Best Practice Guidelines for Sea Turtles (*Cheloniidae*)

1st Edition, October 2021

Compiled by:
EUAC / EAZA Sea Turtle Working Group under the umbrella of the EAZA Reptile Taxon Advisory Group

EUAC/EAZA Sea Turtle WG chair: Mark de Boer, Rotterdam Zoo

EAZA Reptile TAG chair: Ivan Rehak, Prague Zoo.

DOI: 10.61024/BPGSeaTurtlesEN

EAZA Best Practice Guidelines disclaimer

Preamble

Right from the very beginning it has been the concern of EAZA and the EEPs to encourage and promote the highest possible standards for husbandry of zoo and aquarium animals. For this reason, quite early on, EAZA developed the “Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria”. These standards lay down general principles of animal keeping, to which the members of EAZA feel themselves committed. Above and beyond this, some countries have defined regulatory minimum standards for the keeping of individual species regarding the size and furnishings of enclosures etc., which, according to the opinion of authors, should definitely be fulfilled before allowing such animals to be kept within the area of the jurisdiction of those countries. These minimum standards are intended to determine the borderline of acceptable animal welfare. It is not permitted to fall short of these standards. How difficult it is to determine the standards, however, can be seen in the fact that minimum standards vary from country to country. Above and beyond this, specialists of the EEPs and TAGs have undertaken the considerable task of laying down guidelines for keeping individual animal species. Whilst some aspects of husbandry reported in the guidelines will define minimum standards, in general, these guidelines are not to be understood as minimum requirements; they represent best practice. As such the EAZA Best Practice Guidelines for keeping animals intend rather to describe the desirable design of enclosures and prerequisites for animal keeping that are, according to the present state of knowledge, considered as being optimal for each species. They intend above all to indicate how enclosures should be designed and what conditions should be fulfilled for the optimal care of individual species.

Management in zoos and aquaria

Introduction

The Sea Turtle Working Group (STWG) is a group of curators, veterinarians and keepers of sea turtles in aquaria organised in the EAZA and/or the European Union of Aquarium Curators (EUAC). STWG's goal is to create an information platform for aquaria holding sea turtles in Europe. The platform shares information, creates guidelines and provides an overview of animals kept in European Aquaria. The STWG is working under supervision of the Reptile Taxon Advisory Group (TAG) of EAZA. The STWG started its activities in 2015 by sending a questionnaire to the EUAC members. The questionnaire aimed to collect information about population, general husbandry information, release, genetic testing, veterinary procedures and collaboration with conservation and research programmes. The data were processed during a workshop in the German Oceanographic Museum Stralsund Germany and presented at the EUAC Conference in Burgers Zoo Arnhem, The Netherlands in 2017 and at the EUAC Conference in The Deep Hull, UK in 2018. At the EAZA meeting in 2017, the Reptile TAG officially installed the Sea Turtle Working Group as part of the EAZA organisation. At the Cretaquarium (Greece) workshop in 2018 and the workshop in L'Oceanogràfic de Valencia (Spain) in 2019, the participants of the working group shared their knowledge to create a best practice guideline for keeping sea turtles in aquaria.

These Best Practice Guidelines therefore mainly focus on the species that will be kept in European aquariums such as the green sea turtle (*Chelonia mydas*), loggerhead sea turtle (*Eretmochelys imbricata*), hawksbill sea turtle (*Caretta caretta*), Kemp's ridley turtle (*Lepidochelys kempii*) and olive ridley turtle (*Lepidochelys olivacea*)

The STWG advises against breeding of sea turtles in aquaria. Non-releasable animals (mostly injured animals) are excellent ambassadors for education to the general public about the problems we see with ocean pollution, entanglement in fishing gear, consumption and illegal trade of eggs, meat, and shells and global climate change. We encourage the aquaria who are willing to obtain a sea turtle to get in contact with rehabilitation centres or other aquaria to home a non-releasable animal.

Several sources such as scientific literature, personal experiences within the participating members of the STWG and personal experience of other holders have been integrated into this Best Practice Guideline. We like to especially highlight the "Sea Turtle Health & Rehabilitation" edited by Charles A. Manire, Terry M. Norton, Brian A. Stacy, Charles J. Innis, and Craig A. Harms, as source a for much of the information in this guideline. However, some aspects of husbandry are still subject to further investigation; there are always new opportunities to improve our knowledge and husbandry of sea turtle species in human care.

Acknowledgements

This Best Practice Guidelines for Sea Turtles (Cheloniidae) is the result of a common work with several Aquariums and Zoos involved in husbandry sea-turtles (listed in appendix III). We would like to particularly acknowledge Pablo Montoto from Zoo Aquarium Madrid, Nicole Kube from German Oceanographic Museum Straslund and Sidonie Catteau from Marineland Antibes for their involvement and for making available data not yet published.

The authors would also like to thank Jose-Luis Crespo from Oceanografic Valencia for his assistance in veterinary section, Frances Baines (UV Guide UK) for writing the Lighting and Photoperiod section and Shoshana Levine from The Deep Aquarium, Hull England for helping us with the textual editing.

Recommended citation: de Boer, A.M., Kube, N & Baer, T. 2021. EAZA Best Practice Guidelines for Sea turtles (Cheloniidae) – First edition. European Association of Zoos and Aquaria, Amsterdam, The Netherlands. 60pp

Section 1: Biology and field data

Biology

1.1 Taxonomy

Order Testudines

Family Cheloniidae

- *Caretta caretta* (Linnaeus, 1758)
- *Eretmochelys imbricata* (Linnaeus, 1766)
- *Lepidochelys olivacea* (Eschscholtz, 1829)
- *Lepidochelys kempii* (Garman, 1880)
- *Chelonia mydas* (Linnaeus, 1758)
- *Natator depressus* (Garman, 1880)

Family Dermochelyidae

- *Dermochelys coriacea* (Vandelli, 1761)

Table 1: List of scientific names of recent species of sea turtles with corresponding common names.

Scientific name	English	French	German	Italian	Spanish
Caretta caretta	Loggerhead turtle	Torture Caouanne	Unechte Karettschildkröte	Tartaruga comune	Tortuga boba
Eretmochelys imbricata	Hawksbill turtle	Tortue imbriquée	Echte Karettschildkröte	Tartaruga embricata	Tortuga carey
Chelonia mydas	Green turtle	Tortue verte	Grüne Meeresschildkröte	Tartaruga verde	Tortuga verde
Lepidochelys kempii *Lepidochelys olivacea*	Kemp's ridley turtle Olive ridley turtle	Tortue de Kemp Tortue olivâtre	Atlantik-Bastardschildkröte Oliv-Bastardschildkröte	Tartaruga di Kemp Tartaruga bastarda olivacea	Tortuga lora Tortuga olivácea / golfina
Natator depressus	Australian flatback turtle	Tortue à dos plat	Wallriffschildkröte	Tartaruga a dorso piatto	Tortuga plana
Dermochelys coriacea	Leatherback turtle	Tortue luth	Lederschildkröte	Tartaruga liuto	Tortuga laúd

These guidelines will not focus on the Australian flatback or the Leatherback sea turtles, as they are not kept in European aquaria.

1.2 Morphology

Sea turtles have a body protected by a shell with four broadly flattened limbs that form large paddle-like flippers. The shell can be bony or keratinized and consists of a dorsal carapace, a ventral plastron, and two bridges that connect them laterally. All but one species of sea turtle is part of the family Cheloniidae, a defining feature of which is a hard shell. These are covered with species-specific patterns of keratinised scales or scutes. These scale patterns are used to distinguish sea turtle species (Wyneken, 2001). The sole member of the family Dermochelyidae, the Leatherback, has a leathery carapace that lacks bony scales, but has lateral dermal ridges. Leatherback hatchlings will have scales, but lose them rapidly during development.

1.2.1 Measurements / Morphometrics

When keeping sea turtles in aquaria it is important to regularly take weights and measurements of your turtles to monitor body condition and growth rates. Accurate weights are important when administering supplements or medications. Carapace length is expressed as both a Curved Carapace Length (CCL), with the measurement taken from the middle of the nuchal notch to the longest posterior scale along the curve of the shell, and a Straight Carapace Length (SCL), with the measurement taken straight across from the middle of the nuchal notch to the longest posterior scale and is best measured with a set of callipers (Fig. 1a). Carapace width is expressed similarly with both a Curved Carapace Width (CCW) and a Straight Carapace Width (SCW), with measurements taken in the same manner as the length running across the carapace from one lateral scale to the other at the widest point (Fig. 1b). Plastron length can also be determined by measuring the greatest distance running anterior to posterior. If monitoring sexual maturity, it may also be beneficial to take tail measurements.

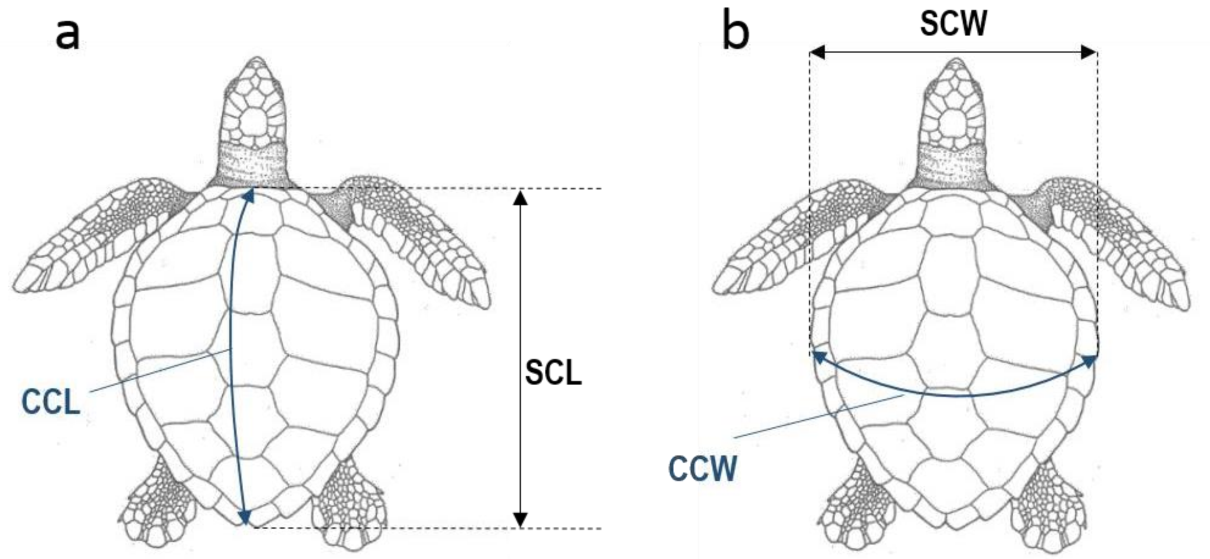

Figure 1: CCL - Curved carapace length; SCL – Straight carapace length; CCW — Curved carapace width; SCW — Straight carapace width. Scheme of CCL (SCL) and CCW (SCW) measurements (adapted from J. Moravec, in Boehme 2005)

1.2.2 Species description

Caretta caretta – Loggerhead turtle

Colour	carapace reddish-brown; plastron yellow-creamy
Average weight	males: 68-101 kg; females 65-107 kg
Average carapace length (SCL)	males 75-104 cm; females 69-105 cm
Characteristics	large eyes, a thick and massive head and neck, powerful beak.
Head scales	have between 4 and 5 prefrontal scales

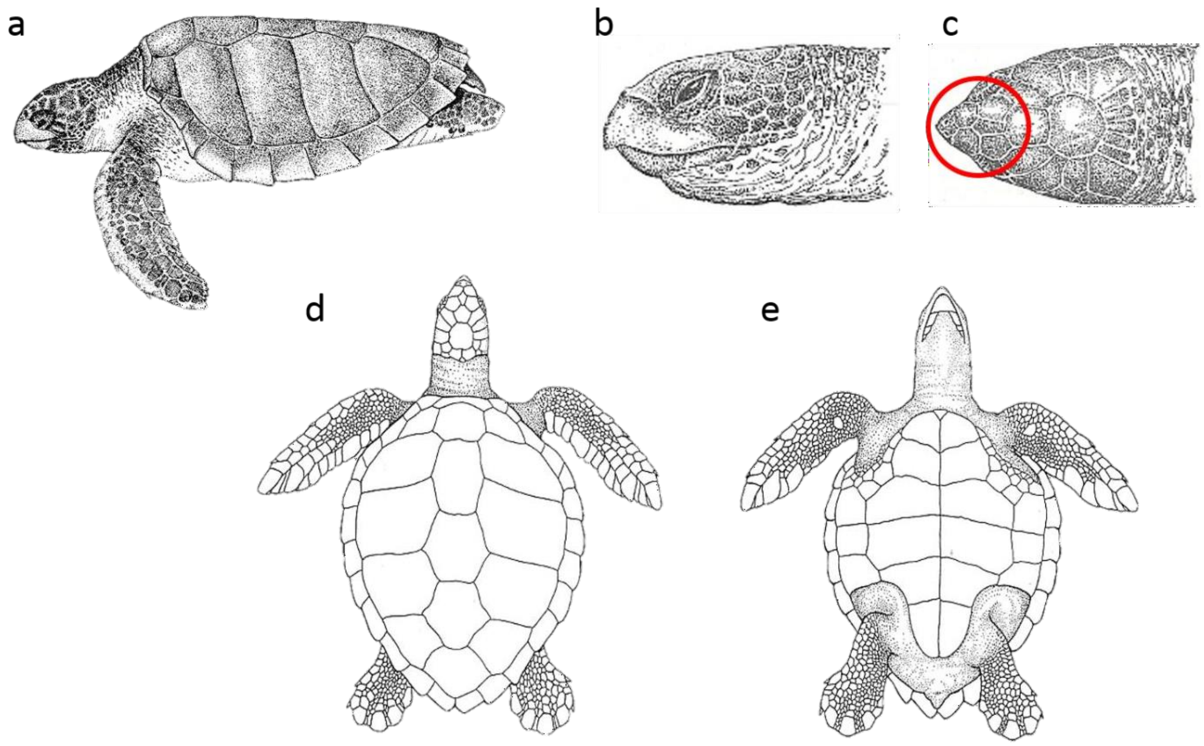

Figure 2: C. caretta*, lateral (a, Marquéz et al 1990, FAO125vol11), dorsal and ventral (d & e, J. Moravec, in Boehme 2005). Head of* C. caretta*, lateral and dorsal (b & c, Boehme 2005). Red circle highlights prefrontal scales.*

Eretmochelys imbricata – Hawksbill turtle

Colour	carapace greenish dark-brown with yellow, red and black spots and stripes; plastron yellowish
Average weight	females 27-77 kg; no weights available for males (Marquéz 1990)
Average carapace length (SCL)	females 53-114 cm; males 16-85 cm (juv. and adult), but highly variable (Marquéz 1990)
Characteristics	long neck, overlapping scales, hooked beak
Head scales	4 prefrontal scales

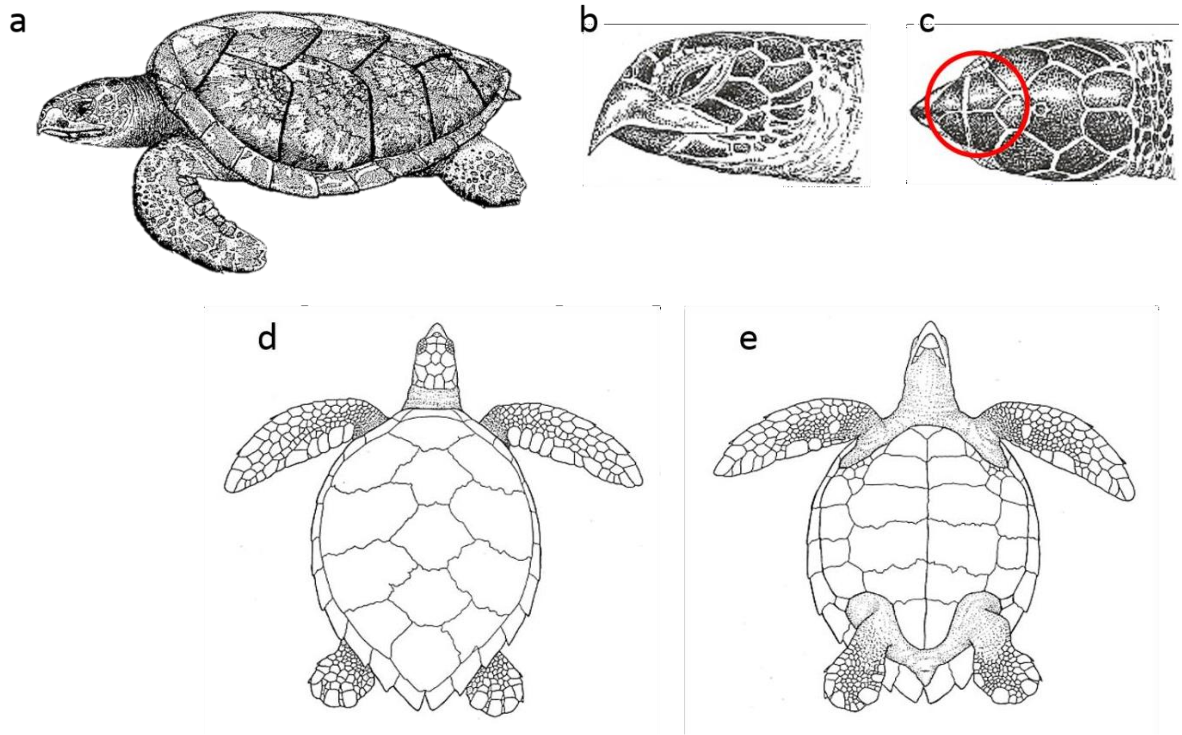

Figure 3: E. imbricate, lateral (a, Marquéz et al 1990, FAO125vol11), dorsal and ventral (d & e, J. Moravec, in Boehme 2005). E. imbricata*, lateral and dorsal (b & c, Boehme 2005). Red circle highlights prefrontal scales.*

Chelonia mydas – Green turtle

Colour	carapace olive-brownish; plastron yellowish
Average weight	males & females: 65-200 kg (max: 235 kg)
Average carapace length (SCL)	80-120 cm
Characteristics	Rounded and serrated beak, almond shaped eyes, and green flesh. The largest member of the Cheloniidae family.
Head scales	2 prefrontal scales

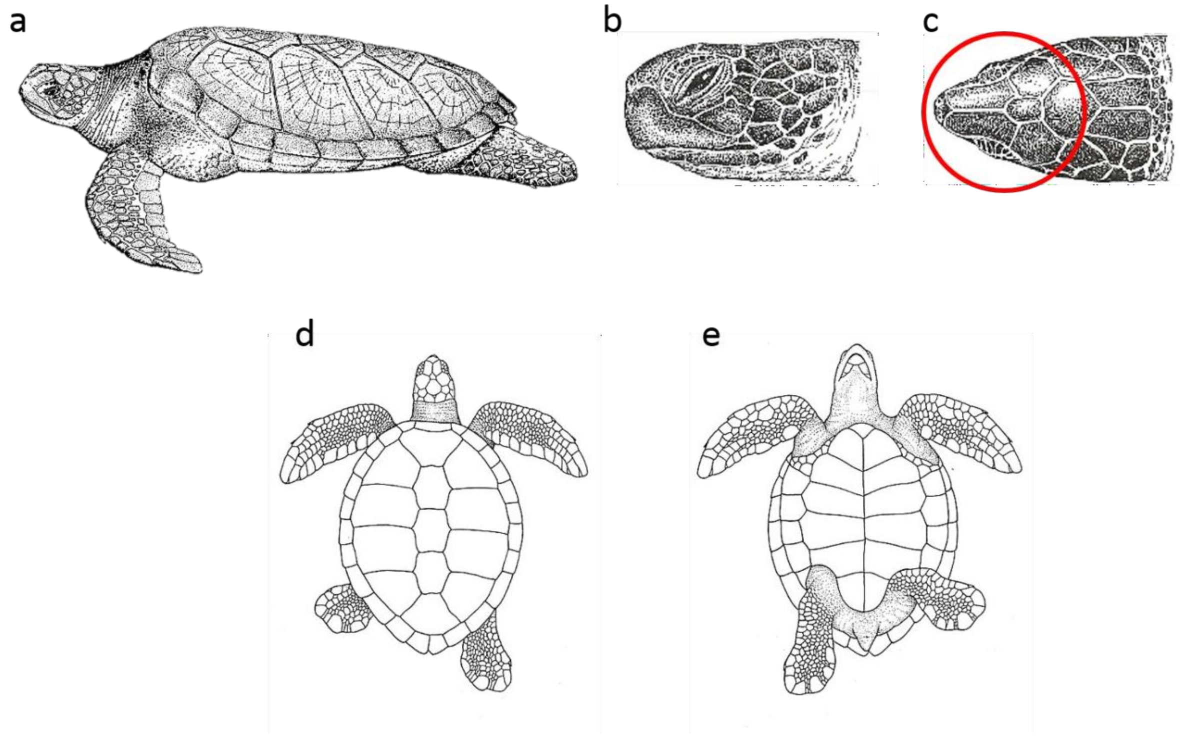

Figure 4: C. mydas*, lateral (a, Marquéz et al 1990, FAO125vol11), dorsal and ventral (d & e, J. Moravec, in Boehme 2005). Head of* C. mydas*, lateral and dorsal (b & c, Boehme 2005). Red circle highlights prefrontal scales.*

Lepidochelys kempii / Lepidochelys olivacea – Kemp's Ridley / Olive Ridley

Colour	*L. kempii* - carapace olive-grey; plastron white or yellowish; *L. olivacea* - carapace olive-grey, plastron creamy or whitish
Average weight	*L. kempii* females: 32 – 49 kg males: 35 kg; L. olivacea females: 33 – 43 kg, males: -2 kg
Average carapace length (SCL)	*L. kempii* 52 – 75 cm; *L. olivacea* females51 – 75 cm, males +3 cm
Characteristics	The two *Lepidochelys* species look very similar and are often described together in literature. However, the number of lateral scales can be used to distinguish the species. L. kempii has 5 lateral scales and *L. olivacea* has 5-9 lateral scales.
	L. olivacea is slightly darker than *L. kempii* and there are slight differences in weight and length. *L. kempii* is the smallest of all marine turtles.

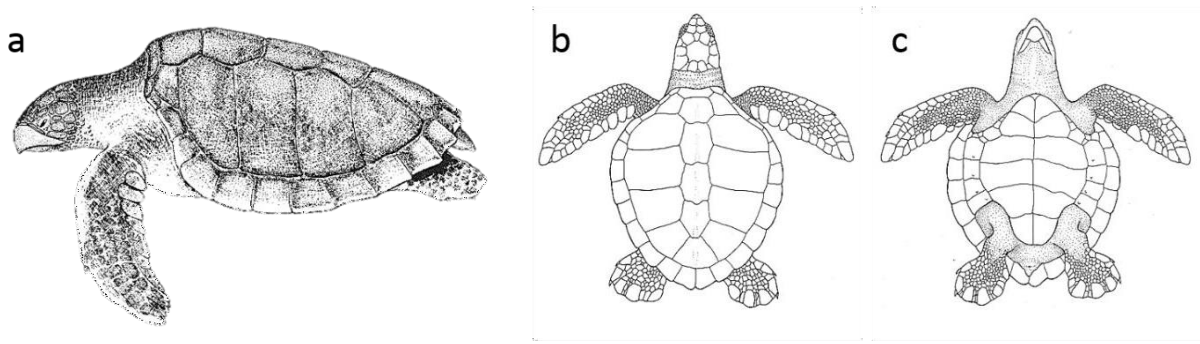

Figure 5: L. kempii*, lateral (a, Marquéz et al 1990, FAO125vol11), dorsal and ventral (b & c, J. Moravec, in Boehme 2005).*

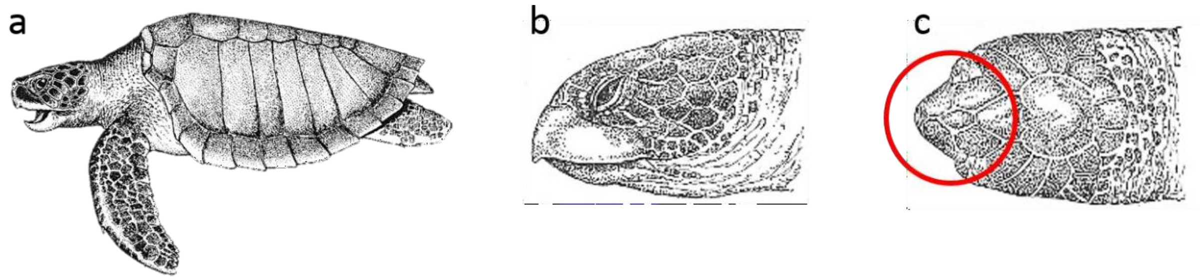

Figure 6: L. olivacea*, lateral (a, Marquéz et al 1990, FAO125vol11), head lateral and dorsal (b & c, Boehme, 2005)*

1.2.3 Sexual dimorphism

It can be difficult to distinguish males and females in early life stages. Once they reach maturity males are generally smaller than females with very long and wide (Fig. 7 right, Fig. 8) tails which have a cloacal opening near the end (Fig 7 right). Males have strongly curved claws located on the second digit of their front flippers (Fig 8 right). Females typically have shorter tails (Fig. 7 left) with cloacal openings higher up, located between the end of the tail and the anal scale of the plastron.

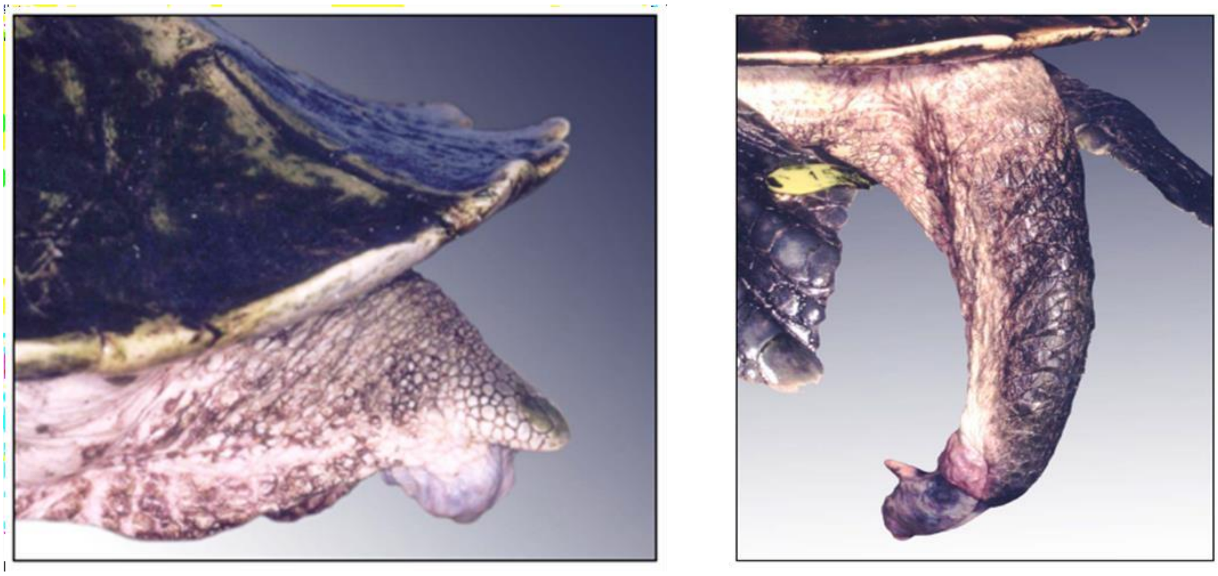

Figure 7: Tail of a female Kemp's Ridley on the left, Tail and penis of a male Kemp's Ridley on the right (Wyneken, 2001)

Figure 8: Male C. mydas *on the left, Claw of a male* C. mydas *on the right (picture Brno Zoo)*

Sexual differentiation in sea turtles occurs during incubation of the embryos in the nest. The temperature of the embryo during development will determine the gender, with warmer temperatures resulting in females and cooler temperatures yielding males (Hays et al. 2003, Blechschmidt et al. 2020)

1.3 Physiology

Sea turtles are marine reptiles and are poikilothermic/ectothermic. These aquatic living animals have some morphological and physiological adaptations that allow production and retention of body heat and also the minimisation of heat loss (Goff and Stenson 1988; Hochscheid et al. 2002) but their body temperature is mainly dependent on their environment. Therefore it is important to maintain the appropriate water temperature. From adult leatherback turtles (*Dermochelys coriacea*) is known that they exhibit thermal gradients between their bodies and the environment of ≥8°C in sub-polar waters and ≤4°C in the tropics. There has been no direct evidence for thermoregulation in leatherbacks although modelling and morphological studies have given an indication of how thermoregulation may be achieved (Bostrom et al. 2010)

Sea turtles can hold their breath for long periods and have adaptations that allow them to dive to great depths (Williard 2013). During periods of activity sea turtles may take a breath approximately every 15 to 45 minutes. However, if they are resting, they may not take a breath for several hours.

As sea turtles live in a salt water environment, they have several mechanisms to deal with excess salt intake. These include lacrimal salt glands that can excrete salt and papillae in their throat that allow them to trap food so they can eject the excess salt water (Wyneken 2001).

1.4 Longevity / generation length (wild and captive)

It is difficult to categorize the lifespan of sea turtles as they have a wide distribution throughout the oceans and data is not readily available. Sea turtles never stop growing throughout their lifetime, but growth rates slow as they age. (Braun-McNeill et al 2008). Environmental pressures in their early life stages push for an increased growth rate at earlier stages. There are a wide range of estimates for life span and how to look at the longevity. These include using carapace measurements to estimate age or looking at the generation length for each species. The IUCN Redlist defines generation length as the average age of the parents in a population. (IUCN Standards and Petitions Committee. 2019). Unfortunately, no matter which criteria are used to evaluate lifespan there is incomplete data across all of the sea turtle species in conjunction with insufficient data, age determinations based on size can be inaccurate as varying sub-populations can differ in size. Age and size may also be different in aquaria vs. the wild. Similarly, turtles in aquaria may reach sexual maturity at younger ages than in the wild. Even without the complete picture, these are long lived animals that can reasonably live 50+ years (Mayne et al. 2020).

1.5 Conservation status / Zoogeography / Ecology

1.5.1 Distribution

All sea turtles dealt with in this guideline are distributed worldwide in tropical and subtropical areas which are in between 25°N and 35°S (Fig. 9-13). While water temperatures vary, 20°C is considered to be the minimum long-term temperature for sea turtles. The only exception is *Caretta caretta* that have been found in the winter in temperatures as low as 16°C.

C. caretta: Global distribution in subtropical and temperate regions of the Mediterranean Sea and Pacific, Indian, and Atlantic Oceans. (Wallace *et al*. 2010).

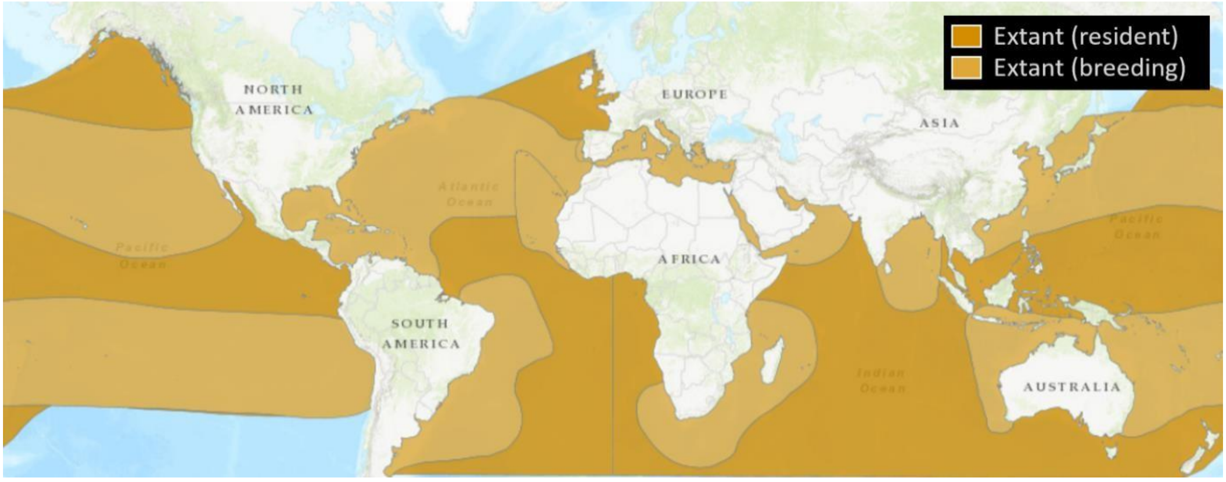

Figure 9: Map showing the global distribution of Caretta caretta *(OBIS-SEAMAP: The World Data Center for Marine Mammal, Sea Bird, and Sea Turtle Distributions 2015.* Caretta caretta*. The IUCN Red List of Threatened Species. Version 2019-2).*

E. imbricata: Global distribution in tropical and subtropical waters of the Atlantic Ocean, Indian Ocean, Eastern Mediterranean, and Pacific Ocean in at least 108 countries with nesting sites in at least 70 countries (Groombridge and Luxmoore 1989, Baillie and Groombridge 1996).

Figure 10: Map showing the global distribution of Eretmochelys imbricata *(IUCN 2014.* Eretmochelys imbricata*. The IUCN Red List of Threatened Species. Version 2019-2).*

L. olivacea: Global tropical distribution in waters of the Pacific Ocean, Indian Ocean, Atlantic Ocean in at least 80 countries (Pritchard 1969). Nesting sites are found in tropical waters worldwide in almost 60 countries but not in the Gulf of Mexico.

Figure 11: Map showing the global distribution of Lepidochelys olivacea *(IUCN 2014.* Lepidochelys olivacea*. The IUCN Red List of Threatened Species. Version 2019-2).*

L. kempii: Mainly the Gulf of Mexico and Atlantic coast of the US (Pritchard and Marquez-M. 1973; Marquez 1984, 1994; Pritchard 2007), rarely Atlantic coasts of Canada, Europe, as well as Bermuda, the Azores, Madeira, and the Mediterranean Sea (Carr and Caldwell 1956; Carr 1957, 1980; Mowbray and Caldwell 1958; Zwinenberg 1977; Brongersma et al. 1979; Brongersma 1982; Bolton and Martins 1990; Tomás et al. 2003; Marquez-M. et al. 2004; Guzman-Hernandez et al. 2007; Witt et al. 2007; Tomás and Raga 2008; Ernst and Lovich 2009; Insacco and Spadola 2010; Caillouet et al. 2015). Nesting areas are restricted to Western Gulf of Mexico from Texas (US) to Veracruz (MX). The most important nesting area is close to Playa de Rancho Nuevo, Mexico (Pritchard and Marquez-M. 1973, Marquez 1994, Pritchard 2007, NMFS et al. 2011, Shaver et al. 2016).

Figure 12: Map showing the global distribution of Lepidochelys kempii *(IUCN SSC Marine Turtle Specialist Group 2019.* Lepidochelys kempii*. The IUCN Red List of Threatened Species. Version 2019-2).*

C. mydas: Global distribution in tropical and subtropical waters with sea surface temperatures over 20°C. This is a highly migratory species, inhabiting coastal waters of over 140 countries with nesting sites in at least 80 countries (Groombridge and Luxmoore 1989; Hirth 1997).

[Summer: west 40°N-35°S; east 30°N-25°S // Winter: west 30°N-25°S; east 20°N-15°S]

Figure 13: Map showing the global distribution of Chelonia mydas *(Marine Turtle Red List Authority 2004.* Chelonia mydas. *The IUCN Red List of Threatened Species. Version 2019-2).*

1.5.2 Habitat

Life cycle and corresponding habitats

Sea turtles are migratory species that travel across the globe in search of feeding, breeding, and nesting areas (Figure 14). Depending on the life stage and event, sea turtles can be found in different habitats throughout the ocean. Females come out of the water to nest, depositing their eggs on sandy beaches. Once the nests complete their incubation period the hatchlings will make their way to the water where they will often use algae mats for protection. These early years are often referred to as “the lost years” as it is difficult to gather data on early life stages. During these early growth periods it is thought that the juvenile turtles are transported on ocean currents, such as the Gulf Stream, allowing them access to feeding grounds in coastal shallow waters. Adults will travel around the ocean to locate good feeding and breeding grounds and are known to undertake large migrations to return to the beaches where they hatched to lay their own nests (Bowen et al., 2004; Lohmann et al., 2008).

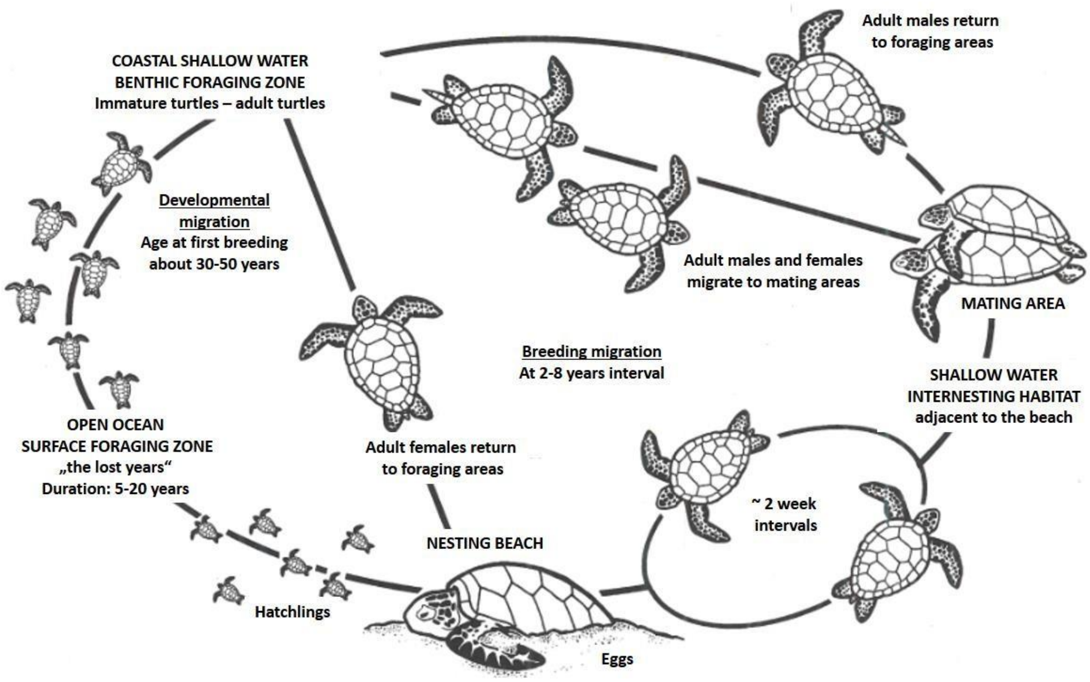

Figure 14: Generalised life cycle of Sea Turtles (Redrawn from Lanyon, J., Limpus, C.J., and Marsh, H., in Biology of Seagrasses, Larkum, A.W.D., McComb, A.j., and Sheperd, S.A., Eds., Elsevier, New York, 1989, 610).

Table 2: the life stages of sea turtles and their sizes, water phases and habitat

Life stage	Size / age	Phase in water	Migration / habitat	Sources
Hatchling	<10 cm length, <55 g weight	Oceanic	Mostly pelagic/planktonic in ocean gyres and great current systems	Arthur et al, 2008; Bolten and Witherington 2003; Putman and Mansfield 2015
Juvenile	>20 to 40 cm	Neritic	Migration to tropical and subtropical estuaries, coral reefs / other inshore habitats, depending on species	González Carman et al. 2011; Berube et al. 2012
Adult	>40 cm from 7 to 40 years	Transoceanic	Migration between foraging grounds and nesting areas. Migrations are performed transoceanic by all species except C. mydas, which carries out migrations along the coasts	Chaloupka and Musick 1997

Table 3: Feeding, internesting and nesting habitats of sea turtles.

Species	Feeding / Internesting habitat	Nesting habitat
C. caretta	Juvenile: epipelagic, but hatchlings and juveniles of some populations stay near nesting beach (Witzell and Banner 1980). Immature / adult: coastal shallow waters (Ernst et al. 2000; Hopkins-Murphy 2003; Limpus and Limpus 2003)	sandy beaches
E. imbricata	Juvenile: epipelagic Immature / adult: coastal areas with coral reefs and rocky shallow waters or bays, estuaries and lagoons;	near coral reefs, upper area of small beaches between vegetation; substrate ranges from gravelly sand to coarse shell and coral fragments (Carr et al. 1966; Hirth 1963; Hirth and Carr1970; Bustard 1974)
L. olivacea	Juvenile: epipelagic Immature / Adults: epipelagic habitats and coastal shallow waters with clay substrate, near highly productive estuarine ecosystems (Pritchard and Trebbau 1984; Reichart 1993; Bjorndal 1997; Marcovaldi 2001)	sandy beaches
L. kempii	Juvenile: bays, lagoons, brackish waters near the estuaries of huge rivers in the Gulf of Mexico Immature / adult: crustacean-rich coastal shallow waters with sandy, muddy seabed, in the north-eastern Gulf of Mexico, west coast of Florida but also at the east coast of Florida up to Nova Scotia.	Sandy beaches
C. mydas	Juvenile: coastal and coral reef habitats near estuaries Immature / adult: seagrass meadows and algae-rich areas	>25°C water temperature, fine sandy beaches (Marquez 1990)

1.5.3. Conservation status

All species of sea turtles are listed in CITES Convention Appendix I and are listed on the IUCN Red List as Vulnerable to Critically Endangered with the exception of the *Natator depressus* which is data deficient (IUCN 2020). IUCN red list status indicates the overall assessment of the entire species, subpopulations within each species may have varying assessment levels. An overview of the conservation status of the regional populations can be found in Appendix I.

1.5.4. Threats to the wild population

Sea turtles are a migratory species that travel great distances between feeding, breeding, and nesting areas. The widespread distribution and the diversity of the habitats increases the threats they face. While they do face natural threats, particularly in early life stages, many of the problems significantly influencing sea turtle populations are due to human interference.

Anthropogenic threats:

Sea turtles face a wide array of threats that originate from human activity. Some of the major issues include: habitat loss (specifically the loss of nesting beaches due to development and tourism), pollution (including both micro and macro plastic), fishing practices (that lead to injury or death), human harvesting (for consumption of meat and eggs and shell trade) and tourism and recreational activities (injuries from boats, obstacles left on beaches, interference with nesting, and light pollution) (Bjorndal et al. 1994, Humphrey and Salm 1996, Lutcavage et al. 1997, Pandav and Choudhury 1999, Fleming 2001, Fretey 2001, Panagopoulos 2003, Thomé et al. 2003, Godfrey and Chevalier 2004, Tuxbury and Salmon 2005, Campbell 2007, Cardona et al. 2009, Mancini and Koch 2009, Humber 2011, Nada and Casale 2011, Plotkin 2007, Wallace 2011, Lagueux 2017).

Less direct human influence can be seen in the effects that climate change and rising ocean temperatures have on sea turtle species. Rising ocean levels add to the loss of important nesting grounds, while rising beach temperatures effect sex determination in the nests, leading to an increase of females within the population (Hays et al. 2003, Weishampel 2004, Fuentes 2010, Janzen 1994, Tomillo 2012, Saba 2012).

Natural threats:

At early life stages the pressures for the survival of sea turtles are high. Nests can be destroyed through natural events (such as being washed away by storms), demolished by predators (like birds or unleashed dogs, raccoons and coatis), or succumb to pathogens (such a fungal infections). If the nests survive, the hatchlings and juveniles are vulnerable to predators. Threats from predators decrease as the turtle size increases, but never disappear.

1.6 Diet and feeding behaviour

Table 4: Natural diet of the different sea turtle species

Species	Diet
C. caretta	Carnivorous opportunistic feeders: benthic Invertebrates Porifera, Cephalopoda, Bivalvia, Crustacea, Echinodermata, Teleostei, Gastropoda, Polychaeta, Cirripedia, Cephalopoda, Tunnicata (Laurent and Lescure 1994, Godley et al 1997, Spoto 1997)
E. imbricata	Omnivorous feeders: predominantly benthic Invertebrates in and near to coral reefs (Ernst et al 2000), Demospongiae (main component in the Carribean) (Groombridge 1982, Meylan 1988), brown algae (*Sargassum*), green algae, seaweed, crabs (*Inachus*, *Pleuroncodes*), marine angiosperms, Porifera, Coelenterata, Echinodermata, Bryozoa, Mollusca, Actiniaria (Carr and Stancyk 1975, Limpus 1970, Alcala 1980, Den Hartog 1979, Steinbeck 1951, Witzell 1983, Marquéz 1990);
L. kempii	mostly carnivorous feeders: benthic crabs (*Areneus, Calappa, Callinectes, Hepatus, MennipePanopeus, Persephone, Portunus, Ovalipes,*), shrimp (*Penaeus, Sicyonia*), Cirripedia, Gastropoda, Bivalvia (*Corbula*, *Mulinia*, *Nuculana*, *Polinices*), sea urchins, Cephalopoda (squid, octopus and their eggs), jellyfish (*Physalia*), Pisces, insects (Carr 1952, Liner 1954, Dobie et al. 1961, Pritchard and Marquéz 1973, Zwinenberg 1977, Pritchard 1979, Hildebrand 1982, Mortimer 1982, Lutcavage and Musick 1985, Marquéz 1990, Shaver 1991, Burke 1994)
L. olivacea	fish, salps, crustaceans, small invertebrates (Pritchard and Trebbau 1984; Reichart 1993; Bjorndal 1997, Wildermann 2012)
C. mydas	Adults (diet is mostly herbivorous): Green algae (*Caulerpa, Ulva*), brown algae, red algae, mangroves (roots and leafs), seaweed (*Zostera, Thalassia, Cymodocea, Syringodium, Diplantera, Halophila, Posidonia, Halodule, Portulaca*); also, in small amounts, *Mollusca, Crustacea, Poriphera and Cnidaria* (Carr 1952, Pritchard 1971, Marquéz 1990, Ernst et al. 2000) Juveniles (diet is mostly carnivorous): Fauna of sargassum mats (Weis 1968, Fine 1970, Ryland 1974, Carr et al. 1980), e.g. Cnidaria (jellyfish), Ctenophora (comb jellies) and Mollusca (gastropods) (Bustard 1976, Frick 1976, Limpus 1978, Witham 1980); also, in small amounts, algae and seaweed (same genera like adults)

Among the sea turtle species, Green turtles (*Chelonia mydas*) are the only ones to stay ashore for hours for other reasons than nesting: It is assumed that they might be “sunbathing” to compensate for low amount of vitamin D in plant-based food (Ernst et al. 2000).

1.7 Reproduction

1.7.1 Mating

Males and females typically mate in breeding grounds located near nesting beaches. Males will compete for the privilege of mating with a female. Once a male is selected, he uses his claws to fix himself onto a female's carapace while she swims. Females may choose to mate with multiple males which can lead to multi-paternity within a single nest (Chassin-Noria et al. 2017). Females are oviparous, with internal fertilization, and can store spermatozoa over years (Gist and Jones, 1989).

1.7.2 Nesting

Females will take place on terrestrial sandy tropical/subtropical beaches. It typically occurs seasonally over 2-6 months of the year. For all but the Kemp's Ridley, nesting occurs at night. A female can lay 1-14 times per season, amounting to up to 1000 eggs a season (Limpus 1993, Wallace et al. 2005, Hays et al. 2010). With the exception of Kemps Ridley's and Olive Ridley's sea turtles, individuals nest independently of each other. Both Ridley's species nest in so called "Arribadas", which are aggregations of thousands of females that nest simultaneously. Each clutch will contain between 50 to 150 eggs that are 3-6 cm in diameter, with soft, leathery shells. After nesting is complete, females will migrate to foraging grounds, which could be located thousands of kilometres away (Schroeder et al. 2003, Shillinger et al. 2008). The eggs will them complete their embryonic development within the amniotic egg. The time interval between nesting seasons can vary and may be years apart, while males are more likely to return to breeding grounds annually.

1.7.3 Development of eggs

Eggs will develop within the nest over a period of 45-70 days depending on the species and the incubation temperature. Sex determination is dependent on the incubation temperature during the middle trimester (Morreale et al. 1982). The "pivotal temperature" is the incubation temperature that yields a 50:50 male to female sex ratio. It varies per species, but the range is 28 – 31°C (Ackerman 2017). Higher incubation temperatures yield a greater number of females and lower more males. Temperature influences successful hatching, with sustained temperatures over 36°C and below 24°C being fatal to developing embryos (Ackerman 2017, Tomillo et al. 2009)

1.7.4 Hatching

When hatching begins, hatchlings (<10 cm, <55 g) stimulate each other vocally when breaking free from eggs. (Ferrara et al 2014). This leads to mass hatchings. Hatchlings will participate in upwards digging for 2-3 days to emerge from the nest. High temperatures negatively affect the digging. The hatchlings reach the surface at night and crawl towards the brightest horizon (moon, stars, and the reflections in the ocean) (Lucas 1992). Once they enter the water, they enter a period of continuous swimming for up to 1 week (Wyneken and Salmon, 1992). For the next several years they will go through an "oceanic phase" where they will drift along with ocean currents and gyres and become part of planktonic communities (Arthur et al. 2008).

Figure 15: L. kempii hatchling (picture by Jimena Gutiéterrez)

Table 5: Average egg and hatchling sizes and weights of extant sea turtle species (from Marquéz 1990, FAO125/vol11)

Species	Egg size	Egg weight	Hatchling size	Hatchling weight
C. caretta	35 – 55 mm	26 – 47 g	34 – 55 mm	19 – 21 g
E. imbricata	30 – 45 mm	20 – 32 g	38 -46 mm	8 – 18 g
L. kempii **(data from Rancho Nuevo, Mexico)**	34 – 45 mm	24 – 40 g	44 mm	17 g
L. olivacea	32 – 45 mm	30 – 38 g	35 – 45 mm	12 – 22 g
C. mydas	34 – 59 mm	21 – 66 g	35 – 59 mm	15 – 35 g

1.8 Behaviour

1.8.1 Activity

Sea turtles are most active during the day. Activities will alternate through phases of feeding and resting. They spend the majority of their time submerged, with the length of time underwater dependent on their activity level. While the most active they may only hold their breath for several minutes at a time, but this can increase to hours during a resting phase or at night (Parrish 1958, Bjorndal 1980, Lutcavage and Lutz 1991, Schwartz and Jensen 1991). Resting areas can be found in a variety of locations (e.g., ledges, caves, or open water) and may be distant from feeding grounds (Carr and Ogren 1960, Bjorndal 1980).

1.8.2 Navigation over long distances / Imprinting

Sea turtles are able to navigate and travel long distances, and are known to return to the beaches where they hatched to lay eggs. It is believed that they use an array of information to make these return journeys. When hatchlings first make their way to the ocean it is thought that the location of the beach is imprinted. They have specialised cells which allow them to use the earth's magnetic fields for navigation (Lohman et al. 2012). They will also use a combination of olfactory cues, recognisable landmarks, and natural characteristics (e.g., currents, star positions, and salinity) to make these return journeys possible.

1.8.3 Locomotion

Sea turtles spend the majority of their lifetime in an aquatic environment. They use their flippers to swim through the water. The front flippers are powerful and used to propel the turtle through the water using a lift-base propulsion system, analogous to bird-wings (Renous et al. 2000). The rear flippers are much shorter than the front flippers and are used for steering rather than powerful propulsion. They act similar to a rudder on a boat to provide directionality while swimming.

On the occasions where sea turtles are found in terrestrial environments, they use their flippers to walk across the land. Hatchlings will use all their flippers at once as they make their way from the nest to the water. Conversely, adults will alternate diagonal flippers simultaneously to accomplish their necessary movement. Females will also use flippers to dig their nests. They will use all four flippers to dig a body pit before using the rear flippers to dig an egg pit. This is accomplished by scooping out sand with alternating scoops of the rear flippers. Once complete, the female will conceal the nest by using her rear flippers to fill in the pit and then cover it with dry sand.


Figure 16: Tracks of a hawksbill turtle and a green turtle (pictures by Jimena Gutiéterrez)

1.8.4 Social / Sexual behaviour

Sea turtles are migratory species that are mostly solitary and are therefore not found living in social groups. Their complex life cycle is not fully understood. Once males and females reach maturity, they are known to participate in seasonal migrations between feeding and mating grounds. Breeding grounds have been found to be in the area of their own birthplaces (Limpus et al. 1992, Fitzsimmons et al. 1997). Once they arrive at the mating grounds, the males try to attract the females. Males and females can be seen participating in a courtship behaviour which is characterised by stereotypic elements, such as head or flipper movements, tweaking (Zwicken), and biting. Readiness of females is presumably shown by pheromones (Wood 1953, Ehrhart 1982, Limpus 1985, Miller et al. 2003). Once united, mating can last several hours and studies have shown that females often copulate with more than one male (Dodd 1988, Harry and Briscoe 1988, Marquez 1990, Miller et al. 2003). Eggs are typically deposited during the night, but could also occur during the day (Carr et al 1966, Frits and Hoffman 1982, Ernst et al. 1994, Moulis 1994, Mortimer and Bresson 1999).

Section 2: Management in zoos and aquaria

2.1 Enclosure

Sea turtles live most of their life in water and therefore do not need a large dry surface. However, a resting place (see 2.1.3: Furnishings and Maintenance) is mandatory and for the females it is necessary to provide a beach to give them the opportunity to dig nests (Fig. 17). Enclosure sizes are set to satisfy the need of the turtles allowing the animals to show natural behaviours at all ages. Minimum tank dimensions (see also section 2.1.5: Dimensions) are given in Appendix II.

Figure 17: resting place and beach at Marineland, Antibes, France (Marineland)

2.1.1 Boundary

Enclosure barriers should be designed to keep the public at considerable distance from the animals. For the temporary division of space within the tank materials like strong nets or wooden fences can be used. It is important to remark that sea turtles are strong animals and in case of stress able to knock down barriers if not well attached to the pool. Nets with too large mesh sizes can entangle sea turtles. Mesh sizes larger than 2 cm^2 are not recommended. It is also necessary to ensure that the public does not have the ability to throw objects (e.g., plastic bottles or eye glasses) into the exhibit as the animals might ingest these.

Be aware that sea turtles may cause damage, such as scratches, to acrylic panels. Sea turtles have a very powerful jaw; if the exhibit is open to the public, it is necessary to provide some form of separation (e.g., fencing) to ensure that the turtles do not have the opportunity to bite guests or have an adverse reaction to the public.

If habitats are outdoors, it may also be necessary to provide a form of separation (e.g., fencing) to keep the animals safe from birds (e.g., seagulls). Birds may bite the turtle’s eyes or interfere with feeding. Therefore, turtles should not be fed when birds are present to help discourage unwanted behaviour. It may be necessary to remove nearby nests or relocate birds.

2.1.2 Substrate

Turtles are prone to swallowing objects and this can cause serious health issues. For this reason, if substrate is used within the exhibit, avoid silicate sand and any artificial constructions containing small pebbles and stones. The amount of substrate ingested can be as much of a problem as the type. When possible, animals should be monitored using x-ray when first introduced to an enclosure. The only substrate which can be used to help in avoiding complications is coral sand or $CaCO^3$.

2.1.3 Furnishings and maintenance

It is mandatory that resting places are provided. These can be located both inside and outside of the main exhibit. Examples are: a beach, platform, ramp, or construction in shallow water. If females are kept, it is necessary to provide a beach to give them the opportunity to dig nests.

A good example of a nesting beach for sea turtles is the beach at the Sealife aquarium in Brighton. During the renovation of the aquarium, a beach was created in 2018 for their more than seventy-year-old Green sea turtle. The experiences in Europe (personal communication after consulting several aquaria and Japan (Teruya et al. 1997) were considered. A year after the aquarium was reopened, camera images showed that the female sea turtle regularly came to the beach and eventually deposited eggs up to three times. Important success factors seem to be a smooth enough ramp gradient for the turtle to exit the water as easily as possible, the undewater depth of the ramp edge (it is suggested for this to be about 50 cm so that the animal can start exploring the slope meantime still fully submerged) and the ramp width which need to be enough for the turtle to move confidently (a minimun of 2 meters wide is advised for large green turtles).

The recommended dimensions of the beach with coral sand are 3x 3 meters with a depth of 1.20 meter. The temperature of the sand should match as closely as possible the one of the water of the tank.

A 24 hour surveillance with cameras (with night light) to observe behavior is strongly recommended to be able to monitor when, how often and for how long the sea turtle visits the beach and whether it is digging and laying eggs. Sea turtles may do several exploring events before deciding to lay their eggs and that this may go on for the entire season (perss. comm. Monica Solda, SL Brighton).

Table 6: Dimensions of the ramp and beach at SeaLife Brighton

Slope Gradient	**1:7**
Slope Percentage	**13%**
Ramp length (Run)	**5,2 m**
Ramp high (Rise)	**0,7 m**
Ramp depth under water	**0,5 m**
Ramp width	**2,0 m**
Sand pit depth	**1,2 m**
Sand pit area width (larger part)	**1,4 m**
Sand pit area width (narrow part)	**0,9 m**
Sand pit area length	**3,1 m**
Substrate type: Moist Quartz Silica Sand	

Water movement throughout the exhibit can stimulate normal swimming behaviours and help maintain physical conditioning. Current flow pumps in the aquarium can be used to achieve laminar flows. Pumps like the Hydro Wizard of PanthaRhei can also be used to make wave simulations.

Theming the enclosure should provide hiding spaces for the animals and must be sea turtle proof: any materials must be able to withstand the strong bite of the turtles and it is therefore highly recommended that theming be built out of concrete. All decorative theming, such as artificial corals, must not be easily broken. All theming that can be easily broken and subsequently swallowed, especially if made of plastic, should be avoided (Whitaker and Krum 1999).

Sea turtles need to have the opportunity to scrub their carapace. Building in ledges or other structures within the theming that can facilitate this is recommended.

2.1.4 Environment

Filtration

Exhibit filtration systems need to be of the same type and maintained at the same standards used in keeping fish. For keeping sea turtles, it is recommended that the system contains means of mechanical filtration (e.g., sand filter), biological filtration (e.g., fluidized bed), disinfection unit (e.g., UV), and heat control (e.g., heat exchanger). The system must have the ability to be water changed. Ozone may be used on systems housing sea turtles.

Water and water quality parameters

Water used in the habitat should be similar in composition to natural sea water and maintained to the water quality standards required to keep fish.

Water quality parameters (e.g., NH_4^+, NO_2^-, NO_3^-, PO_4^{3-}, redox potential, oxygen saturation, and water hardness) should be maintained at safe levels for keeping fish. As salinity and pH are the most important parameters for sea turtles, it is recommended that salinity is kept between 20-38 ppt and the pH between 7.8- 8.5.

Recommendations for closed aquarium systems:

NH_4^+ & NO_2^- at 0.00 mg/L
PO_4^{3-} at 20 mg/L (max.)
NO_3^- at 150 mg/L (max.)

More information on water quality parameters and testing can be found in *Sea Turtle Health & Rehabilitation* (Manire et al. 2017, p53-55).

Temperature

It is recommended that the habitat temperature be adjusted to mimic annual temperature trends based on species and origin, as follows:

Caretta caretta: Minimum 17°C (winter), maximum 28°C (summer) or keep in between 23 – 25 °C if annual temperature cycle is not an option. Time at lower temperatures should be limited and behaviour should be monitored. If housing turtles in an indoor habitat, please maintain a slightly elevated minimum temperature.

Chelonia mydas: Minimum 20°C (winter), maximum 28°C (summer) or keep in between 23 – 26 °C if annual temperature cycle is not an option.

Eretchomelys imbricata: Minimum 20°C (winter), maximum 26°C (summer) or keep in between 23 – 26 °C if annual temperature cycle is not an option.

Lepidochelys kempii and L. olivacea: Minimum 22°C (winter), maximum 26°C (summer) or keep in between 23 – 26 °C if annual temperature cycle is not an option.

Sea turtles are marine reptiles that breathe air from the surface. For this reason, it is important that the air temperature does not vary greatly from the water temperature. Under ideal conditions the air temperature will be the same as the water temperature. Avoid cold draughts.

Lighting and photoperiod

Under ideal conditions sea turtles are provided with natural sunlight. However, many aquaria are unable to provide sufficient sunlight and should therefore use artificial lighting. As we know from literature, many reptiles require ultraviolet-B radiation (UV-B) to synthesize vitamin D3 to enable absorption of dietary calcium. For reptiles in human care with not enough exposure to UV-B radiation and without vitamin D3 supplementation, falling levels of serum 25(OH)D3, the metabolite used as a marker of vitamin D3 status, are often seen. As deficiency develops, hypocalcaemia and metabolic bone disorder may follow. For sea turtles in human care, there are very few studies with regard to vitamin D3, UV-B and the health problems related to this subject. There are several detailed studies on sea turtle blood chemistry, with serum calcium and phosphorus measurements, but only two studies measured 25(OH)D. Purgley et al (2009) demonstrated a definite decline in serum D3 levels when green sea turtles (*Chelonia mydas*) were housed indoors. Scott et al (2019) evaluated the effect of UVB radiation on calcium metabolism in *Chelonia mydas*. 25(OH)D, parathyroid hormone (PTH), and ionized calcium (iCa) were measured in juvenile (n = 18, 9 indoor, 9 outdoor) and adult (n = 8, 4 indoor, 4 outdoor) turtles. All animals were fed an identical diet. Outdoor animals had access to unfiltered sunlight, whereas indoor animals were housed under artificial lighting without UV-B radiation. Sun exposure had a significant effect on 25(OH)D with highest values in adult outdoor turtles. These results suggested that UV-B exposure is an important source of 25(OH)D for green sea turtles and has significant effects on calcium metabolism in this species.

To see whether the artificial UV-B radiation provided by UV-B emitting fluorescent tubes can improve wound healing and general health status of indoor kept marine turtles Lukac et al. (2018) started a project on such an influence in the Marine Turtle Rescue Centre Pula. A semi-adult loggerhead sea turtle (*Caretta caretta*) with shell injuries and in bad general condition was rescued in the area of Cres Island. Upon arrival to the Centre, the animal was debilitated, anorexic and dehydrated. It also had severe injury of the caudal part of the body, with loss of bone structures and soft tissue. The wound was old and infected, with an opened coelomic cavity. The animal was exposed to artificial UV-B light four Arcadia T5 12% fluorescent tubes fitted in Arcadia Zoo Bar reflector units suspended 60cm above the water for 12 hours per day – following the protocol developed for the sizes of the tanks to get the gentle, oval UV zone with index 3-5. Two months after the initial UVB exposure, a gradual increase in total vitamin D serum levels was detected. Ca and P values varied during the healing period, but remained within the normal range for Loggerhead sea turtles. The wound healing and general health condition improvement as assessed by visual inspection, seemed to be much faster than in non-exposed animals. Lukac et al. (2018) concluded that UVB exposure accelerated wound healing and improved general health conditions in injured marine turtles kept indoors. Therefor it seems that its usefulness is plausible in such cases. A research project on a larger number of animals and the interpretation of its results are in progress and shows similar results so far.

Literature as well as anecdotal observations suggest that sea turtles do utilise sun-basking behaviour to expose themselves to UV-B radiation. Balazs and Ross (1974) reported sun-basking behaviour - actually leaving the water and hauling out onto ledges - in captive juvenile *Chelonia mydas*.

Sapsford and van der Riet (1979) studied basking behaviour in *Caretta caretta*. They suggest that animals were not simply basking for thermoregulatory reasons, similar to freshwater turtles as described by Manning and Grigg (1997). They were observed doing so in overcast conditions when there would have been UV-B exposure, but body temperature remained at the temperature of the sea water. It is therefore possible that basking may be, at least in part, for UV-B absorption.

Cardona et al. (2005) followed five wild juvenile loggerheads over one spring and summer and reported: "On average, tracked turtles spent 35.1 ± 19.7% of the time at the surface"

Godley et al. (2003) studied diving patterns in adult *Caretta caretta* and these too seem to engage in only short, shallow dives in the daytime - suggesting they too obtain much UVB during the day just by being at shallow depths.

Minamikawa et al. (2000) measured dive depths in a small group of adult loggerheads and the results show that by far the majority of dives are to depths of less than 10 metres.

UV-B radiation penetrates water quite well. How deep this UVB penetration actually reaches, however, depends upon the quality of the water as organic particles and mud absorb and scatter the light. Along the coasts, the higher concentrations of particulate matter near harbours and estuaries reduce the penetration depth drastically Vasilkov (2001). A paper by Booth and Morrow (1997) summarises some of the data, and they point out Smith and co-workers “deployed custom designed instrumentation in Antarctic waters and reported that “UV radiation” penetrates to ecologically significant depths-"in excess of 60- 70 meters,'' while Piazena and Hader reported “similar levels in less than 1 m in coastal lagoons”. However, neither paper states the actual spectral range investigated. Working with sea turtles in permanent human care, we are not going to be concerned about water depths greater than a few metres and in relatively clean tank water the penetration is going to be at least as good as in real clear deep-sea water.

In an aquarium, what we need to concentrate on is not water penetration, but getting the UV-B radiation at the air/water surface to resemble natural sunlight on the sea, at a time of day when UV-B levels are neither very weak (such as in the very early morning or late afternoon, or in bad weather) nor very strong (such as mid-day on a clear summer's day in the tropics). The levels should be gentle yet generally effective at vitamin D synthesis in most species that regularly expose themselves to moderate amounts of full sunlight - as these sea turtles apparently do. Frances Baines (pers. comm.) suggests that they might be classified as Ferguson Zone 3 since their regular diving behaviour suggests that they probably get similar UV-B exposure to species that bask in full sunlight, but generally avoid full sun exposure all day. Ferguson Zone 3 animals frequent "sun basking areas" with a UV-B gradient reaching levels in the range UVI 2.9 - 7.4. (Baines et al 2016). This would suggest that provision of a large area - at least as big as the whole body of the turtle, and ideally considerably larger - at what the World Health Organisation define as a "moderate" UV Index, between about UVI 3 - 5 - would be suitable, as long as this area only covers part of the surface of their tank, so they can move in and out of the UV gradient as they wish.

Practical lighting suggestions

Until recently, covering a large area with anything resembling an UVI of 3.0 was completely impossible. Mercury vapour lamps and UVB-emitting metal halide lamps only provide small areas of maybe 30 – 60 cm across. However, BIAZA zoos in the UK are now finding that it is possible to create “basking zones” of virtually any required dimensions, with the UV-B lamps hung up to 2 metres above the animals, using multiple T5-HO UVB-emitting tubes in hydroponics fixtures fitted with reflectors.

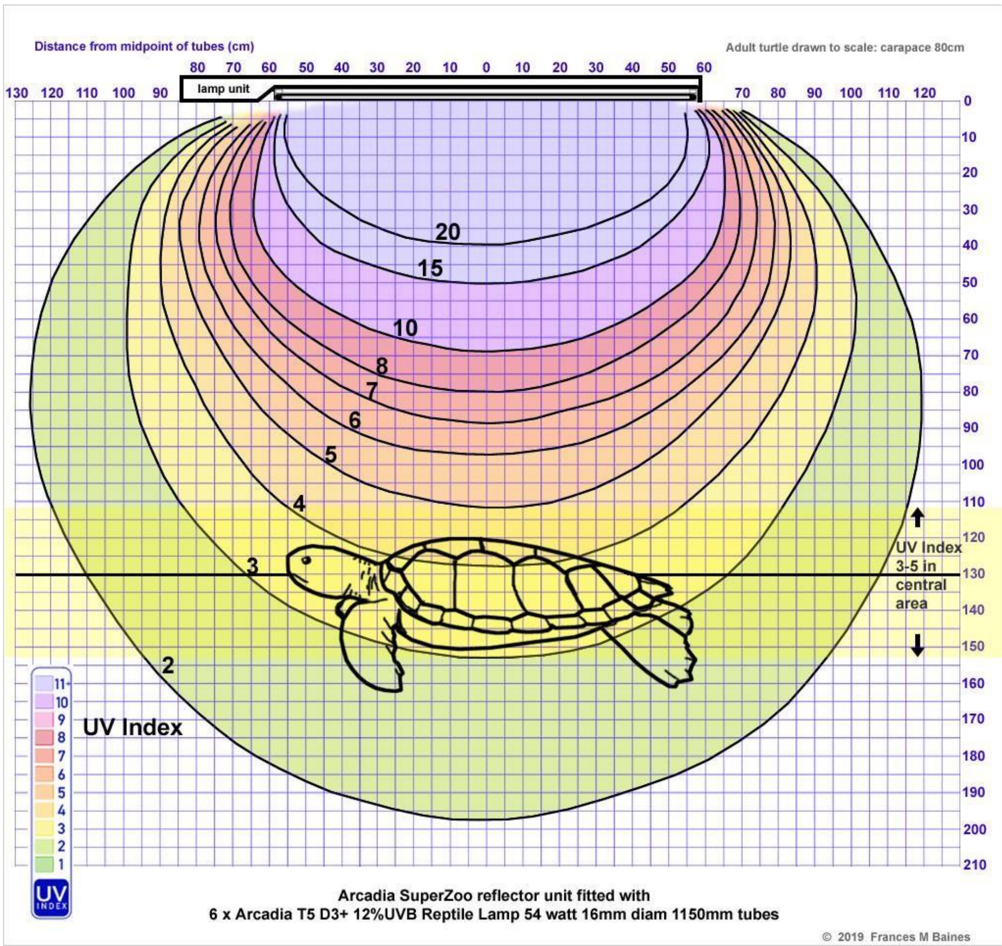

Figure 15: The ISO-irradiance chart for an Arcadia "SuperZoo" unit, which is waterproof and holds six 54-watt T5-HO tubes. When fitted with Arcadia 12%UVB tubes, at a distance of 1m30 above the water, the lamp produces a UVB zone with an UVI 3.0 – UVI 4.0 with a footprint 1m30 wide, big enough for any turtle's body to be all within that zone.

A big problem with indoor enclosures is that it is difficult to provide visible light levels even remotely resembling daylight levels, let alone sunlight levels. The irradiance of visible light is actually extremely important for stimulating the brain, setting circadian and circannual rhythms and activity levels.

The installation of very bright metal halide floodlights, up to 1,000 watts, can turn the UV-B zone into something much more like a "patch of sunlight" which seems to attract most animals. These are commercial metal halide floodlights with "daylight" bulbs (between 4,000 – 6,000K colour temperature).

Short-wavelength infrared "patio heaters" (the units with bright orange glow) can be used to complete the "sunbeam"; this type of infrared is closest to what the sun provides (infrared-A) and penetrates keratin and therefore warms deeper tissues, unlike long-wavelength infrared (or infrared B and C) from panel heaters and ceramic heat emitters. These big heaters likewise have a wide coverage, creating the desired basking zone temperatures.

At the moment there is very little scientific evidence to support husbandry recommendations on this subject. Current suggestions are based upon work with large terrestrial tortoises, the literature about UV-B radiation and vitamin D and basic lighting practices used in other areas of reptile husbandry. We urgently need zoos to conduct trials with full spectrum lighting. When taking routine health checks involving blood sampling, it is highly recommended to also run tests for serum 25(OH)D levels as standard.

2.1.5 Dimensions

Tank dimensions

The minimum space requirement for each turtle with a straight carapace length measurement greater than 65 cm is nine times the length of the carapace by four times the width of the carapace, with a minimum water depth of two meters. Tank size should allow for natural behaviour, easy movement, and the ability for the turtle to dive. For an additional turtle, increase the surface area by 50% from the requirements for a single turtle. If more depth is provided, the surface area can instead be increased by 25% for each additional meter of water depth. Further increases must be made for each additional turtle (see Appendix II).

Example: Marine turtle of size 1.00 m carapace length by 0.80 m carapace width:

(9x 1.00 m) x (4 x 0.80 m) = 9.00 m x 3.20 m = 28.8 m² surface area for one animal

For more details about this and for the requirements for smaller animals please refer to USFWS 2013 and in *Sea Turtle Health & Rehabilitation* (Manire, 2017. p45-53).

It is mandatory that there is an area which can be used for the isolation of the turtles. Isolation may be required for many reasons, including behavioural problems, separation during mating season, injuries, or health issues. The isolation area can be attached to the habitat by a gate or in a separate area of the aquarium.

Figure 19: Sea turtle in a stretcher at German Oceanographic Museum Stralsund

The isolation area or other access point, such as a beach or platform, can be utilized for training, veterinary procedures, or feeding. The ability to access the tank with a stretcher is highly recommended. Ideally the stretcher can be attached to a crane to allow for easy movement of the animals.

2.2 Feeding

Proper nutrition is essential to ensure individuals health and wellbeing as a basic point for any husbandry guidelines. Under natural conditions, sea turtles have a very diverse diet that varies depending on the species as well as the phase of the life cycle. Lack of abundant references about natural nutritional requirements in these species makes the formulation of diets especially complex. As part of the veterinary program, it must be ensured that the food supplied to turtles has been stored, transported, thawed and prepared based on established food safety protocols (Crissey & Spencer, 1998), which maximizes the maintaining of nutritional qualities.

2.2.1 Basic diet

The natural diet of the different sea turtle species is described in table 3 in section 1.6 of these guidelines.

Herbivorous sea turtles

Of the species described in these guidelines, the green sea turtle, *Chelonia mydas,* is the only herbivorous species. In aquaria, the green sea turtles receive a combination of leafy vegetables (endive, chicory, pak choi) supplemented with a gelatine feed containing the essential vitamins and minerals. Rotterdam Zoo has good experience with Mazuri Herbivore Aquatic Gel.

Table 5: Feeding schedule Chelonia mydas *Rotterdam Zoo*

Frequency	Product	Amount / animal	Remarks
Daily	Leafy vegetables	1000 g	Variation: endive, chicory, pak choi
3x / week	Mazuri Herbivore Aquatic Gel	230 g	115 g dry powder mixed with 125 ml water makes 230 g for one portion.

Carnivorous sea turtles

Despite the availability of commercial formulas for sea turtle feeding, most institutions use natural items (fish, shellfish, squid) as the main component of the diet of carnivorous sea turtles.

The questionnaire sent for the first workshop in 2017 shows a varied picture between the different aquaria, but the majority of them use squid, hake and herring combined with a vitamin and mineral supplement such as Akwavit Shark (Kasper Faunafood). The amount of food offered varies per aquarium and per animal, but we recommend feeding between 1-5% of the body weight per day.

Squid is often used both for its availability and for the acceptance of this food by turtles. However, it must be considered that it has a high phosphorous content and low calcium percentage, so it should be used sparingly, never as the only source of protein in a long-term diet. Some individuals tend to be selective with diet, different techniques could be used to avoid this behaviour (i.e., offer the food crushed in jelly blocks).

Food should always be weighed properly, and the quantity recorded in advance for each turtle. Not ingested food remains will be discarded and recorded as well as possible observations on daily reports.

The amount of food provided depends on different factors such as physical condition, blood parameters, age, species and frequency of feeding days. As a general rule, sea turtles are feed daily with a percentage that ranges between 1% to 5% of their body weight (Bluvias & Eckert, 2006), although, depending on the physiological state of the individual, food percentage could be adapted if energetic requirements increase (i.e., reproduction, disease) or adjusted if fasting days are included. It should be kept at low percentages in maintenance diets and towards the highest values in juveniles or turtles under rehabilitation. Routine turtle weighting is mandatory as an important part of the regular health check and to recalculate food percentage.

Food supplementation is necessary especially in diets that rely on fish items since a large part of the nutrients can be degraded during the freezing process, especially antioxidant vitamins such as vitamin C and vitamin E. In addition, many species of commercial fish have thiaminase, so it is important to also supplement with thiamine to avoid deficiencies. There are many commercially available vitamins and mineral supplements formulated for sea turtles.

Proper food preservation is essential to prevent nutrient loss and degradation. Frozen fish should be kept between -30°C and -18°C in order to minimize oxidation and thiaminase activity. Safe defrosting takes place under refrigeration at a temperature of 2.0°C to 3.5°C. Other defrosting methods (microwave, running water) should be avoided. You should never refreeze food that has already been thawed.

Minimum hygiene guidelines should be followed during food preparation and handling. These affects both, personnel and processing tools. Hand washing and hand disinfection on a regular basis and use of gloves are essential in preparation of diets and animal feeding. Tools, including knives, containers and cutting boards, should be washed and stored properly.

2.2.2 Method of feeding

For sea turtles in long-term aquarium care it is recommended that they are trained to be fed at the surface. It is helpful if the turtles are trained using one or a combination of sound, light, or target to help facilitate recall and feeding. Husbandry manuals for animals in rehabilitation centres with the aim to be release back to the wild suggest feeding turtles on the bottom of their habitat or free feeding throughout the habitat to make sure they learn to search for food to emulate natural behaviours before release (Bluvias and Eckert (2010) Marine Turtle Husbandry Manual, page 29).

2.3 Social structure

2.3.1 Basic social structure

Wild sea turtles are usually found to be solitary. In aquaria, experience has shown that small groups of adult animals (3 to 5 animals) can be kept together without aggression or patterns of dominant behaviour. The following group structures have been kept successfully:

Caretta caretta: Adults can be kept in single gender groups and mixed gender groups. More than one male may be kept in a group, but there must be the ability to separate animals during breeding season as the males will bite the females. More conflicts between turtles were seen if their habitat was too small or if the habitat was over crowded.

Juveniles tend to bite more than adults and therefore require separation. Juveniles should be separated until they reach one year of age. Although they may still fight, biting behaviour will begin to decline from this point.

Chelonia mydas: Adults can be kept in single gender groups and mixed gender groups.

Eretmochelys imbricata: Adults can be kept in small groups.

Mixed turtle species: All three species have been kept together successfully. The only problems observed were the same as seen in any mixed gender groups with *C. caretta* or *E. imbricata*, as the males will bite during mating season.

2.3.2 Sharing enclosure with other species

Sea turtles can be combined with elasmobranchs and bony fish. However, there were some instances reported where there were problems (e.g., biting) with the following species:

Nurse sharks (*Ginglyomostoma cirratum*), Southern stingray (*Hypanus americana*), Giant Grouper (*Epinephelus lanceolatus*), Bluestreak cleaner wrasse (*Labroides dimidiatus*), Sunfish (*Mola mola*), Horse-eye jack (*Caranx latus*) and Grey Triggerfish (*Balistes capriscus*).

Some fish species are known to be beneficial to habitats containing sea turtles because they eat algae from the carapace and create cleaning stations within the habitat. These species include:

Salema (*Sarpa salpa*), several surgeonfish, and Porkfish (*Anistroms virginicus*).

2.4 Breeding

Breeding of sea turtles holding in human care for long term is not recommended. Legislation varies but in most countries, hatchlings born in aquaria cannot be released. There are, however, a few aquaria / research programs that are involved in conservation projects that have special permits which allow them to release the offspring back into the wild.

2.4.1 Mating

Mating behaviour in mixed groups can occur according to natural mating periods, especially when seasonality is mimicked. When turtles are kept at a constant temperature it is possible to get egg production outside of the natural egg laying periods. Mating can be very aggressive and the animals need to be closely monitored. Females should be closely watched as males will bite the neck, shoulders, and flippers of females which can lead to serious injuries or even drowning. Females of different species may compete for attention. It may be necessary to separate males or females from the group based on behavioural responses.

During these periods of mating and egg production you may observe changes in behaviour, including decreased appetite.

Mating seasons within aquaria have been observed for the following species:

Caretta caretta: November – April (with egg laying from April - July)

Chelonia mydas: April (limited observations)

Eretmochelys imbricata: Spring, lay eggs around May which hatch July or August.

2.4.2 Pregnancy / Egg laying and incubation

Female sea turtles can produce eggs even without mating. During egg production you may observe changes in behaviour, such as decreased appetite, changes in swimming patterns, floating at the surface, or increased resting time. As there can be veterinary issues associated with egg production, it is highly recommended that turtles undergo ultrasound examinations to monitor egg production.

Experience has shown that a beach is necessary for successful breeding and egg laying (see paragraph 2.1.3). If a beach is not provided or is not constructed properly it can result in eggs being laid in the water. If eggs are unfertilized, they may also be laid directly into the water. Especially when a beach is not available, females may reabsorb eggs during production rather than lay them.


Figure 20: Vet using an ultrasound to monitor egg production. (Marineland)

Veterinary issues on egg retention and other abnormal conditions are mentioned in paragraph 2.7

It is not recommended to breed sea turtles within aquaria and therefore the incubation of eggs is not recommended.

2.4.3 Population management

Current population management plans for the three main species of sea turtles kept in aquaria (*Caretta caretta, Chelonia mydas,* and *Eretmochelys imbricata*) is to monitor the long-term population in aquaria. If breeding is planned in the future, it is important to protect the genetic stock. It is therefore mandatory to complete genetic testing to identify the sub populations from the varying geographic regions (e.g., South West Atlantic Ocean, Mediterranean Sea, Cape Verde).

2.4.4 Acquisition

The Sea Turtle Working Group advises against breeding of sea turtles in aquaria and obtaining healthy animals from the wild. Non-releasable animals (mostly injured animals) are excellent ambassadors for education to the general public about the problems we see with ocean pollution, entanglement in fishing gear, consumption and illegal trade of eggs, meat, and shells and global climate change. We encourage the aquaria who are willing to obtain a sea turtle to get in contact with rehabilitation centres or other aquaria to home a non-releasable animal

2.5 Behavioural enrichment

Enrichment and training can be valuable tools to help encourage natural behaviour and stimulate the animals. The need and availability of enrichment and training should regularly be assessed to correspond to the changing needs of the turtles.

Added enrichment can be beneficial in the long-term care of sea turtles. Enrichment can be supplied in varying manners such as presenting novel foods (e.g., jellyfish, mussels, etc.) or offering food in a device or hiding place (e.g., buckets, pipes, etc.). Environmental enrichment can be supplied through manipulations to the habitat (e.g., creation of waves or currents, rain, thunder, etc.). For more ideas and detailed descriptions of enrichments for sea turtles please see *Marine Turtle Trauma Response Procedures* by Bluvias and Eckert (2010).

2.6 Handling

2.6.1 Individual identification and sexing

*Figure 21: **left:** ID by using nail polish; **right:** placing a PIT tag (Marineland)*

As all marine turtle species are listed in CITES Appendix I, the individual identification of captive animals by a PIT tag (Passive Integrated Transponder) is mandatory. Check your national legislation to see if a certain location on the body (e.g., flipper or neck) or type of transponder needs to be applied in a defined area to fulfil the administrative requirements.

Nail polish or paint pens are good tools to mark small individuals for identification until they are large enough (>500 g) to receive a transponder. PIT tags should be regularly checked (during every catch-up/weighing) as tags can migrate or get overgrown by tissue to eventually be non-readable in which case a new tag needs to be inserted. Photo identification can also be used to document the unique patterns on the carapace and plastron. Check your local legislation to determine if there are any mandatory requirements.

Figure 22: Identification by using unique patterns on head, carapace and plastron (Marineland)

The sex of sea turtles is determined by the incubation environment during the middle third of incubation. Eggs incubated at constant temperatures produced females at warmer temperatures, males at cooler temperatures (see also 1.7.3). Sea turtles don't have heteromorphic sex chromosomes. According to Wyneken et al. (2007) modified laparoscopic procedures can be used to sex very young sea turtles. Laparoscopy is the only method that is 100% accurate and nonlethal for neonates. The sex of larger juveniles (SCL > 25 cm) and subadults can be identified by hormone assays (Allen et al, 2015; pers. comm. Wyneken, October 13, 2019). Adult animals can be sexed visually by checking the length of the tail. The tail of an adult male extends beyond the carapace. The tail of an immature male or female usually does not (see also figures 11 and 12 at paragraph 1.2.3.).

2.6.2 General handling

Sea turtles should be considered dangerous animals and appropriate precautions must be in place when working with them. Local legislation may have requirements for handling and should be followed where applicable. Sea turtles can have powerful jaws, especially *Caretta caretta*, so keepers should put preventative measures in place to safeguard against bites. It is recommended that feeding be done with stainless steel tongs, rather than plastic tongs which can break and result in turtles ingesting plastic.

Precautions should be taken when diving with sea turtles. Turtles should be closely monitored during the entirety of the dive, especially during mating season. It is suggested that there always be two divers for additional security. If a secondary diver is not available, it is advisable to have a supervisor at the surface with a long stick for added security. Additional separation between the animals and the divers may be achieved by utilizing tools during the dive that facilitate separation (e.g., a ball made for dogs to bite attached to a pole). Health and safety dive protocols should be adapted for diving with sea turtles.

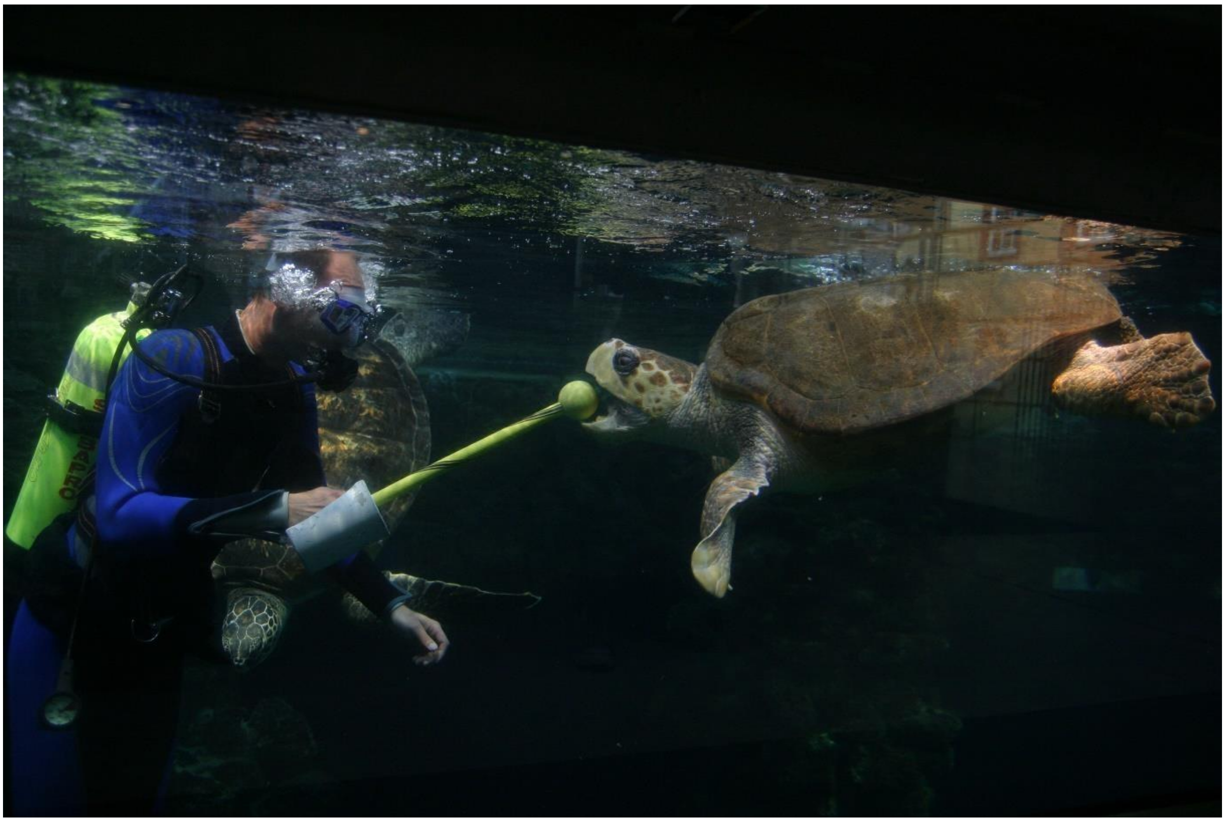

Figure 23: Separation between diver and turtle at German Oceanographic Museum Stralsund

2.6.3. Catching and restraining

Sea turtle handling can be difficult due to their size and weight, but physical restraint can be applied in a non-invasive way. Chemical restraint should only be used, if necessary, for invasive veterinary procedures.

Catching sea turtles can be done in various manners. Animals less than 50 kg can typically be caught with a net. When animals weigh more than 50 kg it is advisable to use a stretcher or a large bag. Larger animals may need to be caught by divers. Turtles can be trained to follow a target into a stretcher. Once the turtle is in the stretcher it can be moved. Due to the size and weight, it is advisable to move large turtles with a crane or forklift.

Figure 24: Movement of a large turtle using a forklift (Marineland)

If a sea turtle is small, it might be possible to be moved by one individual by grabbing at the top of the carapace behind the head in the nuchal scute and at the back of the carapace above the tail at the supracaudal scutes. For larger turtles two or more individuals might be needed to grab the carapace on the marginal scutes above each front and hind flipper. The shoulder joints of sea turtles are particularly vulnerable and can be prone to dislocation or breaking the flippers should never be used as holding points when lifting and moving sea turtles.

Figure 25: Stretcher for moving sea turtles (Marineland)

The stretcher used to move sea turtles should not be too much larger than the animal being moved to help minimize the movement within the stretcher. Once the animal has been removed from the exhibit, it is recommended that either a bucket or a tire is used to hold the turtles. This keeps their flippers from being able to gain purchase on the ground or table (Manire et al. 2017) Be cautious when working at height if there is a risk that the turtle could launch itself off of the work area.

Figure 16: Holding turtles by using a bucket (Marineland)

There are several ways to reduce animal stress while working with them. Dimming room lights and avoiding loud noises during procedures can help calm the turtles. If working with an individual that is trying to bite, a bucket can be carefully placed over their head. A soft wet towel can be placed over the eyes as well as applying light pressure on the neck behind the head.

2.6.4 Transportation

The US Fish and Wildlife Services standard permit conditions for care and maintenance of sea turtles in human care state that sea turtles must be transported in a climate-controlled environment, protected from extremes of heat and cold, and kept moist (USFW, 2013). Most sea turtles should be transported at temperatures between 21°C and 27°C. If temperatures are greater than 24°C, the turtle should be cooled by placing a towel on the carapace and periodically adding water. Water and wet towels on the carapace should not be used for temperatures less than 24°C or at any time if they are exposed to an air-conditioned environment. If the transport is longer than 45 minutes, ophthalmic gel may be used to maintain moisture in the turtles' eyes to avoid eye damage. Do not use a wet towel on the eyes during transport to remove the risk of scratching the eyes. Similarly, for long transports, lubricating gel (e.g., a water-based lubricant) can be placed on the skin and body of the turtle to maintain moisture throughout the transport.

During transport, turtles must be placed in closed containers with sufficient holes for adequate ventilation, but avoid draughts. Turtles must not be transported in water. The box size should be suitable to the size of the animal, but should not provide a lot of extra room for movement. The containers housing turtles during transport must be padded on the bottom (e.g., a foam pillow or towel) to protect the plastron and must not contain any material that could be accidentally ingested. Detailed transportation legislation can be obtained from the IATA Live Animal Regulations (IATA, 2019).

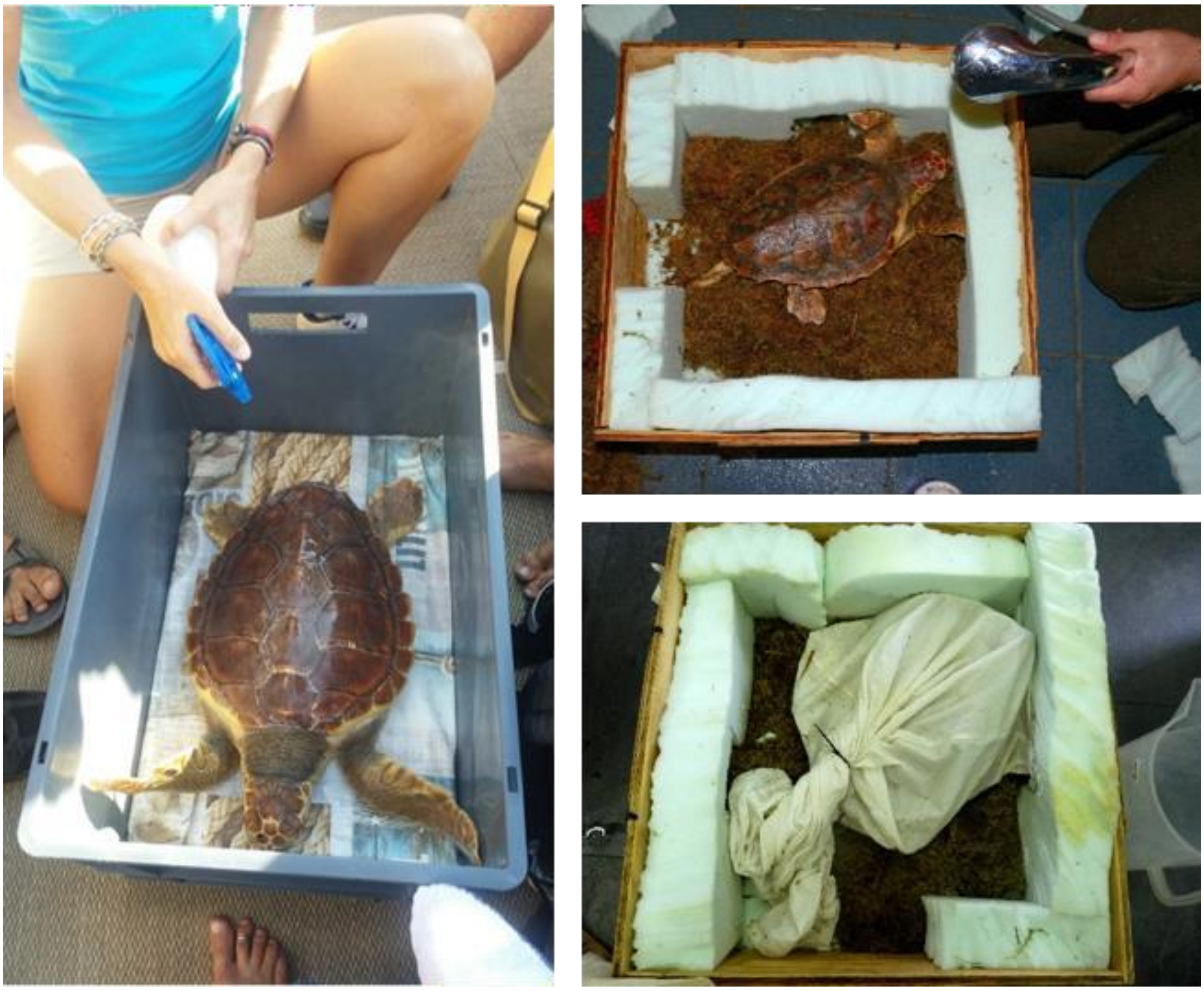

Figure 17: Transporting a sea turtle (picture left: Marineland, pictures right: Rotterdam Zoo)

2.6.5 Safety

Adult sea turtles are large, powerful animals. When working with them biting can be a problem. Be careful during feeding, diving, and while restraining. The front flippers are very strong and have claws. Be aware of flipper slaps both in water and when moving animals. When turtles are out of water, the flipper movement can be controlled by holding it at the shoulder and at the end of the flipper; if doing so be careful not to cause injury to the shoulder joint. The flipper should not be restrained, but you can control the flapping by moving with the flipper. Turtle restraints can be made that wrap around the turtle and fasten at the top of the carapace. The flipper should be placed in a natural position and held tight to the body before being secured by the restraint. Do not ever force the shoulder into an unusual position or heavily restrain. Diving and handling protocols should be amended for working with sea turtles.

To minimize the risk of zoonoses use general biosecurity rules (e.g., washing/disinfecting hands and wearing gloves during handling) when working with turtles. If turtles are kept in an open exhibit accessible to the public it is mandatory that there is fencing to keep the animals separate from the guests.

2.7 Veterinary: Considerations for health and welfare

The health of your sea turtles should be maintained in cooperation with a veterinarian. All medical assessments and determinations should come from a veterinarian based on each individual case. What follows is a general summary of health-related matters most relevant to keeping sea turtles in aquaria.

2.7.1 Quarantine for new animals

- If there are suspicions of a viral infection it is advised that the quarantine period should be no less than two months
- Blood test (biochemistry and haematology), x-ray, swabs / antibiogram (rectum for *Chlamydia*, *Salmonella*, etc.), parasitology (repeat 3 times in 1 month);

Prevention

It is advised that at minimum an annual full veterinary exam is completed, which covers the overall external condition of the animal including carapace, plastron, skin, cloaca, head, and mouth. At this time biometrics and blood analysis should also be completed.

On the advice of your veterinarian, periodic swaps / antibiograms can be completed to follow up on any known issues.

Most common issues

- External lesions (trauma, due to bite wounds, skin infections, Papilloma-like lesions, Herpes virus, carapace lesions/bacterial shell disease, redness in the plastron, eye.)
- Changes in behaviour (e.g., buoyancy, lethargy)
- Ingestion of foreign bodies
- Feeding disorders (e.g., anorexia or constipation)
- Parasites, fungal infections

Less common issues

- Suffocation
- Prolapses of the penis or cloaca
- Metabolic diseases (e.g., vitamin D deficiency)
- Arthrosis

Abnormal conditions involving the reproductive system

Most of the abnormalities involving the reproductive system are related to egg productions. Extensive information on the reproductive biology of sea turtles, clinical evaluation and abnormal conditions can be found in chapter 15 of Sea Turtle Health & Rehabilitation (Manire et al. 2017) and in the article of Spadola et al. (2017): Reproductive Disorders and Perinatology of Sea Turtles.

Treatments

Manire et al. (2017) can be referred to for more information. It is mandatory that all treatments occur under the advice and supervision of a veterinarian included. Information on causes of adult mortality is also included.

2.8 Recommended research

All members of the EUAC/EAZA Sea Turtle Working Group have shown interest in participating in conservation programs, campaigns, and research projects. The first joint research project proposed is to take blood samples from all the registered animals in the monitoring programs and analyse the samples at the same laboratory to standardize testing. This will give the group the opportunity to compare all parameters regarding the status of the health of the sea turtles currently in our long-term care with the other turtles in the group in conjunction with survey information on how they are being kept (e.g., biometric data, nutritional state, Vitamin D-levels according to available lighting).

The STWG would like to explore completing research programs that would help determine the correct feeding regimes. There is currently a great deal of variation in the feeding of sea turtles in aquaria. Gaining a better understanding of what foods and methods work best can help solve heath related issues commonly seen, such as calcium deficiencies, buoyancy problems, overweight animals, and vitamin D supplementation, leading to healthier turtles.

2.9 Recommended literature

Much information about sea turtles appears in the scientific literature as well as in the popular press and on the Internet. As Sea Turtle Working Group we have made a small selection of articles and books that are worth reading if you are housing sea turtles in an aquarium.

One of the main sources we have used for these Guidelines is Manire, Norton, Stacy, Innis and Harms book: SEA TURTLE Health & Rehabilitation. Published in 2017 by J. Ross Publishing. ISBN: 978-1-60427-099-0.

We recommend the following books and articles for further reading:

Books:

Bluvias, J.E. & Eckert, K.L., 2010. Marine Turtle Trauma Response Procedures: A Husbandry Manual. Wider Caribbean Sea Turtle Conservation Network (WIDECAST) Technical Report No. 10. Ballwin, Missouri. 100 pp.

Lutz P.L., Musick J.A., editors. 1997. The biology of sea turtles. Boca Raton: CRC Press. 432 pages.

Lutz P.L., Musick J.A., Wyneken J, editors. 2003. The biology of sea turtles. Volume II. Boca Raton: CRC Press. 455 pages.

Wyneken J, Lohnmann K.J., & Musick, J.A. editors. 2013. The biology of sea turtles. Volume II. Boca Raton: CRC Press. 457 pages.

Articles:

Miller, J.D., Mortimer, J.A., & Limpus, C.J. (2017). A field key to the developmental stages of marine turtles (Cheloniidae) with notes on the development of *Dermochelys*," Chelonian Conservation and Biology, 16(2), 111-122

Monreal-Pawlowsky, T., Marco-Cabedo, V., Manteca, X., Palencia Membrive, G., Sanjosé, J., Fuentes, O., & Jiménez, E. (2017). Environmental enrichment facilitates release and survival of an injured loggerhead sea turtle (*Caretta caretta)* after ten years in captivity. Journal of Zoo and Aquarium Research, 5(4), 182–186. https://doi.org/10.19227/jzar.v5i4.303

Purgley, H., Jewell, J., Deacon, J.E., Winokur, R.M. & Tripoli, V.M. (2009). Vitamin D3 in captive green sea turtles (*Chelonia mydas*). Chelonian Conservation and Biology 8 (2): 161–167. doi: https://doi.org/10.2744/CCB-0765.1

Scott, G.N., Nollens, H.H., & Schmitt, T.L. (2019). Evaluation of plasma 25-hydroxyvitamin D, ionized calcium, and parathyroid hormone in green sea turtles (*Chelonia mydas*) exposed to different intensities of ultraviolet B radiation. Journal of Zoo and Wildlife Medicine, 50(2), 421-426.

Spadola, F., Morici, M., Santoro, M., Oliveri, M., & Insacco, G. (2017) Reproductive disorders and perinatology of sea turtles. Veterinary Clinics of North America: Exotic Animal Practice. Volume 20, Issue 2, 345-370

Section 3: References

Abourachid, A. & Renous, S. (2000). Bipedal locomotion in ratites (Paleognatiform): examples of cursorial birds. *Ibis*, *142*(4), 538-549.

Abreu-Grobois, A & Plotkin, P. (IUCN SSC Marine Turtle Specialist Group). (2008). *Lepidochelys olivacea*. The IUCN Red List of Threatened Species 2008: e.T11534A3292503. https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T11534A3292503.en. Downloaded on 20 January 2021.

Ackerman, R. A. (2017). The nest environment and the embryonic development of sea turtles. In The biology of sea turtles (pp. 83-106). CRC Press.

Alcala, A.C. (1980). Observations on the ecology of the Pacific hawksbill turtle in the central Visayas, Philippines. *Fisheries Res. J. of the Philippines*, *5*(2), 42-52.

Allen, C.D., Robbins, M.N., Eguchi, T., Owens, D.W., Meylan, A.B., Meylan, N.M., Kellar, J.A., Schwenter, H.H, Nollens, R.A., LeRoux, P.H., Dutton, J.A. & Seminoff, J.A. (2015) First assessment of the sex ratio for an East Pacific green sea turtle foraging aggregation: Validation and application of a testosterone ELISA. *PLoS ONE 10* (10): e0138861. https://doi.org/10.1371/journal.pone.0138861

Arthur, K.E., Boyle, M.C., & Limpus, C.J. (2008). Ontogenetic changes in diet and habitat use in green sea turtle (*Chelonia mydas*) life history. *Marine Ecology Progress Series*, *362*, 303-311.

Baillie, J., Groombridge, B., Barden, A., Cox, N., Gray, B., Stuart, S., Sneary, M., Johnson, T., Reay, J., (1996). 1996 IUCN red list of threatened animals. Gland, Switzerland.

Baines, F.M., Chattell, J., Dale, J., Garrick, D., Gill, I., Goetz, M., Skelton, M. & Swatman, M. (2016). How much UVB does my reptile need? The UV-Tool, a guide to the selection of UV lighting for reptiles and amphibians in captivity. *Journal of Zoo and Aquarium Research*. Vol 4 No 1. pp. 42-63.

Balazs, G.H. & Ross, E. (1974). Observations on the basking habit in the captive juvenile Pacific green turtle. *Copeia*, Vol. 1974, No. 2 pp. 542-544

Berube, M.D., Dunbar, S.G., Rützler, K., & Hayes, W.K. (2012). Home range and foraging ecology of juvenile hawksbill sea turtles (*Eretmochelys imbricata*) on inshore reefs of Honduras. *Chelonian Conservation and Biology*, *11*(1), 33-43.

Bjorndal, K.A. (1980). Nutrition and grazing behavior of the green turtle *Chelonia mydas*. *Marine Biology*, *56*(2), 147-154.

Bjorndal, K.A., Bolten, A.B., & Lagueux, C.J. (1994). Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. *Marine pollution bulletin*, *28*(3), 154-158.

Bjorndal, K. A. (2017). Foraging ecology and nutrition of sea turtles. In *The biology of sea turtles* (pp. 199-231). CRC press.

Bjørndal, T. & Moenro, G. R. (1997). *The economics of fisheries management: a survey*: Centre for Fisheries Economics, Norwegian School of Economics and Business Administration.

Blechschmidt, J., Wittmann, M.J. & Blüml, C. (2020). Climate change and green sea turtle sex ratio—preventing possible extinction. *Genes*, 11, 588.

Bluvias, J.E. & K.L. Eckert (2010). Marine turtle trauma response procedures: a husbandry manual. Wider Caribbean Sea Turtle Conservation Network (WIDECAST). Tech Report No. 10, Ballwin, MO.

Bolten, A.B. (2003). *Loggerhead sea turtles*. Washington, DC. USA: B.E. Witherington. Smithsonian Institution Press

Bolton, A.B. & Martins, H.R. (1990). Kemp's ridley captured in the Azores. *Marine Turtle Newsletter* 48: 23.

Booth, C.R. & J. H. Morrow. (1997). The penetration of UV into natural waters. *Photochemistry and Photobiology*. Volume 65, Issue 2, pp 254-257

Bostrom, B. L., Jones, T. T., Hastings, M., & Jones, D. R. (2010). Behaviour and physiology: the thermal strategy of leatherback turtles. *PLoS ONE*, 5(11), e13925. https://doi.org/10.1371/journal.pone.0013925

Bowen, B.W., Bass, A.L., Chow, S.-M., Bostrom, M., Bjorndal, K.A., Bolten, A.B., Okuyama, T., Bolker, B.M., Epperly, S., Lacasella, E., Shaver, D., Dodd, M., Hopkins- Murphy, S.R., Musick, J.A., Swingle, M., Rankin-Baransky, K., Teas, W., Witzell, W.N. & Dutton, P.H. (2004). Natal homing in juvenile loggerhead turtles (*Caretta caretta*). *Molecular Ecology*, *13*(12), 3797-3808.

Braun-McNeill, J., S.P. Epperly, L. Avens, M.L. Snover, & Taylor, J.C. (2008) Growth rates of loggerhead sea turtles (*Caretta caretta*) from the Western North Atlantic. *Herpetological Conservation and Biology* 3(2):273-281.

Brongersma, L.D. (1982). Marine turtles of the Eastern Atlantic Ocean. In: K.A. Bjorndal (ed.), *The Biology and Conservation of Sea Turtles*, pp. 407-416. Smithsonian Institution Press, Washington, D.C.

Brongersma, L.D., Pritchard, P.C.H., Ehrhart, L., Mrosovsky, N., Mittag, J., Marquez Millan, R., Hughes, G.H., Witham, R., Hendrickson, J.R., Wood, J.R. & Mittag, H. (1979). Statement of Intent. *Marine Turtle Newsletter* 12: 2-3.

Burke, V.J., Morreale, S.J., & Standora, E.A. (1994). Diet of the Kemp's ridley sea turtle, *Lepidochelys kempii*, in New York waters. *Fishery Bulletin*, *92*(1), 26-32.

Bustard, H.R. (1976). World's largest sea turtle rookery. *Tiger paper*, *3*(3), 25.

Caillouet Jr., C.W., Shaver, D.J., and Landry Jr., A.M. (2015). Reintroduction of Kemp's ridley (*Lepidochelys kempii*) sea turtle to Padre Island National Seashore, Texas and its connection to head-starting. *Herpetological Biology and Conservation* 10 (Symposium): 309–377.

Campbell, L.M., Haalboom, B.J., & Trow, J. (2007). Sustainability of community-based conservation: sea turtle egg harvesting in Ostional (Costa Rica) ten years later. *Environmental conservation*, *34*(2), 122-131.

Cardona, L., Revelles, M., Carreras, C., San Félix, M., & Aguilar, A. (2005). Western Mediterranean immature loggerhead turtles: habitat use in spring and summer assessed through satellite tracking and aerial surveys. *Marine Biology* 147: 583. https://doi.org/10.1007/s00227-005-1578-9

Cardona, L., Revelles, M., Parga, M. L., Tomás, J., Aguilar, A., Alegre, F., & Ferrer, X. (2009). Habitat use by loggerhead sea turtles *Caretta caretta* off the coast of eastern Spain results in a high vulnerability to neritic fishing gear. *Marine Biology*, *156*(12), 2621-2630.

Carr, A.F. (1952). *Handbook of Turtles*. Ithaca, N.Y. (Cornell University Press), 542p.

Carr, A.F. (1957). Notes on the zoogeography of the Atlantic sea turtles of the genus *Lepidochelys*. *Revista de Biología Tropical* 5(1): 45-61.

Carr, A.F., Hirth, H.F., & Ogren, L.H. (1966). The ecology and migrations of sea turtles. 6, The hawksbill turtle in the Caribbean Sea. *American Museum novitates*; no. 2248.

Carr, A.F. (1967). *So Excellent a Fishe; A natural history of sea turtles*. Natural History Press, Garden City, N.Y.

Carr, A.F. & Caldwell, D.K. (1956). The ecology and migration of sea turtles, 1. Results of field work in Florida, 1955. *American Museum Novitates* 1793: 1-23.

Carr, A.F., & Ogren, L.H. (1960). The ecology and migrations of sea turtles. 4, The green turtle in the Caribbean Sea. *Bulletin of the AMNH*; v. 121, article 1.

Carr, A., & Stancyk, S. (1975). Observations on the ecology and survival outlook of the hawksbill turtle. *Biological Conservation*, *8*(3), 161-172.

Carr, A., & Meylan, A.B. (1980). Evidence of passive migration of green turtle hatchlings in Sargassum. *Copeia*, *1980*(2), 366-368.

Casale, P. & Tucker, A.D. 2017. *Caretta caretta* (amended version of 2015 assessment). *The IUCN Red List of Threatened Species* 2017: e.T3897A119333622. https://dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T3897A119333622.en. Downloaded on 20 January 2021

Chassin-Noria, O., Macip-Ríos, R, Dutton, P.H., & Oyama, K. (2017). Multiple paternity in the East Pacific green turtle (Chelonia mydas) from the Pacific coast of Mexico. *Journal of Experimental Marine Biology and Ecology*. Volume 495, 43-47.

Colman, L. P., Sampaio, C.L.S., Weber, M.I., & de Castilhos, J.C. (2014). Diet of olive Ridley sea turtles, *Lepidochelys olivacea*, in the waters of Sergipe, Brazil. *Chelonian Conservation and Biology*, *13*(2), 266-271.

Da Silva, A.C., Dos Santos, E.A., Oliveira, F.L.D.C., Weber, M.I., Batista, J.A., Serafini, T.Z., & De Castilhos, J.C. (2011). Satellite-tracking reveals multiple foraging strategies and threats for olive ridley turtles in Brazil. *Marine Ecology Progress Series*, *443*, 237-247.

Den Hartog, J.C. (1979). Notes on the food of sea turtles: *Eretmochelys imbricata* (Linnaeus) and *Dermochelys coriacea* (Linnaeus). *Netherlands Journal of Zoology*, *30*(4), 595-611

Dobie, J.L., Ogren, L.H., & Fitzpatrick, J.F. (1961). Food notes and records of the Atlantic ridley turtle (*Lepidochelys kempi*) from Louisiana. *Copeia*, *1961*(1), 109-110.

Dodd Jr, C.K. (1988). Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta (Linnaeus 1758)* (No. FWS-88 (14)). Florida Cooperative Fish and Wildlife Research Unit Gainesville.

Eckert, S.A., Nellis, D.W., Eckert, K.L., & Kooyman, G.L. (1986). Diving patterns of two leatherback sea turtles (*Dermochelys coriacea*) during internesting intervals at Sandy Point, St. Croix, US Virgin Islands. *Herpetologica*, 381-388.

Eckert, S.A., Eckert, K.L., Ponganis, P., & Kooyman, G.L. (1989). Diving and foraging behavior of leatherback sea turtles (*Dermochelys coriacea*). *Canadian journal of zoology*, *67*(11), 2834-2840.

Ehrhart, L.M. (1982). A review of sea turtle reproduction. *Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, DC*, 29-38.

Ernst, C.H., Lovich, J.E. & Barbour, R.W. (1994). *Turtles of the United States and Canada*. Washington, D.C. and London (Smithsonian Institution Press), 578p.

Ernst, C.H., Altenburg, R.G.M., & Barbour, R.W. (2000). Turtles of the world. World biodiversity database, version 1.2. *Biodiversity Center of ETI, Amsterdam, CD-ROM*.

Ernst, C.H. & Lovich, J.E. (2009). *Turtles of the United States and Canada. Second edition*. Johns Hopkins University Press, Baltimore.

Ferrara, C.R., Vogt, R.C., Harfush, M.R., Sousa-Lima, R.S. Albavera, E. & Tavera, A. (2014). First evidence of leatherback turtle (*Dermochelys coriacea*) embryos and hatchlings emitting sounds. *Chelonian Conservation and Biology* 13 (1): 110–114.

Fine, M.L. (1970). Faunal variation on pelagic Sargassum. *Marine Biology*, *7*(2), 112-122.

FitzSimmons, N.N., Limpus, C.J., Norman, J.A., Goldizen, A.R., Miller, J.D., & Moritz, C. (1997). Philopatry of male marine turtles inferred from mitochondrial DNA markers. *Proceedings of the National Academy of Sciences*, *94*(16), 8912-8917.

Fleming, E.H. (2001). *Swimming against the tide: recent surveys of exploitation, trade, and management of marine turtles in the northern Caribbean* (Vol. 1). Washington, DC: TRAFFIC North America.

Fretey, J. (2001). *Biogeography and conservation of marine turtles of the Atlantic coast of Africa*. United Nations Premises in Bonn.

Frick, J. (1976). Orientation and behaviour of hatchling green turtles (*Chelonia mydas*) in the sea. *Animal Behaviour*, *24*(4), 849-857.

Hoffman, W., & Fritts, T.H. (1982). Sea turtle distribution along the boundary of the Gulf Stream current off eastern Florida. *Herpetologica*, 405-409.

Fuentes, M.M.P.B., & Abbs, D. (2010). Effects of projected changes in tropical cyclone frequency on sea turtles. *Marine Ecology Progress Series*, *412*, 283-292.

Gist, D.H., & Jones, J.M. (1989). Sperm storage within the oviduct of turtles. *Journal of Morphology*, *199*(3), 379-384.

Godfrey, M.H., & Chevalier, J. (2004). The status of olive ridley sea turtles in the West Atlantic. *Report requested by the olive ridley sea turtle assessment group of the Marine Turtle Specialist Group–SSC/IUCN*.

Godley, B.J., Smith, S.M., Clark, P.F., & Taylor, J.D. (1997). Molluscan and crustacean items in the diet of the loggerhead turtle, *Caretta caretta* (Linnaeus, 1758) [Testudines: Chelonidae] in the eastern Mediterranean. *Journal of Molluscan Studies*, *63*(3), 474-476.

Goff, G.P., & Stenson, G.B. (1988). Brown adipose tissue in leatherback sea turtles: a thermogenic organ in an endothermic reptile? *Copeia* 1988: 1071-1075.

González Carman, V., Álvarez, K.C., Prosdocimi, L., Inchaurraga, M.C., Dellacasa, R.F., Faiella, A., Echenique, C., González, R., Andrejuk, R., Mianzan, H.W., Campagna, C. & Albareda, D.A. (2011). Argentinian coastal waters: A temperate habitat for three species of threatened sea turtles. *Marine Biology Research*, *7*(5), 500-508.

Godley, B.J., Broderick, A.C., Glen, F. & Hays, G.C. (2003). Post-nesting movements and submergence patterns of loggerhead marine turtles in the Mediterranean assessed by satellite tracking. *J. Exp. Mar. Biol. Ecol.* 287 119–134.

Groombridge, B. and Wright, L. (compilers). 1982. *The IUCN Amphibia – Reptilia Red Data Book*. Part 1: Testudines, Crocodylia, Rhynchocephalia. Gland, Switzerland and Cambridge, UK.

Groombridge, B., Luxmoore, R. A., & Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1989). *The green turtle and hawksbill (Reptilia, Cheloniidae): World status, exploitation and trade*. Lausanne, Switzerland: Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Guzman-Hernandez, V., Cuevas-Flores, E.A. & Marquez-Millan, R. (2007). Occurrence of Kemp's ridley (*Lepidochelys kempii*) along the Yucatan Peninsula. *Chelonian Conservation Biology* 6: 274-277.

Harry, J.L., & Briscoe, D.A. (1988). Multiple paternity in the loggerhead turtle (*Caretta caretta*). *Journal of Heredity*, *79*(2), 96-99.

Hays, G.C., Broderick, A.C., Glen, F., & Godley, B.J. (2003). Climate change and sea turtles: a 150-year reconstruction of incubation temperatures at a major marine turtle rookery. *Global Change Biology*, *9*(4), 642-646.

Hays, G.C., Fossette, S., Katselidis, K.A., Schofield, G., & Gravenor, M.B. (2010). Breeding periodicity for male sea turtles, operational sex ratios, and implications in the face of climate change. *Conservation Biology*, *24*(6), 1636-1643.

Hildebrand, H.H. (1982). A historical review of the status of sea turtle populations in the western Gulf of Mexico. *Biology and conservation of sea turtles*, 447-453.

Hirth, H.F. (1963). The ecology of two lizards on a tropical beach. *Ecological Monographs*, *33*(2), 83-112.

Hirth, H.F. (1997). *Synopsis of the biological data on the green turtle Chelonia mydas (Linnaeus 1758)* (Vol. 2). Fish and Wildlife Service, US Department of the Interior.

Hirth, H., & Carr, A.F. (1970). *The green turtle in the Gulf of Aden and the Seychelles Islands* (No. 5). North-Holland Publishing Company.

Hochscheid, S., Bentivegna, F. & Speakman, J.R. (2002). Regional blood flow in sea turtles: implications for heat exchange in an aquatic ectotherm, *Physiol. Biochem. Zool*. 75: 66-76.

Hopkins-Murphy, S.R., Owens, D.W., & Murphy, T.M. (2003). Ecology of immature loggerheads on foraging grounds and adults in internesting habitat in the eastern United States. *Loggerhead sea turtles*, *1*, 79-92.

Humber, F., Godley, B.J., Ramahery, V., & Broderick, A.C. (2011). Using community members to assess artisanal fisheries: the marine turtle fishery in Madagascar. *Animal conservation*, *14*(2), 175-185.

Humphrey, S.L., & Salm, R.V. (1996). Status of sea turtle conservation in the Western Indian Ocean. *UNEP Regional Seas Reports and Studies*, (165).

IATA (2019). Live Animals Regulations, 45th Edition. International Air Transport Association, 2019. Available at:
https://www.iata.org/publications/store/pages/live-animals-regulations.aspx

Insacco, G. & Spandola, F. (2010). First record of Kemp's ridley sea turtle, *Lepidochelys kempii*, (Garman, 1880) (Cheloniidae, from the Italian waters (Mediterranean Sea). *Acta Herpetologica* 5: 113-117.

IUCN Standards and Petitions Committee (2019). Guidelines for Using the IUCN Red List Categories and Criteria. Version 14. Prepared by the Standards and Petitions Committee.

IUCN 2020. The IUCN Red List of Threatened Species. Version 2020-2. https://www.iucnredlist.org. Downloaded on 03 December 2020.

Janzen, F.J. (1994). Climate change and temperature-dependent sex determination in reptiles. *Proceedings of the National Academy of Sciences*, *91*(16), 7487-7490.

Karl, S.A., & Bowen, B.W. (1999). Evolutionary significant units versus geopolitical taxonomy: molecular systematics of an endangered sea turtle (genus *Chelonia*). *Conservation Biology*, *13*(5), 990-999.

Lagueux, C.J., Campbell, C.L., & Strindberg, S. (2017). Artisanal green turtle (*Chelonia mydas*) fishery of Caribbean Nicaragua: II. Characterization and trends in size, sex, and maturity status of turtles killed, 1994–2011. *Marine biology*, *164*(3), 60.

Lanyon, J.M., Limpus, C.J., & Marsh, H. (1989). *Biology of seagrasses: a treatise on the biology of seagrasses with special reference to the Australian region*. (Eds AWD Larkum, AJ McComb, and SA Shepherd.) 610pp.

Laurent, L., & Lescure, J. (1994). L'hivernage des tortues caouannes *Caretta caretta* (L.) dans le sud Tunisien. *Revue d'écologie*.

Limpus, C.J. (1978). The reef: uncertain land of plenty. *Exploration North, A Natural History of Queensland. Richmond Hill Press, Melbourne*, 187-222.

Limpus, C.J. (1979). Notes on growth rates of wild turtles. *Marine Turtle Newsletter*, *10*(3-5), 8.

Limpus, C.J., Miller, J.D., Paramenter, C.J., Reimer, D., McLachlan, N., & Webb, R. (1992). Migration of green (*Chelonia mydas)* and loggerhead (*Caretta caretta*) turtles to and from eastern Australian rookeries. *Wildlife Research*, *19*(3), 347-357.

Limpus, C.J. (1993). The green turtle, *Chelonia mydas*, in Queensland: breeding males in the southern Great Barrier Reef. *Wildlife Research*, *20*(4), 513-523.

Limpus, C.J., Reed, P.C., & Miller, J.D. (1985). Temperature dependent sex determination in Queensland sea turtles: intraspecific variation in *Caretta caretta*. *Biology of Australasian frogs and reptiles*, *1985*, 343-351.

Limpus, C.J., & Limpus, D.J. (2003). Loggerhead turtles in the equatorial and southern Pacific Ocean: a species in decline. *Loggerhead sea turtles*, 199-209.

Liner, E.A. (1954). The herpetofauna of Lafayette, Terrebonne and Vermilion Parishes, Louisiana. In *Louisiana Academy of Science* (Vol. 12, pp. 65-85).

Lohmann, K.J., Putman, N.F., & Lohmann, C.M. (2008). Geomagnetic imprinting: A unifying hypothesis of long-distance natal homing in salmon and sea turtles. *Proceedings of the National Academy of Sciences*, *105*(49), 19096-19101.

Lohmann, K.J., Putman, N.F., & Lohmann, C.M. (2012). The magnetic map of hatchling loggerhead sea turtles. *Current opinion in neurobiology*, *22*(2), 336-342.

Lucas, M., Salmon, M., Fritz, E., & Wyneken, J. (1992). Seafinding by hatchling sea turtles: role of brightness, silhouette and beach slope as orientation cues. *Behaviour*, *122*(1-2), 56-77.

Lukač, M., Baines, F., Gobić, K., Belić, M., & Mičić M. (2018). The impact of artificial UVB light on wound healing of injured loggerhead sea turtle (*Caretta caretta). 6th Mediterranean conference on marine turtles, Poreč, Croatia*, Oct. 16-19 2018. Book of Abstracts, p146.

Lutcavage, M., & Musick, J.A. (1985). Aspects of the biology of sea turtles in Virginia. *Copeia*, 449-456.

Lutcavage, M.E. (2017). Human impacts on sea turtle survival. In P. Lutz & J.A. Musick (Red.), *The Biology of Sea Turtles, Volume* I (pp. 387-409). Boca Raton, FL, USA: CRC Press.

Lutz P.L., Musick J.A., editors. 1997. *The biology of sea turtles*. Boca Raton: CRC Press. 432 pages.

Lutz P.L., Musick J.A., Wyneken J, editors. 2003. *The biology of sea turtles*. Volume II. Boca Raton: CRC Press. 455 pages.

Mancini, A., & Koch, V. (2009). Sea turtle consumption and black market trade in Baja California Sur, Mexico. *Endangered Species Research*, *7*(1), 1-10.

Manire, C.A., Norton, T.M., Stacy B.A., Innis, C.J. & Harms, C.A. (2017). *Sea turtle health & rehabilitation*. Plantation, FL., USA : J. Ross Publishing.

Manning, B. & G.C. Grigg. (1997). Basking is not of thermoregulatory significance in the basking freshwater turtle *Emydura signata. Copeia*: 579-584.

Marcovaldi, M.A., Gallo, B.G., Lima, E.H.S.M., & Godfrey, M.H. (2001). Nem tudo que cai na rede é peixe: an environmental education initiative to reduce mortality of marine turtles caught in artisanal fishing nets in Brazil. *Ocean yearbook*, *15*, 246-256.

Marquez, M.R. (1984). Kemp's ridley turtle overview of biology. *Proceedings of the Western Atlantic Turtle Symposium* University of Miami Press, Miami: 96-100.

Márquez, M.R. (1990). Sea turtles of the world. *FAO species catalogue*, *11*, 1-81.

Marquez, M.R. (1994). Synopsis of biological data on the Kemp's ridley sea turtle, *Lepidochelys kempi* (Garman, 1880). *NOAA Technical Memorandum* NMFS-SEFC-343.

Marquez, M.R., Diaz-F., J., Guzman-H., V., Bravo-G., R. & Del Carmen Jimenez-Q., M. (2004). Marine turtles of the Gulf of Mexico: abundance, distribution, and protection. In: M. Caso, L. Pisanty and E. Excurra (eds), *Environmental Analysis of the Gulf of Mexico*, pp. 89-107. Harte Research Institute for Gulf of Mexico Studies Special Publication Series No. 1. Texas A&M University Press, Corpus Christi, TX.

Mayne, B., Tucker, A.D., Berry, O. & Jarman, S. (2020). Lifespan estimation in marine turtles using genomic promoter CpG density. *PLoS ONE* 15(7)

Meylan, A. (1988). Spongivory in hawksbill turtles: a diet of glass. *Science*, *239*(4838), 393-395.

Miller, J.D., Limpus, C.J., & Godfrey, M.H. (2003). Nest site selection, oviposition, eggs, development, hatching, and emergence of loggerhead turtles. *Loggerhead sea turtles*, *12*.

Miller, J.D. , Mortimer, J.A., & Limpus, C.J. (2017). A field key to the developmental stages of marine turtles (Cheloniidae) with notes on the development of Dermochelys," *Chelonian Conservation and Biology*, 16(2), 111-122

Minamikawa , S. Naito, Y., Sato, K., Matsuzawa, Y., Bando, T., & Sakamoto. W. (2000). Maintenance of neutral buoyancy by depth selection in the loggerhead turtle *Caretta caretta*. *Journal of Experimental Biology* 2000 203: 2967-2975

Monreal-Pawlowsky, T., Marco-Cabedo, V., Manteca, X., Palencia Membrive, G., Sanjosé, J., Fuentes, O., & Jiménez, E. (2017). Environmental enrichment facilitates release and survival of an injured loggerhead sea turtle (*Caretta caretta*) after ten years in captivity. *Journal of Zoo and Aquarium Research,* 5(4), 182–186. https://doi.org/10.19227/jzar.v5i4.303

Morreale, S.J., Ruiz, G.J., & Standora, E.A. (1982). Temperature-dependent sex determination: current practices threaten conservation of sea turtles. *Science*, *216*(4551), 1245-1247.

Mortimer, J.A. (1982). Feeding ecology of sea turtles. *Biology and conservation of sea turtles. Smithsonian Institute Press, Washington, DC*.

Mortimer, J.A., & 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), 318-325.

Mortimer, J.A & Donnelly, M. (IUCN SSC Marine Turtle Specialist Group). 2008. *Eretmochelys imbricata*. *The IUCN Red List of Threatened Species* 2008: e.T8005A12881238. https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T8005A12881238.en. Downloaded on 20 January 2021.

Moulis, R.A. (1997). Predation by the imported fire ant (*Solenopsis invicta*) on loggerhead sea turtle (*Caretta caretta*) nests on Wassaw National Wildlife Refuge, Georgia. *Chelonian Conservation and Biology*, *2*(3), 433-436.

Mowbray, L.S., & Caldwell, D.K. (1958). First record of the ridley turtle from Bermuda, with notes on other sea turtles and the turtle fishery in the islands. *Copeia* 1958: 147-148.

Musick, J.A., & Chaloupka, M.Y. (2017). Age, growth, and population dynamics. In P. Lutz & J.A. Musick (Red.), *The Biology of Sea Turtles, Volume* I (pp. 233-276). Boca Raton, FL, USA: CRC Press.

Nada, M., & Casale, P. (2011). Sea turtle bycatch and consumption in Egypt threatens Mediterranean turtle populations. *Oryx*, *45*(1), 143-149.

Nicolson, S.W., & Lutz, P.L. (1989). Salt gland function in the green sea turtle Chelonia mydas. *Journal of experimental biology*, *144*(1), 171-184.

NMFS, USFWS and SEMARNAT. (2011). Bi-national recovery plan for the Kemp's ridley sea turtle (*Lepidochelys kempii*), Second Revision. National Marine Fisheries Service, Silver Spring, Maryland. Available at: https://www.fws.gov/kempsridley/pdfs/DraftKRRP.pdf

Omeyer, L.C.M., Godley, B.J. & Broderick, A.C. (2017) Growth rates of adult sea turtles. *Endang Species Res* 34:357-371

Panagopoulos, D., Sofouli, E., Teneketzis, K., & Margaritoulis, D. (2003). Stranding data as an indicator of fisheries induced mortality of sea turtles in Greece. In *First Mediterranean Conference On Marine Turtles* (p. 202).

Pandav, B., & Choudhury, B.C. (1999). An update on the mortality of the olive ridley sea turtles in Orissa, India. *Marine Turtle Newsletter*, *83*, 10-12.

Phillips, K.P., Jorgensen, T.H., Jolliffe, K.G., Jolliffe, S.M., Henwood, J. & Richardson, D.S. (2013). Reconstructing paternal genotypes to infer patterns of sperm storage and sexual selection in the hawksbill turtle. *Molecular Ecology*, *22*(8), 2301-2312.

Plotkin, P. T. (Ed.). (2007). *Biology and conservation of ridley sea turtles*. JHU Press.

Polovina, J.J., Howell, E., Parker, D.M., & Balazs, G.H. (2003). Dive-depth distribution of loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific: might deep longline sets catch fewer turtles? *Fishery Bulletin*, *101*(1), 189-193.

Polovina, J.J., Balazs, G.H., Howell, E.A., Parker, D.M., Seki, M.P., & Dutton, P.H. (2004). Forage and migration habitat of loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific Ocean. *Fisheries Oceanography*, *13*(1), 36-51.

Pritchard, P.C.H. (1969). *Studies of the systematics and reproductive cycles of the genus* Lepidochelys. Ph.D. dissertation, University of Florida, FL.

Pritchard, P.C.H. (1971). Galapagos sea turtles: preliminary findings. *Journal of Herpetology*, 1-9.

Pritchard, P.C.H. (1979). *Encyclopedia of turtles* (p. 876). New Jersey, Estados Unidos: TFH.

Pritchard, P.C.H. & Marquez-M., R. (1973). *Kemp's Ridley Turtle or Atlantic Ridley*. Monograph No. 2. marine turtle series. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland.

Pritchard, P.C., & Trebbau, P. (1984). *The turtles of Venezuela*. [Oxford, Ohio]: Soc. for the Study of Amphibians and Reptiles.

Pritchard, P.C.H. (2007). Evolutionary relationships, osteology, morphology, and zoogeography of ridley turtles. In: P.T. Plotkin (ed.), *Biology and Conservation of Ridley Turtles*, pp. 45-57. Johns Hopkins University Press, Baltimore, MD.

Purgley, H., Jewell, J., Deacon, J.E., Winokur, R.M. & Tripoli, V.M. (2009). Vitamin D3 in captive green sea turtles (*Chelonia mydas*). *Chelonian Conservation and Biology* 8 (2): 161–167. doi: https://doi.org/10.2744/CCB-0765.1

Putman, N.F., & Mansfield, K.L. (2015). Direct evidence of swimming demonstrates active dispersal in the sea turtle “lost years”. *Current Biology*, *25*(9), 1221-1227.

Red List Standards & Petitions Subcommittee. 1996. *Natator depressus*. The IUCN Red List of Threatened Species 1996: e.T14363A4435952. https://dx.doi.org/10.2305/IUCN.UK.1996.RLTS.T14363A4435952.en. Downloaded on 20 January 2021.

Reichart, H.A. (1993). Synopsis of biological data on the olive ridley sea turtle *Lepidochelys olivacea* (Eschscholtz, 1829) in the western Atlantic. *NOAA Technical Memorandum* NMFS-SEFSC-336.

Reina, R.D., Jones, T.T., & Spotila, J.R. (2002). Salt and water regulation by the leatherback sea turtle *Dermochelys coriacea*. *Journal of Experimental Biology*, *205*(13), 1853-1860.

Ryland, J.S. (1974). Observations on some epibionts of gulf-weed, *Sargassum natans* (L.) Meyen. *Journal of Experimental Marine Biology and Ecology*, *14*(1), 17-25.

Saba, V.S., Stock, C.A., Spotila, J.R., Paladino, F.V., & Tomillo, P.S. (2012). Projected response of an endangered marine turtle population to climate change. *Nature Climate Change*, *2*(11), 814.

Sampson, L., Payán, L.F., Amorocho, D.F., Seminoff, J.A., & Giraldo, A. (2014). Intraspecific variation of the green turtle, *Chelonia mydas* (*Cheloniidae*), in the foraging area of Gorgona Natural National Park (Colombian Pacific). *Acta Biológica Colombiana*, *19*(3), 461-470.

Sapsford, C.W. & Riet, M. van der. (1979). Uptake of solar radiation by the sea turtle, *Caretta caretta*, during voluntary surface basking. *Comparative Biochemistry and Physiology*, Part A: Physiology. Volume 63, Issue 4, pp. 471–474

Schroeder, B.A. (2003). Nesting patterns, reproductive migrations, and adult foraging areas of loggerhead turtles. *Loggerhead sea turtles*, 114-124.

Scott, G.N., Nollens, H.H., & Schmitt, T.L. (2019). Evaluation of plasma 25-hydroxyvitamin D, ionized calcium, and parathyroid hormone in green sea turtles (*Chelonia mydas*) exposed to different intensities of ultraviolet B radiation. *Journal of Zoo and Wildlife Medicine*, 50(2), 421-426.

Seminoff, J.A. (Southwest Fisheries Science Center, U.S.). 2004. *Chelonia mydas*. *The IUCN Red List of Threatened Species* 2004: e.T4615A11037468. https://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T4615A11037468.en. Downloaded on 20 January 2021.

Shaver, D.J. (1991). Feeding ecology of wild and head-started Kemp's ridley sea turtles in south Texas waters. *Journal of Herpetology*, 327-334.

Shaver, D.J., Rubio, C., Walker, J.S., George, J., Amos, A.F., Reich, K., Jones C. & Shearer, T. 2016. Kemp's ridley sea turtle (*Lepidochelys kempii*) nesting on the Texas Coast: geographic, temporal, and demographic trends through 2014. *Gulf of Mexico Science* 33 (2).
Retrieved from https://aquila.usm.edu/goms/vol33/iss2/4

Shillinger, G.L., Palacios, D.M., Bailey, H., Bograd, S.J., Swithenbank, A.M., Gaspar, P., Wallace, B.P., Spotila, J.R., Paladino, F.V., Piedra, R., Eckert, S.A. & Block, B.A. (2008) Persistent leatherback turtle migrations present opportunities for conservation. *PLoS Biol* 6(7): e171.
https://doi.org/10.1371/journal.pbio.0060171

Spadola, F., Morici, M., Santoro, M., Oliveri, M., & Insacco, G. (2017) Reproductive disorders and perinatology of sea turtles. Veterinary Clinics of North America: *Exotic Animal Practice*. Volume 20, Issue 2, 345-370

Spoto, M. (1997). Osservazione sulla presenza di *Caretta caretta* (L.) nel Golfo di Trieste (Adriatico settentrionale) dal 1983 al 1993. Gortiania – Atti Museo Friul. *Storia Nat*., 19, 68.

Steinbeck, J. (1995). The Log from the Sea of Cortez. 1951. *New York: Twentieth-Century Classics*.

Teruya, H., Kamei,Y., Uchida, S. & Adachi, K. (1997). New sea turtle tank with nesting-ground and its effect. *Proceedings of the Fourth International Aquarium Congress* Tokyo. 113-118.

Thomé, J.C.A., Marcovaldi, M.A., Marcovaldi, G.G., Bellini, C., Gallo, B.M.G., Lima, E.H.S.M., Silva, A.C. & Barata, P.C.R. (2003). An overview of Projeto TAMAR-IBAMA's activities in relation to the incidental capture of sea turtles in the Brazilian fisheries. *Proceedings of the Twenty-Second Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-503,* 119-120.

Tomás, J. & Raga, J. 2008. Occurrence of Kemp's ridley sea turtle (*Lepidochelys kempii*) in the Mediterranean. *Marine Biodiversity Records* 1: e58.

Tomás, J., Formia, A., Fernández, M. & Raga, J.A. 2003. Occurrence and genetic analysis of a Kemp's Ridley sea turtle (*Lepidochelys kempii*) in the Mediterranean Sea. *Scientia Marina* 67: 367-369.

Tomillo, P.S., Suss, J.S., Wallace, B.P., Magrini, K.D., Blanco, G., Paladino, F.V., & Spotila, J.R. (2009). Influence of emergence success on the annual reproductive output of leatherback turtles. *Marine Biology*, *156*(10), 2021-2031.

Tomillo, P.S., Saba, V.S., Blanco, G.S., Stock, C.A., Paladino, F.V., & Spotila, J.R. (2012). Climate driven egg and hatchling mortality threatens survival of Eastern Pacific leatherback turtles. *PLoS ONE*, *7*(5), e37602.

Tuxbury, S.M., & Salmon, M. (2005). Competitive interactions between artificial lighting and natural cues during seafinding by hatchling marine turtles. *Biological Conservation*, *121*(2), 311-316.

U.S Fish and Wildlife Service (USFWS 2013). Standard permit conditions for care and maintenance of captive sea turtles. Available at: https://www.fws.gov/northflorida/SeaTurtles/Captive_Forms/20130213_revised%20_standard_permit_conditions_for_captive_sea_turtles.pdf

Vasilkov, A., Krotkov, N., Herman, J., McClain, C., Arrigo, K., & Robinson, W. (2001). Global mapping of underwater UV irradiances and DNA-weighted exposures using Total Ozone Mapping Spectrometer and Sea-viewing Wide Field-of-view Sensor data products. *Journal of Geophysical Research Oceans*. Volume106, Issue C11, pp 27205-27219

Wallace, B.P., Williams, C.L., Paladino, F.V., Morreale, S.J., Lindstrom, R.T., & Spotila, J.R. (2005). Bioenergetics and diving activity of internesting leatherback turtles *Dermochelys coriacea* at Parque Nacional Marino Las Baulas, Costa Rica. *Journal of Experimental Biology*, *208*(20), 3873-3884.

Wallace, B.P., Lewison, R.L., McDonald, S.L., McDonald, R.K., Kot, C.Y., Kelez, S., Bjorkland, R.K., Finkbeiner, E.M., Helmbrecht, S. and Crowder, L.B. (2010), Global patterns of marine turtle bycatch. *Conservation Letters*, 3: 131-142. https://doi.org/10.1111/j.1755-263X.2010.00105.x

Wallace, B. P., DiMatteo, A.D., Bolten, A.B., Chaloupka, M.Y., Hutchinson, B.J., Abreu-Grobois, F.A., Mortimer, J.A., Seminoff, J.A., Amorocho, D., Bjorndal, K.A., Bourjea,J., Bowen, B.W., Briseño Dueñas, R., Casale, P., Choudhury, B.C., Costa, A., Dutton, P.H., Fallabrino, A., Finkbeiner, E.M., Girard, A., Girondot, M., Hamann, M., Hurley, B.J., López-Mendilaharsu, M., Marcovaldi, M.A., Musick, J.A., Nel, R., Pilcher, N.J., Troëng, S., Blair Witherington, B. & Mast, R.B.. (2011). Global conservation priorities for marine turtles. *PloS ONE*, *6*(9), e24510. https://doi.org/10.1371/journal.pone.0024510

Wallace, B.P., Tiwari, M. & Girondot, M. 2013. *Dermochelys coriacea*. *The IUCN Red List of Threatened Species* 2013: e.T6494A43526147. https://dx.doi.org/10.2305/IUCN.UK.2013-2.RLTS.T6494A43526147.en. Downloaded on 20 January 2021.

Weis, J.S. (1968). Fauna associated with pelagic Sargassum in the Gulf Stream. *American Midland Naturalist*, 554-558.

Weishampel, J.F., Bagley, D.A., & Ehrhart, L.M. (2004). Earlier nesting by loggerhead sea turtles following sea surface warming. *Global Change Biology*, *10*(8), 1424-1427.

Whitaker, B.R. & Krum, H. (1999). Medical management of sea turtles in aquaria. Pages 217 -231 in Fowler, M.E. and R.E. Miller (editors). *Zoo and Wild Animal Medicine: Current Therapy* (4th edition). W.B. Saunders Company, Philadelphia, PA.

Wibbels, T. & Bevan, E. 2019. *Lepidochelys kempii* (errata version published in 2019). *The IUCN Red List of Threatened Species* 2019: e.T11533A155057916. https://dx.doi.org/10.2305/IUCN.UK.2019-2.RLTS.T11533A155057916.en. Downloaded on 20 January 2021.

Wildermann, N.E., & Barrios-Garrido, H. (2012). First report of *Callinectes sapidus* (Decapoda: Portunidae) in the diet of *Lepidochelys olivacea*. *Chelonian Conservation and Biology*, *11*(2), 265-268.

Williard, A.S. (2013). Physiology as integrated systems, in *Biology of Sea Turtles*, Vol. 3, Wyneken, J, K. Lohmann, and J. Musick, Eds., CRC Press, Boca Raton, pp.1-30.

Witham, R. (1980). The "lost year" question in young sea turtles. *American Zoologist*, *20*(3), 525-530.

Witt, M.J., Penrose, R. & Godley, B.J. (2007). Spatio-temporal patterns of juvenile marine turtle occurrence in waters of the European continental shelf. *Marine Biology* 151: 873-885.

Witzell, W.N., & Banner, A.C. (1980). The hawksbill turtle (*Eretmochelys imbricata*) in Western Samoa. *Bulletin of Marine Science*, *30*(3), 571-579.

Witzell, W.N. (1983). *Synopsis of biological data on the hawksbill turtle, Eretmochelys imbricata (Linnaeus, 1766)* (No. 137). Food & Agriculture Org.

Wood, F.G. (1953). Mating behavior of captive loggerhead turtles, *Caretta caretta caretta*. *Copeia*, *1953*(3), 184-186.

Wyneken, J., & Salmon, M. (1992). Frenzy and postfrenzy swimming activity in loggerhead, green, and leatherback hatchling sea turtles. *Copeia*, 478-484.

Wyneken, J. (2001). The anatomy of sea turtles. U.S. Department of Commerce *NOAA Technical Memorandum* NMFS-SEFSC-470, 1-172pp.

Wyneken, J., Epperly, S.P., Crowder, L.B., Vaughan, J. & Blair-Esper, K. (2007). Determining sex in posthatchling loggerhead sea turtles using multiple gonadal and accessory duct characteristics. *Herpetology* 63 (1). 19-30.

Wyneken J, Lohnmann K.J., & Musick, J.A. editors. 2013. *The biology of sea turtles*. Volume II. Boca Raton: CRC Press. 457 pages.

Zwinenberg, A.J. (1977). Kemp's ridley, *Lepidochelys kempii* (Garman 1880), undoubtedly the most endangered marine turtle today (with notes on the current status of *Lepidochelys olivacea*). *Bulletin of the Maryland Herpetological Society*, *13*(3), 378-384.

Appendices

APPENDIX I - IUCN Red List Conservation status of the regional populations

(Status at Jan. 1 2020)

Loggerhead (*Caretta caretta*)

Global status: Vulnerable (Casale & Tucker, 2017)

- Mediterranean Subpopulation (Least Concern)
- North East Atlantic Subpopulation (Endangered)
- North East Indian Ocean Subpopulation (Critically Endangered)
- North Pacific Ocean Subpopulation (Least Concern)
- North West Atlantic Ocean Subpopulation (Least Concern)
- North West Indian Ocean Subpopulation (Critically Endangered)
- South East Indian Ocean Subpopulation (Near Threatened)
- South Pacific Ocean Subpopulation (Critically Endangered)
- South West Atlantic Subpopulation (Least Concern)
- South West Indian Ocean Subpopulation (Near Threatened)

Green turtle (*Chelonia mydas*)

Global status: Endangered (Seminoff, 2004)

- Hawaiian (Central Pacific Ocean) Subpopulation: Least Concern
- North Indian Ocean Subpopulation: Vulnerable
- South Atlantic Ocean Subpopulation: Least Concern

Leatherback (*Dermochelys coriacea*)

Global status: Vulnerable (Wallace, Tiwari & Girondot, 2013)

- East Pacific Ocean Subpopulation: Critically Endangered
- Northeast Indian Ocean Subpopulation: Data Deficient
- Northwest Atlantic Ocean Subpopulation: Endangered
- Southeast Atlantic Ocean Subpopulation: Data Deficient
- Southwest Atlantic Ocean Subpopulation: Critically Endangered
- Southwest Indian Ocean Subpopulation: Critically Endangered
- West Pacific Ocean Subpopulation: Critically Endangered

Hawksbill (*Eretmochelys imbricata*)

Global status: Critically Endangered (Mortimer & Donnelly, 2008)

Kemp's ridley (*Lepidochelys kempii*)

Global status: Critically Endangered (Wibbels & Bevan, 2019)

Olive ridley (*Lepidochelys olivacea*)

Global status: Vulnerable (Abreu-Grobois & Plotkin, 2008)

Flatback (*Natator depressus*)

Global status: Data Deficient (Red List Standards & Petitions Subcommittee, 1996)

APPENDIX II – Tank dimension

Number of Animals	9 x Largest Carapace Length	4 x Largest Carapace Width	Surface Area	Depth of Tank (min. 2m)	% Increase Surface Area
1 Animal Ex: Turtle 1: 1.00 m L x 0.80 m W	9 m 9 x 1.0 m L = 9 m	3.20 m 4 x 0.80 m W = 3.2 0m	28.8 m² 9 m x 3.2 m = 28.8 m²	2 m	N/A
2 animals Ex: Turtles 1 and 2 each: 1.00m L x 0.80 m W	13.5 m ((9 x largest carapace L) + (9 x 0.50) x (smaller carapace L) = 9 m + 4.5 m = 13.5 m	4.80 m 3.20m + 1.6m = 4.80 m	64.8 m² 13.5 m x 4.8m = 64.8 m²	2 m	50% additional added to dimensions for 1 animal
2 animals Ex: Turtles 1 and 2 each: 1.00 m L x 0.80 m W	11.25m (9 x 0.25, because of one additional 1 m depth) = 9 m + 2.25 = 11.25 m	4.00m 3.20 m + .80 m = 4.00 m	45m² 11.25 m x 4 m = 45 m²	3m	25% additional added to dimensions for 1 animals due to increased depth
Example: 3rd animal, depth of tank stays 3 m					
3 animals Ex: Turtles 1, 2, and 3 each: 1.00 m L x 0.80 m W	16.90 m ((11.25 m x 0.5) + 11.25m) = 16.9m	6.00 m ((4.00 m x 0.5) + 4.00m) = 6.00 m	101.40 m² 16.9 m x 6.00 m = 101.4 m²	3m	50% increase in addition to dimensions for 2 animals
Example: 3rd animal, depth of tank at 4 m					
3 animals Ex: Turtles 1, 2, and 3 each: 1.00 m x 0.80 m	14.00 m ((11.25 m x 0.25) + 11.25 m) = 14.00 m	5 m ((4.00 m x 0.25) + 4.00 m) = 5.00 m	70 m² 14.00 m x 5.00 m = 70 m²	4m	25% increase in addition to dimensions for 2 animals

APPENDIX III – Participants of the 2018 and 2019 workshops

Name	Organisation	Country
Aspasia Sterioti	Cretaquarium	Greece
Jose Luis Crespo	Oceanogràfic Valencia	Spain
Karin Gobic	Aquarium Pula	Croatia
Laura Castellano	Acquario di Genova	Italy
Louise Overy	Dingle Oceanworld	Ireland
Maja Belic	Faculty of Veterinary Medicine, University of Zagreb	Croatia
Manja Rogelja	Aquarium Piran	Slovenia
Mark de Boer	Rotterdam Zoo	The Netherlands
Milena Micic	Aquarium Pula	Croatia
Nicola Pussini	Acquario di Genova	Italy
Nicole Kube	German Oceanographic Museum	Germany
Olivier Briard	Aquarium Biarritz	France
Olivier Brunel	Musee Oceanographique	Monaco
Pablo Montoto	Zoo Aquarium Madrid	Spain
Petr Sramek	Brno Zoo	The Czech Republic
Shoshana Levine	The Deep	United Kingdom
Sidonie Catteau	Marineland Antibes	France
Vicente Marco	Oceanogràfic Valencia	Spain
Virginia Bachiller	Oceanogràfic Valencia	Spain
Zana Moslavac	Aquarium Pula	Croatia