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Fall and Rise of Nesting Green Turtles (*Chelonia mydas*) at Aldabra Atoll, Seychelles: Positive Response to Four Decades of Protection (1968–2008)

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1 **Abstract. – When Aldabra Atoll became a nature reserve in 1968, its endangered nesting green turtle (*Chelonia mydas*) population was the first to be protected in the Indian Ocean. In 1983, Aldabra became a UNESCO World Heritage Site managed by the Seychelles Islands Foundation (SIF). But prior to 1968, its green turtles suffered intense exploitation documented by trade statistics, historical literature, and a scientific study in 1927. Three population surveys conducted just before, during, and shortly after 1968 provide baseline data by which to assess the long-term population recovery monitored since 1980 using a standardized track count protocol. The 52 nesting beaches distributed along the 83-km outer rim of Aldabra were classified into 6 beach groups (WGT, SETT, DDM, DJL, CC, and North), with total beach length of 5.2 km. During Phase 1 (1980–1994) of the study, 17 index beaches (WGT #1–17) were monitored 4 times per month and other beaches opportunistically. During Phase 2 (1994–2008), index beaches (WGT #1–22 and SETT) were monitored at least 4 times per month and remote beaches monthly. Track counts were converted to estimated egg clutch production using nesting success data. Reproductive output for the atoll rose from a mean annual estimated 2000–3000 clutches in the late 1960s to 15,669 (SD = 2776) during 2004–2008, equivalent to a mean estimated 3100–5225 females nesting annually (assuming an average of 3–5 egg clutches per female). This represents a 500%–800% increase during 40 years of complete protection. During Phase 2, the rate of increase was highest at the Settlement Beach (SETT) which had historically suffered the most intense exploitation.**

Key Words. – Reptilia; Testudines; Cheloniidae; Indian Ocean; nesting trends; population assessment; track counts

2 The green turtle (*Chelonia mydas*) is classified as a globally endangered species (International Union for Conservation of Nature [IUCN] 2010), with populations worldwide conservatively estimated to have declined by 37%–61% over the 141 years prior to 2002, mostly because of exploitation for eggs, meat, and other products (Seminoff 2002). By the 1950s, resource managers worldwide were aware of dangerous population declines and during the 1960s and 1970s implemented protection at major rookeries, including Tortuguero, Costa Rica in 1955 (Troëng and Rankin 2005); Ascension Island from the late 1950s (Huxley 1999; Godley et al. 2001); Queensland, Australia, in 1968 (Limpus 2008); French Iles Eparses in 1971 (Lauret-Stepler et al. 2007); and Hawaii in 1978 (Balazs and Chaloupka 2004). The first significant protection afforded Indian Ocean green turtles was at Aldabra Atoll Seychelles in 1968 (Stoddart 1971).

Fortunately, sea turtle populations respond well to protection of their nesting sites, especially if provided for extended periods (i.e., several decades; Chaloupka et al. 2008). So, although many populations have disappeared (McClenachan et al. 2006) and some are still threatened with extinction, other severely depleted populations have rebounded under protection, and global extinction no longer threatens the species (Broderick et al. 2006; Chaloupka et al. 2008). Aldabra is situated in the Western Indian Ocean in the vicinity of other islands that host important green turtle rookeries (Fig. 1). Green turtle tagging data and genetic studies (Bourjea et al. 2007) demonstrate interconnectivity among the nesting populations and foraging grounds in this region.

Aldabra Atoll, in the western Indian Ocean, provides an unusual opportunity to track both the decline and the recovery of an overexploited green turtle population (Frazier 1984; Mortimer 1984, 1988). Historic literature from the 18th and 19th centuries makes little mention of green turtle exploitation at Aldabra, leading some to conclude that it may have lacked intensity. But indirect evidence suggests otherwise: 1) By the end of the 1700s, green turtles had become rare in the Mascarenes, and the

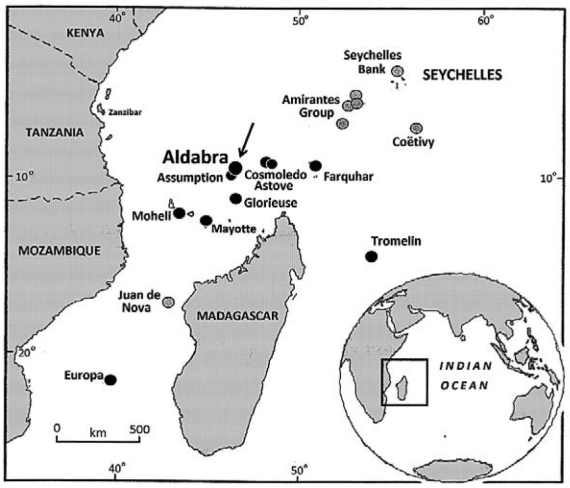

Figure 1. Location of Aldabra Atoll (arrow) in the western Indian Ocean relative to other important green turtle rookeries indicated by black and gray circles. Major sites with more than 1000 egg clutches laid annually are denoted by black and minor ones by gray. Politically, the islands of Glorieuse, Tromelin, Europa, and Juan de Nova comprise the French Iles Eparses; Moheli is part of Comoros; and all the other rookeries indicated belong to Seychelles.

French were importing them from Seychelles (Parsons 1962); 2) as early as 1842, there were complaints about the apparent overexploitation of the hawksbill turtle (*Eretmochelys imbricata*) at Aldabra (Colonial Secretary 1842); and 3) giant tortoises (*Aldabrachelys gigantea*) were so intensely exploited at Aldabra that they may have come close to extinction on the atoll by the end of the 19th century (see review by Stoddart 1971). In this context, it is unlikely that Aldabra green turtles would have been spared intense exploitation during the same period. Hornell (1927) states that prior to 1906, as many as 1500 live green turtles were landed annually in Mahé from the outer islands even though no more than one-third of those put aboard the island schooners reached their destination alive. The inhabitants of the first recorded settlement of Aldabra in 1888 are known to have engaged in sea turtle exploitation (Stoddart 1971). In 1889, a group of 15 people were granted permission by the Administrator of Seychelles to catch green turtles and reportedly took ~ 660 over a period of 6 months (Needham 1890). In 1890, James Spurs acquired the lease for Aldabra and proposed to ''turn'' upwards of 12,000 green turtles per year (Griffith 1892; reported in Stoddart 1971), although the actual numbers killed are unknown.

Green turtles were severely overexploited at Aldabra during the first two-thirds of the 20th century, primarily to produce calipee for ''turtle soup'' for the London market and *quitouze* (salted and sun-dried turtle meat) for the home trade (Hornell 1927; Frazier 1974; Stoddart 1971). The average adult turtle produced 1.5 kg of calipee, obtained by drying the dense semicartilaginous connective tissue joining the bones of the carapace and the plastron. Systematic commercial exploitation began in Seychelles in 1906, with a substantial but unknown portion of the turtles coming from Aldabra. Government records indicate that during 1907–1968, a minimum of 232,942 kg of calipee was produced in Seychelles, equivalent to some 113,845 turtles (Stoddart 1984). Production declined dramatically during those 62 years—initially involving ~ 5760 turtles annually during 1907–1915 (Mortimer 1984) but dropping to only a few hundred per year in the late 1960s (Stoddart 1971). During the 1920s, most (~ 74%) of the turtles killed were females turned onto their backs on the nesting beach (Hornell 1927). Hornell (1927) reported that more than 1200 females were turned on the beaches of Aldabra in 1926.

During that period of systematic calipee production, little control was imposed. As early as 1908 and 1909, Fryer (1912) complained that ''turtles are now being killed so rapidly and the waste is such at both Aldabra and Assumption that their numbers are already markedly on the decrease.'' The Turtle Act of 1925 protected only green turtles smaller than 30 inches in carapace length and focused more on ownership rights than on conservation (Mortimer 1984). Between 1945 and 1955, economic factors caused commercial exploitation at Aldabra to lapse temporarily, and between 1948 and 1962, a 6-month-long closed season was established for female turtles at Aldabra (Mortimer 1985). Finally, on 13 August 1968, the Green Turtle Protection Regulations 1968 were implemented throughout the territory. Since 1968, turtles at Aldabra have been well protected both in law and in fact, with virtually no evidence of poaching. Effective protection at the national level, however, did not come until 26 years later with implementation of the 1994 Turtle Protection Regulations (Mortimer and Collie 1998). In 1983, Aldabra became a UNESCO World Heritage Site managed by the Seychelles Islands Foundation (SIF). Since 1968, the human population at Aldabra has comprised only personnel directly employed on behalf of the Aldabra Research Station.

Fortunately, at the point that the status of Aldabra's green turtles was deemed as dire as to warrant complete protection, 3 separate studies were conducted—just before, during, and after enactment of the 1968 protective measures. These studies, conducted between 1967 and 1976 (Hirth and Carr 1970; Frazier 1976, 1984; Gibson 1979), provide a baseline with which to assess the long-term recovery of the population under protection. The present study uses consistent monitoring methodology implemented since 1980 (Mortimer 1988, 1997) to document population trends during the recovery period from 1967 onward and to estimate current size of the nesting population at Aldabra in terms of total numbers of nesting emergences and egg clutch production.

METHODS

Study Site. — Aldabra atoll (lat 09°24′S, long 46°20′E), is a slightly elevated coral reef on the summit

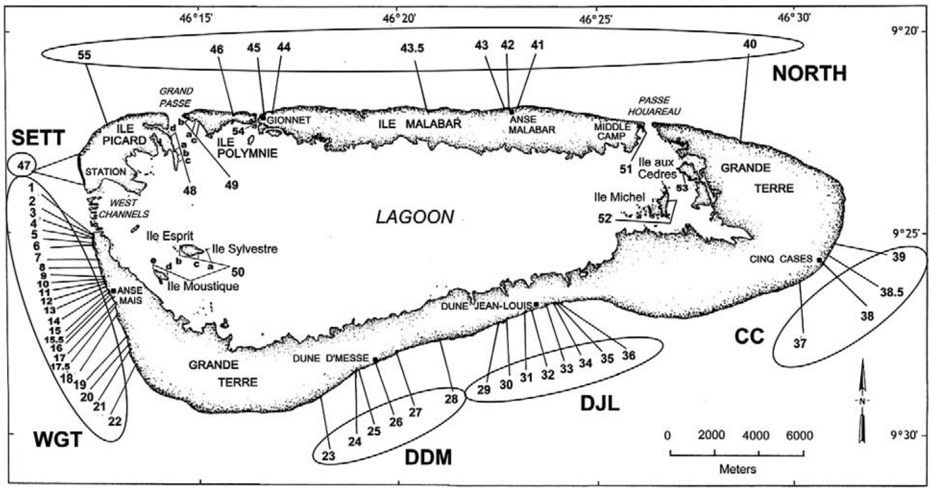

Figure 2. Map of Aldabra showing location of each of the turtle nesting beaches and major beach groups considered in the present study: West Grande Terre beaches #1–22 (WGT), Dune D'Messe beaches #23–28 (DDM), Dune Jean Louis beaches #29–36 (DJL), Cinq Cases beaches #37–39 (CC), North Coast beaches #40–46 and 55 (North), and Settlement beach #47 (SETT).

of a volcanic peak rising from a depth of 4000 m. Aldabra has a total land area of 155 km^2, with 4 main islands, the areas of which range from 1.8 to 110 km^2 (Stoddart et al. 1971), plus hundreds of smaller islets (Fig. 2). It is roughly oval in shape and measures 35 by 14 km at its widest points. The combined outer perimeter of the 4 islands is 83.0 km, including Grand Terre, 54.5 km; Malabar, 18.3 km; Picard, 6.7 km; and Polymnie, 3.6 km (Google Earth). Along the outer rim of that coastline are 52 turtle nesting beaches with a combined total length of 5.2 km. These 52 beaches occur within 6 beach groups (Fig. 2), comprising beaches of the following lengths: West Grand Terre (WGT) #1–22, 1764 m (mean = 74 m, SD = 55, n = 24); Dune D'Messe (DDM) #23–28, 360 m (mean = 60, SD = 24, n = 6); Dune Jean Louis (DJL) #29–36, 699 m (mean = 87, SD = 54, n = 8); Cinq Cases (CC) #37–39, 215 m (mean = 72, SD = 19, n = 4); the northern beaches (North #40–46, 55), 299 m (mean = 33, SD = 24, n = 9); and Settlement Beach (SETT #47) 1880 m, (n = 1). At some sites, new beaches occasionally appeared, and these have been assigned intermediate numbering (i.e., 15.5, 17.5, 38.5, 43.5, and comprise 4 of the 52 beaches). Inside the lagoon are another 16 beaches, including 7 inside Grand Passe (#48a–d, #49a–c), 1 near Passe Gionnet (#54), 1 near Passe Houareau (#51), and 7 distributed among 5 small islands within the inner lagoon (#50a–e, 52, and 53; Fig. 2). Small numbers of hawksbill turtles (*E. imbricata*) also nest at Aldabra, primarily on beaches within the inner lagoon (J. Mortimer and SIF, unpubl. data). Nearshore waters of Aldabra provide important developmental habitat for both hawksbills and green turtles (Mortimer et al. 2003; J.A. Mortimer and SIF, unpubl. data).

Field Methods for Turtle Track Count Surveys. — In 1981, under World Wildlife Fund (WWF)/IUCN Project 1809, Mortimer (1984, 1985, 1988) devised a standardized protocol to monitor long-term trends in green turtle nesting activity at Aldabra Atoll through monthly track counts, year-round, at index beaches situated along 3.7 km of the rugged coastline of West Grand Terre (WGT), separated from the Aldabra Research Station by the 1.8-km-wide West Channels (Fig. 2). Aldabra green turtles nest year-round (Mortimer 1988), with a season defined as December–November (J. Mortimer and SIF, unpubl. data). The program was enhanced and expanded under GEF-EMPS Project J1: Turtle & Tortoise Conservation, 1995–1998 (Mortimer 1998), and GEF SEYMEMP: Turtle Component, 2001–2004 (Mortimer 2004).

The current Aldabra turtle monitoring program can be considered in 2 phases: 1) Phase 1, from late 1980 to 1994, and 2) Phase 2, from late 1994 to 2008. Prior to 1995, most track counts were conducted single-handedly by the Aldabra Warden or interested visiting scientists, whereas from 1995 onward, enhanced logistical support and staffing (i.e., a research officer, 2–4 rangers, and volunteer assistants) enabled a more rigorous monitoring schedule. During Phase 1, the protocol was for the 17 most easily accessed WGT beaches (#1–17) to be surveyed 4 times monthly and other beaches opportunistically (WGT #18–22, SETT #47, DDM #23–28, DJL #29–36, CC #37–39, and North #40–46, 55). During Phase 2, it was for all of the WGT beaches (#1–22) and SETT #47 to be surveyed at least 4 times monthly and each of the remote beaches (DDM #23–28, DJL #29–36, CC #37–39, and North #40–46, 55) at least once a month. For SETT #47, percent of total days surveyed gradually increased from 20% to 96% between 1995 and 2008. The actual survey frequency for each of the 52 beaches during these 2 phases is shown in Table 1. Survey effort is not indicated for the 16 beaches inside the lagoon that host insignificant green turtle nesting.

Track count survey protocol entailed walking the beach at daybreak, counting all tracks produced during the previous 24 hours, and completing the survey by 9:00 AM

Table 1. Comparison of sampling effort at Aldabra during Phase 1 (1981–1994) and Phase 2 (1995–2008) of the turtle monitoring project, based on total counts made, number of years in which surveys were conducted, and the mean (and SD) numbers of counts conducted and months surveyed per year surveyed.

		Sampling effort							
		Phase 1: 1981–1994[a]				Phase 2: 1995–2008			
				Mean # (SD) per year sampled				Mean # (SD) per year sampled	
Beach group	Beach ID #	Total counts	Years	Counts	Months	Total counts	Years	Counts	Months
WGT	1–14	331	9	36.8 (20.6)	8.2 (3.6)	608	14	43.4 (10.0)	11.7 (0.7)
WGT	15	334	9	37.1 (20.6)	8.2 (3.6)	641	14	45.8 (10.1)	11.7 (0.7)
WGT	15.5	206	9	22.9 (12.0)	5.7 (3.0)	623	14	44.5 (9.9)	11.7 (0.7)
WGT	16	330	9	36.7 (20.6)	8.2 (3.6)	619	14	44.2 (9.9)	11.7 (0.7)
WGT	17	330	9	36.7 (20.6)	8.2 (3.6)	617	14	44.1 (9.7)	11.7 (0.7)
WGT	17.5	194	9	21.6 (19.3)	5.0 (3.5)	612	14	43.7 (10.0)	11.7 (0.7)
WGT	18	276	9	30.7 (23.3)	6.4 (3.8)	613	14	43.8 (9.9)	11.7 (0.7)
WGT	19	272	9	30.2 (23.0)	6.4 (3.8)	595	14	42.5 (10.2)	11.6 (0.9)
WGT	20	245	9	27.2 (23.7)	6.2 (3.7)	588	14	42.0 (10.0)	11.6 (0.9)
WGT	21	210	9	23.3 (24.1)	5.1 (3.8)	587	14	41.9 (9.9)	11.6 (0.9)
WGT	22	69	5	13.8 (16.5)	2.6 (2.3)	371	13	28.5 (15.9)	9.5 (2.5)
DDM	23	3	3	1.0	1.0	113	14	7.9 (4.0)	7.2 (3.4)
DDM	24	4	3	1.3 (0.6)	1.0	159	14	11.1 (2.6)	9.8 (2.1)
DDM	25	4	3	1.3 (0.6)	1.0	162	14	11.6 (2.7)	9.9 (2.0)
DDM	26	9	5	1.8 (1.3)	1.2 (0.4)	225	14	16.1 (3.7)	10.3 (1.9)
DDM	27	6	3	2.0 (1.7)	1.0	140	14	9.6 (2.7)	8.2 (2.0)
DDM	28	7	4	1.8 (1.5)	1.0	133	14	9.0 (2.9)	7.9 (2.6)
DJL	29	6	3	2.0 (1.0)	1.0	154	14	11.0 (3.9)	9.0 (2.4)
DJL	30	8	5	1.6 (0.9)	1.0	160	14	11.4 (3.9)	9.1 (2.2)
DJL	31	9	5	1.8 (0.8)	1.2 (0.4)	174	14	12.4 (3.7)	9.7 (2.1)
DJL	32	87	7	12.4 (10.8)	3.1 (2.5)	246	14	17.6 (4.8)	10.4 (1.5)
DJL	33	32	5	6.4 (7.7)	1.8 (1.8)	214	14	15.3 (4.6)	10.2 (1.4)
DJL	34	33	5	6.6 (7.6)	1.8 (1.8)	214	14	15.3 (4.6)	10.2 (1.4)
DJL	35	32	5	6.4 (7.2)	1.8 (1.8)	212	14	15.1 (4.8)	10.2 (1.4)
DJL	36	23	5	4.6 (3.8)	1.8 (1.8)	207	14	14.8 (4.8)	9.9 (1.4)
CC	37	2	2	1.0 (0)	1.0 (0)	155	14	11.1 (4.4)	7.6 (2.1)
CC	38	34	4	8.5 (7.3)	1.8 (1.0)	184	14	13.1 (4.8)	8.5 (2.2)
CC	38.5	2	2	1.0	1.0	169	14	12.1 (4.4)	8.2 (2.3)
CC	39	2	2	1.0	1.0	153	14	10.9 (3.9)	8.0 (2.2)
North	40	6	3	2.0	1.3 (0.6)	47	11	4.3 (3.1)	3.5 (1.9)
North	41	27	6	5.4 (1.9)	1.8 (0.8)	239	14	17.1 (6.8)	10.1 (2.0)
North	42	35	5	7.0 (3.3)	1.8 (0.8)	244	14	17.4 (6.8)	10.1 (2.0)
North	43	27	5	5.2 (3.0)	1.4 (0.9)	243	14	17.4 (6.8)	10.1 (2.0)
North	43.5	3	2	1.5 (0.7)	1.5 (0.7)	95	11	8.6 (6.3)	5.4 (3.0)
North	44	6	5	1.2 (0.4)	1.0	174	14	12.4 (9.5)	6.7 (3.8)
North	45	9	5	1.6 (0.9)	1.2 (0.4)	187	14	13.4 (9.5)	7.2 (3.6)
North	46	4	4	1.0	1.0	168	13	12.9 (9.5)	7.0 (3.6)
North	55	0	0	0	0	261	14	18.6 (13.2)	8.2 (3.1)
SETT	47	77	5	15.4 (13.6)	2.6 (1.5)	2390	14	170.7 (102.8)	11.7 (0.8)
Total individual beach surveys		7597				21,600			

[a] Excluding 1980, with 3 counts at WGT #1–17.5 in December, and 1992, with 1 count at WGT #1–22 in March and 3 counts at SETT #47 in April. No track counts were conducted in 1990, 1991, 1993, and 1994.

when tracks produced during the night would dry in the sun. Three categories of fresh tracks were recorded during each survey: TD (track with digging) with or without egg laying, ESBO (emergence stopped by obstacle) with no digging because the female was discouraged by obstacles on the beach (i.e., logs, rocks, erosion platforms, and so on), and HM (half moon) with neither digging nor evidence of disturbance (see also track type description by Mortimer and Bresson 1999). Although the protocol (Mortimer 1997) was in effect since 1981, we calculated relative overall proportions of TD, HM, and ESBO tracks using data collected between 1997 and 2008 when greater emphasis was placed on differentiating HM and ESBO tracks from each other.

Calculating Annual Nesting Activity. — Nesting activity, defined here as annual number of TD tracks, was quantified for individual beaches using 2 types of calculations: individual year estimate (IYE) and mean multiple-year estimate (MMYE). The basic unit for both calculations is estimated number of TD produced per month, and that was derived by taking an average of all daily TD counts recorded at a site during the month and multiplying by the number of days in that month.

The IYE was used to assess trends in the most consistently surveyed beaches, that is, sites surveyed on multiple occasions each month throughout the year. This included WGT #1–22 during both Phase 1 and Phase 2 and SETT #47 during Phase 2. An IYE for each of these sets of beaches each season was calculated by summing estimated numbers of tracks produced per site per month. In cases where data were missing for 1 or 2 consecutive months, estimates for the missing months were extrapolated by averaging track counts recorded during the months immediately before and after. But if more than 2 consecutive months of data were missing, IYEs were not attempted.

The MMYE was used to estimate average number of TD produced annually (December–November) over a specified period of time. This was especially useful for the more remote beaches (i.e., DDM, DJL, CC, and North), where frequency of track counts was not sufficient to produce reliable IYEs. An MMYE incorporates all track counts conducted at a beach during specified seasons, but (as for the IYE) the basic unit of calculation is the estimated number of tracks per beach per month. Each of the 12 months is considered separately, and an average is taken of estimated tracks produced in that month for each of the seasons under consideration. For example, to calculate MMYE during Phase 2, an average was taken of estimated tracks produced in January during each of the 14 seasons (1994–1995 to 2007–2008). If January data were missing for 1 or more years, the mean January figure was calculated using only those years for which January data exist. The same was then done for each of the other 11 months of the year, and all 12 figures were summed to provide an estimate of mean numbers of TD produced during the specified seasons, that is, the MMYE. Standard deviation (SD) was calculated across years.

To quantify the change in nesting activity over the period of our long-term turtle monitoring program (i.e., between 1980 and 2008), we compared the MMYEs for seasons 1980–1981 to 1984–1985 (1981–1985) with those of seasons 2003–2004 to 2007–2008 (2004–2008). These 2 5-season periods were chosen for the following reasons: 1) Preliminary analysis of green turtle tagging data at Aldabra indicates the predominant remigration interval to be at least 3–5 years (J.A. Mortimer and SIF, unpubl. data), 2) they represent beginning and end points of the period surveyed, and 3) they include periods characterized by relatively consistent survey effort. Data collected during Phase 2 were adequate for all beaches to calculate the MMYE for any 5-year period between 1994–1995 and 2007–2008. So, for the period 2004–2008, the MMYEs were calculated directly for all beach groups in the manner described above.

During Phase 1, however, WGT was the only beach group for which survey effort was adequate to directly calculate MMYE (Table 1). At the other beach groups (DDM, DJL, CC, North, and SETT), the data were used only as a guide for estimating levels of nesting activity during Phase 1. Remote beach data (DDM, DJL, CC, and North) were considered separately from SETT data. At the remote beaches, the change in levels of nesting activity between Phase 1 and Phase 2 was considered likely to fit some combination of the following patterns: 1) Increases were proportional to those recorded at WGT, or 2) levels were unchanged. There is no evidence to suggest a decline in nesting activity between Phase 1 and Phase 2 at the remote beaches. In contrast, SETT, situated adjacent to the Aldabra Research Station, was easily accessible and often visited during Phase 1 but formally surveyed only occasionally because nesting activity was consistently low. In fact, between 1981 and 1992, the SETT beach platform was largely covered by grasses and *Casuarina* sp. root mats and appeared to be relatively unsuitable for nesting (J. Mortimer, pers. obs.). So, estimated mean annual TD at SETT during 1981–1985 was derived from calculations of average TD per month based on data collected during 77 surveys conducted during Phase 1.

Assessing Population Size. — Ideally, one would assess size of a sea turtle nesting population by estimating average numbers of individual females nesting annually. But unless saturation tagging is achieved at a site (not currently possible at Aldabra), such estimates need to be derived indirectly from track counts. In some studies, raw track counts provide the basis for comparison with other populations (Dow et al. 2007; Laurent-Stepler et al. 2007). Estimated numbers of egg clutches laid (Bourjea et al. 2007) are a better index of population size although more complicated to derive. Most fieldworkers can easily distinguish between TD, HM, and ESBO tracks, but determining which TD resulted in egg laying is more

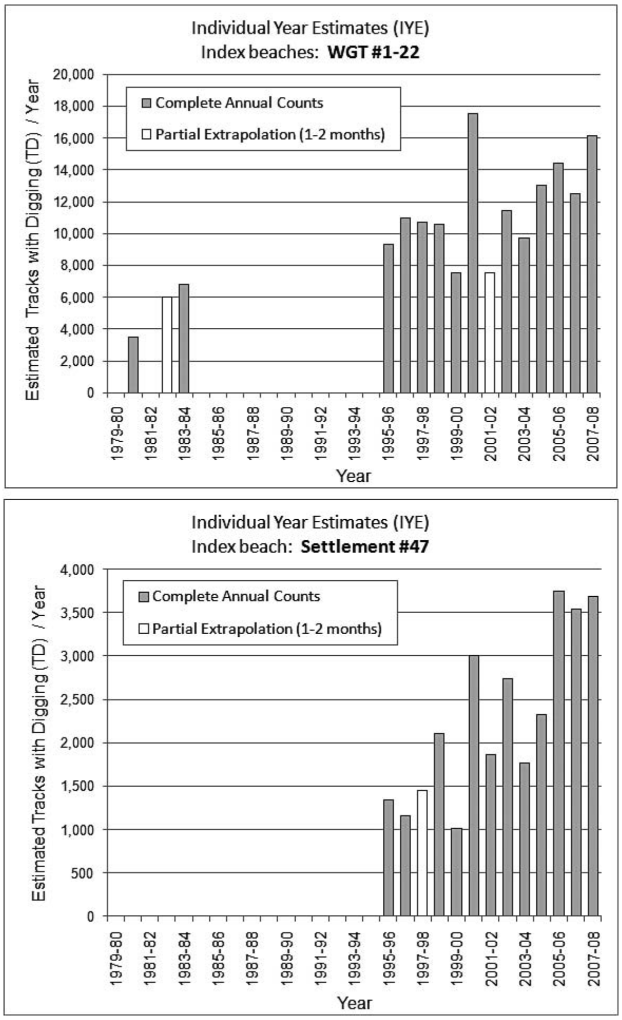

Figure 3. Individual year estimates (IYEs) of numbers of tracks with digging (TD) calculated for index beaches at West Grand Terre (WGT #1–22) during 1981–2008 and for Settlement beach (SETT #47) during 1996–2008. Gray bars indicate years with complete annual counts and open bars those for which partial extrapolation of missing data was required. Data collected in gap years were insufficient to calculate IYEs.

difficult. On beaches with coarse dry sand, construction of egg chambers tends to be relatively difficult, causing females to make multiple trial nest holes and reemergences before depositing eggs (Mortimer 1990), and rates of egg-laying success vary according to sand texture and moisture content. To convert TD counts to estimated numbers of egg clutches produced, we used data on egg-laying success derived by scoring fresh tracks at Aldabra in the 1980s (Mortimer 1988).

Evaluating Historic Status of Aldabra Turtles Prior to 1980. — To provide a baseline from which to assess long-term recovery of the Aldabra population following implementation of protective measures in 1968, we compared levels of nesting activity reported at Aldabra in the studies conducted between 1967 and 1976 (Hirth and Carr 1970; Frazier 1976, 1984; Gibson 1979) with data collected during 1980–2008. These findings are presented in the ''Discussion'' section.

RESULTS

Annual Nesting Activity (1981–2008). — Of the 43,469 tracks examined between 1997 and 2008, 87.2% were TD, 3.4% HM, and 9.4% ESBO. Considering only the index beaches, Fig. 3 depicts 1) the IYEs for WGT #1–22 between 1980–1981 and 2007–2008 and 2) for SETT #47 between 1995–1996 and 2007–2008. Based on these IYEs, nesting activity at the 2 index sites are comparable during the period 1995–2008. The mean IYEs for the first and last 5-season intervals between 1995 and 2008 were the following: 1) WGT #1–22: 9822 (SD = 1424) for 1996–2000 and 13,159 (SD = 2395) for 2004–2008 and 2) SETT: 1416 (SD = 425) for 1996–2000 and 3011 (SD = 911) for 2004–2008. A comparison of 1996–2000 and 2004–2008 figures at the 2 index sites indicates that nesting activity increased by ~ 34% at WGT #1–22 and ~ 113% at SETT #47.

For all beaches on the outer rim of Aldabra, Table 2 compares recorded levels of nesting activity during 1980–1994 and 1994–2008 in terms of MMYE for each WGT beach #1–22 during the period 1981–1994 and for all 52 beaches and 6 beach groups for the period 1994–2008. Nesting at WGT increased between Phases 1 and 2, from a MMYE of 6943 (SD = 2262) during 1981–1994 to 11,529 (SD = 2716) during 1995–2008.

Table 3 presents a comparison of nesting activity at each of the beach groups during 1981–1985 and 2004–2008 (i.e., the beginning and end of the survey period). The recent (2004–2008) Phase 2 estimate of total green turtle nesting activity at the atoll, 28,152 (SD = 4867) TD, was derived by combining the MMYEs for 2004–2008 for each of the 6 beach groups (Table 3). Estimates of total green turtle nesting activity during the early years of Phase 1, 1981–1985 (columns c–f in Table 3), were derived in the following manner. For WGT, MMYE for 1981–1985 was calculated directly (5527 (SD = 743). The bracketed extrapolations for each of the remote beaches (DDM, DJL, CC, and North) comprise 2 components: 1) an upper estimate, equivalent to the MMYE for 1995–2008 (Phase 2; i.e., assuming stable levels of nesting activity during Phases 1 and 2), and 2) the lower estimate, equivalent to 42.1% of the 2004–2008 MMYE (i.e., assuming that rates of increase in nesting activity at remote beaches between 1981 and 1985 and 2004 and 2008 were proportional to those recorded at WGT during the same period). The estimates for SETT (350–550 TD/y) derive from the fact that in none of the 14 months surveyed during 1981–1983, 1987–1988, and 1992 did the mean number of TD per day exceed 2.1, even though all 77 surveys were conducted during peak nesting season between March and September (J.A. Mortimer and SIF, unpubl. data). Total estimated nesting activity for the atoll, measured as TD, was 10,930–16,456 during 1981–1985, increasing to 28,152 (SD = 4867) during 2004–2008.

Table 2. Comparison of levels of green turtle nesting activity defined as mean annual numbers of tracks with digging (TD) recorded at Aldabra during Phase 1 (1981–1994) and Phase 2 (1994–2008) of the turtle monitoring project. Indicators of nesting activity at each beach include comparisons of mean multiple-year estimates (MMYE) and standard deviation (SD) calculated for WGT beaches during 1981–1994 and for all beaches and beach groups during 1994–2008.

		Mean multiple-year estimates (SD)			
		1980–1994		1994–2008	
Beach group	Beach ID #	Beach	Beach group	Beach	Beach group
WGT	1–14	2044 (981)		4376 (1084)	
WGT	15	773 (254)		1353 (416)	
WGT	15.5	39 (71)		84 (63)	
WGT	16	211 (133)		461 (133)	
WGT	17	365 (190)		1149 (247)	
WGT	17.5	238 (295)		89 (78)	
WGT	18	648 (255)		878 (280)	
WGT	19	1370 (407)		1588 (450)	
WGT	20	595 (162)		770 (252)	
WGT	21	615 (239)		753 (234)	
WGT	22	67 (150)	6943 (2262)	27 (50)	11,527 (2716)
DDM	23			418 (189)	
DDM	24			0 (0)	
DDM	25			33 (66)	
DDM	26			251 (168)	
DDM	27			32 (32)	
DDM	28			197 (90)	932 (447)
DJL	29			177 (242)	
DJL	30			631 (247)	
DJL	31			223 (154)	
DJL	32			1239 (412)	
DJL	33			352 (113)	
DJL	34			780 (272)	
DJL	35			312 (173)	
DJL	36			297 (170)	4011 (1229)
CC	37			11 (25)	
CC	38			50 (50)	
CC	38.5			72 (119)	
CC	39			32 (47)	164 (122)
North	40			1410 (741)	
North	41			502 (214)	
North	42			924 (259)	
North	43			571 (199)	
North	43.5			271 (242)	
North	44			939 (284)	
North	45			139 (100)	
North	46			539 (270)	
North	55			32 (34)	5327 (1283)
SETT	47			2222 (970)	2222 (970)
Total				24,183 (5490)	24,183 (5490)

Egg Clutches Laid (1981–2008). — Estimated numbers of egg clutches laid annually at each beach group during 1981–1985 and 2004–2008 are also presented in Table 3 along with descriptions of how these figures were derived. Nesting success data collected during the 1980s estimated the following average numbers of TD per egg clutch laid at each beach group: 1.65 for WGT, DDM, DJL, CC, and SETT; 2.3 for North #43.5–46 and 55; and 2.9 for North #40–43 (Mortimer 1988). Total estimated egg clutch production for the atoll was 6038–8734 during 1981–1985, increasing to 15,669 (SD = 2776) during 2004–2008.

DISCUSSION

Lowest Levels of Nesting Activity in the Late 1960s/Early 1970s. — The Aldabra green turtle population probably reached its lowest level in 1967–1968, when turtles were still hunted at Aldabra, just prior to the enactment of protective measures. Remarkably, the following 3 studies conducted during 1967–1976 provide us baseline data with which to assess the long-term recovery of the Aldabra population: 1) Harold Hirth in 1967, 2) Jack Frazier during 1968–1970, and 3) T.S.H. Gibson in 1975–1976. From late February to early March 1967, during what is usually early-peak nesting season at Aldabra (J. Mortimer and SIF, unpubl. data), Hirth conducted an 11-day turtle survey of Aldabra on behalf of the UN Food and Agricultural Organization (Hirth and Carr 1970). During his survey, only 1 female emerged on the WGT beaches, none along the south coast (DDM, DJL, and CC), and 6 on the North beaches. He observed that all these beaches were littered with the bones and scutes of slaughtered turtles. At Settlement Beach, he found no evidence of either recent or old nesting activity and noted that ''a century ago this was apparently one of the best green turtle nesting beaches in the world.'' Hirth concluded that the green turtle population of Seychelles was ''at a critical low level'' and recommended that Aldabra be made a nature reserve with complete turtle protection (Stoddart 1971). The second study, conducted by Frazier in 1968–1970, over a period of 20 months, coincided with the enactment of complete protection for Aldabra turtles. Frazier (1976, 1984) estimated approximately 3000 egg clutches laid annually at the atoll. The third study, conducted between May 1975 and April 1976 by Gibson (1979), systematically surveyed all the beaches by counting tracks on WGT beaches at fortnightly intervals and at all the other beaches approximately 6 times per year. His methodology involved assessing longevity of individual tracks and body pits so as to estimate tracks and egg clutch production over defined periods of time. He estimated annual egg clutch production for the atoll at ~ 1950–2150, with numbers of tracks estimated at 1757 for WGT and 2518 for all other beaches combined. These 3 studies together indicate that at its low point during the late 1960s and early 1970s, the Aldabra green turtle population probably produced about 2000–3000 egg clutches annually.

Trends from 1968 to 2008. — Analysis of population trends in sea turtles requires many years of data (National Research Council 1990) largely because trends can be obscured by variation in annual number of nesting females (Limpus 1995; Bjorndal et al. 1999) and because individual females rarely nest during 2 consecutive nesting seasons (Miller 1997). But, in fact, the interannual variation recorded at Aldabra (Fig. 3) has not been as extreme as that documented at green turtle nesting sites (Chaloupka et al. 2008) in Florida and Queensland, Australia, where, respectively, 10- and 20-fold fluctuations in green turtle nesting activity during consecutive seasons have been recorded (Chaloupka et al. 2008).

Our study indicates that in recent years (2004–2008), Aldabra green turtles produced an estimated 28,152 (SD = 4867) tracks with digging (TD) equivalent to 15,669 (SD = 2776) egg clutches. Estimates of how many individual female green turtles nested annually during this period are more difficult without reliable saturation tagging data to quantify how many egg clutches the average female lays per season. Elsewhere in the Indo-Pacific, Bourjea et al. (2007) estimate 3 clutches per female, while Limpus (2008), based on a program of saturation tagging at Heron Island, Australia reports 5. Using both figures to derive a bracketed estimate, we tentatively conclude that 3100–5225 females nested annually at Aldabra during 2004–2008.

When compared to estimated nesting activity during the late 1960s/early 1970s (2000–3000 egg clutches) and 1981–1985 (10,930–16,456 TD, and 6038–8734 egg clutches), our figures from 2004–2008 indicate a 175–250% increase since 1981–1985 and a 500–800% increase during the 40-year interval since 1968, when nesting turtles were afforded complete protection. We believe that protection accounts for the increase in nesting activity given that no other discernible changes to the atoll likely to affect the turtles have been apparent. Moreover, similar increases in nesting activity have been recorded for green turtles at Glorieuse and Europa, 250 and 1640 km south of Aldabra (map, Table 4; Fig. 1), both protected since the early 1970s (Lauret-Stepler et al. 2007). Likewise, an 8-fold increase in nesting activity over the past 4 decades has recently been reported for hawksbill turtles (*E. imbricata*) at Cousin Island in the granitic Seychelles (Allen et al. 2010), 1150 km northeast of Aldabra. Both Cousin and Aldabra were declared nature reserves in 1968, and both have been well protected during the past 4 decades.

Our figures for 1981–1985 nesting activity accord well with the results of an earlier analysis of the same Aldabra track count data that used different methods to extrapolate missing data. Mortimer (1988) produced the following bracketed estimates of numbers of egg clutches laid annually during 1981–1985: 1981, 4851–8558; 1982, 5203–8789; 1983, 5357–10,428; 1984, 5957–11,814; and 1985, 4510–7986. The mean of the midpoints of these early estimates is 7345, which coincides almost exactly with that (7386) of the present study.

During Phase 2 of the study, the index beaches (SETT #47 and WGT #1–22) together accounted for 62.5% of estimated total egg clutch production at the atoll (Table 3). But the 2 sites differed in their rates of increase in nesting activity. During the 13-year period between 1996 and 2008, nesting activity at SETT increased 3 times as fast (113%) as that recorded at WGT (34%). During 2004–2008, egg clutches were distributed amongst the 6 beach groups as follows: WGT (50.8%), DJL (17.8%), North (14.6%), SETT (11.7%), DDM (4.5%), and CC (0.6%; Table 3). In light of the fact that SETT accounts for 36% of available beach length but only ~ 12% of total egg clutches laid at Aldabra and given its relatively high rate of increase in nesting activity, SETT can be expected to host a significantly higher proportion of nesting turtles in the coming years.

Regional Perspective. — Our estimates of nesting activity during 2004–2008 indicate that Aldabra Atoll now hosts one of the largest green turtle rookeries in the western Indian Ocean (see map, Fig. 1), rivaled only by the Europa Atoll of the French Îles Éparses (Le Gall et al. 1986; Le Gall 1988; Laurent-Stepler et al. 2007). Aldabra green turtles are the best protected in Seychelles and comprised more than half of all estimated nesting green turtles in Seychelles in the early 1980s (Mortimer 1984), so their relative importance nationally is likely to have increased since the 1980s given that the Aldabra population has been well protected while other sites have been subjected to various degrees of exploitation both before and after implementation of the 1994 Turtle Protection Regulations. Elsewhere in Seychelles (Fig. 1),

Table 3. Estimated levels of nesting activity defined as numbers of tracks with digging (TD) and egg clutches laid, at each of the 6 beach groups at Aldabra during 1981–1985 and 2004–2008. Mean individual year estimates (IYEs) and mean multiple-year estimates (MMYEs) for index beaches in 2004–2008 are compared. MMYE for WGT in 1981–1985 is presented along with the conversion figures used to extrapolate MMYE 1981–1985 for the 4 remote beach groups (DDM, DDJ, CC, and North). Estimates of mean annual egg clutch production at each beach group during 1981–1985 and 2004–2008 are calculated from published estimates of nesting success (g) at Aldabra beaches (Mortimer 1988). NA = not available.

		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
		Calculated TD (Phase 2)		Calculated and extrapolated TD (Phase 1)				Estimated # egg clutches laid per year			
						Bracketed estimates for 1981–1985			1981–1985 (bracketed)		2004–2008
Beach group	Beach ID #	Mean IYE for 2004–2008 (SD)	MMYE 2004–2008 (SD)	Conversion factor to extrapolate MMYE 1981–2985 from MMYE 2004–2008	MMYE 1981–1985 calculated directly[a] or extrapolated from MMYE 2004–2008 (SD) (b) * (c)	Lower	Upper[b]	Mean estimated # TD per egg clutch based on Mortimer (1988)	Lower (e)/(g)	Upper (f)/(g)	(b)/(g)
WGT	1–22	13,159[c] (2395)	13,133 (2416)	NA	5527 (743)[a]	5527 (743)	5527 (743)	1.65[d]	3350 (450)	3350 (450)	7959 (1464)
DDM	23–28	NA	1164 (486)	0.421[e]	490 (205)	490 (205)	932 (447)	1.65[d]	297 (124)	529 (271)	705 (294)
DJL	29–36	NA	4591 (1047)	0.421[e]	1932 (441)	1932 (441)	4011 (1229)	1.65[d]	1171 (267)	2431 (745)	2782 (635)
CC	37–39	NA	156 (51)	0.421[e]	66 (22)	66 (22)	164 (122)	1.65[d]	40 (13)	100 (74)	94 (31)
North	40–43	NA	3881 (930)	0.421[e]	1633 (392)	1633 (392)	3352 (1081)	2.9[f]	563 (125)	1156 (373)	1338 (296)
North	43.5–46, 55	NA	2211 (437)	0.421[e]	930 (184)	930 (184)	1920 (481)	2.3[g]	405 (80)	835 (209)	961 (190)
SETT	47	3011[h] (911)	3016 (887)	NA	NA	350[i]	550[i]	1.65[d]	212	333	1828 (538)
Total			28,152 (4867)			10,930 (1427)	16,456		6038 (803)	8,734	15,669 (2776)

[a] MMYE 1981–1985 for WGT was calculated directly.
[b] Upper estimates for remote beach groups (DDM, DJL, CC, and North) based on Phase 2 MMYE 1995–2008 (Table 2).
[c] IYEs for WGT #1–22: 2003–2004 = 9694; 2004–2005 = 13,061; 2005–2006 = 14,420; 2006–2007 = 12,484; 2007–2008 = 16,138.
[d] Midpoint between 1.4 and 1.9 for beaches #1–39 and 47 (Mortimer 1988).
[e] For WGT #1–22, the ratio of MMYE for 1981–1985 to MMYE for 2004–2008 is 0.421.
[f] Midpoint between 2.6 and 3.2 for beaches #40–43 (Mortimer 1988).
[g] Midpoint between 1.4 and 3.2 for beaches #43.5–46, 55 (Mortimer 1988).
[h] IYEs for SETT #47: 2003–2004 = 1761; 2004–2005 = 2320; 2005–2006 = 3745; 2006–2007 = 3545; 2007–2008 = 3686.
[i] Based on track counts recorded during Phase 1 (see text).

estimated annual green turtle egg clutch production is ~ 1000–5000 at each of the remote southern atolls (Cosmoledo, Astove, Assumption, and Farquhar), numbers in the hundreds at some islands of the Amirantes (Mortimer 1984, Mortimer et al. 2011; J.A.Mortimer, Island Conservation Society and D'Arros Research Centre, unpubl. data), and approaches extinction on islands of the Seychelles Bank, where > 99% of humans reside and an estimated total of < 100 clutches are laid annually (J. Mortimer, L. Vanherck, North Island, and Bird Island Lodge; unpubl. data). Meanwhile, some of the largest green turtle rookeries in the western Indian Ocean region occur in the French Îles Éparses, Mayotte, and Comoros (Bourjea et al. 2007; Laurent-Stepler et al. 2007). Table 4 summarizes published population parameters from those sites (see map, Fig. 1) to facilitate comparison with the present study.

Management Recommendations. — We recommend that total protection of nesting green turtles and their habitats continue as it has at Aldabra since 1968. Such a policy of noninterference is consistent with the mission of the Seychelles Islands Foundation (SIF) for Aldabra ''to manage and conserve the natural life and to initiate and instigate scientific research into such natural life.'' It would also provide the following benefits: 1) enable a better scientific understanding of the mechanisms of green turtle population increase, carrying capacity, and maintenance at a natural site lacking significant human interference; 2) enhance the unique ecological value of Aldabra as a relatively pristine site comprising naturally functioning ecosystems and abundant charismatic megafauna; and 3) allow green turtles to increase in number to the point that they can fulfill their ecological roles and possibly enhance the general productivity of sea grass ecosystems (Bjorndal and Jackson 2003) at Aldabra and regionally, including at other sites in Seychelles. To those ends, we also recommend that SIF maintain long-term monitoring of turtle nesting activity at Aldabra, especially at WGT #1–22 and SETT #47 index beaches and at the more remote DJL #32–36 and North #40–44.

Proper management of habitats adjacent to Settlement Beach (SETT #47) is particularly important given that SETT is likely to host much of the increased nesting activity anticipated for Aldabra in the coming years. Especially important is that no infrastructural development occurs along the pristine northern half (i.e., 1000 m) of Settlement Beach, where nesting density is particularly high, and we suggest that human infrastructure already in place farther south be evaluated to identify and mitigate any existing impacts on nesting turtles, especially from artificial light visible at night. Because green turtles now nest at SETT virtually every night of the year, we recommend the promotion of ''turtle tourism'' at Aldabra as long as all visitors are accompanied on the beach by SIF personnel.

Efforts to conserve sea turtles need to focus on maintaining rookeries for centuries to come. But this can

Table 4. Published parameters used to evaluate levels of nesting activity at green turtle rookeries in the western Indian Ocean region. NA = not available.

Nesting site	Seasons	Percent of total beach length surveyed	Estimated mean annual production			Average annual percent rate of increase	Source
			Total tracks	Tracks with digging (TD)	Egg clutches		
Aldabra	1981–1985	100%	12,534–18,872	10,930–16,456	6038–8734	2.2–3.6%/y, 1981–2008	Present study
	2004–2008	100%	32,284	28,152	15,669		
Europa	1982–1985	100%	NA	NA	8750–30,363[a]	NA	Le Gall et al. (1986); Le Gall (1988)
	1984–2005	26%	1361	NA	NA	3%/y	Lauret-Stepler et al. (2007)
Tromelin	1982–1984	100%	NA	NA	2250–3850[b]	NA	Le Gall et al. (1986); Le Gall (1988)
	1986–2005	100%	7178	NA	NA	< 1%/y	Lauret-Stepler et al. (2007)
Grand Glorieuse	1987–2005	16%	1480	NA	NA	6%/y	Lauret-Stepler et al. (2007)
Mayotte	1998–2005	~ 50%	NA	NA	4681	NA	Bourjea et al. (2007)

[a] Extrapolation based on reported estimate of 750–1100 females and 2.8 clutches per female (Le Gall 1988).
[b] Extrapolation based on reported estimate of 3125–10,844 females and 3–3.5 clutches per female (Le Gall 1988).

happen only if both turtles and habitats are adequately protected. To this end, critical stretches of nesting habitat must be designated and maintained in perpetuity as protected sites (nature reserves) off limits to coastal development. We recommend that the Seychelles government assign such protection to a network of important green turtle nesting sites, especially along parts of the now undeveloped coastlines of Cosmoledo, Astove, Assumption, and Farquhar atolls. Tourist developments planned for these remote and largely uninhabited atolls could benefit greatly from the ecotourism attractions that nature reserves provide. Moreover, conservation of these important green turtle rookeries would benefit Seychelles and other nations in the wider western Indian Ocean by ensuring that green turtles propagate successfully and disperse throughout the region to fulfill their ecological roles and contribute to the healthy functioning of marine ecosystems.

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LITERATURE CITED

ALLEN, Z.C., SHAH, N.J., GRANT, A., DERAND, G.D., AND BELL, D. 2010. Hawksbill turtle monitoring in Cousin Island Special Reserve, Seychelles: an eight-fold increase in annual nesting numbers. Endangered Species Research 11:195–200.

BALAZS, G.H. AND CHALOUPKA, M. 2004. Thirty-year recovery trend in the once depleted Hawaiian green sea turtle stock. Biological Conservation 117:491–498.

BJORNDAL, K.A. AND JACKSON, J.B.C. 2003. Roles of sea turtles in marine ecosystems: reconstructing the past. In: Lutz, P.L., Musick, J.A., and J. Wyneken, J. (Eds.). The Biology of Sea Turtles. Volume 2. Boca Raton, FL: CRC Press, pp. 259–274.

BJORNDAL, K.A., WETHERALL, J.A., BOLTEN, A.B., AND MORTIMER, J.A. 1999. Twenty-six years of green turtle nesting at Tortuguero, Costa Rica: an encouraging trend. Conservation Biology 13(1):126–134.

BOURJEA, J., LAPÈGUE, S., GAGNEVIN, L., BRODERICK, D., MORTIMER, J.A., CICCIIONE, S., ROOS, D., TAQUET, C., AND GRIZEL, H. 2007. Phylogeography of the green turtle, *Chelonia mydas*, in the Southwest Indian Ocean. Molecular Ecology 16:175–186.

BRODERICK, A.C., FRAUENSTEIN, R., GLEN, F., HAYS, G.C., JACKSON, A.L., PELEMBE, T., RUXTON, G.D., AND GODLEY, B.J. 2006. Are green turtles globally endangered? Global Ecology and Biogeography 15:21–26.

CHALOUPKA, M., BJORNDAL, K.A., BALAZS, G.H., BOLTEN, A.B., EHRHART, L.M., LIMPUS, C.J., SUGANUMA, H., TROËNG, S., AND YAMAGUCHI, M. 2008. Encouraging outlook for recovery of a once severely exploited marine megaherbivore. Global Ecology and Biogeography 17(2):297–304.

COLONIAL SECRETARY. 1842. [Hawksbills on Aldabra.] Letter from the Colonial Secretary in Mauritius to the Civil Commission in Seychelles. 31 Aug. 1842. On file in the Seychelles Archives. In: Letter Book (Inward) for 1841–1844, 42 pp.

DOW, W., ECKERT, K., PALMER, M., AND KRAMER, P. 2007. An Atlas of Sea Turtle Nesting Habitat for the Wider Caribbean Region. WIDECAST Technical Report No. 6. Beaufort, NC: The Wider Caribbean Sea Turtle Conservation Network and The Nature Conservancy, 267 pp., plus electronic appendices.

FRAZIER, J. 1974. Sea turtles in Seychelles. Biological Conservation 6(1):71–73.

FRAZIER, J. 1976. Report on sea turtles in the Seychelles area. Journal of the Marine Biological Association of India 18(2): 179–241.

FRAZIER, J. 1984. Marine turtles in the Seychelles and adjacent territories. In: Stoddart, D.R. (Ed.). Biogeography and Ecology of the Seychelles Islands. The Hague: Junk Publishers, pp. 417–468.

FRYER, J.C.F. 1912. The structure and formation of Aldabra and neighbouring islands with notes on their flora and fauna. Transactions of the Zoological Society of London 14: 397–442.

GIBSON, T.S.H. 1979. Green turtle (*Chelonia mydas*) nesting activity at Aldabra Atoll. Philosophical Transactions of the Royal Society of London 286:255–263.

GODLEY, B.J., BRODERICK, A.C., AND HAYS, G.C. 2001. Nesting of green turtles (*Chelonia mydas*) at Ascension Island, South Atlantic. Biological Conservation 97:151–158.

Griffith, T.R. 1892. [Letter to the Governor of Mauritiius]. Colonial Reports—Annual. No. 40. Mauritius (Seychelles and Rodrigues). Annual Report for 1889 and 1890, with a report on the island of Aldabra. London: HMSO, pp. 44–45.

Hirth, H. and Carr, A. 1970. The green turtle in the Gulf of Aden and the Seychelles Islands. Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen 58:1–44.

Hornell, J. 1927. The Turtle Fisheries of the Seychelles Islands. London: HMSO, 55 pp.

Huxley, R. 1999. Historical overview of marine turtle exploitation, Ascension Island, South Atlantic. Marine Turtle Newsletter 84:7–9.

International Union for Conservation of Nature. 2010. IUCN Red List of Threatened Species. Version 2010.4. www.iucnredlist.org/apps/redlist/details/4615/0<www.iucnredlist.org (3 June 2010).

Lauret-Stepler, M., Bourjea, J., Roos, D., Pelletier, D., Ryan, P., Ciccione, S., and Grizel, H. 2007. Reproductive seasonality and trend of *Chelonia mydas* in the SW Indian Ocean: a 20 yr study based on track counts. Endangered Species Research 3:217–227.

Le Gall, J.Y. 1988. Biologie et évaluation des populations de tortues vertes *Chelonia mydas* des atolls Tromelin et Europa (Océan Indien S.O.). Mésogée 48:33–42.

Le Gall, J.Y., Bosc P., Château D., and Taquet, M. 1986. Estimation du nombre de tortues vertes femelles adultes *Chelonia mydas* par saison de ponte à Tromelin et Europa
3 (Océan Indien) (1973–1985). Océanog. Trop. 21:3–22.

Limpus, C.J. 1995. Global overview of the status of marine turtles: a 1995 viewpoint. In: Bjorndal, K.A. (Ed.). Biology and Conservation of Sea Turtles. Revised edition. Washington, DC: Smithsonian Institution Press, pp. 605–609.

Limpus, C.J. 2008. A Biological Review of Australian Marine Turtle Species. 2. Green Turtle, *Chelonia mydas* (Linnaeus). Queensland: State of Queensland Environmental Protection Agency, 95 pp.

McClenachan, L., Jackson, J., and Newman, M. 2006. Conservation implications of historic sea turtle nesting beach loss. Frontiers in Ecology and the Environment 4(6):290–296.

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.

Mortimer, J.A. 1984. Marine Turtles in the Republic of Seychelles: Status and Management. Gland, Switzerland: IUCN Conservation Library, 80 pp.

Mortimer, J.A. 1985. Recovery of green turtles on Aldabra. Oryx 19(3):146–150.

Mortimer, J.A. 1988. Green turtle nesting at Aldabra Atoll—population estimates and trends. Bulletin of the Biological Society of Washington 8:116–128.

Mortimer, J.A. 1990. Influence of sand characteristics on the nesting behavior and hatching success of the green turtle (*Chelonia mydas*). Copeia 1990:798–813.

Mortimer, J.A. 1997. Turtle monitoring at Aldabra—1997 version. Monitoring protocol produced by EMPS Project J1: Turtle & Tortoise Conservation, 47 pp.

Mortimer, J.A. 1998. Turtle & Tortoise Conservation. Project J1: Environmental Management Plan of the Seychelles. Final report to the Ministry of Environment Republic of Seychelles and the Global Environment Facility (GEF). January 1998. Volume 1: 82 pp; Volume 2: App 1–50.

Mortimer, J.A. 2004. Seychelles Marine Ecosystem Management Project (SEYMEMP): Turtle Component. Final Report. Volume 1: 243 pp.; Volume 2: 158 pp.

Mortimer, J.A. and Bresson, R. 1999. Temporal distribution and periodicity in hawksbill turtles (*Eretmochelys imbricata*) nesting at Cousin Island, Republic of Seychelles, 1971–1997. Chelonian Conservation and Biology 3(2):292–298.

Mortimer, J.A., Camille, J.-C., and Boniface, N. 2011. Seasonality and status of nesting hawksbill (*Eretmochelys imbricata*) and green turtles (*Chelonia mydas*) at D'Arros Island, Amirantes Group, Seychelles. Chelonian Conservation
and Biology 10(1):XXX–XXX. 4

Mortimer, J.A. and Collie, J. 1998. Status and conservation of sea turtles in the Republic of Seychelles. In: Epperly, S.A. and Braun, J (comps.). Proceedings of the 17th Annual Sea Turtle Symposium. NOAA Tech. Memor. NMFS-SEFSC-415, pp. 70–72.

Mortimer, J.A., Collie, J., Jupiter, T., Chapman, R., Liljevik, A., & Betsy, A. 2003. Growth rates of immature hawksbills (*Eretmochelys imbricata*) at Aldabra Atoll, Seychelles (Western Indian Ocean). In: Seminoff, J.A. (comp.). Proceedings of the 22nd Annual Symposium on Sea Turtle Biology and Conservation, NOAA-NMFS-SEFSC Tech. Memor. 408, pp. 247–248.

National Research Council. 1990. Decline of the Sea Turtles: Causes and Prevention. Washington, DC: National Academy Press.

Needham, Cdr. E. 1890. 7 January 1890, in Seychelles Archives: Aldabra Group, Correspondence relating, 1889 1943 (C/SS/73), pp. 247–248.

Parsons, J.J. 1962. The Green Turtle and Man. Gainesville: University of Florida Press, 126 pp.

Seminoff, J. 2002. 2002 IUCN Red list global status assessment, green turtle *Chelonia mydas*. IUCN Marine Turtle Specialist Group Review, 93 pp.

Stoddart, D.R. 1971. Settlement, development and conservation of Aldabra. Philosophical Transactions of the Royal Society of London. Series B. Biological Sciences 260:611–628.

Stoddart, D.R. 1984. Impact of man in the Seychelles. In: Stoddart, D.R. (Ed.). Biogeography and Ecology of the Seychelles Islands. The Hague: Junk Publishers, pp. 641–654.

Stoddart, D.R., Taylor, J.D., Fosberg, F.R., and Farrow, G.E. 1971. Geomorphology of Aldabra Atoll. Philosophical Transactions of the Royal Society of London. Series B. Biological Sciences 260:31–65.

Troëng, S. and Rankin, E. 2005. Long term conservation efforts contribute to positive green turtle (*Chelonia mydas*) nesting trend at Tortuguero, Costa Rica. Biological Conservation 121: 111–116.

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In addition, please make the following changes:

Page 1. Author credits.

- Line 2. Delete the 2nd and 3rd email addresses which no longer work:
  [mortimer@ufl.edu ~~annacarina@hotmail.com; squidinc1970@googlemail.com~~];
  Line should read: ***[mortimer@ufl.edu]***
- Line 4. Change misspelled Tshwanse to **Tshwane**
  Should read: **Tshwane** University of Technology

Page 5. Column 2. Lines 5-7.

- Line 5. Insert the word "early" between "for" and "seasons".
  Should read: "we compared the MMYEs for **early** seasons 1980-1981 to 1984-1985"
- Line 7. Insert the word "recent" between "of" and "seasons".
  Should read: "with those of **recent** seasons 2003-2004 to 2007-2008"

Page 9. Table 3. Column (c). Column heading.

- Change "1981-2985" to "1981-1985"
- Reformat to bring "from" down to following line

Should read: Conversion
factor to
extrapolate
MMYE
1981-**1985**
from MMYE
2004-2008

Page 11. Column 1. Acknowledgments. Paragraph 2.

- Line 3. Insert the word "Fleischer-" between "F." and "Dogley".
  Should read: , F. **Fleischer-**Dogley, and"

- Lines 9-13. Rearrange order of supporting institutions and individuals bringing the two GEF projects ahead of the expeditions.

  Should read: "With support from WWF/IUCN Project 1809 (1981-1984); **the GEF-EMPS Project J1: Turtle & Tortoise Conservation (1995-1998); the GEF-SEYMEMP: Turtle Component (2000-2004);** Smithsonian Expeditions to Aldabra in 1983, 1986, and 1992; D. Rowat and the *Indian Ocean Explorer* in 2001; and the D'Arros Research Centre Expedition to Aldabra in 2005, J.A.M. was able to initiate and coordinate data collection at Aldabra during the past 3 decades."