business as usual, while those in developing countries struggle to survive day to day and are most likely astonished at the enormous wealth that has been concentrated into the hands of few.

But we shouldn't be exceptionally pessimistic nor dramatic. Despite the glumness, I can see some hope. First, there is a growing trend at international organizations and in several governments around the globe in working seriously towards ecological and social justice, which are entirely intertwined. Second, there is now an outstanding base of knowledge - produced by many young researchers - upon which management and conservation schemes can be firmly based. Finally, and despite our current efforts to behave carelessly as a species, we can in fact be responsible and ingenious. When circumstances become truly rough we may well rise to a new level of intellect and wisdom, and start at last performing like a proper *Homo sapiens*.

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Reproductive Data of Loggerhead Turtles in Laganas Bay, Zakynthos Island, Greece, 2003-2009

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Laganas Bay on the Island of Zakynthos, Greece, hosts the largest nesting aggregation of the loggerhead turtle (*Caretta caretta*) in the Mediterranean (Margaritoulis *et al.* 2003, Margaritoulis 2005). Laganas Bay has a southeastern orientation with a coastline of approximately 20 km, with an opening of about 12 km. The nesting area consists of 5.5 km of suitable nesting habitat which covers six distinct beaches (see Fig. 1 and Table 1). These beaches vary greatly in the degree of development, human use, accessibility, slope, orientation, substrate composition, and color. Detailed descriptions of these beaches, the major problems they face, together with their climatic conditions, appear in Margaritoulis (2005).

Because of the importance of Laganas Bay, the National Marine Park of Zakynthos (NMPZ) was established in 1999 and in 2000 a specific Management Agency was formed. The creation of the NMPZ and its Management Agency are major steps forward in the protection of the area, primarily by incorporating local opinions and through promoting a more balanced situation, enforcement of existing regulations, and the implementation of an effective wardening scheme on the nesting beaches.

The nesting effort and associated reproductive data in Laganas Bay have been systematically monitored by ARCHELON since 1984; in the last few years the monitoring work has been carried out in cooperation with the NMPZ under a more detailed protocol. Nesting data from 1984 through 2002 have shown no specific population trends probably because of the relatively high inter-annual variability of nesting effort (Margaritoulis 2005). We present here the main reproductive data of the loggerhead turtles in Laganas Bay for the 7-year period 2003-2009.

The basic methodology of the monitoring work is described in Margaritoulis (2005). For the

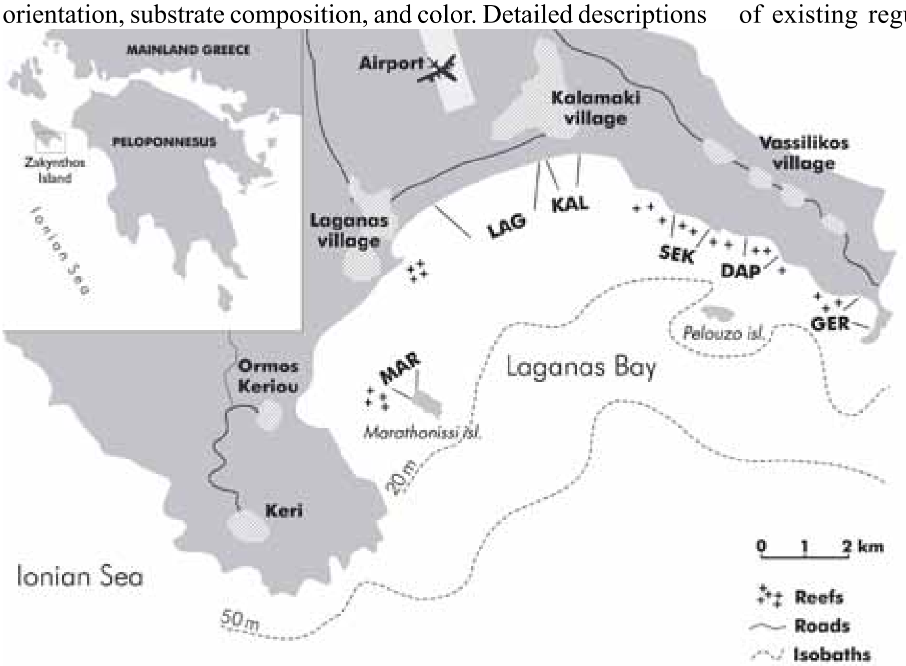

Figure 1. Laganas Bay, Zakynthos Island, Greece, with the six beaches comprising loggerhead nesting habitat: MAR=Marathonissi, LAG=East Laganas; KAL=Kalamaki, SEK=Sekania, DAP=Daphni, GER=Gerakas).

	MAR (0.4 km)			LAG (2.8 km)			KAL (0.5 km)			SEK (0.6 km)			DAP (0.6 km)			GER (0.6 km)			Total (5.5 km)			
Year	E	N	NS	E	N	NS	E	N	NS	E	N	NS	E	N	NS	E	N	NS	E	N	NS	ND
2003	276	117	42.4	321	93	29.0	372	79	21.2	1855	603	32.5	440	79	18.0	148	54	36.5	3412	1025	30.0	186.4
2004	370	158	42.7	511	131	25.6	483	92	19.0	2382	854	35.9	588	69	11.7	171	66	38.6	4505	1370	30.4	249.1
2005	353	82	23.2	468	98	20.9	423	76	18.0	1726	474	27.5	541	55	10.2	145	48	33.1	3656	833	22.8	151.5
2006	262	85	32.4	405	107	26.4	366	107	29.2	1332	455	34.2	980	133	13.6	228	70	30.7	3573	957	26.8	174.0
2007	271	103	38.0	459	146	31.8	401	103	25.7	1475	523	35.5	802	130	16.2	305	87	28.5	3713	1092	29.4	198.5
2008	269	100	37.2	438	147	33.6	358	100	27.9	1415	470	33.2	762	119	15.6	181	47	26.0	3423	983	28.7	178.7
2009	234	47	20.1	646	159	24.6	226	79	35.0	1208	400	33.1	847	51	6.0	281	88	31.3	3442	824	23.9	149.8
Mean	291	99	33	464	126	27	376	91	25	1628	540	33	709	901	13	208	66	32	3675	1012	27.5	184.0

Table 1. Annual nesting activity per beach at Laganas Bay; E: number of emergences, N: number of nests, NS: nesting success (%), ND: nesting density (nests/km); MAR: Marathonissi, LAG: East Laganas, KAL: Kalamaki, SEK: Sekania, DAP: Daphni, GER: Gerakas. Beach lengths are given in parentheses.

facilitation of the reader, we provide below a short summary with emphasis on the points in which data collection has been improved.

Determination of nesting and hatching activity. Emergence tracks of adult females as well as hatchlings' tracks were recorded daily during surveys from mid May through mid-October. Each nest's location was marked by measuring distances to two fixed points at the back of the beach and its distance to the water. Emerged nests were identified by the presence of hatchling tracks, and were marked and monitored until their post-hatch excavation. The position of an emerged nest was matched with the position of a laid nest through triangulation measurements. Further, a number of nests were marked during night work by inserting a small coded stone at the bottom of the egg chamber (before egg laying). In this way the identification of a particular nest could be double-checked during post-hatch excavation. In addition, some nests were caged in situ to avoid human disturbances; in these cases the precise location of the egg chamber was effected by hand-digging the sand, in the day following oviposition, until the appearance of the uppermost eggs in the clutch. Nests caged in situ were monitored until emergence and subjected to post-emergence excavation; if nests showed no sign of hatchling emergence, they were excavated after about 90 days after egg-laying. Further, a small number of nests were relocated to avoid inundation, but these nests were excluded from the present analysis.

Clutch size, hatching success, emergence success. Clutch size, hatching success, and hatchling emergence success were calculated from emerged nests that were neither relocated nor depredated. Emerged nests were usually excavated 10-17 days after the first hatchling emergence. Excavation was done by hand and nest contents were sorted as hatched eggs, unhatched eggs and hatchlings (dead or alive). The number of hatched eggs was determined by counting egg shells greater than 50% of a whole egg shell.

Hatchlings found live in the nest were considered as non-viable. By counting the grouped categories of nest contents we calculated: (1) clutch size as the sum of hatched and unhatched eggs, (2) hatching success as the percentage of hatched eggs relative to clutch size, (3) hatchling emergence success as the percentage of eggs, which produced hatchlings able to exit the nest (viable hatchlings), relative to clutch size. A clutch size of 200 or more eggs was excluded from the analysis as assumed to be excavation of two nests laid next to each other, which is not uncommon in beach zones that have the highest nest density.

Incubation duration. Incubation duration, i.e. elapsed days from egg-laying until the emergence of the first hatchling, was calculated for non-relocated and non-depredated nests with a known date of egg-laying.

Emerged hatchlings. The annual number of viable hatchlings produced was calculated, over the entire nesting habitat, by multiplying total the number of hatched nests by the average clutch size and by the average hatchling emergence success of the particular season.

Year	First female emergence	First nest	First nest emergence	Last nest	Last nest emergence	Last survey	ED	Days from first to last nest	Days from first to last emergence
2003	18 May	18 May	14 Jul	21 Aug	21 Aug	18 Oct	58	96	96
2004	01 Jun	02 Jun	01 Aug	20 Aug	28 Aug	15 Oct	61	80	89
2005	27 May	29 May	28 Jul	17 Aug	23 Aug	15 Oct	61	81	89
2006	27 May	30 May	23 Jul	28 Aug	28 Aug	15 Oct	55	91	94
2007	17 May	17 May	21 Jul	28 Aug	28 Aug	15 Oct	66	104	104
2008	29 May	29 May	24 Jul	10 Aug	10 Aug	15 Oct	57	74	74
2009	26 May	26 May	25 Jul	23 Aug	23 Aug	10 Oct	61	90	90
						Mean ±SD	59.9 ±3.6	88.0 ±10.3	90.9 ±9.1

Table 2. Important seasonal dates at Sekania, the most turtle-frequented beach in Laganas Bay. First survey alwasy started on 15 May except 2008 when it started on 16 May. ED: Elapsed days from first nest to first nest emergence.

Statistical analysis. Mean differences were tested using ANOVA and Student Newman Keuls test (post hoc), for comparisons on clutch sizes and incubation durations. Nesting trends were analysed with Generalised Linear Models (GLM) with Poisson errors and corrected for over dispersion. Analyses were carried out in SPSS v16 and R v2.9 (R Development Core Team, 2009) respectively. The main results are presented below.

Overall nesting activity. Over the 7-year period (2003-2009) 25,724 adult female turtle emergences were recorded, of which 7,084 resulted in egg-laying, along the six nesting beaches of Laganas Bay. The annual number of emergences ranged from 3,412 to 4,505 with an average of 3,674.9 emergences, and the annual number of nests ranged from 824 to 1,370 with an average of 1,012.0 nests (Table 1). A slight downward trend, albeit not significant, was observed in the annual number of both emergences (t=-1.007, p=0.360) and nests (t=-1.200, p=0.284). Nesting success, i.e. the percentage of emergences resulting in nests, over the entire nesting area varied from 22.8% to 30.4%, with an overall mean value of 27.5% (Table 1). Nesting density over the total beach length of 5.5 km ranged from 149.8 to 249.1 nests/km/season with an average of 184.0 nests/km/season over the 7-year period.

Spatial distribution of nesting. The nesting effort varied greatly from beach to beach; the mean annual number of emergences per beach ranged from 208.4 in Gerakas to 1,627.6 in Sekania and the mean annual number of nests from 65.7 in Gerakas to 539.9 in Sekania (Table 1). The percentage contribution of each individual beach to total nesting in Laganas Bay appears as follows: Marathonissi = 9.8%, East Laganas = 12.4%, Kalamaki = 9.0%, Sekania = 53.3%, Daphni = 9.0%, Gerakas = 6.5%.

Nesting success per beach varied greatly within and among seasons. The lowest values of nesting success were recorded in Daphni (overall mean = 13.0%; range of annual means = 6.0%-18.0%) and the highest values in Marathonissi (overall mean = 33.7%; range of annual means = 20.1%-42.7%) (Table 1). As nesting success depends on both environmental and anthropogenic factors, it is believed that the low success on Daphni is a combination of both. Indeed, from 2006 onwards the Park has established cooperation with local owners at Daphni which resulted in the reduction of some disturbances which in turn have apparently increased nesting success (Table 1); the extreme low of 6% during 2009 was attributed to the bad condition of the beach due to a substantial increase of stones and pebbles. It is noted that Daphni is an unstable beach with its sands being alternately eroded and re-deposited depending on wind and surf action (see also Margaritoulis 2005).

As a result of the varying nesting effort per beach, nesting density is also uneven among the individual beaches; lowest nest concentrations were recorded in East Laganas (mean = 45.3 nests/km; range of annual means = 33.5-57.2 nests/km) and highest concentrations at Sekania (mean = 830.6 nests/km; range of annual means = 615.4-1,313.8 nests/km) and Marathonissi (mean = 267.3 nests/km; range of annual means = 127.0-427.0 nests/km).

Start/end dates of nesting activity and duration of nesting season. For Sekania beach, with the most nesting in the area, the date of first hatchling emergence occurred on average at 59.9 days (±3.6 SD, range = 55-66) after the first nest (Table 2). The average duration of nesting season over the 7-year period was 88.0 days (±10.3 SD, range = 74-104) from first nest to last nest, or 90.9 days (±9.1 SD, range = 74-104) from first emergence to last emergence (Table 2).

Within-season evolution of nesting activity. Combining the total nesting effort, for all 7 seasons (2003-2009), we infer the following monthly distribution of nesting: May 0.8%; June 40.0%; July 51.1%; August 7.9%; September 0.1%.

Fate of nests. All emerged nests (i.e. nests that produced hatchlings at the surface of the beach) during the fieldwork period were marked and evaluated. The annual percentage of emerged nests to laid nests ranged from 71.3% to 93.8%, with an overall mean of 87.6% (Table 3). It should be stressed, however, that the recorded numbers of emerged nests represent a minimum because (1) some nests emerged after the end of the fieldwork (about mid-October), and (2) some emerged nests may have escaped detection due to unfavourable beach characteristics (e.g. coarse sand, which does not show hatchling tracks well), as well as to adverse weather conditions or human trampling, which may erase hatchling tracks. Therefore, the annual number of emerged nests, derived as above, does not imply that the remaining nests did not produce hatchlings, rather it is an indicator of the emergence success for a particular season. Further, it reflects to a certain degree the consistency of the monitoring work, and especially the accurate mapping of nest locations.

To approximate better the overall percentage of nests that did not emerge, we use a sample of nests monitored in situ from egg laying until emergence or, in the case of no emergence, until excavation after about 90 days from egg laying. During 2003-2009, a sample of 561 such nests resulted in 26 nests (4.6%) that did not emerge;

Year	Laid nests	Emerged nests	% emerged
2003	1025	920	89.8
2004	1370	977	71.3
2005	833	773	92.8
2006	957	872	91.1
2007	1092	1001	91.7
2008	983	922	93.8
2009	824	739	89.7
Overall	7084	6204	87.6

Table 3. Number of laid and emerged nests per season, and percentage of emerged nests (until termination of field work) in Laganas Bay.

Year	Clutch size mean±SD		Range	n	Hatching success	Hatchling emergence success	In-nest hatchling mortality
2003	110.5±27.4	C	7-199	496	73.8	72.3	1.5
2004	108.7±26.9	BC	36-197	854	72.0	69.2	2.8
2005	106.3±26.4	AB	18-177	507	73.9	68.6	5.3
2006	106.7±24.8	AB	11-189	639	74.7	70.6	4.1
2007	104.1±24.9	A	23-190	650	73.3	67.4	5.9
2008	103.8±26.4	A	13-168	505	72.6	64.6	8.0
2009	105.9±24.8	AB	11-194	366	76.7	69.5	7.2
Overall	106.7±26.1		7-199	4017	73.6	68.9	4.7

Table 4. Clutch size, hatching success, emergence success and in-nest hatchling mortality per season in Laganas Bay. Clutch sizes with the same letter were not significantly different (p>0.05).

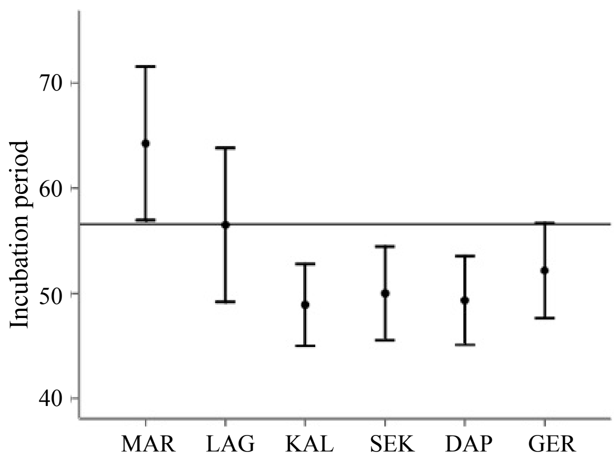

Figure 2. Mean incubation durations ±1 SD per beach in Laganas Bay. The horizontal line represents the pivotal incubation duration (56.6 days) at nearby Kyparissia Bay (Mrosovsky et al. 2002).

Beach	Mean±SD		Min	Max	n (nests)
Marathonissi	64.3±7.3	B	43	89	461
East Laganas	56.5±7.3	C	44	88	576
Kalamaki	48.9±3.9	A	43	65	459
Sekania	50.0±4.5	D	42	77	1597
Daphni	49.3±4.2	A	43	79	415
Gerakas	52.2±4.5	E	43	73	333
Overall mean*	52.5		42	89	3841

Table 5. Mean incubation periods (days) per beach in Laganas Bay from 2003-2009. Values with the same letter were not significantly different (p>0.05). *Weighted per beach contribution to total nesting

excavation revealed only unhatched eggs and, in one nest, 4 half-pipped dead hatchlings.

Clutch size, hatching success, hatchling emergence success. The mean clutch size per season was 106.7 eggs (range = 103.8-110.5), but with significant differences among seasons (Table 4). Mean annual hatching success ranged from 72.0% to 76.7% whereas hatchling emergence success ranged from 64.6% to 72.3%. Mean values, over the 7-year period, gave 73.6% for hatching success, 68.9% for hatchling emergence success, and 4.7% of within-nest hatchling mortality (Table 4). Main apparent reasons for increased within-nest hatchling mortality were invasion of plant roots, especially of tamarisk trees (*Tamarix* sp.) at East Laganas, flooding of nests by rising of water table, mainly at Gerakas, and deposition of clay, eroded by rainfall from nearby slopes, which after hardening can hinder the emergence of hatchlings, particularly at Sekania and Daphni.

Emerged hatchlings. The minimum annual number of viable hatchlings produced ranged from 54,391 to 73,500 with a weighted mean of 65,095 hatchlings per season, over the 7-year period 2003-2009. It should be noted that these figures are considered as underestimates because the numbers of emerged nests, on which the relevant calculations were made, were definitely underestimated. It should also be noted that these numbers represent hatchlings which managed to exit their nests and do not include subsequent mortality.

Incubation duration. The overall mean incubation duration, weighted as per contribution of the individual beaches to total nesting, was calculated to be 52.5 days (range = 42-89, n = 3,841 clutches). However, substantial differences were found among the individual beaches. Mean incubation durations shorter than 56.6 days (the pivotal incubation duration assessed by Mrosovsky et al. (2002) in nearby Kyparissia Bay) were recorded at Kalamaki (48.9 days), Daphni (49.3 days), Sekania (50.0 days), and Gerakas (52.2 days). Close to the pivotal incubation duration was East Laganas (56.5 days), while the only beach with incubation duration longer than the pivotal was Marathonissi (64.3 days) (Table 5, Fig. 2). All mean incubation durations per beach were significantly different (p<0.05) from one another with the exception of the durations at Kalamaki and Daphni (Table 5).

The effect of this spatial variation of incubation durations on hatchling sex ratios is apparent. Indeed, four beaches in Laganas Bay (i.e. Kalamaki, Daphni, Sekania and Gerakas, totalling 77.8% of all nests deposited in Laganas Bay) produced predominantly female hatchlings; East Laganas beach (12.4% of all nests), being very close to the pivotal incubation duration, produced about 50% females and 50% males; Marathonissi beach (9.8% of all nests) produced predominantly, if not exclusively, male hatchlings (Fig. 2). These results confirm previous data indicating a large spatial variation of incubation durations among the individual beaches of Laganas Bay, with Marathonissi beach characterized by relatively

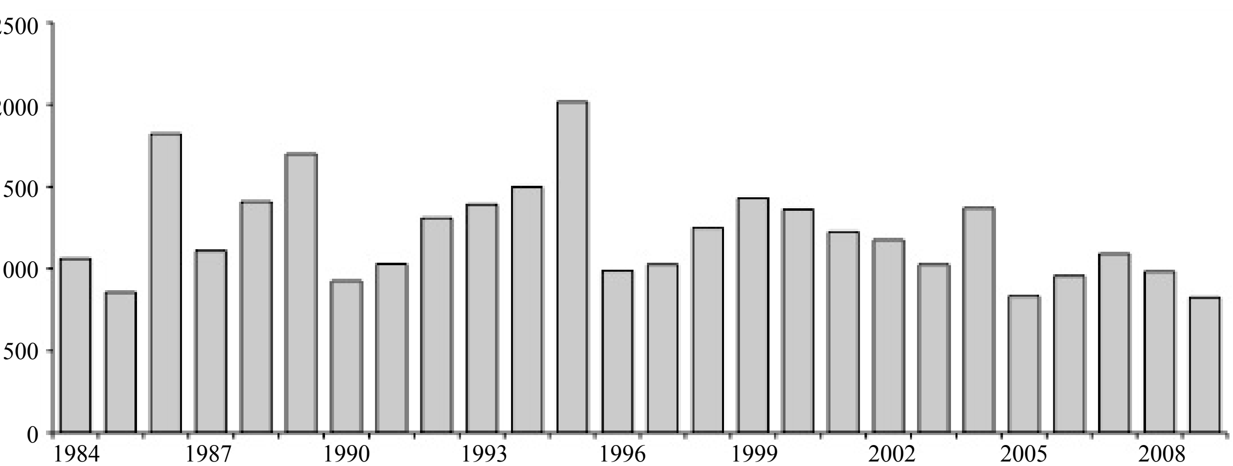

Figure 3. Evolution of the annual number of nests over the 26-year period (1984-2009) at Laganas Bay, Zakynthos.

low incubation temperatures (Margaritoulis 2005, Zbinden *et al.* 2007a). In view of the forthcoming global temperature increase, where a greater proportion of female hatchlings is expected, such "cold" beaches may become essential for the survival of the species (Zbinden *et al.* 2007a).

Previous analyses of data from 1984-2002 have shown high inter-annual variability but no specific trend in the annual number of nests (Margaritoulis 2005). Nesting data in the subsequent 7-year period (2003-2009) show a downward trend, although not significant. If we combine the two periods, a slight downward trend appears over the 26-year period (1984-2009), which, although not statistically significant (t=-1.637, p=0.115), should be looked upon with appropriate concern (Fig. 3).

The recorded decline could be caused by either drifting of nesting to other areas due to disturbances at the nesting beach or problems experienced at sea. Indeed, during most of this 7-year period, with the possible exception of 2004 and 2005 seasons, protection measures at the nesting beaches of Laganas Bay were generally improved. In 2004 and 2005 the Marine Park was largely inactive but ARCHELON kept basic protection measures on the nesting beaches and the situation in general wasn't much worse than the years before the functioning of the Park. It is known that loggerhead turtles nesting in Laganas Bay are able to change nesting beaches within the Bay (Katselidis *et al.* 2004, unpublished data), so in case of disturbances at a particular beach they could select a more favourable beach within the Bay. Large-scale drifting of nesting to other areas seems improbable because the nearby major nesting area of southern Kyparissia Bay is closely monitored, including an ongoing tagging project, by ARCHELON; so far very few turtles tagged in Zakynthos have been observed nesting there (Margaritoulis 1998, unpublished data). Therefore a possible explanation of the apparent decline rather should be investigated at sea, both within Laganas Bay and also at the main foraging areas of this population.

From the data collected through ARCHELON's Stranding Network, in 2007-2009 turtle strandings in Zakynthos have increased with turtles bearing injuries attributed to fishing gear, boat strikes and monk seal predation (unpublished data, Margaritoulis et al. this volume). Further, the number of Turtle-Spotting-Boats, operating in Laganas Bay for turtle watching, has increased greatly without the establishment of a specific regulation or even the adequate enforcement of existing regulations on the part of the NMPZ. These boats frequent the parts of the Bay where turtles concentrate for basking and resting and certainly create a substantial disturbance to turtles in their inter-nesting habitat (Schofield *et al.* 2007, Zbinden *et al.* 2007b).

It is known that loggerheads nesting at Zakynthos migrate long distances and occupy distant foraging areas mainly in the Adriatic Sea and in the Gulf of Gabès (Margaritoulis *et al.* 2003, Lazar *et al.* 2004, Zbinden *et al.* 2008). Both these extensive areas are characterized by intense fishing activities interacting with sea turtles (e.g. Casale *et al.* 2004, Jribi *et al.* 2007). With indications of a possible long-term population decline, the continued monitoring and protection work at the nesting area must be accompanied by concomitant conservation measures at distant foraging areas to prevent this situation from worsening. Nevertheless, this is apparently a supranational issue, beyond the statutory competence of the NMPZ, requiring a strong involvement of regional political will and cooperation.

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