beach 2 (126-140).

The beaches along the transect varied in the size of the berm or sand dune, in its inclination and their flora. Rayo 1 is very sloped, and the berm is short and covered with shrubs and king grass (*Pennisetum purpureum* cv king grass). There are three small estuaries: in sector 1, between sectors 8 and 10 and, between sectors 16 and 17. Rayo 2 and 3 lack vegetation on the berm, and at the edge of the beach in these two sectors are almond trees (*Terminalia catappa*), majagua (*Hibiscus tiliaceus*), columnar cactus (*Stenocereus aragonii*) and beach morning glory (*Ipomoea pes-caprae*). Abruptly in sector 25 the berm opens to a width of more than 20 meters. In the wet season the mouth of the estuary creates terraces 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 local inhabitants for fences. The town of Ostional stretches from sectors 45 to 59, where people have planted spiny succulent fences, and also coconut and almond trees. A small estuary opens in 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, at the beginning of the MNB, which ends at the Las Cocineras reef in sector 78 (Figure 1). A large mangrove swamp occurs at this point, 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, averaging 30 meters, and generally lack vegetation. This zone was described previously (Cornelius et al. 1991), and the conditions remain similar.

The last estuary opens in sectors 79 and 80 (Escondido estuary), at the beginning of Nosara Beach. This beach has a high slope, and a berm covered with vegetation that includes spiny succulents, majagua, morning glory beach and king grass. Debris are abundant in this area and include logs, tree branches and garbage from the Nosara River. Mangrove vegetation occurs between sectors 95 and 140 where the Montaña River runs parallel and close to the beach (Figure 1).

Data Collection

Because the data in this paper come from different collecting techniques and type of analysis, it is useful to give a brief history of the last 38 years of turtle observations at our study site. The arribadas in Ostional beach were first brought to the attention of the scientific community in September of 1969, when John Hyslop, a Peace Corp volunteer resident in Ostional, informed Dr. Douglas Robinson at the Universidad de Costa Rica that huge number of sea turtles were nesting on this beach (Cornelius et al. 1991). In 1971 Dr. Robinson, in collaboration with Peace Corp volunteers, students from Associated Colleges of the Midwest and Universidad de Costa Rica initiated studies on the arribadas, mainly estimating the numbers of turtles, determining the average number of eggs in a nest, and the total time each female spent on the beach. A research station was finished in Ostional beach at the end of 1972 and a program of daily data collection was established. During the first decade, correlations were established between weather, moon phases, currents, and the occurrence of the

arribadas, and two modest tagging efforts in 1971-1973 and 1977-1978 that involved only a few thousands of females were conducted. The embryonic development of the olive ridley was also described (Cratz 1982).

Two problems made continuity of the monitoring program impossible to carry on in the seventies. First, the Ostional arribadas attracted the attention of the egg poachers from many parts of Costa Rica, and physical danger to the researchers interfered with data collection. Second, it was necessary to travel at least 150 km by boat on the Pacific Ocean during the rainy season to reach the beach, as the road to Ostional was only passable during the dry season. This discouraged the stay of workers.

The impressive size of the arribadas in Costa Rica and Mexico stimulated the creation of ridley fisheries for meat consumption in the sea turtle feeding areas of Mexico and Ecuador (Carr 1992). In the beginning the annual harvest was low, but it increased abruptly to more than one hundred thousand animals per year when the fishery gave way to the leather industry, when the crocodile populations declined (Márquez 1996). The need to evaluate the impact of those fisheries on the olive ridley populations resulted in the creation of a regional research program in 1980, funded by the US Fish and Wildlife Service and The World Wildlife Fund-US, that included an intensive five year monitoring program in Ostional and Nancite beaches to study the arribadas. To gather data in Ostional, Robinson created the position of Director of field activities, which was occupied by a graduate student from the Universidad de Costa Rica who remained at the beach for at least nine months each year (except in 1980 and 1984, when only four months in the wet season were monitored). Improvements in the

Ostional road permitted the collaboration of many volunteers (students, visitors, tourist, etc.). The Director recorded the daily solitary nesting, estimated the size of the arribadas and tagged sea turtles to evaluate the migration of the ridleys (Cornelius and Robinson 1986).

In the middle of the 1985 the monitoring program ended, but in October of 1987 it re-started, this time related to a project on arribada egg harvest by the Association for the Development of the Ostional Community (ADIO). A biologist directed the data collection, in collaboration with a field assistant, both of them contracted for the ADIO, but under the supervision of the Biology Department of the Universidad de Costa Rica. This monitoring program focused on the arribadas, and neglected the solitary nesters. Unfortunately, the monitoring program had several problems and some of the masses nesting events were not recorded between 1996 and 1999.

In March of 1999, the monitoring program re-started, this time involving the collaboration of an ADIO biologist, a field assistant, and a biologist of the Universidad de Costa Rica as scientific supervisor. With more personnel on the beach and with the collaboration of more than a thousand volunteers, the new team has increased the data collection, recording many variables from the arribadas, monitoring every day of the year the number and status of the solitary nesters and determining the hatching success for each arribada. This team research continues to the present.

In sum, we have complete data for only few arribadas in the seventies. From 1980 to the present we have complete data on the frequency of them (we have gaps only in 1986). In relation to the size and the length of each arribada data are available

only for some years in the eighties, but since 1987 to the present the only gaps are in 1996 and 1998.

Analysis

The frequency of the arribadas was measured as the total number of nesting events occurring per year and portions of the beach (zones). The inter-nesting time was the number of days between two consecutive arribadas, and the length of an arribada was the number of days that mass-nesting event occurs.

Only arribadas larger than one thousand turtles are analyzed in this paper (with the exception of the July 1988 arribada with 800 turtles). Because the arribadas have used different zones of the beach during the study period, we evaluated the trends in each zone separately. As climatic conditions affect the nesting behavior of turtles (Miller 1997), most of the arribadas variables were evaluated in relation to the seasonal rainfall also. Using two-way ANOVA test we evaluated the variation in mean of arribada for each variable describe above by zone, by year, and climatic season, then used a least squared differences (LSD) to test the statistical significance of these differences. Trends through the study period were evaluated by mean of correlations. Using chi squared independent tests we compared the total number of arribadas by month, by year, and by zone. For analyses if the monthly arribadas frequencies were uniformly distributed around the year in the MNB we used the Raleigh's test for circular uniformity (Zar 1996).

Several methods were utilized to estimate arribada size. In the seventies the numbers of turtles were estimated by sampling several times the number of turtles on

the sand, and with this data determined a minimum of animals but without any mathematical formula that converted these numbers to total population estimates (Richard and Hughes 1972).

At the beginning of the eighties, Cornelius et al. (1991), elaborated a method to estimate the arribada size that involved establishing sample plots and a mathematical extrapolation to estimate total population size. This methodology standardized the data from Ostional and Nancite beaches, it also corrected for the false nesting emergences (female that retrieve to the sea without laying eggs), for monthly variation in the available nesting spaces, and for different distribution of the nesting densities along the beach (Cornelius et al. 1991). From 1982 to 1997 the number of sea turtles nests in Ostional was estimated using the Cornelius and Robinson equation for three sampled plots of 300 square meters in the berm.

$$((N_i + 0.94 D_i + 0.47 V_i) * 1.25 A_i/A_{ci}) * H_i/(1.08 C_i)$$

Where

N_i = sum of sea turtle seen nesting or with a completed nest in the quadrant

D_i = sum of turtles seen excavating a nest cavity in the quadrant

V_i = sum of turtles seen wandering on the beach inside the quadrant

A_i = quadrant area (m^2)

A_{ci} = MNB area (m^2)

H_i = period time (hours)

C_i = total of samples.

0.94 = a constant that represents the proportion of turtles seen inside the quadrants in the nest cavity construction phase that would continue on to successfully complete the nest

0.47 = a constant that represents the proportion of turtles seen inside the quadrants that had not yet begun to excavate a nest cavity but that would eventually nest successfully.

1.25 = a constant that extrapolated from the number of turtles seen on the berm to include those nesting in the low beach zone.

1.08 = the average time (hours) that one sea turtle needs to construct the nest and lay her eggs.

In the middle nineties, the mathematician Charles E. Gates along with several arribadas investigators developed a new methodology to estimate the size of the mass-nesting event, based on an instantaneous counting index (Gates et al. 1996). This new methodology permits several possibilities in relation to the areas sampled and the variables to be estimated. Because the Cornelius and Robinson method was complicated and we introduced new techniques to the study of nests density and hatchling production independent of estimates of the arribada size (Chaves et al. unpublished data), in 1999 two of the authors (GC and RM) decided to apply a modified version of the Gates et al. methodology. The Cornelius and Robinson method was discontinued because it was impractical to maintain both methodologies.

In our modified method, a line transect 15 m wide and 890 m long was established in the MNB at the edge of the beach, where the ocean waves soaked the sand a low tide. This sampling scheme differs from the method chosen by the UICN

Sea Turtles Specialist Group (Valverde and Gates 2000). It was chosen for reasons discussed elsewhere (Chaves et al. in preparation).

With the new methodology the arribadas were sampled every ten minutes in the MNB; and only when many volunteers were present we were able to apply it in the other zones of the beach.

To estimate arribada size we used the following equation:

$$T = n \cdot H / (4.2 \cdot c).$$

Where

T = Total of sea turtles,

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.

We present data only for arribadas that were evaluated every day that lasted. When it was impossible to sample a few hours of the arribada on one day, we applied a correction to estimate the number of sea turtles:

$$C = m \cdot s.$$

Where

C = Total of sea turtles,

m = Mean number of sea turtles per minute during the sampled period and

s = Total time per day that it is possible to count at least one sea turtle in the sampled transect (minutes).

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

By means of two-way ANOVA and LSD tests we compared the annual mean of the arribada sizes estimated with the Cornelius and Robinson and the Chaves and Morera methods independently. The trend in arribada size through time was analyzed by means of a correlation test separately for each of the two methods.

The arribada size calculated using the same technique was also averaged by month. Only the data from 1982 to 2006 were evaluated, because there were not enough data collected in the seventies. By means of two-way ANOVA and LSD tests we compared the means calculated using the same technique among months.

Results

Frequency

Massive nesting of the olive ridleys in Ostional started abruptly during the wet season of 1959 on the MNB (JRA personal observation), and has occurred every year since, for a total of 294 arribadas between 1970 and 2006 on the MNB. During eight years of the seventies, only 25 arribadas were monitoring (Table 1). The number of arribadas per year in this zone has varied from 7 to 16 (10.87 ± 2.22); there has been no clear tendency for this number to increase or decrease (Table 2). In Contrast, the frequency in other zones of the beach has tended to increase significant through time (Tables 1 and 2).

Commonly one arribada occurred each month, with an inter-nesting period average of 30.87 ± 14.72 days. During the dry season the average inter-nesting interval (37.08 ± 14.02) was larger than in the wet season (28.62 ± 14.36), but this

difference was not significant ($F = 0.79$, $gl = 1/153$, $P = 0.38$). The inter-nesting interval of arribada varied among years ($F = 2.10$, $gl = 25/153$, $P < 0.01$), and since the 2000 year there has been a slight tendency to decrease (Figure 2).

Before 1985 the arribadas outside MNB occurred sporadically, with only four events recorded during this period. But in the following 20 years, there was a significant gradual increase in the use of these zones (Table 1 and 2). During the first 10 years turtles arrived at sites to the north of MNB (R4 to R2), and later they began to extend to Nosara beach. There were significant differences in the frequencies of the arribadas between the zones ($\chi^2 = 205.35$ $gl = 132$, $P < 0.01$). The lowest frequencies of arribadas occurred in the zones located farthest from MNB. Rayo 1 and Nosara 2 had only 2.67 ± 1.97 and 2.29 ± 0.95 arribadas per year, with totals of 16 and 17 respectively.

With respect to yearly cycles, the cumulated arribadas per months and zones (Table 3) showed that between January and June the arribadas occurred mainly in the MNB and sometimes in the Rayo 4. The rest of year occurred in all zones but the MNB had the high frequencies ($\chi^2 = 125.78$, $df = 66$, $P < 0.01$). During the wet season few arribadas started first outside the MNB, we recorded the first in November of 1988, then in October and November of 1992 and between August and November of 1999 and 2000. Most of them occurred first in the Rayo zones, but at least one using the Nosara beach almost exclusively. Normally the arribada started in the MNB and then moved to the others zones two or four days latter, following this sequence: Rayo 4 (second day), Nosara 1 (second or third day), Rayo 3 (second or third day), Rayo 2 (third or fourth day), Nosara 2 (third or fourth day) and Rayo 1 (fourth day). The total number of

arribadas per month peaked in July in the MNB (Ralieg test $r = 0.13$, $z = 4.26$, $P < 0.02$) and then steadily decreases to about half the peak number around (Table 3).

During the seventies and the early eighties the arribadas were uncommon on the MNB between January and March (JRA and MA personal observation, Table 4), and sometimes only periodic increases in solitary nesting occurred during this period. This seasonality in the distribution of arribadas decreased gradually through the eighties, until it disappeared completely (Table 4). The arribadas failed to occur in all months of the year, with the exception of July. The incidence of two arribadas per month was most common during the wet season ($\chi^2 = 132.45$, $n = 11$, $P < 0.01$), especially in July and August.

Duration

The durations of arribadas varied between one to fourteen days. The arribadas of the first six months were shorter (3.50 ± 0.18 days) than those of the rest of the year (5.45 ± 2.37 days, $F = 7.10$, $gl = 1/419$, $P = 0.01$). They were larger August and November (6.25 ± 0.13 days), while July and December had intermediate averages (4.63 ± 0.18 days, Figure 3).

The durations of the arribadas varied significantly between zones ($F = 14.26$, $gl = 30/419$, $P < 0.01$). There were three groups of similar values (LSD test): the MNB with the largest average (5.45 ± 2.37 days); Rayo 2 (4.33 ± 2.37), Rayo 3 (4.59 ± 2.15 , Rayo 4 (4.45 ± 2.12) and Nosara 1 (4.03 ± 2.05); and Nosara 2 (3.13 ± 2.53) and Rayo 1 (2.31 ± 1.81).

The average durations of arribada in the MNB varied irregular from year to year (Figure 3), and the different were significantly ($F= 5.62$, $df = 30/419$, $P < 0.01$), showing a peak in 1991 (8.03 ± 3.04 days in the wet season). Duration increased significant during the study in the MNB ($r = 0.47$, $P < 0.01$, $n = 34$).

Number of turtles

The number of turtles per arribada in the seventies was estimated at several thousands; it is not possible to judge the number even reached more than one hundred thousands, as frequently occurred in the next decades.

According to the lower frequency and duration of arribadas during the dry season, their sizes were also small (Figures 4, 5). Between 1981 and 1997 the annual average arribada size in the MNB during the wet season varied between 40,000 and 111,000 turtles, but in the dry season it reduced to 4,000 animals (Figure 4) and the different were significant ($F = 7.73$, $df = 1/88$, $P = 0.01$). Arribada size fluctuated throughout this period ($F = 2.57$, $df = 14/88$, $P < 0.01$), but neither wet nor dry season showed a clear trend ($r = 0.23$, $df = 13$, $P = 0.45$, $r = 0.04$, $df = 10$, $P = 0.91$ respectively for wet and dry).

From 1999 to 2006, the annual average arribada size changed more drastically (Figure 4), and commonly reached annual averages larger than one hundred thousand turtles during the wet season. In spite of this variation the differences were not statistically significant ($F = 1.04$, $df = 7/79$, $P = 0.41$), the difference in the size average between seasons was barely significant ($F = 4.27 = 1/79$, $P = 0.04$).

Discussion

The olive ridley arribada population in Ostional changed from a strictly seasonal to a year-round nesting during the last 25 years. Lack of seasonality is common in sea turtle populations close to the equator (Miller 1997). But in those populations where year-round nesting occur most of the nesting take place in a peak that spread for several months, but only few animals are found out of the peak (Hamann et al. 2003). At Ostional, in contrast, several thousand of turtles nest during the period with low activity. Hamann et al. (2003) suggest that three factors that control the span of the nesting in sea turtles, the ability to find mates and copulate; the suitability of the beach to incubate eggs; and the suitability of the beach to permit the dispersion of the hatchlings.

The year-round nesting population in Ostional satisfies the first factor, because in front of the Nosara beach, is very common to find olive ridleys copulating each month of the year, where sometimes is possible to find more than 20 pairs in one day (JRA and GC personal observation) and this high concentration of males is implicated in the great percent of multiple paternity (92%) in this population (Jensen et al. 2006).

In relation to the second factor, the mortality of eggs between March and June is usually 100% (Cornelius et al. 1991), due to the high temperatures on the beach and the absent of rainfall (Ugalde 1986). Nevertheless, there was good hatchling success in 2000 during the dry season (GC personal observation), the most recent cold ENSO (El Niño Southern Oscillation) or La Niña year, when it rained during the dry season in Costa Rica. Perhaps the frequency of the La Niña is involved in maintaining reproduction during the dry season. Unfortunately there has been a reduction in the

frequency of La Niña events and an increase in El Niño events since 1975 (Capel-Molina 1999). If this warming tendency continues, the nesting behavior during the dry season it likely to be eliminated by the natural selection.

There is no research in relation the suitability of the beach for dispersion of the hatchlings for olive ridley (Musick and Limpus 1997). The currents in the Pacific move far away from the coast between January to March and they can difficult the navigation of the olive ridley to the Costa Rica beaches (Cornelius and Robinson 1986).

Why is there big nesting population during the dry season at Ostional? We suggest that the presence of a large number of turtles out the peak period may simple be the result of the larger number of turtles. The number of turtles that participated in the mass nesting events between February and April correspond only to one or two percent of the turtles in the nesting peak in Ostional. Maybe this percent is similar in other arribadas, but it is rare that researchers recording the turtles out of the nesting peak, due the difficult of monitoring so few turtles. Another possibility is the establishment of a non-migratory local population of ridleys in Ostional. This was suggested by Cornelius and Robinson (1986), based on a 16.9% recovery rate of tags between December to March during the decline of the regular nesting season. In addition, many females ridleys had been seen during the inter-nesting time, resting many hours on the surfaces of the ocean for many hours and also mating near Nosara beach during all months of the year (GC and JR personal observation). This behavior is different near Nancite, where the females remained more time under the water for longer during inter-nesting periods (Plotkin et al. 1995), and the males tended to depart in September (Plotkin et al. 1996).

We suppose that this non-migratory population is able to copulate and nest year around because if the turtles don not expend energy in travel activities and can nest during the dry season in spite of poor hatching success. Later, during the wet season, the local arribada population is joined by migratory populations of ridleys from Mexico and Ecuador (Cornelius and Robinson 1986).

Our most important finding is that the number of turtles arriving during the arribadas seems to be increasing in Ostional; the area where arribadas has increased, as have the total numbers of turtle. There are several possible reasons for this increase in Ostional. It may be related to the closure of the turtle's fisheries in México and Ecuador in the beginning of the eighties (Márquez 1996), which could also explain the recovery of the ridley population in Escobilla beach, México (Márquez et al. 1996). Other more local causes may also be involved, because the Nancite arribadas have never recovered (Valverde et al. 1998). Cornelius and Robinson thought that the poor hatching success in Nancite arribadas (only 2%) limited the possibilities of recuperation of this population (Cornelius et al. 1991). But hatching success at Ostional also is very low too (7% to 13%), and has remained constant through the years (Chaves et al in prep.). The annual production of several million newborns in Ostional, which results from several protection measures, such as excluding eggs and hatchlings predators, cleaning the beach every month by inhabitants Ostional who belong to the ADIO and to the absence or a least reduced of direct fishing (incidental fishing may still occur), must explain at least some of the population growth.

The migration of turtles form other colonies of ridleys to Ostional (specially those form Nancite) is still another possibility explanation of the population increase at

Ostional (and the decline at Nancite). The two beaches are close (less than 100 km), and the recovery of turtles tagged at Nancite had been recovered at Ostional and vice versa (Cornelius and Robinson 1986). The low frequency of interchange turtles between both these beaches (56 records out more than 7000 recaptures) demonstrated a high degree of site fidelity, however (Cornelius and Robinson 1986). Sea turtles in general show strong homing behavior (Carr 1992, Lohmann and B.E. Witherington 1997, Avens et al. 2003) to both nesting beaches and foraging areas. But this does not mean that they don't sometimes use other beaches also (Hughes and Richard 1974, Cornelius and Robinson 1986). We do not believe that migration of the Nancite population to Ostional explain the increase at Ostional.

The increase in the population at Ostional contrasts with the other arribada beaches in the world, where the tendencies are all toward declines (Carr 1992, Das 1998, Valverde et al. 1998). We do not think this increase is an artifact of the change in the monitoring methods. Each samples a different things (nests vs. turtles) and samples in different places (bank of sand vs. low tide area). *Lepidochelys olivacea* nest near of the upper edge of the intertidal area (Márquez 1996), and in the Cornelius and Robinson methodology only the turtles nesting above this limit were sampled. When both methodologist where use in two arribadas in 1999, we found that the new methodology produce estimations 33% lowest than the other one. This contradictory result we suspect that it is influence by the variation in the "constants" used in the Cornelius and Robinson methodology. These problems obligated to Robinson and Cornelius to calibrate the "constants" each year (Cornelius et al. 1991). The important here is that the new methodology produces conservative's estimations of the arribadas.

In preliminary analyses we determined that the estimations deviated from the actual number of turtles between 5 and 10% (Chaves et al. in prep.).

For these reasons, if the size of the arribadas in the MNB changes in some particular direction through the monitoring period, it is impossible to answer by mean of the estimation data. In this case, we can use our personal experience in the arribadas of Ostional to approach an answer to this question. The number of turtles of the big arribada in the MNB seems to be very similar through the years, and years with only small mass nesting events (less than one hundred thousand turtles) never occurred. We have never witnesses such a massive aggregation of turtles at Ostional as in the rainy season arribadas of 2002. Thousands of turtles cover the surf area for several kilometers of the coast, and on the beach it was literally difficult to find a squared meter without a turtle in at least four kilometers during both day and night. We counted between one hundred and two thousand turtles entering to the beach every 10 minutes for many hours every day. On some arribada was estimate at above four hundred thousand turtles in the MNB alone.

The most extraordinary event was the incursion of the turtles into the town where they destroyed the bromeliad fences, they tried to nest in gardens, the soccer field, and even inside the local bar. Some walked more than 200 hundred meters inland. Hundreds of turtles died when they tried to nest in the forest and were trapped in the grassy vegetation, in spite of the effort of many local inhabitants to rescue them.

We can conclude that the turtle population at Ostional is the most stable arribada site in the world. Ostional and the green turtle rockery of Tortuguero (Bjorndal et al. 1999) are the best examples of sea turtle conservation in Costa Rica, although

they employ very different conservation strategies (Cornelius et al. 1991, Troëng and Rankin 2005). We believe that the long-term success of these projects will depend on the use of conservation practices that are based on both an adequate knowledge of the animal population, and on the needs of the local community.

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Table 1. Number of arribadas recorded each year between 1970 and 2006 for each zone of the beach. We considered as incomplete study year (*) those in what only some few months are monitored, and others that we know that the arribada occurred out the study period by communication of the Ostional people.

YEAR	Effort	ZONES						
		NOSARA 1	NOSARA 2	MNB	RAYO 1	RAYO 2	RAYO 3	RAYO 4
1970	Sep-Oct*	1		2				
1971	Aug*	1		1				
1972	Jan-Dec			10				
1973	Jan-Oct*			5				
1974	Nov*			1				
1975	Mar*			1				
1977	Feb-Apr, Aug*			1				2
1978	Aug-Oct*			4				
1980	Aug-Dic*			4				
1981	Apr-Dec			10				
1982	Jan-Nov			11				
1983	Apr-Dec			7				
1984	Aug-Nov*			8				
1985	Apr-Aug*	1		7	1	1	1	2

YEAR	Effort	ZONES						
		NOSARA 1	NOSARA 2	MNB	RAYO 1	RAYO 2	RAYO 3	RAYO 4
1986	ND							
1987	Oct-Dec*			3			1	1
1988	Jan-Dec			8		1	2	2
1989	Jan-Dec			13			2	2
1990	Jan-Dec	1		13				3
1991	Jan-Dec			16				
1992	Jan-Dec			10		3	3	3
1993	Jan-Dec			11				
1994	Jan-Dec			10				
1995	Jan-Dec			11		2	2	2
1996	Jan-Dec			10		4	4	4
1997	Jan-Dec		1	12				
1998	Jan-Dec			9	2	5	5	6
1999	Jan-Dec	6		12		5	6	8
2000	Jan-Dec	3	3	9		4	4	4
2001	Jan-Dec	4	1	8		3	3	3
2002	Jan-Dec	5		11	1	5	7	7
2003	Jan-Dec	5	2	10	1	5	5	6
2004	Jan-Dec	4	3	10	2	4	4	5

YEAR	Effort	ZONES						
		NOSARA 1	NOSARA 2	MNB	RAYO 1	RAYO 2	RAYO 3	RAYO 4
2005	Jan-Dec	6	3	14	4	5	6	8
2006	Jan-Dec	6	3	15	6	6	7	11
Total		43	16	294	17	53	62	79

Table 2. Correlations (r) and probabilities (P) for the annual number of arribadas and the years for each zone in Ostional and Nosara beaches, Ostional National Wildlife Refuge. n = 23.

ZONE	r	P
MNB	0.19	0.39
Rayo 1	0.64	<0.01
Rayo 2	0.85	<0.01
Rayo 3	0.81	<0.01
Rayo 4	0.80	<0.01
Nosara 1	0.81	<0.01
Nosara 2	0.73	<0.01

Table 3. Monthly cumulated number of arribadas occurred at different zones between 1972 and 2006. The data for incomplete recorder years were excluded.

MES	ZONES						
	NOSARA 1	NOSARA 2	MNB	RAYO 1	RAYO 2	RAYO 3	RAYO 4
January	0	0	16	0	0	0	0
February	0	0	15	0	0	0	2
March	0	0	19	0	0	0	3
April	0	0	16	0	0	0	0
May	0	0	19	0	0	0	1
June	0	0	21	0	0	0	0
July	2	1	32	0	2	6	11
August	9	3	30	3	9	10	11
September	6	4	22	3	6	7	7
October	6	2	20	1	9	9	9
November	7	2	25	3	11	12	12
December	5	2	23	1	4	5	7
Total	35	14	258	11	41	49	63

Table 4. Annual distribution of the number of the arribadas per month occurred in the MNB, between 1972 and 2006.

YEAR	MONTHS											
	January	February	March	April	May	June	July	August	September	October	November	December
1972	0	0	1	0	2	1	1	0	2	1	1	1
1981	0	0	0	1	1	1	1	2	1	1	1	1
1982	0	0	0	1	1	1	2	2	1	1	1	1
1983	1	0	0	0	1	1	1	2	0	1	0	0
1984	0	0	0	1	1	0	1	1	1	2	1	0
1988	0	1	1	0	0	1	1	1	0	1	1	1
1989	1	1	1	1	1	1	1	2	1	1	1	1
1990	1	1	1	1	1	1	2	1	1	0	1	2
1991	1	1	1	0	0	1	2	2	2	2	2	2
1992	1	1	1	1	1	1	1	1	1	2	2	1
1993	1	1	1	0	1	1	1	1	1	1	1	1
1994	0	1	0	2	1	0	1	1	1	1	1	1
1995	1	1	1	1	1	1	1	1	1	0	2	0
1996	1	1	1	0	1	1	1	1	1	0	1	1
1997	1	1	1	0	1	1	2	1	1	2	0	1
1998	1	1	1	1	1	1	1	1	1	0	0	0
1999	1	0	1	1	1	2	2	1	1	1	1	1

YEAR	MONTHS											
	January	February	March	April	May	June	July	August	September	October	November	December
2000	1	0	1	1	1	1	1	1	0	1	0	1
2001	0	0	1	1	0	1	1	2	0	1	0	1
2002	1	1	1	0	1	0	2	1	0	2	1	1
2003	1	0	1	1	0	0	1	1	2	0	2	1
2004	0	1	1	1	0	0	2	1	1	1	1	1
2005	1	1	1	1	1	1	2	2	1	0	2	1
2006	1	1	1	1	1	1	2	1	2	1	2	1
Total	16	15	19	17	20	20	33	30	23	23	25	22

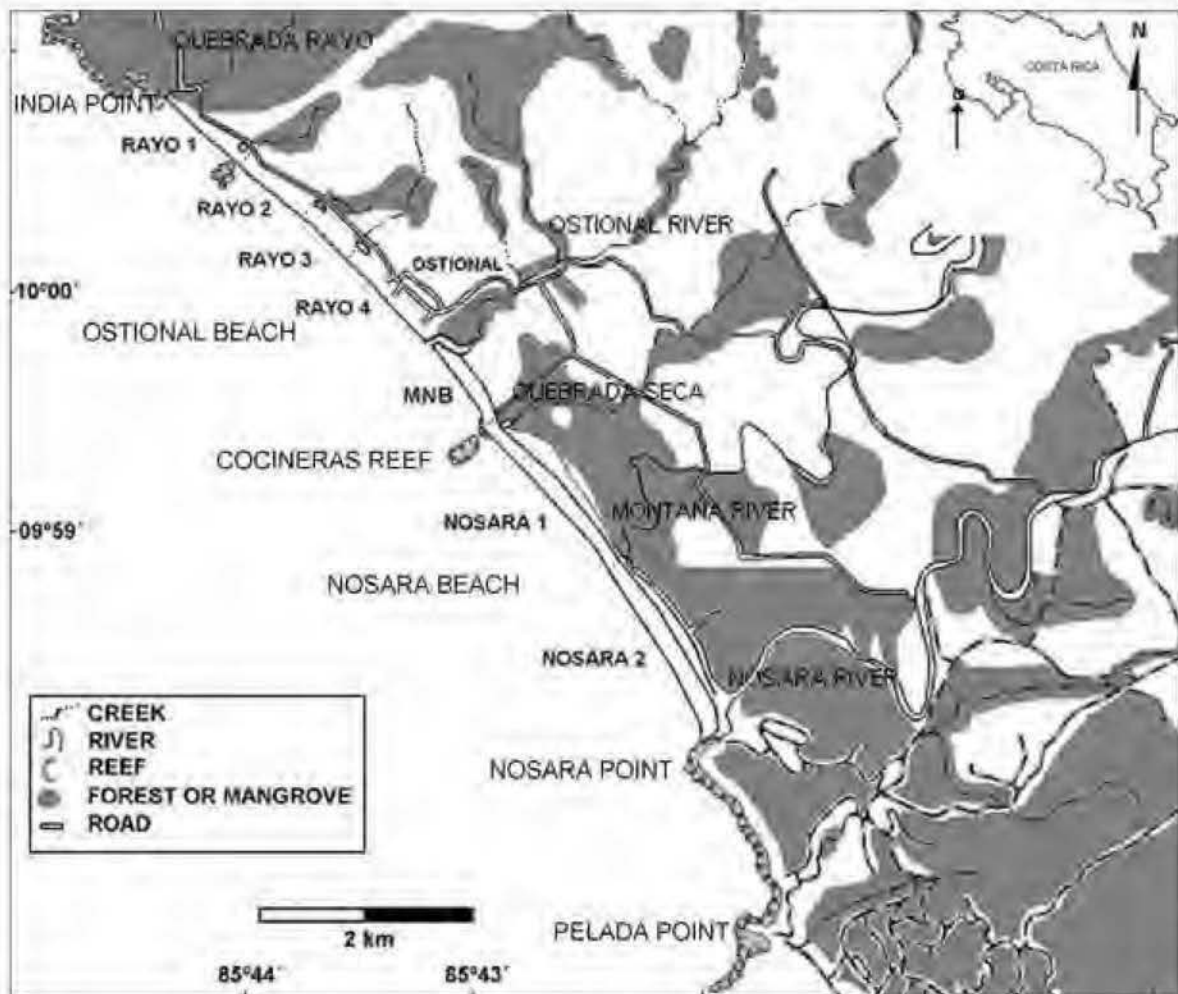


Fig. 1. Ostional National Wildlife Refuge in Costa Rica. It is showed the Ostional and Nosara beaches, and the zones established within them for data collection: Rayo 1-4, Major Nesting Beach (MNB) and Nosara 1 and 2.

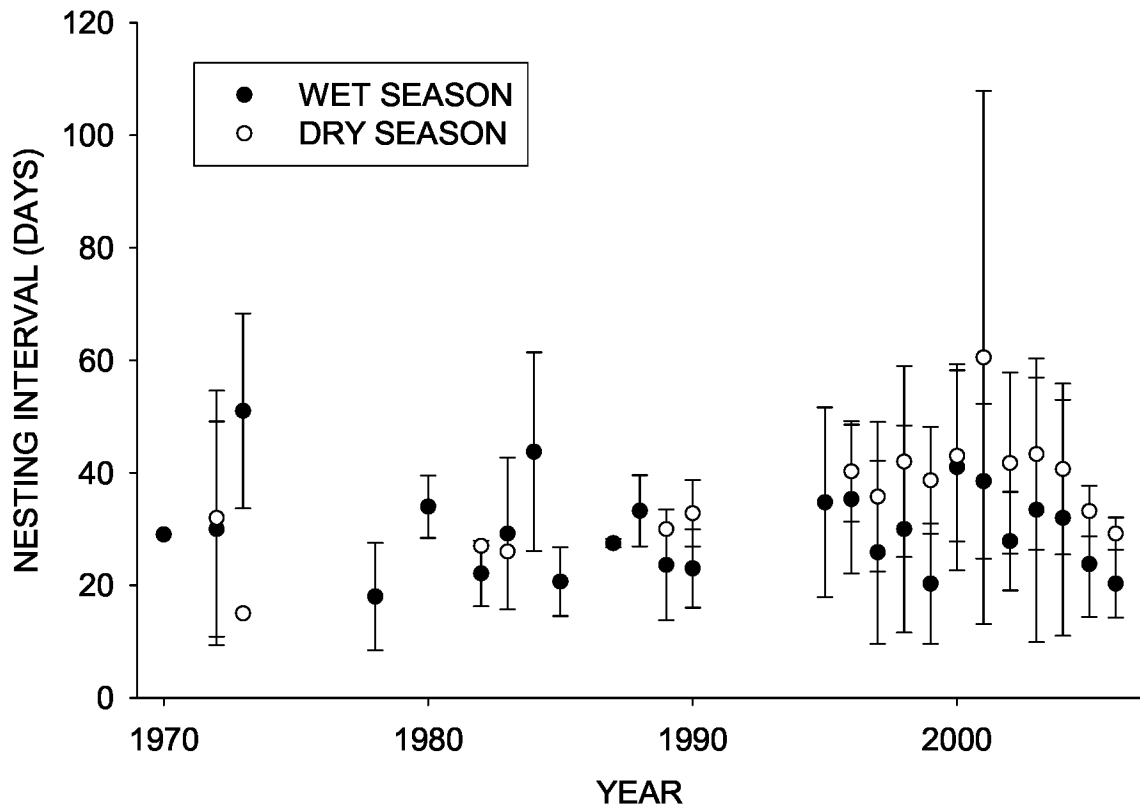


Fig. 2. Seasonal average and standard deviation of the duration of the arribadas nesting interval (days) by climatic season, since 1970 to 2006 in the MNB of the OWNRR.

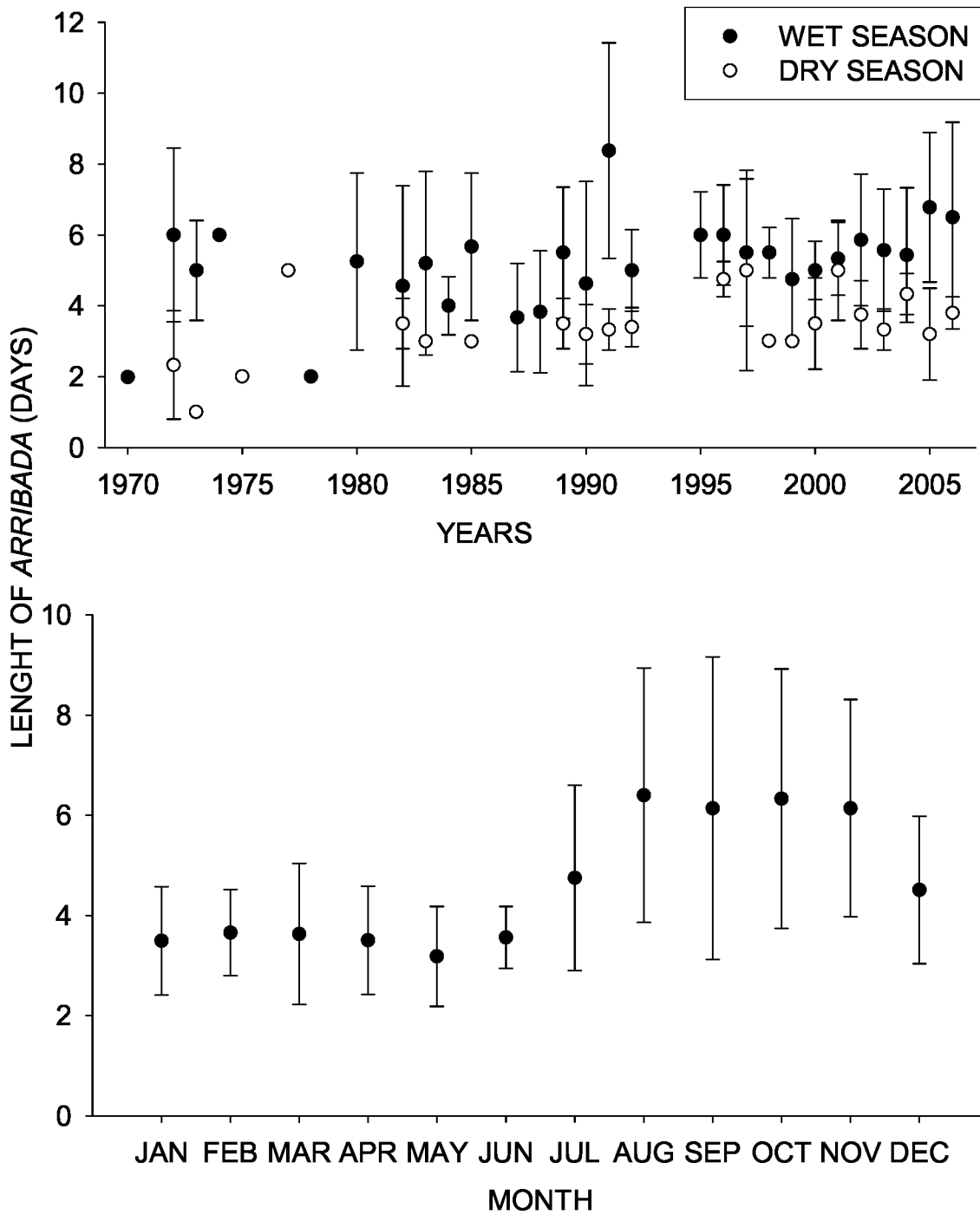


Fig. 3. Annual and monthly average and standard deviation of the duration of arribadas in the Major Nesting Beach of the Ostional National Wildlife Refuge during 1970 - 2006.

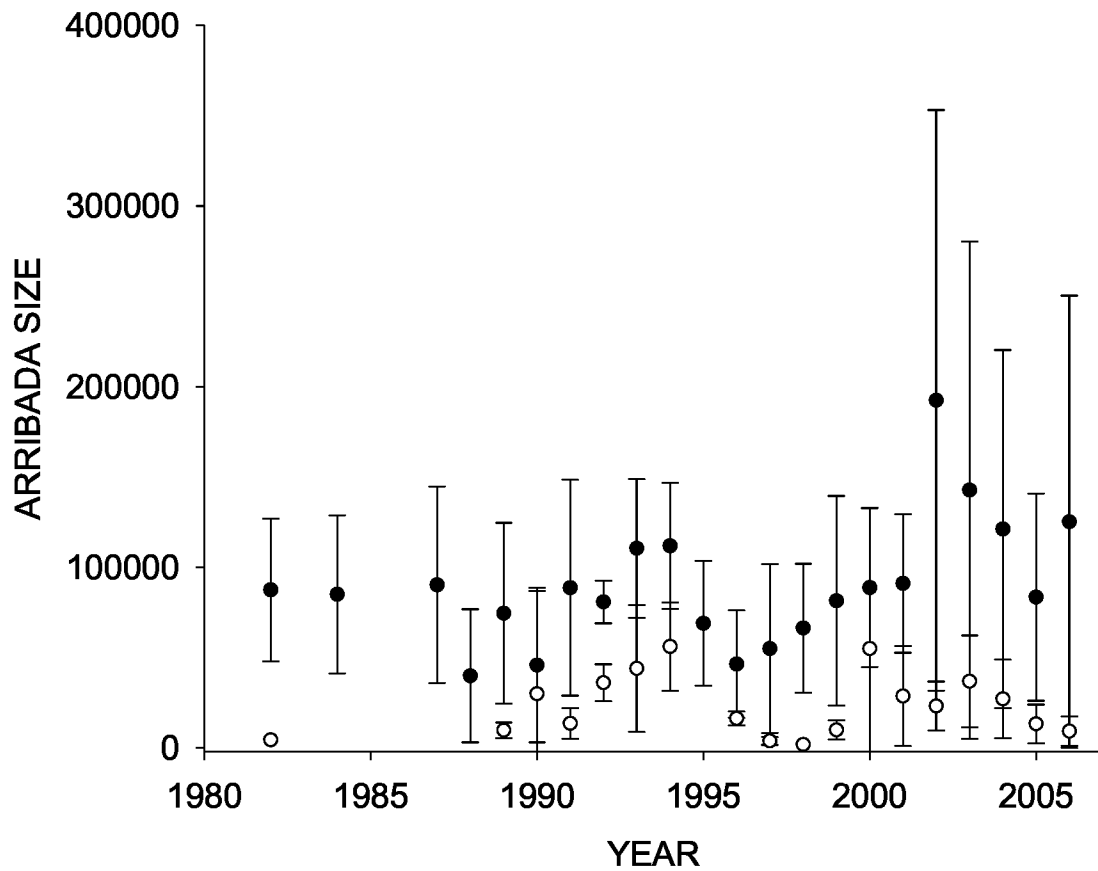


Fig. 4. Average and standard deviation of the arribadas size in the Major Nesting Beach of the Ostional National Wildlife Refuge between 1980 and 2006. The Cornelius and Robinson methodology was used from 1981 to 1997 (Cornelius et al. 1991) to estimate the number of nests. Between 1999 and 2006 the Chaves and Morera method were used.

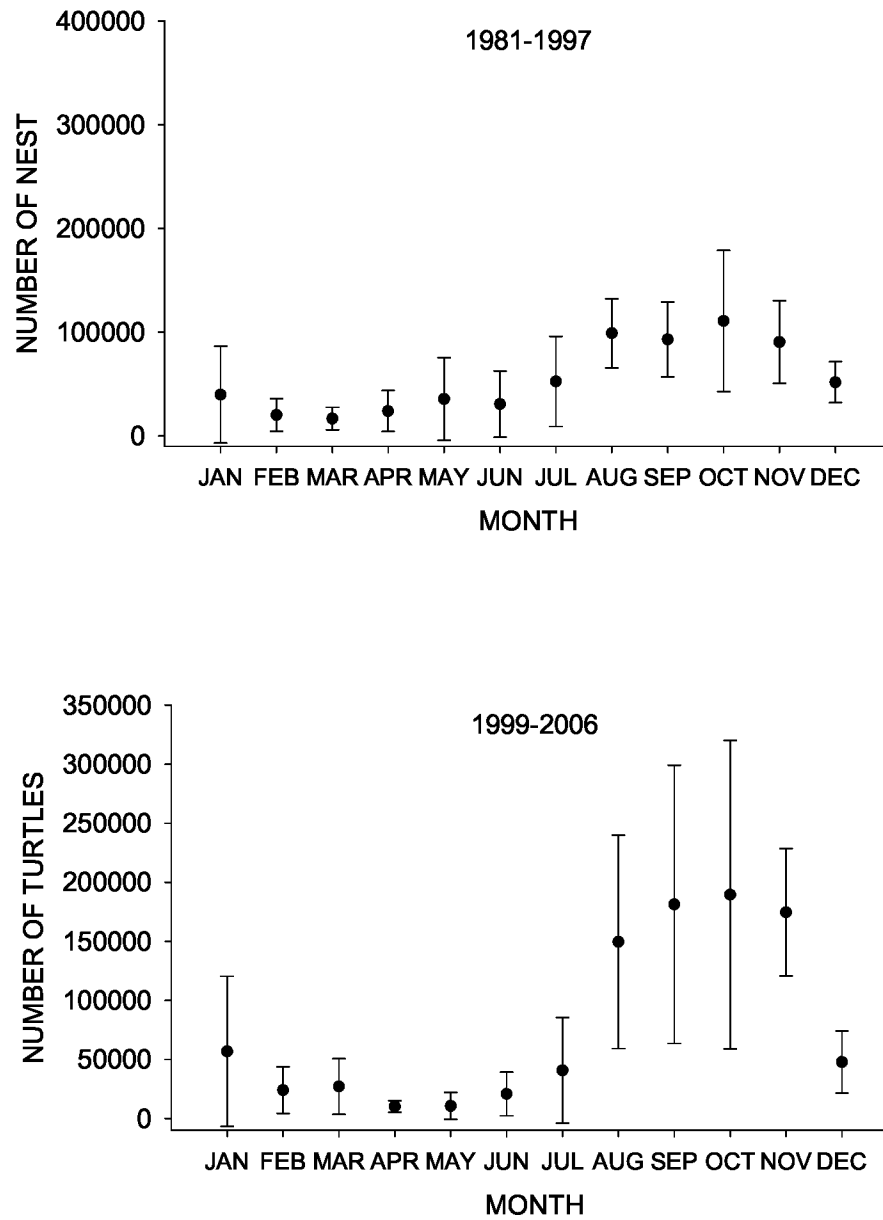


Fig. 5. Monthly average and standard deviation of the arribada size in the Main Nesting Beach of the Ostional National Wildlife Refuge. The Cornelius and Robinson methodology was used from 1981 to 1997 (Cornelius et al. 1991) to estimate the number of nests. Between 1999 and 2006 the Chaves and Morera method were used.

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Apéndice 2

En formato de artículo científico para ser sometido a la Revista Ecology

Influence of the high nests density in the early embryonic mortality and hatching success of the olive ridley sea turtles (*Lepidochelys olivacea*) in Ostional National Wildlife Refuge

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Abstract.

We evaluated the influence of the high nest density in the early embryonic mortality (first week of development) and hatching success in olive ridley sea turtles in Ostional beach. An assessment of the nests from 202 mass nesting events (arribadas) showed that close to 80% are impacted by one or two arribadas during the incubation time and the number of nests by arribada reduced to 30% at the hatch time. For 76 arribadas (1998-2006) we analyzed 5,509 nests of which 23.91% had overlapped the

nest chamber. The percentage of developed eggs during the first week of incubation and the hatching success tended to decrease with the number of overlapped nest. The nest density varied from 0 to 14 nests/m² with a peak in October and November (2 nests/m²). The larger densities were found in the central area of the main nesting beach (MNB, 1.19 nests/m²), and in the low area of the berm (1.21 nests/m²). The percentage of developed eggs during the first week of incubation changed between 80% to less than 40%, and decreased with the nest density. The hatching success was always less than 30% and did not show a tendency in relation to the nest density. The density of eggshell debris measure as the number of nests with more than two months of incubation (old nests) varied between 0 and 24 nests/m². The density of old nests was lower in the area close to the estuary (2.00 old nests/m²), and in the low zone (2.77 old nests/m²). The percentage of developed eggs during the first week of incubation did not change with the density of old nests, while the hatching success was affect negatively. Although the lower viability of the arribada nests, they produced more than one million of hatchlings at the year. Reduction of the nests and eggshell debris by ocean and river erosion was considered to explain the nest site selection in olive ridleys.

Keywords: Reptilia, Testudinata, *Lepidochelys olivacea*, arribada, hatching success, viability

Introduction

Most of the studies in sea turtles are made in populations with just a few hundreds of nesting females each season (Heppell et al. 2003). But the historical

population analysis (Hildebrand 1982, Ross 1982, Carrillo et al. 1999, Huxley 1999, Meylan 1999, Chaloupka 2001) shows that larger populations were more common in a no more distant past. There is few information of the influence of density on the vital rates and population growth (Heppell et al. 2003). Examples of larger population are rare at present, in some sites ten thousands of females of green (Bjorndal et al. 1999), leatherback (Girondot and Fretey 1996) and loggerhead (Ross and Barwani 1982) nest each season. In genus *Lepidochelys*, the mass nesting events called "arribada" (the Spanish word for arrival) sometimes occur (Carr 1992), with more than one hundred thousand sea turtles nesting in one week and on a few kilometers of beach. In olive ridley (*Lepidochelys olivacea*) arribada beaches (Hughes and Richard 1974, Márquez 1996) the space for the development of the nests is reduced, where the nest density can reach 7 or 14 nests/m² (Cornelius and Robinson 1983). The average size of the arribadas in Ostional beach in Costa Rica varied during the dry season between 1,000 to 50,000 turtles and from 40,000 to 200,000 turtles in the wet season, with an average of eleven arribadas per year. This population has never declined (Chaves et al unpublished), as has occurred in all the other mass nesting sites around the world (Reichert 1993, Valverde et al. 1998, Shanker et al. 2003). However the overall hatching success was only 7% (Cornelius et al. 1991). Under arribadas conditions, density dependent factors have significant effects on the embryonic mortality (Bustard 1979). The most frequently studied factor is digging, when some turtles nest in the same place that another turtle has previously laid her eggs destroying those eggs. The incubation time in the olive ridley varies between 45 and 55 days, while the frequencies of the arribadas fluctuate from 15 to 30 days (Miller 1997). So there is a high possibility that some nests may be damaged by one or two subsequent arribadas. Between 20

and 40% of nests are destroyed by the same turtles in the arribadas of Ostional beach (Cornelius et al. 1991).

During the mass nesting events many nests are partially destroyed by other turtles. The main effects in those overlapped nests are the rotation or destruction of eggs and an increase in the clutch mass by union of several egg chambers. Increased clutch mass may result in a reduction in gas exchange and higher temperatures (Ackerman 1980). In leatherback turtles larger clutch mass causes the minimum nest oxygen level to decrease and the maximum temperature increased (Wallace et al. 2004). The rate of consumption of O₂ determines the time to incubation of the eggs, because it reduces the movement of gases, slows down the rate of growth and increases embryonic mortality (Ackerman 1980). The nests that undergo the partial destruction of the eggs are contaminated with egg residues and sand. The absence of sand inside the nest cavity results in a volume of gas that is adequate for the development of the central eggs. Although, the alteration of the organization of the eggs in the nest by disturbance increases the partial pressure gradient two to three times, and raises egg mortality (Ackerman 1980). Egg breakage during incubation increases the embryonic mortality of the rest of the clutch (Hill 1971). Rolling of eggs after the vitelline membrane has adhered to the shell can kill the embryo, because gravity attracts the vitelline sac and can separate it from the shell and cause death (Ewert 1979). Cautl et al (2006) propose that this effect could explain the negative effect of the destruction rate, in particular at the beginning of the incubation when eggs are highly sensitive to incubation condition.

The low hatching success of the arribadas (Cornelius et al. 1991, Márquez 1996) produce several millions of post hatching nests that remains in the beach for

several months. When the nest chamber is created, the turtles try to eliminate all the debris inside the hole (Ehrenfeld 1979); but it is likely that in high densities of eggshell debris the development of the eggs is even affected. On the Ostional beach the turtles demolished all the vegetation in the berm and sometimes in the land also during the big arribadas in the rainy season. This amount of organic material can alter the physical condition of the beach (Bjorndal and Jackson 2003), increase problems with fungus and bacteria (Mo et al. 1995), and attract predators (Brown and Macdonald 1995).

In this study we use data on reproduction of arribadas to explore the impact of nest density on the viability of the eggs and to determine how important it is to consider the absolute number of hatchlings produced and the dynamics of the beach to evaluate the prevalence of the larger population of sea turtles.

Material and Methods

Study Site

The study took place in the Ostional National Wildlife Refuge (ONWR), a small area in the Guanacaste province of Costa Rica, in the Ostional and Nosara beaches (85° 43'50" W, 10° 01'00" N). The ONWR belongs to the Holdridge life zones (Bolaños and Watson 1993) of the basal humid rain forest and humid rain forest transition to dry forest. The dry season lasts from December to April and the rest of the year is rainy. The annual mean precipitation is 2,100 mm and the annual mean temperature was 27.5 C (Barrantes et al. 1985).

Data was collected on the Main Nesting Beach area (MNB), which corresponds to the central kilometer of the Ostional and Nosara beaches (Figure 1). Numbered

posts were placed each 50 meters and the space between two consecutive posts was called sector. The first four sectors were located in front of the Ostional estuary, and ocean waves and estuary waters covered them during some days each month during the extraordinary high tides events. Two sectors MNB (77-78) were behind a reef (“Las Cocineras”), where few turtles nested due to the difficult access.

The intertidal area is wide (can reach more than two hundred meters during some big tides) and the high tides can reach three meters high. The beach has a slope of 3° and the surf is strong. The bank of sand or berm is wide, close to an average of 30 meters, generally without vegetation, as result of the management practices (beach cleaning). The berm area changed constantly by the erosion of the ocean waves and the Ostional estuary, and in some sectors the berm was eliminated temporally. An average of 14.92 ± 2.75 sectors were evaluated per arribada to an average area of $58,254.16 \pm 25,830.36$ m². The sand is black as a result of deposits of sediments by the Nosara River and the grain size varies from 0.063 to 4.00 mm (Cornelius and Robinson 1985).

Nests density, viability and hatching success

The size of the arribadas in the MNB fluctuates between 1,000 and 400,000 turtles per event and the mean number of arribadas per year is close to eleven, or about one arribada per month (Chaves et al. unpublished data). We present data of the incidence of arribadas on the development of eggs in relation to the number of arribadas occurred during the incubation period for 202 arribadas recorded by the Universidad de Costa Rica project between 1970 and 2006.

We evaluated the nests density in the berm of the MNB in 76 arribadas between 1998 and 2006 as follows. One week after the end of the arribada or during the hatch time, we excavated at random a square meter hole with 30 cm depth in the area close to the vegetation (high area), in the middle of the berm (middle area) and in the area close to the upper limit of the tides (low area) for each sector. In each hole, we counted the number of nests. We established the age of the nests by the stage of development of the embryo in one or two eggs from some nests and compared them with the dates of previous arribadas. The experience was important in determining the age of the nests. For this reason, one of the authors (GC) participated in all excavations.

The percentage of destruction of nests by sea turtles, predation, erosion, etc. during incubation was estimated by comparing the estimated numbers of nests from the same arribada between periods of 2, 4, 6 (hatch time) and 8 weeks of development, using the data of nests density and berm area.

If the egg chambers of two or more nests from the same arribada partly overlapped, the nests were recorded as overlapping. The recognizable number of egg chambers defined the number of nests that overlapped. All the eggs from overlapped nests were count together and they were recorded as incomplete nests because some of them lost eggs during the digging process. Some non-overlapping nests were considered incomplete because broken eggs were present or the nest had very few eggs (less than fifty eggs).

Normally it is very difficult to distinguish between infertility and the early embryonic mortality. For this reason, the term undeveloped eggs is used (Miller, 2000). We measured the percentage of eggs with development (developed eggs) as the number of eggs with detectable embryo after the first week of incubation. The

existence of the embryo at this stage is indicated by the presence of a white circle in the shell (Whitmore and Dutton 1985). The hatching success was calculated as the percentage of eggs hatched (empty shells vs. unbroken shells) for each nest after more than 50 days of incubation that were present in our sampled holes. For overlapped nests, the percentage of developed eggs and hatching success were calculated in relation to the total eggs from all nests connected.

The density of eggshell debris was quantified by mean of the number of post hatching nests that were more than two months old found in the bottom of the square holes that we dug. These nests were called "old nests". The eggs in these old nests were frequently dry and brown in color. It was possible that some pile of eggshells represent more than one old nest, but for the purpose of this study, we believe that these data provides a useful approximation of the amount of organic material produced by non-hatching eggs.

Hatchling production

Because many nests are destroyed during the incubation time (Cornelius et al. 1991) and most of the survival nests were disturbed at the hatch time and had less eggs than at the beginning of incubation, we estimated the hatchlings production multiplies the density of all eggs hatched in each hole sample by the berm area.

Analysis

All averages are presented with one standard deviation. We tabulated the frequencies of overlapped and non-overlapped nests and compared them with chi-

square tests. To determine the homogeneity in the distribution of the overlapped nests in the berm we analyzed the frequencies of the number of united nests in the high, medium and low area by mean of chi-square contingency tests. A profile of the distribution per month, sector and the zones of the berm were elaborated for development nest and old nest densities recorded in the eight years of the study. Using ANOVA and least squared difference (LSD) tests we compared the means for each variable described above by month, sector and zone of the berm. The influence of the nest density in the viability of the eggs were determined comparing the average of the percent of developed eggs and hatching success for overlapped nests and for the nests incubated at different densities by mean of ANOVA test and then compared the tendency with the orthogonal polynomial linear contrasts test (Mullen 1989).

When the samples were lower than 5 we combined the class of nest density or overlapped nests. As the hatching success during the dry season is close to zero, we eliminated the dry season data from the analyses.

Results

Density of developed nests

Nests belonging to 202 arribadas in Ostional between 1970 and 2006 showed that 19.70% were not directly affected by another arribada, 22.22% were affected by two events and 58.08% by only one. In the first four weeks of development the average of nests density reduced to $47.74\% \pm 25.62\%$, at the hatch time, the reduction was of $30.67\% \pm 21.41\%$ and at eight weeks of development only the $5.77\% \pm 9.46\%$ of the original number of nests remained in the beach. The difference between these numbers

was significant ($F = 10.42$, $df = 2/38$, $P > 0.01$), and the difference was found between all weeks of development (LSD $P > 0.04$).

From 1998 to 2006 we revised 76 arribadas and made 5,256 holes for the density study. We analyzed 5,509 nests, of which 23.91% were overlapped. For the non-overlapped nests, 13.67% were incomplete nest. Two-overlapped nests were the most abundant of the united nests (55.58%), but the three-overlapped nest showed an important percent of the united nests (15.03%). United nests with four clutches represent 4.56% of total overlapped nests, and only one group of six-overlapped nests was found.

The distribution of the overlapped nests in the berm (table 1) was heterogeneous ($\chi^2 = 31.51$, $df = 8$, $P < 0.01$). Separated nests were most abundant in the low zone, while the two and three overlapped nests were common in the medium zone. Most nests were in the lower portion (36.92%) and few turtles nested in the upper zone (27.59%).

The number of nests that were united affected the percentage of developed eggs negatively (Figure 2). Separated nests had the developed eggs highest average ($F = 5.60$, $df = 3/3746$, $P < 0.01$), and this average decreased linearly with larger number of united nests (orthogonal polynomial contrast for linear trends OPCLT $F = 5.11$, $df = 1/3746$, $P < 0.01$). Hatching success decreased in relation to the number of united nests too (Figure 2), although was no statistically significant ($F = 1.60$, $df = 2/1525$, $P = 0.20$).

Nests density varied from 0 to 14 nests/m², but densities greater than 8 nests/m² were rare. The average nest density (Figure 3) were very low during the first six months (close to zero), but rose gradually the rest of the year to more than 2 nests/m²

in October and November; the difference between the average was significant ($F = 55.04$, $df = 11/1545$, $P < 0.01$). The nests density was low in the first three and the last two sectors; the central portion of the beach had a uniform density but never more than one nest/m² (Figure 3) the differences between densities in different portions were significant ($F = 3.75$, $df = 17/1545$, $P < 0.01$). On the berm the high zone had a lower nest density and the low zone had a higher nest density; the difference was significant ($F = 7.53$, $df = 2/1545$, $P < 0.01$).

The percentage of developed eggs ranged from 80% to less than 40% (Figure 4). The greatest percentage of developed eggs occurred in areas with low nests density ($F = 6.04$, $df = 7/708$, $P < 0.01$, OPCLT $F = 18.65$, $gl = 1/708$, $P < 0.01$). Hatching success was always less than 50% and values around the 20% were common, but between March and June the hatching success was zero. Hatching success increased with the density for densities less than four nests, then it reduced steadily. However, this variation in the hatching success was not statically significant ($F = 0.55$, $gl = 7/610$, $P = 0.79$).

Density of old nests

The density of old nests in the MNB varied between 0 and 24 nests/m² (Figure 5), and densities larger than 10 were rare. The highest density of old nests (2.77 ± 3.86 to 8.14 ± 3.02) occurred between January and August, and during the rest of the year was always less than 2.5 nests/m²; the difference was significant ($F = 44.04$, $df = 11/1278$, $P < 0.01$). Along the beach, the density of old nests was low in the first 4 sectors with values close to two nests/m²; while the values for the rest of the beach were between three and four old nests/m²; the difference was significant ($F = 8.65$, $df =$

17/1278, $P < 0.01$). In the berm the medium zone had the highest density of old nests, and the low zone had the lowest density; the difference was significant ($F = 7.90$, $gl = 2/1278$, $P < 0.01$).

The average of developed eggs was greater where the density of old nests was greater (Figure 6); the relationship was statistically significant ($F = 7.17$, $gl = 10/3644$, $P < 0.01$). However, the percentage of developed eggs did not change in relation to the density of old nests ($F = 0.39$, $gl = 1/3644$, $P = 0.39$). The hatching success average varied between 2% and 28% (Figure 6). The average hatching success was lower in areas with greater density of old nests ($F = 5.83$, $gl = 9/486$, $P < 0.01$), and the negative linear trend was significant (OPCLT $F = 15.66$, $gl = 1/486$, $P < 0.01$).

Hatchling production

For 37 arribadas (1998 – 2006) evaluated at the hatch time, we estimated 12,026,006 hatchlings produced (arribada average $325,027 \pm 417,833$ hatchlings). The distribution of the average of number of hatchling by sector (Figure7) showed that most of them were produced in the first six sectors of the MNB (61-66) with averages above 30,000 hatchlings, while the rest of the beach presented an average less than 20,000 hatchlings and the differences were significant ($F = 3.30$, $gl = 17/1629$, $P < 0.01$). The average number of hatchlings in the low and middle zones of the beach was two times larger than in the high zone (Figure 7) and the difference was significant ($F = 5.60$, $gl = 2/1629$, $P < 0.01$).

Discussion

The negative effect of the density-dependent nest destruction found in arribadas beaches, occurred in other species that laid eggs in sandbanks. Horseshoe crabs, *Limulus polyphemus* (Gerhart 2007), where the females also nest massively in the middle of the intertidal zone, the eggs lost by the disturbance of others nesting crabs is considered the principal cause of mortality (Penn and Brockmann 1994). In some populations less than 1% of the eggs survive (Carmichael et al. 2003). Giant South American river turtle (*Podocnemis expansa*) emerge to lay eggs in larger groups too (Ernst and Barbour 1989) in the sandbanks of the Amazonian rivers and historically were documented female aggregations comparable to *Lepidochelys* arribadas (von Humboldt and Bonpland. 1907). When the numbers of turtles of *Podocnemis expansa* are high, some females nesting in the same place (von Humboldt and Bonpland. 1907), provoke nests destruction more than 2% (Valle et al. 1973). For some green iguana populations (*Iguana iguana*) that nest collectively and synchronously (Bock and Rand 1989), the digging later produce great mortality until females, after several years, create more complex tunnels and lay their eggs deeper. For a leatherback population in French Guiana, Caut et al. (2006) found when the number of nests deposited per season in the beach was above 60,000 the number of viable nests started to decrease to less than 10%.

The changes in the nest density over the year reflect similar changes in the sizes of the arribadas (Chaves et al. unpublished data); the mean of the size of the arribadas was about one order of magnitude less during the dry season. The decline of density of old nests between September and December (Figure 5) occurring during the large arribadas of more than one hundred thousand turtles (Cornelius et al. 1991); old

nest are probably mostly eliminated during next construction (Ewert 1979). During the dry season the high temperatures and low humidity presumably caused high embryonic mortalities while the small sizes of the arribadas reduced the effects of digging turtles. During this period old nests probably accumulated.

Our findings show that while nest density is high embryonic mortality provoked by digging turtles reduces the fitness of the gregarious behavior (Bustard 1979, Cornelius et al. 1991, Caut et al. 2006), and the interaction between overlapped nests and eggshell debris reduced the quality of nesting sites. Cornelius et al. (1991) found in two arribadas of Ostional, that the digging turtles, predation and erosion destroyed between 10% and 23.4% of the marked nest at hatch time. This numbers are very small compared to our results (70%). The difference can be relative to the size of the sample use in both studies (2 vs. 34 arribadas) and the great variation of the erosion and the digging turtles effects among arribadas. Any way, the great magnitude of natural nests destruction is very important and becomes a feature of the massive behavior in sea turtles (Márquez 1996).

Two results that do not fit the interpretation just given are the fact that the percentage of developed eggs was not affected by the density of old nests and, the high nest density did not affect the hatching success. There are no studies of the possible effects of eggshell debris on development in sea turtles other than the attraction of predators (Brown and Macdonald 1995). The eggshell debris is a problem for the incubation in birds with interspecific brood parasitism (Hauber 2003). In the Eastern Phoebe (*Sayornis phoebe*) eggs with eggshell debris adhered increment the mortality to 60%. The greater density of old nests can reduce the permeability of the sand, and the salinity condition of the beach can increase because less salt is washed

out by rainfall (Foley et al. 2006). Higher levels of salinity in the sand reduce the ability of eggs to absorb water and reduce the humidity in the nest chamber (Miller 1985). However during the extreme conditions in the dry season (higher temperatures and lower humidity) some embryos survive the firsts days of development (Chaves 1986). This means that sea turtle eggs resist severe conditions, at least for a short time and, the presence of eggshell debris may not kill the embryo before it attaches from the shell.

If the nest density influenced negatively the percentage of developed eggs, must influence negatively the hatching success too. Caut et al. (2006) found in leatherbacks turtles that the percentage of eggs damaged and the time of destruction have a significant impact in the hatching success. Nests with more than 50% of eggs destruction and nest laid on one nest containing living embryos has an almost insignificant percentage of hatching success. The reason for our data did not show a relation between hatching success and nest density maybe in relation to the destruction of nests through the incubation by erosion, other arribadas and predation (Cornelius et al. 1991). For example, overlapped nests with more than three nests were more rare at the emergence time, and this group had the greater early embryonic mortality. Otherwise, four nests density seems to be a critical density where the hatching success reach a maximum value. When the nests density exceed this number hatching success decrease. However higher nest densities are rare at the hatch time (Fig. 4).

Girondot et al. (2002) suggested that the reduction in the viability by high nest density is important to explain the decline of leatherback population in French Guiana. However in Ostional, the lower average of hatching success (similar to Guiana leatherback population) represents several hundred of thousands of hatchlings per

arribada (Cornelius et al. 1991, this paper). We need to analyze the number of hatchlings produce and not only the percentage of hatching success, to establish the true impact of the lower viability in the maintenance of larger population. The critical question is whether this number of hatchlings is enough to replace the adult population or not. Arribadas in Ostional produced more than one million of hatchlings each year in the last 8 years in the MNB alone, but other areas of the beach produced larger number of hatchlings too (GC unpublished data). The stability of the arribada population in Ostional since 1970 (Cornelius et al. 1991, Chaves et al. unpublished data) may indicate that this number of hatchlings is enough to conserve the population. Of course, lower level of juvenile and adult mortality is imperative. Studies established that the mechanization of the fisheries in India (Kocherry 2000), provoked the increment in adult mortality of the olive ridley turtles reducing the size of the arribadas.

The nest site selection in mass nesting sea turtles populations is a trade-off between better conditions to embryo development and the high rates destruction by the ocean and estuaries erosion. The olive ridley turtles generally lay close to spring high tide level (Márquez 1996) and estuaries (Loveridge 1946). Only one arribada failed to use this last area between 1998 and 2006, and on 76% of the days in which there was an arribada the turtles laid in front of the Ostional estuary, arribadas always started there (GC unpublished data). Deraniyagala (Loveridge 1946) suggested that fine grain and the dilution of the salt water in the beach close to estuaries influence the nest site selection in olive ridley. Cornelius and Robinson (1991) proposed that if the putative soil organisms (fungus and bacteria) those causing the nest mortality in the open beach are intolerant of salt water, then the washed over by the extreme high tides would be advantageous and result likely in an increase in hatching success. We suggest that a

lower density of nests, overlapped nests and eggshell debris, are factors to take into account to explain the high viability in these areas.

Considering that the reduction of the nest density increase the viability of the sea turtles eggs on massive nesting events, collecting nests during the first two days of the arribadas by the project of sustainable use of arribada eggs in Ostional (Cornelius et al. 1991) must be considered a conservation tool. In addition cleaning the beach by hand two times each month by the Ostional inhabitants (Chaves 2000), improves the access to the beach and left sea turtles have more chance to choose the nesting site. The conservation of the rivers and their estuaries become essential to maintain the good conditions for incubation. Most of the river and stream in Ostional covers short areas and they are tending to flood even with little precipitations. Preserving the riparian forest stabilizes the rivers and reduces the flood risk (Sáenz Maroto 1981). As most of the hatchlings are producing in the sectors close to the estuary, the quality of its water is important in the development of the eggs. Polycyclic aromatic hydrocarbons (PAH) from oil spill and incomplete combustion of carbon (including forests fire) are involved in deformities in freshwater turtles (Bella et al. 2006). These kinds of problems will become most common in relation to the development of the coastal area.

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Table 1. Frequency of the overlapped nests from 76 arribadas (1998-2006) occurred in the low, medium and high area of the berm in the MNB of the Ostional Wildlife Refuge.

NUMBER OF OVERLAPPED NESTS	BERM AREA		
	LOW	MEDIUM	HIGH
2	68	82	5
3	42	60	0
4	12	12	0
6	6	0	0



Fig. 1. Main nesting beach (MNB) area in Ostional Wildlife Refuge shows the important water bodies, mangrove forests and the position of the numbered posts used in the study.

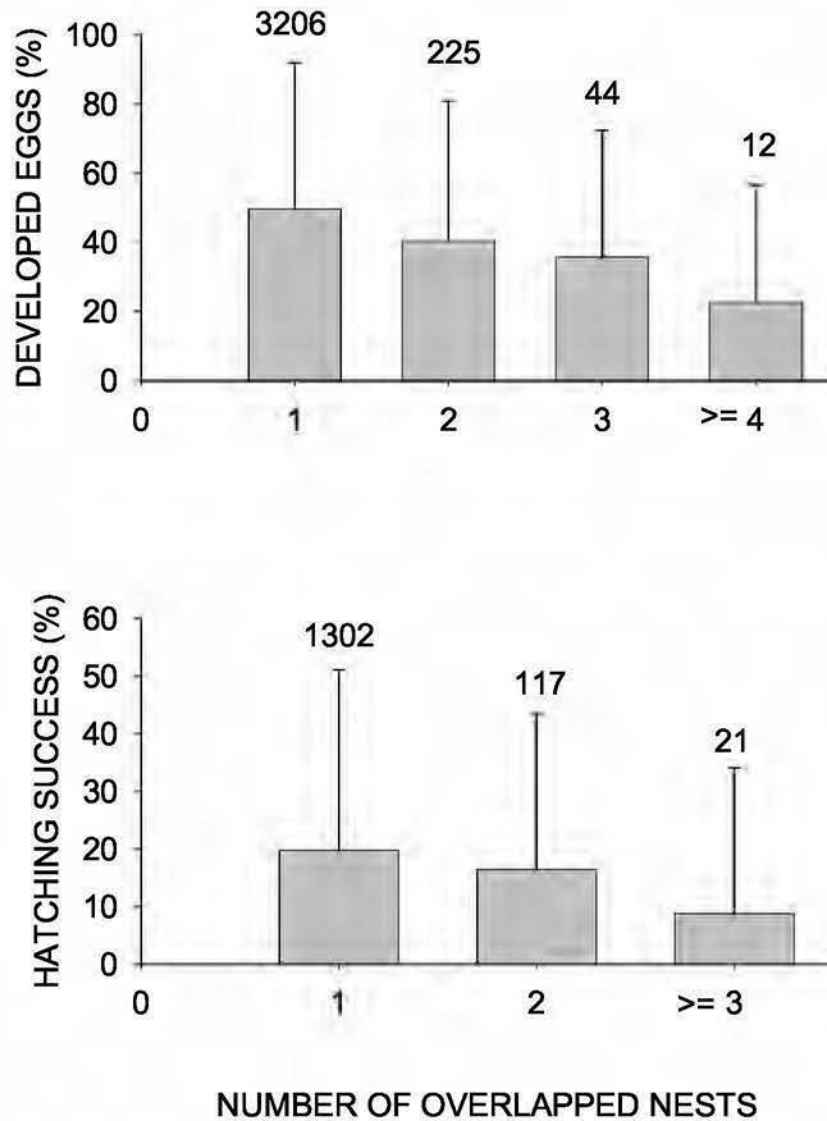


Fig. 2. Trends in the average of the percentage of developed eggs and hatching success in relation to the number of non-overlapped and overlapped nests in the MNB of the Ostional Wildlife Refuge. The number of nests analyzed is located above the columns.

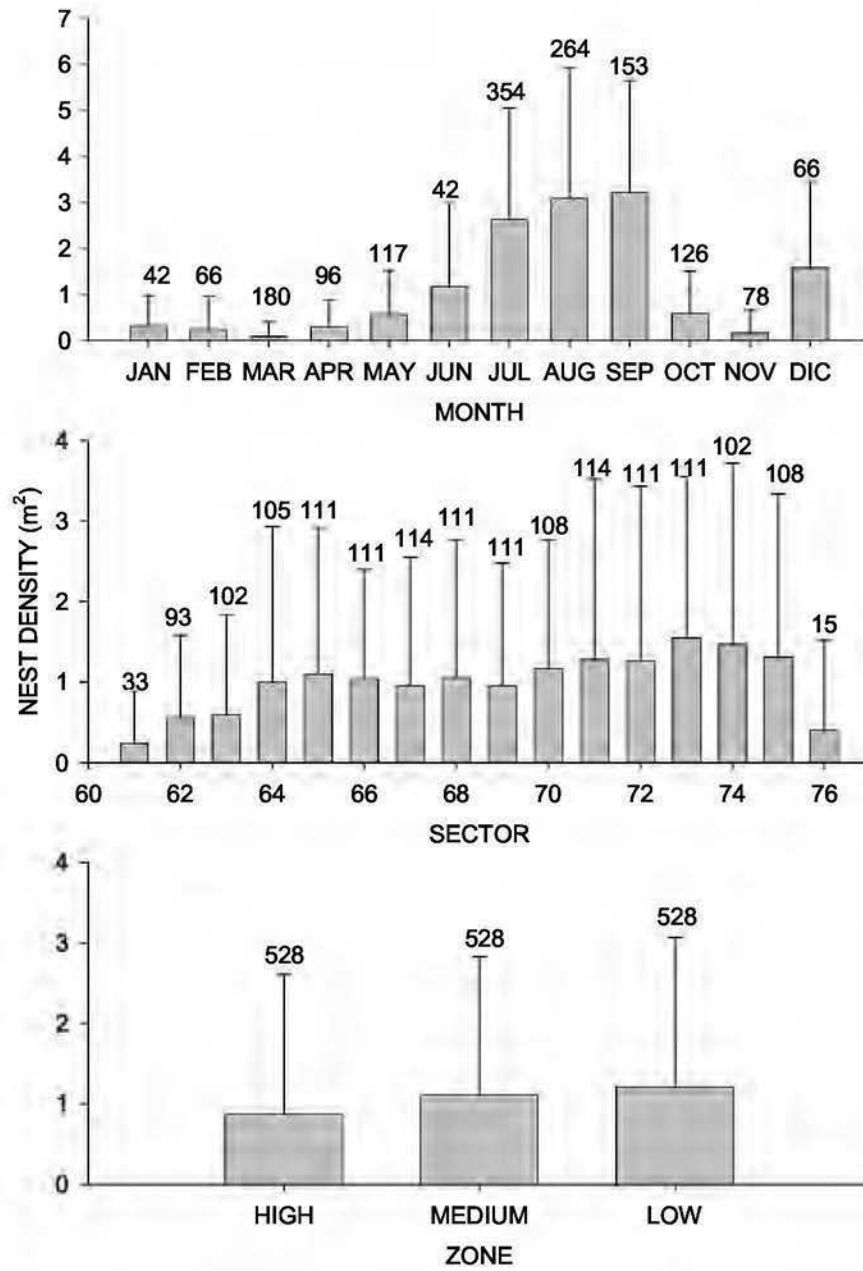


Fig. 3. Nests density average distributed by month, sector and zone of the MNB in Ostional (1998-2006). Above the columns are the numbers of holes sampled to the study.

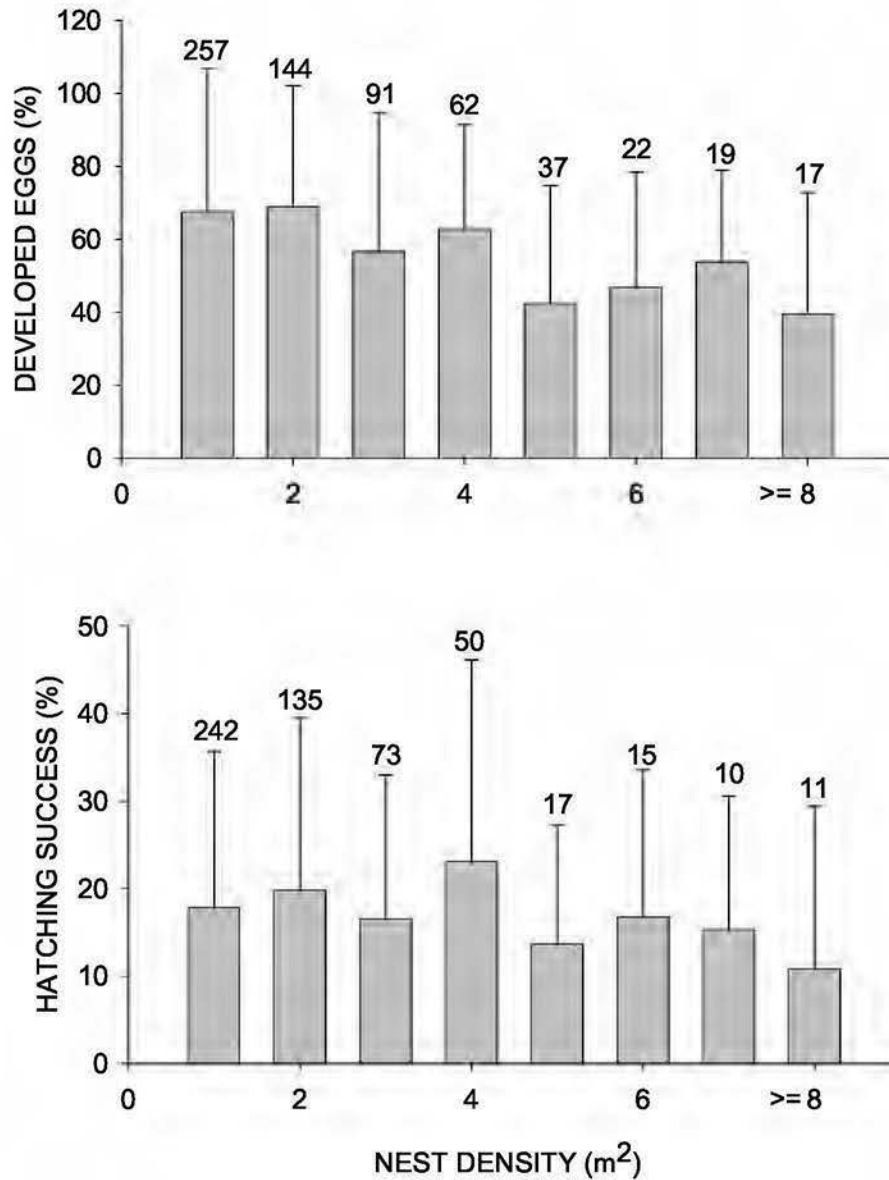


Fig. 4. Tendency in the average of the percentage of developed eggs and hatching success in relation to the nests density in the MNB of the Ostional Wildlife Refuge. The number of nests analyzed is located above the columns.

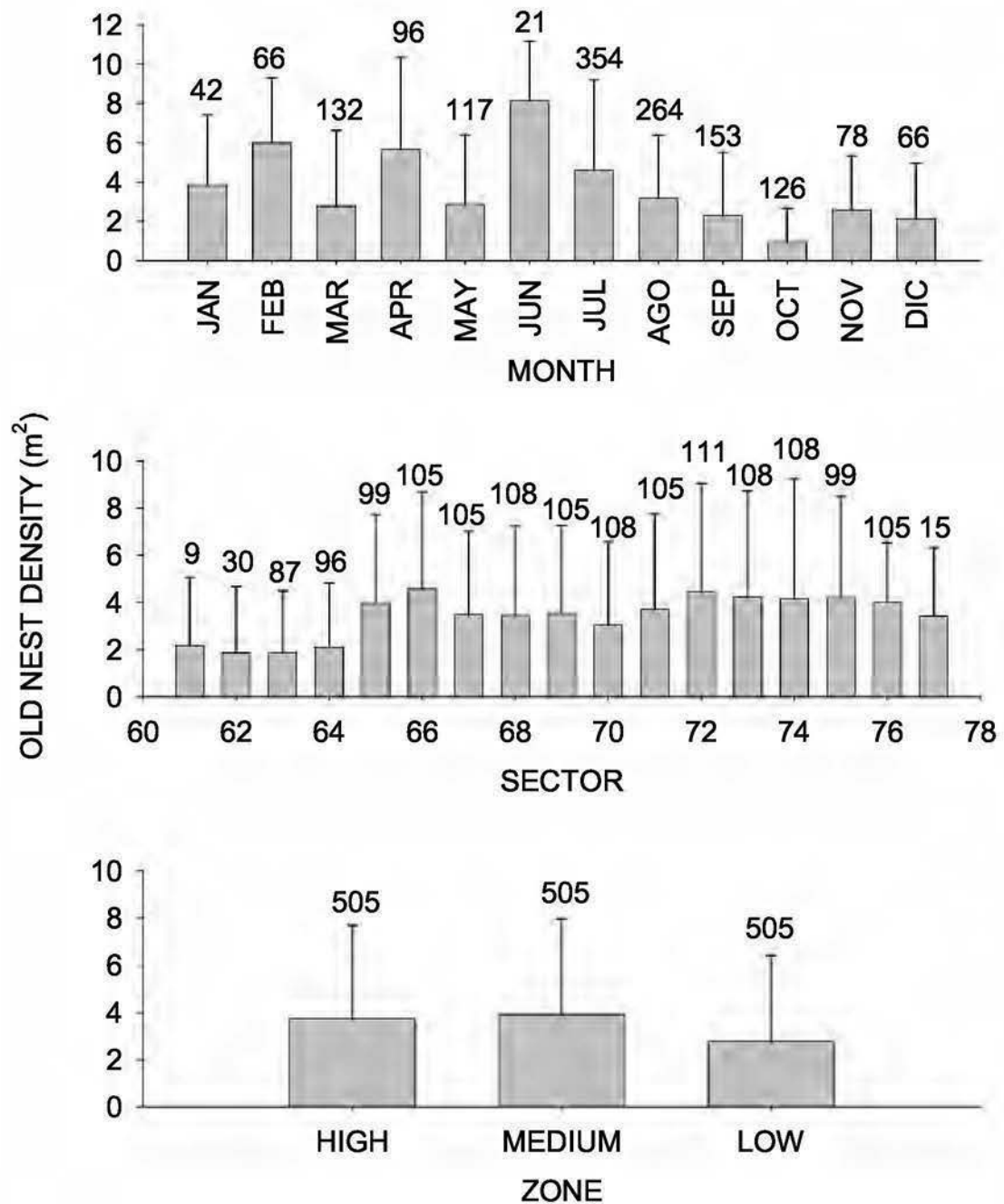


Fig. 5. Distribution of the average of the density of old nests by month, sector and zone of the MNB in Ostional (1998-2006). The number of holes sampled is located above the columns.

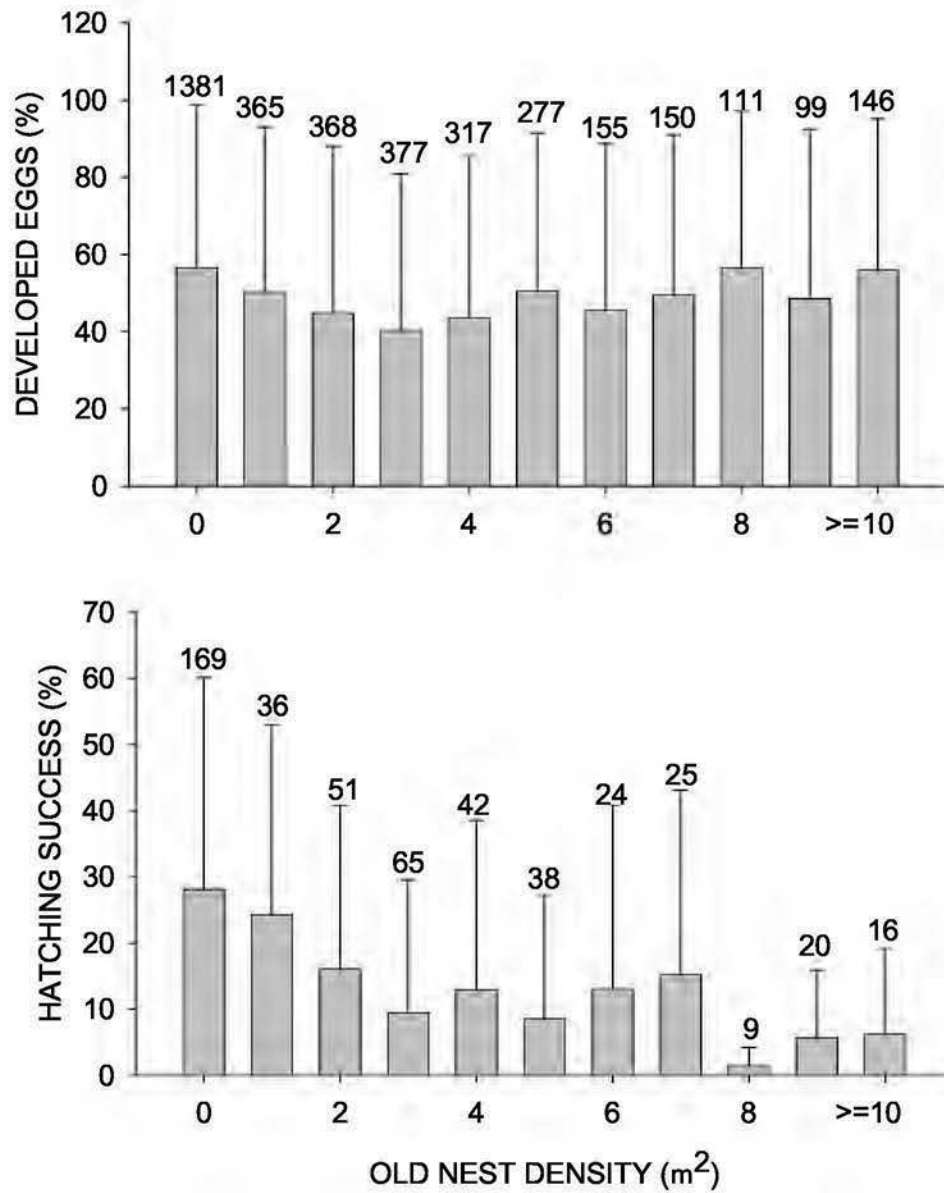


Fig. 6. Tendency in average of the percentage of developed eggs and hatching success in relation to the density of old nests the MNB in Ostional beach (1998 – 2006). The number of nests analyzed is located above the columns.

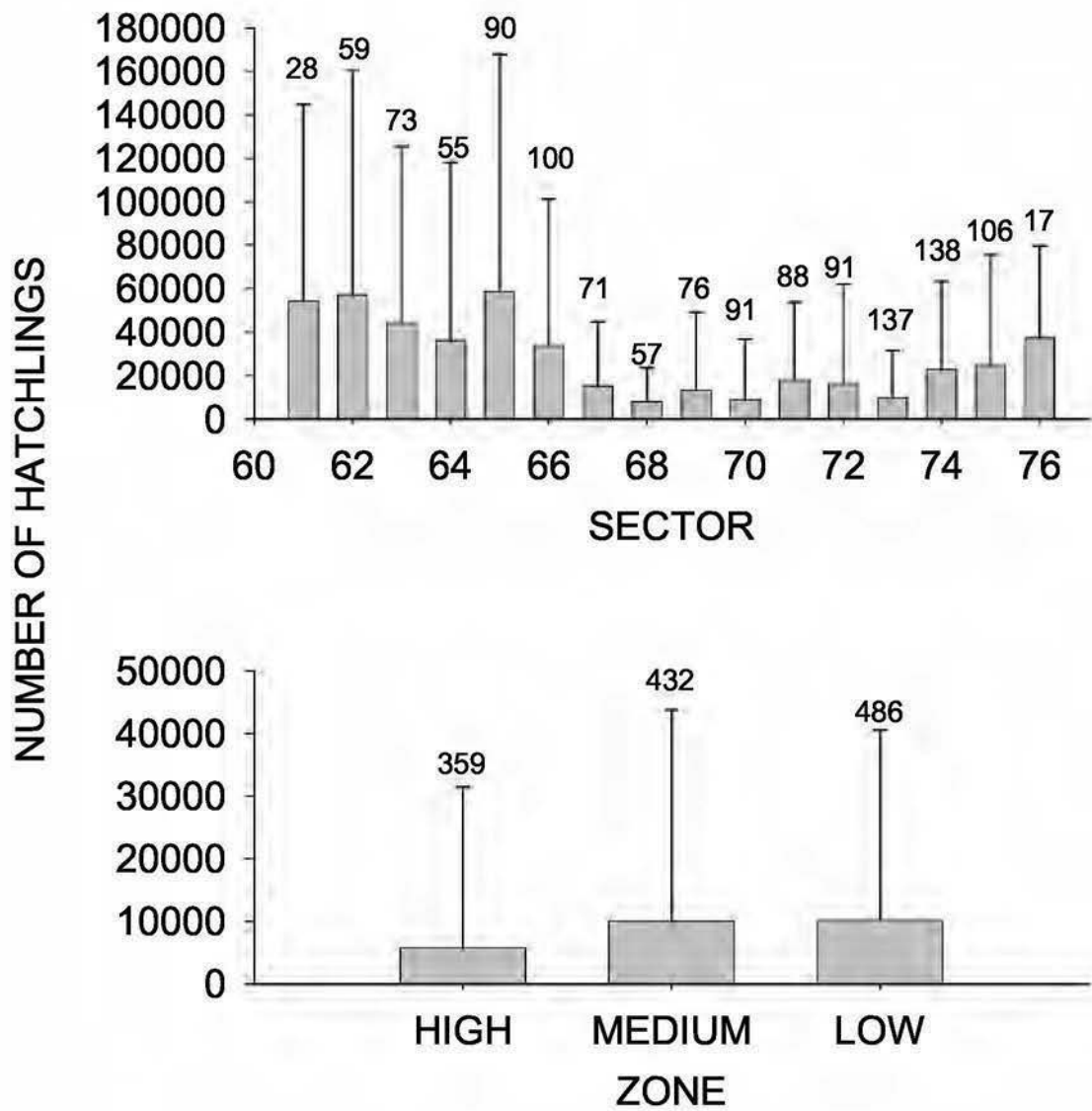


Fig. 7. Average of hatchlings produced by sector and area of the berm per arribada in the MNB of the Ostional beach (1998 – 2006). The number of nests analyzed is located above the columns.

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