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For sea turtle biologists, veterinarians, sea turtle enthusiasts, and the general public that care about sea turtles, finding injured or distressed sea turtles is distressing in itself. Our reaction is to seek humane help for these animals and our hope is that they will receive the best care possible, given the source and seriousness of their injuries. When I first started out as a budding sea turtle biologist forty years ago, there were only a limited, handful of facilities and a handful of veterinarians to receive and treat injured or distressed sea turtles. The knowledge upon which to base short- and long-term treatment was equally sparse. The availability of both facilities and attendant expertise to help sea turtles in distress was limited geographically and functionally, and sea turtles frequently had to be transported significant distances to receive specialized care. Today there are numerous facilities that ring the US Atlantic, Gulf of Mexico, California, and Hawaii coasts as well as strategically placed facilities in much of the rest of the world. These facilities include public and private aquaria, dedicated sea turtle “hospitals,” and government-supported institutions that receive and care for injured and distressed sea turtles. As sea turtle conservation and recovery programs are founded and/or grow, the need for new or expanded facilities and enhanced expertise to care for injured sea turtles increases. Events such as large-scale cold-stunning of sea turtles and recent human-caused environmental catastrophes such as the Deepwater Horizon oil spill in the Gulf of Mexico have required treating hundreds to thousands of sea turtles during single events. These events require extensive coordination among multiple rehabilitation facilities, development of new treatment protocols, enhanced veterinary and sea turtle caregiver expertise, and sharing of information in real time.

Concomitant with the growth of rehabilitation facilities has been the growth of knowledge regarding sea turtle health and husbandry. Significant science-based advances have been made over the past several decades in how we care for injured sea turtles, including how we house them, diagnose and treat their ailments, understand their physiology, understand the causes of their injuries, and ready them for return to the wild. These advances have been made across numerous institutions treating turtles around the globe, however, the sharing of this information has in some cases been limited simply by caseloads and geographic separation. A comprehensive compendium of these advances, drawn from experienced individuals working on the front lines around the world, did not heretofore exist. As a result, new techniques and treatments, best practices for housing sea turtles, assessing their health status, and reasons for their injuries have not been readily available—until now! This volume serves as a go-to resource for assessing, treating, and housing turtles during the rehabilitation process, understanding and assessing causes of death, and assessing health in wild turtles as well.

Beyond the veterinary science of caring for injured and distressed sea turtles are the reasons why we should do this to the best of our ability. Those reasons begin with a humane and ethical foundation that we owe these magnificent animals and extend to our conservation and recovery programs for these species. Well executed rehabilitation programs can convey critically important education messages to the public about the human-caused threats that sea turtles face—ultimately we depend on and must have public support to implement meaningful conservation actions. Thorough evidence-based assessments of mortality sources are absolutely critical to developing effective conservation measures. And finally, sea turtles released back to the wild provide the possibility that an individual will contribute to species recovery.

Whether you actively rehabilitate sea turtles, participate in a stranding network, study sea turtles on their nesting beaches or in their marine environment, simply care about these animals, or work with other turtle species there is a wealth of information in this book to interest and inform you. I am certain that this volume will advance sea turtle conservation and move us closer to a day when sea turtles are no longer endangered or threatened—a testament not only to the authors herein, but to all of the individuals around the world who are dedicated and committed to sea turtle conservation and recovery.

Barbara A. Schroeder
National Sea Turtle Coordinator
National Oceanic and Atmospheric Administration
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For several years it had been apparent to those of us working with sea turtles that there was a need to assemble within one work the knowledge that had been gained in the relatively new field of sea turtle veterinary medicine over the past 40 years. Some of it had been published in various journals and proceedings, but much of it was in unpublished case records, note books, and tucked away in the back of the minds of a large number of veterinarians, biologists, and others working in the field. So, five of us decided to put in the effort to co-edit a comprehensive volume to address this need. We enlisted experts from around the world to share their knowledge and thoughts and experiences to produce a work that should serve as a comprehensive starting point in the field. Rather than include only published references, we have included much more information in the form of personal communications and unpublished data, and identified it as such, that can serve as impetus for future research.

This book is written primarily for veterinarians, those with experience as well as those with limited or no experience with turtles or reptiles. As such it requires the basic knowledge obtained during veterinary training and is not meant to serve as a replacement for veterinarians in the captive care of sea turtles or in the rehabilitation process, but rather as a supplement. We hope that biologists, researchers, technical staff, and volunteers will find it interesting and useful as well. We have organized the material of this book into six sections as follows:

1. Section 1, Introduction, is edited by Dr. Terry Norton, and contains two chapters. Chapter 1 focuses on sea turtle life history and conservation and was written by one of the preeminent sea turtle biologists of our time, Dr. Blair Witherington. An understanding of the life histories of sea turtles is key to successful rehabilitation care and provides valuable insight into health-related issues. The information provided in this chapter will be helpful to the novice as well as more advanced sea turtle biologists and veterinary professionals. Chapter 2, Sea Turtle Rehabilitation: Past, Present, and Future, was written by Dr. Terry Norton and Meghan Koperski and provides an overview of the history of sea turtle rehabilitation, the essentials of the "modern" facility, and recommendations for the future. Both of these individuals have significant expertise in the development and oversight of sea turtle rehabilitation facilities and implementation of successful rehabilitation programs. This chapter provides useful information for those endeavoring to either start a new rehabilitation center or expand and enhance current practices in an established facility. The importance of multifaceted programs in the rehabilitation setting that benefit sea turtle awareness, conservation education, and research are emphasized throughout the chapter.

2. Section 2, Husbandry, is edited by Dr. Terry Norton, and contains two chapters focusing on sea turtle husbandry and nutrition. Chapter 3: Environmental/Water Quality/Biosecurity was written by three aquatic veterinarians with substantial experience in facility design, life support system management, and preventive medicine. In addition to shared personal experience, this chapter reviews and combines the existing relevant literature into a singular helpful reference. The information found in this chapter will be useful to the rehabilitator, veterinary technician, veterinarian, and biologist working with sea turtles in the captive setting for research, rehabilitation, or public display. Chapter 4 focuses on sea turtle nutrition and was written by two nutritionists and a clinical veterinarian with expertise in sea turtles. The chapter covers nutritional concepts in wild and captive sea turtles and introduces practical aspects of nutrition such as food preparation and storage, quality control, diet selection and formulation, vitamin and mineral supplementation, and nutritional support of the ill sea turtle patient. Husbandry and nutrition are the backbone of a successful sea turtle rehabilitation program.

3. Section 3, Basic Veterinary Techniques, is edited by Dr. Charles Manire, and contains four chapters covering basic techniques and how they can or must be modified when caring for sea turtles. Chapter 5 describes how a comprehensive physical examination is carried out and is written by two clinical veterinarians with extensive experience. Chapter 6 describes the basics of performing imaging of sea turtles in various modalities, including radiology, ultrasonography, computed tomography, magnetic resonance imaging, and scintigraphy.
It was written by an international team of imaging specialists and clinical veterinarians. Chapter 7, Clinical Pathology, is written by a veterinary clinical pathologist and a clinical veterinarian and describes the basics of sample collection, preparation and processing, analysis, and interpretation. Chapter 8, Necropsy, is contributed by three specialists with experience from different regions of the world and describes the steps necessary to perform a comprehensive necropsy. Important related topics such as sample collection and preservation, recognition of human interaction, diagnosis of drowning, and other frequently encountered challenges are discussed in detail.

4. Section 4, Sea Turtles by System, is edited by Dr. Brian Stacy, and includes 11 chapters covering all of the major organ systems. Each chapter reviews anatomy, key aspects of physiology, essentials of clinical assessment, and pathology. Normal features of the different systems as viewed by physical examination, diagnostic imaging, and gross evaluation, as well as associated laboratory analyses, are presented side-by-side with examples of abnormal states, with an emphasis on form and function and recognition of common disorders. These chapters complement other sections of the book by providing additional detail on each organ system and delving into specific considerations relevant to clinical and postmortem evaluation. The contributing authors, each with expertise in the different elements in each chapter, draw from the literature and their collective experience to discuss various conditions encountered in sea turtles, describe approaches and challenges related to medical evaluation and diagnosis, and highlight important areas of future study.

5. Section 5, Current Therapy, is edited by Dr. Charles Innis, and contains nine chapters focusing on contemporary medical and surgical management of sea turtles. Subject matter includes critical care and emergency medicine, therapeutics, analgesia and anesthesia, surgery, and endoscopy, with additional chapters dedicated to specific management of cold-stunning, trauma, buoyancy disorders, and chronic debilitation. The 14 authors of these chapters are among the most experienced sea turtle clinicians worldwide, having cumulatively managed thousands of individual cases. Relevant primary literature is thoroughly covered, complemented by the unique experiences of the authors, and deficiencies in our current state of knowledge are discussed. While much of this material focuses on high-level care that can be provided at well-equipped facilities, the authors have also included practical, less costly methods that can be used in less developed settings. The reader will be well prepared to manage the majority of medical and surgical problems of sea turtles after learning the principles and methods described in the section.

6. Section 6, Special Topics, is edited by Dr. Craig Harms, and contains 11 chapters covering pathogens occurring in both captive and free-ranging environments (parasites, viruses, bacteria, and fungi), natural and anthropogenic toxins (harmful algae and biotoxins, contaminants, and oil), special considerations for working with the smallest size classes of sea turtles (hatchlings and wash backs), and large-scale population medicine with free-ranging sea turtles (field techniques, fisheries interactions, mortality event investigations, and health assessments). These chapters illustrate the valuable interplay between rehabilitation centers and population biology studies. Rehabilitation centers provide a window into the challenges faced by wild sea turtles and serve as incubators for developing techniques that can be applied in broader studies of free-ranging turtles. Field studies help to define what is normal or expected for individual case management and inform fisheries, wildlife, and environmental management decisions with potential for reducing caseloads in rehabilitation. The 24 authors in the section have built careers bridging gaps among clinical, laboratory, and field research settings.

This book has been written by experts in the field and reviewed by all of the co-editors, and in some cases by external reviewers. We have endeavored to make the contents as complete and accurate as possible, but neither the editors, authors, nor the publisher can accept legal liability for any errors and omissions. Rapid advances in the field and variation among individual patients and populations dictate that the book not be prescriptive in any particular case, nor substitute for the judgment of the responsible veterinary professional.
ABOUT THE EDITORS

DR. CHARLES MANIRE received his Bachelor of Science degree with high honors from Texas A&M University in 1971, followed by his Doctor of Veterinary Medicine degree cum laude in 1973. He was in private practice (small animals and exotic pets) in Texas for 10 years, then took a four-year sabbatical to teach scuba diving in the Virgin Islands. In 1988 he took a position at University of Miami’s Rosenstiel School of Marine and Atmospheric Sciences conducting shark research. In 1992 he accepted a position at Mote Marine Laboratory in Sarasota, Florida, where he continued with shark research and practiced marine veterinary medicine. His first patient there was a blind green turtle that was unreleasable. In the 16 years that followed, he designed, built, and managed the sea turtle rehabilitation hospital at Mote and additionally worked with dolphins, whales, manatees, and fish. In 2008 he accepted a position as staff veterinarian at Atlantis Resort in the Bahamas where he was responsible for the veterinary care of the more than 50,000 marine animals. Loggerhead Marinelife Center, in Juno Beach, Florida, hired Dr. Manire in 2012 as the Director of Research and Rehabilitation and he has been focused strictly on sea turtle rescue, rehabilitation, care, and research since that time. Over the years, he has authored or co-authored over 70 peer-reviewed articles on various marine species and has made scientific presentations at conferences around the world. He regularly reviews manuscripts for several professional journals and has served on multiple masters’ and doctoral committees for graduate students from the University of Florida, Texas A&M University, and Nova Southeastern University.

DR. TERRY NORTON is the Director, Veterinarian, and Founder of the Georgia Sea Turtle Center (GSTC). He earned his Doctor of Veterinary Medicine at Tufts University in 1986 and completed a residency in Zoo and Wildlife Medicine at the University of Florida in 1989. He became a Diplomate in the American College of Zoological Medicine in 1992. He has provided veterinary care for White Oak Conservation Center, Riverbanks Zoo, North Carolina State Zoo, and the Wildlife Conservation Society’s St. Catherines Island (SCI) Wildlife Survival Center. He developed and implemented the Georgia Wildlife Health Program, which has evaluated the health of many state and federally listed species including sea turtles, alligator snapping turtles, diamondback terrapins, Barbour’s map turtles, gopher tortoises, box turtles, eastern indigo snakes, eastern diamondback and canebrake rattlesnakes, eastern king snakes, American alligators, American oystercatchers, brown pelicans, and marine mammals. Currently, he provides veterinary care for the Jekyll Island Authority’s GSTC and SCI Foundation programs. He volunteers his services for the Turtle Survival Alliance’s Turtle Survival Center. He has published numerous articles for refereed journals and book chapters. He is Adjunct Professor at the University of Georgia, University of Florida, North Carolina State University, and Tufts University Cummings School of Veterinary Medicine. Dr. Norton is the Vice President of the St. Kitts Sea Turtle Monitoring Network. He is a graduate of the 2009 Institute of Georgia Environmental Leadership (IGEL) program. He was the Chair of the Conservation Planning Committee for Jekyll Island. Dr. Norton has worked around the world on several projects including in Indonesia for the Bali mynah reintroduction project, Madagascar for lemur health assessments, the Yucatan Peninsula in Mexico for Flamingo health related work, Panama for Capuchin monkey and sea turtle health assessments, several Caribbean countries for avian and sea turtle health related work, and most recently Costa Rica for sea turtle and other wildlife conservation efforts. He was recently honored by the American Association of Zoo Veterinarians with the Emil Dolensik Award.
DR. BRIAN STACY attended the University of Georgia and received his doctorate of veterinary medicine in 2001. He completed a residency in anatomic pathology at the University of California, Davis, and Zoological Society of San Diego and became board certified by the American College of Veterinary Pathologists in 2004. In 2008, he completed graduate studies at the University of Florida, College of Veterinary Medicine and was awarded a doctor of philosophy for his work on sporocyst trematodes (blood flukes) and associated disease in wild sea turtles. He serves as the veterinarian for the National Sea Turtle Program under the National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources where he provides veterinary support and training for sea turtle stranding networks within the US and abroad, investigates causes of strandings and mass events, and oversees a variety medical and welfare concerns related to anthropogenic activities, animal health, and disease. This role also included serving as lead veterinarian for sea turtle rescue and response during the massive Deepwater Horizon oil spill in 2010 and the subsequent Natural Resource Damage Assessment. In addition, he is a member of the IUCN Marine Turtle and Crocodile Specialist Groups and holds a courtesy faculty appointment at the University of Florida, College of Veterinary Medicine. He provides regular consultations on wildlife health, forensic pathology, and disease issues worldwide, especially those involving aquatic species and reptiles. He has written a number of peer-reviewed publications, technical reports, and book chapters on sea turtles and other reptiles, diagnostic pathology, and mortality investigation. His professional ethos is to apply knowledge as a veterinarian and scientist to inform sound management of natural resources and sustainability of wildlife and habitat.

DR. CHARLES INNIS received his bachelor’s degree in biology from Cornell University in 1990, and his doctorate in veterinary medicine from the University of Pennsylvania School of Veterinary Medicine in 1994. He was in private practice working with small animals and exotic animals from 1995–2005, and has been working full time at the New England Aquarium in Boston since 2005, where he is currently the Director of Animal Health. He oversees veterinary care of the Aquarium’s large and diverse collection of invertebrates, fish, amphibians, reptiles, birds, and marine mammals. In addition, Dr. Innis directs the veterinary management and rehabilitation of free ranging sea turtles that are stranded along the coast of New England, and participates in national and international emergency responses for injured and ill turtles. Dr. Innis holds adjunct teaching positions at Tufts University Cummings School of Veterinary Medicine and the University of Connecticut. He is a member of the IUCN Tortoise and Freshwater Turtle Specialist Group, the IUCN Marine Turtle Specialist Group, and is Past President of the Association of Reptilian and Amphibian Veterinarians. He has published numerous scientific articles and several textbook chapters on the medical and surgical management of turtles, and has been an invited speaker at national and international veterinary conferences. He is regularly solicited to provide peer review for scientific publications involving veterinary management and conservation of turtles and other aquatic species. In 2011, Dr. Innis became one of the first veterinarians in the United States to be recognized as a reptile and amphibian specialist by the American Board of Veterinary Practitioners.

DR. CRAIG HARMS grew up in northwest Iowa, received his A.B. in Biology from Harvard University in 1984, his D.V.M. from Iowa State University in 1989, and PhD in Immunology from North Carolina State University in 1989. He worked in private practice in Eagle River and Anchorage, Alaska, from 1989 to 1991; completed an internship in exotic, zoo, and wildlife medicine at Kansas State University from 1991 to 1992; and a residency in zoological medicine with an aquatic animal focus at North Carolina State University (NCSU) from 1992 to 1995. He earned board certification in the American College of Zoological Medicine (ACZM) in 1995. Dr. Harms joined the faculty of the NCSU College of Veterinary Medicine in 1999, and is now Professor of Aquatic, Wildlife and Zoo Medicine and Director of Marine Health Programs at the NCSU Center for Marine Sciences and Technology, and adjunct faculty at the Duke University Marine Laboratory. He is a Past President of the ACZM and of the International Association for Aquatic Animal Medicine. He has authored or co-authored over 125 peer-reviewed publications and several book chapters on zoological medicine. In 2011, he received the Stange Award for Meritorious Service by the Iowa State University College of Veterinary Medicine. Dr. Harms provides clinical services to several North Carolina coastal facilities and organizations, including the Karen Beasley Sea Turtle Rescue and Rehabilitation Center, NCSU aquaculture research laboratories, the North Carolina Aquariums, and the sea turtle and marine mammal stranding networks. He also trains residents in zoological medicine and veterinary students, and conducts clinically applied research on aquatic animal and wildlife medicine.
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Having been raised in a rural community in Texas, I developed an interest in nature at an early age. In the 9th grade, my science teacher, Donald Stringer, instilled a deep appreciation for the scientific method and scientific writing which stayed with me throughout my career. Many other teachers and professors, too numerous to mention, helped build on that foundation. From the science end, I thank Sonny Gruber for forcing me to improve my research approaches and my writing skills. From the veterinary end, I have to thank many aquatic veterinarians that have shared, and continue to share, their insight and expertise over the years. In addition, I specifically thank Howard Rhinehart, Lynne Byrd, Andrew Clarke, Nicole Montgomery, and Samantha Clark, the veterinary technicians about whom I have frequently joked that they are the ones that have done all of the work for which I take credit. I am very appreciative of all the support they have provided over the years. I also have to thank the many other staff and volunteers who have helped care for so many marine animals. I thank Jack Lighton and all of the team at Loggerhead Marinelife Center for their support and patience in the three years that it took to complete this book.

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Terry Norton

My experiences during childhood shaped me for the rest of my career. Competitive swimming taught me to be dedicated and focused. My coach throughout my younger years, Russ Lauber, pushed me to be the best swimmer I could be but more importantly taught me how to use this dedication in my future career. He was my first mentor. During veterinary school at Tufts University, I was fortunate to meet my first veterinary mentor, Dr. Chuck Sedgewick, a true pioneer in zoological and wildlife medicine. He provided me with the initial guidance and framework to get me started in working with nondomestic animals. He has always been my inspiration. My residency at University of Florida College of Veterinary Medicine was pivotal in shaping me for my professional career. I thank my two mentors during that time, Drs. George Kollias and Elliot Jacobson, for their expertise and the opportunities they gave me. The staff and colleagues I worked with during my time at White Oak Conservation Center, Riverbanks Zoo, North Carolina Zoological Park, and North Carolina State University all contributed to my development as a zoo and wildlife veterinarian. However, my time working on St. Catherines Island (SCI) has probably been the most important in getting me to where I am at today. For the first 8 years that I worked on SCI, I traveled there every 2 weeks from my primary job to take care of the captive collection. During this time I fell in love with this amazing island and the coast of Georgia. Eventually I moved to Georgia to develop the veterinary program on SCI. I thank all the staff and researchers that have come and gone during my tenure on the Island for the last 27 years. The Georgia Wildlife Health Program was developed during my time on SCI and it was through this program that I was first connected to sea turtles in Georgia. Additionally, I was able to develop collaborations with many amazing wildlife biologists including Brad Winn, Mark Dodd, Adam McKinnon, Clay George, Tim Keyes, John Jensen, Dirk Stevenson, Gale Bishop, Natalie Hyslop, Laura Smith, Felicia Sanders, Stacia Hendricks,
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Brian Stacy

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Charles Innis

I have been very fortunate. My parents, Richard and Alma, provided a loving home, outstanding education, opportunity to explore the world, and freedom to pursue my interests. My older siblings, Rick, Peter, and Mary, helped to raise me. My family taught me to be punctual, reliable, and honest, and to study hard, work hard, and play hard. I spent my childhood playing in the woods, building forts, riding my bike, exploring beaches, selling vegetables, reading, and making music. Turtles became my obsession around 1973, I think, largely under Peter’s influence, and when Mary was old enough she frequently drove me to local ponds to go “turtleing”. I have dreamt of turtles regularly for as long as I can remember, and I have pursued and cared for some number of thousands now. I regret that I caused the demise of some by ignorance,
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Craig Harms

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I am grateful to a long series of outstanding teachers and mentors too numerous to name all individually. My small town K-12 public school in Laurens, Iowa, provided a high quality education outsized for its resources. With teachers like Mr. Lowell Bonnema (biology and chemistry) and Mrs. Elvira Johnson (German) keeping subjects exciting and rigorous, solid college preparation was a given, and the odd idea of pursuing a career in marine biology from a landlocked state was not unreasonable. Dr. Raymond A. Paynter, Jr., Curator of Birds at the Museum of Comparative Zoology, through coursework and four years employing me in a part time job, introduced me to museum collections as a portal into studies of evolutionary ecology and diversity. His afternoon teas offered a welcome respite from the routine stressors of college life, while providing valuable insights on academic life and fieldwork. Dr. Rich Aronson, then a graduate student, immersed me in the scientific process as a research and dive assistant studying behavioral ecology of octopus and brittle stars in Eleuthera, where I saw my first wild sea turtle. Faculty at Iowa State University College of Veterinary Medicine, especially the Pathology Department (Dr. Larry Arp, Dr. Ron Myers, Dr. Andy Fix), provided a firm foundation in comparative medicine applicable to any taxon, even aquatic animals, even though they did not feature prominently in the curriculum.

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Downloads for *Sea Turtle Health and Rehabilitation* include:

- Chapter 7, Clinical Pathology, Figures in RGB format
- Appendix 4A: Sea Turtle Stranding Network—Gross Necropsy Report
- Appendix 4B: Sea Turtle Stranding and Salvage Network—Short Gross Necropsy Report
- Appendix 6: Sea Turtle Neurological Examination Form
- Appendix 8: Sea Turtle Stranding and Salvage Network—Stranding Report
- Appendix 9: Sea Turtle Clinical Evaluation Form
- Appendix 10B: Sea Turtle Stranding Event—Case Summary Data Sheet
- Appendix 10C: Sea Turtle Stranding Event—Sample Checklist
SECTION 1

INTRODUCTION

Terry M. Norton, Section editor
SEA TURTLES IN CONTEXT: THEIR LIFE HISTORY AND CONSERVATION

Blair E. Witherington

WHAT IS A SEA TURTLE?

Sea turtles are marine reptiles. They have both the specific adaptations required for life at sea and the evolutionary history of organisms tied to land and the open atmosphere. As reptiles, all turtles are amniote vertebrates, which develop from an embryo within four extraembryonic membranes (amnion, yolk sac, chorion, and allantois) that protect the embryo, contain energy stores, support hydration, and store waste (Laurin 2005). Sea turtle eggs have a papery but firm calcareous shell that protects the developing embryo and retains water within the egg but is permeable enough to allow gas exchange. The shelled egg is an adaptation for development on land (Tracy and Snell 1985).

Living reptiles and birds make up the clade Sauropsida, a monophyletic group of animals that have scales or feathers, lay eggs on land, and share anatomical features of the lungs and respiratory muscles, heart, and forebrain. Among the sauropsids, the turtles (order Testudines) are a unique, monophyletic group. These animals share characteristics including: (1) a bony dorsal carapace of dermal bone that incorporates vertebrae and ribs; (2) a bony ventral plastron; (3) limb girdles that are within the ribcage and enclosed by the shell [laterally joined carapace and plastron]; (4) a middle ear supported by a large quadrate bone [with no external ear]; (5) no teeth, which are replaced on the jaws by a horny beak with cutting edges and grinding surfaces; and (6) a robust skull with a variety of unique features (Gaffney 1975, Pritchard 1979).

The sea turtles stand out as a monophyletic group within the turtles (Hirayama 1994). Sea turtle characteristics include: (1) flippers—flattened, wing-like forelimbs and rudder-like hind limbs, each with elongated phalanges; (2) an inability to retract the head into the shell; and (3) a general hydrodynamic, streamlined form to the head, shell, and limbs (Pritchard 1997). In addition, the sea turtles show several other morphological and physiological adaptations to life at sea. Large adult body size (relative to other reptiles) is thought to be an important factor in avoiding predation by fish, and may allow more efficient swimming against currents (Williard 2013). Sea turtle body size also allows gigantothermy (Standora et al. 1982, Paladino et al. 1990), which is retention of body heat correlated with a reduced surface area relative to volume. A body temperature higher than ambient waters likely benefits a number of metabolic demands. Other sea turtle adaptations for heat conservation include endothermic heat production from brown adipose tissue, and management of heat loss in the flippers by vessels that form a counter-current heat exchange system (Gaffney and Stenson 1988, Hochscheid et al. 2002).

Numerous adaptations permit sea turtles to withstand the rigors of deep diving—such as shell flexibility to allow lung collapse, shunting of blood flow, and cerebral resistance to anoxia (Williard 2013). Life at sea also means managing water and salt balance. Sea turtles have well-developed lacrimal (salt) glands behind the eyes that excrete salts. Sea turtles also manage salt intake by squeezing ingested food with a muscular esophagus lined with posterior-pointed spike-like papillae (Wyneken and Witherington 2001).

TAXONOMY AND SPECIES IDENTIFICATION

The sea turtles are within the order Testudines and the superfamily Chelonioidea. They are divided between two families—Cheloniidae, comprising six species of thecate, or hard-shelled sea turtles, and Dermochelyidae, with the leatherback turtle (Dermochelys coriacea) as its only living member (Hirayama 1994). The six living cheloniid turtles are the
loggerhead (*Caretta caretta*), Kemp’s ridley (*Lepidochelys kempii*), olive ridley (*Lepidochelys olivacea*), hawksbill (*Eretmochelys imbricata*), green (*Chelonia mydas*), and flatback (*Natator depressus*) turtles.


**Loggerhead Turtle, *Caretta caretta* (Linnaeus 1758)**

Loggerheads are within a global species comprising 10 biologically described regional management units (RMUs), which describe subpopulations divided by migratory and geographic limits (Wallace et al. 2010).

**Appearance**—Loggerheads stand out as having a large head relative to their body size (Figure 1.1). The turtle’s carapace is an elongated heart shape with a domed anterior portion and a vaulted rear portion that peaks at a pronounced sacral hump. The carapace has nonoverlapping scutes. A typical loggerhead carapace has five pairs of costals, five vertebrals, and a nuchal scute that contacts the first pair of costals. The plastron is connected to the carapace by a bridge with three pairs of poreless inframarginal scutes. Deviations in scute/scale numbers are common. The juvenile and adult carapace color ranges from mahogany to red-brown, and the plastron ranges from cream to yellow. The smallest juveniles have thickly keratinized scutes in ridges of spines along their shell—three ridges along the carapace and two along the plastron. All of these carapace features may be obscured by growth of commensal organisms, which may include barnacles, hydroids, and macroalgae. The dorsal head and flippers are covered by orange to brown scales with yellowish margins. There are two pairs of prefrontal scales between the eyes. These prefrontal scales often have one or two intervening scales, for a total of four to six. The limbs each bear two claws. Sparsely scaled skin of the neck and insertions of the flippers are brown dorsally and yellowish below. Adult female size is approximately 70–170 kg and 70–110 cm straight carapace length (SCL). Mature loggerheads in the Pacific average about 6 cm smaller than Atlantic loggerheads, and those in the Mediterranean average about 18 cm smaller (Tiwari and Bjorndal 2000, Margaritoulis et al. 2003)—differences that are likely to be due to phenotypic plasticity (Piovano et al. 2011).

**Distribution and habitat**—Loggerheads can be found throughout temperate and tropical waters of the Mediterranean Sea and the Atlantic, Pacific, and Indian Oceans. The majority of loggerhead nesting occurs on beaches along the western rims of the Atlantic and Indian Oceans. The only loggerhead nesting aggregations that approach or exceed 10,000 females nesting per year are in southern Florida (USA) and Masirah Island (Oman) (Bolten and Witherington 2003). Coastal foraging habitats include coastal, estuarine, and continental shelf waters as poleward as 40° north and south latitudes, and include oceanic waters to 50° north and south. As young juveniles, loggerheads make transoceanic migrations. Juveniles and adults

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**Figure 1.1** Adult female loggerhead sea turtle (illustration by Dawn Witherington).
in coastal waters may make extensive seasonal movements, and adults make periodic breeding migrations between foraging waters and nesting beaches.

Diet—Loggerhead hatchlings are sustained by retained yolk for a few days preceding their first food at the surface of the open sea (Kraemer and Bennett 1981). The young turtles feed on animals associated with oceanic surface convergence zones, which include algal associates, pleuston, gelatinous plankton, and dead insects (Witherington 2002). In the Atlantic, post-hatchlings and young juveniles feed on associates of the pelagic Sargassum drift community such as hydroids, copepods, bryozoans, and serpulid tubeworms, with Sargassum ingested as a possible incidental item (Witherington 2002, Witherington et al. 2012). Larger surface-pelagic juveniles (1–25 kg) feed on pleustonic drifters and jellies such as Porpita, Janthina, Physalia, Glaucus, and salps, barnacles (Lepas species), and pelagic red crabs (Pleuroncodes planipes) (Bjorndal 1997, Parker et al. 2005, Witherington et al. 2012). Larger juvenile and adult loggerheads in the neritic zone feed on benthic invertebrates including large mollusks, crabs, Limulus, and sea-pen octocorals (Burke et al. 1993, Plotkin et al. 1993, Youngkin 2001, Seney 2003). Loggerheads also feed opportunistically on discarded fish bycatch from nearshore fisheries (Youngkin 2001)—a diet item that becomes more frequent as other prey species diminish in abundance (Seney and Musick 2007).

Conservation status—Loggerheads have declined from their historical abundance. Threats to their survival remain, including bycatch mortality from trawl, gillnet, longline, and other fisheries; hatchling mortality from artificial lighting; and habitat loss from coastal armoring. Individual known nesting populations are either declining, stable, or increasing; but many populations have incomplete data. The loggerhead has a global, International Union for the Conservation of Nature (IUCN), Red List Category of Vulnerable, with 10 regional management units that range in status from Least Concern to Critically Endangered. Loggerheads were initially listed as Threatened under the United States (US) Endangered Species Act (ESA). The measure was revised to a listing of nine Distinct Population Segments as either Threatened or Endangered. The species is protected under the Convention on International Trade in Endangered Species (CITES), Appendix I, throughout its range.

Kemp’s Ridley Turtle, Lepidochelys kempii (Garman 1880)

Kemp’s ridley has a single recognized population and regional management unit (Wallace et al. 2010).

Appearance—Kemp’s ridley is a small, circular-shelled, pale sea turtle (Figure 1.2). The turtle’s carapace is a disc-like, rounded-heart shape that is different from the other sea turtles. The shell scutes are nonoverlapping and number five pairs of costals and five vertebrals, with the nuchal scute contacting the first pair of costals. The smallest juveniles have thickly keratinized scutes in ridges (spines) along their shell—three ridges along the carapace and two along the plastron. These ridges diminish as the turtles approach adult size. The plastron is connected to the carapace by a bridge with four infra-marginal scutes—each having a conspicuous pore (Rathke’s gland opening). Deviations in scute/scale numbers are

Figure 1.2  Adult female Kemp’s ridley (illustration by Dawn Witherington).
Olive ridleys make up a global species comprising eight biologically described regional management units (Wallace et al. 2010).

**Appearance**—Olive ridleys are small sea turtles with a similar general appearance to their congener, Kemp's ridley. But by comparison, the olive ridley has a less circular, more vaulted carapace and is darker in color (Figure 1.3). The shell scutes are nonoverlapping and number 5–9 pairs of costals (most commonly 6 or 7) and 5–9 vertebrals. The nuchal scute contacts the first pair of costals. Costal scute rows are often asymmetrical in olive ridleys, a condition that is rare in Kemp's ridleys. As in Kemp's ridley, the smallest olive ridley juveniles have thickly keratinized scutes in ridges of spines along their shell—three ridges along the carapace and two along the plastron. The central carapace ridge is the last to diminish as a turtle matures. The plastron is connected to the carapace by a bridge with four inframarginal scutes—each having a Rathke's gland pore. Deviations in scute numbers are common. The olive ridley has two pairs of prefrontal scales on the head and only rarely has additional intervening prefrontal scales, as loggerheads frequently do. There is one claw on the leading edge of each front flipper and two claws on each rear flipper. Coloration in Kemp's ridley changes significantly during development. Hatchlings are gray-black above and below; surface-pelagic juveniles are dark gray above and light cream below; and larger juveniles and adults are pale gray-olive on top and cream to yellow below. Adults weigh 32–49 kg and have an SCL of 60–65 cm (Snover et al. 2007).

**Distribution and habitat**—Kemp's ridley has a distribution restricted largely to the Gulf of Mexico and the Atlantic coast of the US. Nearly all nesting occurs on beaches in the state of Tamaulipas, Mexico. Some nesting also takes place to the south in Veracruz, Mexico, and to the north in southern Texas (USA), but nesting elsewhere is rare (Márquez 1994). Kemp's ridleys forage in coastal waters throughout the Gulf of Mexico and along the US Atlantic coast north to Massachusetts. Surface-pelagic juveniles may occur in oceanic waters as far north as the Grand Banks (Watson et al. 2005). Juveniles and adults in coastal waters may make seasonal movements north and south and between shallow and deeper water. Adults make periodic breeding migrations between foraging waters and nesting beaches mostly within the Gulf of Mexico.

**Diet**—Young Kemp's ridleys feed within oceanic convergence zones on animals associated with the pelagic *Sargassum* drift community and on pleustonic drifters (mostly colonial hydroids), gelatinous plankton (medusae, hydromedusae), and dead insects (Witherington et al. 2012). *Sargassum* drift community animals include hydroids, bryozoans, gastropods, copepods, amphipods, serpulid tubeworms, fish eggs, and portunid crabs, with *Sargassum* ingested as a possible incidental item (Witherington et al. 2012). Larger juvenile and adult ridleys in the neritic zone feed mostly on crabs, principally *Callinectes*, *Libinia*, *Hepatus*, and *Menippe* (Shaver 1991, Burke et al. 1993, Burke et al. 1994, Márquez 1994, Seney and Musick 2007, Servis et al. 2015). Other animals in the diet include horseshoe crabs, mollusks, sea horses, and tunicates (Shaver 1991, Burke et al. 1993, Burke et al. 1994, Witzell and Schmid 2005, Servis et al. 2015). In some regions, Kemp's ridleys commonly feed on fishes associated with fishery bycatch and have been caught by hook and line on shrimp and fish baits (Shaver 1991, B. Stacy, pers. comm.).

**Conservation status**—Kemp's ridley nesting underwent a dramatic decline during the mid-20th century but has increased over the last three decades. Threats to their survival remain, including bycatch mortality in coastal trawl fisheries. Kemp's ridley has a global IUCN Red List Category of Critically Endangered. The turtle is listed as Endangered under the ESA and is protected under CITES, Appendix I, throughout its range.

**Olive Ridley Turtle, *Lepidochelys olivacea* (Eschscholtz 1829)**

Olive ridleys make up a global species comprising eight biologically described regional management units (Wallace et al. 2010).

**Appearance**—Olive ridleys are small sea turtles with a similar general appearance to their congener, Kemp's ridley. But by comparison, the olive ridley has a less circular, more vaulted carapace and is darker in color (Figure 1.3). The shell scutes are nonoverlapping and number 5–9 pairs of costals (most commonly 6 or 7) and 5–9 vertebrals. The nuchal scute contacts the first pair of costals. Costal scute rows are often asymmetrical in olive ridleys, a condition that is rare in Kemp's ridleys. As in Kemp's ridley, the smallest olive ridley juveniles have thickly keratinized scutes in ridges of spines along their shell—three ridges along the carapace and two along the plastron. The central carapace ridge is the last to diminish as a turtle matures. The plastron is connected to the carapace by a bridge with four inframarginal scutes—each having a Rathke's gland pore. Deviations in scute numbers are common. The olive ridley has two pairs of prefrontal scales on the head, and there is one claw on the leading edge of each front flipper and two claws on each rear flipper. Coloration changes during development. Hatchlings are gray-black above and below, surface-pelagic juveniles are dark gray above and light cream below, and larger juveniles and adults are olive on top and cream to yellow underneath. With algal growth and varying level of sun exposure, the topsides of an olive ridley can be light gray, olive-green, brown, or dark gray. Average adult females weigh 36 kg and have an SCL of 63–75 cm (Reichart 1993).

**Distribution and habitat**—Olive ridleys occur in tropical regions of the Atlantic (except the Gulf of Mexico), Pacific, and Indian Oceans (Bowen et al. 1997). Nesting takes place on the beaches of about 60 countries, although mass-arrival (arribada) nesting occurs only in the eastern Pacific and the northern Indian Oceans. Foraging habitats include coastal and oceanic tropical waters (Plotkin et al. 1995, Shanker et al. 2003). As young juveniles, olive ridleys are surface-pelagic and largely oceanic (Kopitsky et al. 2000). Larger juveniles and adults are either pelagic or benthic feeders (Reichart 1993, Plotkin 1994, Morreale et al. 2007).

**Diet**—Young olive ridleys likely feed within oceanic convergence zones on animals associated with these areas, but little evidence confirms this. Adults are also associated with oceanic feeding, but are able to dive deeper and feed in...
coastal benthic habitats as well. In a review by Bjorndal (1994), diet items examined were largely from breeding olive ridleys found off nesting beaches. Items included pelagic species such as salps (*Metcalfina*) and pyrosomes, medusae, and pelagic red crabs. Turtles had also fed on benthic species such as mollusks, crustaceans, bryozoans, and algae.

**Conservation status**—Most nesting populations of the olive ridley have declined from their historical abundance. Threats to their survival remain, including bycatch mortality in trawl, gillnet, and longline fisheries, and targeted catch by humans for food. Individual known nesting populations are declining, stable, or increasing—but many populations have incomplete data. The species has a global IUCN Red List Category of Vulnerable. The ESA lists the olive ridley populations nesting on the Pacific Coast of Mexico as Endangered, and those nesting elsewhere as Threatened. The species is protected under CITES, Appendix I, throughout its range.

**Hawksbill Turtle, *Eretmochelys imbricata* (Linnaeus, 1766)**

The hawksbill is a globally distributed species with 13 biologically described regional management units (Wallace et al. 2010).

**Appearance**—Hawksbills are medium-sized sea turtles with a long neck and a narrow-ovate shell that displays striking color patterns (Figure 1.4). The carapace is also conspicuous in having overlapping (imbricate) scutes, except in the oldest individuals. The shell scutes are much thicker than in other sea turtles. A typical hawksbill carapace has four pairs of costal scutes, five vertebral scutes, and a nuchal scute that does not contact the first pair of costals. The plastron is connected to the carapace by a bridge with four pairs of poreless inframarginal scutes. Deviations in scute/scale numbers are occasional. Hatchlings are tan or brown, and gain a patterned shell within their first year. The juvenile and adult carapace color pattern shows radiating streaks of amber, black, tan, and brown within each scute. The pattern varies between individuals from mostly light to mostly dark. Small juveniles (10–20 cm SCL) have thickly keratinized scutes in three ridges along their carapace and in two ridges along the plastron. Until they approach adult size, juveniles also have pronounced serrate points on their posterior marginals. Healthy hawksbills may have moderate acorn barnacle growth. The dorsal head and flippers are covered by dark scales with light seams. There are two pairs of prefrontal scales between the eyes. The beak of a hawksbill is narrow and birdlike, but without a pronounced cusp. The flippers each have two claws. Sparsely scaled skin of the neck and insertions of the flippers are dark dorsally and light below. Adult female size ranges 27–86 kg and 60–93 cm SCL (Witzell 1983).

**Distribution and habitat**—Hawksbills occur throughout tropical waters of the Atlantic, Pacific, and Indian Oceans. Nesting occurs in mostly small assemblages, with records from at least 70 countries (Mortimer and Donnelly 2008). Foraging habitats include coastal waters with coral reefs, other hard bottoms, or seagrass (Musick and Limpus 1997). Young juveniles are surface-pelagic before recruiting into coastal waters, where the turtles increase in size and inhabit deeper sites as they mature (Van Dam and Diez 1997). Adults make periodic breeding migrations between foraging grounds and breeding areas (Witzell 1983).
Diet—The youngest hawksbills feed within oceanic convergences on animals that collect in these zones. In the Atlantic, prey animals include associates of pelagic *Sargassum* such as hydroids, crustaceans, bryozoans, copepods, amphipods, serpulid tubeworms, and jelly animals. Young hawksbills also feed on plustonic animals like floating colonial hydroids, and on dead insects that accumulate in these concentrations of floating material (Witherington et al. 2012). Pelagic *Sargassum* and other plant material are also ingested (Witherington et al. 2012). Larger juveniles recruit to shallow coastal reefs and seagrass beds where they feed on a variety of items such as colonial anemones (zoanthids), sea cucumbers, mollusks, jelly animals, and algae (Bjorndal 1997), but the most common items in a hawksbill’s diet are sponges (Meylan 1988). As they mature, 95% of the volume in their diet will be sponges. Hawksbills favor a limited number of sponge species with glasslike silica spicules belonging to the order of demosponges.

Conservation status—Known hawksbill nesting populations have declined from their historical abundance. Threats to their survival remain, including bycatch mortality in gillnet fisheries and targeted capture and killing for bekko (tortoise shell). Individual populations are either declining, stable, or increasing—but many populations have incomplete data. The species has a global IUCN Red List Category of Critically Endangered. The ESA lists all populations of hawksbills as Endangered. The species is protected under CITES, Appendix I, throughout its range.

Green Turtle, *Chelonia mydas* (Linnaeus 1758)

The green turtle is a globally distributed species comprising 17 biologically described regional management units (Wallace et al. 2010). Although both skeletal (Kamezaki and Matsui 1995) and genetics (Bowen and Karl 1997) support assigning all green turtle populations to a single species, Pritchard (1999) cites the appearance and biology of the eastern Pacific black turtle as evidence that the population makes up a separate species, *Chelonia agassizii* (Bocourt 1868).

Appearance—Green turtles are the largest of the hard-shelled sea turtles. They have a blunt head and a broadly ovate carapace that is flattened in juveniles and becomes domed as an adult (Figure 1.5). The carapace scutes bear striking patterns and do not overlap. A green turtle’s carapace scutes typically number four pairs of costals and five vertebrals, with a nuchal scute that does not contact the first pair of costals. The plastron is connected to the carapace by a bridge with four pairs of poreless inframarginal scutes. Deviations in scute/scale numbers are occasional. Hatchlings are dark blue-gray on their upper surface and immaculate white below. Within their first year, green turtles acquire the juvenile carapace color pattern of radiating streaks of olive, black, brown, and tan within each scute. The pattern varies between individuals from mostly light to mostly dark. In older juveniles and adults, the carapace pattern of radiating streaks is often replaced by a brown or olive background with lighter spatters of dark brown or black. The dorsal head and flippers are covered by dark scales with light seams. Scale seams, and the skin of the neck and shoulders, are darker in sun-exposed individuals and lighter in turtles residing in deep water or a shaded tank (B. Witherington, unpublished data). There is only one pair.
of prefrontal scales between the eyes (a key diagnostic feature). The beak of a green turtle is blunt in profile with serrated
tomia for clipping seagrass and algae. The flippers each have one claw. Adult female size ranged from 104–177 kg in a
group of 15 green turtles from a Florida nesting beach with a range of 88–109 cm SCL (Ehrhart 1980). Green turtles from
populations in the eastern Pacific average about 18 cm smaller in SCL (Hirth 1971).

**Distribution and habitat**—Green turtles have a worldwide tropical and subtropical distribution. The turtles nest on
beaches of more than 80 countries, with large nesting assemblages (thousands of females nesting annually) in eastern
Australia, Indonesia, Oman, Seychelles Islands, Comoros Islands, Les îles Eparses, Europa, Guinea-Bissau, Ascension Is-
land, eastern United States, and eastern Costa Rica (Seminoff 2004). Young green turtles are surface-pelagic within a life
stage that lasts 3–5 years in the Atlantic and up to 10 years in the Pacific (Zug et al. 2002, Reich et al. 2007). Older juveniles
recruit to coastal waters and estuaries, foraging in habitats including hard bottom, seagrass, and other shallow waters with
marine algae (Musick and Limpus 1997). Maturing green turtles inhabit deeper sites as they grow in size (Bresette et al.
2010). Adults make periodic breeding migrations between foraging grounds and breeding areas, which can extend across
oceanic zones and span thousands of kilometers (Carr 1967).

**Diet**—The youngest green turtles feed within oceanic convergences on organisms found at the sea surface (Parker et
al. 2011, Witherington et al. 2012). Prey animals include associates of pelagic *Sargassum* and other algae such as hydroids,
amphipods, bryozoans, serpulid tube worms, and gastropods. These surface-pelagic turtles also eat a variety of jelly ani-
ma ls, including cnidarians (medusae, hydromedusae, and floating colonial hydroids), ctenophores, and pelagic tunicates
(salps and pyrosomes). Drift carrion (mostly insects) is also commonly taken. Pelagic *Sargassum* and other plant mate-
rial in the diet occur at a lower frequency than animal material, and may be incidental (Witherington et al. 2012). Larger
juveniles and adults are mostly herbivorous, feeding on seagrasses, macroalgae, and occasionally other plants such as
mangroves (Forbes 1994, Bjorndal 1997). The animal component of the diet in these green turtles is small, and includes
medusae, small crustaceans, and fish as carrion.

**Conservation status**—Green turtle nesting populations have declined from their historical abundance. Threats to their
survival include bycatch mortality in gillnet fisheries, and targeted catch for food. Individual known nesting populations
are declining, stable, or increasing—but many populations have incomplete data. The species has a global IUCN Red List
Category of Endangered, but the population nesting in Hawai i has a separate status of Least Concern. The ESA recognizes
11 Distinct Population Segments, each with a listing of Threatened or Endangered. The species is protected under CITES,
Appendix I, throughout its range.

**Flatback Turtle, *Natator depressus* (Garman, 1880)**

Flatbacks are a narrowly distributed coastal species with two biologically described regional management units (Wallace
et al. 2010).
Appearance—Flatbacks are a medium-sized sea turtle with a rounded shell and a blunt head. As their name suggests, flatbacks have a low-domed carapace (Figure 1.6). Hatchlings are gray dorsally, with carapace scutes outlined in black and with light margins at trailing edges of the flippers. The hatchling’s ventral surfaces are white. Juveniles and adults retain a gray to olive dorsal color and have a cream-colored underside. The shell scutes are non-overlapping and thinly keratinized, and the flattened carapace is turned up along the sides. Carapace scutes typically number four pairs of costals, five vertebrals, and a nuchal scute that does not contact the first pair of costals. There is occasional deviation in these scute numbers. The plastron is connected to the carapace by a bridge with four pairs of poreless inframarginal scutes. The head has only one pair of prefrontal scutes. In addition to the flattened carapace, a wedge-shaped head and the presence of one or more preocular scales anterior to each eye are distinctive flatback features that separate them from green turtles. Adult females average 90 cm in curved carapace length and 71 kg in weight (Limpus and Fien 2009).

Distribution and habitat—Flatbacks have a restricted distribution that seldom extends off the Australian continental shelf, and all known nesting beaches are in the tropical region of northern Australia (Walker and Parmenter 1990). Foraging is limited to tropical waters near Australia and is not known to extend into oceanic waters (Limpus and Fien 2009). This largely neritic distribution is explained by the lack of an oceanic drifting phase (Walker and Parmenter 1990), which most sea turtles have as young juveniles. Although the youngest juveniles are known from surface-pelagic convergence zones, older turtles have benthic foraging within shallow, soft-bottom habitats (Robins and Mayer 1998, Pendoley et al. 2014). Adults undertake breeding migrations between foraging areas and nesting beaches that may be over 1000 km (Limpus and Fien 2009).

Diet—The youngest flatbacks are largely surface-pelagic within shelf waters and feed on pleuston (Porpita, Janthina), cuttlefish, and stalked barnacles (Limpus and Fien 2009). Larger flatbacks feed on benthic soft-bodied invertebrates such as medusae, sea pens, sea cucumbers, and cuttlefish (Limpus and Fien 2009).

Conservation status—Although it is likely that many nesting populations of flatbacks declined during the 20th century (Limpus and Fien 2009), most populations have appeared stable over the last 20–30 years. The species has not been assessed for Red List status. In Australia, the flatback is listed as Vulnerable under the Environment Protection and Biodiversity Conservation Act. The species is protected under the Convention on International Trade in Endangered Species (CITES), Appendix I.

Leatherback Turtle, Dermochelys coriacea (Vandelli, 1761)

The leatherback is a globally distributed oceanic species with seven biologically described regional management units (Wallace et al. 2010).

Appearance—Leatherbacks are highly specialized and differ in appearance from all other turtles. Their scale covering is reduced to the point that juveniles and adults have only smooth skin on most external surfaces (Figure 1.7). Hatchlings have beadlike scales over most of their body, but these disappear months after hatching. As they age, some thin scales remain on the neck and eyelids. Other keratinous structures are reduced as well. Leatherbacks have no claws (except in hatchlings), and the beak sheaths (rhamphothecae) are relatively weak. However, key features of the beak make it suited for biting gelatinous prey: the lower jaw shears closed inside the upper jaw, and a pair of recurved cusps lead the upper

Figure 1.6  Adult female flatback turtle (illustration by Dawn Witherington).
The leatherback's teardrop-shaped carapace has seven longitudinal ridges (keels) ending in a pronounced caudal projection. The turtle's dorsal coloration is dark gray-black with light gray spots, and the ventral pattern is mostly light with dark splotches. This coloration is variable between individuals and among circumstances (Pritchard and Trebbau 1984). General dorsal appearance ranges from black with only faint spots, to abundant contrasting spots. Wet leatherbacks appear darker, and dry leatherbacks are grayer. Lighter skin can also be pink in a warm turtle. An additional highly variable feature is the leatherback's cranial pink spot. Although the irregular mark has the appearance of a scar, it is a normal area of light vascular skin above the turtle's pineal gland. The shape of a leatherback's body in transverse section varies with the turtle's condition and whether it is supported by water. On a beach, a healthy leatherback carapace is domed, whereas the same turtle in the water is barrel-shaped. Adult size is highly variable in leatherbacks, with mature turtles ranging approximately 200–900 kg and 115–175 cm curved carapace length. Leatherbacks in the Atlantic average about 10 cm greater in carapace length in comparison to Pacific leatherbacks (Eckert et al. 2012).

Distribution and habitat—Leatherbacks have the widest distribution of any reptile, spanning all oceans between the Polar Regions. Nesting is mostly on tropical beaches. Large nesting assemblages with more than a thousand females per year occur only in the Atlantic, on beaches of French Guiana-Suriname, Trinidad, and Gabon (Wallace et al. 2013). Leatherbacks forage exclusively in pelagic waters, and almost exclusively in oceanic zones (Musick and Limpus 1997). Although juveniles are thought to be restricted to warm tropical waters (Eckert 2002), adults make extensive seasonal movements and nesting migrations that may cross ocean basins.

Diet—Leatherbacks of all sizes consume gelatinous marine animals in the phyla Cnidaria (medusae, hydromedusae, and floating colonial hydroids), Ctenophora, and Chordata (Class Thaliacea, salps and pyrosomes). A variety of other prey species known to be commensal with these jellies have been found in the stomachs of leatherbacks and were likely to have been incidentally ingested (Eckert et al. 2012).

Conservation status—Leatherbacks have declined from their historical abundance. Populations that were formerly large are now small or have been extirpated, but some small populations have grown at dramatic rates. Important threats to their survival remain, including bycatch mortality in longline and trawl fisheries. The species has a global IUCN Red List Category of Vulnerable. The ESA lists all populations of leatherbacks as Endangered. The species is protected under CITES, Appendix I, throughout its range.

BASIC CONCEPTS

What Is a Life Cycle?

A sea turtle life cycle describes discrete life stages (developmental stages) and their sequence, from egg to adulthood. The definitions of a sea turtle life stage include size (or age) and appearance, but also involve behavior and occupied habitats (developmental habitats). Commonly used terms for sea turtle life stages are:
Egg—This life stage begins when a shelled egg with an embryo is laid as part of a clutch within a sand nest, and it ends with a hatching escaping from the eggshell. The developmental stages of embryonic growth are also described (Miller 1985).

Hatchling—This stage begins within the nest and ends in the sea when feeding begins. At least four divisions of the hatchling stage are important to note and are largely defined by behavior: periodic thrashing within the nest (ending with emergence), sea-finding (orientation and movement from nest to sea), nearshore swim frenzy (gradually ending when activity is no longer constant), and periodic oriented swimming (gradually ending when feeding begins or when swimming is infrequent or not periodic) (Wyneken and Salmon 1992).

Post-hatchling—Turtles in this transitional stage have begun to feed, but may retain some of their residual yolk. They are also referred to as neonates, or perhaps more precisely as young of the year. These terms exclude older turtles that have dispersed away (by hundreds of kilometers) from nesting beaches (Bolten 2003).

Surface-pelagic juvenile—Also termed oceanic juvenile (Bolten 2003) or lumped with young of the year and neonates (Witherington 2002). However, this stage is more discretely described as beginning after a turtle’s first year (and dispersal away from waters off the nesting beach) and ending with an abrupt change in habitat—such as a move into shallow coastal waters. This stage is shortest (a few years) in hawksbills, Kemp’s ridleys, and Atlantic green turtles, and is about a decade in loggerheads and Pacific green turtles. The stage is bypassed (or variably brief) in flatbacks. Olive ridleys in the Atlantic have this stage as relatively discrete, but olive ridleys in the Pacific and Indian Oceans do not—meaning that these turtles may remain pelagic in oceanic waters as they mature into adults. Leatherbacks also remain in open-sea waters as they mature, and do not fit a surface-pelagic definition because of their deep dives (Eckert et al. 1989).

Neritic juvenile—This term may best fit turtles that have undertaken the pronounced habitat shift described in the previous paragraph (Bolten 2003). The term is not helpful to describe life stages in leatherbacks and some olive ridley populations, which have individuals that only occasionally use neritic waters. Neritic juvenile also applies poorly to flatbacks, which occupy neritic (shelf) waters their entire lives (Walker and Parmenter 1990).

Juvenile—Any immature sea turtle could be described as a juvenile, and thus, this term and the term immature often encompass the two stages for juveniles defined above. The terms juvenile, and subadult (below) are helpful to separate immature individuals that are partitioned by age/size. For example, body size in green turtles explains portioning of foraging habitats (Bresette et al. 2010).

Subadult—This term is often a substitute for neritic juvenile, especially in loggerheads (Bjorndal et al. 2001), which recruit into coastal waters only after about a decade in oceanic waters (Bolten 2003).

Pubescent—Within this stage, males show elongation of the tail, and both sexes have gonads undergoing sexual maturation. The stage ends when males have bred and females have ovulated (Ishihara and Kamezaki 2011).

Breeding adult—This stage begins with sexual maturity, but it is possible that some adults do not breed in their first season. This life stage ends at death. Varied evidence supports the hypothesis that sea turtles do not undergo reproductive senescence, including constant adult survival over time (Chaloupka and Limpus 2005) and no senescence found in other turtles (Gibbons and Semlitsch 1982).

What Is a Life History?
A life history is more involved than a life cycle. Often, authors describe sea turtles as having a complex life history. Although the sequence of a sea turtle life cycle is relatively basic, the stages are highly variable in their duration, survival rates, spatial distributions, and in the habitats and ecological niches they occupy. All of these factors affect fecundity, which is the principal way that life history is described.

Sea turtle reproductive strategies and traits are predictable from life-history theory. For example, sea turtles mature late, have a relatively long reproductive lifespan, and produce a lot of offspring. These traits coincide with survival rates that increase dramatically with age. Life-history information like this is critical to conservation because it can help prioritize conservation efforts (Heppell 1998). Typically, efforts to manage threats to sea turtles generally focus on a single life-history stage, or occasionally, on two overlapping stages. When Turtle Excluder Devices (TEDs) were required on shrimp trawls in US waters, the action reduced drowning deaths mostly in neritic-stage juvenile and adult loggerheads and Kemp’s ridleys that were foraging in southeastern US waters (Crowder et al. 1994).

What Is a Population?
In the strictest sense, a sea turtle population is all of the potentially interbreeding individuals within a geographic area. Informally, references are often made to nesting populations (groups of turtles nesting on the same beach). A population can be
defined for a region, an ocean basin, or for the species wherever it occurs. The latter definition is a population in the truest sense because the definition of a species is that all members can interbreed. But sea turtle population members do not all interbreed with equal frequency, so working definitions for subpopulations become important. These are known as stocks, regional management units (RMUs), and in ESA legal terms, recovery units (NMFS and USFWS 2008, Wallace et al. 2010).

**Philopatry, Natal Homing, and Genetic Stocks**

Although sea turtles are highly migratory, there are important patterns to their spatiotemporal distributions. Sea turtles show philopatry, a term applied to animal behavior and ecology, which describes the tendency of individuals to return to their birthplace (Mayr 1963). Sea turtles display a pronounced form of philopatry called natal homing (Carr 1967), in which females are significantly more likely to nest on the regional beaches where they hatched (Bowen and Karl 1997). Important implications of natal homing stem from how males and females contribute differently to their population’s genetic structure. We assess these contributions by sampling turtles’ genetic material that is either biparentally inherited (nuclear DNA) or is inherited only down maternal lines (mitochondrial DNA) (Bowen et al. 1992, Karl et al. 1992, FitzSimmons et al. 1997). As in most populations, distance and geography separate sea turtles. This scale is such that males are most likely to mate with females they encounter within a single side of an ocean basin. But females create more precise genetic structure by only returning to specific beaches to breed (Bowen and Karl 1997). In conservation terms, this means that threats can cause nesting beach population declines (and extirpation) even when the broader population is stable. And just as threats near nesting beaches can affect a single genetic stock, threats in foraging areas can affect many stocks due to the mixing of nesting-beach populations at sea. The at-sea frequencies of turtles from different nesting beaches can be determined through mixed-stock analyses of mitochondrial DNA haplotypes (Bowen 1995). However, individual turtles are seldom identified as being from a specific nesting beach, unless that turtle has a haplotype found only at one beach.

**What Are Vital Rates?**

Vital rates (demographic rates) are parameters like hatching success and survival rates, which determine the potential for population change. These rates not only help us know how many turtles there are, but also how many turtles there will be (Crouse et al. 1987). Sea turtles are hard to count, except where they emerge to nest on beaches. As a result, the most reliable estimates of sea turtle abundance come from nesting-beach counts. But these snapshots of a single life stage do not provide an adequate population assessment. To understand and predict trends in sea turtle populations, modeling efforts require vital rates for the population, especially stage- or age-specific survival and life-stage duration (NRC 2010). Without these rates, we are less confident in trend evaluation, effects from threats, and risk of extinction.

**SEA TURTLE LIFE HISTORIES**

**Conceptual Life-History Models**

Bolten (2003) presented three models describing sea turtle life-stage progression across habitats. He chose three models to represent the variation in this progression among the seven sea turtle species. The addition of demographic rates to these models is incomplete in all the species, but the data at hand still allow these models to act as important heuristic tools (Heppell 1998, NRC 2010). A description of how these conceptual models inform numerical models is in NRC (2010) and Heppell (1998).

For the summary treatment in this chapter, I describe four spatiotemporal patterns of sea turtle life history (Figure 1.8). Because only females provide the data for demographic models, the figures represent only that sex.

The principal differences between the models are in the water depths that turtles occupy. This depth defines a dichotomy between habitats that are oceanic (depth greater than the euphotic zone of 200 m) or neritic (depths entirely within the euphotic zone), and nesting beaches (terrestrial zone). The oceanic/neritic dichotomy divides the life history of sea turtles in important ways, including differences in both natural and anthropogenic mortality. Turtles in oceanic waters are mostly pelagic (distributed in the water column) and do not have access to benthic habitats because they are too deep. The youngest sea turtles in oceanic waters are surface-pelagic. Larger turtles tend to have a greater capacity to dive, allowing them to occupy the epi-pelagic zone (all waters less than 200 m depth). Leatherbacks occupy deeper oceanic waters as well as those of the relatively shallow continental shelves, and are not known to use benthic habitats. Adult sea turtles show the greatest variation in habitat use among species (Figure 1.8). Adults either remain in neritic (shallow, coastal)
waters, occupy mostly oceanic waters, or move between these zones. Other than the flatback, there is likelihood that most populations have adult females that make reproductive migrations through oceanic waters.

Despite the differences in where sea turtles live by their life stage, the seven species share general life-history characteristics (Van Buskirk and Crowder 1994). These are high fecundity (hundreds of eggs per season), iteroparous reproduction with skipped breeding seasons, late maturation (a decade to several decades), large adult size (thousands of times mass at hatching), and a Type III survivorship curve (survival rate proportional to age, Iverson 1991). Some approximate values for fecundity and maturation age are presented for each species below. However, empirical values for stage survivorship and reproductive lifespan are generally lacking. Commonly, population models use annual rates of survival of 0.5 to 0.7 for juveniles, with decades required to graduate from this stage, and annual survival rates of 0.8 for adults.

**Life-History Strategies by Species**

**Loggerhead**—Loggerheads lay an average of 575 eggs per nesting season and migrate to nest about every second to fourth year (NMFS and USFWS 2008). Age at maturity is approximately 35 years (NMFS and USFWS 2008). The hatchlings disperse from the nesting beach and remain in deep-neritic and oceanic waters for about 10 years (Bjorndal et al. 2000). At about a third of their mature age, loggerheads recruit into neritic waters. The juveniles (1 to n, in Figure 1.8) may move through multiple (n) developmental habitats. As adults, loggerheads may remain in neritic waters, shift into oceanic waters, or move between these two habitat depths. This pattern is roughly similar to that of olive ridleys in the Atlantic and southwestern Pacific (Figure 1.8). Mating occurs along migration routes and occasionally near nesting beaches.

**Kemp's ridley**—In a nesting season, a Kemp's ridley female lays an average of about 250 eggs and typically skips a year between reproductive seasons (NMFS et al. 2010). A female's age at maturity is approximately 10–16 years (NMFS et al. 2010). The hatchlings disperse from the nesting beach and are surface-pelagic in both neritic and oceanic waters for about 2 years. At less than a sixth of their mature age, Kemp's ridleys recruit into shallow coastal habitats. The juveniles may move through multiple developmental habitats. Kemp's ridley adults remain almost exclusively in neritic waters. This pattern is roughly similar to that of hawksbills and green turtles (Figure 1.8), except with key differences in maturation age. Mating occurs near nesting beaches.

**Olive ridley**—Olive ridleys are similar to Kemp's ridleys in terms of their fecundity and maturation, but are most like either loggerheads or leatherbacks in terms of their habitat use. Among populations, female olive ridleys lay about 105–315 eggs per nesting season and migrate to nest every year or every other year (NMFS and USFWS 1998). Age at maturity is approximately 13 years (Zug et al. 2006). The hatchlings disperse from the nesting beach and are thought to remain in oceanic waters for several years, but there is little evidence from this life stage. Olive ridleys in the Atlantic and southwestern Pacific apparently recruit into neritic waters to forage, although both juveniles and adults can also be found in oceanic waters. Populations in the northern Indian and Pacific Oceans tend to remain oceanic, but with some individuals found foraging in benthic habitats in neritic waters (Plotkin 2007). Thus, there are two models used to illustrate olive ridley life history (Figure 1.8). Mating occurs near nesting beaches.

**Hawksbill**—Female hawksbills lay an average of 260 to 390 eggs in a nesting season. Females will migrate to nest every 2–3 years (Witzell 1983, Richardson et al. 1999). Age at maturity is approximately 17–22 years (Snover et al. 2013). Hatchlings disperse from nesting beaches and are surface-pelagic in both neritic and oceanic waters for about 3 years. At roughly a seventh of their mature age, hawksbills recruit into shallow seagrass and reef habitats. The juveniles may move through multiple (n) developmental habitats. As older juveniles and adults, hawksbills remain almost exclusively in neritic waters, except for breeding migrations (Figure 1.8). Mating occurs near nesting beaches.

**Green turtle**—Green turtle females average laying 300 to 700 eggs in a nesting season. This rate is highly variable between populations, with green turtles in the eastern Pacific having the smallest clutches and lowest fecundity (Hirth 2004). Green turtle females mature in approximately 27–40 years and typically migrate to nest every 2–3 years (Seminoff 2004). Hatchlings disperse from nesting beaches and are surface-pelagic in both neritic and oceanic waters for about 3–5 years in the Atlantic and 10 years in the Pacific. Juveniles leaving the oceanic environment recruit into shallow seagrass and hard bottom habitats. Juveniles (Figure 1.8) may move through multiple (n) developmental habitats. Older green turtle juveniles and adults remain almost exclusively in neritic waters, except for breeding migrations (Figure 1.8). Mating occurs near nesting beaches.

**Flatback**—Flatbacks have a unique life history among the sea turtles and are thought to be without an oceanic juvenile stage. Female flatbacks average only about 150 eggs laid per nesting season and migrate to nest every 2–3 years (Limpus and Fien 2009). Age at maturity is approximately 20 years, although data in support of this estimate are rare (Limpus and Fien 2009). The hatchlings disperse from the nesting beach and are thought to remain in neritic (continental-shelf)
Figure 1.8  Conceptual life-history models for females of the seven sea turtle species, with olive ridley populations divided between two of the models. The diagrams show progression between life stages, and between habitats (beach, neritic, oceanic), and transitions (in red) where demographic parameters would apply. These vital rates, with their constituent factors, are: A—egg production, as a function of remigration frequency, influenced by nutrition and health; B—egg production, as a function of clutch size and clutch frequency, influenced by nutrition and health; C—egg survival, influenced principally by erosion, predation, poaching, and pathogens; D—proportion of females, influenced by incubation temperature; E—sea-finding success, influenced by light pollution and predation; F—survival during frenzy, as a function of annual survival and stage duration, influenced by fish predation and somatic growth; G—survival at sea, as a function of annual survival and stage duration, influenced by fisheries mortality, plastics ingestion, petroleum, and somatic growth; H—survival at sea, as a function of annual survival and stage duration, influenced by fisheries mortality and somatic growth; I—survival at sea, as a function of annual survival and stage duration, influenced by fisheries mortality, boat strikes, harvest, and somatic growth; J—adult female reproductive lifespan, as a function of annual survival on foraging grounds, influenced by fisheries mortality, boat strikes, harvest, and somatic growth; and K—adult female reproductive lifespan, as a function of survival during breeding migrations, influenced by fisheries mortality, boat strikes, harvest, nutrition, and health. Additional constituent factors affecting these vital rates include environmental stochasticity, disease, parasitism, habitat loss, oceanographic cycles, and climate change.
waters as they mature. Juveniles may transition through multiple shallow-water habitats and overlap with adult distributions. Although the smallest juveniles are pelagic, larger turtles feed in benthic habitats (Figure 1.8). Mating occurs near nesting beaches.

**Leatherback**—This species is the most pelagic and oceanic of the sea turtles. Among populations, female leatherbacks lay about 360–600 eggs per nesting season and migrate to nest every 2–3 years (Eckert et al. 2012). Estimates of age at maturity vary widely. Minimum estimates are 5–6 years (not widely accepted), with means among estimation methods ranging from 13 to 29 years (Zug and Parham 1996, Avens et al. 2009). Leatherback hatchlings disperse from the nesting beach and remain in oceanic or deep-neritic waters through adulthood (Figure 1.8). Larger juveniles and adults are regularly observed foraging in continental shelf waters. Different life stages may have a reduced overlap in distribution because of the tendency of juveniles to be restricted to the tropics. Adults make extensive oceanic movements and may also migrate seasonally along coastlines. There is little information on where mating occurs.

**Developmental Habitats and Migration**

As sea turtles mature, their habitat needs change. Small turtles are more vulnerable to fish predation and would be expected to seek lower risk areas where predators are less abundant; such as in the oceanic environment, or where larger predators cannot reach, like shallow, near-intertidal waters (Musick and Limpus 1997). During development, diet requirements also may change, meaning that turtles may need to shift foraging habitats in order to optimize their somatic growth (Bjorndal 1997). And as adults, multiple habitats may be required, including foraging areas; breeding migration corridors; courtship and mating areas; nesting beaches; and inter-nesting areas (Musick and Limpus 1997). The fact that immature sea turtles tend to distribute themselves relative to size/age class means that the requirements of reduced predation risk and/or diet alone are enough to drive habitat choice (Meylan et al. 2011). Among adults, habitat choice may be strategic in terms of access to mates and nesting beaches. Although breeding migrations are the largest movements that most sea turtles make, seasonal movements may occur on an equal scale of hundreds of kilometers (Hawkes et al. 2007).

Important implications of developmental habitat shifts in sea turtles are that size and season determine where a turtle should be. Even small transitions in somatic growth may result in enormous geographic shifts. Such is the case for loggerhead sea turtles where, in the Pacific Ocean, a juvenile’s graduation to the next 10 cm in size class can mean a geographic shift of 10,000 km (Bowen et al. 1995). Seasonal changes also may result in large geographic changes, and these shifts cannot always be predicted by water temperature. For example, loggerheads along the Atlantic coast of North America may have seasonal movements that are either north and south or east and west (coastal and oceanic), or they may remain as nonmigratory residents (Hawkes et al. 2007).

**Life-History Consequences for Conservation**

*Risk and exposure in habitats occupied*—The variation in occupied sea turtle habitats (Figure 1.8) represents variation in risk from both natural and anthropogenic mortality factors. We assume that the evolution of life-history strategies has responded to predictable levels of risk from predators, cold water, reduced food availability, disease, and other threats. Thus, a juvenile turtle may move from the oceanic environment where predation and foraging opportunities are low, to coastal waters where predation risk and foraging availability are greater, if the turtle’s size can meet the challenges of avoiding predation and diving to forage on benthic food items. But anthropogenic threats are not expected to have influenced sea turtle life history. As a result, a lengthy oceanic stage duration that provides a long exposure to oceanic fisheries may result in mortality that is not avoided by a species’ life-history strategy.

*Risk associated with migration*—Important exposure to mortality risk also occurs during migration. This is especially pronounced where sea turtles that forage in waters with few anthropogenic threats must migrate through less-protected waters to breed or reach winter foraging areas.

*Reproductive value of life stages*—One of the consequences of sea turtle life history is a wide variation in reproductive value (RV) among life stages (Crouse et al. 1987, Cunnington and Brooks 1996, Heppell et al. 1996). In a theoretical sense, sea turtle RV describes the tradeoffs between reproduction, growth, and survivorship. That is, a function of RV affects the decision a turtle makes to wait and grow before reproducing rather than reproducing sooner. But in an applied (conservation) sense, RV explains critical differences between individuals’ values to the population. A sea turtle’s RV is its expected contribution to population growth through future reproduction. To express reproductive value, a female sea turtle must survive, mature, gain energy for her eggs, lay them, and repeat these steps (except maturation) over decades. The key difference between a young turtle and a turtle that is just maturing is that young turtles are far less likely to lay
eggs because they are less likely to survive the many years before they mature. Adult turtles have won the survival lottery and have a much higher probability of contributing to population growth.

Variation in RV among sea turtle life stages can be described in terms of relative value. In loggerhead sea turtles, if an egg with the potential to become a female turtle is given the value x, then the RV of a juvenile entering coastal habitats is roughly 100x, and an adult is roughly 500x (Crouse et al. 1987). This extreme range in RV among life stages means that anthropogenic mortality in adults can easily be so high that no reduction in egg mortality will reverse population collapse. However, although early life stages have a lower RV, many are needed in order for enough to survive to adulthood to sustain or recover a population.

CONSERVATION AND PROTECTIONS

Conservation Frameworks

Sea turtle conservation does not occur without a critical framework for regulation, funding, and action. Conservation action takes place through agencies, institutions, nongovernmental groups, for-profit companies, and individuals. These entities may conduct hands-on protection, monitoring, and research, or may provide outreach that inspires change in human behavior. These changes in human behavior need to be made within individuals and groups with the potential to harm sea turtles either intentionally (poachers) or incidentally (fishers, beach residents, construction companies, boaters). Behavioral changes can also affect the regulatory environment and cultural norms that influence how people and companies conduct their affairs. The details of sea turtle conservation activities are too much to describe here, but there are some important sources that provide a thorough treatment (Frazer 1992, Campbell and Smith 2006, Campbell 2007, NRC 2010). Although independent conservation actions are important, they are unlikely to take place without protective regulation and mechanisms for funding. Of these two, protective regulation is the most influential.

Protective Regulation

Institutional rules—Many institutions (especially universities, zoos, and aquaria) recognize the need to regulate actions that affect animal welfare—including husbandry, research, and exhibits. In the US, institutions that use vertebrate animals for federally funded research must have an Institutional Animal Care and Use Committee (IACUC). These committees review research protocols and evaluate housing and both field and laboratory animal use. Similar committees oversee the care of sea turtles in aquaria. This oversight applies more directly to individual sea turtles than to sea turtle population concerns.

Local laws—Laws enacted by counties, prefectures, cities, and towns vary widely, as do rules enforced at higher levels that pertain to parks and other protected areas. These local laws and rules are a key way that sea turtles are protected. Most are simple and apply to a specific conservation challenge—such as fires on the beach, artificial lighting, or even beach furniture. In the US, local laws are the principal way that hatchling mortality from light pollution is minimized.

State and provincial laws—At this level of regulation, laws protecting sea turtles are more comprehensive and come closer to protecting entire populations. In the US, states enact conservation programs guided by state and federal legislation, and devote agencies to conservation research and coordination of activities. For many US states, there are cooperative agreements with the federal wildlife management agencies directing the cooperation with the states to carry out programs governed by federal law (namely, the US Endangered Species Act).

National laws—National laws to protect sea turtles vary. Laws are still nonexistent in many countries where sea turtles nest and forage. In other countries, some national rule of law results from requirements of international treaties (discussed more in an ensuing section). There is also variation in how completely sea turtles are protected. Direct protections that prohibit targeted harvest are more common than regulations required to protect sea turtles from otherwise lawful activities like dredging, construction, or fishing. These more comprehensive laws are rare, and they are exemplified by the US ESA.

Under the ESA, jurisdiction over US sea turtle populations is shared by the National Marine Fisheries Service (NMFS), which is part of the National Oceanic and Atmospheric Administration within the US Department of Commerce, and the US Fish and Wildlife Service (USFWS), which is within the US Department of the Interior. The USFWS has primary responsibility for sea turtles on land, and NMFS has primary responsibility for sea turtles in the water. These agencies conduct conservation research; fund research conducted by universities and state agencies; manage refuges and marine protected areas; assess sea turtle populations; set recovery goals; plan population recovery; regulate activities that affect sea turtle populations; and enforce the ESA.
Although the ESA specifies explicit prohibitions on *take* (to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect), there are provisions under Sections 7 and 10 of this Act that allow take during the course of otherwise lawful activities. Two general types of take are recognized under the ESA. *Directed take* is intentional capture or other interaction with sea turtles (e.g., for research purposes or mitigation of a known threat). Unintentional interaction with sea turtles is considered *incidental take*, and includes actions such as bycatch in fishing nets or entrainment in coastal power plants. Section 7 specifically involves the actions of federal agencies or those that they fund or authorize; for example, federally managed commercial fisheries or gas and petroleum development. These federal activities require a consultation process that comprehensively evaluates the effects of the activities on listed species. Incidental take may be exempted from the prohibitions of the ESA within the Section 7 consultation. Section 10 of the ESA deals with both directed take for research purposes and incidental take resulting from nonfederal activities. Any research involving directed take of sea turtles requires an ESA permit as defined under Section 10(a)(1)(A). Incidental takes may be authorized under Section 10(a)(2)(A). As a condition of the permit for incidental takes, an applicant must have an approved habitat conservation plan that outlines actions to minimize and mitigate negative impacts—this includes identifying funding for mitigation efforts. NMFS and USFWS also enforce other federal laws that apply to sea turtles in the US, including the Lacey Act of 1900, which restricts domestic trade in wildlife, and the Magnuson–Stevens Fishery Conservation and Management Act, which requires conservation of many protected marine species affected by fisheries bycatch.

**International treaties and agreements**—For most countries where sea turtles are protected by national laws, an international agreement has influenced this protection. These agreements are often the only protections for sea turtles in international waters, although there is the potential for inter-governmental organizations like the International Commission for the Conservation of Atlantic Tunas (ICCAT) to take sea turtles into account in managing the species for which their members fish.

Two critical agreements protecting sea turtles that are global in scope include the Convention on the Conservation of Migratory Species of Wild Animals of 1979 (CMA or the Bonn Convention) and the CITES (1973). The CMS addresses endangered species, including sea turtles that travel from one nation’s jurisdiction to another. The convention is a framework on which other conservation agreements can be based and that facilitates individual governments enacting their own laws to protect endangered migratory species. The CITES agreement protects sea turtles and other listed species by subjecting international trade to regulation. In each of the over 145 parties to the CITES agreement, import and export of sea turtles and their parts must be licensed through CITES, which relies on Scientific Authorities to advise them on the effects of trade on species survival. The sea turtles are listed under CITES on Appendix I, which includes species threatened with extinction and permits trade in specimens only in exceptional circumstances (https://cites.org/eng/app/index.php).

Other important and ground-breaking regional international sea turtle agreements include the Inter-American Convention (IAC) for the Protection and Conservation of Sea Turtles, and South-East Asian (IOSEA) Marine Turtle Memorandum of Understanding. The IAC is the only legally binding sea turtle treaty and provides the framework for American and Caribbean countries to take national actions to benefit sea turtles, including protective regulations and other conservation actions. The IOSEA is a nonbinding intergovernmental agreement with the goal of recovering sea turtles in the Indian Ocean and South-East Asia. It is an agreement that has status under the CMA. Other international agreements that tangentially protect sea turtles involve general protections for the marine environment such as the International Convention for the Prevention of Pollution from Ships (MARPOL), which establishes prohibitions on ocean dumping of plastic trash and petroleum.

**Do I need a permit to do this?**—Yes, you probably do. More than likely, conducting an activity that affects sea turtles or their eggs, even incidentally, or that involves holding or transport of individual turtles, including dead ones, or possession of sea turtle specimens or samples such as blood, scute, skin, bone, or DNA, including DNA artificially amplified by polymerase chain reaction, requires one or more permits. The institutional rules, legislation, and treaties listed above have provisions for these permits. In the US, federal and state agencies offer websites on permitting and application processes and other useful online resources. Consulting with someone who has the necessary permits for similar activities also can be informative.

**Threats to Sea Turtle Populations**

Sea turtle populations are principally threatened by harm from humans. This is not to say that various nonanthropogenic mortality factors have no effect on sea turtle populations—they do. But these factors do not explain the historical declines that sea turtles have incurred or the lack of recovery in many populations. It is also sensible to separate factors that
negatively affect sea turtle populations into those that can be managed and those that cannot. Anthropogenic threats to sea turtles all have some potential for reduction through management actions.

There are numerous sources containing lists of threats to sea turtles (Dodd 1988, NRC 1990, Seminoff 2004). But lists alone are minimally helpful in focusing conservation efforts to meet these challenges. Among manageable threats to sea turtles, useful analyses rate threats by their lethality, magnitude in turtles affected, and reproductive value of those individuals to the population (Bolten et al. 2010). Analyses like these allow general assessments of how effective conservation efforts might be in achieving population recovery. But allocating conservation resources requires much more. The varied landscape of sea turtle conservation opportunities also matters, as does the chain of results that must occur in order to achieve measurable conservation objectives. Recovery plans for sea turtles strive to outline this conservation landscape. Tools, such as the planning software Miradi (https://www.miradi.org), can facilitate the practice of evidence-based conservation (Sutherland et al. 2004).

How Rehabilitation and Aquarium Facilities Contribute to Understanding and Conserving Sea Turtles

Sea turtle rehabilitation and managed care are uniquely applicable to conserving sea turtles. The reasons for this are much more extensive than numbers of turtles saved by a facility. Turtles rescued, rehabilitated, and released back into the wild are indeed a measure of success, but this contribution to sea turtle recovery may be small in comparison to other results. For example, observations and study of sea turtles under care can yield valuable insight into elucidating pathways to disease, testing treatments, and assigning causes of morbidity and mortality to turtles that strand. Moreover, veterinarians, care staff, and others who work in these facilities frequently are engaged more broadly in activities that benefit sea turtles, applying their knowledge and experience to facilitate important research and various conservation initiatives.

Among the varied conservation roles that sea turtle care facilities can play, the most important is outreach. Solutions to sea turtle conservation challenges all involve changes in human behavior. A singular opportunity held by facilities that house sea turtles is to initiate those human-behavior changes by harnessing the charisma of the animals in need of help. Bringing people close to sea turtles moves these animals from abstract concepts to tangible elements of the human experience. And the turtles at care facilities that contribute to this experience can be especially engaging. Commonly, they are material witnesses with compelling stories of survival that outline the consequences of fisheries, boating, ocean trash, and other threats in ways that beg for human action. Because of the importance of education and outreach to the greater conservation mission of rehabilitation centers and aquaria, these facilities are nearly always destinations for people who desire a sea turtle experience. At these facilities, rescue, rehabilitation, and release, and the featuring of nonreleasable turtles takes place to further key conservation goals: to have people come to know sea turtles, care about them, and accept the responsibility to act to save them. These concepts are discussed in more detail in Chapter 2.

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REFERENCES


