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Front cover | Capa: Loggerhead turtle *Caretta caretta,* Praia da Ponta Cosme, Boavista, 8 July 2004 (Daniel Cejudo).

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The international importance of the archipelago of Cape Verde for marine turtles, in particular the loggerhead turtle *Caretta caretta*

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Keywords: sea turtles, loggerhead turtle, green turtle, hawksbill turtle, Cape Verde Islands, reproductive biology, conservation

ABSTRACT

The shores of Cape Verde hosts one of the most important nesting populations of the loggerhead turtle *Caretta caretta* in the world, as well as important feeding grounds for hawksbill *Eretmochelys imbricata* and green turtles *Chelonia mydas*. In the past few years, a number of scientific studies have demonstrated the relevance of the waters and beaches of this archipelago for the conservation of these endangered marine megavertebrates. This article aims to bring together the most relevant scientific information published on the subject so far. In addition, we will provide an overview of the current situation of sea turtles in Cape Verde, their conservation status and their importance in an international context.

RESUMO

A costa de Cabo Verde possui uma das maiores colónias reprodutoras da tartaruga comum *Caretta caretta* no mundo, bem como uma área muito importante para a alimentação de juvenis de tartaruga de-casco-levantado *Eretmochelys imbricata* e de tartaruga verde *Chelonia mydas*. Nos últimos anos, vários estudos científicos têm demonstrado a importância das águas costeiras e das praias do arquipélago para a conservação desta megafauna marinha que se encontra em perigo de extinção. Este artigo tem por objectivo compilar as informações científicas mais relevantes que têm sido publicadas sobre o assunto até agora. Além disso, vamos tentar fornecer uma visão global da situação actual das tartarugas marinhas em Cabo Verde, seu estado de conservação e sua importância no contexto internacional.

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INTRODUCTION

Five different species of sea turtle have been observed in the Cape Verde Islands, an archipelago situated in the eastern Atlantic, *ca.* 500 km west of Senegal, West Africa: loggerhead turtle *Caretta caretta*, hawksbill turtle *Eretmochelys imbricata*, green turtle *Chelonia mydas*, olive ridley turtle *Lepidochelys olivacea* and leatherback turtle *Dermochelys coriacea* (López Jurado *et al.* 2000a). Olive ridley and leatherback migrate through the waters of the archipelago and are difficult to observe. Hawksbill and green turtle juveniles are often found feeding in neritic waters of Cape Verde. These four species do not nest in the archipelago. Loggerheads are the most common, and without any doubt, the most representative Capeverdean sea turtle. Every year, thousands of female loggerheads migrate from their feeding grounds to Cape Verde to nest and hundreds of thousands of hatchlings emerge from their nests and enter into the sea. At the beginning of their marine life, they quickly leave the coast, undertake long oceanic migrations and, after reaching sexual maturity, return to Cape Verde several years later to nest on the beaches.

Although they do not nest in the Cape Verde Islands, juvenile green and hawksbill turtles are very common and can remain feeding in shallow and protected bays for several years, migrating far away when they approach sexual maturity. Genetic studies of green turtle juveniles in the archipelago have revealed that they do not come from one single nesting population, but from different populations that are widely dispersed through the Atlantic. Over 30% of the Cape Verde feeding grounds are populated by green turtles that hatched on the American continent and undertake transatlantic migrations (Monzón Argüello *et al.* 2010c). Other juvenile green turtles come from the coasts of West Africa, Brazil and Ascension Island in the South Atlantic (Monzón Argüello *et al.* 2010c).

Results of genetic studies of hawksbill juveniles in the Cape Verde Islands indicate the existence of populations that have not yet been genetically characterized elsewhere (Monzón Argüello *et al.* 2010b), but also suggest that a small proportion of these turtles may come from the Caribbean.

THE CAPE VERDE LOGGERHEAD TURTLE

References to the presence and abundance of sea turtles in the archipelago of Cape Verde go back to the 15th century (see Lazar & Holcer 1998, López Jurado *et al.* 2000a, López Jurado 2007, Loureiro & Torrão 2008). These old texts describe the capture of turtles for meat consumption and also for alleged medical purposes. During the past decade, the nesting population of the Cape Verde loggerhead turtle became known to the scientific world thanks to the studies started by the biologist, Luis Felipe López Jurado, of the University of Las Palmas de Gran Canaria (Cabrera *et al*. 2000, Cejudo *et al*. 2000, López Jurado *et al*. 2000a, b).

Today, the loggerhead turtle nesting population of Cape Verde is considered the second largest population of this species in the Atlantic and the third worldwide, after the nesting populations in Florida and Oman (López Jurado *et al*. 2007). The presence of loggerhead turtles has been documented on all the islands in the archipelago, as well as on some of the islets, but with highly variable densities among the various islands. Around 85-90% of nesting is concentrated on the easternmost island of Boavista, where the population is currently estimated at more than 10,000 nests per year. (López Jurado *et al.* 2007, Marco *et al.* 2008, 2010). The islands of Maio, Sal and São Nicolau support a much lower number of nests, with an annual mean of around 500 nests on each of these islands (Cozens 2009, Cozens *et al.* 2009, Lino *et al.* 2010, A. Marco unpubl. data). On the remaining islands in the archipelago, nesting density is much lower and is estimated to be less than 150 nests annually per island (Loureiro 2008, A. Marco *et al.* unpubl. data).

The Cape Verde loggerhead turtle constitutes a regional conservation unit (Wallace *et al.* 2011), genetically distinct from other loggerhead populations in the Atlantic and Mediterranean (Monzón Argüello *et al.* 2010a). This genetic distinctiveness indicates considerable reproductive isolation, with little gene flow from other populations (Monzón Argüello *et al.* 2010a). Phylogeographic analysis shows that the loggerhead turtle population of Cape Verde is more closely related to the populations of northeastern Florida, North Carolina and Brazil than to those of West Africa (Monzón Argüello *et al.* 2010a).

Although many turtles exhibit high nesting site fidelity (they usually nest at the same beach during one or several seasons), some turtles have been observed making two consecutive nests at different islands that were more than 70 km from each other and separated by waters over 1,000 m deep, within a single nesting season (Abella *et al*. 2010). These observations are consistent with the genetic results of the population structure analysis in the archipelago, in which no genetic differences were observed between reproductive females from different islands (Monzón Argüello *et al.* 2010a). There is a great plasticity in nesting fidelity and a significant flow of nesting females between islands. Therefore, the whole Capeverdean archipelago can be considered as a single management and conservation unit.

Through the analysis of molecular microsatellite markers, it has been possible to evaluate the levels of multiple paternity in this loggerhead population. In research conducted by Sanz *et al*. (2008a, b), 66.7% of the analyzed nests had been fertilized by more than one male. The average number of males found per nest was 2.2, although within one nest, a single male often fertilized more than half of the eggs. The high level of paternity, together with the fact that males of nests from different females were also different, suggests that the adult male population is abundant, despite being persecuted by poachers, as some of their body parts are believed to be aphrodisiac. Furthermore, the loggerhead nesting aggregation of Boavista has the highest rate of multiple paternity registered to date for this species.

Fig. 1. Exceptional diurnal nesting of a loggerhead turtle *Caretta caretta*, Praia do Carreto, Boavista, 3 September 2007 (Adolfo Marco).

Fig. 2. Egg laying by a loggerhead turtle *Caretta caretta* in a vegetated dune in southeastern Boavista, 29 August 2006 (Adolfo Marco).

REPRODUCTIVE PATTERN AND NATURAL THREATS

While in continental rookeries nesting commonly takes place along thousands of kilometres of coast (Florida, Caribbean, Gulf of Mexico, Brazil, eastern Mediterranean), the main nesting grounds of this insular population are concentrated on *ca.* 40 km of beach. At the *Reserva Natural das Tartarugas*, along the southeastern coast of the island of Boavista, 15 km of beach host around 60% of all nesting females in Cape Verde and possibly contain the highest nesting density of this species in the world, with more than two nests per linear metre of beach in stretches over 800 m long. This makes these nesting beaches extremely vulnerable to any kind of disaster (oil spills, tropical storms, etc.) or artificial impacts (urbanization, linear infrastructures, artificial lighting, mass tourism, etc.).

The reproductive biology of the Cape Verde loggerhead turtle is peculiar because of the small size of nesting females. The annual average curved carapace length of nesting females is around 82 cm (min. = 67; max. = 107.7; SD = 3.97; N = 4334) (Ballell Valls & López Jurado 2004, Varo Cruz *et al.* 2007). This is slightly larger than Mediterranean loggerhead turtle populations from Greece, Turkey and Cyprus, which have the smallest reproductive size found in this species (see Ballell Valls & López Jurado 2004).

In Cape Verde, many adult males and females can be observed mating in waters close to shore from April-May to just before the nesting season that starts in June and ends mid-October. Nesting success (number of nests laid against the total number of tracks on the beach) on the most important nesting beaches varies, but is usually between 26% and 44% (López *et al.* 2003, Díaz Merry & López Jurado 2004, Varo Cruz *et al.* 2007). Nests have an average depth of around 48.4 cm (min. = 34; max. = 67; SD = 6.56; N = 68) (Varo Cruz *et al.* 2007, Martins *et al.* 2008). The percentage of developing embryos at the start of incubation is higher than 83.5%, ranging from 75 to 100% (SD = 7.39; N = 29) (Abella *et al.* 2006). Clutch size averages 85 eggs (min. = 24; max. = 143; SD = 16.9; N = 109) (Lozano Fernández & López Jurado 2004, Varo Cruz *et al.* 2007) and incubation time averages 58 days, varying from 45 to 74 days (SD = 3.9; N = 432) (Varo Cruz *et al.* 2007), depending on the beach, month and nesting season. Emergence of hatchlings takes place from the end of August until December. The mean emergence success of natural nests on the main nesting beaches of Boavista is extremely variable and relatively low, with mean values varying from 20 to 60% (Del Ordi *et al.* 2003, García Carcel & López Jurado 2004, Varo Cruz *et al.* 2007). Compared to other loggerhead populations around the world, this demographic parameter is relatively low (see García Carcel & López Jurado 2004). The main causes of this low emergence success in natural nests are 1) predation of eggs by the ghost crab *Ocypode cursor* (Da Graça *et al*. 2010), 2) flooding of nests by high tides and 3) the high clay content of some incubation substrates (Marco *et al.* 2008a). The mean rate of nest predation by crabs can be over 50 % on high density nesting beaches (Da Graça *et al.* 2010). There are no native mammalian predators of eggs on the main nesting beaches, although predation by feral cats and dogs occurs. The ghost crab is the main predator of eggs, but there are other secondary predators, such as the brown-necked raven *Corvus ruficollis*, which feeds on nests destroyed by crabs. In addition, colonies of the fungus *Fusarium solani* have been identified in Cape Verde turtle nests, which in some situations can act as pathogens (Abella *et al.* 2008a, Sarmiento Ramírez *et al.* 2010). Once hatchlings hatch and emerge from the nest, ghost crabs and ravens are their main predators and feral cats can sometimes be seen prowling around turtle nests.

Fig. 3. Predation by ghost crabs *Ocypode cursor*, the inundation of nests by high tides and the presence of clay in the incubation substrate are the main natural causes of mortality in sea turtle nests in the Cape Verde Islands (Adolfo Marco).

Incubation temperature varies depending on the year, the time of incubation within the same nesting season and the nesting site, but on the main nesting beaches the annual average temperature of sand at 40 cm depth ranges from 26.5ºC to 30.6ºC (Abella *et al.* 2007, 2008b). On beaches with black sand, incubation temperature can be considerably higher, causing problems to developing embryos. From the average incubation temperature during the period of sex determination (i.e. the second third of incubation), it is estimated that the sex ratio produced at the main nesting beaches is biased towards females, representing *ca.* 65-75% of hatchlings (Abella *et al.* 2007). Delgado *et al*. (2008) obtained very similar results in their histological analysis of dead hatchlings found on the beach. Compared with other Atlantic populations, where it is estimated that the ratio of female hatchlings is around 90% (Marcovaldi *et al.* 1997, Hanson *et al.* 1998, Baptistotte *et al.* 1999), these data indicate that despite the high production of females a considerable number of males is produced.

MARINE LIFE

The feeding grounds of adult female loggerheads are located in waters off the Atlantic coast of Africa. From satellite tracking studies of adult turtles, we know that females, and possibly also males (Cejudo *et al.* 2008), appear close to the coast between Mauritania and Sierra Leone during the non-reproductive period between nesting seasons (Hawkes *et al.* 2006). In addition, a dichotomy has been observed in the migratory behaviour of females: the larger turtles migrate southward to benthic feeding grounds along the coast of Sierra Leone, whereas small-sized females migrate to oceanic waters off Mauritania, The Gambia and Senegal (Hawkes *et al.* 2006).

Loggerhead turtles usually carry many epibionts. Which species of epibiont attaches to a sea turtle depends on the migration route it follows. The most common genus of epizoic flora found on loggerheads in Cape Verde is *Polysiphonia* and the most common fauna are two species of Cirripedia, i.e. *Lepas anatifera* and *Conchoderma virgatum*, a species of barnacle *Chelonibia testudinaria*, many Amphipoda (Caprellidae, Gammaridae), a number of isopods and also Tanaidacea (Loza & López Jurado 2008). Another epizoic group that has been found on loggerheads in Cape Verde are the Hydroidea, represented by *Obelia geniculata* (Loza & López Jurado 2008).

Juvenile loggerheads originating from Cape Verde have been genetically identified at feeding grounds off the Canary Islands, Madeira, the Azores and the western Mediterranean (Monzón Argüello *et al.* 2009). They share these feeding grounds with juveniles of the same species from other Atlantic and Mediterranean populations. Although the northward dispersal of Capeverdean juveniles is clear, Monzón Argüello *et al*. (2010a) concluded that *ca.* 43% of Capeverdean juveniles are not found in the studied feeding areas. These juveniles could be feeding at unknown and/or non-studied foraging grounds, but could also represent juveniles eliminated from the metapopulation (e.g. mortality in the early stages or in fisheries). Recently, a juvenile specimen found in an area near the coast of Ceará, Brazil, carried a haplotype that to date has only been identified in Cape Verde (Cardinot Reis *et al.* 2009). This indicates the need for genetic studies at other feeding grounds in the western Atlantic and the possible existence of feeding grounds of juvenile loggerheads yet to be discovered. It is possible that a significant number of juveniles disperse to American waters or southward to the Gulf of Guinea (Monzón Argüello *et al*. 2010a).

Fig. 4. Carcass of a slaughtered loggerhead turtle *Caretta caretta*, Praia da Boa Esperança, Boavista, 15 September 2009 (Hector Garrido). The slaughter of turtles for meat consumption and the destruction of nesting habitats due to the development of the tourism industry are the main human caused threats to sea turtles in the Cape Verde Islands.

NEW THREATS AND CONSERVATION STATUS

The conservation status of the Cape Verde loggerhead turtle population is of great concern. In Cape Verde, the consumption of sea turtle meat is a long-standing tradition, as is the consumption of eggs on some islands, the hunting of males for aphrodisiacs and the use of turtle shells in handicrafts (Cabrera *et al*. 2000, Loureiro & Torrão 2008). In 1987, the Cape Verde government first regulated the hunting of sea turtles during the nesting season (Decree-Law No. 97/87). In 2002, hunting was banned during the whole year (Decree-Law No. 7/2002), but only from 2005 onwards, possession, hunting, consumption and exploitation of sea turtles and their eggs became explicitly prohibited by law (Article No. 40 of Decree-Law No. 53/2005). These legal measures have probably decreased the hunting pressure, but have not stopped the long decline of sea turtles in Cape Verde (Cabrera *et al.* 2000, Loureiro & Torrão 2008). At present, a fast developing tourist industry is threatening turtle nesting habitats on several islands (see Taylor & Cozens 2010). The widespread use of quads and 4-wheel drive vehicles has a devastating effect on loggerhead nesting areas, while the arrival of many low-waged workers from continental Africa, who work in the construction of new hotels, has increased hunting pressure on sea turtles in recent years. This critical situation, as manifested by the uncontrolled illegal killing of females on the beach (Marco *et al.* 2008b), has brought about an increased commitment and involvement by regional, national and international organizations for the conservation of sea turtles in the archipelago. It seems that the protection and awareness efforts of recent years are starting to bear some fruit, but it remains necessary to increase protection and cooperation initiatives for sustainable development in order to safeguard the survival of this emblematic Atlantic population. Recently, the Capeverdean Sea Turtle Network (TAOLA) was created to coordinate efforts and improve communication between various organisations and governmental bodies.

On 13 December 2010, the Government of Cape Verde approved the National Plan for the Conservation of Marine Turtles (Resolution nº 72/2010). The general objective is to improve and ensure the conservation and sustainable use of marine turtles for ecotourism in Cape Verde in an integrated way. This should provide competent institutions with the means to coordinate the implementation of activities of the conservation plan, promote enforcement of laws for the conservation of marine turtles, contribute to a better understanding of the species of marine turtles in Cape Verde and promote a favourable attitude toward conservation and sustainable use of marine turtles with touristic enterprises and the general population. This National Plan is an important guiding tool in the conservation of these endangered marine species and will not only contribute to the conservation of these species in Cape Verde, but also on an international level.

Cape Verde supports the only major nesting area for loggerhead turtles along the entire eastern Atlantic coast. The high philopatry of female sea turtles and extremely slow dispersion of sea turtle nesting grounds implies that the Cape Verde nesting grounds are going to be essential for the reproduction of loggerhead turtles during the next decades and beyond. We are confident that with the efforts of all Capeverdean institutions (Roder 2009), as exemplified in the recently approved National Plan for the Conservation of Marine Turtles, the increasing awareness and education of the local communities (Espirito Santo *et al.* 2008), the economic and social development associated with an emerging ecotourism, the increase in international cooperation and a combination of many supportive contributions, the necessary recovery and conservation of sea turtles in Cape Verde will become a reality.

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On the history of the green monkey *Chlorocebus sabaeus* (L., 1766) in the Cape Verde Islands, with notes on other introduced mammals

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Keywords: green monkey, *Chlorocebus sabaeus*, introduced mammals, Cape Verde Islands

ABSTRACT

The history of the green monkey *Chlorocebus sabaeus*, a species introduced by man, in the Cape Verde Islands is discussed. The earliest reference to the presence of monkeys on the island of Santiago dates from the late 16th century, when they were said to be abundant, suggesting that their introduction took place during the first 100 years since the first arrival of European navigators in the archipelago around 1460. Brava is the only other island in the Cape Verdes where the green monkey has been introduced. Reports of the former existence of feral monkey populations on other islands (e.g. Santo Antão and Fogo) are unsubstantiated. Today, populations of the green monkey survive on both Santiago and Brava, although – due to heavy persecution because of the damage they caused to plantations – their numbers are now probably less then they may have been in the past. In addition, the occurrence of other mammals introduced to the Cape Verde Islands is discussed. These encompass rodents (house mouse *Mus musculus*, brown rat *Rattus norvegicus*, black rat *R. rattus*) and the rabbit *Oryctolagus cuniculus*. Finally, the history of free-living ungulates, particularly goats, in the archipelago is briefly discussed.

RESUMO

Neste artigo é discutida a história do macaco verde *Chlorocebus sabaeus*, uma espécie introduzida pelo homem nas ilhas de Cabo Verde. A referência mais antiga à sua presença na ilha de Santiago data do final do século XVI. A referência indica que o número de exemplares era abundante, sugerindo que a sua introdução na ilha se terá dado no século seguinte à chegada dos primeiros navegadores europeus ao arquipélago por volta de 1460. A ilha Brava é a outra ilha onde os macacos foram introduzidos. Existem relatos de populações de macacos noutras ilhas (e.g. Santo Antão e Fogo), mas são insubstanciados. Actualmente, sobrevivem populações de macacos em Santiago e Brava, embora o número de exemplares tenha provavelmemte vindo a diminuir em virtude da caça devido aos estragos que trazem à agricultura. O artigo discute ainda outros mamíferos introduzida em Cabo Verde, como roedores (ratinho-caseiro *Mus musculus*, ratazana-castanha *Rattus norvegicus*, ratazana-preta *R. rattus*) e o coelho-bravo *Oryctolagus cuniculus*. Finalmente, é discutida de forma breve a história de mamíferos ungulados em regime de quase completa liberdade no arquipélago, particularmente cabras.

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INTRODUCTION

The Cape Verde Islands are an oceanic archipelago of volcanic origin situated in the East Atlantic Ocean between 14º48´, 17º22´N and 22º44´, 25º22’W, 500 km west of Senegal, West Africa (Fig. 1). There are nine main islands (ilhas), varying in size from 991 km² (Santiago) to 35 km² (Santa Luzia), as well as a number of smaller islets (ilhéus), some of which are entities of their own (Raso, Branco, ilhéus do Rombo), while others are satellite rocks of the main islands. In this paper, the term ‘island’ refers to the former, while the term ‘islet’ refers to the smaller entities.

The Cape Verde Islands are part of the Sahel zone and climate is dry tropical, with monsoon rains occurring from August into November, which – as the islands are situated just north of the Intertropical Convergence Zone – are unpredictable and by no means annual. Rainfall during the monsoon period may vary enormously from year to year and drought periods of up to 18 years have been recorded during the islands’ history. The local climate shows great variability and the higher parts of the geologically younger islands of Santiago, Fogo, Brava, Santo Antão and São Nicolau may receive some precipitation at any time from August until March, while the lower parts of these islands, as well as the eroded and geologically older eastern islands of Sal, Boavista and Maio, are extremely arid most of the year. The northwestern and relatively flat islands of São Vicente and Santa Luzia are also very arid.

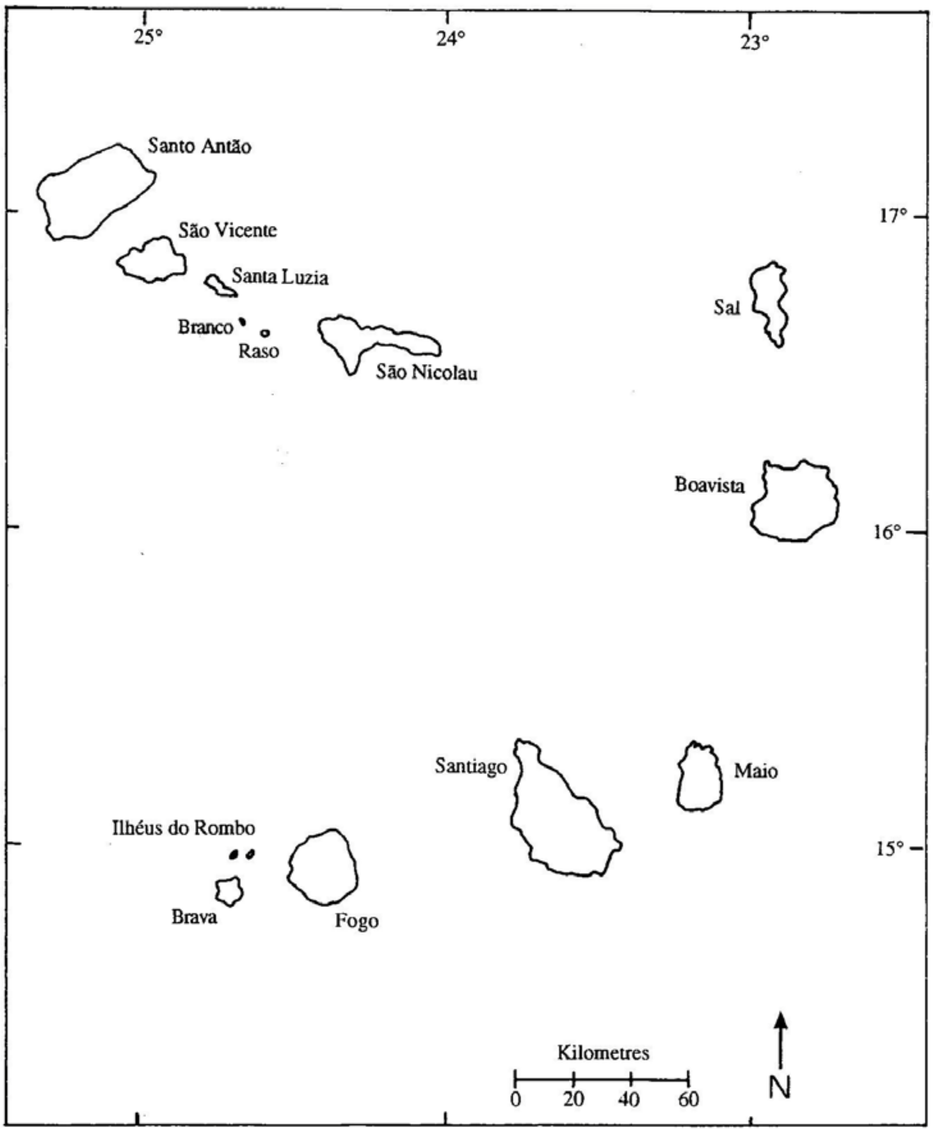

Fig. 1. Map of the Cape Verde Islands.

Typical of many geologically young oceanic islands, no indigenous terrestrial mammals occur in the Cape Verde Islands except for bats (see Azzaroli Puccetti & Zava 1988, Jiménez & Hazevoet 2010), all non-volant land mammals having been introduced by man. As the islands were uninhabited at the time of their discovery, these introductions must have taken place during the past 550 years, i.e. since *ca*. 1460 (the precise year is disputed among historians), when the first European navigators arrived in the archipelago.

There exists hardly any environmental information dating from the earliest period of human settlement, but there can be little doubt that the natural environment of the islands has been highly modified since the arrival of man and his inevitable menagerie of domesticated animals. The following is taken from Hazevoet (1995) and references therein. The Cape Verdes, in their virgin state, did not support any woodland with a closed canopy. At lower elevations, the islands were probably covered with herbaceous savannah or steppe vegetation. The windward slopes at higher elevations were probably mainly covered with *Euphorbia* bushes and scattered dragon *Dracaena draco* and ironwood trees *Sideroxylon marmulano*. The flat and arid eastern islands, as well as São Vicente and Santa Luzia, supported a steppe and semi-desert vegetation. Over the past five centuries, the combined effects of poor agricultural techniques, the introduction of large numbers of alien plants and trees, overgrazing by an abundance of wide-roaming goats and other lifestock and a high population pressure have led to an almost complete destruction of the original vegetation cover. Afforestation started in the 1930s, especially in the interior of Santiago (mainly *Eucalyptus* spp.) and in the higher parts of northern Santo Antão, where large tracts of pines *Pinus* spp were planted. Since independence in 1975, millions of trees (mainly *Prosopis juliflora* and *Parkinsonia aculeata*) were planted in the low and arid areas.

Among the mammals introduced by man since the discovery of the islands and of which feral populations exist until today is a species of monkey. In this paper, we discuss the historical presence of the green monkey *Chlorocebus sabaeus* (L., 1766) in the Cape Verde Islands. We also comment on the history and occurrence of a number of other introduced mammals, particularly rodents and lagomorphs, and we briefly discuss the role wide-roaming ungulates have played in shaping the present environment in Cape Verde.

METHODS

Data on the occurrence of introduced mammals in the Cape Verde Islands were collected by 1) searching the literature, especially historical descriptions and narratives of early voyagers, 2) personal observations by the first author and 3) observations provided by correspondents on various islands. Data obtained from the literature were evaluated as for their reliablity. Reports of alleged occurrences mentioned in a number of compilation works and popular guides were deemed useless, as these were evidently not based on first-hand observations, but merely repeating – often erroneous – reports from earlier works. Observations of rodents obtained from the literature or provided by correspondents (see Acknowledgements), but not identified at the species level, were rendered to the next inclusive taxonomic level.

RESULTS

Green monkey *Chlorocebus sabaeus* (L., 1766)

Although having been introduced in the archipelago by man, the Cape Verde Islands enjoy the distinction of being the type locality of the green monkey. Linnaeus (1766) based his *Simia sabaea* on the ‘St. Jago Monkey’ of Edwards (1758), a specimen of which had been brought to England from St. Jago (Santiago) island in the Cape Verdes at some time during the 18th century (Fig. 2). Edwards (1758) gave a fairly accurate description of the animal, also commenting on its behaviour, and remarking that "it's often called the green monkey", but "our seamen generally call them St. Jago monkies, they being brought from St. Jago, one of the Cape de Verde Islands" (Edwards 1758: 10).

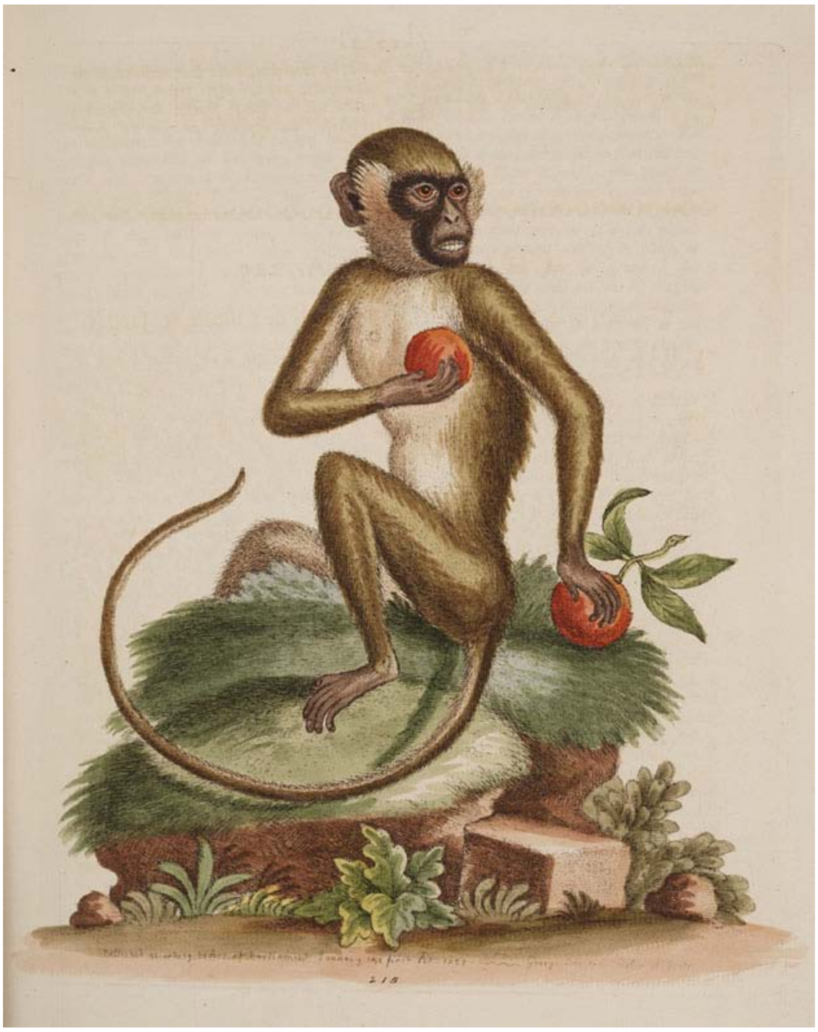

Fig. 2. The St. Jago Monkey, as depicted in Plate 215 of George Edwards' (1758) Gleanings of Natural History, on which Linnaeus (1766) based his *Simea sabaea*.

Formerly placed in *Cercopithecus* L. 1758 and commonly treated as a 'subspecies' of *C. aethiops* (L., 1758), it was separated and placed, along with several other subsaharan monkeys previously placed in *Cercopithecus*, in a resurrected *Chlorocebus* Gray, 1870 by Groves (2001, 2005). In West Africa, the green monkey is widespread in the northern savannahs from Senegal and Sierra Leone in the west to the Volta river in the east (Kingdon 1997, Grove 2001, 2005). It seems likely that the monkeys introduced in the Cape Verde Islands originated from former Portuguese Guinea (now Guinea-Bissau), as there were regular maritime connections between these two Portuguese colonies and for centuries Portuguese Guinea was administered from Cape Verde's capital (first Cidade da Ribeira Grande, later Praia). However, we do not have hard evidence for this and introductions of animals originating elsewhere cannot be excluded with certainty. Moreover, the Casamance region of present day southern Senegal was also under Portuguese colonial rule until well into the 19th century.

Historically, free living populations of green monkeys in the Cape Verde Islands have only existed on the islands of Santiago and Brava. Reports suggesting that monkeys also occurred on other islands appear to have been based on monkeys kept as pets there. The island of Santo Antão has sometimes figured among the islands where feral monkey populations have occurred, but this is clearly in error for Santiago (e.g. Friedlaender 1913), uncritically repeated by later authors and not based on first-hand observations (e.g. Muzio 1925, Masseti & Bruner 2009, Masseti 2010). Indeed, Rocha (1990), in his account on the history of Santo Antão, does not mention the presence of monkeys on that island, although he reported on other wildlife. There are no athenticated records of feral green monkeys from Santo Antão. Masseti & Bruner (2009) and Masseti (2010) included a photo of a pet monkey kept on Fogo, which led these authors to mistakenly infer that a population of feral monkeys previously existed there.

The earliest reference of monkeys in the Cape Verde Islands that we have found is by Carletti (1965) in the narrative of his voyage around the world during the years 1594-1606. The Florentine merchant and voyager, Francesco Carletti, stayed on Santiago island from January to April 1594 and wrote that there were “a large number of monkeys of a kind that we call meerkat, with a long tail, and which are called *bugios* by the Portuguese” (Carletti 1965: 21; translated from the Dutch). Thus, 135 years after the first humans arrived in the archipelago, monkeys were already numerous on Santiago, indicating that their introduction probably took place during the first 100 years of colonization. This clearly contradicts Chevalier (1935: 786-787), who stated that “according to tradition, all the monkeys are descendents of a single pregnant female, imported from Portuguese Guinea, that escaped from captivity about 150 years ago and raised its young in the bush” (translated from the French). Another version of the monkeys’ origin comes from de Naurois (1969: 151, 1994: 22) who wrote that “according to our information, the import [of monkeys] has been due to a strange misunderstanding: a Portuguese inhabitant of Santiago asked one of his friends in [Portuguese] Guinea to send him one or two monkeys. The correspondent did not get the words right and thought the request was for 102 of them. He could not obtain that many, but sent 20. When disembarking at Praia, Santiago, and Furna, Brava, the monkeys escaped from their cages” (translated from the French, being a combination of de Naurois’ slightly different 1969 and 1994 versions). Still another version was offered by Ferlin (1979: 23), who was of the opinion that the green monkeys “descended from a guenon imported from Portuguese Guinea at the end of the 18th century” (translated from the French). If anything, de Naurois’ (1969, 1994) account, in which part of 20 animals escaped at two different ports, does not appear very convincing and probably represents an example of an ‘urban legend’. Although the presence of monkeys on Santiago clearly predates any of these renderings, it can of course not be excluded that there has been more than a single importation or escape, especially on the main island of Santiago. Until the development of Porto Grande, on the island of São Vicente, during the first half of the 19th century, the capital Praia (and earlier Cidade da Ribeira Grande) was the main port and centre of commerce in the archipelago.

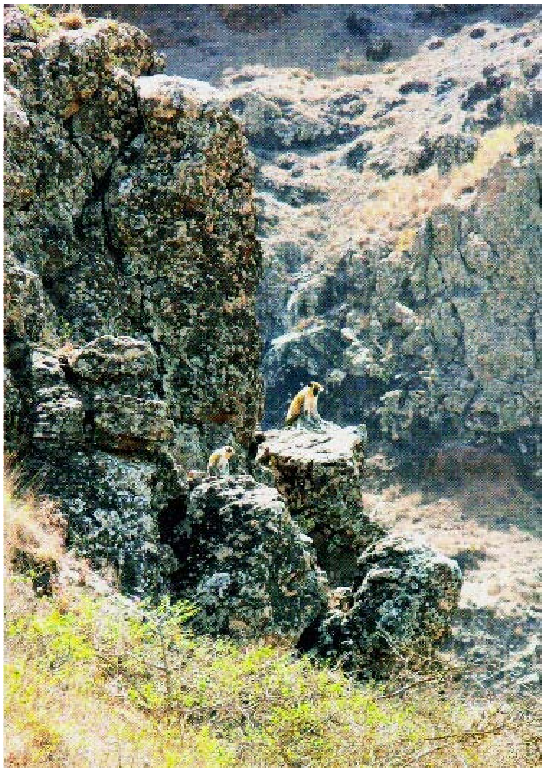

Fig 3. Green monkeys *Chlorocebus sabaeus*, Achada Mula, Santa Catarina region, Santiago (Pitt Reitmaier/after a postcard).

In 1673, John Fryer (*in* Crooke 1909) saw natives selling monkeys at the beach on Santiago and William Dampier, who was at the old capital, Cidade da Ribeira Grande (now Cidade Velha), in 1699, mentioned that there were 'black-fac'd long-tail'd monkeys' (Dampier 1981 [1729]). We have not found a reference of monkeys in Cape Verde from the 18th century. António Pusich (*in* Ribeiro 1956), who stayed in the islands during the first decades of the 19th century, wrote that the mountain ranges of Santiago "are arid and sterile and only inhabited by an innumerable number of monkeys" (translated from the Portuguese). The first to mention the presence of 'stealing monkeys' ('*singes voleur*') on both Santiago and Brava appears to have been D'Avezac (1848), who also noted that these were the only two islands where they occurred. The British ornithologist, Boyd Alexander, stayed in the Cape Verde Islands for more than six months in 1897 and wrote about the monkeys on Santiago: "In all the steep valleys are colonies of black-faced West-African monkeys. From our tents we constantly caught sight of them chasing each other in and out of the rocks, while some, bolder than others, would gain the crest-line, where their figures showed clear against the horizon" (Alexander 1898: 79). While on Brava he noted that "In the larger valleys monkeys abound, doing much havoc among the sugar-cane" (Alexander 1898: 90). Robert Rockwell, who stayed on Brava in January-April 1924 as a member of the ill-fated Blossom expedition, remarked about the monkeys there that "these wily creatures were a scourge and a curse, due to their persistent raids on the few vegetable and fruit gardens" (Rockwell 1956: 126). While mentioning their occurrence on both Santiago and Brava, the French botanist, Auguste Chevalier, also noted the harm monkeys caused to the plantations, for which reason a decree prohibited the displacement of monkeys to any of the other islands (Chevalier 1935, Corrêa 1954). Adding to this, de Naurois (1969) mentioned that a premium was paid by the colonial government for any monkey killed in order to promote their extermination. While on Santiago in February 1966, the British ornithologists, David and Mary Bannerman, saw monkeys near São Domingos and at São Jorge dos Orgãos, commenting that "once common, [they] have been driven by persecution to live on the most inaccessible heights in the island" (Bannerman & Bannerman 1968: 88-89).

Today, green monkeys are still widespread on Santiago, particularly in the central mountain ranges of the Serra do Pico da Antónia and Serra Malagueta. During the years 1988-1995, parties of up to 15 animals were regularly seen in the afforestations above São Jorge dos Orgãos in the Serra do Pico da Antónia (CJH pers. obs.), although, according to local inhabitants, during the 1970s hunting had greatly reduced their numbers there (Groh 1982). Green monkeys also occur in the Santa Catarina region in central Santiago (Fig. 3), while Cesarini *et al.* (2008) noted their presence in the Serra Malagueta during the years 2006-2007. A considerable party of these little primates resides in the palm grove behind the beach at Tarrafal, in the north of Santiago island (Fig. 4; YouTube). Until recently, it was thought that green monkeys had gone extinct on Brava (e.g. Hazevoet 1995), but there is a recent observation (of an unspecified number) at Monte Gambia (elevation 500 m), 10 February 2011 (Eyjolf Aistleitner *in litt.*), demonstrating their survival on the island. Apparently, the ban on transporting monkeys to other islands, as mentioned above, is not enforced any longer, as pet monkeys were seen on Sal in 1995, Fogo in 1998 and São Vicente in 2010 (CJH pers. obs.) and are now commonly kept at the tourist resorts near Santa Maria, Sal (Fig. 5; YouTube).

Other introduced mammals

RODENTS The house mouse *Mus musculus* L., 1758 is present on all islands and is common near human habitation. Much of the published information on mice in Cape Verde comes from analyses of the feeding habits of owls (Bourne 1955, Heim de Balsac 1965, de Naurois 1969, 1982, Rabaça & Mendes 1987, Siverio *et al.* 2007, 2008), as well as those of herons (Bourne 1955, de Naurois 1966) and raptors (Bourne 1955, de Naurois 1973, 1987, Ontiveros 2005). Lobin & Groh (1979) and Groh (1982) first reported *M. musculus* from the island of Sal. The presence of mice on all islands during the years 2007-2011 was

Fig. 4. Green monkey *Chlorocebus sabaeus*, Tarrafal, Santiago, July 2005 (Juan Roch).

Fig. 5. Green monkey *Chlorocebus sabaeus* kept as a pet, Santa Maria, Sal, 24 March 2008 (flickr).

confirmed by our correspondents (see Acknowledgements; Fig. 6), as well as through personal observations by the first author on Santiago, São Nicolau and São Vicente.

On the arid island of Santa Luzia, now abandoned but inhabited by a single family until the mid 1960s, mice were abundant at the ruins of the only house there in September-October 1981 (Schleich & Wuttke 1983) and February-March 1986 (CJH pers. obs.). An active nest of the Cape Verde barn owl *Tyto alba detorta* Hartert, 1913 was found on Santa Luzia, 20 October 1999 (Siverio *et al.* 2007). As a result of prolonged deposition of owl pellets, a crevice below the nest was filled with bone remains, revealing a change in prey items through time. While the lower levels only contained remains of lizards Scincidae and geckos Gekkonidae, mouse bones appeared towards the higher levels (Siverio *et al.* 2007), indicating an accumulation of owl pellets for several centuries, i.e. starting before the arrival of humans on the island. In his large work on the African islands, the 17th century Dutch geographer, Olfert Dapper, already mentioned the abundance of mice on Santa Luzia (Dapper 1668). During a three-day visit to Santa Luzia in January 2003, no mice were seen, although mouse remains were found in scats of feral cats (Donald *et al.* 2005), but mice were still found to be abundant there in July 2010 (José Melo *in litt.).*

During the 1980s and 1990s, there were no mice on the uninhabited islets of Raso and Branco (CJH pers. obs.) and still not during the years 2001-2010 (M. Brooke and P. Donald *in litt.*). Neither were there mice on uninhabited ilhéu de Cima (one of the ilhéus do Rombo) in 1989 (CJH pers. obs.). We have no data on the presence or absence of mice on ilhéu Grande (also known as ilhéu de Baixo), the largest islet in the Rombo group, which was never inhabited, but at times was populated by a large number of goats. As these were frequently culled by their owners from nearby Brava, who then stayed on the islet for several days, mice may have been introduced along the way.

Based on morphometric analysis of molar shape, Michaux *et al.* (2007) identified mouse remains from Santa Luzia as *M. m. domesticus* Schwarz and Schwarz, 1943, the commensal house mouse of western Europe, which has spread all over the world in the wake of European colonization. It is highly probable that the mice on other Cape Verde islands are *M. m. domesticus* as well.

Rats *Rattus* sp. have been reported from several islands, but it has not always been clear whether this concerned the black rat *R. rattus* (L., 1758) or the brown rat *R. norvegicus* (Berkenhout, 1769). On Santiago, the presence of brown rats was confirmed in the capital Praia during the 1990s (CJH pers. obs.) and in the Serra Malagueta during the years 2006-2007 (Cesarini *et al.* 2008). It is likely that brown rats also occur elsewhere on the island. During the years 1988-2010, brown rats were occasionally seen in the harbour region of Mindelo on São Vicente (CJH pers. obs.). The presence of black rats has been confirmed on Santiago, i.e. at Trindade (Heim de Balsac 1965, de Naurois 1969, 1982), São Domingos (Rabaça & Mendes 1997) and in the Serra Malagueta (Cesarini *et al.* 2008). Unidentified rats *Rattus* sp. have been reported from Brava, Santo Antão, São Nicolau, Boavista and Maio by our correspondents (see Acknowledgements) and from Fogo by Siverio *et al.* (2008).

Fig. 6. House mouse *Mus musculus*, adult and young, Porto Novo, Santo Antão, 28 April 2008 (Simon Baliteau).

LAGOMORPHS There have been scarce reports of free living populations of rabbits *Oryctolagus cuniculus* (L., 1758) in the Cape Verde Islands. D'Avezac (1848) reported their presence on Santiago, where they were heavily persecuted because of the damage caused to the plantations. While rabbits had greatly multiplied on some islands, they subsequently disappeared completely (Chevalier 1935, de Naurois 1969, 1994). Whether this was a consequence of relentless persecution, the result of droughts or a combination of these factors is unclear. Corrêa (1954) blamed 'the harsh natural conditions' for the rabbit's disappearance, while Matznetter (1960) thought drought to be the cause. It is not known at present on which islands, apart from Santiago, free living populations of rabbits occurred. Today, rabbits are occasionally seen in the semi-arid area north of Porto Novo, Santo Antão, where they are, however, by no means plentiful (Simon Baliteau *in litt.*).

UNGULATES Soon after their discovery, large numbers of goats were set free in the Cape Verdes, especially on the only scarcely populated islands of Sal, Boavista, Maio and São Vicente. These goats belonged to the Portuguese crown. Dapper (1668: 89) wrote that goats were "exceedingly abundant" on São Vicente and were "culled every now and then because of their hides, which are send to Portugal in large quantities". On Maio, there also were large numbers of goats and "every year 5,000 hides are send to Portugal from the island" (Dapper 1668: 89; translated from the Dutch). Dapper's work was a compilation of information obtained from manuscripts by different 16th and 17th century navigators. According to João da Silva Feijó (*in* Carreira 1986), who was in Cape Verde in the 1780s and 1790s, there were 45,000 'wild goats' on Boavista in 1785. Large numbers of donkeys, cattle and horses also lived in a semi-feral state, particularly on Boavista and Maio. However, during times of drought their numbers dropped dramatically. For instance, as the result of prolonged drought, the number of goats on Boavista decreased from 50,000 in 1809 to 1,200 in 1811, while the number of donkeys plunged from 20,000 to 200, cattle from 6,000 to 42 and horses from 4,000 to a mere 4 (Kasper 1987). During the years 1875-1982, the number of goats present on Boavista ranged from a maximum of 15,215 in 1875 to only 719 in 1950 (Kasper 1987). Today, considerable numbers of wide-ranging goats are still present on Boavista and Maio and on ilhéu Grande (ilhéus do Rombo).

DISCUSSION

Excluding goats and other domesticated lifestock, five introduced species of mammals occur in the Cape Verde Islands, i.e. green monkey, house mouse, black rat, brown rat and rabbit.

The Cape Verde Islands have sometimes been included in the distributional range of the slender mongoose *Galerella sanguinea* (Rüppell, 1835) (e.g. Funaioli 1971, Wozencraft 2005). However, this is mistakenly based on a specimen collected at Cap Vert, Senegal, at some time during the 19th century, the collecting locality of which was spelled 'Cape Verd' (without 'Islands' or an abbreviation of that word) on the original specimen label (Roberto Portelo Miguez *in litt.*). The same spelling was subsequently used by Lydekker (1896) and Wroughton (1907), the latter basing his *Mungos melanurus canus* on the specimen. This may have misled some later authors, who interpreted 'Cape Verd' as referring to the archipelago rather than to the peninsula of that name. However, Rosevear (1974) described the slender mongoose's range in West Africa as being from 'Cape Verde to Nigeria', clearly referring to the Senegal locality rather than to the islands, while Taylor (1975) correctly gave the type locality of *Herpestes sanguineus canus* (Wroughton, 1907) as 'Cape Verde', without implying the islands.

The history of the green monkey on the island of Santiago goes back to at least the second half of the 16th century and possibly earlier. It most likely descended from animals imported from former Portuguese Guinea (which until the mid 19th century included present-day southern Senegal), but whether this pertained to a single or multiple importations or escape events is unknown. The timing of its introduction on the island of Brava is equally unknown. There are no authenticated records of the green monkey's occurrence in a feral state from any of the other islands. Further study of historical sources, such as navigators' narratives, may bring to light more details about the green monkey's history in the Cape Verde Islands.

Although there do not exist even remotely precise data on its past numbers, the scarce information available suggests that green monkeys were more common on Santiago in the past than they are today. Apart from the damage inflicted on plantations and gardens on Santiago and Brava, predation of eggs and young by monkeys may also have affected local (including endemic) bird populations. The green monkey's ecology in Cape Verde has as yet not been studied and neither have any studies on population dynamics been carried out.

Of rodents, the house mouse is widespread and occurs on all inhabited islands, as well as on the (formerly inhabited) island of Santa Luzia. Rats are equally widespread, having so far been reported from all islands except Sal and Santa Luzia, but are much less abundant than mice. The seemingly rather marginal occurrence of the brown rat may be related to the fact that most of Cape Verde's environment does not meet its water requirements. On Santiago, both black and brown rat have been identified, while on São Vicente the presence of the brown rat has been ascertained in the harbour area. The taxonomic identity of the rats found on other islands is still to be established. While the brown rat typically occurs in urban and harbour areas, the habitat choice of the black rat in Cape Verde is less clear, as knowledge of its presence is almost exclusively based on its identification as a prey item of birds, particularly the barn owl. Cesarini *et al.* (2008) mentioned the occurrence of both black and brown rats in the Serra Malagueta on Santiago, but did not provide further details.

Rabbits are said to have been common on several islands in the past, but now only occur on Santo Antão, although the scale of their present distribution there has not yet been determined. It is commonly believed that rabbits disappeared on most islands as a consequence of prolonged droughts. Whether the rabbit's current presence on Santo Antão is a holdover from the past or the result of a recent introduction is unknown.

Although the goats and other lifestock that widely roamed many of the Cape Verde Islands in the past were not feral in the strict sense, as they were owned and exploited (be it probably only marginally so during the early centuries of Cape Verde's history), their impact on the natural vegetation of the islands may have been profound. Free ranging goats (and other lifestock) are responsible for denuding soil, resulting in erosion and water loss, as well as the compaction of soil, hindering the regeneration of plants. Such effects can be particularly severe in fragile habitats such as the steppe and semi-desert vegetation that probably existed in the Cape Verde Islands in their virgin state, giving rise to large scale desertification (cf. Clutton-Brock 1999).

Apart from the species discussed above, feral cats and dogs can be found on most islands. On Santa Luzia, together with the islets of Branco and Raso now a nature reserve protected by law, a cat eridication programme is being implemented (José Melo *in litt.*). On Boavista (and possibly elsewhere), predation by feral cats threatens local populations of the red-billed tropicbird *Phaethon aethereus* L., 1758 (Pedro López Suárez *in litt.*). During the past decade, sterilization programmes of feral dogs and cats have been carried out in a number of urban areas in Cape Verde.

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Short note | Nota breve

Seasonality of humpback whale *Megaptera novaeangliae* (Borowski, 1781) records in Cape Verde seas: evidence for the occurrence of stocks from both hemispheres?

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Keywords: Humpback whale, *Megaptera novaeangliae*, Cape Verde Islands, phenology

Humpback whales *Megaptera novaeangliae* perform the longest known migrations among mammalian species (Stone *et al.* 1990, Rasmussen *et al.* 2007), feeding at high latitudes during the summer and undertaking annual journeys to their wintering breeding grounds in warm and shallow tropical waters (Winn & Reichley 1985, Clapham & Mead 1999). Due to breeding site fidelity and temporal separation at low latitudes, gene flow between Northern and Southern Hemisphere populations appears to be very limited (Rizzo & Schulte 2009). However, inter-oceanic exchange has recently been documented (Pomilla & Rosenbaum 2005, Stevick *et al.* 2010), demonstrating that philopatry may not be as strong as previously inferred (cf. Baker *et al.* 1993, 1994, Valsecchi *et al.* 1997).

In the Atlantic Ocean, the seas of the Cape Verde archipelago constitute one of two known breeding grounds for Northern Hemisphere humpback populations, the other being in the Caribbean (Winn & Reichley 1985, Hazevoet & Wenzel 2000). While the total North Atlantic population was estimated at 10,752 animals in 1993 (Stevick *et al.* 2003), the eastern North Atlantic stock is thought to number only *ca.* 100 animals (Punt *et al.* 2006) and there exists substantial uncertainty about the size of the Cape Verde breeding population (Smith & Pike 2009). Both the Caribbean and Cape Verde populations were severely depleted by commercial whaling, especially during the 19th century (Smith & Reeves 2010).

Wintering humpbacks arrive in Cape Verde seas in January (sometimes as early as December), while the last of the animals have generally left the area by mid May (Hazevoet & Wenzel 2000, PLS pers. obs.). In the Caribbean, wintering humpbacks were historically present from January through May (Reeves *et al.* 2001). In Cape Verde, there are photographic matches of animals previously photographed off Bear Island (Norway), in the Denmark Strait (west of Iceland) and in the Azores (Wenzel *et al.* 2009).

Other wintering areas of humpbacks in the eastern Atlantic, but populated by whales originating from the Southern Hemisphere, are situated in the Gulf of Guinea from northern Angola to Gabon (Rosenbaum & Collins 2006, Weir 2007, 2010) and from Nigeria westward to Côte d'Ivoire (Van Waerebeek *et al.* 2001, 2009, Van Waerebeek 2002, Weir 2010). Whether these two areas (possibly connected through continental shelf waters off Cameroon) constitute the breeding grounds of a single or multiple populations is as yet unclear. Humpbacks also winter around the islands of São Tomé, Príncipe and

Annobón (Weir 2010). Off Angola and Gabon, humpbacks are mostly seen from June to October (Rosenbaum & Collins 2006, Weir in press), but records later in the year are not uncommon, while in the northern Gulf of Guinea off Togo and Benin animals are regularly seen into December (Van Waerebeek *et al.* 2001, Van Waerebeek 2002, Weir 2010). Townsend's (1935) whaling charts show that humpbacks in Cape Verde seas were primarily caught from February to May, while in the Gulf of Guinea catches were from June to September.

During the afternoon of 15 August 2010, BG observed an adult humpback whale, accompanied by a small calf, travelling in a westward direction at 16º34,6'N, 22º52,4'W (depth 30-35 m), off Santa Maria along the southern coast of Sal island, Cape Verde Islands (Fig. 1-2). According to local fishermen, more adult humpbacks had been seen in the area during that month. Previously, there was an atypical (i.e. outside of the usual January-May occurrence) record of a humpback in Cape Verde seas at 16º34´N, 24º23´W (southwest of Sal), 16 July 1993 (Reiner *et al.* 1996). In addition, there are two June records from Cape Verde seas (Table 1). No fluke photos for identification purposes of any of these humpbacks were taken and neither have genetic samples been collected.

Fig. 1-2. Humpback whale *Megaptera novaeangliae*, cow and calf pair, off Santa Maria, Sal, Cape Verde Islands, 15 August 2010 (Barbara Gravanita).

Date	Number	Location	Source
12 June 1994	one (sex unknown)	15º57'N, 23º42'W	Reiner *et al.* (1996)
15 June 2003	cow and calf pair	16º09'N, 22º54'W	P. López Suárez
16 July 1993	one (sex unknown)	16º34'N, 24º23'W	Reiner *et al.* (1996)
15 August 2010	cow and calf pair	16º34'N, 22º52'W	B. Gravanita

Table 1. Records of humpback whales *Megaptera novaeangliae* in the Cape Verde Islands outside of the usual January-May occurrence.

While the records in June possibly involve long staying animals of northern origin, those in July and August do not fit into the known seasonality of Northern Hemisphere humpbacks in Cape Verde. This leaves us with three options: 1) all of these June-August records relate to Northern Hemisphere animals that simply stay longer on their wintering ground than previously documented, 2) they belong to Southern Hemisphere animals (although June would be rather early for them to have reached that far north), 3) they represent a mixture of animals from both hemispheres, some late, some early.

Other records of humpbacks off West Africa outside the documented seasonality of Northern Hemisphere humpbacks include stranding records from Guinea (Conakry) in

July and September and a live sighting *ca.* 24.5 km offshore at 09º19´N, 13º41´W, 1 October 2002 (Bamy *et al.* 2010). In Sierra Leone, humpbacks were seen off York (08º16´N, 13º11´W), 10 September 2010 (Kieranna McCormick *in litt.*) and a cow and calf pair was observed off Orango island (11º11´N, 16º30´W) in the Bijagós archipelago, Guinea-Bissau, 30 September 2009 (Anonymous 2009). In addition, Slijper *et al.* (1964) mapped several records of humpbacks off West Africa between 10º-20ºN in September, as well as one in October. Perhaps most intriguing is the sighting of two adult humpbacks and a small calf two miles off Puerto Rico (27º46´N, 15º43´W), Gran Canaria, Canary Islands, 1 October 2007 (Vidal Martin *in litt.*). It should be noted that very little cetacean research has been carried out in the eastern Atlantic between Guinea-Bissau and Côte d'Ivoire and knowledge of species occurrence and species seasonality for this vast area is poor.

Elsewhere in the humpback whale's range, evidence of geographical (but not temporal) overlap comes from areas in the eastern Pacific Ocean known to be used by wintering humpbacks of northern origin in January-February (Steiger *et al.* 1991, Acevedo & Smultea 1995, Calambokidis *et al.* 2000), e.g. sightings off Cocos Island and Costa Rica in August (Acevedo & Smultea 1995), sightings (matched by photo-identification to feeding grounds off the Antarctic Peninsula) off Central America in August and September (Rasmussen *et al.* 2007) and 19th century catches in the Golfo de Panamá in July to September (Best 2008).

In order to settle the assertion that humpbacks of Southern Hemisphere origin may sometimes wander as far north as the Cape Verde Islands, as well as the possibility of Northern Hemisphere humpbacks occasionally staying longer at their wintering grounds (and travelling further south) than documented so far, photo-identification matches or genetic evidence will be required.

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Short note | Nota breve

The last whale: rise and demise of shore-based whaling in the Cape Verde Islands

José J. Cabral & Cornelis J. Hazevoet

Keywords: humpback whale, *Megaptera novaeangliae*, shore-based whaling, Cape Verde Islands

For two centuries, the seas of the Cape Verde archipelago were a favorite whaling ground – known as the 'San Antonio Ground' among whalers – for an international fleet of whaling ships and especially for the 'Yankee whalers' from New England, USA. One of their main targets was the humpback whale *Megaptera novaeangliae*, of which large numbers were caught (e.g. Clark 1887, Townsend 1935, Reeves *et al.* 2002, Smith & Reeves 2003, 2010).

Whaling in Cape Verde seas commenced during the mid 18th century, when American whalers began exploring these waters (Starbuck 1878). In 1732, the production of whale oil by foreign companies and its taxation was regulated by law for the islands of Boavista, São Nicolau and Santo Antão (Carreira 1983). Early 18th century documents already mention requests by English whalers for the right to anchor at the port of Tarrafal, São Nicolau. The Portuguese naturalist, João da Silva Feijó, who stayed in Cape Verde during the 1780s and 1790s, remarked on the abundance of whales and the large number of American, English and French whalers frequenting these waters, "who often visit our ports to prepare our, or rather their, whale oil" (J. da Silva Feijó *in* Carreira 1986: 33; translated from the Portuguese). From the late 18th century onwards, many male inhabitants of the islands, especially those from Brava, Fogo and São Nicolau, fled the droughts and epidemics that haunted their land and embarked on American whaling ships, over the years becoming much sought after as expert harponeers, with some eventually becoming mates or captains (Warrin 2010). Many eventually moved to New England and settled in New Bedford, Massachusetts, and Providence, Rhode Island, places that still have considerable Capeverdean communities.

Despite these activities by foreign whalers, there was hardly any local attempt at catching whales and the Portuguese colonial power never built a whaling fleet, a fact ascribed to the lack of industries capable of profitably processing whale products in Portugal (Carreira 1983). Already in 1761, in a letter to the Portuguese crown, the *Ouvidor-Geral das ilhas de Cabo Verde*, Custódio José de Sousa e Matos, wrote that whales were numerous around the island of Santiago and that it was regretable that their exploitation was left to foreigners, whereas the establishment of a local whaling industry could be achieved without great expenses (Carreira 1983). In his comprehensive work on the productions of the Portuguese colonies, Lima (1844) again emphasized the abundance of whales in Cape Verde and the continuous efforts by American and English whaling ships to catch as many of them as possible.

There are indications that at least some shore-based whaling took place on the islands of Sal and Boavista during the mid 19th century, but details are wanting and catches appear to have been limited (Smith & Reeves 2010). In 1874, an Azorean settled in Tarrafal, São Nicolau, with the purpose of dedicating himself to whaling and to teach the natives whaling skills, thereby laying the foundation for the ensuing *Empresa da Pesca da Baleia do Carriçal e do Tarrafal* (Carreira 1983). The *Boletim Oficial de Cabo Verde* of the years 1874 to 1890 made regular mention of the presence of whalers at the ports of Carriçal, Garça and Tarrafal. In his *Roteiro*, which provided maritime information for all islands in the archipelago, Barcellos (1892: 54) wrote about São Nicolau that "many whales occur along this coast and many whalers therefore visit Carriçal" where "Sr. Arsenio Firmino owns a house where all the tools needed for these fisheries can be obtained" (translated from the Portuguese). This is the only mention of whaling in the *Roteiro*, underlining the importance of São Nicolau as a center of whaling activities in the archipelago during the last decades of the 19th century. It should be noted that what is usually referred to as the Carriçal station in fact consisted of two separate entities, i.e. one at Barreiras, to the east of Carriçal (Fig. 1), and the other at Garça, to the west of Carriçal. There were no whaling installations at the village of Carriçal itself.

In 1883, a similar but apparently less ambitious company was created on the island of Sal (Carreira 1983). All of this took place at a time when American and other foreign whalers began to abandon these waters due to the whales having become more and more scarce there, leaving what remained for the local shore-based industry. Friedlaender (1913), who stayed in the islands in 1912, mentioned the existence of a well-equipped whaling station on the island of Maio that was, however, no longer profitable at the time. In addition, Vasconcellos (1916) referred to a whaling station on the island of Brava. We do not have further details about the stations on Sal, Maio and Brava at present. Cardoso Junior (1896) described the techniques and practices employed by local whalers and a vivid account of a whale hunt off the island of São Vicente was given in an English weekly magazine (E.J.M. 1864).

It has proved difficult to obtain reliable figures on the production of most of the Cape Verde whaling stations. Statistical information on exports of small quantities of whale oil and blubber from the Cape Verde Islands is often

Fig. 1. Ruins of the whaling station at Barreiras, São Nicolau, 23 September 2006 (José J. Cabral).

difficult to interpret because much or most of the oil appears to have been imported (possibly from American whaling vessels working in the area) and then reexported (Smith & Reeves 2010). However, Lopes Filho (1996) gave data on the number of whales caught and the amount of whale oil produced on São Nicolau for the years 1874-1918 (see Appendix 1), while also indicating that three 'small whales' were taken in April 1810. From 1874 to 1918, the shore-based whaling industry on São Nicolau captured a minimum of 105 whales. Except for one whale caught in August and another in September, the hunting season extended from February to June.

In 1896, José Gaspar de Conceição was granted the right to store small boats and whaling equipment on the beach at Tarrafal (*Boletim Oficial* No. 48, 20 November 1896). From that year onwards, the whaling company on São Nicolau operated under the name of José Gaspar de Conceição, with 'Herdeiras' (Heirs) added after the first owner's death. Between *ca*. 1912 and 1920, about 12 men were engaged (thus presumably two boat crews) at the Tarrafal whaling station (Smith & Reeves 2010). Friedlaender (1913) still saw large quantities of whale vertebra, ribs and mandibles on the beach at Tarrafal in 1912, but remarked that whales had been all but extirpated in the area and the Tarrafal and Carriçal stations would probably have to close down soon. After 1920, operations appear to have ceased and while the Tarrafal whaling company was still included in the *Anuário Estatistico, Colónia de Cabo Verde* (Statistical Yearbook of Cape Verde) during the 1930s, it was invariably stated that there had been no fishery or production in those years. From the 1940s onwards, no mention at all was made anymore of the company.

Whales caught at Tarrafal presumably mostly concerned humpbacks, not sperm whales *Physeter macrocephalus*, as it was said that the whales often entered the relatively shallow waters of Tarrafal Bay and were often accompanied by a calf (Joaquim Pinheiro pers. comm.). There was also a fishery for 'black fish', i.e. short-finned pilot whale *Globicephala macrorhynchus*.

Tarrafal's present tuna factory was constructed at the site of the old whaling station, even partly using the same premises. Unfortunately, the archives pertaining to the former whaling station have been lost or destroyed (Joaquim Pinheiro pers. comm.). So, by the 1920s, some two centuries of whaling in Cape Verde seas had come to a conclusion. But had it?

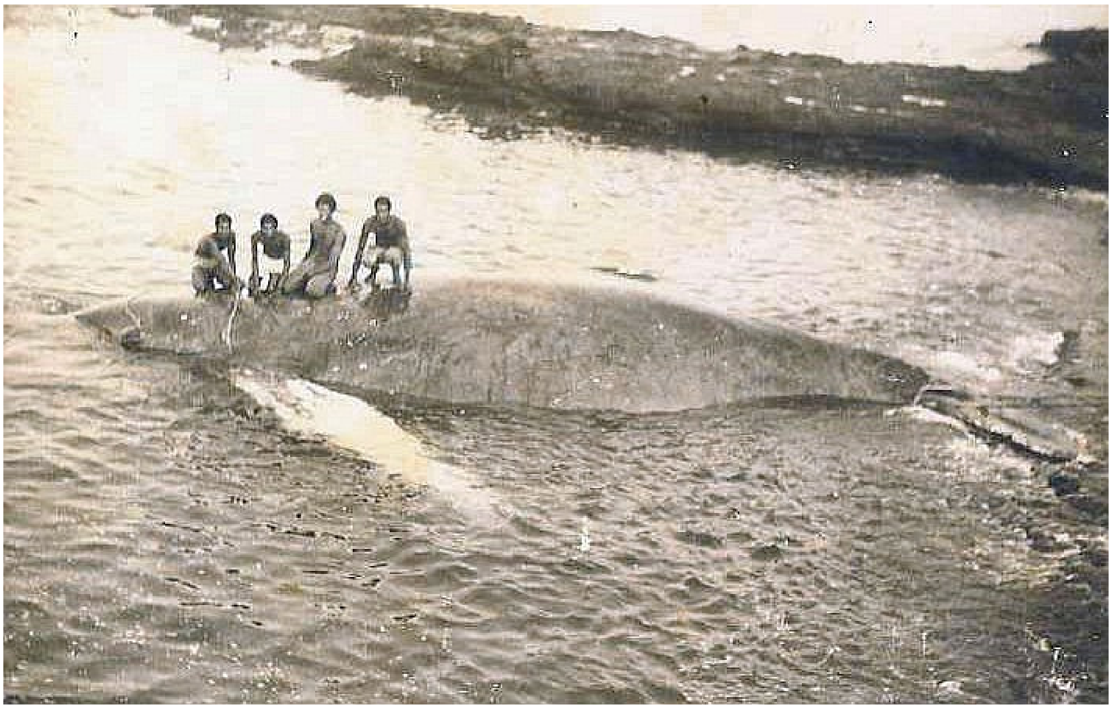

Fig. 2. Humpback whale *Megaptera novaeangliae*, Sinagoga inlet, near Tarrafal, São Nicolau, March-May 1977 (Pedro António dos Santos).

In the Spring of 1977, two years after the Republic of Cape Verde gained independence, a humpback cow and calf pair appeared in Tarrafal Bay, attracting much attention from local inhabitants and causing much excitement on their part. After ample discussions, it was decided to catch the whale and a whaler from the old days, Nhô António Bento, was brought to the scene to instruct the youngsters how to kill it. First, the calf was harpooned, as it was calculated that the mother would not abandon it, after which it was dragged to Sinagoga inlet, where the adult whale was killed as well. The event was photographed by a Capeverdean emigrant (Fig. 2), one of the few persons in Tarrafal in the possession of a camera in those days. Although whales and other cetaceans were protected by law at the time, this did not bother the self-styled whalers and neither did the local authorities interfere. After the whale had been flensed and the stench of the remains became quite unbearable, the carcass was dragged to the open sea, where it was devoured by sharks. Thus ended whaling in Cape Verde.

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Appendix 1. Number of whales caught and quantities of whale oil produced on the island of São Nicolau, Cape Verde Islands, in the years 1810 and 1874-1918 (after Lopes Filho 1996).

Year	Month	Locality	Number of whales	Quantity of whale oil	Source	
					Boletim Oficial	Date
1810	April	Carriçal	3 (small)	1300 gallons	21	27.05.1810
1874	May	Carriçal	2 (large)	3000 gallons	18	02.05.1874
1874	June	Carriçal	1	*ca.* 1000 gallons	24	13.06.1874
1876	March	Ponta Leste	2	??	20	13-05-1876
1877	April	Coasts of island	2	400 gallons	17	28-04-1877
1878	Feb & March	Carriçal	1	1120 gallons	20	18-05-1878
1878	April & May	??	3	2700 gallons	28	13-07-1878
1879	April	Carriçal	2	1100 gallons	20	17-05-1879
1879	June	??	1	1000 gallons	29	19-07-1879
1880	March	Carriçal	2	1000 gallons	15	10-04-1880
1880	April	Carriçal	2	2300 gallons	20	25-05-1880
1881	April	Carriçal	1	1125 bottles	22	28-05-1881
1881	May	Santa Luzia	1	30 barrels ??	22	28-05-1881
1882	May	Carriçal	1	1400 gallons	27	08-07-1882
1883	May (03, 10, 14)	Carriçal	3 (large)	140 barrels	26	30-06-1883
1884	May	Carriçal	3	??	26	28-07-1884
1885	April	Carriçal	1	55 barrels ??	22	30-05-1885
1885	May (14, 29)	Carriçal	2	2000 gallons	31	01-08-1885
1886	May	Tarrafal & Carriçal	5	148 barrels ??	26	26-06-1886
1887	March	Carriçal	1 (small)	25 barrels (775) gallons	17	23-04-1887
1887	April (9, 22)	Carriçal	2	25 barrels ??	21	21-05-1887
1887	June (08)	??	1	20 barrels ??	30	23-07-1887
1887	June (11)	??	1	50 barrels ??	30	23-07-1887
1889	March	Carriçal	2	1020 gallons	18	04-05-1889
1889	April	??	4	2770 gallons	22	01-06-1889
1889	May	Carriçal	1	400 gallons	27	06-07-1889
1890	April	Carriçal	3	3000 gallons	21	24-05-1890
1890	May / June	Carriçal	3	3510 gallons	31	02-08-1890
1893	March	Carriçal	3	2510 gallons	16	22-04-1893
1893	May	Carriçal	2	2200 gallons	28	15-07-1893
1983	May	Garça	2	1980 gallons	28	15-07-1893
1896	March	??	??	??	17	25-04-1896
1896	April	??	??	??	21	22-05-1896
1897	April	??	??	??	21	23-05-1897
1898	April	??	1	??	22	28-05-1898
1899	February	??	1	1300 gallons	12	25-03-1899
1899	March (04, 19)	??	2	1500 gallons	13	09-05-1899
1899	June	Carriçal	1	1250 gallons	30	29-07-1899
1900	February	Carriçal	1	1300 gallons	12	24-03-1900
1900	March	??	1	1400 gallons	20	19-05-1900
1900	April (06, 17, 23)	Carriçal	3	5000 litres	22	02-06-1900
1900	September	Carriçal	1	1000 gallons	46	17-11-1900
1901	February	??	2	5300 litres	12	23-03-1901
1901	March	São Nicolau	3	9600 litres	16	20-04-1901
1901	April	Carriçal	1	2200 litres	22	01-06-1901
1901	May	Carriçal	1	8800 litres	25	22-06-1901
1901	June	Carriçal	1	4800 litres	29	20-07-1901
1901	June	Garça	1	4400 litres	29	20-07-1901
1902	February	??	??	??	13	29-03-1902
1902	March	Tarrafal	1	3200 litres	19	10-05-1902
1902	March	Garça	1	2800 litres	19	10-05-1902
1902	March	Carriçal	1	1320 litres	19	10-05-1902
1902	April (04)	Garça	1	1760 litres	25	21-06-1902
1902	April	Garça	1	2800 litres	25	21-06-1902

Appendix 1 (continued).

1902	April	Tarrafal	1	2480 litres	25	21-06-1902
1902	April	Barreiras ??	1	2400 litres	25	21-06-1902
1902	May (14)	Carriçal	1	400 litres	26	21-06-1902
1902	May (23)	Carriçal	1	2000 litres	26	28-06-1902
1903	March (06)	Tarrafal	1	2400 litres	17	25-04-1903
1903	March	Barreiras ??	1	2200 litres	17	25-04-1903
1903	March (28)	Carriçal	1	4480 litres	17	25-04-1903
1903	March	Barreiras ??	1	2980 litres	17	25-04-1903
1904	February (10)	Carriçal	1	1800 litres	16	16-04-1904
1904	March	Tarrafal	2	3940 litres	18	30-04-1904
1904	Apri l (14, 24)	Tarrafal	2	10,400 litres	25	18-06-1904
1904	May (01)	Carriçal	1	1600 litres	27	02-07-1904
1905	March (15)	Tarrafal	1 + calf	7200 litres	17	29-04-1905
1905	April	Carriçal	1	??	21	27-05-1905
1906	May	Carriçal	1	2800 litres	25	23-06-1906
1908	March	Tarrafal	1	2400 litres	17	25-04-1908
1918	August	Tarrafal	1	2000 litres	41	12-10-1918

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Short note | Nota breve

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

Nuria Varo Cruz

Keywords: loggerhead turtle, *Caretta caretta*, reproductive biology, Cape Verde Islands

This is a summary of Nuria Varo Cruz's Doctoral Thesis 'Biología reproductora de la tortuga boba (Caretta caretta Linneo, 1758) en la isla de Boavista, archipiélago de Cabo Verde', Universidad de Las Palmas de Gran Canaria, Departamento de Biología, 18 October 2010. The complete thesis can be viewed and downloaded here.

The Cape Verde Islands are regarded as one of the most important nesting areas for the loggerhead turtle *Caretta caretta* (L., 1758) worldwide. Although different sea turtle species have been reported from this archipelago's seas, it was not until the late 1990s that detailed studies of these animals were initiated. This thesis reports on research carried out from 1998 to 2004 on the nesting population of the loggerhead turtle in Cape Verde. The study area comprised three beaches on the southeastern coast of Boavista island: Calheta, Ervatão and Ponta Cosme. However, data from other beaches were also taken into consideration. The main objective was to describe the loggerhead turtle's breeding biology. To this end, different characteristics of nesting females, clutches and hatchlings were examined.

The duration of the nesting season was determined. The nesting season extends from June to October, reaching its peak in August and September. Occasionally, some females may nest before or after this period or even during the off-season. Loggerhead turtles may not always manage to nest each time they come ashore. Nesting success varied between nesting localities. Nesting success was defined as the percentage of emergences that resulted in nesting. Significant differences between the surveyed beaches were found, with values of 46.8% at Calheta, 30.2% at Ervatão and 24.0% at Ponta Cosme. These variations could be due to the different physical and ecological features characterizing these beaches.

The number of nests recorded along the 3.1 km of surveyed sandy beach exceeded 1,900 in two out of the four study years (2001 to 2004), with the maximum number recorded being 2,732 nests in 2004. Occasional surveys elsewhere showed that other beaches on Boavista could have similar densities of nests. Since nesting also occurs on other islands, be it in smaller numbers, the total number of nests in the archipelago during each breeding season could be more than 15,000. According to this rough estimate, Cape Verde would be home to the largest loggerhead nesting population in Africa and the second largest (after the southeastern coast of the USA) in the Atlantic Ocean. Mean female body size was 76.0 ± 3.8 cm (straight carapace length). This value is smaller than those found elsewhere in the Atlantic, as well as in the

Pacific and Indian Ocean populations, but is similar to the Mediterranean populations of Greece and Cyprus.

Due to the high energetic costs of reproduction and migration, female loggerhead turtles rarely breed annually. According to capture-recapture data, the most frequent remigration interval was 2 years, followed by a 3-year interval (range = 1-6). Capture-recapture data must be interpreted cautiously, since most of the variables are based on extrapolation from the proportion of individuals monitored on beaches, whereas a large number of nesting emergences were not recorded. Females usually nest several times during a nesting season. The range of observed nesting frequency was 1-6 nests/female, whereas the range of estimated nesting frequency was 1-7 nests/female, with the average values being 1.4 and 1.6 nests/female, respectively. Since many individual nesting emergences were not recorded, these figures could be an underestimate of the real numbers. The average nesting interval was 15.0 ± 1.8 days. The number of loggerheads tagged was 3,920 on Boavista and 273 on Sal. Capture-recapture data confirmed that some turtles may nest on different islands during the same season, as well as in different seasons (n = 6 and n = 8, respectively).

Different methods were used to assess clutch size, i.e. the analyses of inter- and intra-seasonal variations were made by dividing the total sample into different groups of analysis. Nesting seasons were divided into 14-day periods. During these periods, clutch size varied significantly over different seasons. Early clutches were larger than late clutches. On several occasions, intermediate periods yielded larger clutches than the previous period, although the general trend was towards a decrease in clutch size as the nesting season progressed. Female body size seemed to influence clutch size, with larger females usually laying more eggs per nest than smaller females.

Within the area surveyed, length of incubation fluctuated during each season (2003 and 2004) and was distributed according to a U or V curve that followed the inverse pattern of the mean air temperature recorded at the nearby island of Sal. The longest incubation periods occurred at the beginning and end of the nesting seasons for each of the three beaches. Incubation duration at Calheta was longer than at Ervatão and Ponta Cosme, but only during the initial period of each season. Due to differences in orientation, beach temperature may be influenced by different air currents, plausibly explaining differences in incubation duration between beaches. Partial surveys in previous years seem to indicate that annual fluctuations existed between 1999 and 2004.

In sea turtles, sex ratio of hatchlings can be estimated using different methods. An indirect method is by conversing the duration of incubation time into percentage of female hatchlings. This is possible because the sex of the hatchlings is dependent on the incubation temperature, which in turn determines the duration of incubation. This method was used to estimate the sex ratio of the hatchlings born on the surveyed beaches of Boavista in 2003 and 2004, showing that *ca*. 65% of the hatchlings were female. When beaches were considered separately, the range was 60-70%.

Incubation success, defined as the percentage of eggs in a nest that develop successfully, can be assessed by applying different formulae. These formulae consider that clutch size (denominator) can be estimated either at the very beginning of incubation or by counting the egg shell remains in the nest after emergence of hatchlings has occurred. However, clutch size estimated at the end of the incubation period was significantly lower for the three studied beaches. This was mainly attributed to nest predation by ghost crabs *Ocypode cursor* (L., 1758). Moreover, there were different ways of estimating the number of eggs that hatched (numerator), depending on whether the number of hatchlings born or the number of egg shells in the nests were taken into account. Thus, since both numerators and denominators may vary according to the variables used, the calculated incubation success also fluctuated according to the formula applied.

Results showed that there were significant differences among the beaches in terms of loss of eggs and hatching and emergence success. In 2003 and 2004, the only seasons fully surveyed, Calheta recorded the greatest value for egg loss (median = 20.5 eggs/nest), followed by Ervatão (median = 9.0 eggs/nest) and Ponta Cosme (median = 2.0 eggs/nest). As for hatching success, a distinction has been made between the number of remaining eggs once incubation ended (Emergence Success by excavation - ESe), and the number of eggs laid. In the first case, the median values were 88.0% at Calheta, 82.2% at Ervatão and 31.9% at Ponta Cosme. In the second case, and depending on the formula used, the median values were: a) Emergence Success mixed: 51.0% at Calheta, 64.5% at Ervatão and 24.2% at Ponta Cosme; b) Emergence Success by observed hatchlings: 39.8% at Calheta, 55.6% at Ervatão and 8.6% at Ponta Cosme. Taking the data as a whole, we may conclude that the characteristics of the substrate at Calheta and Ervatão may be advantageous for egg development (higher values of ESe), but are subject to higher nest predation by ghost crabs than at Ponta Cosme, the characteristics of which are rather inadequate for egg development (lower value of ESe). Despite the adverse conditions that eggs have to face on either beach, nests at Calheta and Ervatão produced more hatchlings that those at Ponta Cosme.

Human depredation is the main threat to marine turtles in Cape Verde. Throughout all stages (including the survey of loggerhead turtles), the involvement of local communities and authorities was vital for the successful implementation of programmes aimed at biodiversity conservation. Several activities were implemented in order to achieve the loggerhead's conservation. Firstly, local workers were hired to carry out tasks related to surveillance and local people were encouraged to participate in ecotourism schemes. Training and participation of Capeverdean people in field work schemes were amongst the prime objectives. Specific education and awareness activities were aimed at the general public, such as informative lectures, interviews and articles in the media, the 'Day of the Turtle', and the distribution of educational materials.

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Short note | Nota breve

Environmental and management factors affecting embryonic development in the loggerhead turtle *Caretta caretta* (L., 1758): implications for controlled egg incubation programmes

Elena Abella Pérez

Keywords: loggerhead turtle, *Caretta caretta*, embryonic development, management, incubation programmes, Cape Verde Islands

This is a summary of Elena Abella Pérez's Doctoral Thesis 'Factores ambientales y de manejo que afectan al desarrollo embrionario de la tortuga marina Caretta caretta. Implicaciones en programas de incubación controlada', Estación Biológica de Doñana (CSIC) and Departamento de Biología, Universidad de Las Palmas de Gran Canaria, 29 October 2010. The complete thesis can be viewed and downloaded here.

This thesis aims to contribute to our knowledge of the reproductive biology of the loggerhead turtle *Caretta caretta* (L., 1758) in general and the environmental factors affecting embryonic development in particular. Ways of improving current techniques for the management and conservation of sea turtles were assessed and new methods, aimed at increasing the productivity of populations, are proposed.

From 2005 to 2008, field and experimental studies were conducted on the nesting population of loggerheads on the island of Boavista, Cape Verde Islands. Objectives were 1) to improve knowledge of the physical-chemical characteristics of loggerhead nests, 2) to improve knowledge of the factors that influence egg incubation and their eco-physiological and biomechanical effects on embryonic development, and 3) to investigate the effects of egg manipulation on embryonic development. The study also aimed to establish criteria for the technique most suitable for protecting nests, to evaluate the most effective protocols for the implementation of these techniques, and to contribute to the monitoring and conservation of the loggerhead nesting population on Boavista. The thesis has seven chapters, which present the results of an equal number of independent studies.

The island of Boavista, and, in particular, the *Reserva Natural das Tartarugas* (Sea Turtle Nature Reserve), is one the main nesting sites for loggerheads in the Cape Verde Islands, as well as throughout the eastern Atlantic Ocean. The Nature Reserve stretches for 12 km along the southeastern coast of Boavista and is the third most important site worldwide for loggerhead hatchling production, rendering its protection and conservation essential. On Boavista, the most important area for hatchling production is the *ca.* 10 km stretch of beach between Ponta do Roque and Ponta Medronho, located within the *Reserva Natural das Tartarugas*. Here, between 200,000 and 300,000 eggs may hatch each year, i.e. 65-70% of the total number of hatchlings on the island. Along the western coast of Boavista few turtle young hatch, while *ca.* 10% and 15% of young hatch on the northern and eastern beaches of the island, respectively.

The analysis of data from daily counts of nesting activity during the 2005 nesting season showed a great daily variability among different beaches (from João Barrosa to Ladjedo Teixeira) in the number of nests, nesting success and incubation success. It was found that some beaches, such as Ponta Cosme and Curral Velho, where a large number of nests are laid, produced few hatchlings. Calheta and João Barrosa, despite being the beaches with the greatest production of hatchlings, do not host the largest number of nests. Very high densities of nests per linear metre of beach were found in the study area, with a maximum of 2.9 nests at Ladjedo Teixeira beach. This is the highest density of loggerhead nests documented worldwide.

By taking into account the initial clutch size and the number of exhumed nests, it was estimated that the mean emergence success of nests on Boavista, calculated by the number of nests on each beach studied, is 31.3% for the island as a whole. The fertility rate of nests was measured using two different techniques: 1) through observation of the embryonic white spot (animal pole) between 12 and 96 hours after oviposition, and 2) through analysis of the material obtained in exhumed nests. The average fertility rate of loggerhead nests on Boavista is higher than 93% (measured with the white spot technique). It varies between 75% and 100% among nests and does not change seasonally. The results indicate that, at this moment, fertilization of eggs, abundance of breeding males and sexual health are adequate to guarantee an optimal reproductive success. The estimation of fertility rate through the observation of the embryonic white spot is a precise, simple and relatively unsophisticated method, which can be carried out in the field without affecting emergence success of nests or sacrificing embryos. Estimation of fertility rate through exhumation of nests and assessment of dead eggs has proven to be a very imprecise technique and its application is not recommended. The main causes of nest mortality in the field were natural: tidal flooding, predation by the ghost crab *Ocypode cursor* (L., 1758) and deposition of clay and silt substrates. Nests located in the flooding zone had a mortality of 100%.

The nesting and incubation season (June-October) of the loggerhead turtle in Cape Verde coincides with the warmest period of the year. During the study, incubation temperature of the nesting substrate was recorded at different beaches on Boavista (north, south, east and west) with temperature loggers programmed to record the temperature every 30 minutes. The incubation temperature in natural nests was also recorded. During the nesting seasons 2005 to 2008, the average temperature at incubation depth was 29.7ºC. Significant interannual, seasonal and spatial variations were found in incubation temperatures, which complicated the estimation of sex ratio of hatched young. Average temperature during the second third of the incubation period varied between 27.9ºC and 31.4ºC. The average sex ratio among hatchlings was 78% female, but this value can decrease to 47% in years with low temperatures. The average incubation time was estimated to be 57 days. Apparently, sex ratio on Boavista is more balanced than in other populations in the Atlantic and Mediterranean. However, calculating how incubation temperature would change if environmental temperature increased 1 or 2ºC, as has been predicted by some for the next decades, shows that the proportion of females would increase to 89.4% and 95.5% respectively.

Natural nests in substrates with a high content of clay or silt had higher mortality rates than nests in sandy substrates. Experiments showed that clay and silt substrates can cause mass mortality in nests and that those nests relocated to hatcheries with traces of clay or silt had higher mortality rates than nests in substrates without. Eggshells that were exposed to clay and silt in the laboratory suffered from severe dehydration and high and fast embryo mortality. A higher percentage of clay produced more severe egg dehydration and its influence on embryonic development may have lethal effects. It is therefore recommended to relocate nests laid in a substrate containing significant amounts of clay to sandy non-flooding beach areas. Alternatively, they can be relocated to hatcheries with substrates composed of medium or coarse-grained sand, the temperature suitability of which has been previously analyzed.

Even though the eggs of this marine animal are incubated on the beach, loggerhead eggs are highly vulnerable to salinity levels lower than those of sea water. In laboratory experiments, in which eggs were exposed to different salinity levels, it was estimated that a salt concentration of 15.2‰ had a lethal effect on half of the population (LC50) during the whole length of incubation. Samples of natural incubation substrates from Boavista beaches were analyzed, which did not show salt concentrations toxic to eggs. Sub-lethal salt levels increased the time hatchlings needed to completely reabsorb the yolk after hatching and reduced weight and size of the offspring.

Field experiments were carried out by relocating nests 0 h, 12 h, 24 h, 84 h and 96 h after egg deposition. Results showed that nests can be safely and effectively relocated at night or during daytime up to 96 hours after being laid without affecting their emergence success or the hatchling's phenotype. However, in case of delayed nest relocation, more attention needs to be paid to egg handling and transporting in order to avoid sudden movements and rotation. By improving nest protection programmes, delayed relocation can help save a higher number of nests at risk that would not be relocated if traditional relocation procedures – which dissuade from relocating nests later than six hours after oviposition – were followed. It can also improve beach monitoring at night and female tagging, which would reduce human interference in the egg-laying of sea turtles.

An experiment was carried out in the nest hatchery by incubating eggs at different depths (35 cm, 40 cm, 45 cm, 50 cm, 55 cm). The incubation depth of a nest affects the number of born hatchlings, their physical condition and sex ratio. Deeper nests show a higher emergence success, a more balanced sex ratio and produce more vigorous hatchlings in comparison with shallower nests. Measurement of depths in natural nests showed that, during her lifetime, a single female buries her nests at different depths, depending on her body length, but also on environmental and behavioral factors. In nest relocation programmes, depth at which a nest is buried is an important factor that must be taken into account and evaluated.

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