

Biology of
Sea Turtles

Thermobiology
Reproductive biology

Prof. Bojan Lazar PhD

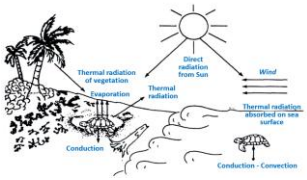
Thermobiology of reptiles

Heat exchange:

- Radiation: solar radiation (dominantly)
- Conduction: heat transfer by direct physical contact
- Convection: heat transfer by currents of moving fluid

Reptiles *control* their T_b by:

- Thermoregulatory behaviour
- Morhphological characters
- Physiological processes



1. Physiology and thermoregulation

Cardiovascular Control / heating and cooling

- Changes in heart rate
- Control of peripheral circulation

Heat Production

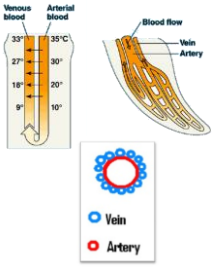
- Muscular production
- Metabolic heat production (aquatic species)
- *Counter-current heat exchange*



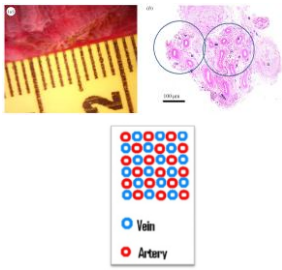


Counter-current heat exchange in sea turtles

Loggerhead and green turtle
- radial form

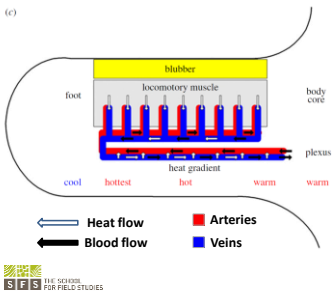


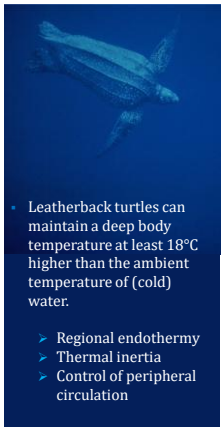
Leatherback turtle
- matrix form



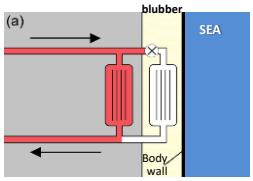
Topsy-turvy: turning the counter-current heat exchange of leatherback turtles upside down

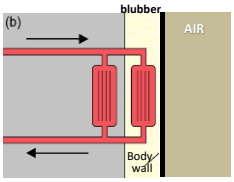
John Davenport[1], T. Todd Jones[2], Thierry M. Work[3] and George H. Balazs[2]





- Leatherback turtles can maintain a deep body temperature at least 18°C higher than the ambient temperature of (cold) water.
  - Regional endothermy
  - Thermal inertia
  - Control of peripheral circulation







2. Control of T_b & morhphological characters

- Morphlogical characters: e.g. crests (not sea turtles)
- Dark colours: melanism



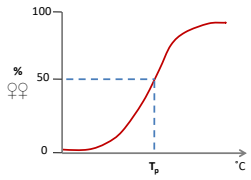
3. Thermoregulatory behaviour

- Environmental heat loads vary with time and among (micro)habitats
- Reptiles attempt to "buffer" variation by thermoregulatory behaviour:
  1. Selection of thermally suitable (micro)habitats
  2. Restriction of activity time
  3. (Adoption of specific positions and postures)



Sea turtles

Temperature Dependant Sex Determination



Pivotal temperature (T_p):

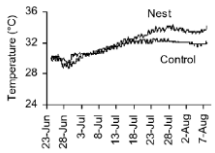
- Sex ratio = 1 : 1
- Incubation temperatures > T_p: higher % of females
- Incubation temperature < T_p: higher % of males

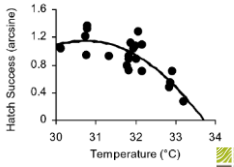
Loggerhead sea turtle, Mediterranean Sea:

Thermal biology of nest

Loggerhead sea turtle (*Caretta caretta*), T_p = 29.3 ˚C, incubation: 52.6 days

- nest depth: 50 cm
- daily variation of temperature: 0.3 – 1.4 ˚C (*temperature data loggers*)
- average nest temperature: 29.5 – 33.2 ˚C
- average temperaure durig *photosensitive period*: 29.3 – 33.7 ˚C



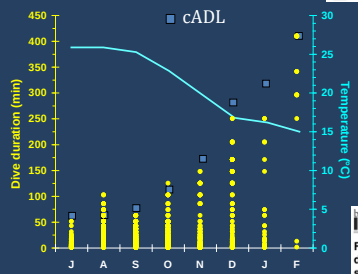


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Loggerhead sea turtle

Thermobiology & Diving






biology letters

First records of dive durations for a hibernating sea turtle

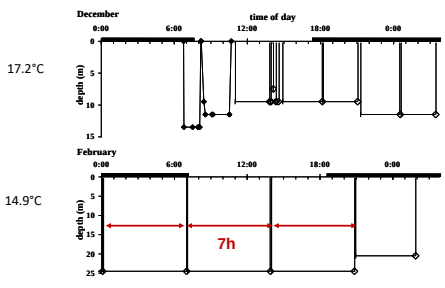
Sandra Hochscheid[1,2,*], Flegra Bentivegna[1] and Graeme C. Hays[2]

Diving profiles - winter

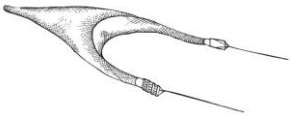

biology letters

First records of dive durations for a hibernating sea turtle

Sandra Hochscheid[1,2,*], Flegra Bentivegna[1] and Graeme C. Hays[2]



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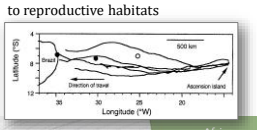
- Bottom-trawl bycath of sea turtles in the Mediterranean: < 30.000 captures/yr (≈ 20% mortality)

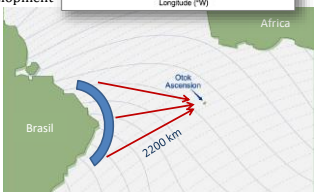


Reproduction

- Reproductive migrations:
  - adult females from foraging ground → to reproductive habitats
  - *remigration interval*: 2-4 yrs
  - males ?

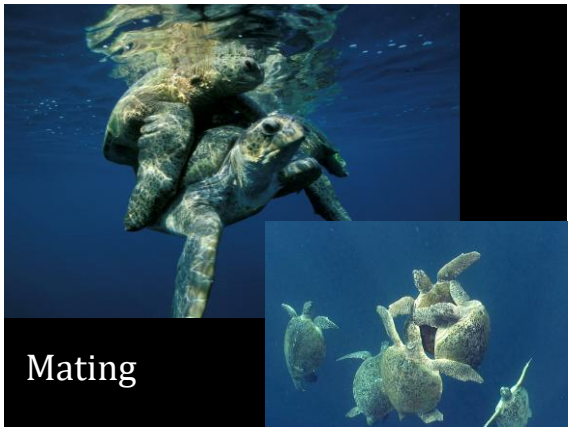
Reproductive habitats - constrains:
- Conditions for adult activity
- Conditions for embryonic development
- Survival of hatchlings





Evolution of migrations

- Split-up of Gondwana (≈ 70 mil. yrs) → splitting of S America and Africa
- Vulcanic activity → Ascension Isl. (7 mil. yrs) – 300 km from the land



Mating

Nesting

- Similar in all sea turtle species
- Duration: 1 – 2 hours, *Ch. mydas*: 2 – 3 hr
  1) Beach selection / ascending the beach
  2) Excavating the body pit (5-10 min)
  3) Digging the egg chamber (20 min)
  4) Ovoposition (20-30 min)
  5) Filling the egg chamber (10 min)
  6) Filling the body pit (10 min)
  7) Returning to the sea



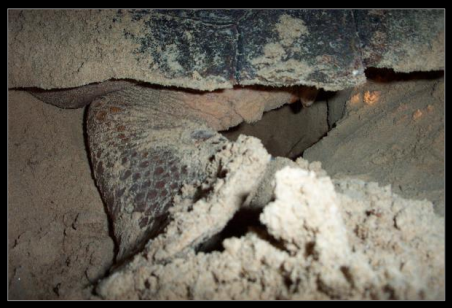
Beach selection

- Accessible from the sea
- High enough to prevent inundation by tides or underlaying water table
- Moist substrate and fine enough to prevent collapse of the egg chamber during construction
- Substrate (particle size) must facilitate gas diffusion

Beach Profile
Beach Elevation
Beach Width
Sand Softness
Sand Composition
Sea Defense
Vegetation
Predation Risk
Beachfront Lighting
...etc



Digging the egg chamber



Caretta caretta

Ovoposition





Filling the egg chamber and the body pit



Chelonia mydas



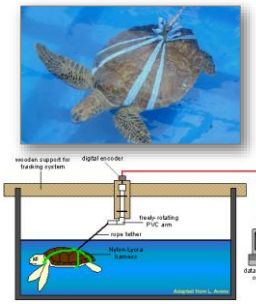
Philopatry and site fidelity

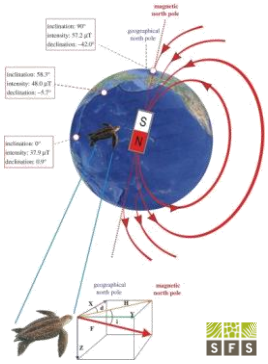
- *Philopatry*: regional discrimination of *reproductive regions*
- *Site fidelity*: fine-scale homing to *beach*



- Flipper tagging (ID code)
- Philopatry (females)
  → isolated reproductive populations
- *mt*DNA haplotypes

Natal beach homing and adult navigation





Reproductive biology

- Remigration period: 2-4 yrs.
- Nest depth: 50–80 cm
  - constant temperature (!)
- 80 – 120 eggs/ nest
- 2-4 nests / reproductive season (range: 1-9)
- Internesting interval: ≈ 10-14 days



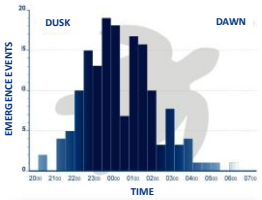
Embryonic development

- Fertility: >80%
- Sex determination: TSD
- $T_p \approx 29$ °C (pivotal temperature)
  - evolutionary conservative across species and populations
- Incubation period: 50-80 days (depending of the incubation temp.)
- Hatching sucess: >80%, but highly variable between populations/ beaches



Hatchling emergence

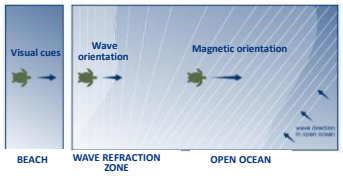
- Brake out from the shell (*piping*)
- Quiescent period (≈ 1 day): resorption of yolk
- Social facilitation (mutual simulation)
- Synchronized upward digging through the nest
- *Inhibition* of the movements by high *temperature*
- *En-masse* emergences, at night and early morning, 1-7 days after pipping





Orientation and navigation

- sea finding: visual cues
  - orientation toward the *brighter*, *lower* oceanic horizon
- nearshore waters (wave refraction zone): wave orientation
  - 24-48 *swiming frenzy* (→ open ocean)
- open ocean: magnetic orientation



Sea turtles in the Mediterranean

Family / Species	
fam. Cheloniidae	
Loggerhead turtle (*Caretta caretta*)	Reproductive population
Green turtle (*Chelonia mydas*)	Reproductive population
Hawksbill turtle (*Eretmochelys imbricata*)	Rare visitor
Kemps ridley (*Lepidochelys kempii*)	Rare visitor
fam. Dermochelyidae	
Leatherback turtle (*Dermochelys coriacea*)	Vagrant

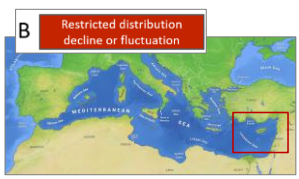
Green sea turtle (*Chelonia mydas*)

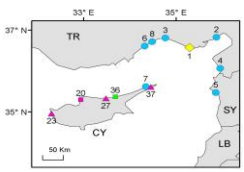
Reproductive populations

Casale et al. 2018. *Endang. Spec. Res.*



- Major green turtle rookeries: Turkey, Cyprus and Syria
  - 13 major nesting locations, >2,200 clutches/year in total
- Mean nest number change 2000-2016: +47.1%
- Regional IUCN status: **Near Threatened** *B2b(ii,iii)* (MTSG 2024)
- *Conservation-dependent*





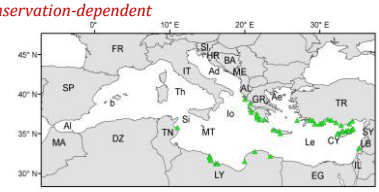
Major nesting sites in the Mediterranean (nests yr^{-1} ≥ 10 and nests km^{-1} ≥ 2.5).

Loggerhead sea turtle (*Caretta caretta*)

Reproductive populations

Casale et al. 2018. *Endang. Spec. Res.*

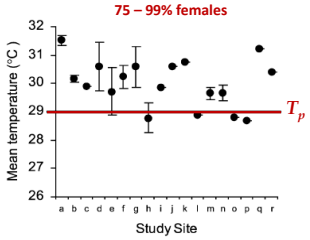
- ≈95% of clutches laid in Greece, Turkey, Libya and Cyprus
  - 52 major nesting sites, >8,100 clutches/year in total
- The mean nest number change since 2000-2016: +26.4
- Regional IUCN status: ***Least Concern*** (LC) (MTSG 2015)
  - population *increase of 7% in 3-generation period*
- *Conservation-dependent*



Major nesting sites in the Mediterranean (nests $yr^{-1} \geq 10$ and nests $km^{-1} \geq 2.5$).

Loggerhead sea turtle, Mediterranean Sea:

Sex ratio of hatchling production



Cyprus: a. Alagadi; **Greece**: b. Bay of Chania; c. Kefalonia; d. Kyparissia Bay; e. Lakonikos Bay; f. Rethymno; g. Rhodes; h. Zakynthos; **Libya**: i. not specified; **Turkey**: j. Akyatan; k. Anamur; l. Dalyan; m. Fethiye; n. Gosku; o. Kizilot; p. Patara; **Egypt**: q. Sinai Peninsula; **Israel**: r. whole coastline.

Sea turtles and polyandry

- **Polyandry**: clutch fertilized by several males – *multiple paternity*
- *Microsatellite* DNA analysis (nuclear DNA)

Fitness benefits:

- Secured fertilization
- Selection of genetic material
- Higher genetic variabilty of offsprings

Costs to females:

- ↑ Mortality risk
- ↑ Predation risk
- ↑ Energetic costs



High frequency of multiple paternity in the largest rookery of Mediterranean loggerhead sea turtles

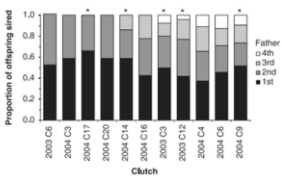


Fig. 1 Relative contribution of fathers to clutches being sired by two to four males. Shown are average values over multiple solutions. From mothers where two clutches were sampled, only the clutch with the higher number of offspring sampled is included. Asterisks above columns designate clutches with skewed paternal contributions.

Operational sex ratios

PROCEEDINGS THE ROYAL SOCIETY B

Turtle mating patterns buffer against disruptive effects of climate change

Lucy I. Wright[1], Kimberley L. Stokes[1], Wayne J. Fuller[2], Brendan J. Godley[3], Andrew McGowan[3], Robin Snape[2,3], Tom Tregenza[1] and Annette C. Broderick[1,3]*

[1]Centre for Ecology and Conservation, College of Life and Environmental Sciences, University of Exeter, Penryn Campus, Penryn TR10 9EZ, UK
[2]Marine and Fisheries Research Institute, European University of Lefke, Gemikonagi, Lefke, Northern Cyprus, Mersin 10, Turkey
[3]Marine Turtle Research Group, Centre for Ecology and Conservation, College of Life and Environmental Sciences, University of Exeter, Penryn Campus, Penryn TR10 9EZ, UK
[4]North Cyprus Society for Protection of Turtles, PK03, Kyrenia, North Cyprus, Mersin 10, Turkey

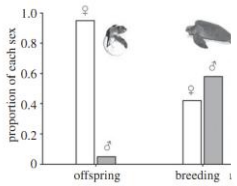


Figure 1. Sex ratios and monogamy of green turtles. The figure shows the proportions of female (un-shaded) and male (shaded) offspring and breeding adults for the 2008 nesting season at our study site. Also shown (hashed) are the proportions of breeding adults that were monogamous at the study site, i.e. the proportion of females that had a single sire for their offspring and the proportion of males that only sired offspring from one female at this rookery (note: use of the term 'monogamy' in this figure relates only to the Alagadi rookery; males may have mated with additional females at other nesting sites within the wider Mediterranean population). Offspring sex is estimated from incubation durations [23] and includes all clutches that hatched successfully at this site in 2008.

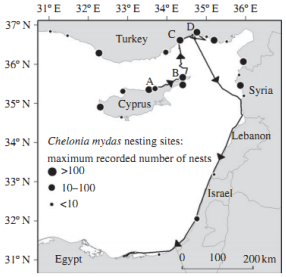


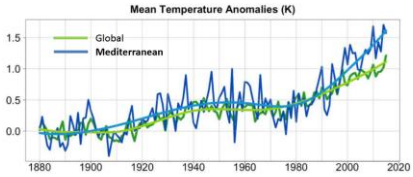
Figure 2. Route of an adult male green turtle that was released post-breeding at Alagadi Beach, Cyprus and tracked to Egypt via the Turkish coast. Major green turtle nesting beaches along the route are labelled (A–D): (A) Alagadi and the Cyprus North beaches, 8–9th June. (B) North Karpaz beaches, 10–11th June. (C) Alata, 14th June. (D) Kazanlı, 15–26th June. Data for nesting numbers are taken from the literature [22,41–43].

Wright et al. 2012. Proc. Royal Soc.

REVIEW ARTICLE
nature climate change

Climate change and interconnected risks to sustainable development in the Mediterranean

Wolfgang Cramer[1*], Joël Guiot[2], Marianela Fader[3], Joaquim Garrabou[4,5], Jean-Pierre Gattuso[6,7], Ana Iglesias[8], Manfred A. Lange[9], Piero Lionello[10,11], Maria Carmen Llasat[12], Shlomit Paz[13], Josep Peñuelas[14,15], Maria Snoussi[16], Andrea Toreti[17], Michael N. Tsimplis[18] and Elena Xoplaki[19]



Mean air temperature anomalies with respect to the period 1880-1899

NATURE CLIMATE CHANGE | VOL 8 | NOVEMBER 2018 | 972-980 | www.nature.com/natureclimatechange

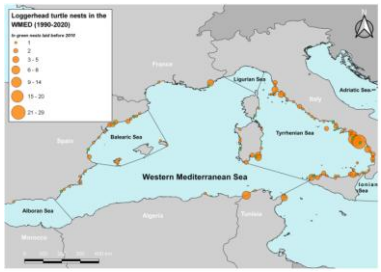


Record levels of sea turtle nesting on the Western Mediterranean coast this season

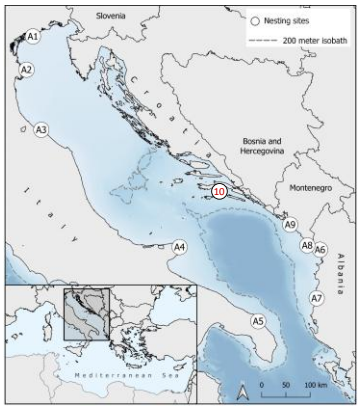
Global Ecology and Conservation 38 (2022) e02194

Nesting range expansion of loggerhead turtles in the Mediterranean: Phenology, spatial distribution, and conservation implications

Sandra Hochscheid[a,b,*], Fulvio Maffucci[a,b], Elena Abella[b,c], Mohamed Nejmeddine Bradai[d,e], Andrea Camedda[f,g], Carlos Carreras[a,h], Françoise Claro[i], Giuseppe Andrea de Lucia[j,k], Imed Jribi[d], Cecilia Mancusi[b,l], Adolfo Marco[a,b], Nicola Marrone[a,m], Luana Papetti[b], Ohiana Revuelta[i], Salvatore Urso[m], Jesús Tomás[i]



Loggerhead sea turtle nest sites in Adriatic Sea
(≈ 20 documented nests in 2010-2025 period)



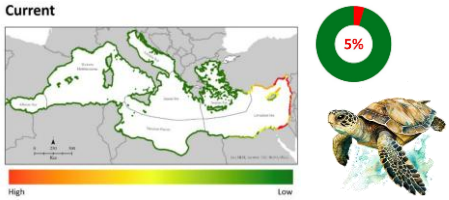
Scientific Reports | (2023) 13:19906

Increase of nesting habitat suitability for green turtles in a warming Mediterranean Sea

Chiara Mancino[1,2], Sandra Hochscheid[3] & Luigi Maiorano[1]



Figure 1. Nesting locations of *Chelonia mydas* in the Mediterranean basin from 1982 to 2019.

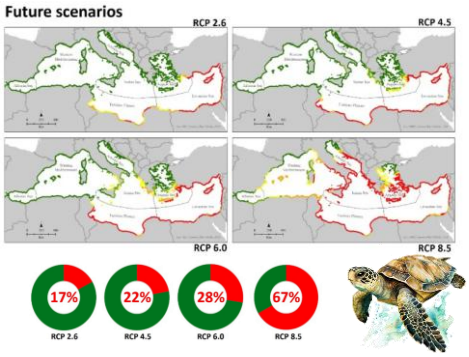


Scientific Reports | (2023) 13:19906

Increase of nesting habitat suitability for green turtles in a warming Mediterranean Sea

Chiara Mancino[1,2], Sandra Hochscheid[3] & Luigi Maiorano[1]

RCP2.6: Peak-and-decline scenario ending in very low greenhouse gas levels by the end of the 21st c.
RCP4.5 and RCP6.0: Greenhouse gas concentrations stabilizing
RCP8.5: increasing emissions over time, leading to high greenhouse gas concentration levels

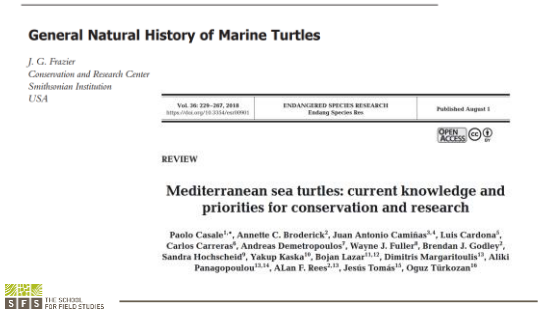


Homework → Field Class

Nesting beach suitability assessment

- Mandatory readings
  - 4 papers provided on sharepoint (Course „Conservation planning", folder „Nesting beach suitability readings")
- Main Questions:
  - Which parameters would you use to assess beach suitability for loggerhead sea turtle nesting?
  - What would be the methodological approach to measure identified parameters?
- Discussion and field work instructions on March, 3rd

Readings



General Natural History of Marine Turtles

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REVIEW

Mediterranean sea turtles: current knowledge and priorities for conservation and research

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