MARINE TURTLES

Recovery of Extinct Populations

Edited by: L.F. López-Jurado & A. Liria Loza

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Recovery of Extinct Populations

TORTUGAS MARINAS

Recuperación de Poblaciones Extinguidas

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PREFACE / PREFACIO

Luis Felipe López-Jurado

PREFACE

An international meeting was held in Fuerteventura, in December 2002, to discuss the recovery of extinguished populations of marine turtles. Fortuitous causes beyond our control have delayed the publication of this book for just over three years. For this reason, some of the results presented at the time could be somewhat out of date, but an overwhelming majority of them are valid.

Marine turtles are our common goal. Throughout history, these species have been one of the main resources used by human communities; initially as a primarily food resource and now as a cultural and scientific resource.

The rise in importance of turtles in western history, especially from the 15th century onwards, with the European voyages of exploration, in many cases meant the end of the traditional and mainly sustainable exploitation of this resource by many indigenous communities.

As a consequence, especially of get-rich-quick trading activities, many turtle populations, especially island populations, suffered a rapid decline and in some places led to their radical extinction.

At least two variants must be added to this very brief and general overview however. On the one hand, recently discovered uninhabited islands that were never settled by man, such as the Cape Verde archipelago, for example, where the marine turtle populations became a resource, both for the subsistence of the less favoured social classes and, supposedly, for curing contagious diseases that were widespread at the time, like leprosy, syphilis, etc.

The survival of these turtle populations in the Cape Verde archipelago and the discovery of their world wide importance in the late 20th century was undoubtedly made possible thanks to a lucky combination of factors of a geographic, social and possible natural history nature concerning the species in this area.

Whatever the reasons may be, the result is that over 3,000 females currently lay their eggs in the Cape Verde Islands, making the islands the second largest breeding ground for *Caretta caretta* in the Atlantic, and the third largest in the world after Oman and the United States of America.

On the other hand, some islands, like the Canary Islands, were conquered by the European settlers after years of fighting against aboriginal populations that had settled the islands centuries earlier. Human communities had been living on the seven main islands of the Canary Archipelago since the first century A.D., human communities that had been there for 14 centuries. The most striking aspect is that none of the indigenous communities of the seven Canary Islands knew anything about the art of sailing, not even in small canoes.

For this reason, the small, uninhabited islands situated around some of the larger islands were never visited by anyone until the arrival of the Europeans in the early 15th century. One of the first consequences of this historic development was, for example, the disappearance of an emblematic species for the Macaronesia region - the monk seal -, from the Canary Islands. The monk seal had managed to survive on some of these small islets of the Canaries, safe from the aboriginal populations and the hunting activities that they had to engage in to survive.

There are also written references that suggest that marine turtles used to breed on these islets, at least up until the end of the 18th century. These have been included in the pertinent chapter of this book.

For this reason, and well aware of the fact that marine turtles in general and *Caretta caretta* in particular, need to become key objectives for developing activities that will help to guarantee their conservation, with the results described in this book, our intention is to evaluate and implement actions aimed at recovering marine turtle populations that apparently used to nest in the Canary Islands up until the 18th century.

With this book, we hope to open a scientific process of analysis and discussion concerning the pertinence, the pros and the cons and the appropriate methods for addressing this task, based on the little but loquacious evidence that we have.

To attain our goals, we have also had the appreciable help of colleagues involved in the only successful reintroduction activities in the world to date: the reintroduction of the Kemp's Ridley turtle *Lepidochelys kempii*, and we hope that this book will help to lay a solid foundation for future conservation activities with this marine turtle species, which has been given the maximum level of protection under Canary Island, Spanish, European and international legislation.

PREFACIO

En Diciembre del año 2002 se celebró en Fuerteventura una reunión internacional para tratar sobre la recuperación de poblaciones extinguidas de tortugas marinas. Causas fortuitas ajenas a nuestra voluntad han retrasado durante algo más de tres años la publicación de este libro. Por ello, algunos de los resultados presentados entonces, podrían estar algo desfasados pero en su gran mayoría siguen vigentes.

Las tortugas marinas representan para todos nosotros un objetivo común. Estas especies han constituido desde los primeros tiempos de la historia hasta hoy en día, uno de los principales recursos utilizados por las comunidades humanas; primero como recurso principalmente gastronomico y actualmente en calidad de recurso cultural y científico.

La entrada de las tortugas marinas en la historia occidental, especialmente a partir del siglo xv coincidiendo con los viajes y exploraciones europeas, significo el fin en muchos casos, de los sistemas tradicionales y en gran parte sostenibles de explotación por parte de muchas comunidades indígenas.

Como consecuencia especialmente de actividades comerciales basadas en el enriquecimiento rápido, muchas poblaciones de tortugas, especialmente insulares, sufrieron un rápido declive y en algunos lugares extinciones radicales.

Sin embargo a este esquema generalista y apresurado habría que añadir al menos dos variantes. Por un lado, las islas deshabitadas recién descubiertas y que nunca estuvieron pobladas por seres humanos, como por ejemplo el archipiélago de Cabo Verde, vieron como sus poblaciones de tortugas marinas se convertían en un recurso tanto para la subsistencia de las clases sociales más desfavorecidas como para la supuesta curación de enfermedades contagiosas muy extendidas en esos días: lepra, sífilis, etc.

La supervivencia hasta nuestros días de estas poblaciones de tortugas en el archipiélago de Cabo Verde y el descubrimiento de su importancia mundial a finales del siglo XX, fue posible sin duda gracias a una combinación afortunada de factores de índole geográfica, social y posiblemente también ligados a la historia natural de esta especie en esta zona.

Sea como fuere, el resultado es que en las islas de Cabo Verde actualmente nidifican cada año un numero superior a las 3.000 hembras; lo que convierte a estas islas en la segunda mayor área de reproducción de Caretta caretta en el atlántico y la tercera más numerosa del mundo tras Omán y los Estados Unidos de América.

Por otro lado, algunas islas como Canarias, cuando fueron conquistadas por los europeos, lo fueron tras años de lucha contra poblaciones aborígenes asentadas allí siglos atrás. En las siete islas principales vivían desde el siglo I de nuestra era, comunidades humanas que llevaban allí 14 siglos. Lo más llamativo es que ninguna de las comunidades indígenas de las siete islas canarias conocía el arte de la navegación, ni siquiera en pequeñas canoas o piraguas.

Debido a este hecho, las pequeñas islas deshabitadas que estaban situadas en las proximidades de algunas de estas islas mayores, nunca fueron visitadas por persona alguna hasta la llegada de los europeos a principios del siglo XV. Una de las primeras consecuencias de este suceso histórico fue por ejemplo la desaparición en Canarias de una especie emblemática para la región macaronesica: la foca monje; que había logrado sobrevivir en algunas de estas pequeñas islas Canarias a salvo de las poblaciones aborígenes y de sus necesarias actividades cinegéticas de supervivencia.

Existen también referencias escritas que sugieren la existencia de actividad reproductora de tortugas marinas en estas pequeñas islas al menos hasta finales del siglo XVIII, y han sido expuestas en el correspondiente capítulo de este libro.

Por ello y conscientes de que las tortugas marinas en general y *Caretta caretta* en particular, necesitan convertirse crecientemente en objetivos clave para el desarrollo de actividades que ayuden a garantizar su conservación, con los resultados expuestos en este libro, pretendemos evaluar y en su caso implementar, una actuación consistente en recuperar, en la medida de lo posible, aquellas poblaciones de tortugas marinas que al parecer nidificaban en las islas Canarias hasta el siglo XVIII.

Con este libro queremos abrir un proceso científico de análisis y discusión acerca de la pertinencia, las ventajas e inconvenientes y los métodos apropiados en su caso, para emprender esta tarea; sobre la base de las escasas pero contundentes pruebas que tenemos.

Contamos para ello también con la apreciable ayuda de los colegas implicados en la hasta ahora única y exitosa actividad de reintroducción que se ha realizado en el mundo con éxito: la de la tortuga golfina *Lepidochelys kempii*, y esperamos que con este libro queden perfectamente delineados los cimientos de una futura actividad práctica para la conservación de esta especie de tortuga marina incluida en el máximo nivel de protección tanto por la legislación canaria como española, europea e internacional.

Resumen general

ANA LIRIA LOZA

CONDICIONES OCEANOGRÁFICAS DEL ESPACIO MARINO MACARONÉSICO. RELACIÓN CON LA DISTRIBUCIÓN Y COMPORTAMIENTO DE LA TORTUGA *CARETTA CARETTA.*

O. Llinás*, M. J. Rueda*, J. Pérez-Marrero*, M. Villagarcía*, C. Barrera*, A. Cianca**, J. Godoy*, L. Maroto* , L. Cardona*, E. González-Roncero* y C. Llerandi*.

En este artículo se revisa y analiza la información disponible sobre las características oceanográficas del Espacio Marino Macaronésico, que es el espacio oceánico entre los archipiélagos del Atlántico Centro Oriental y la costa occidental africana.

La circulación general que afecta a este espacio, denominada “Giro subtropical del Atlántico Norte”, es probablemente uno de los procesos circulatorios conocido desde más antiguo. La gran cantidad de datos que se tienen sobre esta zona, junto con los avances tecnológicos que han aportado información mucho mas precisa, permiten delimitar el Espacio Marino Macaronésico con bastante exactitud, situándolo entre dos frentes claramente caracterizados, El Frente de Azores al norte y el Frente de Cabo Verde al sur.

El Espacio Marino Macaronésico se caracteriza por presentar gradientes de distintas propiedades observables que se relacionan e interconectan, pudiéndose considerar como un “espacio singular” que proporciona condiciones características particulares.

Este trabajo presta atención especial a la información sinóptica obtenida desde satélite, que permite observar la conexión en tiempo casi real de los fenómenos que ocurren en dicho espacio, relacionándolos con el desplazamiento y comportamiento de especies migratorias como la tortuga común (*Caretta caretta).*

EL mejor entendimiento oceánico de este espacio permitirá sin duda una mayor aproximación al conocimiento de los ciclos vitales de animales migratorios oceánicos como es el caso de las tortugas marinas.

REVISIÓN HISTÓRICA DE TORTUGAS MARINAS EN AGUAS DE MACARONESIA.

L. F. LÓPEZ-JURADO.

Los archipiélagos de Azores, Madeira, Salvajes, Canarias y Cabo Verde forman un arco que atraviesa la zona este del Atlántico norte. Este conjunto de islas configuran una unidad biogeográfica conocida como la MACARONESIA, caracterizada principalmente por sus afinidades biológicas y geológicas.

De las siete especies de tortugas marinas, seis pueden verse con distintas frecuencias en las aguas de Macaronesia. La presencia de cada especie varía según el archipiélago. La tortuga boba (*Caretta caretta*) es la más común en todos los archipiélagos, presente en estadio juvenil en todos los archipiélagos menos en Cabo Verde, siendo este el único en el que nidifica. La tortuga laúd (*Dermochelys coriacea*) también esta presente en todos los archipiélagos, aunque no nidifica en ninguno de ellos a excepción de algún caso esporádico en las islas de Fuerteventura (Canarias) y de Santiago (Cabo Verde). Las tortugas verde y carey (*Chelonia mydas y Eretmochelys imbricada*) se encuentran en estadio juvenil en Canarias y Cabo Verde; La tortuga lora (*Lepidochelys kempii*) solo se ha observado esporádicamente en Azores y Madeira mientras que la tortuga olivácea (*Lepidochelys olivacea*) solo en Cabo Verde, aunque nunca nidificando.

Sabemos que las tortugas marinas juegan un papel importante en cada archipiélago, pero desde el punto de vista científico todavía se sabe muy poco sobre su historia. Considerando que el estado actual de una población es el resultado de una serie de interacciones, que comenzando en el pasado, han llevado a dicha especie hasta el punto en el que se encuentra actualmente; el manejo, protección y conservación de dicha especie no podrá llevarse a cabo mientras sigamos ignorando cuál era su estado en el pasado.

Además, los datos históricos no solo nos introducen en la relación existente entre esta especie y los archipiélagos macaronésicos, sino que nos dará una valiosa información para manejar estas poblaciones en el presente e incluso a afrontar posibles cambios que puedan llegar en el futuro.

El objetivo de este artículo es destacar y recopilar toda una serie de datos históricos y prehistóricos de las tortugas marinas y los archipiélagos Macaronésicos de Canarias y Cabo Verde. Muchos de estos datos no han sido publicados previamente o incluso han sido malinterpretados por varios autores en el pasado.

Las primeras citas de tortugas marinas en el archipiélago de Cabo Verde fueron las de Eustache de la Fosse en 1480 y de Valentim Fernandes en 1506, en las que hacen referencia al uso de estos animales para la cura de la lepra. Otras citas importantes fueron las del mercader inglés William Dampier, que realizó muy buenas descripciones de un gran número de especies de fauna y flora, y que en 1683 nombró en su primer libro la presencia de tortugas marinas en el archipiélago de Cabo Verde.

El doctor inglés George Glass describe en 1764 como los nativos de las Islas Canarias también daban a la sangre de las tortugas marinas un gran valor medicinal, como remedio contra las enfermedades. Incluso se cita la nidificación de tortugas marinas en el archipiélago canario a finales del siglo XVIII, descrita por José de Viera y Clavijo.

Las referencias bibliográficas de los siglos XIX y XX se han omitido en este artículo ya que la mayor parte de la información referente a las islas de Cabo Verde del siglo XX han sido recopiladas por López-Jurado et al (2000a), y las referencias del siglo XIX son solo las de Rochebrune (1884) y Bocage (1896) y son bastante imprecisas.

REVISIÓN ACTUALIZADA DE LAS TORTUGAS MARINAS DEL MEDITERRÁNEO.

D. Margaritoulis.

El Mediterráneo fue colonizado por dos de las especies mas cosmopolitas de tortugas marinas, la tortuga común (*Caretta caretta*) y la tortuga verde (*Chelonia mydas*), procedentes de las poblaciones residentes en el océano Atlántico.

En la actualidad, la nidificación de ambas especies ha quedado restringida a la zona este del Mediterráneo. Las poblaciones nidificantes de tortuga común se encuentran en Grecia, Turquía, Chipre y Libia mientras que las de tortuga verde nidifican solo en Turquía y Chipre.

En la actualidad se ha podido observar que se ha producido una gran divergencia genética entre las poblaciones atlánticas y mediterráneas debido a la disminución progresiva del intercambio genético entre ambos hábitats. Así pues, gracias a los estudios genéticos y a las diferencias observadas en el tamaño de las hembras nidificantes, queda constatada la existencia de sub-poblaciones, para cada una de las especies, en las aguas del Mediterráneo.

Hasta hace relativamente poco tiempo, toda la información sobre las tortugas marinas se obtenía en las zonas de nidificación, pero en la actualidad diversos estudios han permitido obtener muchos datos sobre el uso de otros hábitats. Por ejemplo, el marcaje intensivo ha revelado importantes áreas bentónicas para tortuga común en el Golfo de Gabes y en el Adriático norte; el gran número de capturas incidentales en los palangres del Mediterráneo sugiere la utilización de los hábitats pelágicos por diferentes poblaciones de tortuga común, aunque las rutas migratorias aún nos son desconocidas; y aún más, las capturas incidentales de tortugas marcadas demuestran un intercambio muy activo entre las zonas este y oeste del mar Mediterráneo. Otros estudios, como los de seguimiento por satélite sugieren la migración de tortugas verdes hacia las costas del norte de África tras su nidificación en Turquía y Chipre.

Al igual que el resto de los mares y océanos, las tortugas marinas que frecuentan las aguas del Mediterráneo se ven afectadas por una gran variedad de actividades humanas, tanto en el mar (contaminación, pesca incidental, colisiones con embarcaciones...) como en la tierra (degradación y ocupación de las playas, predación humana de huevos...).

Los Convenios internacionales, las legislaciones a nivel nacional de la mayoría de los países afectados, los planes de gestión y los proyectos de conservación intentan llevar a cabo la protección de dichas poblaciones y de sus hábitats. Sin embargo, su naturaleza migratoria y la maduración tardía de estas especies, así como los conflictos de elevados intereses económicos tanto en el mar como en la tierra, hacen de esta una labor muy difícil y complicada.

COMPORTAMIENTO ECOLÓGICO Y CONSERVACIÓN DE LAS TORTUGAS MARINAS EN ESTADO OCEÁNICO.

THOMAS DELLINGUER.

Las crías de tortuga boba (*Caretta caretta*) entran en el mar inmediatamente después de la emergencia del nido, en el que nacieron unas horas antes. Una vez en el agua nadan desesperadamente hacia mar abierto donde pasarán los primeros 6-12 años de vida en la que se denomina etapa juvenil u oceánica. La tortuga boba es la especie de tortuga marina con la etapa oceánica de más larga duración.

La existencia de esta etapa oceánica ha intrigado a los investigadores de todo el mundo, ¿por qué abandonan estos animales las zonas litorales, con gran abundancia de comida, para adentrarse en el océano, donde los recursos son bastante mas escasos? ¿Para evitar el gran número de predadores que hay en el litoral?, o ¿para aprovechar la baja densidad de competidores que encontramos en mar abierto?. Además, hay que tener en cuenta que la condición de reptil brinda a estos animales una gran ventaja para sobrevivir en estas condiciones, que es la capacidad de pasar grandes temporadas sin comer debido a su lento metabolismo.

En la zona este del Atlántico norte, donde se sitúan los archipiélagos de Azores y Madeira, se encuentra una de las zonas más importantes de alimentación de juveniles de tortuga boba. Investigadores como Brongersma (1967) y Archie Carr (1986) teorizaban sobre el origen de estas tortugas en la costa este de EEUU, hecho que han demostrado actualmente los estudios genéticos. Además los tamaños de las tortugas encontradas en los archipiélagos de Madeira y Azores se corresponden con los tamaños que no se observan en la costa este de EEUU.

En la actualidad, se están llevando a cabo estudios de seguimiento por satélite para obtener más información y más fiable sobre el comportamiento y la ecología de las tortugas marinas durante este estadío oceánico. En Madeira, en los últimos años se han colocado transmisores de satélite a 10 tortugas de diferentes tamaños encontradas en estas aguas. Gracias a estos transmisores ha quedado demostrado que estas tortugas están en continuo movimiento, que son capaces de nadar en contra de las corrientes predominantes (aunque se cree que la talla del animal juega un papel importante), que utilizan las zonas en calma, generalmente al sur de las islas para termoregularse, e incluso permiten suponer posibles migraciones estacionales. Además, se ha observado que las tortugas permanecen cerca de la superficie, realizando escasas y cortas inmersiones generalmente en busca de alguna presa.

Toda esta información se suma a otra serie de estudios que se llevan a cabo desde hace años en Madeira, como son los censos desde embarcaciones, censos aéreos, estudios estomacales o la toma de datos de pesca accidental en los pesqueros artesanales de la isla. Todos estos esfuerzos definen con bastante precisión la población de tortuga boba que ronda las costas de Madeira, dándonos, por ejemplo, su rango de tamaño de 131-694mm (en longitud recta de caparazón). De este dato se deduce que el estadio oceánico tiene una duración de unos 7 años y que las tortugas abandonan estas aguas a una edad de unos 12 años.

Por otro lado, toda esta información también indica la gran mortalidad que está sufriendo esta población, bien sea por captura accidentales por pesqueros, o el gran número de tortugas muertas que presentan plásticos en el estomago, así como el gran porcentaje de tortugas atrapadas en la basura a la deriva y manchas de petróleo y aceite.

Todo ello deja claro que deberían tomarse mayores y nuevas medidas para la conservación y protección de esta especie ya que la creación de áreas protegidas no protege a estos animales en constante movimiento. Nuevos métodos de pesca, un aumento de la educación ambiental, así como la creación de centros de recuperación especializados y el reforzamiento de los convenios internacionales podrían ayudar a que esta especie no desaparezca de nuestros mares.

RECUPERACIÓN DE TORTUGAS MARINAS ACCIDENTADAS EN LAS AGUAS DEL ARCHIPIÉLAGO CANARIO ENTRE LOS AÑOS 1998 Y 2003.

Calabuig Miranda, P. y Liria Loza, A.

Desde principios de los años 90, el Centro de Recuperación de Fauna Silvestre (CRFS) del Cabildo de Gran Canaria (Islas Canarias, España) acoge un gran número de animales salvajes para su recuperación. Además de aves y algunos mamíferos recupera un importante número de tortugas marinas. Durante los 6 últimos años (1998-2003) han llegado a ingresar más de 100 tortugas al año, de las cuales más del 80% fueron recuperadas y liberadas. Este número tan elevado indica la importancia de esta área geográfica para las tortugas marinas y principalmente para su etapa oceánica todavía tan desconocida. El estudio de las tortugas en esta etapa de su vida es muy importante ya que podría ayudar a responder numerosas preguntas sobre el comportamiento migratorio de estos animales. La situación geográfica del archipiélago canario brinda una gran oportunidad para el estudio de esta etapa oceánica.

La especie más abundante en Canarias es la tortuga común (*Caretta caretta*) representada principalmente por individuos juveniles. Otras especies de tortugas marinas que pueden observarse en Canarias son ejemplares juveniles y adultos de tortuga laúd (*Dermochelys coriacea*), juveniles de tortuga verde (*Chelonia mydas*) y alguna juvenil de tortuga carey (*Eretmochelys imbricata*).

En la actualidad, las poblaciones de tortugas marinas de todos los océanos están sufriendo grandes daños, por lo que para su protección y conservación es muy importante saber las verdaderas causas que les afectan. Es por ello que la información proveniente de los centros de recuperación es de gran importancia ya que nos da una valiosísima información sobre dichas causas, en que proporciones se producen y en que grado están afectando a las poblaciones.

En el caso de Canarias, las principales causas de ingreso de las tortugas se deben mayormente a las actividades pesqueras, es decir, tortugas que quedan enmalladas en redes, que ingieren anzuelos, o que son heridas directamente por los propios pescadores.

Otras causas de ingreso importantes son las derivadas de la contaminación marina. Las tortugas marinas se alimentan principalmente en superficie y por lo tanto se interesan por cualquier objeto a la deriva que encuentren en su camino. En la actualidad una gran parte de esos objetos son restos y desechos del ser humano, tales como redes o líneas de palangre perdidas o desechadas, cuerdas, plásticos, manchas de hidrocarburos pesados... Las tortugas se aproximan a estos objetos y los ingieren o quedan enredadas con ellos.

Un pequeño porcentaje de los ingresos en el CRFS se deben a causas naturales, como mordeduras de tiburones, diversas enfermedades (principalmente epidérmicas), anemias, problemas de flotación, etc., aunque no se sabe si algunas de ellas son también derivadas de actividades humanas.

En este trabajo se detallan los datos de la recuperación de 906 tortugas marinas accidentadas en aguas del Archipiélago Canario entre los años 1998 y 2003, así como el agradecimiento a la gran colaboración ciudadana que se ha conseguido en el archipiélago gracias a las labores de sensibilización y educación ambiental.

BIOLOGÍA REPRODUCTIVA DE LA TORTUGA COMÚN (*Caretta caretta* L. 1758) EN LA ISLA DE BOAVISTA (CABO VERDE).

N. VARO, D. CEJUDO & L. F. LÓPEZ-JURADO.

La tortuga común, *Caretta caretta* (Linnaeus, 1758), se encuentra presente en todos los océanos del mundo, con numerosos lugares de nidificación conocidos en zonas templadas, subtropicales y tropicales. Uno de estos lugares de desove, que cuenta con una numerosa población reproductora, se sitúa en el Archipiélago de Cabo Verde en el océano Atlántico oriental (CEJUDO et al., 1999). La isla de Boavista es la que alberga un mayor número de hembras nidificantes, seguida de Sal y Maio, y en menor medida de otras islas (CEJUDO et al., 1999; LÓPEZ-JURADO et al., 1999a).

Se exponen a continuación los datos revisados y actualizados de la población nidificante de tortuga común en la isla de Boavista, estudiada desde el año 1998 al 2002. Hasta la fecha se han marcado un total de 2.856 hembras en diferentes playas de la isla. El número de nidos contabilizados en el área de estudio (en las playas de Calheta, Ervatão y Ponta Cosme), para un total de 4.2 km de playa, fué de 833 y 1.917 (únicamente en los años 2001 y 2002, respectivamente). El éxito de puesta en estos dos años se sitúa en torno al 26 %, con diferencias entre playas. Las medias anuales de la longitud curva del caparazón de las hembras se sitúan entre 81,3 y 82,4cm, y del tamaño de las puestas entre 78,3 y 91,5 huevos. El rango de los tiempos de incubación fue de 45-74 días, con diferencias entre años y entre playas. El éxito de eclosión parece no mostrar variaciones entre años, pero el comportamiento en cada playa fue diferente.

Durante la temporada de nidificación del año 1999, se observó que el éxito de eclosión era bajo en las playas de Ervatão y Ponta Cosme respecto al de Calheta (CEJUDO et al., 2000). Por esta razón, en el año 2000 se realizó una experiencia de incubación artificial con nidos procedentes de estas dos playas. El éxito de los nidos incubados artificialmente fue superior al de los incubados en la playa de Ponta Cosme y similar al de los incubados en Ervatão.

INTENTO DE REINTRODUCCIÓN DE LA COLONIA NIDIFICANTE DE TORTUGA LORA (*Lepidochelys kempii*) MEDIANTE IMPRINTING* EXPERIMENTAL Y HEAD-STARTING*.

DONNA SHAVER.

En los años 70 se observó la drástica disminución de las colonias nidificantes de tortuga lora *(Lepidochelys kempii)* en la costa oeste del Golfo de Méjico. En la franja americana del estado de Texas ya era casi inexistente y en la franja mejicana de Tamaulipas disminuía a gran velocidad. Las principales causas de esta disminución son la predación humana de los huevos y el gran número de capturas incidentales de ejemplares juveniles y adultos por los barcos arrastreros camaroneros.

Estos datos alarmantes hicieron que el gobierno americano y mejicano se pusieran de acuerdo para llevar a cabo un proyecto experimental de conservación para reestablecer la colonia nidificante de tortuga lora en *Padre Island Nacional Seashore* (PAIS), Texas, EEUU.

Entre los años 1978-1988 se recolectaron un total de 22.507 huevos de Rancho Nuevo, Tamulipas, Méjico, para su *imprinting** experimental en PAIS, mediante la exposición de dichos huevos a la arena y a las playas de la nueva zona (PAIS). Durante todo el proyecto se llevó a cabo el control de la proporción de sexos en los nidos, resultando que el 77,1% de las huevos eclosionados y de las crías tuvieron una proporción de 1,5F:1M.

Entre los años 1979-1989, se liberaron en el golfo de Méjico, al sur de Texas, 13.211 *head-started** de este proyecto. Durante estos años, también se liberaron 300 tortugas que habían permanecido en cautividad de 2 a 16 años y cerca de 9000 *head-started** de un año que no formaban parte del proyecto experimental de *imprinting**. Estas últimas eran crías que se obtuvieron directamente de Méjico entre los años 1978-1992 para *head-starting** y la mayoría eran hembras.

Entre los años 1989-2002, el 53% de los nidos de tortuga lora documentados en EEUU fueron en PAIS.

Entre 1985-2002, en la costa de Texas se confirmaron 110 nidos de tortuga lora, de los que 106 se encontraron entre 1995-2002. Durante estos años, 10 tortugas que habían sido *imprinting** en PAIS hicieron 19 nidos y 3 *head-started** de las obtenidas directamente de Méjico pusieron 3 nidos en PAIS. Estas 13 tortugas se vieron nidificando por primera vez a una edad de entre 10-15 años. Este hecho representa el primer nido natural confirmado de una tortuga marina *head-started** y el primer dato confirmado de la nidificación natural de una tortuga lora de edad conocida. El *imprinting** experimental de PAIS es el primer *imprinting** experimental de tortugas marinas en el que se ha confirmado la vuelta a nidificar de una tortuga a la zona de *imprinting**.

A pesar de que este hallazgo sugiere que el *imprinting** experimental y el *head-starting** aumentan el número de nidos, entre los años 1986-2002 el número de tortugas adultas muertas en la costa sur de Texas fue mucho mayor que en le resto de estados de EEUU. Es decir, el aumento de la mortalidad de tortugas adultas se concentró principalmente en las playas del sur de Texas, justo durante el período del experimento y sobretodo en los años 1994-2002, coincidiendo con el aumento del número de nidos. Entre 1995-2002, 141 de las 253 tortugas muertas en EEUU vararon en las playas del sur de Texas, y 135 tortugas de las 141, murieron durante la temporada de pesca de camarón.

En la actualidad, el futuro de la población nidificante de tortuga lora en el sur de Texas así como la posibilidad de evaluar los resultados experimentales llevados a cabo en este proyecto dependen directamente de la supervivencia de las tortugas lora adultas de esta área principalmente frente a los barcos arrastreros camaroneros.

LA TORTUGA LORA, *Lepidochelys kempii* (GARMAN, 1880) COMO UN EJEMPLO DE COOPERACIÓN INTERNACIONAL.

RENÉ MÁRQUEZ

Tres años después del descubrimiento de la zona de nidificación de tortuga lora (*Lepidochelys kempii*) en Tamaulipas, Méjico, empezaron a ponerse en marcha las labores de protección. En 1966, se empezó protegiendo 13,5km de playa y fue aumentando gradualmente hasta los 230km que se protegen en la actualidad. En un principio se liberaban entre 20.000 y 25.000 crías de tortugas por año.

En 1978 comienza un programo de colaboración con EEUU y el número de crías protegidas y liberadas aumenta rápidamente. A pesar de todo, la colonia nidificante de tortuga lora sigue disminuyendo, hasta una media de solo 745 nidos por año entre 1985-1987 (cada hembra pone una media de 2,3 nidos cada estación). Diez años después del inicio de esta cooperación, la población empieza a aumentar, de tal manera que en el año 2002 se protegieron un total de 6325 nidos que dieron lugar a 405.000 crías que se liberaron en las playas de seis campamentos de Tamaulipas y uno en Veracruz.

Dentro del programa de cooperación con EEUU se realizó un estudio experimental en el que se realizan actividades de *imprinting** y *head-starting**. Para este estudio se donaron entre 1978 y 1992, 20 nidos al año que produjeron un total de 27.738 crías. Entre el año 1993 y 2000 se suspendieron las entregas de huevos ya que se donaron 1460 crías para otros experimentos de comportamiento relacionados con los TEDs. Estas crías se mantuvieron en cautividad de 9 a 10 meses antes de ser liberadas en las áreas apropiadas. El 85% de las crías fueron *imprinted** en Padre Island, Texas y el resto en Rancho Nuevo, Méjico. Durante la cría en cautividad el porcentaje de supervivencia fue del 75%. Como resultado de este programa, un gran número de estas tortugas se recapturaron en buenas condiciones de salud y algunas de ellas incluso han nidificado en Padre Island, por ejemplo, en el año 2002 se localizaron 35 nidos en Padre Island, de los cuales varios de ellos eran de tortugas del estudio experimental.

En 1980 y debido a que esta especie estaba considerada al borde de la extinción, se transfirieron un total de 100 tortugas juveniles de un año de edad criadas en cautividad en Galveston, Texas, y 100 crías de Rancho Nuevo, a la granja de tortugas marinas de las Islas Caimán, con la finalidad de crear un stock de reserva de esta especie. Estas tortugas se adaptaron rápidamente al estado en cautividad y empezaron a criar a la edad de 5 años. Al principio, estas tortugas ponían muy pocos huevos, y muchos de ellos no eran fértiles. Este hecho fue mejorando conforme las tortugas iban creciendo, por lo que en 1994, en la granja había ya 476 tortugas de diferentes edades (30 de 14 años que estaban criando y 446 tortugas de entre 1 y 5 años, nacidas en la granja). Este año, la directiva de la granja decidió que los objetivos se habían cumplido ya que la población natural mostraba signos de recuperación, por lo que la cría en cautividad se suspendió, y Méjico solicitó la repatriación de su población. Se realizaron los acuerdos y el Parque Eco-Arqueológico de X'Caret creó las condiciones adecuadas para mantener estas tortugas. El 10 de abril de 1999 se transfirieron 110 tortugas (57 hembras y 53 machos). Estas se readaptaron a las nuevas condiciones y en la actualidad están empezando a criar.

La causa principal del aumento en la población de tortuga lora, a parte de las labores de conservación que se han llevado a cabo en las zonas de nidificación, ha sido el desarrollo intensivo del uso de los TEDs en los barcos arrastreros, que se hizo obligatorio a partir de 1992 en EEUU y de 1994 en Méjico. Además, los estudios de temperatura llevados a cabo indican una proporción de hembras mucho mayor, favoreciendo el reclutamiento. Este aumento también se pudo ver favorecido por la disminución de la población de tiburones de la zona.

TRASLOCACIÓN DE TORTUGAS MARINAS: ENSAYOS, SINSABORES Y TRIUNFOS.

N. MROSOVSKY.

Este artículo realiza una revisión de las tentativas de traslocación de huevos y crías de tortugas marinas desde sus playas de nacimiento a playas de nidificación potenciales que no han sido ocupadas, con la finalidad de establecer nuevas colonias.

Hasta el momento, la mayoría de los intentos de traslocación en tortugas marinas han fracasado. Algunos ejemplos son, el caso de Bermuda, en el que no se tuvo en cuenta la temperatura de la arena en las playas y posiblemente la proporción de sexos fue realmente desfavorable; otro intento fue la Operación Tortuga Verde que liberó crías de tortuga verde nacidas en las playas de Tortuguero, Costa Rica, en 17 países del caribe.

Un caso atípico fue el de las tortugas verdes de la Granja de tortugas marinas de las Islas Caimán, ya que durante varios años liberaron crías y *head-started**, pero además el huracán Michelle en el año 2001 hizo que se escaparan un número bastante elevado de tortugas adultas. Gracias a esta experiencia se pudo saber que las tortugas *head-started** pueden sobrevivir hasta la madurez sexual y reproducirse y que las marcas vivas dan una información valiosísima. Además, ninguna de las tortugas liberadas había nacido en las islas Caimán, de lo que se deduce que estas tortugas sufrieron *imprinting** en la propia Granja.

El programa de traslocación que mejores resultados ha obtenido ha sido el proyecto de Padre Island, Texas, con tortuga lora (*Lepidochelys kempii*). Los factores que han favorecido este programa han sido, el estudio en profundidad de las playas de origen, las acciones combinadas de *imprinting** y *head-starting**, el control constante de las temperaturas, el marcaje de las crías con marcas vivas y sobretodo un buen programa de protección de las playas naturales.

De todas estas experiencias se ha podido concluir que los factores mas importantes a tener en cuenta en este tipo de proyectos son, la proporción de sexos (y por lo tanto un buen control de las temperaturas), el *imprinting**, el *head-starting** y el uso de las marcas vivas.

Gracias a toda esta información se puede extraer una serie de consejos para el caso de la reintroducción de tortugas marinas en las islas canarias: Es imprescindible comenzar con la **inspección exhaustiva** de las playas de Canarias en busca de signos de nidificación, así como para la selección de las playas potenciales para la reintroducción. También se considera imprescindible que las tortugas se marquen de tal manera que esa marca se mantenga hasta que lleguen a la madurez. **El marcaje** puede darnos información muy importante como la mortalidad y las migraciones de las crías y juveniles. **La publicación de los resultados**, ya sean positivos como negativos, ya que serían una valiosísima fuente de información de cara a nuevos intentos de traslocación en otras zonas del mundo. Además es muy importante tener en cuenta que se va a trabajar con una especie en peligro, y que por lo tanto el grado de **riesgo** es bastante elevado. Por último, se aconseja la creación de un **grupo control**, es decir, un grupo de tortugas sobre las que se lleve a cabo los mismos tratamientos que a aquellas que se vallan a traslocar, solo que se mantienen en sus playas de origen. Este hecho nos dará una información muy interesante sobre el estado de la población de origen así como del grado de afección de los tratamientos utilizados sobre las tortugas.

NOTAS

IMPRINTING = Proceso por el que una tortuga fija los parámetros locales (teóricamente magnética, química del agua, química de la arena, etc) del lugar de nacimiento para poder identificarlo en un futuro y volver a él.

IMPRINTED = Tortuga que ha fijado los parámetros locales (magnéticos, químicos, etc) de un lugar para poder identificarlo en un futuro y volver a él.

HEAD-STARTING = Proceso por el cual se mantienen las tortugas en cautividad durante su primer año para aumentar su supervivencia.

HEAD-STARTED = Tortuga que ha pasado su primer año de vida en cautividad con la finalidad de aumentar sus posibilidades de sobrevivir.

Oceanographic Conditions of the Macaronesian Marine Space. Relationships with the Distribution and Behaviour of the Sea Turtle *Caretta caretta*

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Oceanographic Conditions of the Macaronesian Marine Space. Relationships with the Distribution and Behaviour of the Sea Turtle *Caretta caretta.*

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ABSTRACT

The information available on the oceanographic conditions of the oceanic space between the archipelagos of the Eastern Central Atlantic and the West African coast is reviewed and analysed, paying special attention to the synoptic information obtained by satellite, which enables us to observe the connection between the phenomena that occurs in the area almost in real time, and to relate it to the movement and behaviour of the turtle *Caretta caretta*. This area as a whole is characterised by the gradients it presents due to a variety of observable, inter-related and inter-connected properties. Thus, it can be considered a "singular space" providing particular and characteristic conditions that will provide, if better understood, an insight into the life cycle of migratory oceanic animals, such as turtles.

INTRODUCTION

For any observer, the widespread perception of the existence of different spaces, areas, and regions on land, all with different climates, land covers, animal populations, and other characteristics, is in contradiction with the "apparent homogeneity" of the seas and oceans, an homogeneity that does not, in fact, go beyond their colour or state.

The term "Macaronesian" has been used since ancient times to describe some or all of the islands in the Eastern Central Atlantic, all of which have also shared the attribute of "fortunate" (a term of Greek origin), derived from the real or imaginary idyllic conditions that could be found in these archipelagos. In the 19th and 20th centuries, botanical studies established the existence of plant elements with a common origin and

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features in these islands, including a large number of unique relict species, which has led to the widespread use of the term Macaronesian to describe the terrestrial ecosystems of the Azores, Madeira, Canary and Cape Verde islands, including by extension, some enclaves on the coast of mainland Africa.

The classification of oceanic spaces had a later and slower development. A pioneer proposal was the "Introduction to General Oceanography" by DIETRICH, 1963, where he proposed seven regions based on general currents and wind systems, separating the bio-geographical factors as the basic elements of classification. In recent years, classifications have gradually incorporated the use of a greater number of factors as a consequence of an ever-more connected and global scale view, in which natural phenomena, geo-physical and biological features amongst others, are integrated (see BAILEY, 1998, for example).

Observations made from remote sensors located on satellites have provided a global spatial view, accompanied by a very high observation frequency only possible with these means. This has made new approaches possible, such as the one taken by PLATT et al, 1991, which led to the introduction of the concept "bio-geo-chemical provinces", used to classify the world's oceans by their productive characteristics.

In this paper, the use of some of these criteria is presented, in order to establish the degree of singularity and coherence of the "Macaronesian Marine Space".

THE EASTERN RECIRCULATION

The general circulation of the Central Atlantic is probably one of the oldest circulatory processes. In fact, in their voyages from Europe to America, 16th century navigators used the southern route on the outbound journey and the northern route on the return voyage, in both cases harnessing the knowledge available on ocean circulation and wind systems to benefit their sailing.

The North Atlantic has obviously seen the first application of ocean observations and knowledge, since institutions and consequently, researchers that pioneered the development of oceanography were located on its shores; from HELLAND-HANSEN, NANSEN, DEFANT, WÜST, ISELIN... to the classical compendium published by SVERDRUP, JOHNSON and FLEMING in 1942.

Between then and now, the "North Atlantic Subtropical Gyre" has accumulated an extensive literature of observation, analysis and modelling works. *The Warmwatersphere of the North Atlantic Ocean* (KRAUSS, 1996), is a good collection of general information and literature on this circulatory system.

Existing information shows that most of the recirculation of the Sub-tropical Gyre occurs in the Western Atlantic, taking the Atlantic ridge as the boundary (see SCHMITZ and MCCARTNEY, 1993, BOWER and HOGG, 1996, while there is a greater debate on the eastern side about possible contributions to and from the North. SIEDLER and ONKEN, 1996 conclude that the transport made by the Azores Current, (associated with the front of the same name between 32º and 37º N), is the main element of the eastern recirculation of the North Atlantic Subtropical Gyre.

Within the Canary Islands Basin, the Gyre to the south is organised in three branches: one is practically along the western side of the Atlantic Ridge, another covers the centre of the basin and the third and easternmost branch bounds with the African coastal zone. It borders Madeira and is defined as the Canary Islands Current (ZENK et al., 1986). The first two converge to the North of latitude 22º N, while the Canary Islands Current branch continues southwest until it reaches the Cape Verde front, where it merges with the North Equatorial Current (or the Cape Verde Current) (SIEDLER and ONKEN 1966).

The Azores Front separates the fresh and cold waters of the North and North East Atlantic from the warm and salty waters of the North Central Atlantic, although this is considered a fairly shallow baroclinical characteristic, as its effects can only be detected at a depth of 700-1000m (ALVES and DE VERDIÈRE, 1999).

According to the Cape Verde frontal system's definition (the term Cape Verde Frontal Zone was introduced by ZENK et al., 1991), it is the area where we find the limit between the ventilated zone of the North Atlantic Subtropical Gyre and the area that is not affected by this process, (Shadow Zone), as stated by LUYTEN et al., 1983, and THIELE et al., 1986). This front varies enormously in shape and location (MANRIQUEZ and FRAGA, 1982; BARTON, 1985, ZENK et al., 1991) although it can be placed around an imaginary line between Cape Blanco and the north of the Cape Verde Archipelago.

From a dynamic point of view, the general circulation pattern here described can be clearly recognised down to a depth of 200 m, while at greater depths (between 200 and 600 metres), this pattern fades away, leaving a well defined thermo-haline front between the North Central Atlantic Water (NCAW) and the South Central Atlantic Water (SCAW) (Hagen, 1985; Zenk et al., 1991; Klein and Siedler, 1995).

This summary suggests the possibility of establishing a well defined "Macaronesian Marine Space", situated between two clearly characterised fronts: the Azores Front to the north and the Cape Verde Front to the south, with a circulatory process of variable intensity formed by the Azores, Canary Island and Cape Verde currents connecting the whole area (Figure a).

In the West African coastal zone, bordering the circulatory process described, a widespread up-welling system may be found, a partially seasonal (which varies in size and position depending on the time of year), and a partially permanent phenomenon, where gradients of characteristic values pertaining to different parameters can be identified. These are situated between the coastal areas where the up-welling occurs, and the warmer, salty and unproductive central oceanic area (see Hempel, 1982; Mittelstaedt, 1983, 1991; Van Camp, 1991; González-Muñoz, 1995. Figure 1 shows a schematic representation of the circulation system, based on a quarterly average of pigment concentration measured from the ocean surface colour sensor SeaWiFS, where the values of high concentrations (yellow and green colours) are observed in the coastal areas, and the low concentration values, out in the open ocean (purple colours). These could be considered the eastern and western limits of the Macaronesian Marine Space respectively.

Modelling the circulation system in the Central Atlantic with different methodological approaches seems to ratify the descriptions mentioned in this paper (see, for example, Johnson and Stevens, 2000).

CHARACTERISTICS OF THE WATER MASSES

On the surface, the Macaronesian Area described can be divided into two areas separated by the Canary Islands Archipelago: the northern area where sufficiently important convention phenomena occur at the end of the winter, and which leads to the formation of Modal Water (to the classical Madeira Modal Water described by Käse et al., 1985; Siedler et al., 1987; a proposal made by Cianca, 2003 has been added), and the southern area, where the conditions of the annual atmosphere-ocean heat exchange conditions seem to make this kind of phenomenon impossible (no sign has

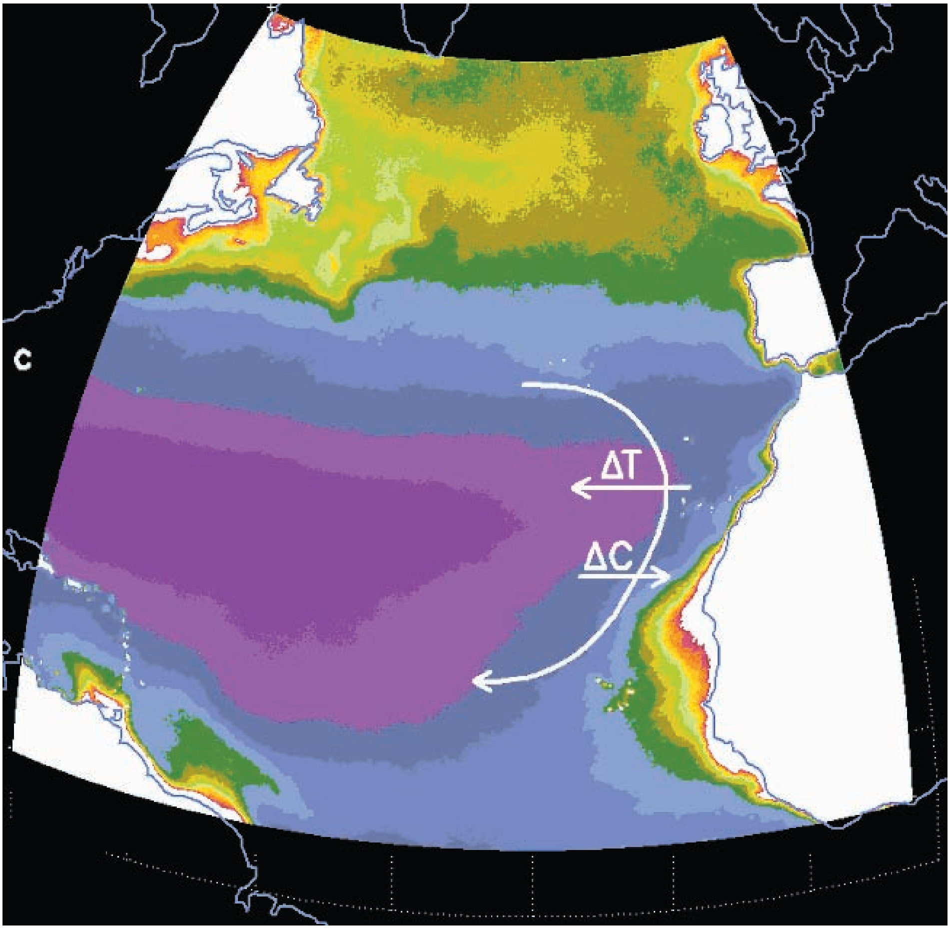

Figure 1. Simplified diagram of the main transport in the Macaronesian Oceanic Space, showing the gradient direction in the properties observed, with transversal arrows.

been reported to date). Since the end of the winter, there is a gradual warming that leads to a very well defined seasonal thermocline. Below this superficial layer is the NCAW characterised by the temperature gradient that is the permanent oceanic thermocline. It spreads throughout the area until it reaches the southern limits, bordering the SCAW, and having the same role in the southern hemisphere (although it spreads across to the northern hemisphere as far as the Cape Verde Front as already mentioned). This water is less salty and warmer. It spreads below and mixes irregularly throughout the Area of Mediterranean Intermediate Waters (MIW) and Antartic Atlantic Intermediate Waters (AAIW), with MIW predominating in the north western zone and the AAIW in the south eastern zone.

As we have already mentioned, there are up-welling waters that vary seasonally around permanent cores on the eastern boundary. Due to their origin (from NCAW), they are colder and less salty than the surface waters. Depending on the time of year, the density of the up-welling water in comparison with the surrounding waters allows these up-welling waters to spread over the surface to a greater or lesser extent. All along the Front, there are reciprocal intrusions of each of these water masses, some of the largest being Cape Guir, Cape Juby, Bojador and Cape Blanco intrusions. The western boundary of the gradient is more gentle and the frontal structures are not as radical as those of the up-welling, although the isolated or trains of gyres of different size and quantity in this area, have received greater attention in recent years. This will, with no doubt, help to characterise this boundary better.

SEA TURTLE, *CARETTA CARETTA*, DISTRIBUTION IN THE AREA

Although there are significant doubts about the meaning of their behaviour in the Macaronesia, ever since there have been written records, we know that these turtles can be found in the four Archipelagos and in several areas of the West African coast (which have been included as part of this area). By the same token, there are also records of turtles nesting in far more extensive areas than the present nesting grounds, which are concentrated in the Cape Verde islands and in some isolated spots on the African coast. The presence and activity of turtles in the area necessarily implies an ample movement of the animals, some of which may obviously be made following the circulation described (the movement of turtles on the current is posed by many authors, both in the Atlantic and in the Pacific, Bowen et al., 1995; Hays and Marsh, 1977; Musick and Limpus, 1997) following the classical hypotheses on the main oceanic life cycle in the North Central Atlantic.

Polovina et al., 2000, point out that these animals do not only harness the main direction of the circulatory systems; they can also use the compensatory movements of the mainstream's boundaries to travel in the opposite direction of the main currents.

On the other hand, Pérez-Marrero et al., 2004, in a satellite tracking study on the behaviour of eight turtles (caught and released in the Canary Islands), found that, in relation to the thermal and productive characteristics observed simultaneously during the time that the transmitters were active, these animals moved during the four seasons in a very narrow temperature range, around 21º C, and this range was always situated in areas of low pigment concentration (Polovina et al., 2004; in a study of 26 turtles in the Pacific, established a broader range of distribution, between 15º and 25º C).

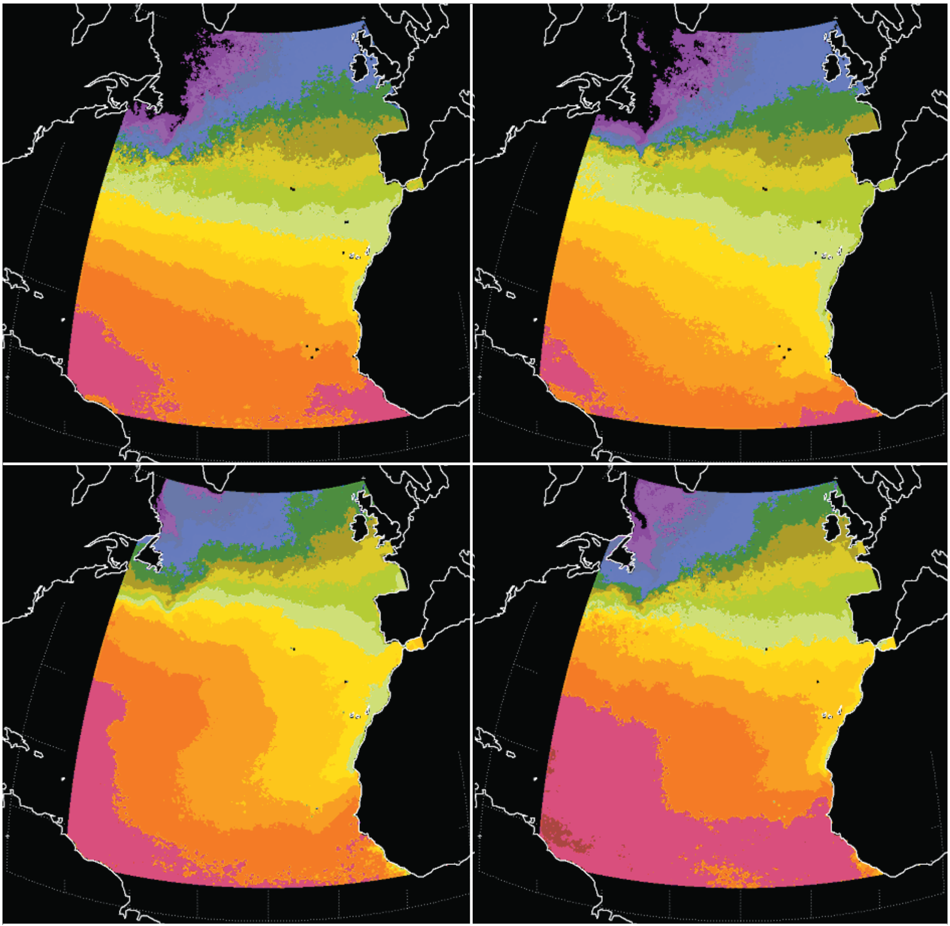

Figure 2. Quarterly averages of superficial sea temperature concentration from sensor A VHRR on board of NOAA satellites. From left to right and from top to botton D, J, F; M, A, M; J, J, A; S, O, N year 2002.

THERMAL CHARACTERISTICS

If the turtles move precisely within a characteristic temperature band, then temperature distribution clearly becomes a key factor in determining the possibility and/or probability of finding them in a given area. Figure 2 shows the average seasonal thermal images obtained from the AVHRR sensor on the NOAA satellites in the North Central Atlantic, which show that the 21° C band is the one that connects the four archipelagos in the course of the year. This isotherm reaches its southern limit during the winter, connecting with the seasonal intensification of the up-welling on the African coast, reaching the islands of Cape Verde. As the spring advances, the up-welling moves north and the 21° C isotherm shifts in the same direction, almost reaching the Canary Islands.

This northern shift of the up-welling continues during the summer and the three northern archipelagos are connected, immersed on average in this isotherm. In autumn, we start to see a recovery of the initial situation, with a relaxation of the seasonal up-welling. The permanent core remains at a position of 25-26° N and the central position of the isotherm also remains in the area. These observations show that the four archipelagos are practically connected throughout the year by a thermal gradient centred on the 21° C isotherm, or within the dispersion that appears to be acceptable to the turtle *Caretta caretta* (actually, the Azores are outside this isotherm during the coldest parts of the winter).

The seasonal nature of the up-welling is directly related to the general system of winds (Trade Winds) that generates it, as can bee seen from the seasonal averages of surface winds obtained from the scatterometre mounted on the Quick Scat satellite (Figure 3). Consideration should be given to the fact that this regimen of winds has a direct impact on the surface layer of the ocean, where the turtles are usually found (according to PÉREZ-MARRERO et al., 2004; the dive records obtained from turtles fit with a sensor show that the turtles spent 90% of the time at a depth of less than three metres).

Apart from this general characteristic of Macaronesia, consideration should also be given to the fact that the islands are obstacles to the general circulation and produce a “shadow” effect that generates warm areas. Local thermal gradients occur on the boundaries of these warming zones that include the range of values preferred by these turtles (BARTON et al., 2000).

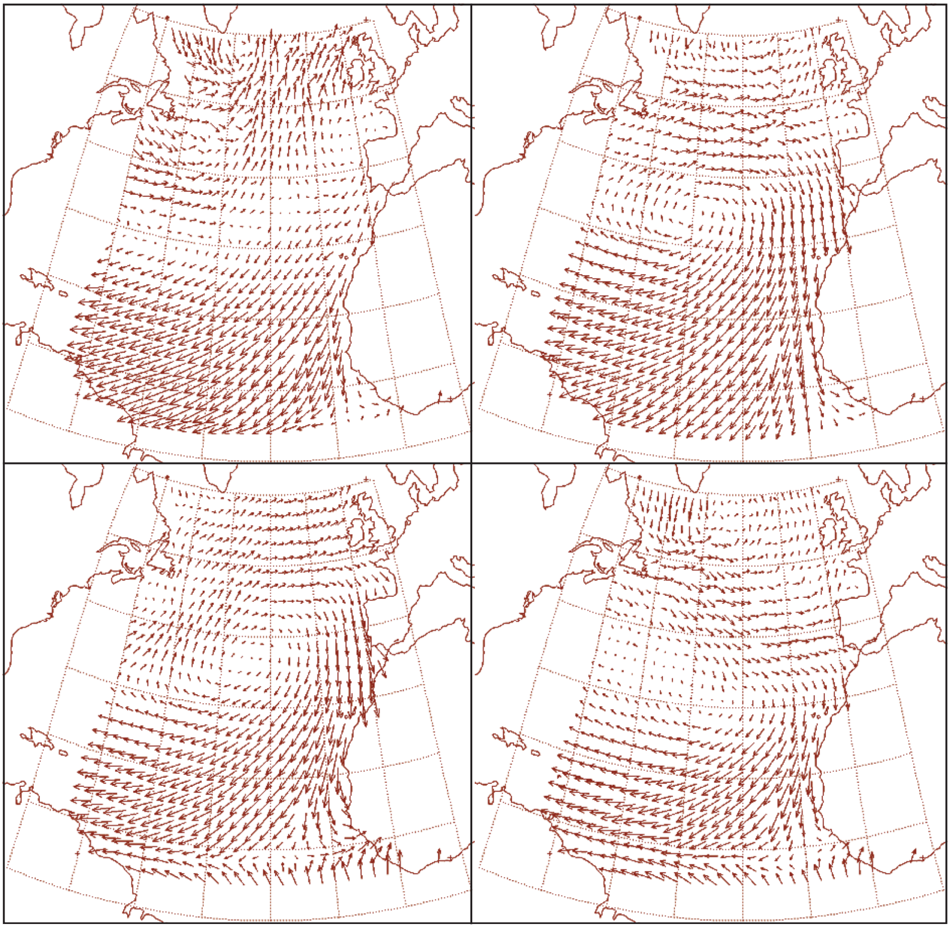

Figure 3. Quarterly average fro wind speed on sea surface in 2002. Obtained from the data offered by SEA WINDS dispersmeters installed in QUIKSCAT satellite. From left to right and from top to bottom D, J, F; M, A, M; J, J, A; S, O, N.

PRODUCTIVITY CHARACTERISTICS

It is well known that satellite observations of chlorophyll pigments have their limitations as a precise direct or indirect measurement of ocean productivity, although there also is a general consensus concerning their use as a relative comparative measure. Furthermore, this improves as the space time proximity of the elements under comparison increases.

Figure 4 shows the seasonal averages of the chlorophyll pigment measurements obtained from the SeaWifs sensor. These clearly show the effects of the South-North shift of the up-welling from winter to summer. The reduction in summer is an apparent effect, caused by the greater difference in density of the up-welling water in comparison with the local surface water. If we compare the distribution of the isotherms with the distribution of pigments, and the paths of the turtles described by Pérez-Marrero et al., 2004, we can see a clear preference of the turtles to remain in optimum

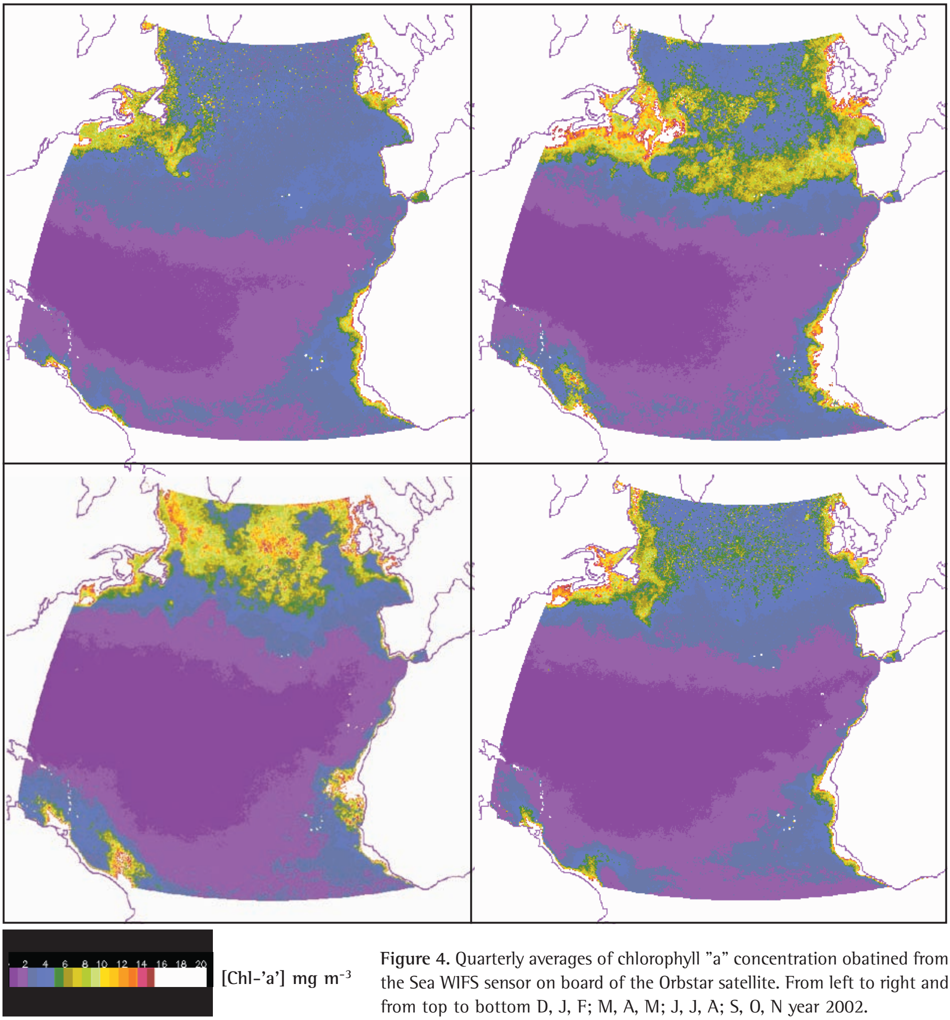

Figure 4. Quarterly averages of chlorophyll "a" concentration obatined from the Sea WIFS sensor on board of the Orbstar satellite. From left to right and from top to bottom D, J, F; M, A, M; J, J, A; S, O, N year 2002.

thermal values. But the trophic role of the up-welling should not be discarded, as some organisms of the higher trophic levels generated by the primary producers observed from the satellite, could be beyond the limits of the pigments distribution observed. In any event, the archipelagos remain approximately in an homogeneous strip of observed pigment concentrations, except for small increases in winter at Cape Verde and the Azores, and during spring in the Azores.

OBSERVED CIRCULATION

As already pointed out, the circulation of the surface layer generated by the wind must be particularly important for sea turtles, as this is where they spend most of their time. Observing the distribution of the average wind data (shown in Figure 3), and bearing in mind that the Ekman component heads 90º to the right, an interesting initial approach is obtained. Figure 5 presents the geostrophic circulation data obtained from altimeter observations. These clearly show what has just been described: there is a predominantly weak circulation system in the Eastern Central Atlantic, in comparison to the western side, in which only the Azores current presents a well defined structure throughout the year. The system then weakens and divides into different branches, much weaker and less defined, with an increase in the number of meanders, individual eddies and sets of several eddies (trains of eddies) until it converges with the North Equatorial Current. This general situation favours *Caretta caretta* feed oportunities, due to the concentration of preys, as POLOVINA et al., 2004, indicated. Moreover, the compensatory mechanisms on the borders of the current's main stream could be important (ALVES and DE VERDIÈRE, 1999; point out that the counter-current reaches a value of 2 SV in the Azores Current, which is estimated to transport 13 SV), and could be used by the turtles to move in the opposite direction to the main current as Polovina et al (2000) have indicated in the Pacific.

DISCUSSION

According to our hypothesis, the main oceanographic characteristics of the Macaronesian Marine Space can be summarised as a thermal gradient with little oscillation

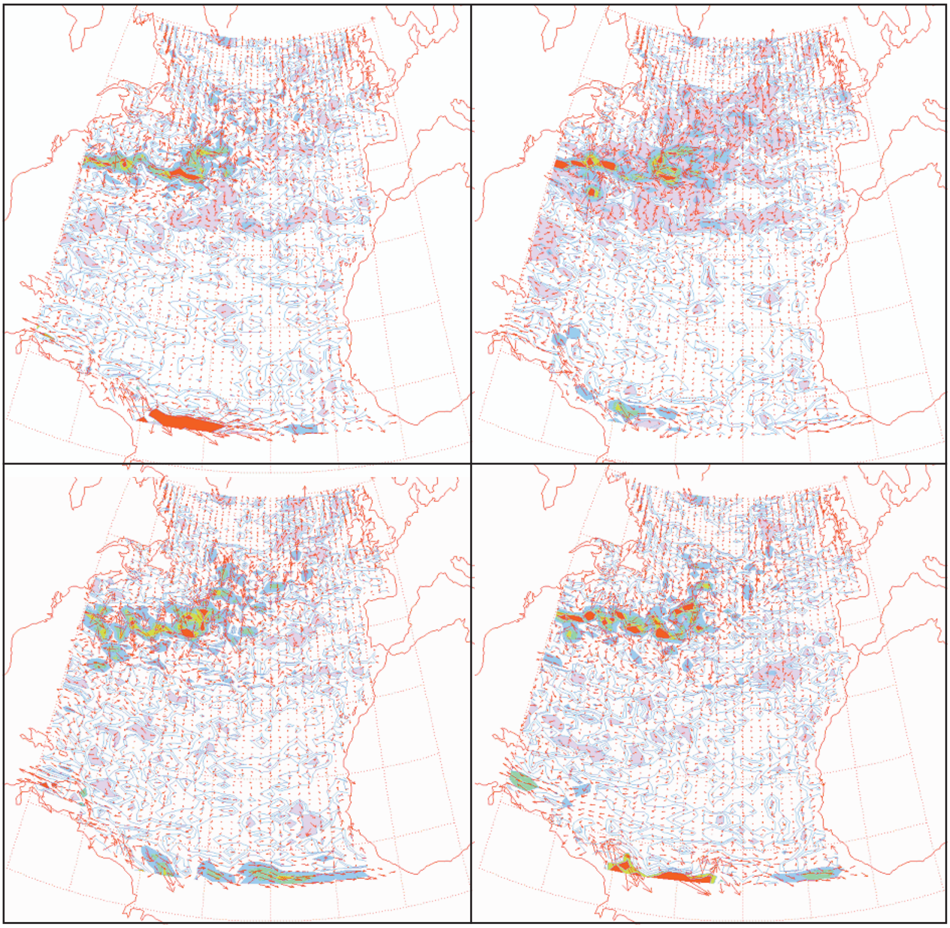

Figure 5. Quarterly average for the superficial geostrophic speed in 2002. Obtained from teh data offered by the altimeters installed in the satellites TOPEX / POSEIDON y ERS.. From left to right and from top to bottom D, J, F; M, A, M; J, J, A; S, O, N.

centred on 21° C that connects the archipelagos during most of the year, accompanied by similar gradients situated down wind of the islands. The general regimen of the Trade Winds shifts the characteristics of the surface circulation and the associated upwelling seasonally, moving it south in winter and north in summer. The weak geostrophic circulation generates isolated or associated gyres and eddies.

These series of elements define the “Macaronesian Marine Space” as a well defined area, characterised not by the homogeneity of the properties found, but by the stability of its gradients, with small seasonal adjustments that are resolved with an annual North-South cyclic oscillation. The core of the set shifts along a well defined arc (as Figure 1 shows), but it also makes transport possible in the opposite direction on the edges, as previously pointed out. Taking into account the homogeneity of the "Macaronesian Marine Space" and its transport potential, a greater understanding of the trans-oceanic migratory species like the turtle *Caretta carretta* is obtained.

Remote tracking of the path and behaviour of turtles fit with sensors and transmitters, together with simultaneous satellite observations of the environment's characteristic parameters, appear to be a unique tool in order to gain a better understanding of the turtle *Caretta caretta*'s behaviour patterns.

ACKNOWLEDGEMENTS

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REFERENCES

ALVES, M. L. G. R. AND COLIN DE VERDIÉRE, A. (1999). Instability dynamics of a subtropical jet and applications to the Azores front current system: Eddy-driven mean flow. Journal of Physical Oceanography; 29:837-864.

BAILEY, R. G. (1998). Ecoregions: the ecosystem geography of the oceans and continents. Springer-Verlag, New York.

BARTON, E. D. (1985). Structure and variability of the central water mass front off Cape Blanco. Int. Symp. Vpw. W.Afr. Inst. Inv. Pesq. Barcelona; 1:49-61.

BARTON, E. D.; Basterretxea, G.; Flament, P.; Mitchelson Jacob, E. G.; Jones, B.; Aristegui, J., and Herrera, F. (2000). Lee region of Gran Canaria. Journal of Geophysical Research (C) Oceans; 105(C7):17173-17193.

BOWEN, B. W.; ABREU-GROBOIS, F. A.; BALAZS, G. H.; KAMEZAKI, N.; LIMPUS, C. J., AND FERL, R. J. (1995). Trans-Pacific migration of the loggerhead turtle (Caretta caretta) demonstrated with mitochondrial DNA markers. Proc. Natl Acad. Sci; 92:3731-3734.

BOWER, A. S. AND HOGG, N. G. (1996). Structure of the Gulf Stream and its re-circulations at 55 degree W. Journal of Physical Oceanography; 26(6):1002-1022.

CAMP, L. VAN; NYKJAER, L.; MITTELSTAEDT, E., AND SCHLITTENHARDT, P. (1991). Up-welling and boundary circulation off Northwest Africa as depicted by infrared and visible satellite observations. Progress in Oceanography; 26(4):357-402.

CIANCA A. (2003). Agua Central Noratlántica Modos y Variabilidad en el Atlántico Centro Oriental (ESTOC). Doctoral Thesis: University of Las Palmas de Gran Canaria.

DIETRICH, G. (1963). General oceanography, an introduction. Inter-science Publishers, New York.

GONZÁLEZ-MUÑOZ, A. (1995). Análisis de la variabilidad espacio-temporal del afloramiento del noroeste africano. Doctoral Thesis: University of Las Palmas de Gran Canaria.

HAGEN, E. (1985). A meandering intermediate front North-West off Cape Verde Islands. Oceanogr. Trop; 20(1):71-83.

HAYS, G. G. AND MARSH, R. (1997). Estimating the age of juvenile loggerhead turtles in the North Atlantic. Can. J. Zool; 75:40-46.

HEMPEL, G. (1982). The Canary Current: studies of an up-welling system. A symposium held in Las Palmas, 11-14 April 1978. Reports Et Proces-Verbaux Des Reunions. Conseil International Pour L'Exploration De La Mer; 180:455.

JOHNSON, J. AND STEVENS, I. (2000). A fine resolution model of the eastern North Atlantic between the Azores, the Canary Islands and the Gibraltar Strait. Deep-Sea Research I; 47:875-899.

KÄSE, R. H.; ZENK, W.; SANFORD, T. B., AND HILLER, W. (1985). Currents, Fronts and Eddy Fluxes in the Canary Basin. Progress in Oceanography; 14:231-257.

KLEIN, B. AND SIEDLER, G. (1995). Isopycnal and Diapycnal Mixing at Cape Verde Frontal Zone. Journal of Physical Oceanography; 25(8):1771-1787.

KRAUSS, W. (1996). The Warmwatersphere of the North Atlantic Ocean. Berlin; Stuttgart: Borntraeger.

LUYTEN, J. R.; PEDLOSKY J., AND STOMMEL H. (1983). The Ventilated Thermocline. Journal of Physical Oceanography; 13:292-309.

MANRIQUEZ, M. AND FRAGA, F. (1982). The distribution of water masses in the up-welling region of northwest Africa in November. Repp. P.V. Reun. Cons. Int. Explor. Mer; 180:39-47.

MITTELSTAEDT, E. (1991). The ocean boundary along the northwest African coast: Circulation and oceanographic properties at the sea surface. Progress in Oceanography; 26(4):307-355.

MITTELSTAEDT, E. (1983). The Up-welling Area Off North West Africa - A Description of Phenomena Related to Coastal Up-welling. Progress in Oceanography; 12(3):307-331.

MUSICK, J. A. AND LIMPUS, C. J. (1997). Habitat utilization and migration in juvenile sea turtles. Biology of Sea Turtles; 137-163.

PEREZ-MARRERO, J.; LOPEZ-JURADO, L. F.; CEJUDO, D.; MAROTO, L., AND LLINÁS, O. (2004). Selección del gradiente térmico por ejemplares juveniles de Caretta caretta visualizado mediante técnicas de seguimiento por satélite. Revista De Teledetección; 21:25-28.

PLATT, T.; CAVERHILL, C., AND SATHYENDRANATH, S. (1991). Basin-scale estimates of oceanic primary production by remote sensing: The North Atlantic. Journal of Geophysical Research (C) Oceans ; 96(C8):15,147-159.

POLOVINA, J. J.; BALAZS, G. H.; HOWELL, E. A.; PARKER, D. M. SEKI M. P., AND DUTTON, P. H. (2004). Forage and migration habitat of loggerhead (Caretta caretta) and olive ridley (Lepidochelys olivacia) sea turtles in the central North Pacific Ocean. Fisheries Oceanography; 13(1):36-51.

POLOVINA, J. J.; KOBAYASHI, D. R.; PARKER, D. M. ; SEKI, M. P., AND BALAZS, G. H. (2000). Turtles on the edge: movement of loggerhead turtles (Caretta caretta) along oceanic fronts, spanning long line fishing grounds in the central North Pacific, 1997-1998. Fisheries Oceanography; 9:71-82.

SCHMITZ, W. J. AND MCCARTNEY, M. S. (1993). On the North Atlantic Circulation. Review of Geophysics; 31:29-49.

SIEDLER, G.; KUHL, A., AND ZENK, W. (1987). The Madeira Mode Water. J. Phys. Oceanogr. 13:828-857.

SIEDLER, G. AND ONKEN, R. (1996). Eastern Recirculation. Berlin: Gebrüder Borntraeger; pp. 339-364. (W. Krauss.

SVERDRUP, H. U.; JOHNSON, M. W., AND FLEMING, R. H. (1942). The Oceans: their Physics, Chemistry and General Biology. Prentice-Hall, Englewood Cliffs, NJ.

THIELE, G.; ROETHER, W.; SCHLOSSER, P.; KUNTZ, R.; SIEDLER, G., AND STRAMMA, L. (1986). Baroclinic Flow and Transient-Tracer Fields in the Canary-Cape Verde Basin. Journal of Physical Oceanography. 16:814-826.

ZENK, W.; FINKE, M.; MÜLLER, T. J., AND LLINÁS, O. (1986). The role of the Canary current in the subtropical Atlantic gyre circulation. TERRA Cognita; 6(N3):375.

ZENK, W.; KLEIN, B., AND SCHRÖDER, (1991). M. Cape Verde Frontal Zone. Deep-Sea Research; 38(1):5505-5530.

Historical review of the archipelagos of macaronesia and the marine turtles

LUIS FELIPE LÓPEZ-JURADO

INTRODUCTION

The Atlantic Ocean is an immense mass of water that separates several continents and with several archipelagos dotting its surface. The archipelagos of the Azores, Madeira, Selvagens, Canaries and Cape Verde form an arch across the eastern central portion of the Ocean. These islands form a bio-geographic area known as MACARONESIA, characterised by its biological affinities and by the fact that these are all volcanic islands of different geological ages, the oldest being the Cape Verde islands and the Azores the most recent.

Sea turtles, on the other hand, are a group of animals that is made up of eight different species, six of which can be seen with varying frequency in the waters of Macaronesia. The specific characteristics of the presence of each species in each archipelago vary however (Table 1). We now have significant zoo-geological data for each species and archipelago, but, from a scientific point of view, very little is known about their history.

	AZORES	MADEIRA	CANARIES	CAPE VERDE
Caretta caretta	*	*	*	*
Dermochelys coriacea	*	*	*	*
Chelonia mydas	?	?	*	*
Lepidochelys kempii	*	*	-	-
Lepidochelys olivacea	-	-	-	*
Eretmochelys imbricata	?	?	*	*

Table 1: Presence (*) of the diferents species of sea turtles in the Macaronesian islands. (? = unknown).

The six species of turtles to be found in the Macaronesian islands are protected both by international legislation and by the domestic legislation of each of the three countries involved: Portugal (Azores, Madeira), Spain (Canaries) and Cape Verde.

Basically, turtle population management requires information concerning their distribution, biology and ecology; the threats they face, etc. But, in our opinion, correct management is not feasible while we remain ignorant about the state of these same populations in the past. Thus, the current state of conservation of a specific population can be seen as the result of a series of interactions that, starting in the past, have led the species to where it is now.

The objective of this article is to highlight a series of historic and pre-historic data about sea turtles and the Macaronesian archipelagos of the Canary Islands and Cape Verde that we have managed to collect. Most of these are either previously unpublished or have been incorrectly interpreted in the past by previous authors. Moreover, these historic data not only provide a direct insight into the species/archipelago relationship, they also provide us with a wealth of bio-ecological data that enables us to assess present situations and face future challenges.

Some of the biological bibliographic references from the 19th and 20th centuries have been excluded. The excluded 19th century references for Cape Verde include a very imprecise report by Rochebrunne, 1884, and one by Bocage, 1896, mentioning the presence of a young *Caretta caretta* turtle on the island of Sao Vicente, and the fact that he suspects that the species breeds on this island. Most of the 20th century biological reports concerning Cape Verde have been collected from Lopez-Jurado et al., 2000aK.

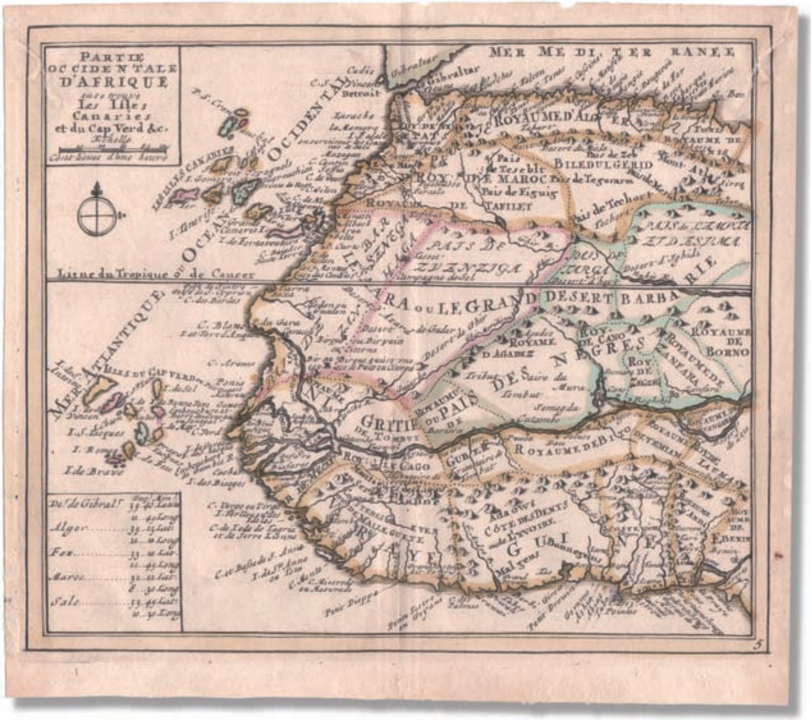

Figure 1. Western Africa.

RESULTS

1. The historic discovery of the archipelagos of the Canary Islands and Cape Verde and their relationships with sea turtles.

The discovery of each of these two archipelagos was very different. They were both settled by Europeans in the 15th century, although the Canary Islands had already been settled since the 1st century A.D. (ONRUBIA, 1979) by societies from the neighbouring African continent that lived there without any major upset until the arrival of the conquistadors.

The Cape Verde archipelago, on the other hand, was uninhabited at the time of its discovery and its settlement started in the late 15th century.

Figure 2. Canary and Cape Verde Islands.

A - THE CANARY ISLANDS

As we have said, the Canary Islands were inhabited in 1402, when Norman explorer Jean de Bethencourt arrived (BONTIER & LE VERRIER, 1453). Each island had a highly differentiated population, but one thing they all had in common was that they had no knowledge of sea travel (CHIL and NARANJO, 1850; JORGE, 1996).

This fact has often been used, correctly in our opinion, to show that the Canary Island aborigines came from inland areas of the African continent. They may have been people that had been driven into exile by Roman conquerors as part of their plans to pacify the territories they had conquered. However, it is surprising that, despite the fact that most of the islands had large areas of forests, and the fact that the islands are in sight of one another, no signs of boat building have ever been found on any of the islands, not even remains.

It appears that the fishing activities of the aborigines of the Canary Islands were restricted to collecting molluscs along the coast, coastal fishing with hooks made from bone, using toxic substances dissolved in inter-tidal pools (latex from *Euphorbia* spp.) and, finally, the occasional catch of larger specimens that probably washed up on the coasts.

However, although the abovementioned medieval book contains reports of several land animals on several of the islands, there is no mention of any sea turtles.

Even though there is a lot of zoological archaeology work remaining to be done on the Canary Island aboriginal sites, there is a reference to the presence of sea turtles in one of these, situated in an aboriginal cave dwelling (Villaverde, Island of Fuerteventura) (Meco, 1999), which was allegedly used as food at a site that is about 5 kilometres from the Fuerteventura coast. This archaeological level has been dated to 1730 B.C. (± 50 years), i.e. one thousand two hundred years before the Europeans arrived in the Canary Islands.

The Canary Island Museum of Las Palmas de Gran Canaria also has two small statues (anthropomorphous idols) in the shape of sea turtles, dating back to approximately the same period. They were discovered in the coastal town of La Aldea (island of Gran Canaria) (Figure 3), and they are assumed to have some religious significance (see Lopez-Jurado and Martinez, 1983).

Figure 3. Anthropomorphous idols of Canary Islands.

B - THE CAPE VERDE ISLANDS

Man discovered the Cape Verde islands by chance. There are two different versions of what happened.

The first attributes the first sighting of the islands to Portuguese explorer Diego Gomes, along with Genoese merchant Antonio da Noli. Briefly, the author claims that, on his return journey back to Portugal, after sailing for two days and one night, they discovered a group of islands. Gomes went ashore on one of them, and he named it Santiago. This occurred between 1458 and 1460 (some sources are more precise, stating that it all took place on the 1st of May 1460). This version (the data of which were recorded by Martin Behain in 1487) adds that the discovery took place two years before the city of Ribeira Grande was founded on the island of Santiago by the first Portuguese settlers (see Crone, 1937).

The quotation is as follows:

> *"Antonio da Noli and myself left the port of Zaya and we sailed for two days and one night towards Portugal, and we saw some islands on the sea, as my caravel bore more sail than the other one, I arrived first to one of these islands, and I saw white sand and it seemed a good port to me and there I dropped anchor, as did Antonio, I told him that I wished to be the first to land, and that is what I did, we saw no sign of man and we named the island Santiago as we had discovered it on that saint's feast day, there we caught fish in great abundance, on the coast we found many strange birds and fresh water creeks, the birds were so tame that we killed many of them with sticks and there were many pigeons, there were also figs in abundance, but they do not grow on trees as they do at home because our figs grow close to the leaf, these ones grow out of the bark from the base of the tree up to the crown, these trees grow in great numbers and there is much grass here".*

The few (and doubtful) descriptions of places apart, the important thing is that he makes no mention of any presence of sea turtles.

The second version, of which we have a far more extensive and accurate version (Crone, 1937), is set in 1456. The first publication of this dates back to 1507, and relates the travels of a Venetian named Alouise da Ca' da Mosto. We have reproduced the first paragraphs below:

> *"On the third day we sighted land, with everybody crying "land ahoy, land ahoy", tremendously surprised as we were not expecting any land in these parts. Two men sent to the*

crow's nest sighted two large islands. As we heard this, we gave thanks to God for allowing us to see new things, because we knew well that islands such as these had not been described in Spain. To find out more and to check our fortune, we sailed towards one of them and we soon arrived.

As, on our arrival, it appeared large to us, we sailed along the coast a short distance until we reached a place that seemed a good anchorage. There we dropped the anchor and, as the weather was calm, we lowered a boat into the water which, with a good crew, was sent ashore to see if there were any people on the island. The boat reached the shore and explored a good amount of territory, but we found no tracks or signs, from which it was concluded that there were no inhabitants.

When they told me of this, in order to gain complete satisfaction, I sent ten men ashore with arms and crossbows the next morning with orders to climb a high and mountainous part of the island to see if they could spot something or see some other island. This was done without observing anything new except that the island was uninhabited and that there were a very large number of pigeons that allowed themselves to be taken by hand, something that was unknown to the men. They brought many of them back to the caravels that they had captured with stakes and sticks.

From the other shore they saw three large islands that we had not seen: one of them lay to the north and the other two to the south of our route, within sight of each other. They could have seen to the West another island far away in the sea, but they could not clearly confirm this due to the distance. I did not want to approach them, as I did not wish to waste any more time before continuing my journey and, moreover I judged that they must be as uninhabited and as wild as the others: but shortly afterwards when others heard the news about the four islands that I had found, they were anxious to explore them: they saw that there were ten islands, both small and large. They were all uninhabited and nothing was found except pigeons, strange species of birds and large schools of fish.

But returning to my tale: leaving this island and continuing on our route we saw the other two islands. Then, sailing along the coast of one of these that seemed to be well forested, we discovered the mouth of a river. Judging that the water must be good there, we anchored to replenish our reserves. Some of my men, having gone ashore, went as far as the mouth of that river where they discovered small amounts of very white and pure salt, some of which they brought back to the ship. Of this we took as much as we needed; also judging the water to be very good we filled up our stocks.

I should also explain that we found here large numbers of turtles some of which we captured. Their shells were larger than a good sized buckle. The sailors killed some of these and added them to our victuals because they said that on other occasions in the Gulf of

> ***Arguin where they had also found them although not of this size, they had eaten them***[1]*... We also fished along the banks of this river and further up stream, where we found fish in such quantities that it is incredible to record. Many species that we had not seen before were large and tasted good... We remained there for two days entertained in the aforementioned gathering of supplies, including many pigeons, of which we killed immense quantities.*
>
> *It is worthy of note that the first island that we stepped ashore on we named Bonavista as it was the first land we had seen in these parts: the other island that appeared to be the largest of the four we named San Jacomo because it was the day of Saint Phillippo Jacomo when we anchored there”.*

In our opinion, the islands discovered in this account were Boa Vista and Santiago; with the islands of Sal, Maio and possibly Fogo being visible in the distance from the heights of Boa Vista. From our own experience we know that after a violent storm, the usual haze that covers the islands disappears and the clarity of the horizon makes it possible to see other islands from the highest peaks.

In our opinion, the reference to small sized turtles is the final proof that Alouise de Ca’ da Mosto reached Cape Verde. Up until 1998, nobody had reliably reported young turtles in Cape Verde (specimens larger than a 15th century belt clasp or buckle) of two species: green turtles (*Chelonia mydas*) and the hawksbill (*Eretmochelys imbricata*) (see the literature review in Lopez-Jurado et al., 2000 a and b). The latter especially are found with great frequency in the more sheltered and warmer bays along the shores of all the Cape Verde islands. So, if nobody except Ca’ da Mosto had realised that these turtles were in the bays of Cape Verde until 1998, this would accredit the Venetian as the discoverer of the Cape Verde islands.

2. Historical data

From the time of the discovery of the two archipelagos, in the Canary Islands to a lesser extent, and especially for the islands of Cape Verde, highly expressive reports start appearing that illustrate their close relations with sea turtles.

---

[1] The underlining is ours.

A - EUSTACHE DE LA FOSSE. 1480. Cape Verde Islands

He published his account in 1548, although the journey itself took place between the end of 1479 and the first five months of 1480, i.e. some 24 years after they had been discovered (Foulché-Delbosc, 1897).

This French merchant from Tournay (south of France) travelled throughout the Iberian peninsular in late 1479, until he reached Seville, attracted by the licenses offered a year beforehand by the Catholic Monarchs of Castile, Ferdinand and Isabel, for all the mariners of Palos (Huelva, in the south of Spain) that wished to do business with the African lands of what was known as the "Gold Coast" (to the south of what is now Liberia). In Seville, he bought a variety of goods for trading and then headed for Cadiz from whence he set off on a merchant voyage at the end of 1479.

Unfortunately for him, shortly after reaching the "Gold Coast", and when he had just started trading with the natives, four Portuguese vessels, always suspicious of Spanish activities in Africa, took him prisoner and confiscated all his cargo. Paradoxically, he helped the Portuguese to sell all this cargo. On the return journey, they reached the islands of Cape Verde around February or March of 1840, and this was the account of what he saw there:

> *"...and after a time, we reached the islands that are off Cape Verde of which we will talk later on, and these islands are 10 in number, and there is not more than one inhabited, on which islands man or leprous creatures are cured in two years: and in fact we went to one of those same uninhabited islands and there were two lepers there for cure. I did not speak to them and they were on said island, I only went to the entrance and we caught a lot of fish in 2 or 3 days, so that we lived (off them) for more than six weeks and there we took a large turtle that we ate and found to be very good; from these turtles the leper is cured by eating them and spreading blood and fat on all his meals (turtle fat) and thus, after two years, they are completely purged and cured of their leprosy. And in fact I was in Gand when I returned from said voyage, where Monsieur Jean de Luxembourg, having been advised that I had been to this place, was happy to hear of my manner for curing leprosy, he later went there and was on the island of Santiago for the space of two years, and he was completely cured. And while making preparations to return, the deadly sickness took him by surprise and there he died as I was later told by some of his servants who had made the journey with him. Therefore, to get back, to our purpose, these turtles are quite large, as a good large shield can be made from their shell to cover oneself when it is necessary for battle..."*

He continues to describe the island and the large numbers of fish and birds. Later on he once again talks of turtles:

> *"...And it is the custom there that when the sea retreats, grass grows on the sandy gravel, and these large turtles go there to graze; and later the peoples of the island turn up side down all the ones they can find, and then they kill them and with their blood they bathe those infected and sick with said leprosy in said blood; and when they are dry they find two or three days that they cannot bathe and ...... and afterwards they are fine and this makes them strong again and they purge their insides by eating of this fish and of the fat of these turtles, so they continue thus for two years and they are completely cured as has been said..."*

In 1483, that is, three years after the journey of Eustache de la Fosse, King Louis XI of France, who thought he was suffering from leprosy, sent Georges Paleologue de Bissipat, to "the Green island and Barbarous country" to find the sanatorium of the island of Santiago described by de la Fosse and to acquire "some very appropriate things for the health of his person". Unfortunately, King Louis XI died, but not of leprosy, before his envoy returned (VILLIERS, 1958). It is striking that the account is situated on an "uninhabited" island. Considering the fact that only Santiago was inhabited in those early years of settlement, this island must have been Maio, Boavista or Sal.

This reference highlights the fact that the sea turtles that nested in Cape Verde were a highly significant element, right from the time they first entered Western history.

B - VALENTIM FERNANDES. 1506-1508. Cape Verde Islands

This type setter and printer of Austrian origins, when called by Queen Leonor of Portugal, widow of King John II, established his residence in Lisbon, where he started printing maps and naval charts of that time.

His works include the first charts and maps of the Cape Verde islands published between 1506 and 1508. These are described by FONTOURA DA COSTA, 1939, whose work we will follow in this article.

In his general remarks on the Cape Verde archipelago, Fernandes writes:

> "*In the months of May, June, July and August, there is in these islands a great abundance of turtles, which the lepers cure in salt. These islands were initially so healthy that any lepers*

> *arriving there were cured. But they are now so unhealthy that the people sicken. I believe that after the negroes that brought them corrupted the air as they had done in their own land, they became unhealthy*".

He then goes on to quote the account of Ca' da Mosto. At that time, only the Cape Verde islands of Santiago and Fogo were settled, according to Valentim Fernandes.

It is striking that the first reports about the seasonal breeding habits of the turtles coincides with the summer months that later authors take on board literally.

C - NICHOLAS SANSON. 1656. Cape Verde Islands

He was an explorer and geographer who, in the mid 17h century, wrote a series of geographic atlases of the continents that included many remarks on the human and natural history of the places he visited. In the atlas devoted to Africa, he writes, in reference to the islands of Sal, Boavista, Maio and Santiago:

> *"...Their turtles are two or three feet long: they come out of the sea and lay their eggs at night, they hide them in the sand and the heat of the sun causes them to hatch..."*

Figure 4. West Coast of Africa and Canary islands.

D - WILLIAM DAMPIER. 1683. Cape Verde Islands

William Dampier was an English citizen, first a merchant and then an adventurer, who made numerous journeys all over the world between the end of the 17th century and beginning of the 18th century. He really was a remarkable observer of the flora and fauna of the regions he visited, leaving us tremendously detailed descriptions of many species, including sea turtles.

In the first of his books (A new voyage round the world, chapter four), he mentions a visit, starting in early September 1683, to the islands of Sal, Sao Nicolau, Maio and Santiago (Cape Verde).

The original work was printed in 1697, six years after Dampier returned from his travels; two editions came out in that same year, and a third one was published in 1698. In the following years, new accounts of his travels were added to the collection, which was culminated in 1729 with an edition of the collection in four volumes; the first of these volumes is the one that was published in 1968 and the one that we use here.

On the 23rd of August 1683, they set sail from the port of Achamack in Virginia (USA) and after a week of storms, a few days later, they arrived at the island of Sal, which they found to be inhabited basically by Portuguese bandits. It was here, and in this moment, that Dampier made his famous account about the flamingos (*Phoenicopterus ruber*) and their peculiar form of nesting, and their culinary qualities. From the island of Sal, they went to the island of Sao Nicolau, and later to Maio, and then to Santiago; before leaving Cape Verde for the African coast south of Sierra Leone.

On the island of Maio, they attempted to buy provisions of meat but just one week before their arrival, another English ship under the command of Captain Bond, of Bristol, had arrived on the island and, with a malicious trick, had taken the Governor of the island prisoner and kept him aboard, offering to release him in exchange for beef and goat meat. But when his demands were met, he sailed away with the Governor still aboard and no more was ever heard of him again. Apart from that, he described the island as follows:

> "...*Here are plenty of Bulls, Cows and Goats; and a certain season of the year, as May, June, July and August, a sort of small Sea-Turtle come hither to lay their Eggs; but these Turtle are not so sweet as those in the West-Indies*..."

This is the only mention made of turtles in Cape Verde that is made in this book. It is surprising that, despite the fact that he arrives during the nesting season of the turtles (according to late 20th century data), he does not report them either in Sal (somewhat surprising although he spent little time on this island) or in Sao Nicolau, or Santiago, the fourth island he visited before leaving for the African coast. It is only on Maio that he appears to collect reliable information on the turtles despite the locals' suspicions of English ships. In fact, he must have eaten their meat as he states that they are not as sweet as the turtles from the West Indies; almost certainly referring to the green turtle (*Chelonia mydas*) that he would have known well from his previous journeys as he started his odyssey in 1679 with a voyage from London to Jamaica, although he wandered extensively around the Caribbean before reaching Cape Verde.

The phenological observations made by Valentim Fernández are extraordinarily accurate and they suggest that, 300 years ago, the breeding season of the nesting population of turtles in Cape Verde was one month earlier than nowadays (see for example DAMPIER, 1729) starting in May and finishing in August; compared with the present season that starts in mid June and finishes in mid October. As we will see later, however, the dates mentioned by Dampier must refer, at least in part, to the months of greatest density of nesting females.

Another interesting point is the mention of their small size; assuming that he was comparing them with the size of the green turtle, a species that he had already come across in the Caribbean and female green turtles grow to a larger size than female loggerheads.

E - FRANÇOIS LEGUAT. 1690. Cape Verde Islands

Leguat was a Huguenot of French origin who had emigrated to settle South Africa and the islands of the Indian Ocean. During this odyssey, they reached the island of Sal on the 30th of October 1690, where they went ashore in search of water, without success. They did, however, make some interesting remarks about the island and the made a couple of mentions of sea turtles:

> "...*We found most of our Companions ashore catching Turtles, we went along with them up into another part of the Country...Here also Sailors come to turn the Turtle, a Term us'd by*

them for killing it, because they turn the Turtle on its Back when they catch it; all the Shore is cover'd with these Animals, specially in the Season, when they lay their Eggs. We turn'd some of these stupid and slow Creatures, and amongst the rest, two which, according to the guess of the Skillful, weigh'd 500 Pound each. We Carry'd all that was good of them aboard with us..."

Figure 5. Cape Verde Islands. By P. du Val.

This suggests that there was a high density of nesting females on the beaches. It s also worth noting that, in late October, there were still females to be found on the beaches: a fact that coincides with the data that we have gathered between 1998 and 2003. We even have records of hatchlings emerging from the nest on the 5th of January 2000 on the beach of Canto (island of Boavista); which, in general terms, would indicate that the eggs were laid in late October, or even in November of the previous year.

F - FRANÇOIS FROGER, 1695. Cape Verde Islands

He was a 19 year old boy who sailed in a French ship named "The English Falcon" on its voyage to "officially" establish a colony in the Magellan Strait. In reality, it was a pirate ship financed by Louis XIV of France. Along with 5 other ships, it spent three years raiding the coasts of Africa, South America and the West Indies, returning to its base in La Rochelle in 1697.

After its visit to Cape Verde in June/July 1695, Froger claims:

> *"In Sao Vicente, there are turtles that weigh from 300 to 400 pounds. The eggs do not need more than 17 days to reach full maturity in the sand, but the little turtles that emerge, need a further nine days before they are capable of reaching the sea, because of which 2/3 of them ordinarily fall prey to the birds."*

During his short stay in this port, Froger saw the arrival of a ship from Nantes that had come to fill its holds with turtles for Martinique.

His remarks highlight the fact that there was a certain export trade of sea turtles; which can only be explained by the fact that the existence of turtles here was common international knowledge at the time.

Figure 6. Cape Verde Islands. By N. Sanson d'Abbeville, mid 17th century.

G - WILLIAM DAMPIER. 1729. Cape Verde Islands

Dampier's second book was published in two parts by James and John Knapton (London). The first part, which includes the part dealing with Cape Verde, was published in 1703; and the second part in 1709. The 1729 edition (which is the one that was edited again in 1981) brought them together and published them as one, and this is the edition used by us.

This voyage commenced on the 14th of January 1699 and, after a few days in Tenerife, they reached the island of Maio on the 11th of February. Here, apart from describing the process of producing and transporting salt, Dampier makes some highly interesting comments about the vegetation and the fauna.

About sea turtles, he says:

> "*...I have already said (Vol.I*[2]*) that the months of May, June, July and August, (that is, the wet Season) are the Time when the green Turtle come hither, and go ashore to laid their Eggs. I look upon it as a thing worth taking Notice of, that the Turtle should always, both in North and South Latitude, lay their Eggs in the wet Months. It might be thought, considering what great Rains there are then in some Places where these Creatures lay, that their Eggs should be spoiled by them. But the Rain, tho' violent, is soon soaked up by the Sand, wherein the Eggs are buried; and perhaps sinks not so deep into it as the Eggs are laid: And keeping down the Heat may make the Sand hotter below than it was before, like a Hot-bed. Whatever the Reason may be why Providence determines these Creatures to this Season of laying their Eggs, rather than the dry, in Fact it is so, as I have constantly observ'd; and that not only with the Sea-Turtle, but with all other Sorts of amphibious Animals that lay Eggs; as Crocodils, Alligators, Guano's, &c...*"

The above is probable one of the oldest records of the relationship between the incubation of sea turtle eggs and the impact of the rains; a fact that, in part at least, explains the relationship between sexes and the incubation temperature. It is striking that he now describes the species as *green Turtle*.

Further on, and once again in reference to the island of Maio, he adds:

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[2] Referring to Dampier (1697).

> "...*When the Turtle-Season comes in they watch the Sandy-bays in the Night to turn them; and having small Huts at particular Places on the Bays to Keep them from the Rain and to sleep in: And this is another Harvest they have for Food; for by Report there come a great many Turtle to this and the rest of the Cape Verde Islands. When the Turtle season is over they have little to do, but to hunt for Guinea-Hens, and manage their small Plantations...* "

In this extract, Dampier clearly shows the importance of turtles as a source of food for the population of this island; and he states that these animals are also to be found on the other islands of Cape Verde. It is interesting to note the system used to capture the turtles. Even now, this is called "velar tartarugas". Finally, he mentions the Guinea hen, or Guinea fowl (*Numida meleagris*) as a source of food when the turtle breeding season comes to an end.

From Maio, Dampier went to Santiago to take on supplies of water and, after a few days there, the expedition set sail for Pernambuco (Brazil).

Figure 7. West Coast of Africa, 1738.

H - ANTOINE-FRANÇOIS PREVOST. 1749. Cape Verde Islands

He wrote a “Histoire generale des voyages” based on pre-published accounts. Chapter five of this work (the first chapter of volume VII) is based mainly on the account that Georges Roberts wrote in 1726, in which he describes his voyage to the Cape Verde islands in 1721.

In September 1721, English Captain George Roberts was commissioned in London to carry merchandise from Virginia (America) to the coast of Guinea (Africa). During the voyage, a storm drove them off course and they ended up in Plymouth. From there, and after a month’s wait because of the conditions of the sea, they finally set sail for Africa.

Roberts’ first visit to Cape Verde (he had previously bought wine in Madeira and in Tenerife, where he apparently sold his cargo) must have taken place between December and January 1721-22. He visited Sal (where he found no-one), Boavista (where he bought salt, horses and donkeys), Maio and Santiago. On this voyage, he makes no mention of turtles and they returned to Barbados in March 1722.

On his arrival he had to sell everything that he had brought from Cape Verde at a loss (most of the animals had died and the wine had gone off) and he bought a ship to go into business for himself. He set off for the coast of Guinea and Cape Verde again in mid July 1722. A fever confined him to his bed for three days and, during this time, the pilot lost his way so, after wandering the ocean, they finally reached the island of Sal in mid October 1722.

This is the moment that his account starts to include observations concerning sea turtles[3].

> *“The anchor was dropped in the Bay of Palmeira, which is in the north of the island. This was the season of the green turtles. On this occasion, Roberts remarked that the French often came to the islands of Cape Verde with the sole intention of catching turtles, which they salt on the shore, just like Newfoundland cod, and they sell them in the West Indies at a great profit. They keep the shells for France, where the profit is greater than in England, especially the shells of the turtles of these islands that have a finer, more transparent shell than those of anywhere else. On the other hand, they sometimes find grey amber, particularly on the island*

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[3] The account continues in the words of Prevost.

of Sal and it is believed that if the wild cats and even the green turtles did not eat this precious gum, much profit could be made. Roberts, who needed provisions, having sent a ship's boat ashore in search of some freshly caught turtles, he saw it return in under two hours. She returned with one that weighed between 200 and 300 pounds, with a negro from the island of Sao Nicolau who gave it to him on behalf of his companions. They had come to Sal from Sao Nicolau, 60 in number to fish turtles there on the orders of an English captain from Bermuda who had left them there and then left to take on salt in Boavista. But such a long absence made them loose hope of seeing him again and they offered Roberts half of their turtles, their oil, their shells and their grey amber in exchange for carrying them and the other half of the merchandise to Sao Nicolau".

And further on, still referring to the island of Sal, he says:

"So many turtles are caught that several sail ships come to load them all every year and they salt them for transporting to the American colonies. These animals use the time of the rains to lay their eggs in the sand and they leave them to warm in the sun. This is when the inhabitants hunt them with no difficulty other than turning them on their backs with stakes as they are so big that they would not have the strength to do this with their hands. The meat of the turtles is as common in the colonies as cod in the countries of Europe".

About the island of Boavista, he says:

"Most of its inhabitants live off goats, whose milk is their main food stuff, together with fish and turtles".

About the island of Maio, he states:

"Turtles there are not so abundant" (compared with Boavista)

The island of Brava:

"...it is abundant in fish. Quantities of turtles come too, which lay their eggs in the rainy season. But the inhabitants do not eat them like those of Santiago and San Felipe (Fogo); despite the fact that on all the other islands, these eggs are considered a delicious feast, as Captain Roberts himself can vouch".

The island of Sao Nicolau:

"It appears that, nowadays, most of their trade is confined to turtles, which they catch in large numbers".

And finally, several references to Sao Vicente:

> *"The fishermen of Sao Nicolau go there to hunt turtles".*
>
> *"With the exception of Sal, there is no other island in all of Cape Verde where they catch so many turtles".*
>
> *"It is essential to mention the amount of shells and small turtle skeletons, the shore is full of them, that come here in very large numbers...*
>
> *Sao Vicente is a desert island on which there are 20 Portuguese from Sao Nicolau that have been there for 3 years devoted to curing the skins of the goats that they catch with trained dogs. Their dwellings were huts in which the furniture they used consists of leather stools and turtle shells that act as chairs and bowls for the water".*

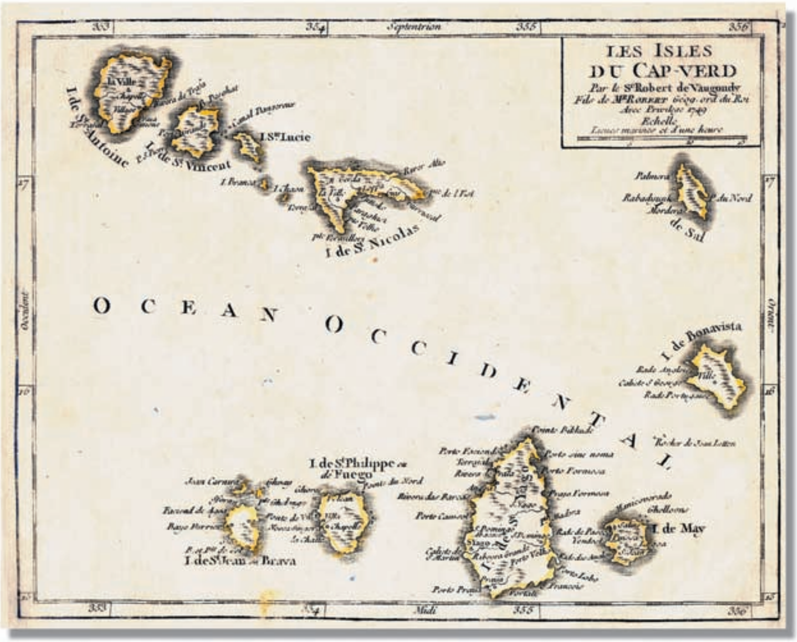

Figure 8. Cape Verde Islands. By St. Robert de Vaugondy, 1749.

The following points from the abundant information above can be highlighted:

- Those 50 years after Froger's reference (see above), the French continued to export turtle meat from Cape Verde to the French West Indies.
- That turtles were highly abundant on the island of Sal.
- That they were large animals, as they had to be turned over with the help of stakes.
- That turtles were also highly abundant on Sao Vicente.
- Those expeditions were sent from Sao Nicolau to both Sal and Sao Vicente to catch turtles.
- That the turtle carapaces were used as household utensils.

I -GEORGE GLASS. 1764. Canary Islands

He was a doctor of the English navy that attempted to set up a commercial factory on the coasts of the Sahara. His adventure ended in tragedy, but, before the end, he left his writings, in which he describes the Canary Islands. They include a reference to sea turtles in association with the east coast of the island of Fuerteventura (Las Playas bay) in late May of approximately 1763:

> *" At that moment, some fishermen caught a large loggerhead turtle in the bay, weighing some five hundred pounds, which they took ashore and they put it on its back on top of a large stone, after cutting its throat, from whence came a flow of steaming blood. As they had no bowl to catch it, the mayor and the rest of his people caught all they could in their hands and they drank it. When they realised our disgust at seeing such a barbaric and bestial manner of eating, they shook their heads and they told us that it was an excellent remedy against the frost itch and they invited us to join in; to our even greater disgust, we noticed their hands full of scabs and sores".*

Apart from the fact that the date of the observation almost coincides with the start of the breeding season of the turtle species *Caretta caretta* in Cape Verde, it is also striking that the animal was an adult, judging from the weight (see above the estimations of the weight of nesting turtles in Cape Verde provided by Leguat, Froger and Roberts); and the fact that they believed that turtle blood had medicinal properties.

J - JOSE DE VIERA Y CLAVIJO. 1799. Canary Islands

A priest and historian, in 1799 he wrote his “Dictionary of the natural history of the Canary Islands” (which was published in 1868-1869); in which he defines the names of places, animals and plants of the Canary Island archipelago.

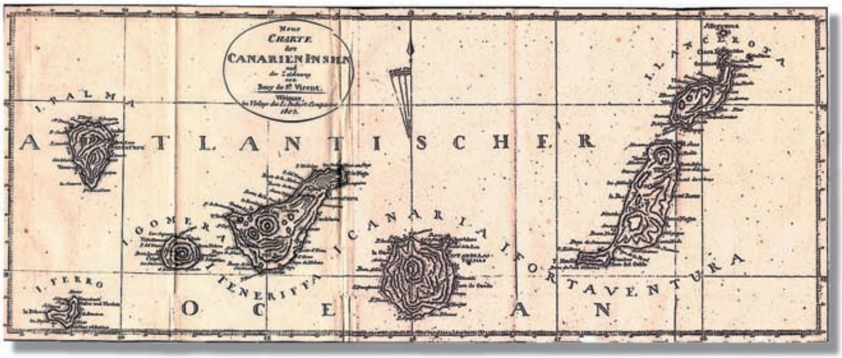

Figure 9. Canary Islands. By Bory de St. Vicent, 1803.

In Tome II, he defines the term “Islets” as follows:

> *“Islets (INSULAE DESERTAE). These are the six smaller islands situated close to Lanzarote, called Alegranza, Montaña Clara, Graciosa, Roque del Este, Roque del Oeste and Isla de Lobos: all of which are arid, mountainous desert lands. On Alegranza, archil is collected; on La Graciosa, the livestock grazes during the winter; on Montaña Clara, the best Canary Island birds are sought; on Isla de Lobos, they used to fish for the sea beasts of this name (monk seals), and on all of them, turtle eggs, shell fish, shells, etc. are to be found”.*

This reference is self-explanatory.

K - PETER SIMMONDS. 1885. Cape Verde Islands

On page 225 of this interesting book on wild animals used for food, the author writes:

> *“In Portugal, syphilitic patients are often sent to the Cape Verde islands to be cured by feeding on turtle flesh. The flesh of the green turtle is eaten in...the Cape Verde islands”.*

What is striking is the fact that although the curative properties of the flesh and blood of Cape Verde sea turtles were considered an efficient remedy for leprosy in the early years after the discovery of the islands, they were still being used 400 years later for curing syphilis. Nowadays, it is the popular belief that they have aphrodisiacal properties.

L - JAMES PARSON. 1962

This is the last of the great unknowns that we quote in our review of the historic literature. In 1962, he wrote a book on the green turtle in the world.

In this highly interesting book, most of the account covering the Cape Verde islands goes to establish that:

- It is the green turtle that nests in these islands
- He establishes a similarity between Ascension Island and Cape Verde to the south and north of the equator.
- He mentions Sal, Boavista and Maio as the most important islands for this species
- He suggests that the coast of Africa is probable the feeding grounds for these populations, from Mauritania south.
- He provides new data, from a certain M. Alexandrino, director of the airport of Sal, who tells him in a letter in 1959, that small numbers of turtles still come to nest on this island in the months of August and September. He adds that at least some of these are Caretta caretta and not Chelonia mydas.
- In the same year, J. Cadenat assures him in a letter, that in several journeys to Cape Verde, he has never seen green turtles, only occasional loggerhead turtles.

He finishes by saying:

> *"The Cape Verde turtles, like those of Ascension, are crying out for a historical and ecological study"*. James J. Parsons. The green turtle and man. Univ. Florida Press Book. 1962. (page. 45).

CONCLUSIONS

In the above article, we have attempted to directly transcribe pre-historic and historic knowledge (although, in some cases, we have reached the mid 20th century) available on sea turtles in the Macaronesian islands of the Canary Islands and Cape Verde.

We believe that there are two clearly demonstrated facts:

- The Cape Verde islands, especially Sal and Sao Vicente, were known as sites with a high density of nesting turtles between the 15th and the 18th centuries.
- Sea turtle eggs were collected on the uninhabited islets of the Canary Islands in the late 18th century.

Obviously this latter fact, together with the archaeological data mentioned above, could suggest that a species of sea turtle (the loggerhead turtle) that used to inhabit the eastern Canary Islands has become extinct. This possibility would be connected to the aboriginal population of the islands that used turtles as food and they considered them as a kind of God, probably in allusion to their value as a natural resource.

The extinction of turtles in the Canary Islands would have taken place in parallel to the extinction process of the monk seal (*Monachus monachus*) in the islands, a mammal that used to be eaten by the pre-historic inhabitants of the larger islands before the arrival of the Europeans, who, in turn, wiped them out from the same uninhabited islets on which Viera y Clavijo mentions that sea turtle eggs were collected (see LOPEZ-JURADO et al., 1995), and which were inaccessible to the aboriginal Canary Islanders because, as has already been mentioned, they did not know how to sail.

REFERENCES

BONTIER ET LE BERRIER 1453. The Canarian. or, Book of the Conquest and Conversion of The Canarians in the Year 1402 by Messire Jean de Bethencourt, Kt. Richard Henry Major, ed. Originally published by the Hakluyt Society. Reprinted 1971. Burt Franklin, New York.

BOCAGE, J.V.B. DU, 1896. Reptis de algumas possessões portuguezas d'Africa que existem no Museu de Lisboa. Jornal de Sciencias Mathematicas, Physicas e Naturaes, Segunda Série, IV (14): 65-104

CHIL Y NARANJO, G. 1876. Estudios Históricos de las Islas Canarias. Isidro Miranda Editor. Las Palmas de Gran Canaria.

CRONE, G.R. 1937. The voyages of Cadamosto. Hakluyt Soc. London

DAMPIER, W. 1697. A new voyage round the world. Dover Pub., 1968. New York

DAMPIER, W. 1729. A voyage to New Holland. A. Sutton ed. 1981, Gloucester.

FONTOURA DA COSTA, A. 1939. Cartas das ilhas de Cabo Verde de Valentim Fernándes 1506-1508.

FOULCHÉ-DELBOSC, 1897. Voyage à la côte occidentale d'Afrique, en Portugal et en Espagne (1479-1480); publié par R. Foulché-Delbosc. A. Picard et fils. Paris.

FROGER, F. 1700. Relation d'un voyage fait en 1695, 1696 & 1697 aux côtes d'Afrique, Détroit de Magellan, Brezil, Cayenne & isles Antilles. N. le Gras. 1891. Paris

GLASS, G. 1764. Descripción de las islas Canarias. Inst. Est. Canarios. 1982. Tenerife

JORGE GODOY, S (1996): Las navegaciones por la costa atlántica africana y las Islas Canarias en la Antigüedad. Estudios Prehispánicos, 4. Santa Cruz de Tenerife.

LEGUAT, F. 1691. The voyage of François Leguat of Bresse. Hakluyt Soc. 1891. London

Lopez-Jurado, L.F. and Martinez-Gonzalez, S. 1983. Las tortugas en Canarias. Aguayro, 147, 29-31

LOPEZ-JURADO, L.F., CABRERA, I., CEJUDO, D., EVORA, C. & ALFAMA, P. 1999. Distribution of marine turtles in the archipelago of Cape Verde, Western Africa. Proc. 19th Annual Turtle Symposium: 245-247. South Padre island

MECO, J. 1999. Los ovicaprinos de Villaverde. D.G. Patr. Hist. Gobierno de Canarias. Tenerife.

ONRUBIA, J. 1987. Les cultures prehistoriques des îles Canaries. Etat de la question. L'Antropologie 91 (2) : 643-678. Paris

PARSONS, J. J. 1962. The green turtle and man, Univ. Florida Press.

PREVOST, A. 1749. Histoire generale des voyages. Tome septieme. Paris.

SANSON, N. 1656. D'Eilanden van Capo Verde. De kust en't Landt der Negeren. Paris

ROCHEBRUNE 1884. Faune de Sénégambie. Reptiles. O. Doin, Paris

SIMMONDS, P.L. 1885. Animal food resources from different nations. Spon ed. London

VIERA Y CLAVIJO, J. 1799. Diccionario de historia natural de las islas Canarias. Mancomunidad de Cabildos, ed. 1982. Las Palmas de Gran Canaria.

VILLIERS, A. 1958. Tortues et cocodriles de l'Afrique noire française. I.F.A.N. Dakar

Status update of marine turtles in the Mediterranean

DIMITRIS MARGARITOULIS

ABSTRACT

Two cosmopolitan marine turtle species, the loggerhead *Caretta caretta* and the green turtle *Chelonia mydas*, have colonized the Mediterranean Sea from stocks in the western Atlantic. Nesting of both species is restricted in the eastern basin. Major nesting grounds of loggerheads are located in Greece, Turkey, Cyprus and Libya, and of green turtles in Turkey and Cyprus. The regional nesting populations seem to have diverged genetically as a result of low levels of contemporary gene flow with Atlantic populations. Further genetic studies and differences in the size of nesting females support the existence of sub-populations, within the Mediterranean.

Information on habitat utilization away from the nesting areas has been recently accumulated. Long-term tagging projects have revealed important benthic loggerhead habitats in the Gulf of Gabès and north Adriatic. High number of incidental captures in drifting longlines suggest that pelagic habitats are shared by distant loggerhead populations from within and outside the Mediterranean. Although migration routes are largely unknown, analysis of incidental captures of tagged loggerheads shows an active passage between the eastern and western basin. Further, recently deployed satellite telemetry has suggested a post-nesting coastal migration of green turtles to northern Africa.

Marine turtles in the Mediterranean are threatened by a diversity of human activities both on land and at sea. A variety of international conventions, national legislation, management plans and conservation projects aim to protect populations and habitats. However, the migratory nature and delayed maturity of the species, and the conflict with high-value economic interests, on land and at sea, make this a difficult task.

THE REGION

The Mediterranean Sea is a semi-closed sea surrounded by three continents Africa, Asia and Europe. It covers an area of about 2.5 million km^2 with a coastline length of approximately 46 270 km and a mean depth of about 1 400 m.

From an oceanographic point of view, the Mediterranean Sea is almost isolated. The Gibraltar Straits have a width of about 12 km and an average depth of 400 m. Because of salinity differences, due to evaporation, the heavier Mediterranean water flows to the Atlantic over the Gibraltar sill. This sustains a permanent surface current flowing in from the Atlantic. Under this rate of circulation, a complete exchange of the Mediterranean water takes about 150 years.

The Mediterranean Sea contains about 16% and 6% of all marine species of flora and fauna, respectively. Considering that its surface is just 1% of all oceans, Mediterranean Sea is ranked high in terms of biodiversity.

Mediterranean Sea can be divided in two major basins, the western and the eastern. Western is shallower (max depth 3.000 m) and with more nutrients while the eastern basin is deeper (max depth 5.000 m) and less productive. An important geographic barrier separates these two basins. The Straits of Sicily limits the water exchange between the two basins creating a differentiation in salinities and temperature regimes; the eastern basin being more saline and warm.

Today, there are 21 states bordering Mediterranean and about 50 million people leaving, exhibiting a multitude of cultures, languages and religions, along its coasts. The wider area, behind the coasts, supports about 400 million people. Although Mediterranean is not considered very productive due to the lack of currents and nutrients, it is heavily fished and runs severe risks of pollution and contamination by the many cities and industries on its coasts as well as of the rather heavy maritime traffic. Around 150 millions tourists visit Mediterranean each summer causing a serious pressure, mostly along its coasts.

THE TURTLES

Three cosmopolitan species of marine turtles, namely the loggerhead *Caretta caretta* (LINNAEUS, 1758), the green turtle *Chelonia mydas* (LINNAEUS, 1758), and the leatherback *Dermochelys coriacea* (VANDELLI, 1761) are encountered regularly in the Mediterranean. The loggerhead and the green turtle have established local populations whereas the leatherback, with a less common occurrence, is a visitor from the Atlantic. The last colonization of Mediterranean by marine turtles seems to have occurred about 10–12 000 years ago (BOWEN et al., 1993; ENCALADA et al., 1996), which coincides with the end of the last glacial period.

NESTING POPULATIONS AND OVERALL NESTING EFFORT

The two breeding marine turtle species (*Caretta caretta* and *Chelonia mydas*) nest almost exclusively in the eastern basin. The main nesting concentrations of *Caretta caretta* are found in Greece, Turkey and Cyprus (MARGARITOULIS et al., in press). Substantial nesting was also discovered in Libya (LAURENT et al., 1997) but the nesting effort there needs to be quantified. Few nests are made each season in Egypt, Israel, Italy, Syria, Lebanon, Tunisia, and occasional nests in Spain (TOMÁS et al., 2002b; MARGARITOULIS et al., in press). Monitoring of nesting areas in Cyprus, Greece, Israel, Tunisia and Turkey, range the total nesting effort in these countries from 3 375 to 7.085 nests per season (MARGARITOULIS et al., in press). However, these numbers are considered minimum figures as they include only nests counted in the context of monitoring projects.

It is of interest to note that mature female loggerheads in the Mediterranean are significantly smaller that those in other parts of the world (MARGARITOULIS, 1982). Moreover, there are body size differences within Mediterranean: females nesting in Greece are bigger than those nesting in Turkey and Cyprus (MARGARITOULIS et al., in press). Genetic studies have shown that although loggerheads in Greece and Cyprus share common haplotypes with those in the western Atlantic, they seem to have diverged genetically as a result of reduced gene flow (BOWEN et al., 1993); this genetic isolation becomes more prominent in nesting areas of Turkey (LAURENT et al., 1998) where it seems to exist further genetic differentiation (SCHROTH et al., 1996) indicating the occurrence of sub-populations (KASKA, 2000).

Green turtles nest exclusively at the easternmost, and warmest, part of the Mediterranean, with the great majority of clutches (about 99%) in Turkey and Cyprus, and the rest in Egypt, Israel and Lebanon. The overall nesting effort of green turtles in the Mediterranean is ranging from 350 to 1 750 clutches per season (KASPAREK et al., 2001). Genetic analyses in Cyprus have revealed endemic haplotypes, indicating an almost isolated green turtle population in the eastern Mediterranean (ENCALADA, 1996).

NON-BREEDING SPECIES AND POPULATIONS

Leatherbacks

Leatherback turtles are the largest of the marine turtles, with shells averaging 1.6 m in length and with a total weight of up to 500 kg. They inhabit tropical and temperate waters feeding almost exclusively on jellyfish. Despite the fact that some emergences have been reported in Malta, Israel and Sicily, no nesting has been adequately documented. Leatherbacks enter Mediterranean from the Atlantic, in the course of their transoceanic migrations, and have a more or less regular occurrence with densities decreasing from west to the east (MARGARITOULIS, 1986; LAZAR AND TVRTKOVIC, 1995; CAMIÑAS, 1998; BRADAI and EL ABED, 1998).

Loggerheads

The relatively large number of juvenile loggerheads caught incidentally in the western Mediterranean invoked the question as to their origin. ARGANO and BALDARI, 1983, suggested that they were derived mostly from populations nesting in the eastern Mediterranean and, in part, from the Atlantic. Further, CARR, 1987, indicated that loggerheads originating from beaches in the western Atlantic seem to follow a transatlantic developmental migration with some of them entering Mediterranean. This hypothesis was confirmed by tag recoveries (e.g. BOLTEN et al., 1992) and, also, by genetic studies in which it was found that about half of the pelagic-stage loggerheads originate from Mediterranean populations and the other half from the western Atlantic (LAURENT et al., 1998).

MIGRATIONS WITHIN THE MEDITERRANEAN

Known turtle movements in the Mediterranean concern mostly loggerhead turtles and are the result of long term tagging projects. Long-range recoveries of loggerheads tagged in Greece show a post-nesting wide dispersion with preference areas, the Gulf of Gabès (Tunisia) and the Adriatic Sea (Margaritoulis, 1988b; LAZAR et al., 2000). In Italy, 1 047 loggerheads, mostly juveniles, were tagged after their capture in fishing gear. Of these, 4.8% have been recovered at both the eastern and western Mediterranean basins; the ones in the eastern basin exhibiting, more or less, the same preference areas as the post-nesting females from Greece (Argano et al., 1992). Further, juvenile loggerheads in the western Mediterranean seem to conduct seasonal migrations (Camiñas and De La Serna, 1995).

Green turtles are not common in the western Mediterranean; this is probably a result of unfavourable temperatures. In the eastern Mediterranean, satellite tracking of green turtles from Cyprus have shown a post-nesting coastal migration to Egypt and Libya (Godley et al., 2002). Although, juvenile green turtles seem to have a restricted dispersal, in comparison to loggerheads (Baran and Kasparek, 1989), the discovery of green turtle developmental habitats in southern Greece (Margaritoulis and Teneketzis, in press) and western Turkey (Türkozan and Durmus, 2000) advocates more investigation to this matter.

Satellite telemetry, already undertaken on a small scale (HAYS et al., 1991; Bentivegna, 2002; Godley et al., 2002; Rees and Margaritoulis, in press), is expected to explore important aspects on migrations of marine turtles in the Mediterranean.

PELAGIC AND BENTHIC HABITATS

Marine habitats of sea turtles in the Mediterranean have been mostly indicated as a result of clumped long-distance tag returns. Through tagging, two major areas have been suggested: Gulf of Gabès and northern Adriatic Sea. These very extensive shallow areas seem to host benthic habitats for adult and juvenile loggerheads (Margaritoulis, 1988b; Argano et al., 1992; Laurent and Lescure, 1994; Lazar et al., 2000). Another way to locate possible marine habitats is by assessing the concentration of incidental captures in various types of fisheries. High number of turtle captures in bottom fishing suggests a benthic habitat, while captures in surface fishing suggest a pelagic habitat. Indeed, the suggested above benthic habitats in the Gulf of Gabès and northern Adriatic have been confirmed as such also through the high number of captures in bottom trawlers. Other benthic habitats of loggerhead and green turtles, indicated by the relatively high number of incidental captures in bottom trawlers, are found in the

Nile delta (LAURENT et al., 1996), the Bay of Iskenderun in Turkey (ORUÇ, 2001) and Lakonikos Bay in Greece (MARGARITOULIS et al., 1992). It is interesting to note that benthic habitats of loggerheads and green turtles are almost exclusively found in the eastern basin. Nevertheless, loggerhead captures in pelagic fisheries as well as recoveries of tagged juveniles (ARGANO et al., 1992) have suggested that both Mediterranean basins contain habitats for loggerheads in their pelagic phase (LAURENT et al., 1998). Considering that about half of the captured loggerheads in drifting longlines in the western basin come from the western Atlantic (LAURENT et al., 1998) we can say that the western Mediterranean hosts actually a pelagic developmental habitat of western Atlantic loggerhead populations.

THREATS ON NESTING AREAS

Most nesting areas in the Mediterranean are severely threatened by tourist development. Tourist facilities impact directly reproductive procedures and either inhibit females from egg-laying or increase mortality of eggs and hatchlings. Systematic use of beach furniture (i.e. umbrellas, deck-chairs) in tourist areas takes up vital space from emerging turtles and disrupts natural incubation of eggs. Mechanized traffic on beaches may destroy incubating clutches and hatchlings about to emerge. Beachfront lights disorient hatchlings which, instead of going to the sea, are attracted landwards succumbing to dehydration and predation. Other issues of concern are sand mining, alteration of nesting habitat for agriculture, coastal industries and constructions meant to protect the beach from erosion (e.g. sea walls, groins).

Urgent attention should be given to the mitigation of threats, described by KASPAREK et al., 2001, on the remaining five green turtle nesting areas in Turkey and Cyprus, hosting about 78% of the total nests in the Mediterranean.

The general degradation of nesting habitats, noted in the Mediterranean, and the increase of human-originated threats have triggered management programmes to address the seemingly natural loss due to nest predation. Predation of eggs, notably by foxes, affects most nesting beaches in the Mediterranean, with the exception of some areas (e.g. Zakynthos, Crete) where foxes are absent. Concerning loggerheads about 48.8% of nests at Kyparissia Bay (Greece) were disturbed by predators in 1987 (MARGARITOULIS, 1988a), 44.8% in Libya during 1995 (LAURENT et al., 1997), 36.0% in Cyprus during 1994 (Broderick and Godley, 1996) and 65-70% in Dalyan (Erk'akan, 1993). Similar predation rates have been documented on green turtle beaches.

THREATS AT MARINE HABITATS

1. Past and Present Exploitation

In the Mediterranean, sea turtles have suffered human exploitation for a long time. It is estimated that from 1915 until the middle 1930s at least 30.000 turtles, of both species, were caught offshore of today's Israel coast (Sella, 1982). A similar situation developed later at Mersin Bay and Iskenderun Bay in Turkey, where it is estimated that from 1952 until 1965 up to 15.000 turtles were taken from the shores of Mersin alone. The turtles were destined for human consumption in Europe. The turtle-fishery stopped in 1965 after depletion of the local *Chelonia* population. In Italy, Di Palma (1978) notes that a specialized fishery operated north of Sicily, catching 500-600 turtles annually. Turtles were also sold until recently in Algeria and Morocco (Laurent, 1990), Malta (Gramentz, 1989), Spain (Mayol and Castello Mas, 1983), and Tunisia (Laurent et al., 1990). The most recent case of turtle exploitation concerns Egypt where, despite an enforcement of prohibition of turtle sales in fish markets, these seem to continue behind the scenes (Nada, 2001).

2. Incidental Catch and Mortality in Fisheries

Today there is a substantial incidental catch of sea turtles in Mediterranean fisheries. An estimated 20.000 juvenile loggerheads are caught annually by the Spanish longline fishery (Aguilar et al., 1995); 2.000-2.500 turtles per year are caught in Tunisian trawlers in the Gulf of Gabès (Bradai, 1992); about 2.500 turtles in the eastern Adriatic (Lazar and Tvrkovic, 1995). Incidental captures of turtles in various fishing gear occur practically in all Mediterranean countries. Recently a cooperative project among France, Greece, Italy and Spain assessed turtle captures in the trawl and drifting longline fisheries (Laurent et al., 2001). Turtle captures seem to be also high in "less industrialized" fisheries, as set gill nets; however, quantification of turtle catch in these widely spread fisheries seems very difficult to be reliably assessed.

Mortality following incidental capture has not been fully documented. Although turtles hooked in drifting long-lines are usually released by cutting the branch line, the effect of hooks and lines left on turtles are not actually known. While turtles caught in trawler nets may suffocate and die, mortalities attributed to this reason appear generally low in the Mediterranean (Margaritoulis et al., 1992; Oruç, 2001; Laurent et al., 2001). On the contrary, mortalities caused by set gill nets seem to be very high, e.g. 94.4% in Corsica (Delaugerre, 1987). Further, a number of incidentally captured turtles, especially in set gill nets, seem to be killed or mutilated deliberately by fishermen (Kopsida et al., 2002).

3. Boat Strike, Oil Pollution, Marine Debris

Other reasons of turtle mortality at sea are boat strikes, oil pollution and ingestion of debris. Sea turtles spend a proportion of their time on the surface to breathe and rest between dives. At this time they are vulnerable to boat strikes, particularly from speedboats. The effect of boat strikes is of great concern in turtle frequented waters with dense tourist activities (e.g. Zakynthos). From a sample of 524 turtle strandings along the coasts of Greece, about 9% had injuries caused presumably by boat strikes (Kopsida et al., 2002).

The effects of oil pollution are not known in detail, although small size specimens can be immobilized and exhausted by heavy oil pollution. Twenty out of ninety-nine loggerheads, examined in the Maltese islands, were found contaminated mostly with crude oil (Gramentz, 1988).

Marine debris has been identified as harmful to sea turtles. Unattended or discarded nets, nylon bags, various buoyant plastics are of main concern. Special attention should be given to floating plastics and tar balls, which are frequently mistaken by turtles for food items. About 80% of juvenile loggerheads, sampled in the western Mediterranean, were found with debris in their digestive tracts, the great majority of which came from human sources (Tomás et al., 2002a).

CONSERVATION AND MANAGEMENT

1. Formal and Legal Aspects

The World Conservation Union (IUCN) has recognized the vulnerability of marine turtles and, according to the new criteria for Red List Categories, has listed all three species, encountered in the Mediterranean, as "Endangered". Further, the IUCN's Marine Turtle Specialist Group (MTSG) produced a Global Strategy for the Conservation of Marine Turtles, which addresses research, management and conservation issues. Recently the MTSG has created regional departments which enhance the regional identity of the network by concentrating at regional topics. The Mediterranean was one of the first regions to be formed.

There are several international conventions containing provisions for the protection of marine turtles in the Mediterranean region. The most important are:

a. The Convention on the Conservation of European Wildlife and Natural Habitats (also known as the Bern Convention), which includes sea turtles in the "strictly protected" list.
b. The Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (known as Barcelona Convention) and its associated protocols, which includes marine turtles in the List of Endangered and Threatened Species.
c. The Convention on the Conservation of Migratory Species of Wild Animals (CMS), also known as the Bonn Convention, provides valuable tools for international co-operation with respect to conservation and management of migratory species, including marine turtles.

These conventions have a varying degree of application in the Mediterranean countries with the exception of Barcelona Convention to which all Mediterranean countries (with the exception of Yugoslavia) are signatories. The significance of Barcelona Convention, as far as marine turtles are concerned, is reflected (1) in the adoption of an Action Plan for the Conservation of Mediterranean Marine Turtles, and (2) in the establishment of a coordinating mechanism, known as RAC/SPA (Regional Activity

Centre for Specially Protected Areas), based in Tunis. Also the Bern Convention, an initiative of the Council of Europe, has taken a leading role, with an effective administrative structure, in establishing conservation recommendations for countries hosting important nesting areas.

Besides supranational obligations, most Mediterranean countries have developed national legislation in protecting sea turtles. Furthermore, some countries have done steps in introducing site-specific protective legislation for nesting habitats. The very important nesting areas on Zakynthos have been recently incorporated in new legislation establishing a National Marine Park (DIMOPOULOS, 2001). In Turkey, the nesting beaches of Belek, Dalyan, Fethiye, Goksu Delta, and Patara were designated a Specially Protected Area (SPA) status with Akyatan, the most important green turtle nesting area, being a Wildlife Reserve. In Cyprus, the Fisheries Regulation contains provisions for protecting the nesting beaches of Lara and Toxeftra, including a maritime zone extending to the 20 m isobath.

2. Protection of Habitats and Populations

The Action Plan for the Conservation of Mediterranean Marine Turtles contains several provisions, both regional and national, regarding the identification of threats and protection measures for important habitats and populations. In general, protection and management measures aim in reducing disturbing factors. However, mechanisms for applying active management on nesting beaches are generally lacking. In some countries, state departments undertake this role, in other countries this is mostly done by NGOs and Universities.

Nevertheless, protection of marine habitats is at an early stage. Management for these habitats, needing international cooperation, should be effected by securing appropriate bodies and mechanisms to enforce maritime legislation and fisheries regulations. Further, mitigation of incidental catch in fisheries and subsequent mortality is very important and only recently have appeared specific projects to tackle it.

The high degree of public sensitization, noted the last years, requires the development of appropriate infrastructure to rehabilitate injured turtles. In the Mediterranean this is done either in existing aquaria or in facilities specifically established for this reason (BENTIVEGNA et al., 1993; CORSINI, 1996; KALLONAS et al., 1998;

PONT AND ALEGRE, 2000; SCHOFIELD and KOPSIDA, 2000). However, hospitalizing sea turtles should not be considered as a compensation scheme for the incidental and intentional mortalities at sea.

3. Public Awareness, Education, Capacity Building

During the last years a considerable effort has been focused in public awareness, education and training. At a regional level, RAC/SPA produces or supports production of various informative material, reports and manuals (DEMETROPOULOS and HADJICHRISTOPHOROU, 1995; GEROSA, 1996; GEROSA and CASALE, 1999). Further, RAC/SPA promotes capacity building on sea turtle conservation and management techniques by organizing or supporting training courses.

At a national level, public awareness projects, either aiming at specific target groups (e.g. fishermen) or at the general public, are conducted in several Mediterranean countries. It is of paramount importance that local stakeholders be incorporated in conservation plans; management techniques be explained to local people; involvement of local communities in conservation and management is a must, so that they comprehend the value of sea turtles and collaborate for their protection. Visitors at nesting areas should be sensitized and encouraged to participate in conservation efforts.

Children comprise another important target group (KREMEZI-MARGARITOULIS, 1992). Presentations by charismatic educators, especially designed traveling kits to be deployed by teachers, guided visits to nesting areas or rescue centres are activities enhancing public participation in conservation practices.

The problem of incidental catch and subsequent mortality can be partly eased through appropriate awareness of fishermen. Awareness of fishermen is done in several countries; sometimes combined with assessment of turtle bycatch in fisheries. The importance of the Italian project with fishermen was not only the collection of valuable data but also the successful sensitization of fishermen. A similar small-scale project gives fruit in Lakonikos Bay, Greece, where fishermen kill no more captured turtles, as they used to do by tradition (MARGARITOULIS et al., 1992).

EPILOGUE

Marine turtles are migratory species, to the extent that conservation efforts in one country could be undermined by harmful practices in another. This is very evident in a relatively small sea bordered by many countries. Therefore, supranational co-operation and cooperative efforts are urgently needed to adequately study and protect marine turtles in the Mediterranean. Further, late maturity and longevity of marine turtles render the results of management to be evident only after many years, probably too long for any corrections. So, the precautionary principle should guide any conservation and management plan.

REFERENCES

AGUILAR R., J. MAS, AND X. PASTOR. 1995. Impact of spanish swordfish longline fisheries on the loggerhead sea turtle *Caretta caretta* population in the western Mediterranean. Pages 1-6 in *Proceedings of the Twelfth Annual Workshop on Sea Turtle Biology and Conservation* (compilers: J.I. Richardson, T.H. Richardson). Jekyll Isl., Georgia, USA, 25-29 February 1992. NOAA Technical Memorandum NMFS-SEFSC-361, Miami, USA.

ARGANO R., AND F. BALDARI. 1983. Status of western Mediterranean sea turtles. *Rapp. Comm. int. Mer Médit.* 28(5):233-235.

ARGANO R., R. BASSO, M. COCCO, AND G. GEROSA. 1992. New data on loggerhead (*Caretta caretta*) movements within Mediterranean. *Boll. Mus. Ist. biol. Univ*. Genova 56-57:137-164.

BARAN I., AND M. KASPAREK. 1989. On the whereabout of immature sea turtles (*Caretta caretta* and *Chelonia mydas*) in the eastern Mediterranean. *Zoology in the Middle East* 3:31-36.

BENTIVEGNA F., P. CIRINO, AND A. TOSCANO. 1993. Care and treatment of loggerhead sea turtles from the Gulf of Naples, Italy. *Marine Turtle Newsletter* 61:6-7.

BENTIVEGNA F. 2002. Intra-Mediterranean migrations of loggerhead sea turtles (*Caretta caretta*) monitored by satellite telemetry. *Marine Biology* 141:795-800.

BOLTEN A.B., H.R. MARTINS, K.A. BJORNDAL, M. COCCO, AND G. GEROSA. 1992. *Caretta caretta* (loggerhead). Pelagic movement and growth. *Herpetological Review* 23(4):116.

BOWEN B., J.C. AVISE, J.I. RICHARDSON, A.B. MEYLAN, D. MARGARITOULIS, AND S.R. HOPKINS-MURPHY. 1993. Population structure of loggerhead turtles (*Caretta caretta*) in the northwestern Atlantic Ocean and Mediterranean Sea. *Conservation Biology* 7(4):834-844.

BRADAI M.N. 1992. Les captures accidentelles de *Caretta caretta* au chalut benthique dans le Golfe de Gabès. *Rapp. Comm. int. Mer Médit.* 33:285.

BRADAI M.N., AND A. EL ABED. 1998. Presence de la tortue luth *Dermochelys coriacea* dans les eaux tunisiennes. *Rapp. Comm. int. Mer Medit.* 35.

BRODERICK A.C., AND B.J. GODLEY. 1996. Population and nesting ecology of the Green turtle, *Chelonia mydas*, and the Loggerhead turtle, *Caretta caretta*, in northern Cyprus. *Zoology in the Middle East* 13:27-46.

CAMIÑAS J.A. 1998. Is the leatherback a permanent species in the Mediterranean Sea? *Rapp. Comm. int. Mer Medit.* 35(2):388-389.

CAMIÑAS J.A., AND J.M. DE LA SERNA. 1995. The loggerhead distribution in the western Mediterranean Sea as deducted from captures by the spanish longline fishery. *Scientia Herpetologica* 1995:316-323.

CARR A. 1987. New perspectives on the pelagic stage of sea turtle development. *Conservation Biology* 1(2):103-121.

CORSINI M. 1996. Notes on the efforts to treat sea turtles. *Biologia Gallo-Hellenica* 23:3-12.

DELAUGERRE M. 1987. Status of marine turtles in the Mediterranean (with particular reference to Corsica). *Vie Milieu* 37(3/4):243-264.

DEMETROPOULOS A., AND M. HADJICHRISTOPHOROU. 1995. Manual on marine turtle conservation in the Mediterranean. UNEP/IUCN/CWS/Fisheries Department. MANRE, Nicosia, Cyprus.

DIMOPOULOS D. 2001. The National Marine Park of Zakynthos: A refuge for the Loggerhead Turtle in the Mediterranean. *Marine Turtle Newsletter* 93:5-9.

DI PALMA M.G. 1978. Notizie sulle tartarughe marine in Sicilia. *Naturalista Sicili*ano S. IV. II(1-2):1-6.

ENCALADA S.E. 1996. Conservation genetics of Atlantic and Mediterranean green turtles: inference from mtDNA sequences. Pages 33-40 in *Proceedings of the International Symposium on Sea Turtle Conservation Genetics* (editors: B.W. Bowen, W.N. Witzell). Miami, Florida, USA, 12-14 September 1995. NOAA Technical Memorandum NMFS-SEFSC-396, Miami, USA.

ENCALADA S.E., P.N. LAHANAS, K.A. BJORNDAL, A.B. BOLTEN, M.M. MIYAMOTO, AND B.W. BOWEN. 1996. Phylogeography and population structure of the atlantic and Mediterranean green turtle (*Chelonia mydas*): a mitochondrial DNA control region sequence assessment. *Mol. Ecol.* 5:473-484.

ERK'AKAN F. 1993. Nesting biology of loggerhead turtles *Caretta caretta* L. on Dalyan beach, Mugla-Turkey. *Biological Conservation* 66:1-4.

GEROSA G. 1996. Manual on marine turtle tagging in the Mediterranean. UNEP/MAP, RAC/SPA, Tunis, Tunisia.

GEROSA G., AND P. CASALE. 1999. Interaction of marine turtles with fisheries in the Mediterranean. UNEP/MAP, RAC/SPA, Tunis, Tunisia.

GODLEY B.J., S. RICHARDSON, A.C. BRODERICK, M.S. COYNE, F. GLEN, AND G.C. HAYS. 2002. Long-term satellite telemetry of the movements and habitat utilization by green turtles in the Mediterranean. *Ecography* 25:352-362.

GRAMENTZ D. 1988. Involvement of loggerhead turtle with the plastic, metal, and hydrocarbon pollution in the central Mediterranean. *Marine Pollution Bulletin* 19(1):11-13.

GRAMENTZ D. 1989. Marine turtles in the central Mediterranean Sea. *Centro* 1(4):41-56.

HAYS G.C., P.I. WEBB, J.P. HAYES, I.G. PRIEDE, AND J. FRENCH. 1991. Satellite tracking of a loggerhead turtle (*Caretta caretta*) in the Mediterranean. *Journal of Marine Biological Association of the U.K.* 71:743-746.

KALLONAS M., D. DIMOPOULOS, AND D. MARGARITOULIS. 1998. After three years at the Sea Turtle Rescue Centre, Greece: The case of Ikaros. Pages 204-206 in *Proceedings of the Seventeenth Annual Sea Turtle Symposium* (compilers: S.P. Epperly, J. Braun). Orlando, Florida, USA, 4-8 March 1997. NOAA Technical Memorandum NMFS-SEFSC-415, Miami, USA.

KASKA Y. 2000. Genetic structure of Mediterranean sea turtle populations. *Turkish Journal of Zoology* 24:191-197.

KASPAREK M., B.J. GODLEY, AND A.C. BRODERICK. 2001. Nesting of the Green Turtle, *Chelonia mydas*, in the Mediterranean: a review of status and conservation needs. *Zoology in the Middle East* 24:45-74.

KOPSIDA H., D. MARGARITOULIS, AND D. DIMOPOULOS. 2002. What marine turtle strandings can tell us. Pages 207-209 in *Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation* (compilers: A. Mosier, A. Foley, B. Brost). Orlando, Florida, USA, 29 February-4 March 2000. NOAA Technical Memorandum NMFS-SEFSC-477, Miami, USA.

KREMEZI-MARGARITOULI A. 1992. Sea turtles stimulate environmental education in Greece. *Marine Turtle Newsletter*, 57 : 21-22.

LAURENT L. 1990. Les tortues marines en Algérie et au Maroc (Méditerranée). *Bulletin de la Société Herpétologique de France* 55:1-23.

LAURENT L., S. NOUIRA, A. JEUDY DE GRISSAC, AND M.N. BRADAI. 1990. Les tortues marines de Tunisie; premieres donnees. *Bulletin de la Société Herpétologique de France* 53:1-17.

LAURENT L., AND J. LESCURE. 1994. L'hivernage des tortues caouannes *Caretta caretta* (L.) dans le sud Tunisien. *Revue d' Ecologie (Terre et Vie)* 49:63-85.

LAURENT L., E.M. ABD EL-MAWLA, M.N. BRADAI, F. DEMIRAYAK, AND A. ORUÇ. 1996. Reducing sea turtle mortality induced by Mediterranean Fisheries: trawling activity in Egypt, Tunisia and Turkey. WWF International Mediterranean Programme, Roma, Italy. 32 pp.

LAURENT L., M.N. BRADAI, D.A. HADOUD, AND H.E. GOMATI. 1997. Assessment of sea turtle nesting activity in Libya. *Marine Turtle Newsletter* 76:2-6.

LAURENT L., P. CASALE, M.N. BRADAI, B.J. GODLEY, G. GEROSA, A.C. BRODERICK, W. SCHROTH, B. SCHIERWATER, A.M. LEVY, D. FREGGI, E.M. ABD EL-MAWLA, D.A. HADOUD, H.E. GOMATI, M. DOMINGO, M. HADJICHRISTOPHOROU, L. KORNARAKY, F. DEMIRAYAK, AND CH. GAUTIER. 1998. Molecular resolution of marine turtle stock composition in fishery by-catch: a case study in the Mediterranean. *Molecular Ecology* 7:1529-1542.

LAURENT L., J.A. CAMIÑAS, P. CASALE, M. DEFLORIO, G. DE METRIO, A. KAPANTAGAKIS, D. MARGARITOULIS, C.Y. POLITOU, AND J. VALEIRAS. 2001. Assessing marine turtle bycatch in European drifting longline and trawl fisheries for identifying fishing regulations. Project EC-DG Fisheries 98-008. Joint project of BioInsight, IEO, IMBC, STPS and University of Bari. Villeurbanne, France, 267 pp.

LAZAR B., D. MARGARITOULIS, AND N. TVRTKOVIC. 2000. Migrations of the loggerhead sea turtle (*Caretta caretta*) into the Adriatic Sea. Pages 101-102 in *Proceedings of the Eighteenth International Symposium on Sea Turtle Biology and Conservation* (compilers: F.A. Abreu-Grobois, R. Briseño-Dueñas, R. Márquez-Millán, L. Sarti-Martínez). Mazatlan, Mexico, 3-7 March 1998. NOAA Technical Memorandum NMFS-SEFSC-436, Miami, USA.

LAZAR B., AND N. TVRTKOVIC. 1995. Marine turtles in the eastern part of the Adriatic Sea: Preliminary research. *Natura Croatica* 4:59-74

MARGARITOULIS D. 1982. Observations on loggerhead sea turtle *Caretta caretta* activity during three nesting seasons (1977-1979) in Zakynthos, Greece. *Biological Conservation*, 24: 193-204.

MARGARITOULIS D. 1986. Captures and strandings of the leatherback sea turtle, *Dermochelys coriacea*, in Greece (1982-1984). *Journal of Herpetology*, 20(3): 471-474.

MARGARITOULIS D. 1988a. Nesting of the loggerhead sea turtle *Caretta caretta* on the shores of Kyparissia Bay, Greece in 1987. *Mésogée* 48:59-65.

MARGARITOULIS D. 1988b. Post-nesting movements of loggerhead sea turtles tagged in Greece. *Rapp. Comm. int. Mer Médit.* 31(2):284.

MARGARITOULIS D., N. KOUSIAS, G. NICOLOPOULOU, AND K. TENEKETZIS. 1992. Incidental catch of sea turtles in Greece: the case of Lakonikos Bay. Pages 168-170 in *Proceedings of the Eleventh Annual Workshop on Sea Turtle Biology and Conservation* (compilers: M. Salmon, J. Wyneken). Jekyll Island, Georgia, USA, 26 February-2 March 1991. NOAA Technical Memorandum NMFS-SEFSC-302, Miami, USA.

MARGARITOULIS D., R. ARGANO, I. BARAN, F. BENTIVEGNA, M.N. BRADAI, J.A. CAMIÑAS, P. CASALE, G. DE METRIO, A. DEMETROPOULOS, G. GEROSA, B.J. GODLEY, D.A. HADDOUD, J. HOUGHTON, L. LAURENT, AND B. LAZAR. In press. Loggerhead turtles in the Mediterranean: Present knowledge and conservation perspectives. In *Ecology and Conservation of Loggerhead Sea Turtles* (editors: A. Bolten, B. Witherington). Smithsonian Institution Press, Washington D.C.

MARGARITOULIS D., AND K. TENEKETZIS. In press. Identification of a developmental habitat of the Green Turtle in Lakonikos Bay, Greece. In

Proceedings of the First Mediterranean Conference on Marine Turtles (compilers: D. Margaritoulis, A. Demetropoulos). Rome, 24-28 October 2001.

MAYOL J., AND M. CASTELLO MAS. 1983. Contribuion al conocimiento de la Tortuga Boba en las Baleares. Ministerio de Agricultura, Pesca y Alimentacion. ICONA, Palma de Mallorca.

NADA M.A. 2001. Observations on the trade in sea turtles at the fish market of Alexandria, Egypt. *Zoology in the Middle East* 24:109-118.

ORUÇ A. 2001. Trawl fisheries in the eastern Mediterranean and their impact on marine turtles. *Zoology in the Middle East* 24:119-125.

PONT S., AND F. ALEGRE. 2000. Work of the Foundation for the Conservation and Recovery of Marine Life. *Marine Turtle Newsletter* 87:5-7.

REES A. F., AND D. MARGARITOULIS. In press. Telemetry of loggerhead turtles (Caretta caretta) in Amvrakikos Bay, Geeece. In *Proceedings of the 23rd Annual Symposium on Sea Turtle Biology and Conservation*. Kuala Lumpur, Malaysia. 17-21 March 2003.

SCHOFIELD G., AND H. KOPSIDA. 2000. Head injury rehabilitation of sea turtles - The positive side of a negative conundrum. Pages 41-43 in *Proceedings of the Nineteenth Annual Symposium on Sea Turtle Conservation and Biology* (compilers: H. Kalb, T. Wibbels). South Padre Island, Texas, USA. 2-6 March 1999. NOAA Technical Memorandum NMFS-SEFSC-443. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, USA.

SCHROTH W., B. STREIT, AND B. SCHIERWATER. 1996. Evolutionary handicap for turtles. *Nature* 384:521-522.

SELLA I. 1982. Sea turtles in the eastern Mediterranean and northern Red Sea. Pages 417-423 in *Biology and Conservation of Sea Turtles* (editor: K. Bjorndal). Smithsonian Institution, Washington D.C., USA.

TOMÁS J., R. GUITART, R. MATEO, AND J.A. RAGA. 2002a. Marine debris ingestion in loggerhead sea turtles, *Caretta caretta*, from the western Mediterranean. *Marine Pollution Bulletin* 44:211-216.

TOMÁS J., J.L. MONS, J.J. MARTÍN, J.J. BELLIDO, AND J.J. CASTILLO. 2002b. Study of the first reported nest of loggerhead sea turtle, *Caretta caretta*, in the Spanish Mediterranean coast. *Journal of Marine Biological Association of the U.K.* 82:1005-1007.

TÜRKOZAN O., AND S.H. DURMUS. 2000. A feeding ground for juvenile green turtles, *Chelonia mydas*, on the western coast of Turkey. *British Herpetological Society Bulletin* 71:1-5.

Behavioural ecology and conservation of oceanic-stage sea turtles: the Madeira Island loggerhead sea turtle project

THOMAS DELLINGER

Loggerhead sea turtles (*Caretta caretta*) enter the sea immediately after emergence from the nest in which they were born hours earlier. They frantically swim for the open ocean in which they will spend the first 6-12 years of their life, far away from coastlines and most human activity (Figures 1, 2). Right in the middle of this open ocean environment lies Madeira Island. Based on this island, our workgroup has studied turtles ever since we caught the first one in 1994. Here we present an overview of our work and summarize some of our results.

The existence of an oceanic or pelagic life stage is intriguing. Why should an animal leave the food abundance of its coastal home and spend its energy demanding growing period in the high seas, were food resources seem unpredictable in space and time? This is the main question motivating us. Two lines of answers seem possible. (1) Turtles might go pelagic to avoid predators, since coastal areas not only have more food abundance but also more predation pressure. (2) The apparent energetic disadvantage of an oceanic life might not be true. Resources, though unpredictable in space

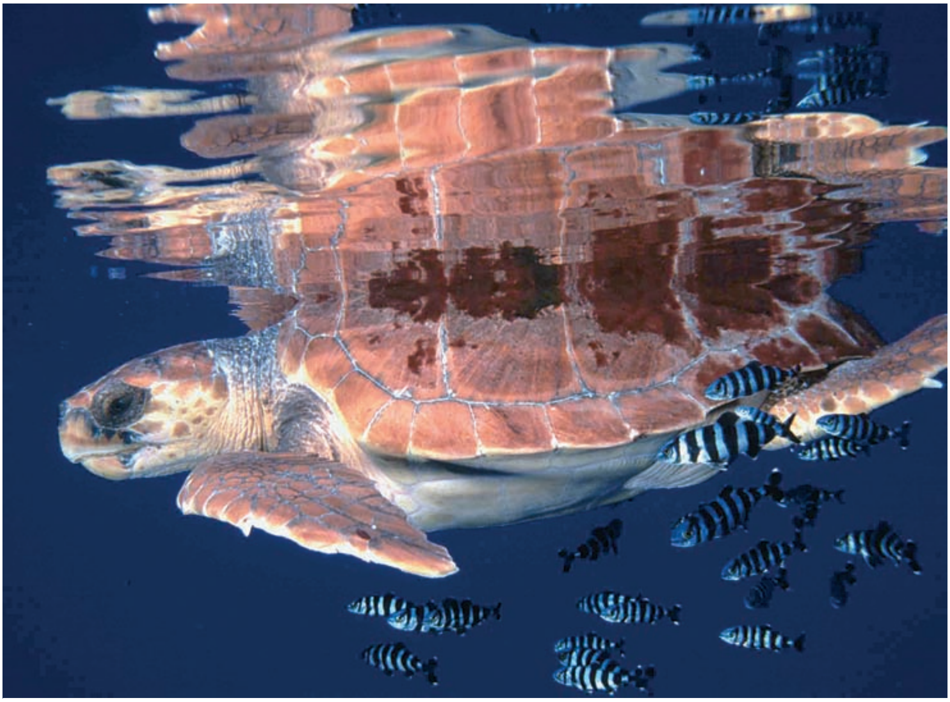

Figure 1. Juvenile oceanic-stage loggerhead turtle swimming at the surface off Madeira Island. Note the pilotfish swarm accompanying her.

Figure 2. Juvenile pelagic loggerhead turtle basking at the surface off Madeira, with pilotfish swarm and an oceanic spotted triggerfish underneath. This photo represents the 1st record of this triggerfish (*Canthidermis maculates*) for Madeira, as well as the 1st account that they associate with sea turtles.

and time, might be at certain times and places actually very abundant. The lower density of food competitors in the open ocean might thus be exploitable for sea turtles, which can overcome periods of food scarcity, as most reptiles, because of their lower metabolic rate. Whatever answers and combinations thereof we can find, growing up and feeding in the pelagic must be advantageous for loggerhead sea turtles because this species has the longest oceanic-stage of all species of sea turtles.

At Madeira we use the above rationale, and specifically the question of how sea turtles survive energetically in the open ocean environment to structure our research on loggerhead sea turtles.

When we started little was known on the biology of this life stage. First DERANIYAGALA, 1938, and LEO BRONGERSMA, 1967, and then ARCHIE CARR, 1986, supposed that loggerhead turtles in European Atlantic waters (including Azores and Madeira) might be of American origin. However this was merely a hypothesis. Collaboration with the Archie Carr Centre for Sea Turtle Research led to prove genetically the American origin of sea turtles found off Madeira and Azores archipelagos (BOLTEN et al., 1998).

In fact turtles from Madeira fit nicely into the size class gap of North American Atlantic captures (Figure 3) as did turtles from the Azores (Bolten et al., 1993). The average size at Madeira is slightly greater than at the Azores, probably due to the fact that first-arrivers would reach Madeira after the Azores if they drift with currents, and are thus slightly larger here at Madeira.

For the next step it was important to understand how the turtles use the pelagic environment. We equipped 10 turtles with satellite linked time-depth recorders for the following objectives:

1) Determine the areas frequented by loggerhead turtles off Madeira.
2) Determine area usage by monitoring movements and diving activity.

The main results are presently being published. No preferential oceanic areas could be identified since juvenile oceanic turtle were constantly on the move, mostly

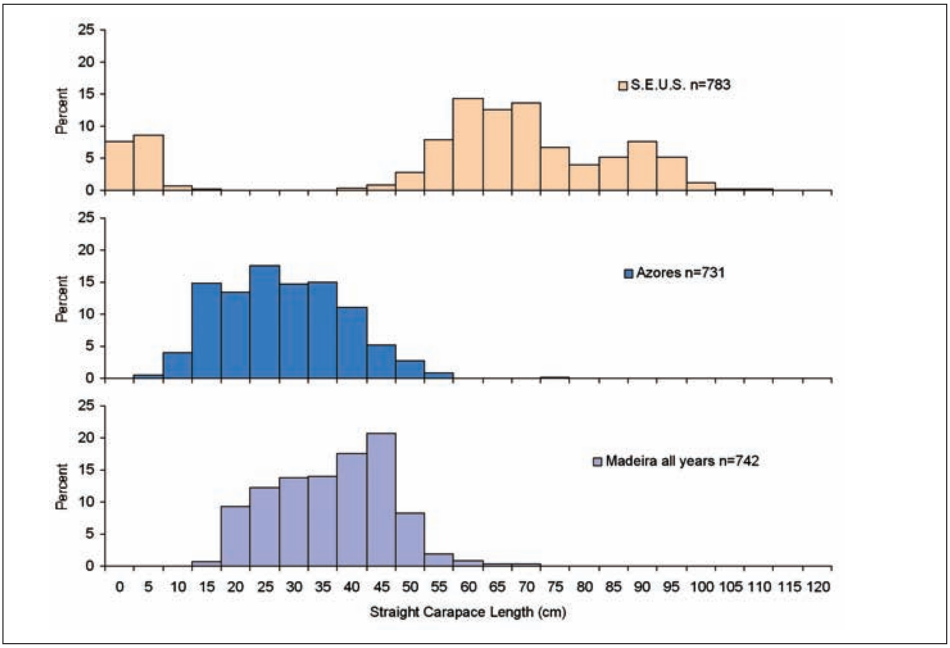

Figure 3: Size frequency distribution of loggerheads captured around Madeira Island. Data are compared to size distributions around the Azores (adapted from (Bolten et al. 1993)) and the south-eastern U S (S.E.U.S.; adapted from (Carr 1986b)). The S.E.U.S. loggerheads include post-hatchlings, benthic juveniles, benthic adults, and nesting females.

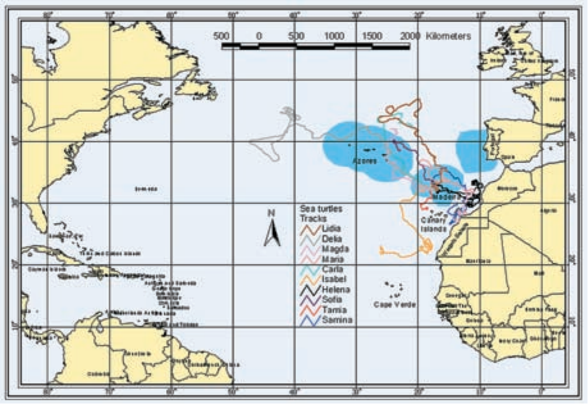

Figure 4. Migratory paths of turtles tagged with satellite transmitters at Madeira Island/Portugal in 1998 and followed till 1999. The darkened areas around the Portuguese archipelagos indicate its 200nm exclusive economic zone.

Figure 5. Basking loggerhead sea turtle in the calm waters on the lee-side of Madeira Island. A roseate tern (*Sterna dougalli*) sits on its carapace. The tern probably benefits by hunting the accompanying fish.

outside the 200nm jurisdictional boundaries (Figure 4). Seasonal variations of turtle abundance as well as differential migratory paths indicated seasonal migratory movements. An important over wintering area was detected off the coasts of Morocco and Mauritania. Turtles searched for and remained near frontal zones were temperature gradients are steepest, not venturing into colder water masses (René, 2000). Frontal zones seem their preferred feeding areas. Islands, such as Madeira, and specially the calm lee sides, are used for basking (Figure 5). However our satellite tracks did not reveal that turtles stay longer within these areas than elsewhere. Basking thus might be done opportunistically when there is the opportunity of calm weather and seas. Basking can raise body temperature well above sea surface temperature. At Madeira we actually measured 4.5degC cloacal temperature, slightly higher than in other reports (Sapsford & van der Riet, 1978; Spotila & Standora, 1985). Why turtles bask is not clear. Higher body temperatures could be advantageous for food digestion and assimilation (Snell & Fritts, 1983), or else it might be a strategy for turtles to free themselves from drag producing epibionts such as algae or barnacles.

Thus turtles survive in the pelagic by finding frontal zones and drift lines, locations with increased productivity, where food and flotsam aggregate and where the probability of finding it is enhanced. A second mechanism that may enhance food encounter rates is swimming against prevailing currents. Half the tagged turtles at Madeira swam against prevailing currents in a north-westerly direction (Dellinger, 2000; Dellinger & Freitas, 2000). This result together with similar findings in the Pacific Ocean (Polovina et al., 2000) does not corroborate the idea put forward by Archie Carr of a passive drifting migration by these turtles (Carr, 1986). However, size might be an important factor. It still is possible that very small loggerheads drift, but our turtles from 360mm curved carapace length onwards did not.

To feed turtles are supposed to swim and dive. Oceanic-stage turtles usually stay near the surface, making short duration dives, as evidenced by our satellite records (Dellinger, 2000; Dellinger & Freitas, 2000). Thus we assume that most of their feeding is within this depth range as well. Their usual food are gelatinous prey (van Nierop & den Hartog, 1984). However, from personal field and captivity observations, turtles are voracious predators, grabbing almost anything that comes into their range and is eatable, including fishery discards or other dead animals. This opportunistic behaviour seems well adapted to an environment were food is unpredictable. Stomach lavages evidenced many prey, including butterflies blown out to sea. Very occasionally turtles make deep dives, or long duration dives. Even the smaller turtles do this, not showing any signs of a body size dive performance relationship as found in marine mammals (KOOYMAN, 1989). Reasons for these occasional dives are not yet apparent, and could be related to feeding on specific prey. On the other hand it might at times be energetically advantageous to stay in deeper and colder environments as turtles in Japan did to escape from adverse oceanographic conditions (SAKAMOTO et al., 1990; SAKAMOTO et al., 1993).

To study these questions in greater detail, and given that satellite linked time-depth recorders only transmit summarized data, we presently engage in a study funded by the Portuguese Ministry of Science with time-depth-recorders that store the diving information onboard. The drawback of having to recover the devices is overcome with the much greater detail of the obtained information. Basically each dive can be profiled and thus the various diving and perhaps feeding strategies can be studied.

A second line in our research, complementary to the first, deals with the conservation of the oceanic loggerhead sea turtles. To protect a species one has to know its population size and composition and identify the dangers it is exposed to, both natural and human induced. Again, through funding by the European Union Life Program, as well as through Portuguese Ministry of Science, we started surveying the turtles off Madeira Island. Boating surveys and aerial surveys showed that turtles actually stay offshore, rarely being seen closer than 3 nautical miles to Madeira Island. However these methods only quantify surface dwelling turtles. Time spent at or close to the surface is dependent on local oceanographic and meteorological conditions, often varying on very small spatial and temporal scales, and thus not predictable. Our third method is essentially weather independent, and uses accidentally caught turtles in local fisheries to yield catch-per-unit-effort relative densities of turtles. In this way we can show that turtles are indeed more abundant in Madeira waters during the summer months (FERREIRA, 2001; DELLINGER et al., 2003 in prep.). However, none of the above methods produces absolute numbers. These can only be inferred by comparing nesting output at the beaches from which the turtles originate with population estimates of them after the oceanic life stage.

To describe the population of oceanic turtles we measure each captured sea turtle, often using more than one of the linear measurements described in the literature (BOLTEN, 1999): Turtles off Madeira range in straight-carapace-length from 131-694mm

SCL_{min} (Figures 3, 4, 5, 6) (corresponds to 150-734mm CCL_{min}). Different measurements can be transformed using our regression equations (Table 1).

Table 1. Regression equations calculated for oceanic-stage loggerhead sea turtles captured off Madeira relating the various linear measurements described in the literature (Bolten, 1999). SCL=straight-carapace-length (mm), CCL=curved-carapace-length (mm), SCW/CCW are the corresponding maximal carapace widths (mm), WT=weight (g). The indices "min" refer to minimal lengths as measured from the anterior point at midline of nuchal scute to the posterior notch at midline between the supracaudals, "nt" refer to notch to tip measurements from the anterior point at midline of nuchal scute to the posterior tip of supracaudals.

Equation	N	R^2	F	p<	
SCL_{min} =	0.9712 ¥ SCL_{nt} + 3.4193	334	0.999	353367.273	0.000
SCL_{min} =	0.9294 ¥ CCL_{min} - 11.8331	315	0.996	70483.109	0.000
SCL_{min} =	0.9003 ¥ CCL_{nt} - 9.2816	316	0.995	62937.226	0.000
SCL_{min} =	1.0925 ¥ SCW + 10.1654	335	0.976	13391.545	0.000
SCL_{min} =	0.9144 ¥ CCW + 4.3067	316	0.990	30031.281	0.000
CCL_{min} =	0.9680 ¥ CCL_{nt} + 2.9410	357	0.999	287729.784	0.000
CCL_{min} =	1.0712 ¥ SCL_{min} + 14.3782	315	0.996	70483.109	0.000
CCL_{min} =	1.0412 ¥ SCL_{nt} + 17.7183	314	0.996	72074.976	0.000
CCL_{min} =	0.9812 ¥ CCW + 18.2933	335	0.989	31042.347	0.000
CCL_{min} =	1.1696 ¥ SCW + 25.4533	315	0.973	11290.990	0.000
CCL_{nt} =	1.0318 ¥ CCL_{min} - 2.5446	357	0.999	287729.784	0.000
SCL_{nt} =	1.0287 ¥ SCL_{min} - 3.1847	334	0.999	353367.273	0.000
WT =	0.0002 ¥ SCL_{min} + 219.7637	549	0.969	17177.654	0.000
SCL_{min} =	5936.4291 ¥ WT + 352475.2488	549	0.969	17177.654	0.000
WT =	0.0001 ¥ CCL_{min} - 108.4565	549	0.970	17808.552	0.000
CCL_{min} =	7734.0364 ¥ WT + 2999163.6131	549	0.970	17808.552	0.000

The oceanic-stage is not only one year long, as the term "lost year" may have induced to think. Skeletochronology of mostly Madeiran turtles done in collaboration with the Archie Carr Centre for Sea Turtle Research shows the duration of the oceanic-stage to be equal or longer than 7 years (Bjorndal et al., 2003 in press). Taking length

Figure 6. Loggerhead turtles captured off Madeira on a single field day waiting to be measured and released. Note the size range of the turtles, all juveniles.

frequency data from the Azores into account, the oceanic-stage can be up to 12 years long (Bjorndal, et al. 2000). Based on these skeletochronology findings, the youngest turtles reach Madeira aged around 8 months, maybe even less. Thus, off Madeira, a mixture of turtles is found of many ages (Figure 6).

It is obviously a mixture of both sexes as well. Laparoscopies as well as hormonal essays indicate at Madeira a sex ratio of 2 females per male. This is indistinguishable from the adult sex ratios off the US coasts . Madeira loggerheads recruit from at least 3 (NE-Florida, SE-Florida and Yucatán: Bolten et al. 1998) of the 5 American northeast Atlantic/Gulf nesting sub-populations . These 3 sub-populations produce jointly an estimated 75% females hatchlings , which are many more females than we find here at Madeira. Thus we are led to believe that differential mortality between the sexes probably happens early in life, and probably before turtles reach Madeira. We are presently analysing our sex-ratio data to detect age effects in sex ratio and thus indirectly address mortality, an important issue for conservation.

Human induced mortality is an important issue for an endangered sea turtle. Fishermen interviews, landing surveys and onboard observation show that around 500 turtles are caught accidentally by longline fisheries (Figures 7, 8) based on Madeira Island (DELLINGER & ENCARNAÇÃO, 2000; DELLINGER et al., 2003 in prep.). In contrast to the Azores swordfish fishery (FERREIRA et al., 2001), were a high percentage of turtles that take the bait survive, turtles at Madeira are almost all killed. At Madeira longlines are set between 700 and 1300m of depth, drowning any turtle that is caught while setting the line.

Figure 7. Turtles are incidentally caught and drowned by the local deep-water black-scabbard-fishery longlines.

Figure 8. Entangled juvenile pelagic loggerhead sea turtle. Her right front-flipper is completely necrotic due to the interruption of blood flow at the entanglement point.

Figure 9. Entangled juvenile pelagic loggerhead. Ghost-fishing and other persistent debris floating in the worlds oceans probably take a major toll of sea turtles in the oceanic-stage.

Dissections of accidentally drowned turtles also show that most turtles have plastic in their stomachs. However, the effects of persistent debris on oceanic-stage turtles are difficult to quantify in terms of mortality. Other important human induced causes of mortality are ghost fishing (Figure 9) and oil slicks (Figure 10). Turtles are curious and attracted to any floating object. Any crude, but especially high viscosity oils stick to turtles and often capture them. I've observed a 3x2m oil slick patch with one seabird and two half decomposed turtles stuck in it.

Conservation means also protective measures. Portugal ratified most international conventions that deal with sea turtles. This alone is not enough since it does not eliminate accidentally induced harm to turtles from human activities. Oceanic turtles do not benefit from protected areas as do other species. Coastal Marine Protected Areas as the ones existing at Madeira cannot adequately defend oceanic-stage sea turtles, since they rarely approach

Figure 10. A turtle found off Funchal completely entrapped in a high viscosity oil slick of only a few square meters, rescued and later cleaned and released by the team.

coastlines. Fisheries interactions account for most of the mortality of sea turtles within Madeira EEZ. Thus improved fishing methods and gear which reduce bycatch must be the method of choice as put forward by a US fisheries project at the Azores (WATSON et al., 2003). Public awareness campaigns are also important to educate fishermen and the coastal population on how to handle turtles and to avoid discarding persistent debris into the ocean. In this regard a sea turtle recovery centre at Madeira is desperately needed, which should combine public exhibition and public awareness (and thus visitor fees) with turtle husbandry and care. On a more political line, bilateral or larger international agreements are important to protect turtles that do not stay with geopolitical boundaries as these oceanic-turtles. For North Atlantic oceanic loggerheads and in regard to the Macaronesian Oceanic Developmental area, which should cover an area encircling the turtle tracks of Figure 5, these agreements should include Portugal, Spain, Morocco and Mauritania as well as the U.S. and Cape Verde.

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REFERENCE

BJORNDAL, K.A., BOLTEN, A.B., DELLINGER, T., DELGADO, C. & MARTINS, H.R. 2003 in press. Compensatory growth in oceanic loggerhead sea turtles: response to a stochastic environment. Ecology.

BJORNDAL, K.A., BOLTEN, A.B. & MARTINS, H.R. 2000. Somatic growth model of juvenile loggerhead sea turtles *Caretta caretta*: duration of pelagic stage. Mar. Ecol. Prog. Ser. 202, 265-272.

BOLTEN, A.B. 1999. Techniques for measuring sea turtles. In: Research and Management Techniques for the Conservation of Sea Turtles (Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A. & Donnelly, M. eds). IUCN/SSC Marine Turtle Specialist Group Publication No.4. pp. 110-114.

BOLTEN, A.B., BJORNDAL, K.A., MARTINS, H.R., DELLINGER, T., BISCOITO, M.J., ENCALADA, S.E. & BOWEN, B.W. 1998. Transatlantic developmental migrations of loggerhead sea turtles demonstrated by mtDNA sequence analysis. Ecol. Appl. 8(1), 1-7.

BOLTEN, A.B., MARTINS, H.R., BJORNDAL, K.A. & GORDON, J. 1993. Size distribution of pelagic-stage loggerhead sea turtles (*Caretta caretta*) in the waters around the Azores and Madeira. Arquipélago 11(A), 49-54.

BRONGERSMA, L.D. 1967. Guide for the identification of stranded turtles on British coasts. British Museum (Natural History). Publication No. 659, London.

CARR, A. 1986. Rips, fads, and little loggerheads. Bio Sci. 36(2), 92-100.

DELLINGER, T. 2000: Conservation support project for North Atlantic *Caretta caretta** sea turtles - Life Nature Project contract no. B4-3200/96/541 (Life96Nat/P/3019). Final Technical Activity Report. Final Technical Activity Report, Funchal. CITMA.

DELLINGER, T. & ENCARNAÇÃO, H. 2000: Accidental capture of sea turtles by the fishing fleet based at Madeira Island, Portugal. Paper pres. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation, South Padre Island, Texas, USA. NOAA Technical Memorandum, NMFS-SEFSC-443.

DELLINGER, T., FERREIRA, T. & ENCARNAÇÃO, H. 2003 in prep. Accidental capture of sea turtles by the fishing fleet based at Madeira Island, Portugal and their seasonality in offshore waters.

DELLINGER, T. & FREITAS, C. 2000: Movements and diving behaviour of pelagic stage loggerhead sea turtles in the North Atlantic: preliminary results obtained through satellite telemetry. Paper pres. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation, South Padre Island, Texas, USA. NOAA Technical Memorandum NMFS-SEFSC-443.

DERANIYAGALA, P.E.P. 1938. The Mexican loggerhead in Europe. Nature 142, 540.

FERREIRA, R.N.L., MARTINS, H.R., DA SILVA, A.A. & BOLTEN, A.B. 2001. Impact of swordfish fisheries on sea turtles in the Azores. Arquipélago - Life and Marine Sciences 18A, 75-79.

FERREIRA, T.M.D.C. 2001. Abundância relativa de tartaruga-comum *Caretta caretta* (Linnaeus, 1758) na ZEE da Madeira. Relatório de Estágio da Licenciatura em Biologia Aplicada aos Recursos Animais, Faculdade de Ciências da Universidade de Lisboa, Lisboa.

KOOYMAN, G.L. 1989. Diverse Divers. Physiology and Behavior. Springer Verlag, Berlin.

VAN NIEROP, M.M. & DEN HARTOG, J.C. 1984. A study on the gut contents of five juvenile loggerhead turtles, *Caretta caretta* (Linnaeus)(Reptilia, Cheloniidae), from the south-eastern part of the North Atlantic Ocean, with emphasis on Coelenterate identification. Zoologische Mededelingen 59(4), 35-54.

POLOVINA, J.J., KOBAYASHI, D.R., PARKER, D.M., SEKI, M.P. & BALAZS, G.H. 2000. Turtles on the edge: movement of loggerhead turtles (*Caretta caretta*) along oceanic fronts, spanning longline fishing grounds in the central North Pacific, 1997–1998. Fisheries Oceanography 9(1), 71-82.

RENÉ, F. 2000. Couplage entre suivis satellitaires de tortues marines juvéniles (*Caretta caretta* L.) et des données environnementales océaniques. DEA Océanologie Biologique, Environnement Marin et Biogéochimie, année 1999-2000, Université Paris VI - Pierre et Marie Curie, Paris, France.

SAKAMOTO, W., SATO, K., TANAKA, H. & NAITO, Y. 1993. Diving patterns and swimming environment of two loggerhead turtles during internesting. Nippon Suisan Gakkaishi 59(7), 1129-1137.

SAKAMOTO, W., UCHIDA, I., NAITO, Y., KUREHA, K., TUJIMURA, M. & SATO, K. 1990. Deep diving behavior of the loggerhead turtle near the frontal zone. Nippon Suisan Gakkaishi 56(9), 1435-1443.

SAPSFORD, C.W. & VAN DER RIET, M. 1978. Uptake of solar radiation by the sea turtle, *Caretta caretta*, during voluntary surface basking. Comp. Biochem. Physiol. A 63, 471-474.

SNELL, H.L. & FRITTS, T.H. 1983. The significance of diurnal terrestrial emergence of green turtles (*Chelonia mydas*) in the Galápagos Archipelago. Biotropica 15(4), 285-291.

SPOTILA, J.R. & STANDORA, E.A. 1985. Environmental constraints on the thermal energetics of sea turtles. Copeia 1985(3), 694-702.

WATSON, J.W., FOSTER, D.G., EPPERLY, S. & SHAH, A. 2003: Experiments in the Western Atlantic northeast distant waters to evaluate sea turtle mitigation measures in the pelagic longline fishery. Report on experiments conducted in 2001 and 2002. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA Fisheries.

Recovery of marine turtles injured in the waters of the canary island archipelago (Spain) between 1998 and 2003.

Pascual Calabuig Miranda & Ana Liria Loza

INTRODUCTION

Since the early 90s, the Gran Canaria Wildlife Recovery Centre (CRFS from its initialls in Spanish) (Canary Islands Spain) has recovered a large number of wild animals. Apart from birds and some mammals, it also recovers a significant number of marine turtles. In the last 6 years (1998-2003), they have admitted over 100 turtles per year, 80% of which recovered and were released. These high numbers indicate the importance of this geographic area for marine turtles, mainly for their pelagic stage, about which so little is still known. The study of turtles in this phase of their lives is essential as it could help to answer many questions about the migratory behaviour of these animals.

The most abundant species in the Canary Islands is the common loggerhead turtle (*Caretta caretta*) represented mainly by juvenile specimens. Other species of marine turtles that can be sighted in Canaries are juvenile and adult leatherback turtles (*Dermochelys coriacea*), juvenile green turtles (*Chelonia mydas*) and occasional juvenile hawksbills (*Eretmochelys imbricata*).

The marine turtle populations in all the oceans are currently suffering major harm, making it essential to discover the true causes of this decline in order to protect and conserve them. That is why information from recovery centres is so important, as it provides us with valuable data on said causes, in what proportions they occur and to what extent they are affecting populations.

In the case of the Canary Islands, the main causes for turtle admission are mainly due to fisheries activities, that is, turtles that get caught in fishing nets, swallow hooks, or which are injured directly by the fishermen themselves. Other causes for admitting turtles to the centre are those arising from marine pollution, for example, due to swallowing heavy hydrocarbons, plastic or waste that they find drifting in the waters. Some turtles are also admitted for natural causes, such as shark bites and a range of illnesses, although these only account for a small percentage in comparison with the other causes.

This paper details the recovery data on 906 marine turtles injured in the waters of the Canary Island Archipelago between 1998 and 2003. This work is carried out in the Gran Canaria Cabildo (Island Government) CRFS in Tafira.

THE TAFIRA WILDLIFE RECOVERY CENTRE (CRFS)

The Tafira CRFS is a hospital that was founded in the mid 1980s to provide care for injured wildlife. For over ten years, it has been working intensely with marine wildlife, especially with marine turtles.

In the early days of the CRFS, very few turtles were admitted to the centre. Thanks to environmental education campaigns, co-operation between different public agencies like the police, guardia civil, red cross, etc. and public interest in general, mainly among people closely associated with the sea, a large percentage of the injured turtles around the islands have been brought to the CRFS (Figure 1). This fact, in turn, is proven by the fall in the number of dead turtles washing up on our shores.

The hospital currently has all the resources and facilities necessary for dealing with the vast majority of turtles admitted. It has 9 pools (Figure 2), constantly fed with sea water for keeping marine turtles in captivity. These pools have been built next to the sea, in the Canary Island Institute for Marine Sciences at Taliarte. The Gran Canaria Cabildo (Island Government) has a co-operation agreement with the marine sciences institute. It is in these pools that the turtles are fed, treated and monitored daily.

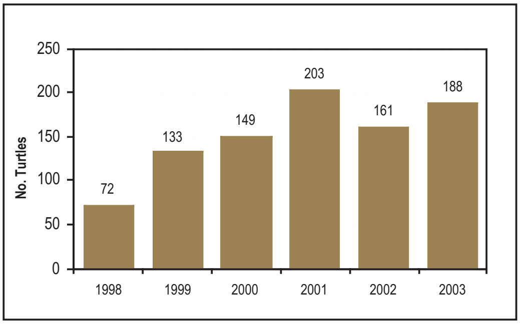

Figure 1. Number of turtles injured annually in Canary Islands.

Figure 2. Installations for the recovery of the turtles.

Most of the marine turtles injured in Canary Island waters are referred to the Tafira CRFS. Transport between islands is provided urgently and free of charge by the different inter island passenger air and ferry services (Figures 3 and 4). Over 560 inter-island marine turtle transfers were made between 1998 and 2003, either to Gran Canaria to admit them to the hospital or from Gran Canaria to other islands for their final release. In recent years, the centre has even received turtles from the United Kingdom that have

Figure 3. Free air services for animals transport.

Figure 4. Free ferry services for animals transport.

washed up in those northern waters, driven by the Gulf Stream and ending up with symptoms of hypothermia when the water masses cool. Initially treated in the UK, the turtles are then sent to Gran Canaria for a check up and to release them into the Gulf Stream currents once again.

GLOBAL RECOVERY BALANCE

Thanks to the toughness of these animals and the advances of the Gran Canaria CRFS, the balance can be said to be a very positive one (Figure 5). A total of 906 marine turtles were admitted between 1998 and 2003, 672 of which (75.2%) were released once they were totally recovered.

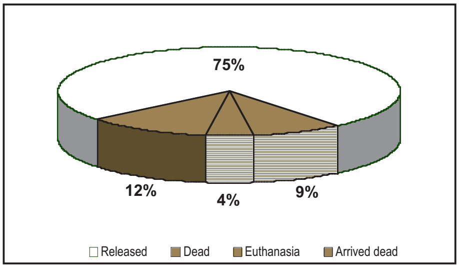

Figure 5. : Global recovery balance

On some occasions, the turtles are pronounced dead on arrival, or they are dead when found, although this only accounts for a small percentage (106 turtles, or 11.7/% of all admissions). We think that these should be added to the figures, to give an idea of the accident figures for these species.

On other occasions, the injuries are so severe that they are considered irreversible, so no attempts are made to recover the turtle, which is put down directly to prevent it from suffering any further. These animals are put down with an overdose of *sodium tiopenthal*, although this has only occurred in 4.2% of all cases (a total of 38 turtles).

And finally, we should also include the turtles that die during the recovery attempt. In general, these are turtles that are already in a poor state of health, which suddenly get worse. (79 specimens died between 1998 and 2003; 8.8% of admissions).

All dead turtles are sent to the Faculty of Veterinary Medicine of the University of Las Palmas de Gran Canaria for necropsies to be carried out on them. These necropsies have revealed some highly interesting data about the causes of death of turtles in the Canary Islands (Oros J., 2003)

ADMISSIONS BY ISLANDS

The islands that have accounted for almost 90% of all admissions are Gran Canaria (51.43%), Tenerife (23.62%) and Fuerteventura (14.68%), mainly due to the fact that these are the largest islands and because they are also the ones with the largest population, so there is far more inter-action between the turtles and man, from the point of view of causing damage to them and for detecting the injured animals.

In recent years, awareness and dissemination campaigns, and above all, co-ordination between wildlife agents of the different island Cabildos has led to a significant increase in the number of admissions.

ADMISSIONS BY MONTHS AND BIOMETRY

Although marine turtles are admitted throughout the year, most injuries occur in the summer months. On the one hand, there seem to be more turtles in Canary Island waters during these months, perhaps due to the rise in the water temperatures, and it also coincides with a large number of leisure and fishing vessels at sea at this time of year, and more people on the beaches. It therefore seems logical that admissions increase during the summer. (Figure 6)

As was said at the beginning of this paper, most marine turtles (97.6%) admitted to the Tafira hospital are juvenile loggerhead turtles, as the average size (in straight carapace length (SCL) is 37.17cm. These figures are fully in line with the turtle sightings at sea, especially in areas of calm, in the lee of the islands, where the

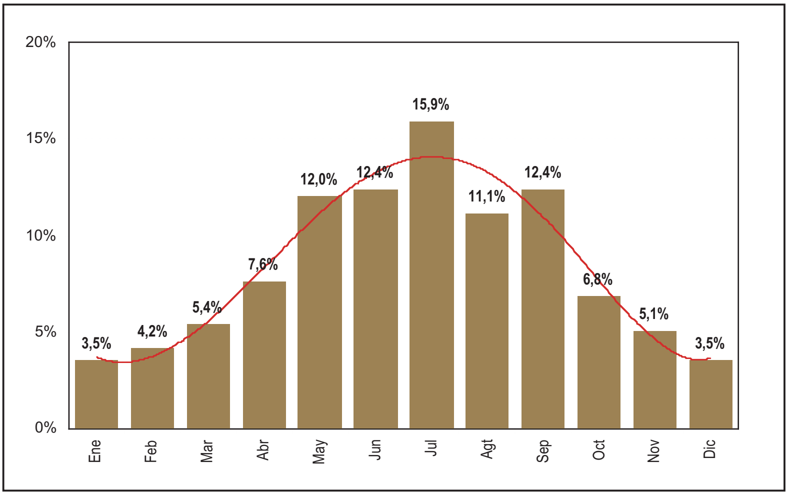

Figure 6. Monthly frequencies along the year.

loggerhead turtles are often seen resting on the surface and probable regulating their body temperatures. (Figure 7)

In recent years, there has been an increase in the numbers of small sized turtles seen (±20cm SCL), although the reason for this remains unknown.

It is important to highlight the fact that the biometry of the turtles found in the Canary Islands is slightly greater than the data for the turtles found in the waters of Madeira, which in turn, is slightly greater than for those found in the waters of the Azores Archipelago.

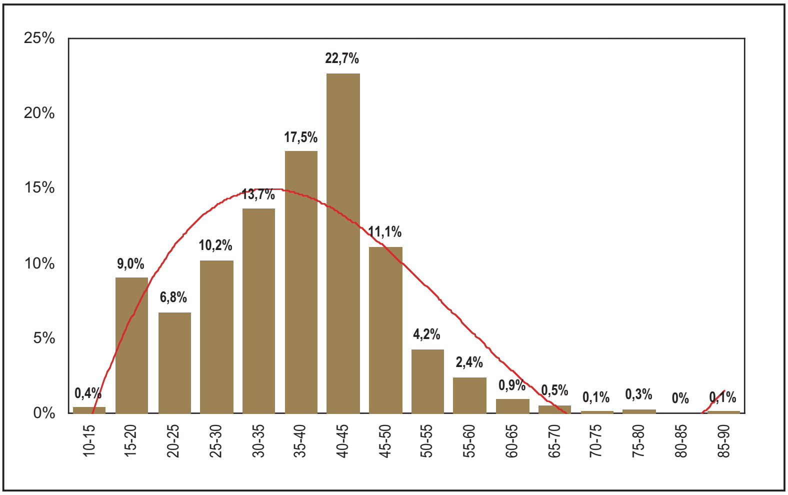

Figure 7. Frequencies of turtle's size.

MAIN CAUSES FOR ADMISSION AND RECOVERY BALANCE

The causes for admission are, in an overwhelming majority of cases, man-made, led by 45% (414 turtle admissions due to **ENTANGLEMENT** in nets, plastic, ropes and other floating debris (Figures 8, 9). We have seen the enormous harm caused by plastic mesh sacks used in agriculture. The turtles usually get their limbs entangled in these objects, leading to the loss of a flipper or even to the death of the animal if the nets, ropes, etc. get entangled around the animal's neck. 87% of all the turtles admitted for this cause were recovered.

Figure 8. Entangled turtle.

Figure 9. Entangled turtle that has lost a flipper.

SWALLOWING HOOKS accounts for 14.9% of cases (135 turtles) (Figures 10, 11). Most of these hooks are rusty, causing the animals serious chronic injuries. These are

Figure 10. Turtle with a hook in their esophagus.

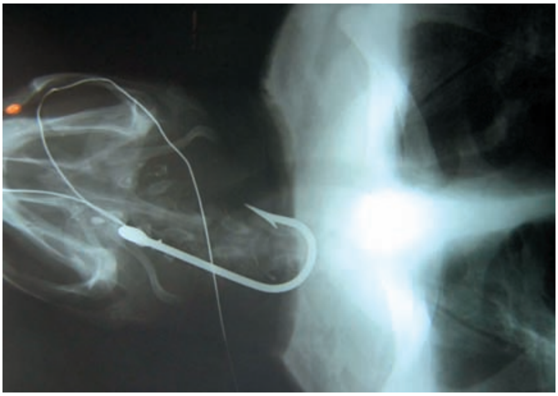

Figure 11. X-rays of a turtle with a hook in their esophagus.

the same hooks and gear as those used in long line fishing for sword fish (*Xiphias gladius*) in the archipelagos of Azores and Madeira. For this reason, we think that these animals have been caught in these islands. But, as there are no recovery activities in these archipelagos, the animals are released after the fishing line has been cut, but the hook is left embedded in the digestive tract. The turtles are then carried on the Gulf Stream, reaching Canary Island waters exhausted and in a poor state, where they are often caught by seafarers, or they wash up directly on our coasts. The hooks are removed with a ventral centre line *cervical oesophagotomy* (DURAL, 1993) or by using endoscope techniques. 76.3% of the turtles admitted for this reason manage to recover.

Different **TRAUMAS** encompass turtles that present injuries arising from collisions with boats and their propellers, fractured shells of unknown origin (Figure 12), shark bites (Figure 13), voluntary attacks by people with machetes, blows to the head, etc. At total of 61 turtles were admitted for this reason, a mere 23 of which (37.7%) could be finally released. In this section, there is an outstandingly high rate of euthanasia, with 9 specimens (14.75%), and turtles that were dead on arrival, with 16 specimens (26.23%), due to the seriousness of their injuries.

OIL AND HEAVY HYDRO-CARBON SLICKS drifting around the oceans are a death trap for marine turtles that approach them, thinking that they could be food (Figure 14), or for turtles that are stained by them when they come up to the surface to breathe. Turtles impregnated with these compounds are washed intensively (Figure 15), both externally and internally (the digestive tract if they have swallowed oil). 37 oil impregnated turtles appeared in the Canary Islands, 81% of which were ready for

Figure 12. : Turtle with fracture of carapace.

Figure 13. Turtle marked by a shark bite.

Figure 14. Turtle impregnated with oil.

Figure 15. Turtle impregnated with oil.

release after exhaustive cleaning and keeping them in captivity for a while to check that they ate and defecated normally.

In some cases, due to the fact that turtles sleep on the surface to regulate their body temperatures, they sleep so deeply that they appear to be dead. People catch these turtles that we classify as **HEALTHY CAPTURES**. These turtles presented no appreciable medical problems after carrying out a battery of tests. 100% of the turtles admitted for this reason were of course released.

Some turtles are admitted with **BUOYANCY ROBLEMS**, i.e., they float on the surface and cannot, generally dive more than a few centimetres, if at all. These problems may be originated by digestive or respiratory causes, generally due to illness, but they are put in a different category because of their seriousness. Of the 39 specimens caught with buoyancy problems, 36 (92.31%) managed to recover. Most of these had suffered from digestive problems. Pulmonary lesions are far more complex and extremely difficult to treat.

The **SWALLOWING** category includes turtles that have swallowed foreign objects other than hooks, like plastic bags, lines (Figure 16), etc. 83.33% of all turtles admitted for this cause were released after expelling the foreign body in question. The other two died during the recovery attempt.

Diseases like skin infections, conjunctivitis, enteritis, nephritis and other eye problems, generally deriving from bacteria, virus or pollutants, have been classified as **DISEASE**. Of the 64 turtles admitted for disease, 41 (64%) were released. This category has the highest percentage of deaths during the recovery process, with 23.44%.

Finally, we are left with the turtles with an unknown cause of admission, most of which (75.82%) were dead on arrival, generally in an advanced state of decomposition. These turtles were included in the **UNDETERMINED** cause of admission category. (Figure 17)

Figure 16. Turtles that have swallowed foreign objects.

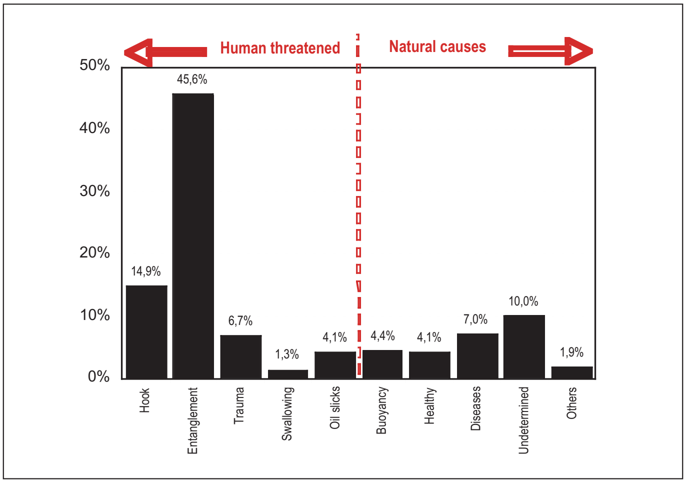

Figure 17.

Grates of mainly causes of admission.

CONCLUSIONS

Three quarters of marine turtle admissions in the Canary Islands are caused by human activity. Of these, floating jetsam causing entanglements (46% of admissions), is the main threat.

After a constant increase over the first four years, the number of admissions has stabilised at around 190 specimens per year. The highest numbers of turtles are seen during the summer months. The average size in terms of Straight Carapace Length is 37.17 cm, so a large majority of these turtles are juveniles.

The urgent transfer of marine turtles between islands (561 transfers), free of charge, is one of the corner stones of the operation organised by the Tafira hospital, in Gran Canaria.

The active participation of the general public and exemplary co-operation among the different Island Government Bodies (Cabildos), have made a significant contribution to the pronounced success of turtle recovery activities in the Canary Islands.

A review of existing information shows that the Tafira Recovery Centre is the hospital with the highest number of marine turtle admissions in the world.

ACKNOWLEDGEMENTS

First of all, we would like to thank the whole team of the Tafira Wildlife Recovery Centre: Ana Belen Casal, Paco Gonzalez, Antonio Lorenzo, Santiago Ramirez, Iballa de Vicente, etc., and all the staff of the Island Cabildos of the other islands in the Canary Island Archipelago. We would also like to thank the Canary Island Institute of Marine Sciences for their support and co-operation.

And above all, we would like to thank all the people who, aware of the problem, have shown their concern for marine turtles by co-operating, helping, collecting and advising of the arrival of animals in a poor state of health, together with all the volunteers that have devoted time and effort to the CRFS over the years, because, thanks to their help and encouragement, many of the turtles that have been admitted are now swimming free in the oceans and seas of the world. (Figure 18).

Figure 18. : Freedom of the rehabilitated turtles.

REFERENCE

I. DURALL Y P. CALABUIG.: *ESOFAGOTOMÍA CERVICAL PARA LA EXTRACCIÓN DE ANZUELOS EN CARETTA CARETTA.* II Jornadas Internacionales de la Sociedad Española de Cirugía Veterinaria. Murcia 1993.

J. ORÓS; A. TORRENT; A. RUIZ; P. CALABUIG AND S. DÉNIZ.: *PATOLOGÍAS Y CAUSAS DE MORTALIDAD EN TORTUGAS MARINAS DURANTE 1998 Y 1999. 2000.* Medio Ambiente Canarias, 16, 22-27

J. ORÓS Y A. TORRENT.: *MANUAL DE NECROPSIA DE TORTUGAS MARINAS. 2001.* Ediciones del Cabildo de Gran Canaria. 74 pp.

J. ORÓS; A. TORRENT; S. DÉNIZ; B. ACOSTA; P. CALABUIG Y A. RUIZ.: *ESTUDIO DE LAS CAUSAS DE MORTALIDAD EN TORTUGAS MARINAS VARADAS EN LAS ISLAS CANARIAS. 2003.* Ediciones del Cabildo de Gran Canaria. 178 pp.

Reproductive biology of the loggerhead turtle (*Caretta caretta* L. 1758) on the island of Boavista (Cape Verde, West Africa)

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& LUÍS FELIPE LÓPEZ-JURADO

ABSTRACT

This paper presents the revised and up-dated data on the nesting population of loggerhead (*Caretta caretta*) on the island of Boavista, studied from 1998 to 2002. To date, a total of 2,856 females have been tagged on different beaches of the island. The number of nests counted in the study area (on the beaches of Calheta, Ervatão and Ponta Cosme), a total of 3.1 km of beach, was 833 and 1,917 (only for the years 2001 and 2002 respectively). Nesting success for these two years is around 26 %, with differences between one beach and another. The annual average curved carapace length for females is between 81.3 and 82.4 cm, and clutch size is between 78.3 and 91.5 eggs. The range of incubation times was 45-74 days, with differences between one year and another and between one beach and another. Hatching success does not appear to show inter-annual variations, but these results does vary from one beach to another. In 2000, a *hatchery* was built with nests from Ponta Cosme and Ervatão beaches, from areas where the eggs were unlikely to develop. Hatching success for the artificially incubated nests was higher than hatching success for Ponta Cosme beach and similar to the success rate for Ervatão beach.

INTRODUCTION

The loggerhead turtle, *Caretta caretta* (Linnaeus, 1758), is found in all the oceans of the world, with many known nesting sites, mainly in temperate, and sub-tropical zones (Dodd Jr, 1988; Marquez, 1990). One of these nesting sites, which has a large breeding population, is located in the Cape Verde Archipelago, in the eastern Atlantic Ocean (Cejudo et al., 1999).

This chain of islands is situated approximately 500 km off the west coast of Africa at its closest point (Verde cape on the coast of Senegal), between 14° 48’ and 17° 18’ north, and between 22° 42’ and 25° 18’ west. The archipelago is made up of 10 volcanic islands and several islets, with appreciable differences in terrain, climate and distance from the African coast (Figure 1). The easternmost islands (Sal, Boavista and Maio) are fairly arid and flan, with a large extension of beaches along their coasts.

The first records of marine turtles nesting in the Cape Verde islands dates back to the 16th century (see quotes in Parsons, 1962). It is now known that the island of

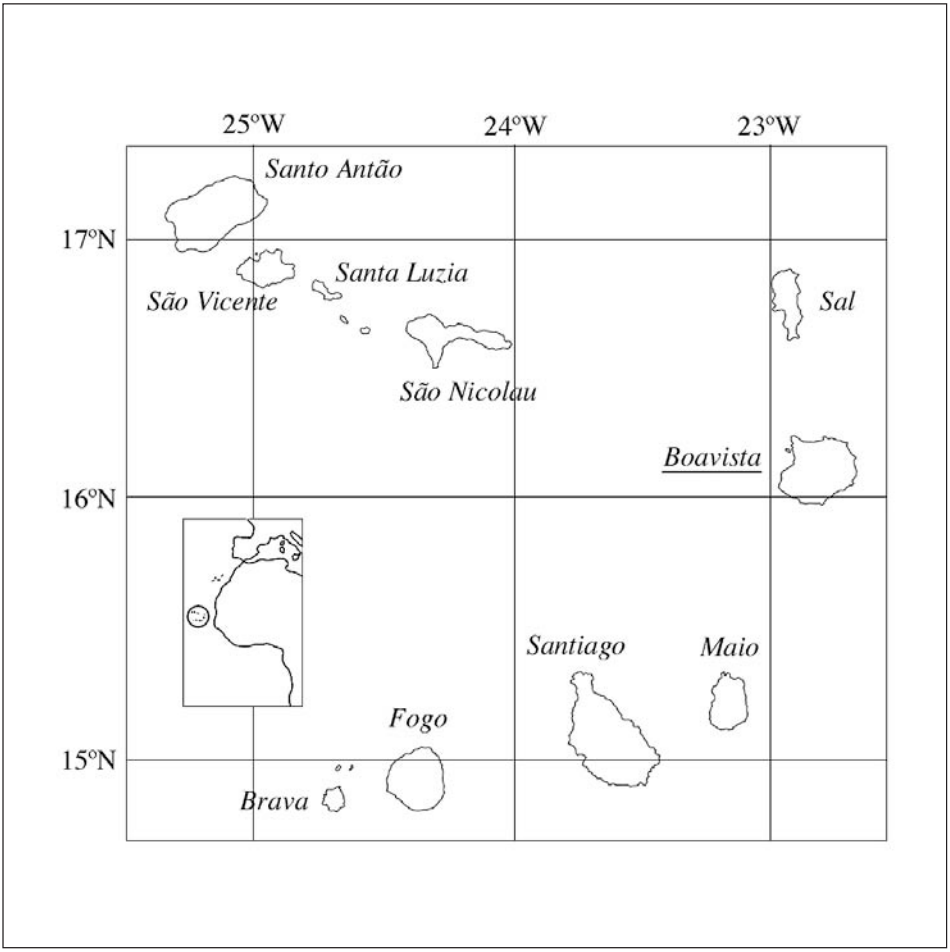

Figure 1. Cape Verde archipelago, Western Africa.

Boavista is the one with the largest population of nesting females, followed by Sal and Maio, and to a lesser extent, the other islands (Cejudo et al., 1999; Lopez-Jurado et al., 1999a). Moreover, juvenile populations of green turtle (*Chelonia mydas)* and hawksbill (*Eretmochelys imbricata)* can be found off the coasts of the archipelago (Linnaeus, 1758) and (Linnaeus, 1766) (Lopez-Jurado et al., 1999a).

A study of the breeding population of *C. caretta* has been on-going since 1998, focussed mainly on the island of Boavista. This article reviews and up-dates the data on their reproductive biology (see preliminary data in Cejudo et al., 1999).

MATERIAL AND METHODS

1. Study area

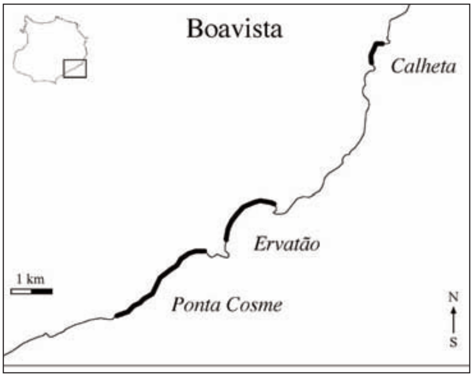

Figure 2. Study area in the island of Boavista.

All the beaches of the island of Boavista were examined in 1998, in search of signs of nesting. This showed that the main areas were to be found on the south-east coast (CEJUDO et al., 1999; CEJUDO et al., 2000). In later years, the study has focussed mainly on this area, although some females have been tagged at other sites. Nests were monitored and a daily record of tracks was kept only for three of these beaches: Calheta, Ervatão and Ponta Cosme (Figure 2). The three beaches are in close proximity to one another, but vary in physical appearance, enabling us to compare certain variables.

The beach of Ponta Cosme is the southernmost of the three and measures 1.7 km long (Figure 3). From north to south, in the first part of this beach, we find abundant vegetation that limits the width of the beach, and which is often reached by the high tide. The second area presents a substrate that is easily flooded and it consists of large

Figure 3. Ponta Cosme beach.

Figure 4. Ervatão beach.

Figure 5. Calheta beach.

amounts of clay. The third area is characterised by its high profile, very disperse vegetation and small dunes.

The beach of Ervatão is one kilometre north of Ponta Cosme beach. It measures 1.05 km in length, forming a bay. There is a ravine mouth at each end of the beach and the width of the beach is limited by vegetation and a stone wall. (Figure 4).

Calheta beach is located to the north of Ervatão, about 4 km away. It measures 350 m long. This is a wide beach with a high profile and little vegetation. (Figure 5).

2. Distribution of tracks and nests

The arrivals of female *C. caretta* were recorded on a daily basis during the 2001 and 2002 nesting seasons, by observing their tracks on the three study beaches. These registers recorded the presence or absence of nests. If we were not certain that there was a nest, it was marked down as doubtful. In 2001, the register started on the 7th of July (10 July in Calheta) and went on until the 22nd of October. In 2002, recordings started on the 14th of July and went through until the 12th of October (11th of October in Ponta Cosme), before the end of the season because of adverse weather conditions. There are some days on which, for different reasons, the track register was not made. The average of the number of tracks and nests counted three days beforehand and three days afterwards was assigned for these days for which no records were taken. These tracks account for 2.3 % of the total number of recordings for each year, and the nests account for 3.7% of nests recorded in 2001, and 2.2% in 2002.

For the analysis of the data, the tracks and nests were grouped together in intervals of seven days, except for the last interval in 2002, which only covered three days.

3. Tagging and biometry

Night patrols were mounted on the three beaches during the nesting season from 1998 to 2002, apart from sampling at different levels of intensity on other beaches of the island. On their way back to the sea, the turtles were stopped, measured and tagged, except in 2001, when most of the turtles were tagged while they were laying, in an attempt to reduce the stress the turtles were subjected to during handling on their way back to the sea.

Metal caliper were used for taking straight measurements for the biometric data, and flexible tape measures for curved measurements. The following measurements were taken (BOLTEN, 1999): minimum curved carapace length (CCL), curved carapace width (CCW), minimum straight carapace length (SCL), straight carapace width (SCW).

The type of external tags used was a Monel Tag applied to each front flipper, on the second scale, i.e. the largest in size (BALAZS, 1999). These tags have a unique, four-digit serial number engraved on one, and a Cape Verde Government registration number on the other. An AVID© PIT (Passive Integrated Transmitter) was injected intra-muscularly into the right flipper.

4. Monitoring nests

During the 1998 and 1999 seasons, eggs were counted by taking them out of the nest once the female had returned to the sea. The depth of the top and bottom eggs in the clutch was also measured (only in 1999). In the following years (2000, 2001 and 2002), the eggs were counted during nesting. Nests with a low number of eggs, leading us to think they were partial nests (MILLER, 1999), were excluded from the results. Nests were marked with a numbered stick to enable them to be identified and monitored later.

The variables associated with nest monitoring (incubation period, percentage of eggs hatched, etc.) were studied from 1999 through 2002. A daily check was done on the nests from the first day of incubation (night and day time patrols) and especially when the nests reached day 45 (HAYS et al., 1992). On day 45, a plastic mesh was placed around the nest to allow monitoring the day the hatchling emerged.

Incubation time was considered as the number of days from nesting (day 0) to the time the first hatchling appeared (PINCKNEY, 1990; GODFREY et al., 1996).

For calculating the percentage of successfully hatched eggs, two different methodologies were used. The first method, defined as "hatching success" in MILLER (1999), is calculated by dividing the number of empty shells found in the nest, by the number of shells plus un-hatched eggs. This formula does not take into account the size of the initial clutch. 9.5% of nests were excluded, as the amount of remains found was abnormally low (less than 20 eggs). The second method, the "excavation success" method, used by PINCKNEY (1990), is calculated as the difference between the initial number of eggs and the number of un-hatched eggs (undeveloped and partially developed), all divided by the initial number of eggs.

5. Artificial incubation experience

During the 1999 nesting season, hatching success was observed to be low on the beaches of Ervatão and Ponta Cosme in comparison with the rate for Calheta (Table 6; CEJUDO et al., 2000). For this reason, an experiment in artificially incubating *C. caretta* nests was carried out in 2000, on a small beach known as Benguinho, situated between Ervatão and Ponta Cosme.

For the experiment, a 225 m^2 area of the beach was prepared with 100 1m^2 plots. A total of 100 nests were transferred from Ervatão and Ponta Cosme beaches. The relocated nests were originally sited in areas considered to be highly unlikely to be successful, such as areas liable to flooding. Clutch sizes were counted at the time the eggs were placed in the artificial nest, and all the rest of the methodology used for monitoring these nests and hatching was exactly the same as for natural nests.

RESULTS

1. Tagged and recaptured females

Between 1998 and 2002, a total of 2,856 female *C. caretta* were tagged on the island of Boavista. Annual distribution and total number of recaptures can be seen in table 1. 87.6% were tagged on the 3.1 km of coastline that is the total length of Ponta Cosme, Ervatão and Calheta beaches.

Table 1. Number of tagged females of *C. caretta*, and number of recaptures from each of the five study seasons in Boavista.

		Recaptures				
	Tagged	1998	1999	2000	2001	2002
1998	92	51	-	-	-	-
1999	510	-	377	-	-	-
2000	740	14	7	446	-	-
2001	487	10	40	1	494	-
2002	1027	8	70	101	1	783

8.8% of the turtles tagged have been recaptured in later years: 9 of them the following year, 155 two years later, 80 three years later and 8 four years later (Figure 6). These data should be taken with caution, however, because tagged turtles may have come ashore on one of the three beaches of the study area, or, indeed, on any other beach that was not under study, without being detected.

Figure 7 shows the frequency distribution of recaptures of female *C. caretta* during the same season, grouped into two-day intervals. The analysis excludes recaptures that are less than five days or more than 26 days apart (Alvarado & Murphy, 1999).

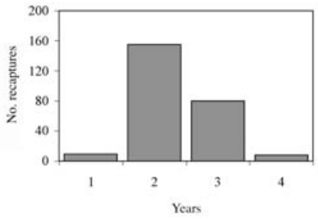

Figure 6. Frequency distribution of remigration interval (years) for loggerhead in Boavista.

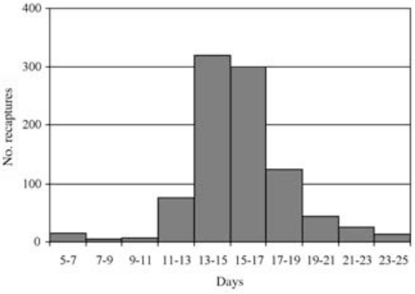

Figure 7. Frequency distribution of loggerhead recaptures in the same season, grouped in two days intervals.

2. Distribution of nests and nesting success

In 2001, sampling started in the first week in July, when there were already some nests to be found on the beaches. There was no more than one nest per beach found after the 13th of October. In 2002, sampling started after nesting activity had commenced, and the entire season could not be covered due to adverse weather conditions in the month of October.

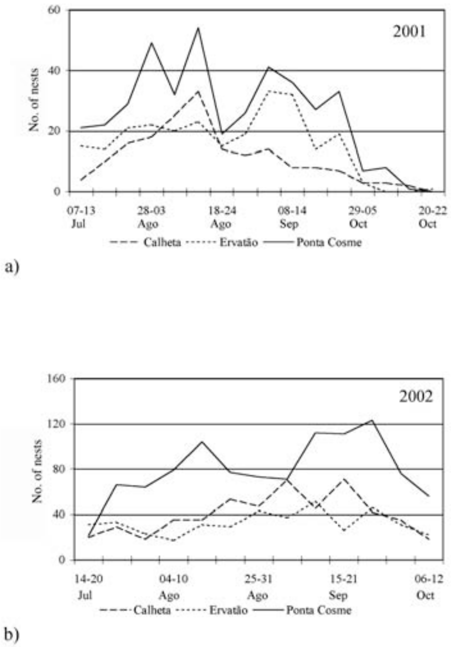

Figure 8. Distribution of nests of loggerhead in the three beaches studied in Boavista in 7 days intervals (a, 2001 season; b, 2001 season).

Concerning the time distribution of nests in 2001, in intervals of one week (Figure 8a), we can observe a fall over the last ten days of August on all three beaches, just as there is in the second ten days of September, although this fall is not as sharp. In 2002, however (Figure 8b), nest distribution shows no pronounced changes.

For the three beaches under study, a total of 3,188 female *C. caretta* tracks were counted in 2001. In the 2002 season, the number increased to a total of 7,444. The distribution by beaches is shown in table 2. Nesting success, i.e. the percentage of tracks that lead to a nest was, in general, similar in the two seasons (Table 2), with differences between the three beaches. This value could be underestimated due to the fact that it was impossible to determine the presence or absence of a nest in 8.0% of tracks in 2001, and in 8.9% of tracks in 2002.

Table 2. Number of crawls, nests, and nesting success of loggerhead in the three beaches studied during 2001 and 2002 seasons.

		Tracks	Nests	Nesting success (%)
2001	Calheta	356	177	49.7
	Ervatão	899	251	27.9
	Ponta Cosme	1.933	405	20.9
	Total	**3.188**	**833**	**26.1**
2002	Calheta	1.198	518	43.2
	Ervatão	1.653	420	25.4
	Ponta Cosme	4.593	1.033	22.5
	Total	**7.444**	**1.971**	**26.5**

3. Biometry of nesting females

Table 3 shows the distribution of biometric data by years, from 1998 to 2002. For the females that came ashore more than once in the same year, only the measures taken the first time they came ashore are recorded. These results include the data for un-tagged females.

Table 3. Biometry of nesting females of loggerhead in Boavista during five years of study (LCC, curve carapace length; LRC, straight carapace length; SD, standard deviation; N, sample size).

	1998	1999	2000	2001	2002
CCL (cm)	82.4	81.9	81.3	81.8	81.5
SD	4.98	4.6	3.99	4.39	3.6
Range	75.0-103.0	72.0-106.0	72.3-104.0	73.0-106.0	67.0-101.0
N	85	479	714	518	1 086
SCL (cm)	77.3	76.3	75.7	76.2	76,0
SD	5.00	4.30	3.99	4.05	3.40
Range	64.0-96.0	66.0-100.0	60.2-96.5	66.0-100.0	59.6-95.4
N	81	386	699	519	1 094

4. MONITORING NESTS

4.1. Size and depth of clutches

The figures for average clutch size obtained for the five years of study (1990-2002) appear in table 4.

Table 4. Clutch size of loggerhead in 1998-2002 seasons in Boavista (SD, standard deviation; N, sample size).

	1998	1999	2000	2001	2002
Nº eggs	90.6	91.5	82.9	78.3	82.5
SD	16.17	17.09	16.70	14.50	17.27
Range	60-137	33-140	24-143	45-124	31-139
N	80	378	353	262	450

An ANOVA shows us that there are significant differences in the size of clutches from one season to another ($F_{4,1518}$ = 30 909, $p < 0.0001$). A later Fischer test shows significant differences between years (Table 5), with the figures being similar in 1998 and 1999, and between 2000 and 2002. In 2001, clutch size was significantly smaller than in other years.

Table 5. Significance levels for the clutch size between different years using an a posteriori Fischer's test

	1998	1999	2000	2001	2002
1998		ns	*	**	**
1999			**	**	**
2000				*	ns
2001					*
2002					

(ns = not significant; * = $p<0.005$; ** = $p<0.0001$)

The lower depth of the clutch of eggs varied from 29 cm to 96 cm, with annual means of 47.1 cm in 1998 and 47. 8 cm for 1999. The upper depth range varied from 3.0 to 44.0 cm, with annual means of 28.8 cm in 1998 and 26.9 cm in 1999.

4.2. Incubation times and hatching success

Average incubation times in the nests studied in the seasons from 1999 to 2002 can be seen in table 6. The incubation time for *C. caretta* in Boavista encompasses a range that varies between 45 and 74 days, with significant differences from one year to another (transformation [1/x]; ANOVA: $F_{3,377} = 47.98$, $p < 0.0001$).

Table 6. Incubation duration (d, days) of loggerhead nests in Boavista in the period 1999-2002.

	1999	2000	2001	2002
Incubation (d)	57.9	59.1	54.2	60.9
SD	4.69	4.20	3.55	4.62
Range	47-74	50-73	45-65	47-74
N	78	88	101	114

Hatching and excavation success turned out to be significantly different ($t = -8.447$, $p < 0.0001$). Excavation success turned out to be higher (Mean = 54.8 %, SD = 36.37, N = 389), than hatching success (Media = 46.0 %, SD = 36.07, N = 542). In later analyses, only hatching success has been used.

Table 7. Hatching success of loggerhead in the three beaches studied in the years 1999-2002,

		1999	**2000**	**2001**	**2002**
Calheta	Mean	76.2	67.0	72.9	79.9
	SD	24.38	32.19	29.01	25.67
	Rango	0.0-98.1	0.0-98.2	0.0-100.0	0.0-98.8
	N	19	21	15	22
Ervatão	Mean	51.1	63.5*	58.4	45.7
	SD	32.84	36.20	35.21	35.12
	Range	0.0-100.0	0.0-100.0	0.0-100.0	0.0-97.6
	N	31	48	57	53
Ponta Cosme	Mean	42.2	33.3*	23.2	32.4
	SD	35.09	34.63	25.69	30.84
	Mean	0.0-97.8	0.0-100.0	0.0-91.2	0.0-94.8
	N	61	57	81	77
TOTAL	Mean	50.5	50.4	41.2	43.9
	SD	34.85	37.97	35.55	35.39
	Range	0.0-100.0	0.0-100.0	0.0-100.0	0.0-98.8
	N	111	126	153	152

(SD = standard deviation; N = sample size).

* Nest of the hatchery (artificial incubation experiment) not included.

If we analyse global hatching success (the three beaches as a whole) between the different seasons (Table 7), we can see that this is similar (Kruskal-Wallis: H = 6.94, p = 0.071). However, the behaviour on each beach varies if we take each season separately (p < 0.005 in all cases), and Calheta is the beach with the highest hatching success in all cases, and Ponta Cosme the lowest. Ervatão varies from one year to another.

5. Artificial incubation of nests

Incubation times for *hatchery* nests (Mean = 58.9 days, SD = 3.10, Range = 51-66, N = 91) were not significantly different (t = 1.252, p = 0.21) from eggs incubated on the original beaches in 2000 (Table 6).

Hatching success for the *hatchery* (Mean = 61.6 %, SD = 24.51, N = 100) is significantly greater than that of Ponta Cosme beach (p < 0.0001), but similar to the figures obtained for Ervatão (p = 0.062) in 2000 (see figure 9; García et al., 2001). Some of the *hatchery* nests came from unlikely sites on the beaches of Ervatão and Ponta Cosme (12 and 82 nests respectively), so the natural hatching success of the nests laid on these beaches could be over-estimated for that year. Therefore, we have compared the results of the *hatchery* for 2000, with the beaches of Ponta Cosme and Ervatão in the preceding year (1999), which shows that hatching success in the *hatchery* is significantly higher than at Ponta Cosme (p = 0.001), but similar to the success rate of Ervatão (p = 0.199).

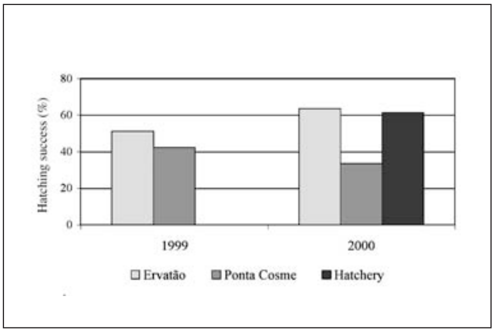

Figure 9. Hatching success in the hatchery, and Ervatão and Ponta Cosme beaches in 1999 and 2000 seasons.

DISCUSSION

The number of female *C. caretta* tagged in Boavista gives different values over the five years of study (Table 1), in which the sampling effort was similar, except in

1998, when the number of staff and time used was less. These data, along with the data for successive years, suggest that the *C. caretta* population in Cape Verde is one of the largest in the Atlantic Ocean (Brongersma, 1982; Marquez, 1990; Ross, 1995; Fretey, 2001).

The number of tracks recorded in the 2001 and 2002 seasons is high (Table 2), bearing in mind that only 3.1 km of beach were sampled. But, as an overall average, only one of every four tracks emerging from the sea leads to a nest (Table 2), a low result if we compare it to the literature (Dodd Jr, 1988). One explanation of this result could lie in the physical characteristics of the beaches themselves, as there is no other kind of disturbance like lights or other activities associated with man, apart from those of the observers. Causes could include the excessive humidity of the substrate on the edge of the water courses, or the presence of stones or other obstacles that make it difficult to dig a nest, especially on the beaches of Ponta Cosme and Ervatão (Lopez et al., 2002); barriers of this kind, or damp zones are not evident on the beach of Calheta, where nesting success is around 50 %.

The average size of nesting female *C. caretta* on the island of Boavista is, in general, small (Table 3), in comparison with most populations of the world (Ballell et al., 2001; see review in Dodd Jr, 1988). They are slightly larger than those found in the Mediterranean (Margaritoulis, 1982; Erk'akan, 1993; Broderick & Godley, 1996), although the minimum values found are similar to those from Cyprus (Broderick & Godley, 1996). Table 8 shows these values for different populations.

The smaller size of clutches laid in the 2000, 2001 and 2002 seasons could be due to the method used for counting the eggs. The method used in 1998 and 1999, extracting the eggs once the female returned to the sea, seems more accurate than the method of counting the eggs as they leave the cloaca, used in later years, as it is sometimes difficult to count them correctly this way. According to the results obtained, in the latter case, we would be under-estimating clutch size, so we would suggest using the former method, or use another method that allows a more accurate count without the need to open up the nests. Our attention was, in turn, also drawn to the smaller clutch size recorded 2001. At the beginning of this season, females were experimentally measured and tagged while they were laying their eggs, in an attempt to reduce stress levels. In some cases, anomalous nesting behaviour was observed, so, approximately half way through the season, we returned to using the usual tagging methodology. Tagging during laying could be one of the causes of the smaller clutch size in 2001.

A maximum difference of six days was observed between average incubation times, in 2001 and 2002, possibly due to the temperature conditions in which the nests were incubated. We also observed differences in incubation times between the different beaches (not included in this study), so a more detailed study will be required later on.

Table 8. Curve (CCL) and straight (SCL) carapace length in different nesting populations around the world (N, sample size). See revision in Dodd (1988), Erk'akan (1993) and Broderick & Godley (1996).

		CCL (cm)	SCL (cm)
Florida	Mean (cm)	98.9	93.9
(USA)	Range	87.9-108.9	82.5-104.4
	N	119	114
Masirah Island	Mean (cm)	-	92
(Oman)	Range	-	79.0-101.0
	N	-	-
Natal	Mean (cm)	84.7	79.2
(South Africa)	Range	71.0-94.0	65.1-87.1
	N	23	23
Zakynthos	Mean (cm)	80.4	-
(Greece)	Range	69.5-95.0	-
	N	27	-
Dalyan Beach	Mean (cm)	-	73.1
(Turkey)	Range	-	60.2-83.9
	N	-	49
Northern	Mean (cm)	73.4	-
Cyprus	Range	65.0-86.5	-
	N	78	-

There are significant differences between the two methods used to count the percentage of eggs from each nest that have been successfully incubated. The first of these, the so called "hatching success" (MILLER, 1999), can be applied if the eggs have not been counted initially. But, if the counting error is calculated (when the initial number of eggs is known), we have observed that this varies in many cases. Nests in which, once opened, the clutch size is less than 20 eggs, have been excluded from the analysis (we do not know if the low number was due to predation by ghost crabs, *Ocypode sp.*, or to other causes). In any event, a general criterion has to be established for excluding nests from the analysis, depending on counting error. In the second method, the “excavation success”, values are significantly higher than in the first method. In this case, once the nest is opened, one only has to count the un-hatched eggs, so the rest (the difference between the number of un-hatched eggs and the initial number of eggs) gives us the number of hatched eggs. We could assume that not all the eggs laid by the female are in the nest (due to predation or other reasons), so the figure will be an over-estimation. As both methods seem to over-estimate the percentage of eggs that hatch, we use the first method for the analysis, which, in our opinion, is closer to the real value.

Although the hatching success does not seem to vary from one season to another, the results suggest that the conditions of each beach studied for incubating eggs, does differ. So, Calheta beach seems to have the best conditions, while the beach of Ponta Cosme has the lowest values every year, perhaps due to the high percentage of the beach that has a low profile, making it susceptible to flooding, or the excessive level of dryness in other areas of the beach.

The artificial incubation experience enabled us to increase hatching success for Ponta Cosme beach, bearing in mind that this may have been even lower if many of these nests had not been re-located to the *hatchery*. However, there were no differences in comparison with the figures obtained for Ervatão (Figure 9). The possibility of relocating nests from Ponta Cosme, and in some cases from very unlikely areas of Ervatão, to other areas of the beach, or to a *hatchery*, should be given consideration in the future, with a view to increasing the hatching success of a population that suffers strong pressure from predation by man (LOPEZ-JURADO et al., 1999b). This task should, however, be addressed with caution, as we may be altering important population parameters like the sex ration (MROSOVSKY, 1994; GODFREY & MROSOVSKY, 1999; MORTIMER, 1999).

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REFERENCES

ALVARADO, J. & MURPHY, T. M. (1999). Nesting periodicity and inter-nesting behaviour. In: *Research and Management Techniques for the Conservation of Sea Turtles* (Ed. by K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois & M. Donnelly), pp. 115-118: IUCN/SSC Marine Turtle Specialist Group Publication.

BALAZS, G. H. (1999). Factors to consider in the tagging of sea turtles. In: *Research and Management Techniques for the Conservation of Sea Turtles* (Ed. by K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois & M. Donnelly), pp. 101-109: IUCN/SSC Marine Turtle Specialist Group Publication.

BALLELL, L., DÍAZ-MERRY, A., M., G., PEÑA, B., ABELLA, E., MADARIAGA, B., LOZANO, M., RUIZ, X., DEL ORDI, D., GONZÁLEZ, S., BORRÁS, S., LÓPEZ, O., NUEZ, M., HIDALGO, J., PÉREZ, N., VARO, N., CEJUDO, D. & LÓPEZ-JURADO, L. F. (2001). Body size of nesting at the island of Boavista (Cape Verde, West Africa). *21st Annual Symposium on Sea turtle Biology and Conservation*. Philadelphia

BOLTEN, A. (1999). Techniques for measuring sea turtles. In: *Research and Management Techniques for the Conservation of Sea Turtles* (Ed. by K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois & M. Donnelly), pp. 110-114: IUCN/SSC Marine Turtle Specialist Group Publication.

BRODERICK, A. C. & GODLEY, B. J. (1996). Population and nesting ecology of the green turtle, *Chelonia mydas*, and the loggerhead turtle, *Caretta caretta*, in northern Cyprus. *Zoology in the Middle East*, 13:27-46.

BRONGERSMA, L. D. (1982). Marine Turtles of the Eastern Atlantic Ocean. In: *Biology and conservation of sea turtles* (Ed. by K. A. Bjorndal), pp. 407-416. Washington, D. C.: Smithsonian Institution Press.

CEJUDO, D., CABRERA, I., LÓPEZ-JURADO, L. F., EVORA, C. & ALFAMA, P. (1999). The reproductive biology of *Caretta caretta* on the island of Boavista (Cape Verde, West Africa). *19th Annual Symposium on Sea Turtle Conservation and Biology*. South Padre Island, Texas (U. S. A.)

CEJUDO, D., VARO, N., CABRERA, I. & LOPEZ-JURADO, L. F. (2000). Biology of nesting loggerheads in the island of Boavista (Cape Verde Islands, West Africa). Incubation period and hatching success. *20th Annual Sea Turtle Symposium*. Orlando, Florida

DODD JR, C. K. (1988). *Synopsis of the Biological Data on the Loggerhead Sea Turtle Caretta caretta (Linnaeus 1758)*. Washington, DC: Fish and Wildlife Service, U. S. Department of the Interior. ERK'AKAN, F. (1993). Nesting biology of loggerhead turtles *Caretta caretta* L. on Dalyan beach, Mugla-Turkey. *Biological Conservation*, 66:1-4.

FRETEY, J. (2001). *Biogeography and Conservation of the Marine Turtles of the Atlantic Coast of Africa*. CMS, Bonn: UNEP/CMS Technical Publication.

GARCÍA, M., PEÑA, B., ABELLA, E., BALLELL, L., MADARIAGA, B., LOZANO, M., DÍAZ-MERRY, A., DEL ORDI, D., GONZÁLEZ, S., BORRÁS, S., RUIZ, X., LÓPEZ, O., NUEZ, M., HIDALGO, J., PÉREZ, N., VARO, N., CEJUDO, D. & LÓPEZ-JURADO, L. F. (2001). Hatching success in natural and relocated nests of loggerhead in the island of Boavista (Cape Verde, West Africa). *21st Annual Symposium on Sea turtle Biology and Conservation*. Philadelphia

GODFREY, M. H., BARRETO, R. & MROSOVSKY, N. (1996). Estimating past and present sex ratios of sea turtles in Surinam. *Canadian Journal of Zoology*, 74:267-277.

GODFREY, M. H. & MROSOVSKY, N. (1999). Estimating hatchling sex ratios. In: *Research and Management Techniques for the Conservation of Sea Turtles* (Ed. by K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois & M. Donnelly), pp. 136-

138: IUCN/SSC Marine Turtle Specialist Group Publication.

HAYS, G. C., SPEAKMAN, J. R. & HAYES, J. P. (1992). The pattern of emergence by loggerhead turtle (*Caretta caretta*) hatchlings on Cephalonia, Greece. *Herpetologica*, 48(4): 396-401.

LE BUFF JR., C. R. (1990). *The Loggerhead Turtle in the Eastern Gulf of Mexico*. Sanibel Is., Florida: Caretta Research Inc. 216 pp.

LÓPEZ, O., DEL ORDI, D., MADARIAGA, B., DÍAZ-MERRY, A., ABELLA, E., GARCÍA, M., HERRAIZ, L., BALLELL, L., BORRÁS, S., VARO, N., CEJUDO, D. & LÓPEZ-JURADO, L. F. (2002). Nesting success on the emergences of *Caretta caretta* in the island of Boavista (Cape Verde Islands, Western Africa). *22nd Annual Symposium on Sea turtle Biology and Conservation*. Miami

LÓPEZ-JURADO, L. F., CABRERA, I., CEJUDO, D., C., É. & ALFAMA, P. (1999a). Distribution of marine turtles in the archipelago of Cape Verde, West Africa. *19th Annual Symposium on Sea Turtle Conservation and Biology*. South Padre Island, Texas (U. S. A.)

LÓPEZ-JURADO, L. F., CABRERA, I., CEJUDO, D., C., É. & ALFAMA, P. (1999b). Proposals for the preservation of marine turtles on the island of Boavista (Cape Verde, West Africa). *19th Annual Symposium on Sea Turtle Conservation and Biology*. South Padre Island, Texas (U. S. A.)

MARGARITOULIS, D. (1982). Observations on loggerhead sea turtle *Caretta caretta* activity during three nesting seasons (1977-1979) in Zakynthos, Greece. *Biological Conservation*, 24:193-204.

MÁRQUEZ, M. R. (1990). *FAO species catalogue. Vol. 11: Sea turtles of the world. An annotated and illustrated catalogue of sea turtles species known to date*. Rome: FAO. 81 pp.

MILLER, J. D. (1999). Determining clutch size and hatching success. In: *Research and Management Techniques for the Conservation of Sea Turtles* (Ed. by K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois & M. Donnelly), pp. 124-129. IUCN/SSC Marine Turtle Specialist Group Publication.

MORTIMER, J. A. (1999). Reducing threats to eggs and hatchlings: hatcheries. In: *Research and Management Techniques for the Conservation of Sea Turtles* (Ed. by K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois & M. Donnelly), pp. 175-178: IUCN/SSC Marine Turtle Specialist Group Publication.

MROSOVSKY, N. (1994). Sex ratios of sea turtles. *The Journal of Experimental Zoology*, 270:16-27.

PARSONS, J. (1962). *The green turtle and man*. Gainesville, Florida: University of Florida Press. 121 pp.

PINCKNEY, J. (1990). Correlation analysis of adult female, egg and hatchling sizes in the loggerhead turtle, *Caretta caretta* (L.), nesting at Kiawah Island, South Carolina, USA. *Bulletin of Marine Science*, 47(3): 670-679.

ROSS, J. P. (1995). Historical Decline of Loggerhead, Ridley, and Leatherback Sea Turtles. In: *Biology and Conservation of Sea Turtles* (Ed. by K. A. Bjorndal), pp. 189-195. Washington, D. C.: Smithsonian Institution Press.

An attempt to re-establish a nesting colony of endangered Kemp's ridley sea turtles *(Lepidochelys kempii)* through experimental imprinting and head-starting.

DONNA SHAVER

ABSTRACT

An experimental, conservation project was conducted to re-establish a nesting colony of Kemp's ridley turtle, *Lepidochelys kempii* (Garman, 1880) at Padre Island National Seashore (PAIS), Texas, USA. From 1978-1988, 22,507 eggs were collected at Rancho Nuevo, Tamaulipas, Mexico for experimental imprinting to PAIS by exposure of the eggs to PAIS sand and exposure of the resulting hatchlings to PAIS sand and surf. Overall, 77.1% of the eggs hatched and the turtles had an estimated sex ratio of 1.5F:1M. From 1979-1989, 13,211 head-started yearling turtles from this project were released, most into the Gulf of Mexico off south Texas. An additional 300 turtles from this project were released after 2-16 years in captivity. Nearly 9,000 other head-started yearlings that were not part of the experimental imprinting project were also released, primarily into the Gulf of Mexico; these turtles had been obtained directly from Mexico as hatchlings between 1978-1992 for head-starting and were mostly females.

From 1989-2002, 53% of the Kemp's ridley nests documented in the USA were at PAIS. From 1985-2002, 110 confirmed Kemp's ridley nests were found on the Texas coast, with 106 of the 110 found between 1995-2002. During these eight years, 10 turtles that had been experimentally imprinted to PAIS laid 19 of these clutches and three head-started turtles that had been obtained directly from Mexico as hatchlings laid three of these. The 13 turtles ranged from 10-15 years in age when first detected nesting. They represent the first confirmed nesting in the wild of head-started sea turtles and first documentation of known-aged Kemp's ridley turtles nesting in the wild. Those experimentally imprinted to PAIS were the first experimentally imprinted sea turtles confirmed to have returned to their imprinting site to nest.

Although these findings suggest that experimental imprinting and head-starting enhanced nesting numbers, from 1986-2002 more adult Kemp's ridley turtles were found washed ashore (stranded) dead in Texas than in any other state in the USA. Strandings became increasingly concentrated on south Texas Gulf of Mexico beaches during this time, with the largest numbers found between 1994-2002, generally coinciding with the increased number of nests. From 1995-2002, 141 of the 253 stranded adult Kemp's ridleys found in the USA, were on south Texas Gulf beaches. One hundred thirty-five of the 141 were located during times when Gulf waters off the Texas coast were open to shrimp trawling. The future of Kemp's ridley nesting in south Texas

Western Gulf of Mexico

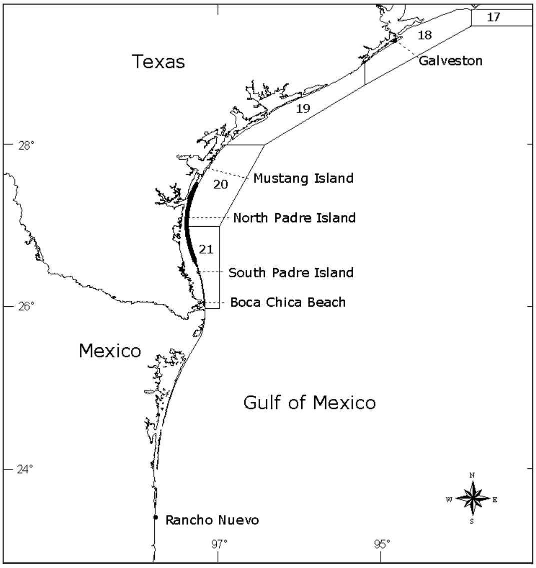

Figure 1. Map of the showing the locations of sites and NMFS Statistical Zones. Padre Island National Seashore is shown as the black shaded area on North Padre Island.

and the ability to evaluate the experimental procedures used in this project are dependent on the survival of adult Kemp's ridley turtles in the area.

INTRODUCTION

The endangered Kemp's ridley turtle (*Lepidochelys kempii*) has been the subject of intensive, long-term, population restoration efforts. Evidence suggests that only one genetically distinct stock of this species exists (Bowen et al., 1991). Most Kemp's ridley nesting occurs in the vicinity of Rancho Nuevo, Tamaulipas, Mexico (Figure 1) (Marquez et al., 1982). In 1947, an estima-ted 40,000 adult females nested at Rancho Nuevo on one day (Hildebrand, 1963). The Mexican Government initiated protection efforts at the Rancho Nuevo nesting beach in 1966 (USFWS and NMFS, 1992), but the nesting population had been deple-ted by that time and continued to plummet through the mid-1980s (Tewg, 1998). This depletion was caused by large-scale removal of eggs from the nesting beach and incidental capture of juveniles and adults by shrimp trawls (USFWS and NMFS, 1992). By 1977, it was feared that the Kemp's ridley would become extinct within a few years unless immediate steps were taken (Carr, 1977).

A bi-national, multi-agency, experimental project was conducted from 1978-1988 to aid in the recovery of Kemp's ridley by re-establishing a nesting colony of them at Padre Island National Seashore (PAIS) (Figure 1), located on North Padre Island, Texas, USA (Shaver, 1989, 1990; Shaver and Miller, 1999). The establishment of a se-condary nesting colony would provide a safeguard for the species, so that if a political or environmental catastrophe occurred in Rancho Nuevo, there would be an area in the USA

Figure 2. Living tags and tag scars on Kemp's ridley turtles found nesting in Texas.

where this species could nest and be protected. PAIS, the longest stretch of undeveloped barrier island beach in the United States, was selected because it offered protection to nesting turtles. Additionally, sporadic Kemp's ridley nesting had already been documented on PAIS (Werler, 1951; Hildebrand, 1963, 1982; Carr, 1967; Francis, 1978), although historic nesting levels were uncertain.

Based on the strong nest site fidelity of adult females, Carr, 1967, and others suggested that marine turtles "imprint" to, and nest on, their natal beach. Attempts were made to experimentally imprint Kemp's ridley turtles to PAIS in hopes that they would later return to nest. This imprinting project involved exposing Kemp's ridley eggs to PAIS sand and hatchlings to PAIS sand and surf (Shaver 1989, 1990, 1997, 1998a, in press). When the experimental imprinting project was initiated, it was unknown whether any of these turtles would return to nest in south Texas. Turtles from the experimental imprinting project, and additional turtles that were taken directly from Mexico as hatchlings, were reared in captivity for at least 9-11 months. It was thought that this experimental procedure termed "head-starting" would increase survival by releasing them when they had outgrown threats from avian and the majority of non-avian predatory species.

Efforts to detect nesting on the Texas coast by turtles from the experimental imprinting and head-starting project began in 1986 and have continued since that time (Shaver, 1990, 1997, 1998a, in press). Although the Kemp's ridley population has recently shown promising signs of increase (Tewg, 1998), mortality of adult Kemp's ridley turtles, particularly in Texas, could impact the success of the experimental pro-ject (Shaver and Caillouet, 1998).

MATERIALS AND METHODS

1. Experimental imprinting and head-starting

From 1978-1988, 22,507 Kemp's ridley eggs (about 2,000/year) were collected in Rancho Nuevo for experimental imprinting to PAIS. The eggs were never allowed to touch Rancho Nuevo sand and were packed into Styrofoam boxes containing Padre Island sand. These boxes were placed in an incubation facility at Rancho Nuevo and shipped to an incubation facility at PAIS during the incubation period (Shaver and

Figure 3. A Kemp's ridley turtle that nested on the south Texas coast.

Fletcher, 1992). Overall, 77.1% of these eggs hatched (Shaver, 1989, in press). All live hatchlings were released on the beach at PAIS and were allowed to crawl down the beach and enter the surf. After they swam approximately 5-10 m, most were captured using aquarium dip nets. Between 1978 and 1988, 287 escaped during release, 810 from the 1980 year-class were intentionally released without capture, and 381 died at PAIS either prior to release or while temporarily held at PAIS after release and net capture (Shaver, 1989, in press). The highest mortality of hatchlings occurred in 1984, when they were retained at PAIS for up to 5 days to receive living tags (Fontaine et al., 1993). During other years, hatchlings were generally held at PAIS for only 0-3 days and the turtles were not tagged prior to shipment. Overall, 15,875 captured hatchlings from the 1978-1988 year-classes were successfully shipped to the National Marine Fisheries Service (NMFS) Laboratory in Galveston, Texas (Figure 1) for head-starting (Fontaine et al., 1989b; Caillouet, 2000).

Thousands of other Kemp's ridley turtles not experimentally imprinted to PAIS that were hatched from 1978-1983 and 1989-1992 within beach incubation corrals at Rancho Nuevo and collected after entering the surf there, were transported directly to the NMFS Galveston Laboratory for head-starting.

A variety of techniques were used to determine the sex of dead individuals and older captive turtles from the experimental imprinting and head-starting projects. Sex was identified for dead late-staged embryos and hatchlings using gonadal histology (PAIS imprinted individuals only), for larger dead turtles using necropsy, and for larger live turtles using laparoscopy, serum testosterone assays, and tail length evaluations (adults only). For the PAIS experimentally imprinted turtles, males predominated in most of the earlier year-classes (Shaver et al., 1988; Shaver, in press). After 1984, incubation facilities and practices for these eggs were modified in an attempt to raise incubation temperatures and increase the proportion of females produced, and females predominated in the 1985-1988 year-classes (Shaver et al., 1988). Collectively, 59.6% of the turtles experimentally imprinted to PAIS were females, for an overall sex ratio of 1.5F:1M (Shaver et al., 1988; Shaver, in press). Females predominated among the 1989-1992 year classes, which had been transferred directly from Mexico to Galveston for head-starting (Caillouet, 1995).

Before release, each head-started turtle was marked for future identification. Tagging methods varied for the different year-classes, as new technology developed (Fontaine et al., 1993; Caillouet et al., 1995a, 1997). Turtles received up to four types of internal and external tags. All turtles received external metal flipper tags. From the 1983 year-class on, virtually all turtles received living tags, which were placed on different scutes to designate different year-classes. All turtles from the 1984-1992 year-classes received internal magnetic tags. Passive integrated transponder (PIT) tags were applied to 247 PAIS experimentally-imprinted turtles from the 1978, 1982, 1986, 1987, and 1988 year-classes that were head-started for extended time periods and to 69 turtles from the 1989 year-class and all turtles from the 1990-1992 year-classes that were obtained directly from Mexico as hatchlings (Caillouet et al., 1997).

Overall, 13,511 surviving head-started turtles experimentally imprinted to PAIS were released into USA waters, including 13,211 released after 9-11 months in captivity and 300 after 2-16 years in captivity (Fontaine et al., 1989a, 1989b, 1990; Caillouet et al., 1995a). Most were released into the Gulf of Mexico, approximately 30 km offshore from Mustang Island and North Padre Island (Fontaine et al., 1990; Caillouet et al., 1995a). However, hundreds were released elsewhere in Texas and most from the 1978 and 1979 year-classes were released off the Gulf coast of Florida.

For the turtles that had been taken directly from Mexico as hatchlings and then head-started, 1,033 survivors from the 1978-1983 year-classes were released off Homosassa, Florida, Mustang Island, Texas, and Campeche, Mexico and 7,846 survivors from the 1989-1992 year-classes were released off Galveston, Texas (Caillouet, 1995; Caillouet et al., 1995a; Fontaine and Shaver, in press).

2. Nest detection efforts and examination of nesting females

Kemp's ridley nests have been detected on the Texas coast through opportunistic sightings made by the public and nesting patrols (Werler, 1951; Hildebrand, 1963, 1982; Carr, 1967; Francis, 1978; Shaver and Caillouet, 1998; Shaver and Miller, 1999; Shaver, in press; Shaver and Wibbels, in press). Systematic efforts to detect and protect nesting Kemp's ridley turtles and their eggs on North Padre Island (including PAIS) through beach patrols and public education began in 1986 and later expanded there and elsewhere on the Texas coast (Shaver, 1990, in press; Shaver and Wibbels, in press).

North Padre Island was patrolled from about April through July, during daylight hours, at least once per day 2-5 days each week from 1986-1994 and at least once per day 7 days each week from 1995-1997 (Shaver, in press; Shaver and Wibbels, in press). Since 1998, North Padre Island has been repeatedly patrolled each day to increase the likelihood of observing nesting females and locating their eggs. From 1986-1998, North Padre Island was the only area on the Texas coast specifically patrolled to detect nesting sea turtles. However, repeated daily patrols have also been conducted during daylight hours on Boca Chica Beach (Figure 1) since 1999 and on South Padre Island since 2000 (Shaver and Wibbels, in press). Additionally, since 1986, biologists working with the Sea Turtle Stranding and Salvage Network (STSSN) have been watchful for nesting when responding to reports of stranded sea turtles and when conducting weekly or bi-weekly surveys to detect stranded turtles on the Texas coast.

Educational programs alerting Texas beach visitors to report nesting Kemp's ridley turtles were implemented in the mid-1980s and expanded since that time (SHAVER, 1990; SHAVER and MILLER, 1999). Visitor reports were investigated, resulting in documentation of a large proportion of the nesting Kemp's ridley turtles and Kemp's ridley nests found in Texas during the last two decades.

Beach patrols to detect and protect nesting Kemp's ridley sea turtles and their nests at Rancho Nuevo began in 1966 (MÁRQUEZ et al., 1982; USFWS and NMFS, 1992). Since 1978, these efforts have progressively expanded to encompass additional areas along the Gulf coast of Mexico in the states of Tamaulipas and Veracruz (MÁRQUEZ et al., 1999, 2001).

When possible, Kemp's ridleys that nested in Texas and Mexico were examined for tags and tag scars to determine linkage to experimental imprinting and head-starting procedures and tagging history (Figures 2, 3). Turtles were identified as head-started if they possessed appropriate metal, living, PIT, and/or magnetic tags. Most nesting turtles examined in Texas and Mexico were measured for carapace length and width. Most eggs detected along the Texas coast were retrieved and transferred to the incubation facility at PAIS and most detected in Mexico were transferred to beach corrals for data collection and protected care. The number of eggs was counted for located nests and hatching and emergence success were calculated. The vast majority of hatchlings from these nests were released on the beach without retrieval for head-starting.

RESULTS AND DISCUSSION

1. Confirmed nests in the USA

From 1948-2002, 119 Kemp's ridley nests were documented on the Texas coast and no others were confirmed there before then (SHAVER and CAILLOUET, 1998; SHAVER, 2000, 2001, 2002, 2003). Other possible nests were reported, but could not be fully documented. Some additional Kemp's ridley nests likely went unnoticed and unrecorded in Texas before and after 1948, particularly on stretches of beach that were difficult to travel and sparsely visited or patrolled. The suspicion that nests go undetected in Texas at egg laying despite patrols and public education was corroborated in 2002 when three nests were located hatching on the beach (SHAVER, 2003).

There has been a general increase in the number of Kemp's ridley nests documented on the Texas coast during recent years (Figure 4), with 106 of the 119 nests found between 1995-2002 (Shaver, 1995a, 1996a, 1997, 1999a, 2000, 2001, 2002, 2003; Shaver and Caillouet, 1998). The increase in the number of detected nests may have reflected increased nesting, improved detection efforts, increased awareness and reporting by the public, or a combination of all.

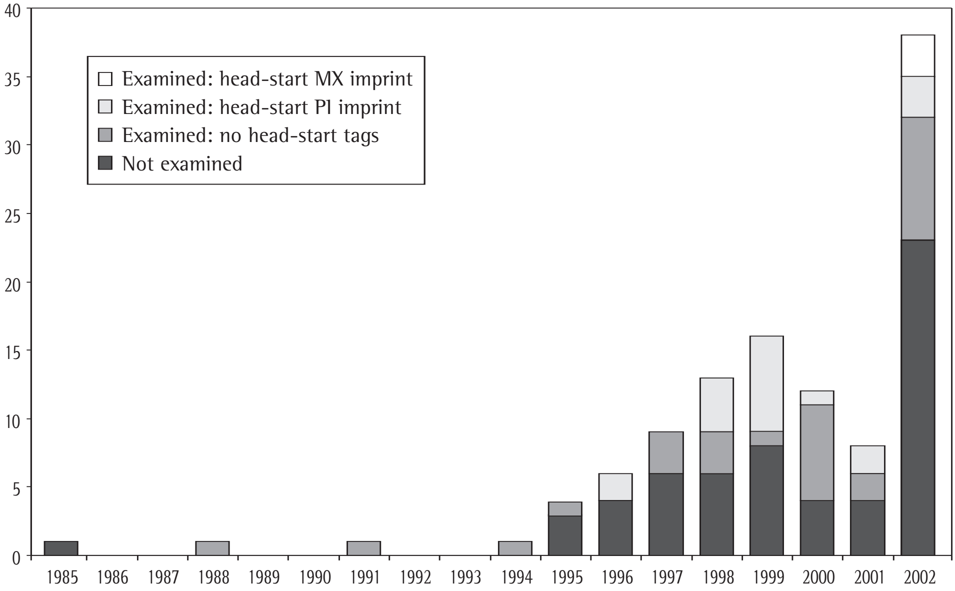

Figure 4. Number of confirmed Kemp's ridley nests found on the Texas coast, 1985-2002.

One hundred fifteen of the 119 nests were found in south Texas, in NMFS Statistical Zones 20 and 21, including 11 on Mustang Island, 78 on North Padre Island (70 of which were at PAIS), 18 on South Padre Island, and eight on Boca Chica Beach. From 1948-2002, more confirmed Kemp's ridley nests were located at PAIS than at any other location in the USA (Shaver, 1992; Shaver and Caillouet, 1998). Fifty-three percent of the confirmed Kemp's ridley nests located in the USA from 1989-2002 were located at PAIS.

Two of the 119 nests were in Zone 18 on Galveston Island and two in Zone 19 on Quintana Beach and the Matagorda Peninsula (Shaver, 2003). These four nests were located on the upper Texas coast during 2002. Although there are possible inferences in the literature that Kemp's ridleys nested on the upper Texas coast historically (Doughty, 1984), this was the first time that their nests had been conclusively documented there.

The Kemp's ridley nests found in Texas could indicate spreading out of nesting to areas where it occurred historically. Hildebrand (1963) suggested that scattered Kemp's ridley nesting in south Texas and a few areas in Mexico other than Rancho Nuevo might represent remnants of Kemp's ridley nesting colonies that existed before the tremendous depletion of the species. As the Kemp's population has increased during the last few years, more nests have been found in these other areas (Shaver and Caillouet, 1998; Tewg, 1998; Márquez et al., 1999, 2001; Shaver, 2000, 2001, 2002, 2003), supporting his hypothesis.

Through 2002, only 14 Kemp's ridley nests were documented at other USA locations, outside of Texas. The 14 clutches were laid from 1989-2002 on the coasts of Florida (n=10), South Carolina (n=1), North Carolina (n=1), and Alabama (n=2) (Meylan et al., 1990; Anonymous, 1992; Palmatier, 1993; Godfrey, 1996; Libert, 1998; Johnson et al., 1999, 2000; Foote and Mueller, 2002; Nichols et al., in press; S. Macpherson, pers. comm.). Bowen et al., 1994) suggested that these nesting turtles could have been from the experimental imprinting project, since there were no previous confirmed records of Kemp's ridleys nesting in this region. These nests were detected because beach patrollers searching for loggerhead (*Caretta caretta*) nests found the tracks left in the sand by the nesting Kemp's ridley turtles, or beach visitors saw and reported the nesting Kemp's ridleys. Although examinations of available nesting turtles or their photographs revealed no external metal or living tags that linked them to the imprinting project, the turtles could have been from the earliest year-classes that were released without living tags.

2. Nesting by head-started turtles

Prior to 1985, no turtles from this project that resided outside of captivity would likely have been mature and able to nest (Wood and Wood, 1988; Caillouet et al., 1995b;

Chaloupka and Zug, 1997; Schmid and Witzell, 1997; Zug et al., 1997). Of the 110 Kemp's ridley nests found in Texas from 1985 through 2002, nesting turtles were examined for tags at 53 of the nests (Figure 4). At 31 of those 53, the turtles did not possess any tags linking them to experimental imprinting or head-starting.

However, 22 of the nests were conclusively linked to 13 different head-started turtles, including 10 individuals experimentally imprinted to PAIS that laid 19 of the clutches and three individuals taken directly from Mexico as hatchlings that laid three of them (Shaver, 1996a, 1996b, 1997, 1998a, 1999b, 2000, 2001, 2002, 2003; Shaver and Caillouet, 1998). The 13 individuals were identified by living tags; most also possessed magnetic tags and metal flipper tag scars. Only a few possessed metal or PIT tags. They represented eight year-classes (1983, 1984, 1986, 1987, 1988, 1989, 1991, 1992) and ranged from 10-15 years of age when first detected nesting. Of the 13 head-started turtles, eight were detected nesting once on the Texas coast, two nesting there during one year with two nests that year, two nesting there during two different years (including two nests within one year), and one nesting there during three different years (including two nests within one year). The 22 nests were found on PAIS (n=14), North Padre Island north of PAIS (n=3), Mustang Island (n=4), and Galveston Island (n=1). The 10 individuals experimentally imprinted to PAIS nested within about 30 km north to 50 km south of the imprinting site, whereas the three that had been taken directly from Mexico as hatchlings nested on Galveston Island (n=1) and PAIS (n=2).

In addition to the 13 head-started individuals that were documented laying 22 clutches of eggs on the Texas coast, only two other head-started Kemp's ridleys have been recorded nesting outside of captivity globally (Shaver and Wibbels, in press). These two other head-started individuals nested at or near Rancho Nuevo, Mexico and laid three clutches (Shaver and Wibbels, in press; M. Carrasco, pers. comm.; R. Márquez, pers. comm.; J. Pena, pers. comm.). One of the two turtles that nested in Mexico had been experimentally imprinted to PAIS and the other had been taken from Mexico as a hatchling.

The 15 head-started Kemp's ridley turtles that nested outside of captivity through 2002 ranged from 58.1-64.1 cm straight-line carapace length from the center of the nuchal notch to the posterior tip of the post-central scute (SLCL) when first detected nesting (SHAVER and WIBBELS, in press). The sizes at maturity for these head-started turtles were larger than the minimum size at maturity reported for wild Kemp's ridley turtles nesting in Mexico (Márquez, 1990). The age of 10-15 years when the head-started turtles were first detected nesting was similar to model predications for age at maturity for wild and head-started Kemp's ridley turtles (Caillouet et al., 1995b; Zug et al., 1997). Of the 15, six were confirmed repeat nesters within a year and/or during different years (Shaver and Wibbels, in press). Nest sites recorded for these six were from 1-68 km apart and their site fidelity was generally better than that recorded for wild Kemp's ridley turtles on the Texas coast (see Tag Returns from Other Kemp's Ridleys that Nested in Texas). The inter-nesting intervals ranged from 20-26 days (Shaver and Wibbels, in press), very similar to the 20-28 days reported for turtles in Mexico (Miller, 1997). The remigration interval was 2-3 years (Shaver and Wibbels, in press), which is comparable to the 2 years estimated as the mean remigration interval for this species based on tag returns at the nesting beach in Mexico (Tewg, 1998).

Clutch size ranged from 71-113 eggs (mean = 94.4, SD = 9.8, n = 25) (Shaver and Wibbels, in press), slightly lower than annual mean clutch sizes for Kemp's ridley turtles measured during 14 years at Rancho Nuevo, which ranged from 96.5-103.8 (mean = 100.8, SD = 2.5) (USFWS and NMFS, 1992). The 22 clutches detected in Texas were incubated in Styrofoam boxes at the PAIS incubation facility and the three in Mexico incubated in a protective corral there (Shaver and Wibbels, in press). Hatching success ranged from 0 - 100% (mean = 62.9, SD = 36.2) and emergence success from 0 - 100% (mean = 61.8, SD = 36.3) in the 23 clutches for which data were available (Shaver and Wibbels, in press). In comparison, during the same period from 1996-2002, overall hatching success for the roughly 30,000 nests held corrals in Mexico was 63.8% (Burchfield, 2002).

3. Tag returns from other Kemp's ridleys that nested in Texas

Between 1991 and 2002, 24 individual Kemp's ridleys that were not linked to experimental imprinting or head-starting were recorded nesting at least once on the Texas coast. Six of these turtles were recorded nesting more than once in Texas or Mexico, either within a year or during different years, and they exhibited a high to low degree of nest site fidelity. The highest site fidelity was recorded for a Kemp's ridley that nested 3 km apart at PAIS on 26 May 1999 and 16 May 2001. The two turtles with the lowest site fidelity nested both in the USA and Mexico. One nested at PAIS on 10 May 1998 and had a PIT tag that was implanted while she nested at Tepehuajes, Mexico, near Rancho Nuevo on 23 April 1996 (Shaver and Caillouet, 1998; Shaver, 1999b). Another was tagged on 31 May 1998 after nesting at PAIS and was observed nesting at Tepehuajes on 24 April 2000 and at Rancho Nuevo on 14 May 2000 (Shaver, 1999b, 2001). These were the first two confirmed records of individual Kemp's ridley turtles nesting in both the USA and Mexico and indicate some movement of Kemp's ridleys between nesting beaches. Valverde et al. (1998) noted that some individual olive ridley turtles (*Lepidochelys olivacea*) have been documented nesting at more than one beach in Costa Rica. Thus, the Kemp's ridleys currently nesting in Texas are probably a mixture of both head-started turtles and others from the wild stock, with some individuals nesting both in Mexico and Texas. They could also include the survivors or descendants from 1,102 hatchlings released in a project conducted at South Padre Island in 1967 (Francis, 1978).

4. Factors limiting nests documented in Texas

The 13 individuals documented laying 22 nests are minimum estimates of reproduction by head-started Kemp's ridley turtles outside of captivity in Texas through 2002 (Shaver and Caillouet, 1998; Shaver and Wibbels, in press). A variety of factors could have limited observations, including tagging, detection efforts, turtles nesting elsewhere, sex ratio, age to sexual maturity, and mortality in the marine environment caused by a variety of factors, including incidental capture in shrimp trawls (Caillouet et al., 1991, 1996; Shaver, 1998b; Lewison et al., 2003).

From 1996-2002, 102 Kemp's ridley nests were documented on the Texas coast, but biologists did not get the opportunity to examine the nesting females for tags at 55 (54%) of them (Figure 4). Of those 47 examined, the turtles that laid 22 (47%) were head-started individuals. Since such a high percentage were from head-started turtles, it would be reasonable to hypothesize that a large portion of the 55 nests at which the nesting turtles were not examined were also laid by head-started turtles.

Some of the turtles that were examined but had no tags linking them to head-starting could have been from the earliest project years that did not receive living tags. Living tags were not widely used until the 1983 year class and have been the most successful tag for identification of head-started turtles.

Some nests likely went undetected on the Texas coast, especially when detection efforts were very limited, such as on North Padre Island prior to 1997 (Shaver and Fletcher, 1992), or in areas where there were no patrols. Additional patrol effort would have increased opportunities to check some of the unexamined nesters for tags and perhaps locate other nesting that went undetected. Although beach visitors were responsible for locating and reporting a large portion of the nests documented on the Texas coast during the last two decades, visitors would not have had the opportunity to locate all nests. Many areas of the Texas coast are difficult to access and sparsely visited, including the southernmost 96 km of North Padre Island which has only one vehicle access point and treacherous driving conditions. The discovery of three nests at hatching in south Texas during 2002 confirmed that nests can be missed at egg laying, even within areas patrolled well or visited heavily.

The number of observations of head-started turtles nesting in Texas may have been limited by these turtles nesting elsewhere. The locations where the NMFS released the turtles after head-starting could have influenced their future nest sites. Most of the head-start turtles were released off the Texas coast and most of their recorded nests have been in Texas. However, the oldest turtles from the project were released off the west coast of Florida and some have hypothesized that the Kemp's ridley nests recorded in Florida and the Atlantic coast of the U.S. were from head-started turtles (Bowen et al., 1994). However, of the thousands of Kemp's ridley turtles that have been examined for tags in Mexico since 1985 and the few that were examined when nesting in the USA outside of Texas, only two were conclusively found to possess head-start tags and both nested in Mexico.

The sex ratio of the head-started turtles may have limited observations of nesting in the wild. Primarily males were produced in the early year-classes of the PAIS experimental imprinting project and thus fewer nesting females would be expected for those years. However, primarily females were produced during the later years of the imprinting project and from 1989-1992 when turtles taken directly from Mexico for head-starting.

The age at sexual maturity probably limited observations. These turtles mature at 10 years of age or older, based on the age that head-started turtles were documented nesting in the wild. Although most of the turtles from the PAIS experimental imprinting project are likely sexually mature, many of those turtles from the 1989-1992 year-classes may not be sexually mature and capable of reproduction yet.

5. Stranded adult Kemp's ridleys

Nesting observations of both wild and head-started Kemp's ridley turtles were also likely limited by mortality of these turtles in the marine environment. Caillouet et al., 1995a, reported tag returns for head-started turtles and predicted that few would survive to adulthood.

Sea turtles found washed ashore (or stranded) alive or dead on USA shores, have been documented by the STSSN since 1980 (Shaver, 1998b). The numbers of dead turtles reported by the STSSN provide minimum estimates of mortality since only a portion of dead turtles actually wash ashore and can be documented (Caillouet et al., 1991, 1996; Shaver, 1998b).

The STSSN database was queried for records of adult Kemp's ridley turtles found stranded in the USA from 1980-2002. Kemp's ridleys measuring 60.0 cm SLCL or greater were considered to be adults (Tewg, 1998; Shaver, in press). Virtually all of the adult Kemp's ridleys documented stranded were located dead. In accordance with STSSN protocol (Shaver, 1998b), the two confirmed head-started adults in the STSSN database were eliminated from stranding tallies and analyses reported below. Some of the other stranded adults could have been head-started individuals that were unidentifiable because they had been released without living tags, had shed their metal flipper tags, or could not be thoroughly examined for tags since they were found stranded without front flippers and/or carapace scutes (Shaver and Caillouet, 1998), but since their linkage to head-starting could not be proven their records were not excluded.

During every year from 1986-2002, more adult Kemp's ridleys were found stranded in Texas than in any other state in the USA (Figure 5), even though adult Kemp's ridleys forage in, and migrate through, nearshore waters of several other USA states (USFWS and NMFS, 1992; Tewg, 1998; Shaver, 1999b, 2000, 2001, 2002, 2003). Adult strandings on Gulf of Mexico (offshore) beaches in south Texas (Zones 20 and 21) increased during this period (Figure 5). The largest numbers were found there from 1994-2002, roughly the same time that increased numbers of nests were detected in south Texas. Of the 253 dead adult Kemp's ridleys found stranded in the USA from 1995-2002, 141 (55.7%) were found stranded offshore in Zones 20 and 21.

A variety of natural and human-related factors cause mortality of both wild and head-started sea turtles in USA waters. Magnuson et al., 1990, concluded that incidental capture in shrimp trawls accounted for more sea turtle deaths than all other human

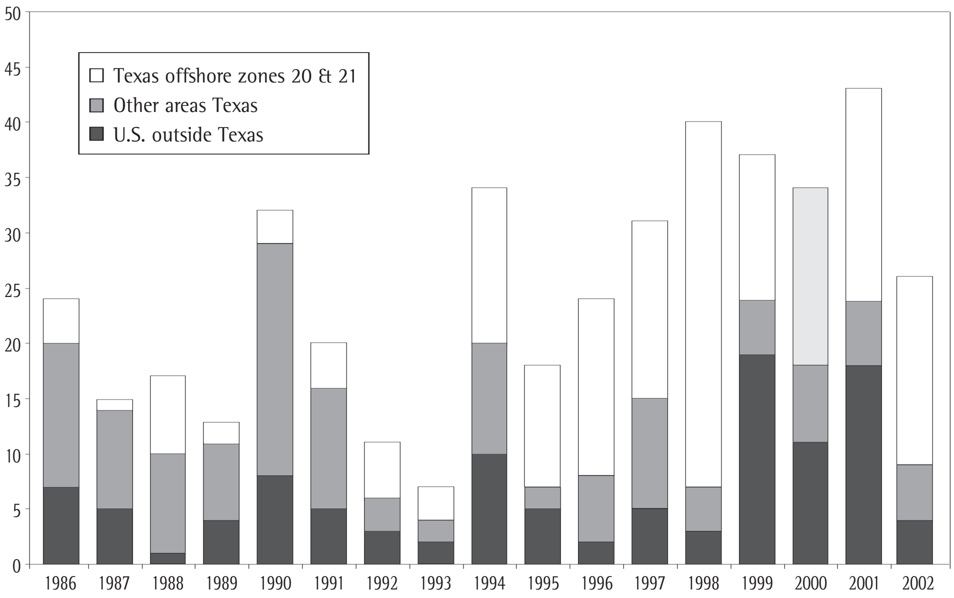

Figure 5. Number of adult Kemp's ridley turtles found stranded in the United States, 1986-2002.

activities combined. To decrease this mortality, mandatory use of Turtle Excluder Devices (TEDs) in USA Gulf of Mexico waters began in 1990 (Caillouet et al., 1996). However, even after mandatory use of TEDs there continued to be a relationship between shrimp trawling and strandings of juvenile and adult Kemp's ridley turtles on the Texas coast (Caillouet et al., 1991, 1996; Shaver, 1994, 1995b, 1996c, 1996d, 1998b, 1999a, 1999b, 2000, 2001, 2002, 2003; Shaver and Caillouet, 1998). Of the 141 dead adults found offshore in Zones 20 and 21 from 1995-2002, 135 (95.7%) were located during times when Gulf waters off the Texas coast were open to shrimp trawling. Only six were found during the annual Texas Closure, when Gulf waters off the Texas coast out to 322 km from shore were closed to shrimp trawling from mid-May through mid-July.

It cannot be proven that the adults that succumbed in Texas waters from 1980-2002 would have mated or nested in Texas. Gulf waters off the Texas coast are also used by Kemp's ridley turtles as foraging habitat (shaver, 1991) and as a migratory corridor between foraging grounds in USA waters and nesting grounds on the Gulf coast of Mexico (Renaud et al., 1996; Shaver, 1999b, 2000, 2001, 2002, 2003). The deaths of adult female Kemp's ridleys in Texas represent a substantial loss, whether the turtles would have nested in Texas or elsewhere (Shaver, in press). The future of Kemp's ridley nesting in Texas, and the future of efforts to evaluate the experimental imprinting and head-starting procedures in this project are dependent on the survival of adult turtles in this area.

Noting the large number of dead adults found stranded on south Texas Gulf beaches, the site of the experimental project and of most Kemp's ridley nests documented in the USA, several environmental groups and biologists suggested the creation of a marine reserve or a closure of the area to commercial fishing (Plotkin, 1999; McDaniel et al., 2000; Shore, 2000; Lewison et al., in press). Texas Parks and Wildlife Department (TPWD) regulations passed in August 2000 established a new annual closure of Gulf waters to shrimp trawling off North Padre Island, South Padre Island, and Boca Chica Beach out to 8 km from shore, from 1 December through mid-May each year, preceding the existing annual Texas Closure. Although this regulation was intended to help sustain the Texas shrimping industry, it may have side benefits to protect adult Kemp's ridley turtles in south Texas and may have been an important factor in the record number of Kemp's ridley nests detected in Texas during 2002. More years of data collection are needed to evaluate the impacts of the TPWD regulation on stranding and nesting numbers. To increase Kemp's ridley nesting in Texas, efforts to protect adults on the nesting beach and in the marine environment must be continued.

6. Implications regarding experimental imprinting and head-starting

The Kemp's ridley turtles that nested on the Texas coast from at least 1996 through 2002 included a mixture of both head-started and wild individuals. One reason for the increase in the number of Kemp's ridley nests found on the Texas coast has been the return of head-started turtles, including both those experimentally imprinted to PAIS and those that had been taken directly from Mexico as hatchlings. These represented the: 1) first nestings in the wild of known-aged Kemp's ridleys; 2) first confirmed records of head-started sea turtles nesting outside of captivity; 3) first confirmed records of sea turtles experimentally imprinted to an area returning to that imprinting area to nest; and, 4) first nestings in the USA of head-started Kemp's ridleys that had been taken directly from Mexico as hatchlings (Shaver, 1996a, 1996b, 1997, in press; Shaver and Caillouet, 1998; Fontaine and Shaver, in press; Shaver and Wibbels, in press).

Information useful to evaluating the results of the experimental imprinting and head-starting has been gathered through nest detection efforts in Texas and Mexico. However, the use of these two experimental treatments and change of procedures to achieve conservation goals for this endangered species complicate assessment of results.

Head-starting is an experimental procedure that has received criticism for various reasons, including cost and the potential to alter normal behavior (see Donnelly, 1994; Mrosovsky, this volume). The documented nesting in the wild by 15 head-started Kemp's ridleys establishes that head-starting does not necessarily prevent turtles from surviving and reproducing (Mrosovsky, this volume). The survival and reproduction of these Kemp's ridleys and some head-started green turtles (Bell and Parsons, 2002; Balazs et al., in press) likely indicate that other sea turtle species could also survive and reproduce after being head-started (Mrosovsky, this volume). Shaver and Wibbels (in press) reviewed existing data on the distribution (Manzella et al., 1988; Fontaine et al., 1989a; Manzella and Williams, 1992), habitat use, movements, diet, nesting, and other biological parameters for head-started turtles and found that they generally compared favorably to their wild counterparts. However, in many cases sample sizes were limited and additional data collection and comparisons would be instructive.

The nestings in south Texas by 10 PAIS experimentally imprinted head-started turtles and in Mexico by one head-started turtle that had been taken from Mexico as a hatchling provided evidence in support of the imprinting and natal homing hypotheses (Owens et al., 1982). Initial supporting evidence that the PAIS experimentally imprinted turtles may have been successfully imprinted was gathered for 4-month-old hatchlings during multiple choice laboratory studies conducted in the early 1980s (Grassman et al., 1984; Owens et al., 1986; Grassman, 1993). Of the 102 Kemp's ridley nests found in Texas from 1996 through 2002, nesting turtles were examined for tags at 47 of the nests. Nineteen of those 47 (40%) were laid by 10 turtles experimentally imprinted to PAIS. This high percentage of PAIS experimentally imprinted turtles among the nesters documented, and the fact that only one other PAIS experimentally imprinted turtle had been documented nesting anywhere else in the world, also support these hypotheses.

However, the nestings in Mexico by one PAIS experimentally imprinted head-started turtle and in Texas by three head-started turtles that had been taken from Mexico as hatchlings generally do not support these hypotheses. These observations could indicate that if imprinting occurs, perhaps there is a prolonged critical period. Release location of these turtles after 9-11 months of head-starting may have influenced their selection of a nesting beach, with random movements occurring in proximity of the release location (MROSOVSKY, this volume). Most of the head-started turtles that had been experimentally imprinted to PAIS were released in that vicinity, whereas none of those that had been taken directly from Rancho Nuevo as hatchlings were released near Rancho Nuevo. This variation in release location for the two groups may explain why 10 of the 11 recorded turtles that were experimentally imprinted to PAIS nested at or near PAIS, whereas only one of the four documented that had been taken directly from Mexico as hatchlings returned there to nest. Social facilitation could be involved in attracting turtles to a nesting beach (HENDRICKSON, 1958; OWENS et al., 1982), but this alternative hypothesis has generally not been supported by data for sea turtles. If nesting distribution had been influenced by social facilitation, one would expect that more head-started turtles would have been recorded nesting in Mexico than in Texas where far fewer turtles nest. Alternatively, it is also possible that the nesting of these head-started individuals in Texas merely reflects an expansion of nesting range.

More years of data collection for nesting Kemp's ridley turtles and their nests are needed to evaluate the experimental imprinting and head-starting procedures used in this project. Nesting has been documented in the wild for 11 PAIS experimentally imprinted turtles in comparison to four turtles that had been taken directly from Mexico as hatchlings. Even though more PAIS experimentally turtles were released, more nesting records may eventually be amassed for those turtles that had been obtained as hatchlings from Mexico. Most of the turtles experimentally imprinted to PAIS were released before mandatory usage of TEDs in the USA, whereas most of the head-started turtles that had been hatched in Mexico between 1989 and 1992 were released after mandatory use of TEDs. Most of the turtles experimentally imprinted to PAIS received fewer tags than those taken directly from Mexico as hatchlings, and hence the former group would be more difficult to identify, especially for those early year-classes that were only marked with metal tags. Additionally, the detection program undertaken in recent years, when those turtles that had been obtained directly from Mexico entered maturity, was comparatively much more comprehensive than was the program when the PAIS imprinted turtles first attained adulthood. Lastly, the sex ratio of the group that was obtained directly from Mexico was more dominated by females and hence a larger proportion of them could potentially nest. When interpreting data collected in future years to evaluate the relative effectiveness of experimental imprinting, it will be important to consider all of these factors that could eventually result in a larger representation of the individuals that had been taken as hatchlings from Mexico in the total number of head-started nesting records.

CONCLUSIONS

This project provides an opportunity to evaluate the utility of experimental imprinting and head-starting to restoration efforts. If this project is judged successful, these experimental procedures could be implemented to further aid in the restoration of this and other depleted sea turtle species in the future. A nesting colony is becoming re-established in Texas, in large part due to the nesting of head-started turtles, and their reproduction outside of captivity is an encouraging sign that the experimental imprinting and head-starting efforts have achieved some success. However, the varying experimental treatments and procedures used from 1978-1992 complicate evaluation. It is currently uncertain whether experimental imprinting, random movements, nesting distribution spreading, or a combination of all of these factors influenced nest site selection for these head-started turtles. Due to the long age to maturity and tremendous difficulty of finding nesting Kemp's ridleys on the Texas coast, additional years of data collection are needed. Assessment of the long-term success of this restoration effort requires the detection and examination of nesting Kemp's ridleys as well as collection of various types of biological data. Evaluation of these procedures and overall conservation efforts aimed at re-establishing a nesting colony of Kemp's ridleys in Texas are also dependent upon survival of adults in Texas waters and protection of the nesting females and nests on Texas beaches.

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Corps, U.S. Coast Guard, U.S. Fish and Wildlife Service, U.S. Navy, and many others. The efforts on South Padre Island and Boca Chica Beach were conducted by the Gladys Porter Zoo, Sea Turtle Inc., U.S. Fish and Wildlife Service, University of Texas at Pan American and others; on Mustang Island by the University of Texas Marine Science Institute and others; and, on the upper Texas coast by NMFS and others.

REFERENCES

ANONYMOUS. 1992. First Kemp's ridley nesting in South Carolina. *Mar. Turtle Newsl.* 59:23.

BALAZS, G.H., NAKAI, G.L., HAU, S., GRADY, M.J., and GILMARTIN, W.G. In press. Year 2000 nesting of a captive-reared Hawaiian green turtle tagged and released as a yearling. Proceedings of the 21st Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum.

BELL, C.D.L., and PARSONS, J. 2002. Cayman Turtle Farm Head-starting Project yields tangible success. Marine Turtle Newsletter 98:5-6.

BOWEN, B.W., CONANT, T.A., and HOPKINS-MURPHY, S.R. 1994. Where are they now? The Kemp's Ridley Headstart Project*. Conserv. Biol*. 8:853-856.

BOWEN, B.W., MEYLAN, A.B., and AVISE, J.C. 1991. Evolutionary distinctiveness of the endangered Kemp's ridley sea turtles. *Nature* 352:709-711.

BURCHFIELD, P.M. 2002. Report on the Mexico/United States of America Population Restoration Project for the Kemp's Ridley Sea Turtle, *Lepidochelys kempii*, on the coasts of Tamaulipas and Veracruz, Mexico 2002. Unpublished report, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 38 pp.

CAILLOUET, C.W., JR. 1995. An update of sample sex composition data for head started Kemp's ridley sea turtles. *Mar. Turtle Newsl.* 69:11-14.

CAILLOUET, C.W., JR. 2000. Sea turtle culture: Kemp's ridley and loggerhead turtles. In: Stickney, R.R. (Ed.). *Encyclopedia of Aquaculture*. John Wiley and Sons, Inc., pp. 786-798.

CAILLOUET, C.W., JR., DURONSLET, M.J., LANDRY, A.M., JR., and SHAVER, D.J. 1991. Sea turtle strandings and shrimp fishing effort in the northwestern Gulf of Mexico, 1986-1989. *Fishery Bull.* 89(4):712-718.

CAILLOUET, C.W., JR., FONTAINE, C.T., MANZELLA-TIRPAK, S.A., and SHAVER, D.J. 1995a. Survival of head-started Kemp's ridley sea turtles (*Lepidochelys kempii*) released into the Gulf of Mexico or adjacent bays. *Chelonian Conservation and Biology* 1(4):285-292.

CAILLOUET, C.W., JR., FONTAINE, C.T., MANZELLA-TIRPAK, S.A., and WILLIAMS, T.D. 1995b. Growth of head-started Kemp's ridley sea turtles (*Lepidochelys kempii*) following release. *Chelonian Conservation and Biology* 1(3), 231-234.

CAILLOUET, C.W, JR., ROBERTSON, B.A., FONTAINE, C.T., WILLIAMS, T.D., HIGGINS, B.M., and REVERA, D.B. 1997. Distinguishing captive-reared from wild Kemp's ridleys. *Mar. Turtle Newsl.* 77:1-6.

CAILLOUET, C.W., JR., SHAVER, D.J., TEAS, W.G., NANCE, J.N., REVERA, D.B., and CANNON, A.C. 1996. Relationship between sea turtle strandings and shrimp fishing effort in the Northwestern Gulf of Mexico: 1986-1989 versus 1990-1993. *Fishery Bull.* 94(2):237-249.

CARR, A.F. 1967. *So Excellent a Fishe: A Natural History of Sea Turtles*. New York: Scribner, 1984 rev. edn. 280 pp.

CARR, A.F. 1977. Crisis for the Atlantic ridley. *Mar. Turtle Newsl.* 4:2-3.

CHALOUPKA, M. and ZUG, G.R. 1997. A polyphasic growth function for the endangered Kemp's ridley sea turtle, *Lepidochelys kempii*. *Fishery Bull.* 95:849-856.

DONNELLY, M. 1994*. Sea Turtle Mariculture: A Review of Relevant Information for conservation and commerce.* The Center for Marine Conservation, Washington, DC, 113 pp.

DOUGHTY, R.W. 1984. Sea turtles in Texas: a forgotten commerce. *Southwest Hist. Quart.* 88:43-70.

FONTAINE, C.T., and SHAVER, D.J. in press. Head starting the Kemp's ridley sea turtle, *Lepidochelys kempii*, at the National Marine Fisheries Service Galveston Laboratory (1978 through 1992): A review. *Chelonian Conservation and Biology*.

FONTAINE, C.T., DURONSLET, M.J., REVERA, D.B., WILLIAMS, T.D., WILLIAMS, J.A., MANZELLA, S.A., STABENAU, E.K., LANDRY, A.M., JR., and CAILLOUET, C.W., JR. 1990. Kemp's Ridley Head Start Experiment and Other Sea Turtle Research at the Galveston Laboratory: Annual Report - Fiscal Year 1989. *NOAA Tech. Memo. NMFS-SEFC-266*, 63 pp.

FONTAINE, C.T., MANZELLA, S.A., WILLIAMS, T.D., HARRIS, R.M., and BROWNING, W.J. 1989a. Distribution, growth and survival of head started, tagged and released Kemp's ridley sea turtle, *Lepidochelys kempii* from year classes 1978-1983. In: Caillouet, C.W., Jr., and Landry, A.M., Jr. (Eds.), First Intl. Symp. on Kemp's Ridley Sea Turtle Biol., Conserv. and Management. *Texas A&M Univ. Galveston, Texas, TAMU-SG-89-105*, pp. 124-144.

FONTAINE, C.T., WILLIAMS, T.D., MANZELLA, S.A., and CAILLOUET, C.W., JR. 1989b. Kemp's ridley sea turtle head start operations of the NMFS SEFC Galveston Laboratory. In: Caillouet, C.W., Jr. and Landry, A.M., Jr., First Intl. Symp. on Kemp's Ridley Sea Turtle Biol., Conserv. and Management. *Texas A&M Univ. Galveston, Texas, TAMU-SG-89-105*, pp. 96-110.

FONTAINE, C.T., REVERA, D.B, WILLIAMS, T.D., and CAILLOUET, C.W., JR. 1993. Detection, Verification and Decoding of Tags and Marks in Head Started Kemp's Ridley Sea Turtles, *Lepidochelys kempii*. *NOAA Tech. Memo. NMFS-SEFC-334*, 40 pp.

FOOTE, J.J. and MUELLER, T.L. 2002. Two Kemp's ridley (*Lepidochelys kempii*) nests on the central Gulf coast of Sarasota County, Florida (USA). In: Mosier, A., Foley, A., and Brost, B. (Compilers). Proceedings of the 20th Annual Symposium on Sea Turtle Biology and Conservation. *NOAA Tech. Memo. NMFS-SEFSC-477*, pp. 252-253.

FRANCIS, K. 1978. Kemp's ridley sea turtle conservation programs at South Padre Island, Texas, and Rancho Nuevo, Tamaulipas, Mexico. In: Henderson, G.E. (Ed.). Proceedings of the Florida and Interregional Conference on Sea Turtles. *Florida Marine Research Publications No. 33*, pp. 51-52.

GODFREY, D. 1996. New riddles about Kemp's ridley. *Velador* 1996:1-5.

GRASSMAN, M. 1993. Chemosensory orientation behavior in juvenile sea turtles. *Brain Behav. Evol.* 1993(4):224-228.

GRASSMAN, M.A., OWENS, D.W., MCVEY, J.P., and MARQUEZ-M., R. 1984. Olfactory-based orientation in artificially imprinted sea turtles. *Science* 224:83-84.

HENDRICKSON, J.R. 1958. The green sea turtle, *Chelonia mydas* (Linn.) in Malaya and Sarawak. *Proc. Zool. Soc. London* 130:455-535.

HILDEBRAND, H.H. 1963. Hallazgo del area de anidacion de la tortuga marina "lora", *Lepidochelys kempi* (Garman), en la costa occidental del Golfo de Mexico (Rept., Chel.). *Sobretiro de Ciencia, Mexico* 22(4):105-112.

HILDEBRAND, H.H. 1982. A historical review of the status of sea turtle populations in the western Gulf of Mexico. In: Bjorndal, K.A. (Ed.). *Biology and Conservation of Sea Turtles*. Washington, DC: Smithsonian Institution Press, pp. 447-453.

JOHNSON, S.A., BASS, A.L., LIBERT, B., MARSHALL, M., and FULK, D. 1999. Kemp's ridley (*Lepidochelys kempii*) nesting in Florida. *Florida Scientist* 62(3/4):194-204.

JOHNSON, S.A., BASS, A.L., LOBERT, B., MARSHALL, M., and FULK, D. 2000. Kemp's ridley (*Lepidochelys kempii*) nesting in Florida, USA. In: Kalb, H., and Wibbels, T. (Compilers). Proceedings of the 19th Annual Symposium on Sea Turtle Conservation and Biology. *NOAA Tech. Memo. NMFS-SEFC-443*, pp. 283.

LEWISON, B., CROWDER, L., and SHAVER, D.J. 2003. The impact of Turtle Excluder Devices and fisheries closures on loggerhead and Kemp's ridley strandings in the western Gulf of Mexico. Conservation Biology 17(4):1089-1097.

LIBERT, B. 1998. Kemp's ridley nesting in Volusia County. In press. In: Epperly, S.P., and Braun, J. (Compilers). Proceedings of the 17th Annual Symposium on Sea Turtle Biology and Conservation. *NOAA Tech. Memo. NMFS-SEFC-415*, pp. 219.

MAGNUSON, J.J., BJORNDAL, K.A., DUPAUL, W.D., GRAHAM, G.L., OWENS, D.W., PETERSON, C.H., PRITCHARD, P.C.H., RICHARDSON, J.I., SAUL, G.E., and WEST, C.W. 1990. *Decline of the Sea Turtles: Causes and Prevention.* National Research Council, National Academy Press, Washington, D.C., 190 pp.

MANZELLA, S.A. and WILLIAMS, J.A. 1992. The Distribution of Kemp's Ridley Sea Turtles (*Lepidochelys kempi*) Along the Texas Coast: An Atlas. *NOAA Tech. Rep. NMFS 110*, 52 pp.

MANZELLA, S.A., CAILLOUET, C.W., JR., and FONTAINE, C.T. 1988. Kemp's ridley, *Lepidochelys kempi*, sea turtle head start tag recoveries: Distribution, habitat and method of recovery. *Marine Fisheries Review* 50(3):24-32.

MAÁRQUEZ-M., R. 1990. FAO Species Catalogue, Volume 11. *Sea Turtles of the World, An Annotated and Illustrated Catalogue of Sea Turtle Species Known to Date.* Food and Agriculture Organization of the United Nations, FAO Species Synopsis No. 125, Volume 11, FIR/S125. 81 pp.

MÁRQUEZ-M., R., BURCHFIELD, P., CARRASCO, M.A., JIMÉNEZ, C., DÍAZ, J., GARDUNO, M., LEO, A., PENA, J., BRAVO, R., and GONZÁLEZ, E. 2001. Update on the Kemp's ridley turtle nesting in Mexico. *Mar. Turtle Newsl.* 92:2-4.

MÁRQUEZ-M., R., DIAZ, J., SANCHEZ, M., BURCHFIELD, P., LEO, A., CARRASCO, M., PENA, J., JIMENEZ, C., and BRAVO, R. 1999. Results of the Kemp's ridley nesting beach conservation efforts in México. *Mar. Turtle Newsl.* 85:2-4.

MÁRQUEZ-M., R., VILLANUEVA O., A., and SÁNCHEZ P., M. 1982. The population of the Kemp's ridley sea turtle in the Gulf of Mexico - *Lepidochelys kempii*. In: Bjorndal, K.A. (Ed.). *Biology and Conservation of Sea Turtles*. Washington, DC: Smithsonian Institution Press, pp. 159-164.

MCDANIEL, C.J., CROWDER, L.B., and PRIDDY, J.A. 2000. Spatial dynamics of sea turtle abundance and shrimping intensity in the U.S. Gulf of Mexico. *Conservation Ecology* 4(1):15. [online] URL:http://www.consecol.org/vol4/iss1/art15.

MEYLAN, A., CANSTANDEA, P., COOGAN, C., LOZON, T., and FLETEMEYER, J. 1990. Kemp's ridley sea turtle reproduction. *Herp. Rev.* 21(1):19-20.

MILLER, J.D. 1997. Reproduction in sea turtles. In: Lutz, P.L., and Musick, J.A. (Eds.). *The Biology of Sea Turtles*. Boca Raton, FL: CRC Press, pp. 51-81.

MROSOVSKY, N. this volume. Translocating turtles: Trials, tribulations and triumphs. In: this volume.

NICHOLS, M.A., DAVIS, T.L., BERRY, K.A., RUSSELL, R.R., and DILLER, A.P. in press. Two additional species of marine turtles nest within Gulf Islands National Seashore's Florida District. In: Proceedings of the 21st Annual Symposium on Sea Turtle Biology and Conservation. *NOAA Tech. Memo.*

OWENS, D., COMUZZIE, D.C., and GRASSMAN, M. 1986. Chemoreception in the homing and orientation behavior of amphibians and reptiles. In: Duvall, D. et al. (Eds.). *Chemical Signals in Vertebrates 4.* New York: Plenum Publishing Corporation, pp. 341-355.

OWENS, D.W., GRASSMAN, M.A., and HENDRICKSON, J.R. 1982. The imprinting hypothesis and sea turtle reproduction. *Herpetologica* 38(1):124-135.

PALMATIER, R. 1993. Kemp's ridley nesting. *Herpetol. Review* 24(4):149-150.

PLOTKIN, P.T. 1999. Resolutions of the participants at the 19th Annual Symposium on Sea Turtle Biology and Conservation. *Mar. Turtle Newsl.* 85:20-24.

RENAUD, M.L., CARPENTER, J.A., WILLIAMS, J.A., and LANDRY, A.M., JR. 1996. Kemp's ridley sea turtle (*Lepidochelys kempii*) tracked by satellite telemetry from Louisiana to nesting beach at Rancho Nuevo, Tamaulipas, Mexico. *Chelonian Conservation and Biology* 2(1):108-109.

SCHMID, J.R. and WITZELL, W.N. 1997. Age and growth of wild Kemp's ridley sea turtles, *Lepidochelys kempi*: Cumulative results of tagging studies in Florida. *Chelonian Conservation and Biology* 2(4):532-537.

SHAVER, D.J. in press. The Kemp's ridley imprinting project at Padre Island National Seashore and Kemp's ridley nesting on the Texas coast. In: *Chelonian Conservation and Biology*.

SHAVER, D.J. 1989. Results from eleven years of incubating Kemp's ridley sea turtle eggs at Padre Island National Seashore. In: Eckert, S.A., and Eckert, K.L. (Compilers). Proceedings of the 9th Annual Workshop on Sea Turtle Conservation and Biology. *NOAA Tech. Memo. NMFS-SEFC-232*, pp. 163-165.

SHAVER, D.J. 1990. Kemp's Ridley Project at Padre Island enters a new phase. *Park Sci.* 10(1):12-13.

SHAVER, D.J. 1991. Feeding ecology of wild and head-started Kemp's ridley sea turtles in south Texas waters*. J. of Herpetol.* 25(3):327-334.

SHAVER, D.J. 1992. Kemp's ridley research continues at Padre Island National Seashore. *Park Sci.* 12(4):26-27.

SHAVER, D.J. 1994. Sea turtle strandings along the Texas coast reach alarming levels*. Mar. Turtle Newsl.* 66:8-9.

SHAVER, D.J. 1995a. Kemp's ridley sea turtles nest in south Texas. *Mar. Turtle Newsl.* 70:10-11.

SHAVER, D.J. 1995b. Sea turtle strandings along the Texas coast again cause concern. *Mar. Turtle Newsl.* 70:2-4.

SHAVER, D.J. 1996a. Head-started Kemp's ridley turtles nest in Texas. *Mar. Turtle Newsl.* 74:5-7.

SHAVER, D.J. 1996b. A note about Kemp's ridleys nesting in Texas. *Mar. Turtle Newsl.* 75:25.

SHAVER, D.J. 1996c. Record numbers of sea turtle strandings along the Texas coast during 1994. In: Keinath, J.A., Barnard, D.E., Musick, J.A., and Bell, B.A. (Compilers). Proceedings of the 15th Annual Symposium on Sea Turtle Biology and Conservation. *NOAA Tech. Memo. NMFS-SEFSC-387*, pp. 290-293.

SHAVER, D.J. 1996d. Sea turtle strandings along the Texas coast during 1994. In: University of New Orleans (Compiler). Proceedings from the 14th Annual Gulf of Mexico Information Transfer Meeting. *Minerals Management Service*, *Gulf of Mexico OCS Region*, *MMS 96-0024*, pp. 45-49.

SHAVER, D.J. 1997. Kemp's ridley turtles from an international project return to Texas to nest. In: University of New Orleans (Compiler). Proceedings from the 16th Annual Gulf of Mexico Information Transfer Meeting. Minerals Management Service, *Gulf of Mexico OCS Region*, *MMS 97-0038*, pp. 38-40.

SHAVER, D.J. 1998a. Kemp's ridley sea turtle nesting on the Texas coast, 1979-1996. In: Epperly, S.P., and Braun, J. (Compilers). Proceedings of the 17th Annual Symposium on Sea Turtle Biology and Conservation. *NOAA Tech. Memo. NMFS-SEFSC-415*, pp. 91-94.

SHAVER, D.J. 1998b. Sea turtle strandings along the Texas coast, 1980-94. In: Zimmerman, R. (Ed.). Characteristics and Causes of Texas Marine Strandings*. NOAA Tech. Rep. NMFS 143*, pp. 57-72.

SHAVER, D.J. 1999a. Kemp's Ridley Sea Turtle Project at Padre Island National Seashore, Texas. In: McKay, M., and Nides, J. (Eds). Proceedings from the 17th Annual Gulf of Mexico Information Transfer Meeting. *Minerals Management Service, Gulf of Mexico OCS Region, MMS 99-0042*, pp. 342-347.

SHAVER, D.J. 1999b. *Padre Island National Seashore Kemp's Ridley Sea Turtle Project and Texas Sea Turtle Strandings 1998 Report.* Department of the Interior, U.S. Geological Survey. Unpublished. 58 pp.

SHAVER, D.J. 2000. *Padre Island National Seashore Kemp's Ridley Sea Turtle Project and Texas Sea Turtle Nesting and Stranding 1999 Report*. Department of the Interior, U.S. Geological Survey. Unpublished. 54 pp.

SHAVER, D.J. 2001. *Padre Island National Seashore Kemp's Ridley Sea Turtle Project and Texas Sea Turtle Nesting and Stranding 2000 Report*. Department of the Interior, U.S. Geological Survey. Unpublished. 59 pp.

SHAVER, D.J. 2002. *Kemp's Ridley Sea Turtle Project at Padre Island National Seashore and Texas Sea Turtle Nesting and Stranding 2001 Report*. Department of the Interior, U.S. Geological Survey. Unpublished. 29 pp.

SHAVER, D.J. 2003. *Kemp's Ridley Sea Turtle Project at Padre Island National Seashore and Texas Sea Turtle Nesting and Stranding 2002 Report*. Department of the Interior, U.S. Geological Survey. Unpublished. 49 pp.

SHAVER, D.J. and WIBBELS, T. in press. Headstarting. In: *Biology and Conservation of Ridley Sea Turtles*. Smithsonian Institution Press.

SHAVER, D.J. and CAILLOUET, C.W., JR. 1998. More Kemp's ridley turtles return to south Texas to nest. *Mar. Turtle Newsl.* 82:1-5.

SHAVER, D.J. and FLETCHER, M.R. 1992. Kemp's ridley sea turtles. *Science* 257:465-466.

SHAVER, D.J. and MILLER, J.E. 1999. Kemp's ridley sea turtles return to Padre Island National Seashore. *Park Sci.* 19(2):16-17, 39.

SHAVER, D.J., OWENS, D.W., CHANEY, A.H., CAILLOUET, C.W., JR., BURCHFIELD, P. and MARQUEZ M, R. 1988. Styrofoam box and beach temperatures in relation to incubation and sex ratios of Kemp's ridley sea turtles. In: Schroeder, B.A. (Compiler). Proceedings of the 8th Annual Workshop on Sea Turtle Conservation and Biology. *NOAA Tech. Memo. NMFS-SEFC-214*, pp. 103-108.

SHORE, T. 2000. Creating a Kemp's Ridley Marine Reserve in Texas: The missing link is a proven protection strategy. *Endangered Species Update* 17(2):35-39.

TEWG (TURTLE EXPERT WORKING GROUP). 1998. An Assessment of the Kemp's Ridley (*Lepidochelys kempii*) and Loggerhead (*Caretta caretta*) Sea Turtle Populations in the Western North Atlantic. *NOAA Tech. Memo. NMFS-SEFSC-409*, 96 pp.

USFWS and NMFS (U.S. FISH AND WILDLIFE SERVICE AND NATIONAL MARINE FISHERIES SERVICE). 1992. *Recovery Plan for the Kemp's Ridley Sea Turtle (Lepidochelys kempii*). St. Petersburg, FL: National Marine Fisheries Service, 40 pp.

VALVERDE, R.A., CORNELIUS, S.E., and MO, C.L. 1998. Decline of the olive ridley sea turtle (*Lepidochelys olivacea*) nesting assemblage at Nancite Beach, Santa Rosa National Park, Costa Rica. *Chelonian Conservation and Biology* 3(1):58-63.

WERLER, J.E. 1951. Miscellaneous notes on the eggs and young of Texas and Mexican reptiles. *Zoologica* 36:37-48.

WOOD, J.R. and WOOD, F.E. 1988. Captive reproduction of Kemp's ridley *Lepidochelys kempi. Herpetol. J.* 1(6):247-249.

ZUG, G.R., KALB, H.J., and LUZAR, S.J. 1997. Age and growth in wild Kemp's ridley sea turtles *Lepidochelys kempii* from skeletochronological data. *Biol. Conserv.* 80:261-268.

The Kemp's ridley sea turtle
Lepidochelys kempii (GARMAN, 1880)
as an example of international co-operation

RENÉ MÀRQUEZ

ABSTRACT

Three years after the nesting beach of the Kemp's Ridley Turtle (*L. kempii*) was discovered in Rancho Nuevo, Tamaulipas, protection measures were put in place in 1966 for 13.5 km of beach, which was gradually extended to the point that it now encompasses 230 km. Initially, 20 to 25 thousand hatchlings a year were released. In 1978, a programme was started in collaboration with the USA and the number of protected hatchlings was increased. Nonetheless, the nesting population continued to fall, to an annual average of 742 nests between 1985 and 1987 (each female produces 2.3 nests per season). 10 years after co-operation started, the population started to increase, so that by 2002, 6,325 nests were protected, producing 405,000 hatchlings, which were released on the beaches of six camps set up in Tamaulipas and one in Veracruz.

Experimental work was also started, in co-operation with the USA, including the activities of "imprinting" and "head-starting". For this work, 20 nests a year were donated between 1978 and 1992, which produced 27,738 hatchlings. From 1993 to 2000, egg deliveries were suspended, but a total of 1.460 hatchlings were donated for behavioural experiments related to the use of TED´s. All these hatchlings were reared in captivity for 9 to 10 months before being released in appropriate areas. 85% of the hatchlings were "imprinted" in Padre Island, Texas, and the rest in Rancho Nuevo. The survival rate during rearing was 75%. As a result of the programme, a large percentage of turtles have been re-captured in healthy condition and some of them have nested on Padre Island, for example, 35 nests of this species were located in 2002, some of which were made by turtles from the experiment.

As this species was considered to be on the verge of extinction, 100 one-year-old juveniles reared in Galveston, Texas, and 100 hatchlings from Rancho Nuevo, were transferred to the Sea Turtle Farm, in Grand Cayman Island to form a reserve stock in 1980. These have adapted to captivity, and started breeding at five years of age. Initially, they only laid a few eggs and these were not very fertile. This improved as the turtles grew older, so that in 1994, the farm had 476 turtles of different ages (30 14-year-old breeding animals and 446 turtles of between 1 and 5 years, born on the farm). That year, the Directors of the Farm decided that the objectives had been met and that the wild population showed signs of recovery, so breeding was suspended and Mexico was asked to repatriate this population. The arrangements were made and the Eco-Archaeological Park of Xcaret created the facilities for maintaining them. On the 10th of

April 1999, 110 turtles (57 females and 53 males) were transferred. These re-adapted and are now starting to breed.

The causes of the increase in the Kemp's Ridley Turtle population, apart from the conservation work that has been done in the nesting grounds, are considered to be the implementation of the use of TEDs in shrimp boats, compulsory in U.S.A. since 1992 and since 1994 in Mexico. Temperature studies indicate that a larger proportion of females is produced, favouring recruitment. The fall in shark populations will probably also support this increase.

INTRODUCTION

Kemp's Ridley turtle (*Lepidochelys kempii*) is one of the most peculiar species, as it emerges from the sea during the day to nest and its geographic range is restricted mainly to the Gulf of Mexico and the East Coast of the United States. Adults meet to breed between March and August off the coasts of the State of Tamaulipas, concentrating between the mouth of the River Soto la Marina and 20 km south of Barra del Tordo (Marquez, 1994). The small groups that still lay their eggs in Texas, on the coast north of de Tamaulipas, between Tuxpan and Tecolutla (Veracruz) and between Aguada Island and Champoton (Campeche), mentioned by CARR (1963), HILDEBRAND (1963), PRITCHARD and MARQUEZ (1973), MAGER JR. (1985), MARQUEZ and FRITTS (1987) and MARQUEZ (1990, 1994), are possibly remnants of older, more numerous breeding colonies.

Up until the 60s, this species was caught commercially along the south east coast of U.S.A. and throughout the Gulf of Mexico (HILDEBRAND, 1981; MARQUEZ, 1990, 1994), so the impact of fishing, together with the constant looting of over 90% of the eggs laid on the beach of Rancho Nuevo (Tamaulipas) and the continued deterioration of the habitat, caused a collapse in the population in the late sixties. Between the 1940s and the 1980s, the fall in the number of breeding females was over 95%, whereas in 1947, CARR (op. cit.) and HILDEBRAND (op. cit.) calculated the size of a wave of arriving turtles at approxi-mately 40,000 females, in 1968 (Figure 1), the largest wave was estimated at just over 2,000 (MARQUEZ, op. cit.). In the eighties and

Figure 1. Wave of turtles in the beach (arribada).

nineties, these waves of turtles consisted of little more than 200 females, but since 2000, there has been at least one wave of over 1,000 turtles each season.

RESEARCH AND CONSERVATION WORK

The beach of Rancho Nuevo, Tamaulipas, was discovered by the scientific community in 1963 and three years later (1966), the Mexican government first set up a "turtle" camp, encompassing 13 km of beach for study and surveillance. This area was gradually extended to twice that length in 1977. When the two nation programme started, between 1978 and 1988, these activities were extended to cover 38 km of beach. Between 1989 and 1990, when they recognised that they were observing an increasing number of nests outside of the controlled area, an extra effort was made and the area under control was doubled. From 1991 to 1996, several temporary camps were built in this zone, thus encompassing over 150 km of beach front. In 1996, the work was officially extended to the state of Veracruz and now covers over 230 km of coastline, where both this and other species of sea turtles nest (Table 1).

Table 1. Evolution of the length of the Kemp´s Ridley (*L. kempii*) nesting beach patrolled and protected.

	Period	From:	To:	+Km	Total
1	1966-67	Brasil Bar	Sn. Vicente Bar	13.4	13.4
2	1968-77	El Tordo Bar	Aparejo Bar	13.3	26.7
3	1978-88	Aparejo Bar	Ostionales Bar	11.6	38.3
4	1989-90	Ostionales Bar	Tepehuajes Bar	9.6	47.9
5	1990-91	Tepehuajes Bar	La Pesca	29.4	77.3
6	1991-	Tordo Bar	Chavarría Bar	42.1	119.4
7	1996-	La Pesca	Enramadas	51.0	170.4
8	1996-	Altamira Beach	Tourist Beach	18.0	188.4
9	2000-	Miramar Beach	Tourist Beach	10.0	198.4
10	1996-	Veracruz state	3 beaches	33.0	231.4

Nos. 1-9 are Tamaulipas State,
+Km = Distance of work added each period

When these activities started, there was an immediate fall in mortality caused by the illicit trade in eggs on the beach. Natural mortality of eggs during nesting was also checked and eggs were transplanted to protected areas (Figure 2) or to incubation pens, thus achieving a hatching survival rate of up to 85% for eggs (annual average of 60-70%). The mortality of hatchlings due to natural predation on the beach was also reduced by protecting them on their journey down to the sea. Since the pro-

Figure 2. Controled incubation area.

gramme started, almost 100% of adults have been protected during nesting.

Since 1973, the Kemp's Ridley turtle has been considered a species in danger of extinction and no licenses have been granted since then for its commercial capture in Mexico. On the other hand, most of the Rancho Nuevo beach was declared a Nature Reserve Zone by official decree (ANONYMOUS, 1977, 1986; MARQUEZ, 1978), and the species is protected throughout its range in Mexico by the Total Prohibition Decree (ANONYMOUS, 1990), which has meant that, in recent years, an increase in the annual number of nestings has been observed in the area of the reserve. However, the major nesting grounds have now been extended, to a stretch of nearly 50 km, from the area known as Barra de Ostionales, to 20 km south of Barra del Tordo, making a modification of the Nature Reserve Zone decree necessary.

OTHER NESTING GROUNDS OF KEMP'S RIDLEY TURTLE

They also nest in Cabo Rojo and between Tuxpan and Tecolutla, Veracruz. Nearly 200 nests are made in this area every year. On Aguada Island, Campeche, there are 1 or 2 nesting events every season. On Padre Island, Texas, small increases in the number of nesting events have been observed each season. In 1978, when the co-operation programme started, between 1 and 3 nestings were recorded per year. In 2002, 35 were observed (SHAVER, com. Per.). Furthermore, there are constant reports of solitary nesting events in Florida, South Carolina, etc., in U.S.A.ç

IMPRINTING AND HEAD-STARTING

As the range of Kemp's Ridley turtle covers both Mexican and American waters, discussions were started in 1977 to carry out joint activities to improve its chances of survival. Thus, the National Fisheries Institute and the Fish and Wildlife Service decided to start an experimental programme with a view to extending the nesting grounds of the species, so the MEXUS-Golfo Programme was started in 1978 with the donation of

2000 eggs to be incubated in the sand of Padre Island beach and the resulting hatchlings were to be released from the beach, and then immediately re-captured and taken to the National Marine Fisheries Service (NMFS) laboratory in Galveston, Texas. The hatchlings would then be reared in the laboratory for 9 to 10 months and then released as juveniles at an appropriate stretch of coast. The experiment was called "Imprinting and Head-starting". In 1988 however, it was considered that "imprinting" was not producing results, so NMFS activities were modified in the following year, 2000, when, instead of donating eggs, 2000 hatchlings, born in Rancho Nuevo, were donated. According to the Turtle Expert Working Group (2000), "our goal is to ensure a nesting population of 10,000 turtles per year before considering up-grading the status of the species to "threatened" under the Endangered Species Act", which is equivalent to 23,000 nests per season.

One important factor was that, from 1978, with the MEXUS-Golfo co-operation Programme, the protection goals and results on the beach were gradually improved, as between 1966 and 1977, an average of 23,300 hatchlings a season were released, and between 1978 and 1987, the figure was 52,500. By 1994, over 100,000 hatchlings a year were released and in 2002, 405,000 hatchlings were released from six camps established in Tamaulipas and one in Veracruz. An intensive tagging campaign has also been carried out on adult females with metal tags and "pit tags" (MARQUEZ, 2001a). Between 1996 and 2000, 40,000 hatchlings were tagged with magnetic wire tags (Table 2). This tagging was done for different purposes, such as studying the dispersion of these creatures, their loyalty to their place of birth, total mortality, recruitment, age of sexual maturity, etc. It is assumed that these turtles will start returning to the nesting beaches sometime after 2005, which will clear up many of the doubts that have been posed.

Table 2. Mass tagging of magnetic wire tags placed to Kemp´s Ridley hatchlings (*L. kempii*), in Rancho Nuevo. (Marquez, 2001a).

YEAR	LOCATION	NUMBER
1996	Right flipper	3,336
1997	Left flip.	10,002
1998	Un-tagged	0
1999	Both flippers	10,010
2000	Right flipper	20,537
TOTAL		**43,885**

EGG DONATIONS

Up to 1992, an essential part of the co-operation programme with USA was to release juveniles reared in the NMFS Laboratory in Galveston, Texas, and hatched from donated eggs. Between 1978 and 1988, 27,157 eggs were donated; between 1989 and 2000, the hatchlings from 14,591 eggs were donated. As a precedent, Mr. Dearl Adams transferred 4,102 eggs from Rancho Nuevo to Brownsville, Texas between 1964 and 1966 (ADAMS, 1966, 1974). In total, this programme donated 45,850 eggs. The following section deals with the hatchlings resulting from the eggs donated to Texas, or those transferred directly from Rancho Nuevo.

DONATION OF HATCHLINGS

Hatchlings were “imprinted” in Padre Island between 1978 and 1988. 18,612 hatchlings were obtained in this period, and they were transferred to the NMFS Laboratory in Galveston for rearing. From 1989 to 2000, the hatchlings sent to Galveston came straight from Rancho Nuevo. There were a total of 9,484. Rearing 2000 hatchlings per year was suspended in 1992 and after 1993, only 200 hatchlings were transferred in the first year, and 180 a year in successive years, until transfers of hatchlings were suspended in 2000. These final hatchlings were not used for “head-starting”, as it is assumed that they were used in a range of behaviour experiments and for assessing the efficiency of TEDs. According to the information available, around 75% of the hatchlings reared managed to reach juvenile sizes (15 to 20 cm straight carapace length), so a total of approximately 22,000 juveniles were released, which are considered to have been recruited into the wild stock and this has slowly been reflected in the number of nestings recorded on Padre Island.

FEEDING

Hatchlings: The composition of the diet during this stage is unknown. In accordance with their pelagic habits, they probably feed on small epi-pelagic organisms.

Juveniles: There is not much information available on this stage of development, as only turtles of over 15 cm carapace length start approaching the coast, where a benthonic stage of feeding is assumed to start (CARR, 1942 y 1952; HARDY Jr., 1962). SHAVER (1991) and MARQUEZ (1994) report that feeding varies from 100% vegetable food to a variety of small crabs, molluscs, shrimps, fish, etc.

Adults: This is the stage that is best known. According to the published literature, this species feeds basically on benthonic crustaceans (*Calappa*, *Callinectes*, *Portunus*, etc.). During their voyages across the open seas, they have been observed feeding off pelagic organisms like fish eggs, tunicates, etc. (SMITH and LIST, 1950; LINER, 1954; MONTOYA, 1966, MARQUEZ, 1970, 1990, 1994 and SHAVER, 1991). MARQUEZ (1994) presents a broad-ranging discussion on what has been found over several decades of studying a wide range of authors.

REPRODUCTION

Fertility: The nesting cycle of a female in a single season can vary from one to 4 or five nests. The annual average goes from 1.7 observed through tagging, to 3.1, directly observing the gonads through laparascopy. Nesting frequency in subsequent seasons gives an almost annual cycle, 1.3 per female (MARQUEZ, 1990, 1994; ROSTAL, 1990). Fertility in terms of the number of eggs per nesting has changed over time. Initially, in 1966, the average was 110.5 eggs per female, increasing to 111.9 in1975, and now females lay 10 o 15 eggs less, 96.8 eggs per female in 1992 (MARQUEZ, 1994) and 93.5 in 2002. According to MARQUEZ (OP CIT.), the explanation could be as follows:

"When conservation measures started in 1966, the recruitment of hatchlings was re-started, but the breeding population continued to age and, therefore, showed a high level of fertility. When young females started to be recruited, the overall fertility of the population started to fall, which was initially observed in 1976 (105.1 eggs), i.e. 10 years after conservation measures were first taken (MARQUEZ, 1994). It can also be noted that, for 1984 (99.6 eggs), a large proportion of the "old" females had been replaced by the new population, indicating that these turtles started to reach maturity in their natural environment between the age of 10 and 18 years."

GROWTH

MARQUEZ (1972), extrapolating rearing and re-capture data for tagged turtles, calculated that the Kemp's Ridley turtle reaches adult size at the age of 6. Later on, in the rearing work done in the NMFS Laboratory in Galveston, Texas, hatchlings reached a straight carapace length (SCL) of 15 to 20 cm in 10 months, and a weight that varies from 300 g to 600 g. Results obtained in rearing experiments done in Grand Cayman indicate that this species can breed at 5 years in captivity, with a size (SCL) of 50 cm and a weight of 25 kg. There is however, a consensus that in general, sea turtles in the wild mature at 15 years. But, for turtles developing in the north east of the Atlantic Ocean, in the Gulf of Mexico, where the waters are warmer, and based on the aforementioned results, a minimum age of 7 years has been determined for reaching sexual maturity (CAILLOUET, com. pers., WOOD and WOOD, 1984). Thus, according to current knowledge, and because Kemp's Ridley is the smallest turtle, it can reach sexual maturity, in the wild, at a minimum age of 7 and a maximum of 15 (MARQUEZ, 1994).

PREDATION

Eggs: There is a high natural mortality rate for nests on the beach, with the coyote as the most efficient predator, followed by skunks, ghost crabs that invade the nests and feed on the eggs (MARQUEZ, 1994). Nests that are transferred to fenced-off areas are mainly affected by crabs and ants. Both "*in* situ" nests and those that are transferred to a fenced-off area are affected by fly larvae, particularly in the days just before the hatchlings emerge from the nest. This mortality has been reduced during incubation by covering the nests with fine mesh netting about two weeks before hatching (MARQUEZ *ET AL.*, 1990).

Mortality in nests that are protected in the fenced-off hatchery, varies annually between 15% and 45%, with an average of 35%. This mortality is due to natural predation, environmental factors of humidity and temperature, and the moment in which the nest is made also has an impact, as does the time it takes to transfer the nest to the hatchery. The fertility of eggs is considered to have been high, as most of the eggs have shown this.

Hatchlings: Natural predators of the hatchlings in the nests include the larvae of carrion fly, ants, occasionally mites and crabs. Once the hatchlings emerge from the nest, they are attacked by crabs, birds (scavengers) on their journey down to the sea. Once in the water, they can fall prey to sea birds and a large variety of carnivorous fish.

Juveniles: There is no information on the total mortality rate among juveniles either in the open sea or close to the coast. According to the information gathered by the Marine Turtle Stranding Network on the coasts of the USA, most juvenile mortality is caused by low temperatures during migrations, mainly along the north east coast of USA, although it has not been duly evaluated.

Adults : Currently, there is practically no natural predation of adults on the beach during nesting. At sea, the odd turtle very occasionally washes up on the shore with signs of having been attacked by sharks when approaching the breeding grounds and off the nesting beaches. Outside this area, adults can also fall prey to sharks, killer whales, etc., although there is no precise information.

TOTAL MORTALITY AND SURVIVAL RATES

As this species is not currently caught commercially, this parameter was determined by analysing the total number of nests produced each season, considering that total fertility does not vary substantially from one year to the next, so, by using the natural logarithm of the total frequency of nests against time, in a linear regression, we find values of -0.0996 for the period 1966-1987, to values of +0.1076 in 1987-2001, for Rancho Nuevo alone, which indicates that there is a clear recovery of the population, so there has been a need to extend conservation activities all along the nesting beach to take in areas that are beyond these limits (Barra del Tordo and Tepehuajes, Tamaulipas). Table 3 and Figure 3 consider the slope to be equivalent to total mortality Z (DOI, 1974) and the survival rate (S) is calculated from the equation $S=e^{-Zt}$.

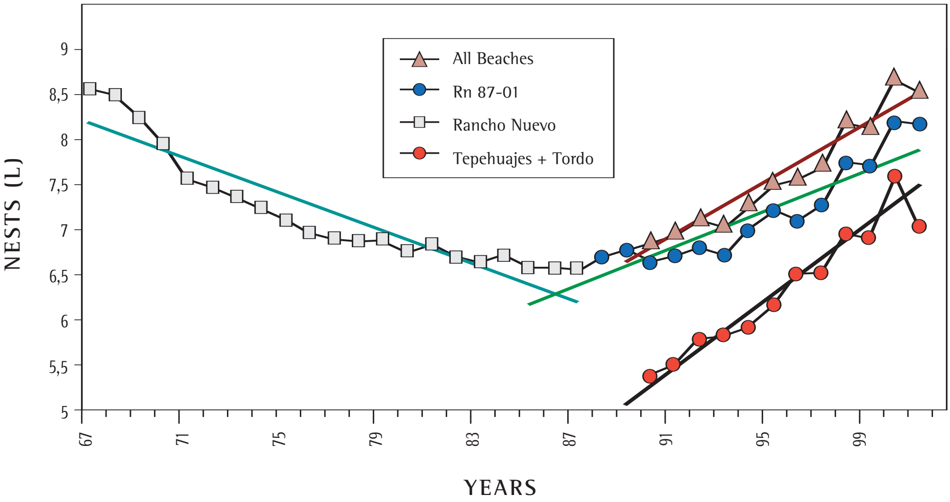

Figure 3. Kemp´s Ridley (*L. kempii*) nesting trend in breeding beaches of México (1967-2001).

Table 3. Mortality (Z) and Survival (S) rates of Kemp´s Ridley (*L. kempii*), derived from the nesting abundance.

PERIOD	SLOPE = Z	B	R
Rancho Nuevo 66-87	-0.0996	8.439	0.92
Rancho Nuevo 87-01	0.1076	4.052	0.9
All the Camps	0.1614	2.778	0.96
Barra Tordo+Tepehuajes	0.2031	0.217	0.97

$S = e^{-Zt}$	Survival
Rancho Nuevo 66-87	0.905
Rancho Nuevo 87-01	1.114
All the Camps 90-01	1.175
Barra Tordo+Tepehuajes 90-01	1.225

MIGRATION

Hatchlings: Their distribution is unknown, once they reach the sea. But, they are considered to have pelagic habits, like other species, which have been found in small numbers, associated with rafts of floating alga and in areas where marine fronts form. It has been observed that, once they have gone beyond the surf zone, the hatchlings move perpendicularly away from the coast until they are lost from sight. When the hatchlings emerge from the nest and are immediately taken for rearing, they will accept no food for the first two or three days, when they have exhausted their reserves of egg yolk. The remains of yolk are considered to be a food reserve, which enables the hatchlings to start their migration and reach the areas where they will have to search for food. For this reason, it is not advisable to keep newly born turtles in captivity just for a few days, as this would affect this adaptive behaviour.

Juveniles: Migration patterns during this stage are unknown. The only thing that is known is that, once they reach a carapace length (SCL) of between 15 and 20 cm, they are seen again in coastal waters. It is important to mention that on the coasts of Virginia and Chesapeake Bay, (USA), juvenile specimens are found every year that are apparently trapped in cold waters during the winter and are washed up on shore either dead or dying. BYLES (1989) assumes that some individual, between 30 and 45 cm, can head back south in autumn, in search of more temperate waters, and some even return to the Gulf of Mexico.

Adults: One of the most wide-spread methods used for determining turtle dispersion after breeding is tagging. Tags can be made of monel steel, inconel (nickel-copper), titanium or electronic tags, known as "pit-tags" (passive integrated transponders). Turtles are tagged during nesting and, if they are re-captured outside this area, this fact is expected to be reported. This system was used while restrictions on commercial or incidental catch were not very strict, but, after 1988, tag returns have been almost non-existent. Information from re-captures has shown that, after nesting, females head north and south from Rancho Nuevo in similar proportions, and that this migration takes place in the coastal strip (CHAVEZ, 1967, 1968; PRITCHARD and MARQUEZ, 1973; CHAVEZ and KAUFMAN, 1974; MARQUEZ, 1990, 1994). In recent years, radio-satellite tags have confirmed the results obtained from using conventional tags (BYLES, 1989) (Figure 4).

ENVIRONMENTAL PARAMETERS

In collaboration with the Alabama University Laboratory of Biology, environmental and incubation temperatures have been recorded each season since 1998, using digital

Figure 4. Distribution of Kemp's Ridley turtle *(L. kempii)*, nesting and feeding grounds and possible Migration routes (Marquez , 2001b).

sensors (data loggers). Thus, a record has been kept of 20 nests per incubation hatchery in the three main camps. From each nest, blood samples are taken from 10 hatchlings, in order to determine the sex. At the end of the incubation period, all the data loggers are sent to Alabama and the recorded temperature information is sent back in the form of condensed tables. The information is analysed jointly, and the conclusion is that the sex ration is weighted in favour of females in the hatchlings produced this way. In the 2001 season, 21 nests were analysed, of which, 12 produced 100% females, 8 were clearly biased in favour of females and only one predicted the birth of males. In comparison with the hatchery nests, the temperature of 10 "in situ" nests was slightly lower, but enough to produce more females than males. (Wibbels and Geis, 2001).

EVALUATION OF ACCIDENTAL CAPTURES

Incidental capture occurs mainly with sub-adults and adults, due particularly to their benthic habits, during feeding (MARQUEZ, 2001b). It is a problem for juveniles when they come in close to the coast and start feeding on benthic organisms.

Table 4 shows the results of different forms of re-capture for female Kemp's Ridley turtle, tagged on the nesting beach, between 1966 and 1988 (MARQUEZ, 1994) and in juveniles reared, tagged and released by the NMFS Laboratory in Galveston, Tx., between 1979 and 1988 (MANZELLA *ET AL.*, 1988), showing that the greatest incidence occurs during shrimp fishing, both for juveniles and for adult females. The next most prejudicial fishing technique is the gill-net for fish and sharks, generally on the bottom, when these are place in feeding grounds or off nesting beaches.

Table 4. By-catch of Kemp´s Ridley (*L. kempii*), females (1966-88) and juveniles (1979-88).

Method	Adults +		Juveniles #	
	%	No.	%	No.
Gill-net	7.91	14	3.6	17
Shrimp trawler	71.19	126	27.6	132
Fish trawling	1.69	3	-	-
Swimming	-	-	0.8	4
Hook	1.13	2	5.7	27
Beach net	1.13	2	0.2	1
Sports fishing	2.26	4	-	-
Purse seine net	0.56	1	-	-
Bag net	-	-	1.1	5
Atarraya	-	-	0.4	2
Butterfly nets	-	-	0.4	2
Crab trap	-	-	0.2	1
Live stranding	-	-	10.0	48
Dead stranding	8.47	15	24.3	116
Nesting *	0.56	1	-	-
Unknown	5.08	9	25.7	123
Totals	**100**	**177**	**100**	**478**

* Supposedly found nesting in Santa Marta, Colombia.
+ Marquez, 1999, # Manzella et al., 1988.

The geographic distribution of these populations is of vital importance with regard to the impact of fishing techniques and because distribution is not homogenous in either space or time. The effectiveness of TEDs to release turtles alive can vary enormously and in some cases their use is unnecessary, inadequate or unjustified, whereas, in other cases they should be compulsory either for some times of year, or for the whole year, in limited areas and in some areas, shrimp trawling should be banned during the nesting and foraging seasons.

When fishing with trawl nets or long lines, live turtles are often pulled aboard, which can be returned to the sea, but they should be carefully examined before releasing them, as they can die later if they present "serious physical traumas" on release, or if they have swallowed a hook or if they are released before they have overcome the stress that occurs during capture.

A detailed study has been carried out by JOHNSON *ET AL.* (1999), on incidental capture in pelagic fishing with long lines by USA boats in the Atlantic. This indicates that the incidence of sea turtles is greater than for mammals. Between 1992 and 1997, 516 turtles were caught in 229 times that the lines were set, breaking down as follows: *Caretta caretta*, 271; *Dermochelys coriacea* 215; *Chelonia mydas* 15; *Eretmochelys imbricata*, 2 and *L. kempii* 2, that is, 2.25 turtles every time the nets or lines are set.

The need to reduce incidental death from being caught on a long line or in a net of some kind is now a top priority to promote the survival of some marine turtle species, so the necessary studies cannot be postponed further.

PROTECTING THE ENVIRONMENT

The beach where Kemp's Ridley turtle most often nests is considered a nature reserve for their "protection, reproduction and development" (ANONYMOUS, 1977, 1986; MARQUEZ, 1978), but, with the knowledge available today, the reserve does not adequately cover the entire area used by the species during breeding. Moreover, it is ambiguous concerning protection for the adjacent waters and for the terrestrial strip, which is not large enough to project the nesting grounds and prevent their degradation. For this reason, there is a need to review the decree and make it more appropriate for the current situation.

REARING AS A CONSERVATION TOOL

Apart from imprinting hatchlings and their intensive rearing ("imprinting and head-starting"), the co-operation programme between Mexico and the USA considered there was a need to carry out an emergency project with the Cayman Turtle Farm (1983 Ltd. (CTF) and the INP, due to the rapid decrease in the population of Kemp's Ridley turtle, involving a programme for rearing and breeding in captivity for this species, which was established with the following objectives:

1. On the 4th of July 1980, the INP and the CTF started a joint programme to establish a breeding colony in captivity. The stock would eventually be returned to Mexico.
2. Use the experience to learn the best method for rearing turtles in captivity.
3. Produce Kemp's Ridley turtles for release in the wild in Mexico.

To start the programme off, 100 juvenile turtles (1 year old) from the NMFS Laboratory in Galveston, Texas, and 100 newly-born hatchlings from Rancho Nuevo, Tamaulipas were transferred to the farm. 2 juveniles and just over 30% of the hatchlings died during the transfer.

Despite the teething troubles, breeding the species in captivity was a complete success and, as a result, two juvenile turtles, on reaching the age of 5 (1984), started breeding, which increased in subsequent years (7 females in 1987), so by 1994, the farm had over 476 turtles of different ages (30 breeding turtles of 14 years old and 446 turtles aged between 1 and 5, born on the farm). Due to administrative changes in the Farm, and because it was considered that the programme had attained its goals, the decision was taken to suspend breeding in 1994, so the total number of Kemp's Ridley turtles gradually diminished until it reached just over 300 turtles of different ages and a search was started for alternatives for repatriating them.

In 1997, negotiations were started for reaching an agreement between the CTF and the INP and Promotora Xcaret S.A. for repatriating as many Kemp's Ridley turtles as possible to the Xcaret Eco-Archaeological Park, located in the state of Quintana Roo, México, defining a protocol of actions at the same time, based on the state of health, physical characteristics, age and sex of the turtles.

A visit was made to the farm in 1998 to make a pre-selection of turtles to be repatriated, sampling 30% of the total population, to study their health status with a physical examination, blood tests, bacteriological and parasite tests. The tests were done on the island of Grand Cayman and the results of the blood tests on some of the turtles revealed certain damage to organs like the liver, skeletal muscle and/or miocardium, possibly caused by chronic diseases or septicaemia. The bacteria found in cultures included *Salmonella sp., Escherichia coli, Vibrio fluvialis, Aeromonas caviae, Serratia marscescens*, the presence of which is considered normal in reptiles (D´Amiano, com. pers.). Parasitological checks were negative for pathogenic organisms.

A visual selection was made in 1999, to determine the exact number of turtles to be repatriated: 57 females and 53 males, which had to be kept in isolation. For this reason, a quarantine area was prepared in the "Xcaret" facilities. The turtles were finally transported on the 10th of April 1999. The preliminary handling that was done consisted of measuring the carapace (length and width), they were weighed and tagged with metal tags. The turtles were placed in individual wooden crates for transport, and they were identified in accordance with their health status, thus separating the clinically healthy animals from those that required immediate daily treatment, in order to monitor their rehabilitation.

During quarantine, new studies were done on the state of health of the turtles and on the outlet waters from the different pools. Three months later, the 57 females were measured, weighed and "pit tags" were placed on them. All these turtles are presently under observation and their feeding is strictly controlled (using a balanced diet), as is their health. Up until 2001, three animals died from different causes. In the 2002 breeding season, 18 nests were built (with 58 eggs on average), of which, two produced 22 viable hatchlings (Arenas, com. pers.). It must be pointed out that, in a similar fashion, in the breeding observed in the first generation of green turtles (*Ch. mydas*) obtained and kept in captivity in the CTF, there was also low fertility initially, which increased over time (Wood, com. pers.). A similar trend is expected with the Kemp's Ridley turtles kept in Xcaret.

CONCLUSIONS

The programme for the Kemp's Ridley turtle (*L. kempii*) was started in 1966 in Rancho Nuevo, Tamaulipas, and 13.5 km of beach were patrolled on foot each day to collect nests, record biological data and tag turtles. Progress was slow up until 1977, releasing an average of 20 to 25 thousand hatchlings a year. In 1978, a programme was started in co-operation with USA, and the number of protected hatchlings was rapidly increased, along with the length of beach patrolled, using motorised transport. Up until 1987, the population of mature females continued to decline. Between 1985 and 1987, the annual average was 740 nests (each female produces 2.3 nests per season). Ten years after the co-operation programme started (1988), the population started to grow, so that by 2002, 6,325 nests were protected, which produced 405,000 hatchlings, released from the beaches of six camps set up in Tamaulipas and one in Veracruz.

The causes for the increase in the Kemp's Ridley turtle population? Historically, nesting probably extended from Texas down to Veracruz. The protection work started in 1966 has led to a gradual re-colonisation of the previous natural range of these animals. Temperature studies indicate that more females are born, which accelerates recruitment. As shark populations have declined, recruitment has probably also increased. The use of TEDs has been compulsory for USA since 1992 and for Mexico since 1994. The range of these conservation activities has been continually extended, from 13.5 km in 1966, to 230 km now, and there is now and Investigation Centre for this work, and 6 camps are set up to cover all the nesting beaches.

The Co-operation Programme between Mexico and USA included experimental "imprinting and head-starting" activities. The project covered a period from 1978 to 1992, making a donation of an average of 20 nests per year. These nests produced a total of 27,738 hatchlings. From 1993 to 2000, hatchlings were donated, instead of eggs (1,460), for behavioural experiments related to the use of TEDs. So far, the programme has included a total of 29,198 hatchlings, which were kept in captivity for 9 to 10 months and the surviving turtles were released in suitable areas. 85% of the hatchlings were "imprinted" on Padre Island, Texas, and the rest in Rancho Nuevo. On average, a survival rate of 75% was obtained, from the time the hatchlings reached the Laboratory in Galveston, Tx., until their release. A large proportion of turtles from the experiment have been re-captured in good health, and some have nested on Padre

Island. In 2002, 35 nests of this species were found; some were made by turtles from this experiment.

The Kemp's Ridley turtles, both juveniles and hatchlings, taken to the Grand Cayman Turtle Farm in 1980 adapted successfully to captivity, and started breeding at 5 years. Initially, only a few eggs were produced, and these were not very fertile, although the situation improved as the turtles grew older, so that by 1994, the farm had 476 turtles of different ages (30 14-year old breeding females and 446 turtles between 1 and 5 years old, born on the farm). The Farm considered that the objectives had been attained and, as the wild population was showing signs of recovery, they could not justify keeping these turtles in captivity, so Mexico was asked to repatriate them. Measures were adopted and the Eco-Archaeological park of Xcaret built facilities for keeping them. On the 10th of April 1999, 110 turtles (57 females and 53 males) were transferred to Xcaret, where they quickly adapted to their new surroundings and the survivors are now starting to breed.

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REFERENCES

ADAMS, D. 1966. More about the Ridley Operation: Padre Island, egg transplanting. *Int. Turtle and Tortoise Society Jour*., 1(1):18-20, 40-43, 45.

ADAMS, D. 1974. The saga of a turtle named Alpha. *Tip-O-Texan*, 9(5):18-19.

ANONYMOUS. 1977. "Acuerdo que establece la Zona de Refugio y Veda para la Protección de la Tortuga Lora". Departamento de Pesca. *Diario Oficial de la Federación*, 4 de julio de 1977. 5pp.

ANONYMOUS. 1986. "Decreto de Zonas de Reserva y Sitio de Refugio para la Protección, Conservación, Repoblación, Desarrollo y Conservación de la Diversas Especies de Tortugas Marinas". Departamento de Pesca. *Diario Oficial de la Federación*, 29 de octubre de 1986. pp. 8-10

ANONYMOUS. 1990. "Acuerdo por el que se establece veda para las especies y subespecies de tortuga marina en aguas de jurisdicción federal del Golfo de México y Mar Caribe, así como en las del Océano Pacífico, incluyendo el Golfo de California". SEPESCA. *Diario Oficial de la Federación*, México, 31 de mayo de 1990. pp. 21-24

BYLES, R.A. 1989. Satellite telemetry of Kemp's Ridley sea turtle, *Lepidochelys kempi*, in the Gulf of Mexico. Proc. 9th Ann. Turtle Workshop Sea Turtle Conservation and Biol. *NOAA Tech. Mem.* NMFS-SEFC-232:25-27

CARR, A.F. 1942. Notes on sea turtles. *Proc. New England Zool. Club*, 21:16p

CARR, A.F. 1952. Handbook of turtles of the United States, Canada and California. *Ithaca, Comstock Pub. Asor., Cornell Univ. Press*. 542p

CARR, A.F., 1963. Pan-specific reproductive convergence in *Lepidochelys kempi*. *Ergebn. Biol*.., 26:298-303

CHAVEZ, H. 1967. Nota preliminar sobre la captura de ejemplares marcados de tortuga lora *Lepidochelys kempii. INP, Bol. Prog. Nal. Marcado Tortugas Marinas*, 1(6): 1-5

CHAVEZ, H. 1968. Marcado y recaptura de individuos de tortuga lora, *Lepidochelys kempi* (Garman). *Pub. Inst. Nal. Inv. Biol. Pesq*., 19:28p

CHAVEZ, H. Y R. KAUFMAN. 1974. Información sobre la tortuga marina *Lepidochelys kempi* (Garman), con referencia a un ejemplar marcado en México y observado en Colombia. *Bull. Mar. Sci*., 24(2):372-377

DOI, T. 1974. Part II. Outline of mathematical analysis on fish populations for practical use in front. *In: Fisheries Biology and Population Dynamics of Marine Resources*. 106-210

HARDY, J.D. JR. 1962. Comments on the Atlantic Ridley turtle, *Lepidochelys olivacea kempii*, in the Chesapeake Bay. *Ches. Sci*. 3:217-220.

HILDEBRAND, H.H. 1963. Hallazgo del área de anidación de la tortuga "lora" *Lepidochelys kempi* (Garman), en la costa occidental del Golfo de México (Rept., Chel.). *Ciencia*, México, 22(4):105-112.

HILDEBRAND, H.H., 1981. A historical review of the status of sea turtle population the Western Gulf of Mexico. In: Biology and Conservation of Sea Turtles. *Proc. World Conf. of Sea Turtle Conserv*., Washington, D.C., Nov. 26-30, 1979. (Ed. Bjorndal, K.) 447-453.

JOHNSON, D.R., C. YEUNG Y C.A. BROWN, 1999. Estimates of marine mammal and marine turtle by-catch by the U.S. Atlantic Pelagic Long line fleet in 1992-1997. *NOAA Tech. Mem*., NMFS-SEFSC-418:70p

LINER, E.A. 1954. The herpeto-fauna of Lafayette, Terrebone and Vermillion parishes, Louisiana. Louisiana *Acad. Sci*. 17:65-85

MAGER JR.,A., 1985. Five year status reviews of sea turtles listed under the Endangered Species Act Off. 1973. *NOAA, NMFS*, U.S. Print Off., 90pp.

MANZELLA, S.A., C. CAILLOUET JR. Y C. FONTAINE. 1988. Kemp´s Ridley, *Lepidochelys kempi*, sea turtle head start tag recoveries: Distribution, habitat, and method of recovery. *Mar. Fish. Rev.*, 50(3):24-32

MARQUEZ-M., R. 1970. Las tortugas marinas de México, I.P.N., Escuela Nacional de Ciencias Biológicas (Tesis Prof.), 106p

MARQUEZ-M., R. 1972. Resultados preliminares sobre edad y crecimiento de la tortuga lora *Lepidochelys kempi* (Garman). *Mem. IV Cong. Nac. Oceanog*. México, D.F., 17-19 Nov. 1969; 1972 p. 419-427

MARQUEZ-M., R. 1978. Natural reserves for the conservation of marine turtles of Mexico, In: *Proc. Fla. Interreg. Conf. on Sea Turtles*, July 24-25, 1976. Fla. Mar. Res. Publ., 30:56-60

MARQUEZ-M., R. 1990. FAO Species Catalogue. Vol. 11: Sea turtles of the World. An Annotated and Illustrated Catalogue of Sea Turtle Species known to date. *FAO Fisheries Synopsis*, 125(11):81p.

MARQUEZ-M., R. 1994. Sinopsis de datos biológicos sobre la tortuga lora *Lepidochelys kempi* (Garman, 1880). *FAO Sinopsis sobre la Pesca*, No. 152. SASR-Tortuga Lora 5.31(07)016.02, 141pp

MARQUEZ–M., R. 2001a. Las tortugas marinas de México. Las Tortugas Marinas en Campeche – Colectiva. *Ecología* – Campeche XXI. p: 33-49

MARQUEZ–M., R. 2001b. Estado de la conservación y distribución de la Tortuga Lora, *Lepidochelys kempii*, en la Región del Gran Caribe. *En*: Eckert and Abreu Eds. Conservación de Tortugas Marinas en la Región del Gran Caribe – Dialogo para un Manejo Regional Efectivo, Sto. Domingo, 16-18 Nov. 1999. WIDECAST, UICN/CSE Grupo Especialista en Tortugas Marinas, WWF y *Programa Ambiental del Caribe PNUMA*. XXI+170pp

MARQUEZ-M., R. y Fritts, T.H., 1987. Prospección aérea para tortugas marinas en la costa mexicana del Golfo de México y Caribe. 1982-1983. *INP-CRIP Manzanillo*, *Bol. Inf.*, 8:22-46.

MARQUEZ-M., R., A. VILLANUEVA-O., M. SANCHEZ-P., J. VASCONCELOS- P., J. DIAZ-F., A. ZAVALLA-C., M. CARRASCO-A. E I. ARGÜELLO-V. 1990. Memoria anual de actividades realizadas en el campamento tortuguero de Rancho Nuevo, Tams., 1989. Tortuga lora, *Lepidochelys kempi*. *Proyecto CONACyT* P22OC-COR880571 "Investigación y Evaluación de la tortuga lora, *Lepidochelys kempi*, en Rancho Nuevo, Tams.

MONTOYA-E, A. 1966. Programa Nacional de Marcado de Tortugas Marinas. *SIC, Inst. Nal. de Inv. Biol. Pesqueras*. México Pub. 34pp

PRITCHARD, P.C.H. Y R. MARQUEZ-M. 1973. Kemp´s Ridley or the Atlantic Ridley, *Lepidochelys kempi* (Garman). *IUCN Monogr*. (Marine Turtle Ser.)., 2:30p.

ROSTAL, D. 1990. The reproductive behaviour and physiology of the Kemp´s Ridley sea turtle, *Lepidochelys kempi* (Garman, 1880). *Texas A & M Univ.*, (Thesis), 138p

SHAVER, D.J. 1991. Feeding ecology of wild and head-started Kemp´s Ridley sea turtles in south Texas waters. *J. Herp*. 25(3):327- 334

SMITH, P.W. Y J.C. LIST. 1950. Notes on Mississippi amphibians and reptiles. *Amer. Midland Naturalist*, 53(1):115-125

TURTLE EXPERT WORKING GROUP. 2000. Assessment update for the Kemp´s Ridley and loggerhead sea turtle populations in the western North Atlantic. *NOAA Tech. Mem*. NMFS-SEFSC-444:115pp.

WIBBELS, T Y A. GEIS. 2001. Evaluation of sex ratios of Kemp´s Ridley hatchlings from natural and relocated nests at Rancho Nuevo, Mexico. Report to the Instituto Nacional de la Pesca, December 2001. University of Alabama at Birmingham. 27pp.

Wood, F.E. y J.R. Wood. 1984. Captive breeding of Kemp's Ridley. *Mar. Turtle Newsletter*, 29:12.

Translocating turtles:
trials, tribulations and triumphs

NICHOLAS MROSOVSKY

ABSTRACT

This paper reviews attempts to translocate sea turtle eggs or hatchlings from their normal natal beaches to currently unoccupied potential nesting beaches, in the hope of establishing colonies in those places. Among topics considered are sex ratio, imprinting, headstarting, and the use of living tags.

> *The trouble is nobody knows how a new resident colony is formed.*
>
> CARR,1984.

> *One of the most urgent limitations which have frustrated students of sea turtle ecology... has been the inability to affix a permanent mark on the animals... The problem has been one of finding a tag which will serve on a growing (from 20 or 30g to 100 kg), developing animal.*
>
> HENDRICKSON and HENDRICKSON, 1986.

INTRODUCTION

A workshop held in December 2002 in Fuerteventura, Spain, considered the possibility of introducing or reintroducing nesting sea turtles to beaches on the Canary Islands by moving eggs or hatchlings from currently used beaches in the Cape Verde Islands. I am in favour of experimentation if carefully carried out and designed in a way permitting evaluation. We need more information on when and why turtles return to their natal beaches, and on what factors influence the strength of philopatry. Testing whether turtles can be induced to nest on beaches other than their natal ones might provide guidance in advance of global warming and sea level rise.

In this context, there follow brief accounts of some past attempts at reintroduction and translocation of turtles. We can learn from these endeavors. “Today is yesterday’s pupil” (THOMAS FULLER).

Transplanting green turtle eggs

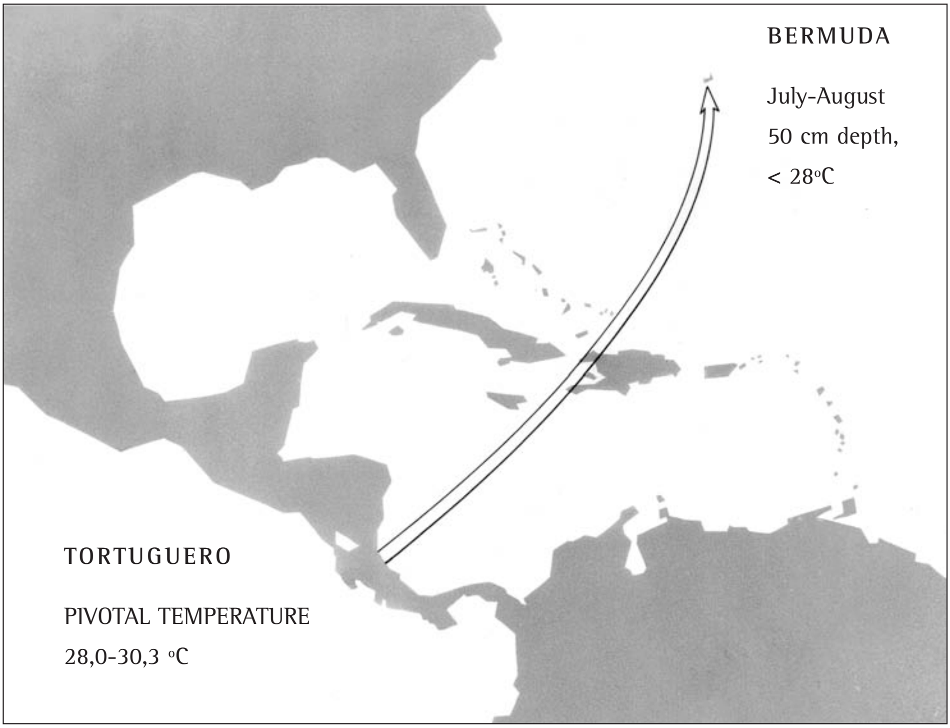

Figure 1. Illustration of the need to consider thermal effects on sex ratio when transplanting eggs.

BERMUDA

Between 1967 and 1977, more than 24,000 green turtles eggs were taken from Tortuguero, Costa Rica, and placed in hatcheries in Bermuda. The eggs were buried at about the same depth as green turtle clutches in nature. The great majority of the resulting hatchlings were released; a small percent were kept for headstarting (BURNETT-HERKES, 1974). The hope was that exposure to Bermudan sand during a sensitive early stage of development would create a lasting preference for stimuli (presumably chemical but possibly magnetic) characteristic of that location, ie that they would become imprinted to those stimuli, causing them to return to their natal area when it came to laying. To the best of my knowledge, these actions have not resulted in restoration of nesting turtles on Bermuda. If that had occurred, the event would surely have been reported and heralded as important.

Quite apart from whether imprinting to Bermudan sand was effective or not, there is a good reason for the failure to establish nesting females on beaches there: probably all or nearly all the turtles hatched on Bermuda were males. It is estimated from field studies of Tortuguero green turtles that their pivotal temperature, the constant temperature producing 50% of each sex (MROSOVSKY AND PIEAU, 1991), lies between 28.0 and 30.3°C (STANDORA AND SPOTILA, 1985). From what readings were taken in Bermuda, it would seem that the sand temperature at 50 cm depth in the hatcheries there did not exceed 28°C, and was therefore on the male side of the pivotal temperature.

The basis for the information given above on translocations to Bermuda comes from personal communications in 1982 from D.B.Wingate to the present author. Temperature was not measured over many seasons. Moreover, perhaps some of the eggs ended up shallower than 50 cm (top of clutches); greater daily cycles of temperature at shallower depths could have had some feminizing influence (GEORGES ET AL., 1994). Therefore, it is not asserted that no female turtles were produced. Nor is it asserted that warmer places in Bermuda could not be found. However, from what information I have been able to glean, it seems likely, even though most of the eggs were buried in August, among the warmest months of the year in Bermuda, that the sand temperatures would have generally been in the male producing range. Mean incubation times in excess of 70 days for most of the years are consistent with this, because incubation takes longer when it is cool (cf Figure 12 in MROSOVSKY ET AL., 1984; Figure 7 in STANDORA AND SPOTILA, 1985).

In addition, in 1981, 3048 green turtle eggs from Suriname were taken to Bermuda and buried there on 12 June at which time the sand was 21°C; even in early August it was still only 25°C (ANON, 1982). Low temperatures probably contributed to the poor hatch rate (11.4%). Almost certainly all the turtles that did hatch were males.

LESSONS

(1) The first lesson that can be learned from the Bermuda project is that sex ratio needs to be taken into account in transplantation attempts (Figure 1). Although the influence of temperature on sex ratio was documented in freshwater turtles by PIEAU (1971) soon after the start of the Bermudan project, the phenomenon

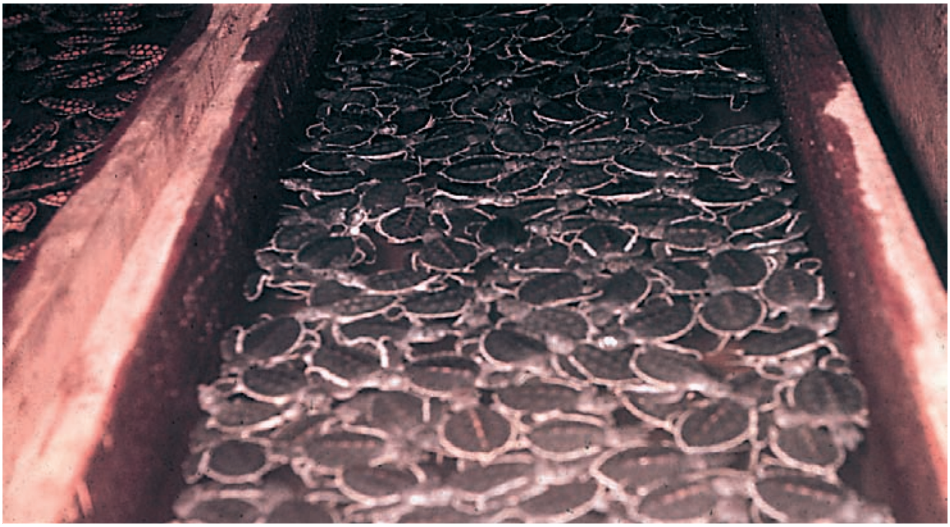

Figure 2. Hatchling green turtles, Tortuguero, Costa Rica, 1965, awaiting translocation to elsewhere in the Caribbean as part of Operation Green Turtle. The exact ages of different batches of turtles, and the stimuli they experienced, have not been published.

was not widely known in the sea turtle community at that time, and was not demonstrated in sea turtles until 1979 (Yntema and Mrosovsky, 1979).

(2) The second lesson is that failure to publish and disseminate the results of what few investigations of temperature were done makes it hard to assess the negative result. Information on conditions before and during transport are also lacking, as are accounts of what patrolling of the Bermudan beaches was undertaken. The absence of details in the public domain becomes an even more salient deficiency when considering Operation Green Turtle from which the transplantations to Bermuda were an outgrowth.

OPERATION GREEN TURTLE

Green turtle hatchlings were taken from Tortuguero, Costa Rica, and released at a number of beaches in the Caribbean where turtles were thought to be currently absent (for a popular account, see Carr, 1984).

A critique of this experiment has been given elsewhere (Mrosovsky, 1983). Details of the apparent inconsistencies and gaps will not be repeated here. If the imprinting hypothesis is to be taken seriously, then information on what stimuli the turtles were exposed to, and at what ages, should be provided (Figure 2). The general point about Operation Green Turtle is that "its failure as science is not that the results are negative but something quite different: the lack of adequately reported details of what actually was done. It is like a scientific paper with no methods section" (MROSOVSKY, 1983). Had turtles appeared on some of these beaches since, even that would have been hard to assess without provision of evidence that none were nesting there previously. As the saying goes, absence of evidence is not evidence of absence.

An abstract on Operation Green Turtle has appeared since (ELIAZAR ET AL., 1998). The number of hatchlings released is given at over 130,000, distributed to 17 different countries. Despite no known nesting resulting from this effort, it was considered a success in that it raised awareness about sea turtles.

LESSONS

(1) The main lesson to be learned from Operation Green Turtle is that little can be learned from it because of inadequate documentation. This is an extremely important point, especially for any long-term project. If this lesson is learned, perhaps Operation Green Turtle can be considered a success on that basis, as well as being a "venture in public relations" (CARR, 1984).

PADRE ISLAND AND KEMP'S RIDLEY

Eggs of Kemp's ridleys (Figure 3) have been taken from what was then the only known major nesting beach for the species, that at Rancho Nuevo, in Tamaulipas, Mexico, and sent to Padre Island, Texas, USA. The transport of these eggs to Padre Island took place at various stages of development. In an attempt to maximize the possible chances of imprinting to Padre Island stimuli, no contact with Mexican sand was permitted: the eggs were incubated in sand from Padre Island only.

After hatching, the turtles were released on Padre Island, allowed to crawl into the surf, and then retrieved (a few escaped). Most were taken to Galveston, Texas, for head-starting, that is rearing them in captivity and then releasing them at a size greater than

Figure 3. Kemp's ridley nesting at Rancho Nuevo, Mexico, in 1985, the year when numbers there reached their lowest level. No other turtles were nesting within sight of this one.

that of hatchlings. Thus the project had two main components, imprinting and headstarting; these two were combined for most of the turtles. A detailed account of the work on Kemp's Ridley at Padre Island appears in Shaver (this volume). However, as there is more information about this turtle translocation than any other, its findings merit commentary and scrutiny by those considering attempts to establish new nesting colonies.

Headstarting: Kemp's ridleys released as yearlings have returned to nest. This establishes that headstarting does not necessarily prevent turtles from surviving and reproducing. Whether headstarting is superior to other conservation measures, and whether it is the most cost effective, are much harder matters to assess.

The pendulum has swung back and forth about the merits of headstarting. Originally it was considered by many as a recommended and needed measure. From that early enthusiasm opinion generally has become negative, an extreme form of which is exemplified in the statement:

"Headstarting should not be utilized in any circumstance as a means of conserving sea turtles. Headstarted turtles are in no better position than their "natural" counterparts. They are not capable of escaping predators. They become accustomed to humans which can be fatal when in the wild. Even more it is not confirmed that they eventually return to their natal beach and succeed to reproduce" Anon, 1996).

Ironically, this appeared in the year when the first return of a headstarted turtle to nest was reported – from the Kemp's ridley programme (Shaver, 1996). But the author of the words quoted above is in good company. Headstarting receives hardly any mention in an IUCN/SSC manual of techniques for conservation of turtles (Eckert et al., 1999).

The demonstration that headstarted turtles can reproduce should perhaps swing opinion back somewhere toward the middle ground of reserving judgement. After all, there is an attractive rationale for headstarting. As Carr (1984) put it:

"Theoretically, it ought to be possible to reduce natural predation on young sea turtles by artificially incubating eggs and rearing the hatchlings to a size too big for the enemies to eat. This seems a promising thing to try, but it will take a great deal of experimentation to show whether it really accomplishes the purpose".

My own doubts about headstarting have concerned not so much the amount of work that might be required but the difficulty in evaluating the attempts made so far (Mrosovsky, 1983; see also Buitrago, 1981; Pritchard, 1981). Definition of the aims at the start of projects has been inadequate; precise formulation of criteria for success has been delayed in coming (Wibbels et al., 1989a; Eckert et al., 1992).

<u>Imprinting: turtles exposed as embryos to Padre Island sand have returned to nest there</u>. We must distinguish between the imprinting manipulations made (exposure to sand at early stages of life history, etc.) and the assumptions about their effects (that there is a biological process whereby such manipulations result in a tendency to return to beach with that sand). The return of a turtle that was subjected to imprinting manipulations does not prove that imprinting as a biological process was responsible.

Some problems with imprinting as an explanation for the results from Padre Island project are:

(1) Two turtles that had nested at or near Rancho Nuevo were also seen either subsequently or previously on the beach at Padre Island (SHAVER AND CAILLOUET, 1998). These turtles were not linked to the imprinting or headstarting procedures, although this cannot be ruled out if the possibility of tag loss is kept in mind. In any case, these 2 cases show that choice of nest site is not ineluctably determined by experiences at an early stage of development.

(2) In 2002, among the nesters on Padre Island, there were 2 headstarted turtles that had not been exposed to Padre Island sand but to Mexican sand (SHAVER, this volume). A third turtle exposed to Mexican sand nested at Galveston, Texas. If imprinting as a biological process had occurred, these turtles should have nested in Mexico.

(3) Nesting Kemp's ridleys have recently been seen along the coast of Florida (review in JOHNSON ET AL., 1999; there may be some more recent instances). Nests have also be laid in North and in South Carolina (PALMATIER, 1993). The Atlantic coast of the USA is outside the known historical nesting range of this species. JOHNSON ET AL. (1999) propose that we may be witnessing the initial stages of the formation of a new colony of this species in Florida. They argue that with daylight nesting, Kemp's ridleys emerging on these beaches in the past would not have been totally missed. The nesting at Padre Island might, however, in part reflect increased monitoring. The number of ridleys seen on Padre Island shows some positive relationship with the amount of patrolling (SHAVER, this volume).

Even if sampling artefacts at Padre Island are discounted, that does not mean that imprinting must have been responsible. An alternative explanation to imprinting for the nesting at Padre Island is that it results from a general increase in the number of Kemp's ridleys and an associated expansion of nesting range (JOHNSON ET AL., 1999; MROSOVSKY, 2000).

Against this explanation must be set the point that out of 47 turtles that were actually seen on Texan beaches, 40.4% had tags linking them to the Padre Island imprinting; 6.4% had experienced Mexican sand as embryos and hatchlings (SHAVER, this volume). This suggests that there is something more than expansion of range at work. However, it is also conceivable that the high percentage of project turtles among the Padre Island nesters comes about through a quasi random wandering. Turtles released at or near Padre Island might disperse somewhat on entering the sea. Some might get as far as Florida, but if movements were not directed in any particular direction in the Gulf of Mexico or Atlantic, more might find themselves still in the general vicinity of Padre Island when they became mature enough for breeding. This suggestion is not negated by a more widely dispersed pattern of tag returns because whether a turtle is caught and a tag noticed and returned is not an unbiased way of determining distribution. So it remains possible that when ready to lay, the turtles from this project might have tended to nest on the nearest available shore, that is the higher percentage of headstarted turtles out of those at Padre Island may reflect a breakdown in orientation more than imprinting. That would still be satisfactory for those who are concerned only that there be more Kemp's ridleys on Padre Island. For those who want to understand the underlying mechanisms, with a view to applications in other areas, it is unsatisfactory.

Unfortunately it is not easy to test for the existence of imprinting of this kind in turtles, and actual data on the topic are few. An experiment by GRASSMAN ET AL. (1984) is sometimes cited as supportive. They took 9- to 12-month-old Kemp's ridleys from the Galveston headstarting operation and presented them with a choice of 4 compartments, one containing a solution of Padre Island sand and seawater, one with a Galveston sand solution, and two with untreated seawater. Time spent in the compartments per entry, total time spent in the compartments, and number of entries were measured. Only on the first of these was there a significant preference for the Padre Island sand solution. Even if one discounts the data from the other 2 measures, the design of the experiment does not leave imprinting as the only possible explanation. There might simply have been a preference for a particular type of water. Imprinting manipulations should have been made with different sand types to ascertain if the behaviour reflected the animals'

Figure 4. Moving eggs from high risk places on the beach in Suriname in the 1970s and 1980s. The eggs are lightly rinsed, and placed in styrofoam boxes.

early experience or a preference by all groups for a solution with particular olfactory and chemical characteristics. Also, it is questionable whether behaviour of juveniles in a tank resembles homing of reproductive adults to natal beaches in the wild.

Altogether, although there is talk of imprinting, the actual evidence for this process is thin. Even if imprinting exists, nothing is known about what stimuli are essential, when the critical periods are, and whether it is totally irreversible. It is, of course, possible that various factors are at work. The results might stem from a combination of expansion of range, random wandering and some imprinting.

<u>Sex ratio: initially, eggs for imprinting and headstarting experienced masculinizing temperatures</u>. Without additional measures, eggs incubated in styrofoam boxes above ground (Figs 4 and 5) tend to be cooler with longer incubation times than those in the sand. So the use of styrofoam boxes might well increase production of male hatchlings. The sea turtle community was warned about this possibility in 1978 (Mrosovsky, 1978) and again verbally at a conference in 1979 (Mrosovsky and Yntema, 1981) and in writing in 1979 (Yntema and Mrosovsky, 1979). Attention was specifically drawn to the longer incubation times of Kemp's ridley eggs (Marquez, 1978; Mrosovsky, 1978; Mrosovsky and Yntema, 1981). That the method of incubating eggs in styrofoam boxes has masculinizing effects on sex ratio was subsequently demonstrated (Morreale et al., 1982; Mrosovsky, 1982; Dutton et al., 1985). That the eggs taken to Padre Island had been similarly affected is supported by the study of tissues from animals that died: in the first 7 years of the translocation project (up to 1985, discounting 1981 for which only 4 specimens were sexed) there were male biased sex ratios (Shaver et al., 1988; Wibbels et al., 1989b, Caillouet, 1995). From 1985-1992, steps were taken to reduce and probably eliminate the male bias (Caillouet, 1995). These modifications appeared effective in that 77.5% of the samples examined for the 1985-1988 year classes were

Figure 5. Simple above ground hatchery in Suriname for protecting styrofoam boxes containing eggs.

females. Considering the 1978-1988 year classes as a whole, it was estimated that 59.6% were females (Shaver, in press).

In fact, the authorities in the USA and Mexico reacted rapidly when the possibility of sex ratio biases arose. Tissue was sent to Yntema and Mrosovsky in 1979. Unfortunately, adequate comparison groups from hatchlings from styrofoam boxes and nests in the sand, matched for time in a thermally changing nesting season, were not constituted. Compounded with small sample sizes and some tissue being too far deteriorated to enable reliable histological diagnosis of sex, definitive results were not obtained.

In my opinion it would have been preferable to take one or two hundred eggs and estimate the pivotal temperature and range of temperatures over which both sexes are produced in a controlled laboratory experiment. If this had been done in the late 1970s when this matter first came up, it would have sped up recognition that the Padre Island hatchery was producing male biased sex ratios. However, Yntema and Mrosovsky were allowed tissue only from turtles that had died. In contrast, transport to Padre Island, application of living tags, and headstarting, all of which entailed some mortality, were permitted. Such is the ambivalence of attitudes toward experiments involving endangered species.

Notwithstanding all deficiencies, difficulties, and irrationalities, much has been learned in this project about Kemp's ridley. This includes knowledge about rearing in captivity, disease, movements, growth, and years to maturity. An extensive list of papers and reports from the Galveston laboratory has been compiled by CAILLOUET (1997) and there have been some more since then. Here I concentrate on points that might inform future attempts to establish turtle colonies.

LESSONS

(1) Premonitoring. To assess the success of a translocation, one needs to know about nesting on the host beach before the experiment starts, or failing that, in the years from its inception up to the earliest possible date for maturation of the introduced turtles. This can be called premonitoring.

(2) Control group. The return of a single or a number of headstarted turtles is insufficient in itself to show that this method is better than other measures in boosting the population, or in causing it to expand its range to new areas. I cannot agree with statements such as: "When a nesting Kemp's ridley can be identified as a head-started animal, the overall project will be considered a complete success (MANZELLA ET AL., 1988)". The same authors also say: "The purpose of the program is to increase the wild population of Kemp's ridleys...." What if the nesting of the headstarted turtle was achieved at the cost of a decrease in the population? Clearly, complete success cannot be established by the occurrence of a single nesting. What would be helpful is a comparison with some control group that was not headstarted. For example, a large group of non-headstarted turtles, released into the water at Padre Island, would have been one approach. Turtles in both groups would have had to have undergone the same tagging procedure, and have the same initial sex ratio.

(3) Experimental design. In this project, most of the turtles experienced imprinting, headstarting, and incubation temperatures potentially distorting natural sex ratios, at least in particular years. Had these turtles done better (or worse), in terms of contributing offspring to the next generation, than a comparably sized group from eggs remaining at Rancho Nuevo, it would have been difficult or

impossible to disentangle the cause of the difference. It should however be recalled that in the 1970s the numbers of Kemp's ridleys were still falling, reaching a record low of 740 nests in 1985 (MARQUEZ ET AL., 1999; a figure of 702 is given by the TURTLE EXPERT WORKING GROUP, 1998). Sometimes conservation imperatives lead to a number of different measures being tried simultaneously, thus sacrificing understanding in a welter of confounded variables in the hope that one of them will work.

(4) Marking. Tagging is key in assessing translocations. What type of tag or tags should be used? With Kemp's ridleys, for demonstration of nesting turtles originating from the Padre Island and Galveston projects, the living tag method is the one that has given the most data (SHAVER, this volume). In this method, a sliver of pale tissue is taken from the plastron and transplanted to a particular scute on the darker carapace; this can be done in under 2 minutes (HENDRICKSON AND HENDRICKSON, 1981b). As this is an autograft, there is no immune response (HENDRICKSON AND HENDRICKSON, 1981a; for photographs see WOOD AND WOOD, 1993; MROSOVSKY, 1982; BELL AND PARSONS, 2002; Figure 6).

Figure 6. Living tag of pale tissue taken from the plastron and transplanted to the carapace of a juvenile green turtle at the Cayman Turtle Farm. The photograph was taken 2 years after the transplant. There is some overgrowth of the transplant, but the paler tissue is still clearly visible (from Mrosovsky, 1982).

(5) Covert aims. It appears that for some of those involved, the translocations to the USA may have been valued primarily as a device for shunting funds to protection on the beach at Rancho Nuevo (Taubes, 1992; see also Mrosovsky, 1983). That is arguably more important for the survival of this species. In their review of the Kemp's ridley headstart program, Wibbels et al. (1989a) emphasized that the primary element was the protection of the turtles in their natural habitat. Earlier on, Klima and McVey (1981) listed 3 components: enhanced survival at Rancho Nuevo, establishing a second breeding population at Padre Island, and an experimental study to evaluate headstarting. The latter was identified as a "major component of the overall recovery plan."

If there was some covert disagreement about the primary aim, it may have distracted attention from the imprinting and headstarting projects in Texas. If — which is hard to believe — those costly and high profile endeavors were truly the only way to get support for the enhanced efforts on the beaches in Mexico, then perhaps they could be justified on that basis alone. As a general rule for the future, explicit statements of all the aims of a project and their rankings would seem the most desirable and least divisive.

CAYMAN TURTLE FARM RELEASES OF GREEN TURTLES

Sea turtles, especially green turtles, used to nest in huge numbers on the Cayman Islands. These populations have been virtually though not totally wiped out (Aiken et al., 2001). Possibly thriving nesting colonies could be re-established in the Cayman Islands.

Between 1980 and 1991, 26,995 green turtles were released from the Cayman Turtle Farm; 39% of these were yearlings and 61% hatchlings (Wood and Wood, 1993). In the 20-year period of 1980-2000, more than 29,000 turtles were released around the Cayman Islands (UK, 2002). In addition, some animals have escaped back to the sea; major losses, including 88% of the adult breeding herd, occurred in 2001 during Hurricane Michelle (UK, 2002).

Green turtles are now found in areas such as North Sound, Grand Cayman, where many of releases were made (Wood and Wood, 1993). They are growing and appear healthy other than those with fibropapillomas which afflict wild turtles also. Although deliberate premonitoring of these areas was not done, the presence of tagged turtles shows that some of the animals there are from the Cayman Farm. Anecdotal reports indicate that following releases more turtles were seen in North Sound (WOOD, 1982). As WOOD AND WOOD said in 1993, "there is no reason to believe that once the animals reach sexual maturity they will not become reproductively successful as well."

Recent events have borne this out, with the bonus that nesting turtles from these releases have been found on the Cayman Islands themselves. In 2002, 3 females, of which 2 were actually nesting, were seen on Seven Mile Beach, Grand Cayman. In addition, 1 male was captured offshore while mating. All of these 4 animals were identified from their living tags (BELL AND PARSONS, 2002).

These are small numbers but it should be mentioned that the discovery of these animals was probably more the result of chance than of any systematic monitoring which has been lacking (PARSONS, pers comm). More beach patrols might well reveal higher numbers nesting on the Cayman Islands. But that would not mean that some of the turtles from these releases will not nest elsewhere. The tag returns for the released turtles did not all come from Cayman Island waters. Some 42% came from other countries, especially from Cuba (WOOD AND WOOD, 1993), perhaps reflecting the amount of fishing there. When it comes to reproduction, released turtles might nest in a variety of places. If they do, the ratio of numbers nesting on the Cayman Islands to nesting elsewhere will be of great interest.

A point of potential relevance here is the diverse origins of the turtles released by the Cayman farm. The stock at the farm is indeed heterogeneous. It comprises turtles and their offspring from Suriname, Costa Rica, Mexico, Ascension Island, and a few from Guyana and Nicaragua. FOSDICK AND FOSDICK (1994) describe collections from some of these places. The turtles that have been released had various origins and environmental experiences during development. Details of these are not always known, or if recorded somewhere, not readily available. From a scientific point of view, this diminishes the value of information obtained when tagged turtles are recaptured. Perhaps most of the recaptured turtles have a particular genetic background, or sex, or early history. Perhaps further details will be forthcoming.

This is not the place to go into the vicissitudes suffered by the Cayman Farm (see FOSDICK AND FOSDICK, 1994). Suffice it to say here that their main biological aim has been to breed and raise turtles in captivity, and in this they have succeeded. The releases are secondary for them, and are "part of a continuing study to assess turtle survival and the establishment of a resident turtle population" (Wood and Wood, 1993). In some cases releases also served to get rid of excess stock in times of financial pressure.

Of course, biologists will wish there was more information available and that experiments had been more extensive and controlled. Nevertheless, as it is, there are a number of points arising that may be useful in designing future attempts to establish or re-establish colonies.

LESSONS

(1) Headstarted green turtles can survive to reproduce; this extends the previous demonstrations with Kemp's ridleys. If this applies to two species of marine turtle, it probably applies to all.

(2) Living tags have provided important data. This is not to say this type of tag is problem free. Eckert et al. (1992) wrote:

"We are not comfortable with relying on living tags as a means to detect headstarted turtles. Living tags are too easily misinterpreted, and there has not been adequate research to determine the retention and detection rate of those tags after release".

Since then, some limited information has become available on retention of living tags. A useful feature of the Cayman Farm releases was that a number of turtles were double tagged. In particular, 243 turtles, originally given external titanium tags before release as yearlings, were later recaptured. Of these 243, 40 "were noted" as having had a living tag visible at release. At recapture, however, only 26 of these 40 "were noted" as having a living tag (Wood and Wood, 1993). It is not clear if the cautious wording implies there is some observer bias or difficulty in detecting a living tag. The average time between release and recapture of a larger number of turtles, including these 40 given living tags, was 795 days, with 50.2% having 3 or more years between release and recapture. It is assumed here that in the subset of 40 turtles there was a comparable percent with long intervals between release and recapture, though this is not specifically stated by Wood and Wood (1993).

At face value, these data indicate that there is tag loss with living tags, as with external tags. Nevertheless, the 65% retention is not bad for early use of a tech-

Figure 7. Nesting beach at the Cayman Turtle Farm, 1982. Clutches laid here were moved into an indoor hatchery. Eggs were exposed to sand from the Cayman Islands only.

nique that could doubtless be improved with further work. So further research and data are indeed needed.

But the criticism about research not being adequate applies also to internal wire tags, and Passive Integrated Transponder (PIT) tags even. The fact is that in both the Kemp's ridley project and in the Cayman Island releases, the living tag was the one that came through best. Moreover, there are already other ways that yearlings can be tagged. With hatchlings, options are much more limited. What would be really valuable is some idea of retention/detection rates for living tags applied to hatchlings. The recent returns of living tags show retention from the hatchling stage to maturity is possible (Bell and Parsons, 2002), but do not tell one if it is probable. Studies of captive turtles, tagged with transplants as hatchlings and kept for a year or two, could provide a survival curve for such tags.

(3) <u>None of the turtles released were from a population nesting on the Cayman Islands</u> (other than on the beach at the Cayman Farm, Figure 7). This makes the nesting on the Cayman Islands of turtles released in its waters encouraging for

further translocations. Whether these turtles had imprinted to Cayman Island stimuli while in the Farm, or whether they were simply nesting near to release sites, it has been shown that turtles whose ancestors nested elsewhere have now nested on the Cayman Islands.

This suggests another option for having turtles nest in the Canary Islands: borrow breeders from elsewhere, allow them to lay in captivity, direct into local sand on an artificial beach, and release offspring at some later time. The expense of this method would be partly compensated for by avoiding the costs and logistics of taking Canary Islands sand to the Cape Verde Islands, and then bringing the eggs back again. There is also the potential for revenue from tourists, judged by the success of the Cayman Farm. And there are also scientific grounds for at least considering this option. After all, even assuming that some kind of attachment to cues in the natal area is responsible for fidelity to that area when it comes to breeding, at what stage that attachment occurs remains a speculation. Experiences after the hatchlings enter the surf might be contributory or even essential. Experience in seawater with particular characteristics might override the influence of cues that impinged on the embryos in the sand. Whatever the case, the initial data from the Cayman Islands (BELL AND PARSONS, 2002) are worth pondering.

OTHER TRANSLOCATIONS

In 1976, 100 green turtle and 10 olive ridley hatchlings were taken from Bigisanti, Suriname, and, after a 10-day stopover in Curaçao, released at Spaans Lagoon, Aruba (ROOZE AND KRISTENSEN, 1977). A small artificial beach had been constructed for the occasion, the aim of which was not primarily to augment turtle populations but to attract attention and publicity for turtle conservation. The release took place by day, and in the heat most of the turtles were unable to reach the water without help.

As part of an experiment on sea-finding orientation, in 1957-1958, 22 green turtle hatchlings were taken from Tortuguero on the Atlantic coast of Costa Rica and released on its Pacific coast (CARR AND OGREN, 1960).

There have probably been been other small-scale translocations that have escaped publicity. The low survival rate of hatchlings and juveniles, and slim chances of recognizing these turtles without tags, make it unlikely that much will be learned from releases comprising few animals. The best that can be hoped is that they do no harm.

SELF-TRANSLOCATIONS: WEAK NEST-SITE FIDELITY

There are several reports of individual female turtles having nested on widely separated beaches. These instances indicate that nest-site fidelity is not the absolute rule. How else would turtles come to nest on newly formed volcanic islands? In the Guianas, beaches are destroyed in one place and built up in another over the course of a few years; in such dynamic areas, turtles move from one beach to another (SCHULZ, 1975). Translocating turtles might then be only hastening a process of colonization of unoccupied areas that could have eventually occurred naturally.

Data on mitochondrial (mt) DNA tend to be overinterpreted. When it is said that populations using different nesting beaches are genetically distinct, this does not mean there is no gene transfer, but that it is limited. It means that there are statistically significant differences in haplotype frequency between the samples from different nesting beaches. Nevertheless, even though on average the various haplotype frequencies differ among geographical areas, often some of the individuals in the samples from the different beaches still have the same haplotypes.

Moreover, most of the work on molecular genetics has been based on mtDNA rather than nuclear (n) DNA. However, for green turtles, it has been found that differentiation between populations is less when nDNA rather than mtDNA is studied. This greater gene flow may be mediated by movements of the males (KARL ET AL., 1992).

Populations of turtles nesting on beaches even separated by some distance, and each having different haplotype frequencies of mtDNA, need not necessarily be thought of as neatly isolated genetic packets. In any case, regardless of interpretation of studies of mtDNA, there is some support for movements between different nest sites from tagging data. The list that follows is probably not inclusive.

A loggerhead has been documented nesting on both the west and on the east coast of Florida (LEBUFF, 1974); the sites were separated by about 600 kms. Another loggerhead nested both in North Carolina and in Florida at sites separated by 725 km (STONEBURNER AND EHRHART, 1981).

In the Indian Ocean, a green turtle tagged while nesting on Tromelin was seen almost 9 years later on Europa Island, some 2200 kms away (LeGall and Hughes, 1987). Another green turtle nested on both Mona Island, Puerto Rica, and some 560 km away on Aves Island, Venezuela (Kontos et al., 1988).

Individual leatherbacks have laid eggs on beaches as much as 110 km apart in the Caribbean (Eckert et al., 1989). Movements of this species for nesting are also known between Trinidad and Suriname, that is >500 km (Hilterman and Goverse, 2002). The longest distance to date between nests of the same leatherback is >1000 kms, from Playa Grande, Costa Rica, to Tierra Colorado, Mexico (Sarti, pers comm).

The 2 Kemp's ridleys that nested at both Padre Island and Rancho Nuevo (see above) should also be included in this list, for a distance of approximately 250 km.

A green turtle encountered on the beach at Tortuguero in July 2000 carried a tag with a different type of letter and number combination from that used in tagging at Tortuguero but similar to that used in Mexico (Mangel and Troeng, 2001; Troeng, pers comm). The vast majority of tags in Mexico have been attached to turtles when on land for nesting. Presumably this turtle nested in Mexico and then later in Costa Rica. There is a problem with this explanation: it requires not only lack of nest-site fidelity but also lack of species fidelity! The Mexican records had this tag being attached to a Kemp's ridley.

This little mystery exemplifies something that must arise not infrequently with so much tagging going on in so many places: errors of transcription, errors of reading tag numbers from worn tags or in the dark. Such errors are more common in the hours after than before midnight (Godfrey, pers comm), as might be expected from a chronobiological perspective. It all makes one wonder how much weight should be attached to findings based on single tag returns. In the case of the change of nest site in the Indian Ocean, it is somewhat reassuring that the authors state that there was no doubt about the identification of the turtle on Europa. It was seen onshore there on two successive nights (Le Gall and Hughes, 1987).

RECOMMENDATIONS FOR THE CANARY ISLANDS PROJECT

These recommendations for what is desirable may well assume an idealized choice of options. They are one person's opinion, after watching what has happened in other translocations. Those in the Canary Islands concerned with this project are wisely seeking input from a variety of sources.

1. Premonitoring. Inspections of beaches in the Canary Islands for signs of nesting before any potential returns of translocated turtles is essential for evaluation. This may sound simple, but since turtles will not necessarily return to the exact beach of release, and since there are many beaches in this archipelago, monitoring may be expensive and arduous. Moreover, eggs/turtles should probably be translocated to several beaches. On theoretical grounds, arising from a survey of translocations of 93 species of bird and mammal, there is a higher chance of success if available animals are split between two or more release sites, unless very few are involved. This is because the chance of success at a given site does not increase linearly with the number of animals released, but asymptotes (GRIFFITH ET AL., 1989).

   However, all beaches need not be inspected every day. What is more important is that there be something systematic to which comparisons can be made in the future. Protocols should not be so demanding as to make it unfeasible to keep them going over many years. Information on how long tracks remain visible in windy conditions in this region might be collected as a preliminary step. Perhaps a combination of helicopter surveys with some ground truthing on accessible beaches would be possible. But some form of premonitoring is essential, for reasons given above.

   This is obviously an unglamorous task because the expectation is that turtles will not been seen. However, as Dr Margaritoulis has pointed out at this meeting, there could be some surprises in the Canary Islands. In fact there is already at least one recent record worth noting: a juvenile loggerhead (ca 50 cm curved carapace length) has been seen on Cofete beach, Fuerteventura, though in the unusual circumstances of daytime and winter (CEJUDO, 2000). Altogether, it is essential that premonitoring be undertaken — if this is to be a scientific as well as a conservation exercise.

2. Marking. For assessment, it is imperative that turtles are marked in a way that will still be present when they mature. If turtles do not come up on the Canary Islands in the future but go elsewhere, marking will help learn what did happen to those

turtles. Omission of marking prevents the discovery of unexpected outcomes. If, however, as hoped, turtles are found nesting on the Canary Islands, marking will indicate how many are part of the translocation experiment, and whether from particular years of that endeavor with particular conditions pertaining.

Marking might seem a simple demand, but the problem of tagging hatchling turtles has not been satisfactorily solved. PIT tags or other inserted devices may migrate within the body as the animal grows, and so not be readily detectable. Validation of internal tagging for hatchlings is needed. Moreover, such tags cannot be detected without special equipment. People likely to come into contact with a turtle, perhaps fishermen, or tourists on a beach, may not have this equipment. Therefore, an additional external tag is desirable. The living tag would seem to be a good candidate on the basis of the results from the Padre Island project and from the Cayman Farm.

However, there are potential drawbacks. In some of the work on the Kemp's ridley, there was a higher mortality rate in hatchlings given the living tag (32%) than in those not treated (16%) (CAILLOUET ET AL., 1986). This was reported for the 1984 year class. Probably the hatchlings brought to Texas that year were in sub-optimal health anyway, or experienced sub-optimal conditions after arrival (SHAVER, pers comm). In some other cases, survival of hatchling turtles after application of living tags has been excellent and essentially indistinguishable from untagged controls (HENDRICKSON AND HENDRICKSON, 1981b, 1986). It might be decided that a certain mortality rate in animals given living tags is acceptable in the interests of being able to detect animals from this project.

Another potential problem is that although the living tag method can be successful with green turtles and Kemp's ridleys, it is conceivable, as pointed out in this meeting, that it may be less effective with species such as loggerheads whose carapace tends to attract barnacles.

If living tags do not work out for loggerhead hatchlings, and no other method is found, then it may be necessary to consider headstarting simply for the purpose of being able to tag the animal (cf KLIMA AND MCVEY, 1981). A yearling has a higher chance than a hatchling of retaining an external tag; conventional external tags could be combined with PIT tags and with living tags. Also, if the latter are applied to yearlings, time afterwards in tanks can be allowed to make sure the transplant has taken. There would not be the concern, as there might be with hatchlings, to complete the transplant and subsequent release of the animals rapidly, before the juvenile frenzy had waned.

Because the logistic demands of the project would be very different if head-starting were required, simply as means of tagging the turtles, it seems essential for this reason also that evaluation of the suitability of living tags for the present project be undertaken soon. Someone involved with the Canary Islands project should learn as much as possible about living tags and if necessary initiate further research with loggerhead hatchlings. In fact, extensive and carefully designed experiments with loggerhead hatchlings have already been carried out at the Miami Seaquarium by HENDRICKSON AND HENDRICKSON (1981b, 1986). Among their findings were that the percentage of transplant "takes" is higher with pocket grafts than with two other methods, and that it makes little difference whether the graft is done within 24 hours of emergence or 7 days later, and whether the graft is put on a nuchal or costal scute. However, success was influenced by who performed the surgery: procedural details such as how long the glue is left to dry before the turtle is returned to water might be responsible. Data were also provided on evaluation of the clarity of the graft, on a scale from clear to very faint and overgrown with carapacial keratin; there was an 86% consistency in categorization between two observers. The work of the Hendricksons should be studied in detail. "Those who cannot remember the past are condemned to repeat it" (SANTAYANA).

Another point that should be ascertained before using living tags in Macaronesia is what scutes have already received such tags in other projects. In the early 1990s, a few loggerhead hatchlings in Quintana Roo, Mexico, were given living tags, with plans to tag many more in the future (ZURITA ET AL., 1994). It appears that coordination between different groups using living tags has not been adequate, increasing the possibility that different projects will use the same scute (BJORNDAL ET AL., 2003). The need for preserving the integrity of the coding systems with living tags was recognized right away (HENDRICKSON AND HENDRICKSON, 1981b, 1986) and the desirability of announcing which scutes were being used, preferably in advance of tagging, was urged on a wider audience (MROSOVSKY, 1982). Failure to do so would be irresponsible (cf BJORNDAL ET AL., 2003).

3. Public records. Suppose the problems of tagging are satisfactorily addressed, this would be only a part of being able to determine the origin of an individual when a tagged turtle was found. A tag is useless unless there are records of when and where that tag was applied. The organizations and people who find a tagged turtle, perhaps 20 years after the tag was applied, may not be the same as those who did the tagging in the first place. It is recommended that each year it be insisted on, with iron-fisted inflexibility, that details of the project be put into the public domain. This should be a condition of any financial support, or permits (GRIFFITH ET AL., 1989). Such a requirement will force participants to undertake the often time-consuming writing up of procedures and results, even though they might prefer to be walking the beach. Records put on the web can be labelled as preliminary, and when checked can be re-labelled as checked, or "final report" for a given year.

   It is recommended that the Canary Island translocation project, if that eventuates, builds rigorous checking routines and redundancy into their tag numbering system. In my laboratory, we find that the most common source of error is in transcription of numbers from one piece of paper to another. Transcriptions should be checked — preferably later and preferably by someone else.

   Annual accounting and open presentation of data, especially for a long-term project, helps avoid lost data and wasted effort. And it opens up the project explicitly to outside scrutiny. In contrast, there are unfortunately some turtle programmes that are either incapable or unwilling to provide information to interested parties.

4. Risk and mitigation. Should experimental procedures be tried on populations that are threatened? It is notable that the taking of risks is sometimes thought justifiable precisely in circumstances when particular populations are considered imperiled. For Operation Green Turtle, "a major impetus for this effort was the excessive harvest of female green turtles at Tortuguero .... and the bleak survival outlook of the population if the harvest continued" (ELIAZAR ET AL., 1998). For the Padre Island project, it has been said that "the ridley situation was so desperate that the agencies decided to take the risk of failure" (CARR, 1979). Such attitudes apply of course to species other than sea turtles. It was only when the situation for the California condor became truly bleak that priorities shifted from a hands-

off policy to experimentation aimed at determining causes of mortality and at breeding in captivity (Snyder and Snyder, 2000).

If experiments and risk taking are acceptable in desperate situations, then surely they are all the more, not less, justified when populations are apparently healthy. In such cases, rather than ask whether the situation is dire enough to demand desperate measures, the more appropriate question might be whether the experiment is likely to do any harm. The take of hatchlings in Operation Green Turtle and the dispatch of ridley eggs sent to Padre Island have not prevented the dramatic increases in the number of nesting females in those areas (Bjorndal et al., 1999; Marquez et al., 1999).

Where there is high natural mortality, and relatively dense nesting, there seems no reason why a take of some eggs —it depends of course on the number involved— for a translocation project need have much impact. But there is a way to insure that it does not: build mitigation measures into the project from the start. The essentials are to identify causes of natural mortality, and then reduce those causes, thus compensating for the take of eggs or hatchlings —for whatever purpose those are needed (Mrosovsky, 1983). In the case of the Cape Verde Islands, use of hatcheries has already protected some eggs from predators and inundation (Garcia et al., in press). All that is needed is to link particular new and extra conservation efforts to the number of eggs taken to the Canary Islands, so that an equal or greater number are saved on the Cape Verde Islands. To reduce the chance of misconceptions arising, mitigation measures should be agreed upon with the authorities in the Cape Verde Islands, and made public there. Any additional conservation benefits coming from increased presence of rangers or biologists on the beach, and increased public awareness about turtles, can be considered as gravy.

The IUCN/SSC (1995) has produced a useful and comprehensive set of guidelines for re-introductions; these raise a number of general issues that should be thought about. It should be remembered, however, that these are guidelines, not requirements, and should not be used to stifle innovation and experimentation.

5. Control group. Without explicit formulation of the aims of the endeavor, it is difficult to comment other than tentatively on what control groups should be considered. It would be nice to have turtles nesting on the Canary Islands where so

many inviting beaches exist; turtles may well have nested there in the past (LÓPEZ-JURADO, pers comm). Promotion or restoration of biodiversity is in general desirable. It seems unlikely that attempts to establish turtles on the Canary Islands would do harm. However, at present the survival prospects of the loggerhead turtle are not so dire as to demand that every possible measure be thrown into action. That leaves one of the main attractions of this project as the chance of obtaining the knowledge and understanding of sea turtle biology that could be so important for conservation in the future in a warming world. Therefore, it would seem appropriate to reduce the number of manipulations in the interests of making outcomes more instructive.

If the only aim is to establish nesting turtles on the Canary Islands, then it could be argued that, with the proviso that premonitoring is well done and reveals little or no nesting, there is no need for groups other than the translocated turtles. Success will be evident simply by increases over the premonitoring baseline levels. If tags last that long, they would provide direct evidence that the newly arriving turtles were translocated animals, and not part of some expansion in range.

However, a project kept to the essentials above seems unduly lacking in ambition. It would be much more interesting if one could learn not only if translocation worked, but how it compared quantitatively to what would have happened to these turtles had they not been moved. A group of turtles untranslocated but otherwise treated in the same way would offer a way of assessing the effectiveness of translocation. Such a group would have to be treated in exactly the same way, with the same amount of time in captivity and the same tagging procedures down to such details, if possible, of the person doing the tagging.

Having an untreated group of turtles at the Cape Verde Islands — untreated except for interventions necessary to tag the hatchlings — could in itself be exciting. It could potentially provide direct data on survival rates of hatchlings, one of the big unknowns in turtle life history. These would be minimal survival rates because some turtles would be missed at nesting, either on account of tag loss or for other reasons. Sex ratio of this group would need consideration. It could be matched to that of the translocated animals by constituting the two groups at the same time of the season. Other hatchlings could be taken for direct specification of sex ratio at that time. Also maturation period would become evident, empirically from data, rather than from extrapolations and modelling. Sometimes what is learned from control groups is more valuable than what is learned from experimental groups!

If either imprinting or headstarting are to be included in the translocation protocol, then additional control groups for those manipulations are wanted. For imprinting, some of the translocated eggs/hatchlings could be kept in Cape Verde Islands sand and water. Beaches on the Cape Verde Islands would have to monitored when these turtles were due to mature.

If headstarting is included, the matter of appropriate control procedures probably becomes more complicated. Tags applied to hatchlings and headstarted yearlings may not have the same retention rates. Probably all tagging would have to be done at the same stage. But if headstarting were being done precisely to facilitate tag retention (see above), this would be contradictory and counterproductive. Another (very expensive) approach would be to headstart animals both in the Canary and the Cape Verde Islands, leaving translocation as the only treatment differing between comparison groups.

In summary, the following are recommended: premonitoring, marking (especially experimentation with living tags), record keeping and publication, mitigation, and a control group. A tall order indeed! But the Canary Islands project has the benefit of being able to build upon past experiences. It has the opportunity to do things right! Buena Suerte!

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REFERENCES

AIKEN, J.J.; GODLEY, B.J.; BRODERICK, A.C.; AUSTIN, T.; EBANKS-PETRIE, G.; HAYS, G.C. (2001). Two hundred years after a commercial marine turtle fishery: the current status of marine turtles nesting in the Cayman Islands. Oryx, 35, 145-151.

ANON. (1982). Report on U.S. FWS and NMFS sea turtle permit activities during 1981. East & Gulf Coast News, 2, 4-13.

ANON. (1996). Headstarting... to what? Turtle Tracks Newsletter of the Sea Turtle Protection Society of Greece, 13, 3.

BELL, C.D.L.; PARSONS, J. (2002). Cayman turtle farm head-starting project yields tangible success. Marine Turtle Newsletter, 98, 5-6.

BJORNDAL, K.A.; BOLTEN, A.B.; ARENAS, A.; ZURITA, J.; D'AMIANO, A.; CALDERÓN, C.; PARSONS, J.; SEMINOFF, J.A. (2003). Green turtle with living tag captured in the southern Bahamas. Marine Turtle Newsletter, 101, 26.

BJORNDAL, K.A.; WETHERALL, J.A.; BOLTEN, A.B.; MORTIMER, J.A. (1999). Twenty-six years of green turtle nesting at Tortuguero, Costa Rica: an encouraging trend. Conserv. Biol., 13, 126-134.

BURNETT-HERKES, J. (1974). Returns of green sea turtles (Chelonia mydas Linnaeus) tagged at Bermuda. Biol. Conserv., 6, 307-308.

BUITRAGO, J. (1981). Percentage of head-started turtles in a population as a criterion. Marine Turtle Newsletter, 19, 3.

CAILLOUET, C.W. (1995). An update of sample sex composition data for head started Kemp's ridley sea turtles. Marine Turtle Newsletter, 69, 11-14.

CAILLOUET, C.W. (1997). Publications and reports on sea turtle research by the National Marine Fisheries Service, Southeast Fisheries Science Center, Galveston Laboratory, 1979-1996. NOAA Technical Memorandum NMFS-SEFSC-397, ii plus 21 p.

CAILLOUET, C.W.; FONTAINE, C.T.; WILLIAMS, T.D.; MANZELLA, S.A.; REVERA, D.B.; KOI, D.B.; INDELICATO, K.L.W.; TYREE, M.G.; LEONG, J.K.; DURONSLET, M.J.; MARVIN, K.T. (1986). The Kemp's ridley sea turtle head start research project: an annual report for fiscal year 1985. NOAA Technical Memorandum NMFS-SEFC-174 ii plus 37 pp, 29 tables, 1 figure and 5 appendices.

CARR, A. (1979). The Windward Road. Adventures of a naturalist on remote Caribbean shores. University Presses of Florida, Tallahassee, FL.

CARR, A. (1984). So excellent a fishe. Revised edition. Charles Scribner's Sons, U.S.

CARR, A.; OGREN, L. (1960). The ecology and migrations of sea turtles, 4. Bulletin of the American Museum of Natural History, 121, 1-48.

CEJUDO, D. (2000). Caretta caretta (tortuga boba), en la playa de Cofete, Fuerteventura (Islas Canarias). Bol. Asoc. Herpetol. Esp., 11, 26-27.

DUTTON, P.H.; WHITMORE, C.P.; MROSOVSKY, N. 1985. Masculinisation of leatherback turtle Dermochelys coriacea hatchlings from eggs incubated in styrofoam boxes. Biol. Conserv., 31, 249-264.

ECKERT, K.L.; BJORNDAL, K.A.; ABREU-GROBOIS, F.A.; DONNELLY, M. (Editors). (1999). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

ECKERT, S.A.; CROUSE, D.T.; CROWDER, L.B.; MACEINA, M.; SHAH, A. (1992). Review of the Kemp's ridley sea trutle headstart experiment. Galveston, Texas. 10 pp.

ECKERT, K.L.; ECKERT, S.A.; ADAMS, T.W.; TUCKER, A.D. (1989). Inter-nesting migrations by leatherback sea turtles (Dermochelys coriacea) in the West Indies. Herpetologica, 45, 190-194.

ELIAZAR, P.J.; BJORNDAL, K.A.; BOLTEN, A.B. (1998). Operation Green Turtle revisited. Proceedings of the 16th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-412, p. 43.

FOSDICK, P.; FOSDICK, S. (1994). Last Chance Lost? Irvin S. Naylor, York, Pennsylvania.

GARCÍA, M.; PEÑA, B.; ABELLA, E.; BALLELL, L.; MADARIAGA, B.; LOZANO, M.; DÍAZ-MERRY, A.; DEL ORDI, D.; GONZÁLEZ, M.; BORRÁS, S.; RUIZ, X.; LÓPEZ, O.; NUEZ, M.; HIDALGO, J.; PÉREZ, N.; VARO, N.; CEJUDO, D.; LÓPEZ-JURADO, L. (in press). Hatching success in natural and relocated nests of loggerhead in the island of Boavista (Cape Verde, Western Africa). In 21st Annual Symposium on Sea Turtle Biology and Conservation.

GEORGES, A.; LIMPUS C.; STOUTJESDIJK, R. (1994). Hatchling sex in the marine turtle Caretta caretta is determined by proportion of development at a temperature, not daily duration of exposure. J. Exp. Zool., 270, 432-444.

GRASSMAN, M.A.; OWENS, D.W.; MCVEY, J.P.; MÁRQUEZ, R. (1984). Olfactory-based orientation in artificially imprinted sea turtles. Science, 224, 83-84.

GRIFFITH, B.; SCOTT, J.M.; CARPENTER, J.W.; REED, C. (1989). Translocation as a species conservation tool: status and strategy. Science, 245, 477-480.

HENDRICKSON, L.P.; HENDRICKSON, J.R. (1981a). A new method for marking sea turtles? Marine Turtle Newsletter, 19, 6-7.

HENDRICKSON, J.R.; HENDRICKSON, L.P. (1981b). “Living tags” for sea turtles. Final Report to U.S. Fish and Wildlife Service, 25 pp.

HENDRICKSON, L.P.; HENDRICKSON, J.R. (1986). Experimental evaluation of graft-marking procedures for sea turtles. Final Report to U.S. Fish and Wildlife Service, 27 pp.

HILTERMAN, M.L.; GOVERSE, E. (2002). The Sea Turtles of Suriname 2001 Project: Aspects of Nesting and Nest Success of the Leatherback Turtle (Dermochelys coriacea) in Suriname, 2001. Report to the World Wildlife Fund, Guianas Forests and Environmental Conservation Project.34 pp.

IUCN/SSC. Guidelines for re-introductions. Retrieved March 3, 2003, from http://www.iucn.org/themes/ssc/pubs/policy/reinte.htm.

JOHNSON, S.A.; BASS, A.L.; LIBERT, B.; MARSHALL, M.; FULK, D. (1999). Kemp’s ridley (*Lepidochelys kempi*) nesting in Florida. Florida Scientist, 62, 194-204.

KARL, S.A.; BOWEN, B.W.; AVISE, J.C. (1992). Global population genetic structure and male-mediated gene flow in the green turtle (Chelonia mydas): RFLP analyses of anonymous nuclear loci. Genetics, 131, 163-173.

KLIMA, E.F.; MCVEY, J.P. (1981). Headstarting the Kemp’s ridley turtle, Lepidochelys kempi. In Biology and Conservation of Sea Turtles. Bjorndal, K.A. (ed). Smithsonian Institution Press, Washington & London. pp. 481-487.

KONTOS, A.; ECKERT, S.; ECKERT, K.; GOMEZ, J.L.; LEE, R.; VAN DAM, R. (1988). Inter-island migration of nesting green turtle, Chelonia mydas. Marine Turtle Newsletter, 42, 10-11.

LE GALL, J.-Y.; HUGHES, G.R. (1987). Migrations de la tortue verte Chelonia mydas dans l’Océan Indien Sud-Ouest observées à partir des marquages sur les sites de ponte Europa et Tromelin (1970-1985). Amphibia-Reptilia, 8, 277-282.

LEBUFF, C.R. (1974). Unusual nesting relocation in the loggerhead turtle, Caretta caretta. Herpetologica, 30, 29-31.

MANGEL, J.; TROËNG, S. (2001). Report on the 2000 Green Turtle Program at Tortuguero, Costa Rica. Caribbean Conservation Corporation, San Pedro, Costa Rica, 58 pp.

MANZELLA, S.A.; CAILLOUET, C.W.; FONTAINE, C.T. (1988). Kemp's ridley, Lepidochelys kempi, sea turtle head start tag recoveries: Distribution, habitat, and method of recovery. Marine Fisheries Review, 50, 24-32.

MÁRQUEZ, R. (1978). The Atlantic ridley in Mexico: 1978 season and conservation programme. Marine Turtle Newsletter, 9, 2.

MÁRQUEZ, R.; DÍAZ, J.; SÁNCHEZ, M.; BURCHFIELD, P.; LEO, A.; CARRASCO, M.; PEÑA, J.; JIMÉNEZ, C.; BRAVO, R. (1999). Results of the Kemp's ridley nesting beach conservation efforts in México. Marine Turtle Newsletter, 85, 2-4.

MORREALE, S.J.; RUIZ, G.J.; SPOTILA, J.R.; STANDORA, E.A. (1982). Temperature-dependent sex determination: current practices threaten conservation of sea turtles. Science, 216, 1245-1247.

MROSOVSKY, N. (1978). Editorial. Marine Turtle Newsletter, 9, 1-2.

MROSOVSKY, N. (1982). Sex ratio bias in hatchling sea turtles from artificially incubated eggs. Biol. Conserv., 23, 309-314.

MROSOVSKY, N. (1982). Editorial. Marine Turtle Newsletter, 22, 1-2.

MROSOVSKY, N. (1983). Conserving Sea Turtles. British Herpetological Society, London.

MROSOVSKY, N. (2000). Sustainable Use of Hawksbill Turtles: Contemporary Issues in Conservation. Key Centre for Tropical Wildlife Management. Northern Territory University, Darwin.

MROSOVSKY, N.; DUTTON, P.H.; WHITMORE, C.P. (1984). Sex ratios of two species of sea turtle nesting in Suriname. Can. J. Zool., 62, 2227-2239.

MROSOVSKY, N.; PIEAU, C. (1991). Transitional range of temperature, pivotal temperatures and thermosensitive stages for sex determination in reptiles. Amphibia-Reptilia, 12, 169-179.

MROSOVSKY, N.; YNTEMA, C.L. (1981). Temperature dependence of sexual differentiation in sea turtles: Implications for conservation practices. In Biology and Conservation of Sea Turtles. Bjorndal, K.A. (ed). Smithsonian Institution Press, Washington, D.C. pp. 59-65.

PALMATIER, R. (1993). Lepidochelys kempii (Kemp's ridley) nesting. Herpetological Review, 24, 149-150.

PIEAU, C. (1971). Sur la proportion sexuelle chez les embryons de deux Chéloniens (Testudo graeca L. et Emys orbicularis L.) issus d'oeufs incubés artificiellement. C.R. Acad. Sc. Paris, 272, Série D, 3071-3074.

PRITCHARD, P.C.H. (1981). Criteria for scientific evaluation of head-starting. Marine Turtle Newsletter, 19, 3-4.

ROOZE, V.; KRISTENSEN, I. (1977). Onze schildpadden verdwijnen. Stinapa, 14, 43-48.

SCHULZ, J.P. (1975). Sea turtles nesting in Surinam. Stichting Natuurbehoud Suriname (Stinasu), Verhandeling Nr. 3.

SHAVER, D.J. (1996). Head-started Kemp's ridley turtles nest in Texas. Marine Turtle Newsletter, 74, 5-7.

SHAVER, D.J. (in press). The Kemp's ridley imprinting project at Padre Island National Seashore and Kemp's ridley nestings on the Texas coast. Chelonian Conservation and Biology.

SHAVER, D.J. (this volume). Efforts to establish a nesting colony of Kemp's ridley sea turtles (Lepidochelys kempii) in south Texas through experimental imprinting and headstarting.

SHAVER, D.J.; CAILLOUET, C.W. (1998). More Kemp's ridley turtles return to South Texas to nest. Marine Turtle Newsletter, 82, 1-5.

SHAVER, D.J.; OWENS, D.W.; CHANEY, A.H.; CAILLOUET, C.W.; BURCHFIELD, P.; MÁRQUEZ, R. (1988). Styrofoam box and beach temperatures in relation to incubation and sex ratios of Kemp's ridley sea turtles. In Proceedings of the

Eighth Annual Conference on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-214. Schroeder, B.A. (compiler). pp. 103-108.

SNYDER, N.; SNYDER, H. (2000). The California Condor. Academic Press, San Diego, CA, USA.

STANDORA, E.A.; SPOTILA, J.R. (1985). Temperature dependent sex determination in sea turtles. Copeia, 1985, 711-722.

STONEBURNER, D.L.; EHRHART, L.M. (1981). Observations on Caretta c. caretta: A record internesting migration in the Atlantic. Herp. Review, 12, 66.

TAUBES, G. (1992). A dubious battle to save the Kemp's ridley sea turtle. Science, 256, 614-616.

TURTLE EXPERT WORKING GROUP. (1998). An assessment of the Kemp's ridley (Lepidochelys kempii) and loggerhead (Caretta caretta) sea turtle populations in the western north Atlantic. NOAA Technical Memorandum NMFS-SEFSC-409. 96 pp.

U.K. CITES MANAGEMENT AUTHORITY. (2002). Application to register a captive breeding operation involving Chelonia mydas on Grand Cayman, Cayman Islands.

WIBBELS, T.; FRAZER, N.; GRASSMAN, M.; HENDRICKSON, J.; PRITCHARD, P. (1989a). Report to the National Marine Fisheries Service: Blue ribbon panel review of the National Marine Fisheries Service Kemp's Ridley Headstart Program. National Marine Fisheries Service, 12 pp.

WIBBELS, T.; MORRIS, Y.A.; OWENS, D.W.; DIENBERG, G.A.; NOELL, J.; LEONG, J.K.; KING, R.E.; MÁRQUEZ, R. (1989b). Predicted sex ratios from the international Kemp's ridley sea turtle head start research project. In Proceedings of the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management. Caillouet, C.W.; Landry, A.M. (eds). Galveston, Texas.

WOOD, F.; WOOD, J. (1993). Release and recapture of captive-reared green sea turtles, Chelonia mydas, in the waters surrounding the Cayman Islands. Herpetological Journal, 3, 84-89.

WOOD, J.R. (1982). Release of captive-bred green sea turtles by Cayman Turtle Farm Ltd. Marine Turtle Newsletter, 20, 6-7.

YNTEMA, C.L.; MROSOVSKY, N. (1979). Incubation temperature and sex ratio in hatchling loggerhead turtles: A preliminary report. Marine Turtle Newsletter, 11, 9-10.

ZURITA, J.C.; HERRERA, R.; PREZAS, B. (1994). Living tags in three species of sea turtle hatchlings in the Mexican Caribbean. In Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-341. Schroeder, B.A.; Witherington, B.E. (compilers). pp. 273-277.