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Kemp's Ridley Sea Turtle (*Lepidochelys kempii*) Head-Start and Reintroduction to Padre Island National Seashore, Texas

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Abstract.— **Kemp's Ridley (*Lepidochelys kempii*) is the most endangered sea turtle and is found in the Gulf of Mexico and North Atlantic Ocean. It nests in greatest numbers near Playa de Rancho Nuevo (RN), Tamaulipas, Mexico. Historically, nesting also occurred on beaches that, in 1962, became part of Padre Island National Seashore (PAIS) near Corpus Christi, Texas, USA. Kemp's Ridley was headed toward extinction when the Mexican government began protecting clutches of eggs (i.e., nests) and hatchlings at RN in 1966, but the population continued to decline. In 1974, the U.S. National Park Service (NPS) proposed reintroduction of Kemp's Ridley to PAIS. Further planning by NPS, U.S. Fish and Wildlife Service (FWS), National Marine Fisheries Service (NMFS), Texas Parks and Wildlife Department (TPWD), and Mexico's Instituto Nacional de Pesca (INP) ensued in 1977 and led to the bi-national Kemp's Ridley Restoration and Enhancement Program (KRREP) implemented in January 1978. Its goals were restoration of Kemp's Ridley through enhancement of nesting success and survival at RN, and reestablishment of a breeding population at PAIS. At the time, head-start (i.e., captive-rearing to sizes thought capable of avoiding most natural predators at sea) was considered essential to the second goal. Tagging and marking were necessary for identification after release, and mass-tagging hatchlings was not feasible. The NMFS Galveston Laboratory, Galveston, Texas, and collaborators head-started, tagged, and released the turtles into the Gulf of Mexico. NPS and collaborators documented nestings. We review head-start and its relationships to the KRREP and reintroduction of Kemp's Ridley to PAIS.**

Key Words.—captive-rearing; conservation; head-starting; *Lepidochelys kempii*; mark-recapture; release; tag returns; translocation; transport

Introduction

Kemp's Ridley (*Lepidochelys kempii*), also referred to as Atlantic Ridley, is the most endangered of the sea turtles. It has existed as a species for 2.5–3.5 million y (Bowen et al. 1991). Its geographic range is encompassed by the Gulf of Mexico (Pritchard and Márquez M. 1973; Zwinenberg 1977; Márquez et al. 2004; Guzmán-Hernández et al. 2007; Pritchard 2007; Ernst and Lovich 2009) and North Atlantic Ocean (Brongersma 1972, 1982; Tomás and Raga 2007; Witt et al. 2007; Insacco and Spadola 2010). According to National Marine Fisheries Service (NMFS) et al. (2011), most nesting takes place on beaches bordering the west-central Gulf of Mexico. The nesting epicenter is Playa de Rancho Nuevo (RN) near the Municipio de Aldama, in the State of Tamaulipas on the northeastern coast of Mexico (Fig. 1).

Nesting also occurs on other beaches in Tamaulipas, in Texas, and southward to Veracruz;

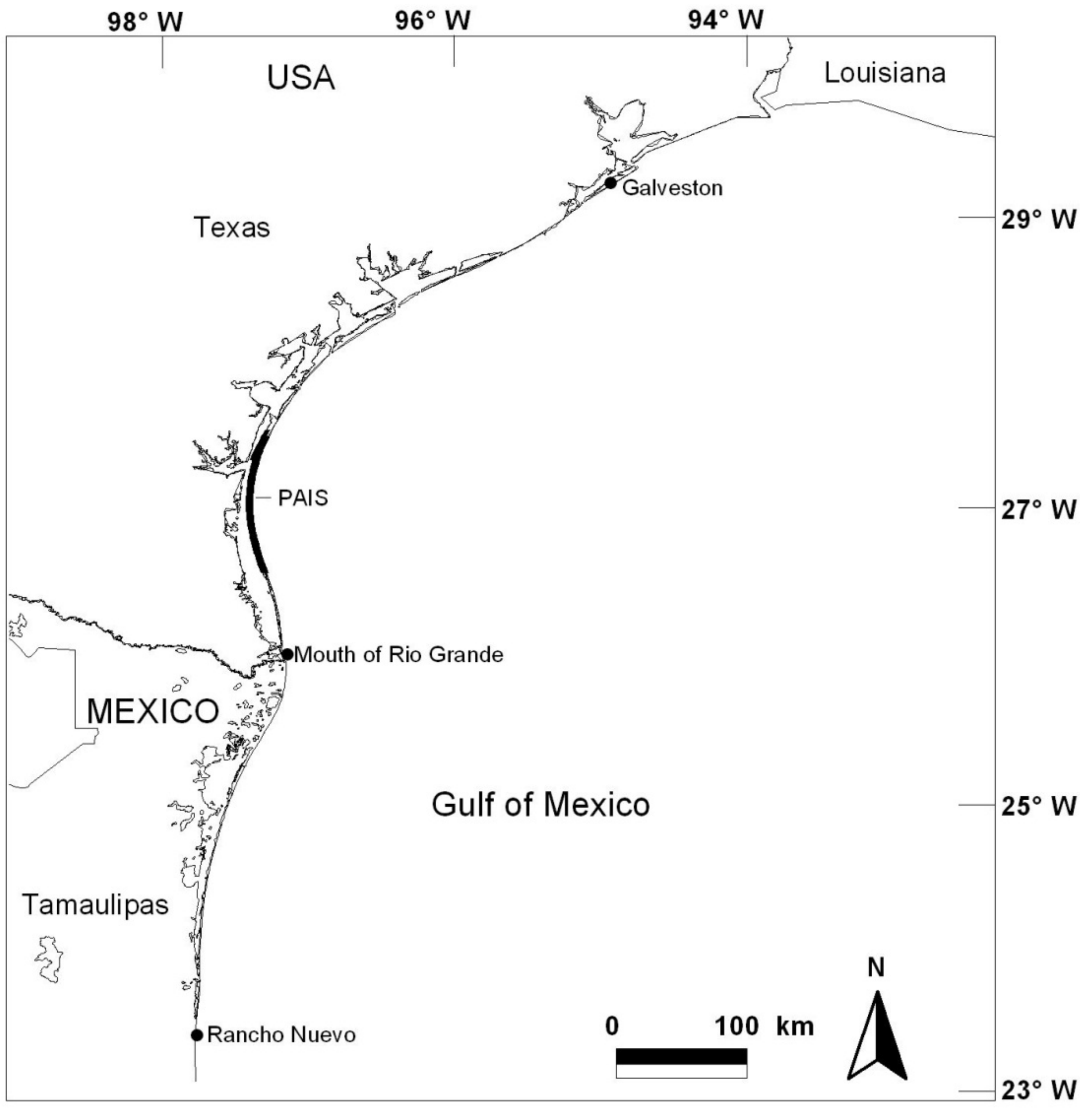

Figure 1. Western Gulf of Mexico showing locations of Galveston, Padre Island National Seashore, and Rancho Nuevo (map prepared by Cynthia Rubio, National Park Service).

nesting is sporadic elsewhere along Gulf of Mexico coasts of the U.S. and Mexico, and rare on the U.S. Atlantic coast (Márquez-M. 2001; NMFS et al. 2011). Werler (1951) was the first to report a Kemp's Ridley nesting (in 1948) in Texas, within the area later established in 1962 as Padre Island National Seashore (PAIS) near Corpus Christi, Texas (Fig. 1).

On 18 June 1947, Andrés Herrera recorded on movie film an enormous arribada (Spanish for arrival by sea) of Kemp's Ridley nesters near RN, representing the earliest recorded mass nesting for this species (Carr 1963, 1967; Hildebrand 1963; Burchfield and Tunnell 2004). Hildebrand (1963, 1982) estimated the size of the arribada at 40,000 and 42,000 nesters, respectively. Carr (1967) explained how Hildebrand (1963) estimated the 40,000 nesters. The 40,000 estimate later became a major benchmark among criteria established for Kemp's Ridley population recovery (U.S. Fish and Wildlife Service (FWS) and NMFS 1992; NMFS et al. 2011). Hildebrand (1963) noted that human exploitation of eggs at RN was a threat to survival of Kemp's Ridley arribadas and recommended that conservation measures be promulgated to prevent their extinction.

Beginning in 1966, Kemp's Ridley population status was indexed by annual numbers of nests (clutches laid) at RN (Heppell et al. 2005, 2007; Márquez-M. et al. 2005; NMFS et al. 2011; Gallaway et al. 2013). Annual numbers of nests on two more beach segments, Tepehuajes and Playa Dos-Barra del Tordo, were later added to the population index (Turtle Expert Working Group (TEWG) 2000; Márquez-M. et al. 2005; NMFS et al. 2011; Burchfield and Peña 2013; Gallaway et al. 2013).

Mexico's Instituto Nacional de Investigaciónes Biológico-Pesqueras, which later became the Instituto Nacional de Pesca (INP; Guzmán del Próo 2012), began protecting nests and hatchlings at RN in 1966 (Chavez et al. 1968), but annual nests continued to decline (Wauer 1978; FWS and NMFS 1992; NMFS et al. 2011). The decline reversed in 1986 (Caillouet 2006, 2010, 2014), with nests later increasing exponentially to more than 20,000 in 2009 (NMFS et al. 2011; Burchfield and Peña 2013; Gallaway et al. 2013; Caillouet 2014). Unanticipated drops in combined annual nest numbers at the three index beach segments in Tamaulipas occurred in 2010, interrupting the pre-2010 exponential increase (Caillouet 2011, 2014; Crowder and Heppell 2011; Allen 2013; Gallaway et al. 2013).

Our description of early attempts to reintroduce Kemp's Ridley to the lower coast of Texas is based on sources listed in Table 1. Andrés Herrera lent a copy of his movie to Fred Lockett who showed it at a meeting of the Valley Sportsmen Club, Brownsville, Texas, in 1962, and the film was discussed during subsequent meetings. Club member Grover Singer began promoting the idea of starting a Kemp's Ridley nesting colony on South Padre Island (SPI) as an attraction for residents and tourists. When Brownsville building contractor Dearl Adams became president of the club, Grover Singer visited him frequently and further promoted the idea. Dearl Adams became more interested in Kemp's Ridley after reading the first chapter of Carr (1956). Later he talked with Henry Hildebrand whom he had heard was transplanting Green Turtle (*Chelonia mydas*) hatchlings on the north end of Padre Island. Information provided by Henry Hildebrand was enough to get Dearl Adams interested from a conservation standpoint.

In 1963, 98 Kemp's Ridley eggs were obtained by Dearl Adams from Francis McDonald who operated a fishing camp called Campo Andrés at Barra del Tordo south of RN (see Fig. 2 in Márquez-M. et al. 2005; see also Fig. 3 in Burchfield and Peña 2013). They were flown to Brownsville and transported to SPI, where 91 were reburied on the beach and seven were kept in a tub of sand by Breuer (1971). Some eggs started development, but no hatchlings were produced. During 1964–1967, Dearl Adams and others collected more than 5,000 eggs at RN and reburied them at SPI (Phillips 1989; Size-

Table 1. Sources covering early attempts to reintroduce Kemp's Ridley (*Lepidochelys kempii*) to the lower coast of Texas.

Adams (1966, 1974)	Phillips (1989)
Breuer (1971)	Sizemore (2002)
Zwinenberg (1977)	Burchfield and Tunnell (2004)
Francis (1978)	Burchfield (2005)

more 2002; Burchfield 2005). Among those assisting Adams were Kavanaugh Francis, Earl and Olive Lippoldt, Ila Loetscher (who later became recognized as the Turtle Lady of SPI) and others (Sizemore 2002; Burchfield 2005). The eggs were transported by vehicle to SPI or flown to Brownville then transported by vehicle to SPI. During 1964–1967, 1,227 hatchlings were released into the Gulf of Mexico from SPI, with most (1,102 or 90%) released in 1967 (Zwinenberg 1977; Phillips 1989; Sizemore 2002; Burchfield 2005). At that time, Kemp's Ridley was thought to reach maturity in 5.5–8 y (Márquez 1972; Pritchard and Márquez 1973; Francis 1978).

Volunteers set up camp in 1973 and began daily patrols of the SPI beach from mid-April through June to search for evidence of adult females, and this continued annually through 1976. One Kemp's Ridley nesting was documented in 1974 and two in 1976. During 1974–1976, additional evidence of adult females in the area included sightings of nesters, turtle tracks on the beach, strandings of dead adult females (some mutilated), hatchling emergences, and one adult female caught (escaped unharmed) in a gill net. Francis (1978) believed the nestings resulted from the 1967 release of hatchlings, stating that there were no Kemp's Ridley conservation programs on SPI prior to 1967; he apparently discounted the combined releases of 125 hatchlings (i.e., 1,227-1,102 = 125) from SPI during 1964–1966. However, the observed nestings and other evidence of adult females in the SPI area during 1974–1976 could have been unrelated to the hatchling releases by Dearl Adams and others (Donna Shaver, pers. obs.); e.g., they might have involved surviving adult females from the pre-1966 residual population, or young adult females from early conservation efforts at RN.

Kemp's Ridley Restoration and Enhancement Program Planning Documents and Planners

***Documents and planners.*—**Beginning in August 2010, one of us (Caillouet) obtained information via e-mail exchanges, telephone conversations, or both with six of the major participants in the early planning (Table 2). We and Shaver and Caillouet (2015) also examined unpublished planning documents archived at PAIS headquarters (copies have since been archived at the National Park Service (NPS) Technical Information Center, Denver, Colorado):

(1) NPS. 1974. Natural Resources Management Plan for Padre Island National Seashore. Prepared by PAIS Staff and Southwest Region Office of Natural Science. Division of Natural Sciences, Southwest Region, NPS, Department of Interior, 23 December 1974. Roland H. Wauer (Chief Scientist) recommended this 5-y plan, John W. Henneberger (Associate Regional Director, Professional Services) concurred, and T. R. Thompson (Acting Regional Director) approved it; all were in the NPS Southwest Region, Santa Fe, New Mexico.

(2) Campbell, H.W. 1977. Feasibility Study: Restoration of Atlantic Ridley Turtle (*Lepidochelys kempii*) as a Breeding Species on the Padre Island National Seashore, Texas. Preliminary Report (USNPS Order # PX7029-7-0505), Gainesville Field Station, National Fish and Wildlife Laboratory, Gainesville, Florida. 2

Table 2. Six of the major participants in early planning of the Kemp's Ridley (*Lepidochelys kempi*) Restoration and Enhancement Program who were contacted by email, telephone, or both for information. (participant's affiliations in 1977 are included).

Roland ("Ro") H. Wauer, Chief, Division of Natural Resources Management, NPS Southwest Region, Santa Fe, New Mexico, U.S.A.
Jack B. Woody, Chief, Endangered Species, FWS Southwest Regional Office, Albuquerque, New Mexico, U.S.A.
Edward F. Klima, Director, NMFS Galveston Laboratory, Galveston, Texas, U.S.A.
James P. McVey, Chief, Aquaculture Research and Technology Division, NMFS Galveston Laboratory, Galveston, Texas, U.S.A.
Peter C. H. Pritchard, Vice President for Science and Research, Florida Audubon Society, Maitland, Florida, U.S.A.
Réne Márquez-M., National Sea Turtle Program Coordinator, INP, Mexico City, Mexico

November 1977. 23 p. including Appendices I-III. Prepared for NPS Southwestern Region, Santa Fe, New Mexico.
(3) NPS, FWS, NMFS, and Texas Parks and Wildlife [Department; TPWD]. 1977. Action Plan Restoration of Atlantic Ridley Turtle as a Breeding Species on Padre Island National Seashore, Texas 1978–1988. December 1977. 36 p. including Appendices I-III.
(4) NPS, FWS, NMFS, TPWD, and INP. 1978. Action Plan Restoration and Enhancement of Atlantic Ridley Turtle Populations Playa de Rancho Nuevo, Mexico and Padre Island National Seashore, Texas 1978–1988. January 1978. 30 p. including Appendices I–III.
(5) NPS. 1978. Environmental Assessment/Review/Negative Declaration, Restoration and Enhancement of Atlantic Ridley Turtle Populations Playa de Rancho Nuevo, Mexico and Padre Island National Seashore, Texas 1978–1988. NPS Southwest Region, February 1978. 9 p. Roland H. Wauer (Chief, Natural Resources Management, Southwest Region and Coordinator, Action Plan) recommended this assessment, and John E. Cook (Regional Director, NPS Southwest Region) concurred.

***Correcting misconceptions.*—**None of us participated in the early planning or early years of execution of head-start or reintroduction. Donna Shaver became involved in the reintroduction efforts by NPS at PAIS in May or June 1980. In October 1981, Charles Caillouet became involved in head-start efforts conducted by the NMFS Galveston Laboratory (hereinafter referred to as Galveston Laboratory). André Landry and his graduate students at Texas A&M University Galveston collaborated in research related to head-start with the Galveston Laboratory beginning in July or August 1984.

Upon close examination of the early planning documents, we became aware of misconceptions and misrepresentations within the literature about the planning for reintroduction, head-start, and their roles within the Kemp's Ridley Restoration and Enhancement Program (KRREP; NPS et al. 1978 *op. cit.*). Unfortunately, we perpetuated some of the misconceptions and misrepresentations in our own publications. The literature contains varying accounts of early planning of reintroduction and head-start, as well as varying opinions regarding their adequacy as experiments or conservation methods (see **EVALUATIONS**). In addition, many important details of early planning have been overlooked, ignored, or forgotten until now. Fortunately, the unpublished planning documents were preserved and provide important details of early planning that can now be compared to published accounts in the literature. We focus needed attention on these historical documents and the planners, because together they provide necessary background and perspective essential to evaluation of reintroduction and head-start. They show that early planning was science-based, thorough, ambitious, optimistic, and remarkably detailed.

Most of the literature covering Kemp's Ridley head-start and reintroduction treat them as if they are equivalent. They certainly were related but definitely not equivalent. Although head-starting of the 11 year-classes (1978–1988) that were putatively imprinted at PAIS was essential to reintroduction, reintroduction was not essential to head-starting the 23 year-classes (1978–2000) that were putatively imprinted at either PAIS or RN. It is essential that readers keep this distinction in mind, because most publications to which our review refers do not make this distinction. Attempts at imprinting were based on a working hypothesis that imprinting was essential to the goal of reintroducing Kemp's Ridley to PAIS. Knowledge of the mechanisms of imprinting, navigation, and homing in sea turtles was limited at the time of early planning and initiation of Kemp's Ridley head-start and reintroduction (Allen 1981). Eggs and hatchlings taken for head-start and reintroduction were intentionally exposed to environmental conditions that were expected to imprint them to PAIS or RN. It also was expected that at least some surviving females would later mature and return to nest at PAIS or RN, where eggs or hatchlings had been putatively imprinted. Herein we use the terms imprint, imprinting, and imprinted only for convenience. They are not meant to imply that the turtles actually imprinted to PAIS or RN, or that surviving females from these treatment groups were thereby predisposed to return to nest at the beaches where they were putatively imprinted.

In addition, we acknowledge that conditions to which the turtles were exposed during head-starting in captivity at the Galveston Laboratory may have altered their behavior, performance, and survivability following release. We emphasize that head-start and reintroduction were not designed or conducted to test hypotheses about imprinting, navigation, or homing.

Head-start and reintroduction to PAIS have been referred to in the literature as experimental, experiments, operations, projects, programs, and even ranching (Table 3). Kemp's Ridley had previously nested at PAIS (Werler 1951; Hildebrand 1963; Carr 1967; NPS 1974 *op. cit.*; NPS et al. 1978 *op. cit.*; Wauer 1978, 2014). Most International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) guidelines for reintroductions (IUCN/SSC 1998) were fulfilled during Kemp's Ridley reintroduction to PAIS. Nevertheless, characterization and adequacy of head-start and reintroduction as experiments have been challenged (see **EVALUATIONS**). We emphasize that head-start and reintroduction were not planned or executed as hypothesis-testing experiments (Klima and McVey 1982; Woody 1986; Eckert et al. 1994; Pritchard and Owens 2005; Shaver and Caillouet 2015), although necessary research and experimentation occurred in conjunction with both. Head-start and reintroduction were largely operational and highly manipulative (Meylan and Ehrenfeld 2000), although scientific considerations influenced their planning and guided their execution, oversight, and evaluation.

Reintroduction and head-start are generally thought to have been planned as ancillary or subsidiary parts of the KRREP, which was not the case (Wauer 1978). In 1974, NPS developed the first plan for reintroduction of Kemp's Ridley to PAIS (NPS 1974 *op. cit.*; Wauer 1978), and the combination of reintroduction and head-start was the primary focus of planning in 1977 and 1978 (Campbell 1977 *op. cit.*; NPS et al. 1977 *op. cit.*, 1978 *op. cit.*). Lest this early focus be misconstrued, recovery priorities later shifted appropriately toward greater focus on protecting nesting beaches, nesters, eggs, and hatchlings in Tamaulipas, developing turtle excluder devices (TEDs) for shrimp trawls, and promulgating and enforcing regulations requiring TEDs in shrimp trawls (FWS and NMFS 1992; NMFS et al. 2011). Although the early planners included head-start as an essential part of reintroduction,

Table 3. Sources that referred to Kemp's Ridley (*Lepidochelys kempii*) head-start and reintroduction to Padre Island National Seashore as experimental, experiments, operations, projects, programs, or ranching.

Pritchard (1976)	Donnelly (1994)
Wauer (1978, 2014)	Ross (1999)
Woody (1981, 1986, 1989, 1990, 1991)	Meylan and Ehrenfeld (2000)
Klima and McVey (1982)	Márquez M., R. (2001)
Magnuson et al. (1990)	Márquez M. et al. (2005)
U.S. Fish and Wildlife Service and National Marine Fisheries Service (1992)	National Marine Fisheries Service et al. (2011)

they made no recommendations or commitments in the early plans to test head-start as a separate conservation method or management tool.

Controversy and conflict.**—**From their beginning in 1978, Kemp's Ridley reintroduction and head-start were controversial within the sea turtle science and conservation communities, despite the good intentions of the early planners, unanimous agreement among them and their agencies, and advice, concurrence, encouragement, and oversight of well-known and respected sea turtle authorities. Bowen and Karl (1999) described sea turtle conservation as war in the sense that deep tensions exist between science and advocacy, and suggested that scientific findings are sometimes misused to promote conservation goals. Tensions deepened when sea turtle science and advocacy began to impinge on the shrimping industry. Ironically, over the years some proponents became opponents and vice versa.

Head-start and reintroduction were drawn into the conflict over incidental capture of sea turtles in shrimp trawls (Magnuson et al. 1990) and NMFS regulations requiring TEDs in shrimp trawls (Condrey and Fuller 1992; Iversen et al. 1993; Yaninek 1995; Epperly 2003). Magnuson et al. (1990) concluded: "Of all the known factors, by far the most important source of deaths was the incidental capture of turtles (especially loggerheads and Kemp's ridleys) in shrimp trawling. This factor acts on the life stages with the greatest reproductive value for the recovery of sea turtle populations." Life stages with the greatest reproductive value are large subadults and adults (NMFS et al. 2011), but all post-pelagic Kemp's Ridley life stages are vulnerable to incidental capture in shrimp trawls. U.S. government responses to the controversy and conflict influenced the direction and duration of various components of reintroduction and head-start, thereby adding to the challenges of carrying out these experiments. Sea turtle conservation and research require patience, resilience, and persistence.

Components of head-start and reintroduction.**—**Table 4 lists some sources that reviewed the components of head-start and reintroduction. Most of these components were elucidated in the video (TPWD. 2010. Saving the Kemp's Ridley Sea Turtle. Available from http://www.youtube.com/watch?v=afgsYchpD_Q [Accessed 6 December 2012]). Operational components of reintroduction combined with head-start, based on about 2,000 or fewer eggs taken annually from RN during 1978–1988, included: (1) collecting, transporting, and incubating clutches of eggs; (2) attempting to imprint eggs and hatchlings; (3) transporting hatchlings to the Galveston Laboratory; (4) head-starting hatchlings at the Galveston Laboratory to sizes thought capable of avoiding most natural predators at sea; (5) tagging head-started turtles in multiple ways at the Galveston Laboratory; (6) transporting head-started yearlings (7–15 mo of age) to release sites in the Gulf of Mexico or adjoining bays; (7) releasing head-started year-

Table 4. Sources that reviewed the components to Kemp's Ridley (*Lepidochelys kempii*) head-start and reintroduction.

Wauer (1978, 2014)	Phillips (1989)
Klima and McVey (1982)	Marquez-M (1994)
Caillouet (1984, 1987, 2000)	Shaver and Caillouet (1998, 2015)
Fontaine and Caillouet (1985)	Shaver (2001, 2005, 2006, 2007)
Fontaine et al. (1985 1988b, 1989a, 1989b)	Higgins (2003)
Márquez M., R. (2001)	Fontaine and Shaver (2005)
Caillouet et al. (1986b, 1988, 1993, 1995a, 1995b, 1995c, 1997a)	

lings; (8) collecting, examining, and interpreting tag returns for head-started turtles; (9) tracking some of the head-started turtles via radio, sonic, and satellite transmitters and receivers; and (10) documenting nestings of head-started turtles in the wild.

Table 5 lists sources covering precautions taken to prevent the eggs for the reintroduction experiment from coming in contact with RN sand. Eggs were carefully placed in PAIS sand within Styrofoam™ boxes and transported to PAIS where they were incubated in the boxes. Hatchlings that emerged were allowed to crawl down the PAIS beach to the surf; after swimming a short while they were scooped up in dip nets, put in cardboard or plastic boxes, and transported to the Galveston Laboratory to be head-started. Putative imprinting at PAIS was terminated in 1989 with release of the 1988 year-class of hatchlings (Woody 1990, 1991), but components (8) and (10) of reintroduction continued and are ongoing (Shaver and Caillouet 2015). Components (1) and (2) were conducted whenever Kemp's Ridley nestings were documented at PAIS and other Texas beaches, whether laid by head-started (including PAIS-imprinted and RN-imprinted turtles) or wild individuals (Shaver and Caillouet 2015).

Head-start also included all components, but it was conducted on 23 year-classes (1978–2000) by the Galveston Laboratory and its collaborators. For the 1989–1992 year-classes, about 2,000 or fewer hatchlings per year were transferred directly from RN (where they were putatively imprinted) to the Galveston Laboratory for head-start. In 1993, the annual number of hatchlings received by the Galveston Laboratory from RN was reduced to about 200 or fewer per year (Byles 1993; Williams 1993; Caillouet 2005, 2006; Shaver and Wibbels 2007). Because head-start methods were applied to year-classes 1993–2000, we consider these year-classes to have been head-started. However, they are referred to by NMFS as captive-reared for research purposes (Benjamin Higgins pers. comm.). Some individuals of the 2000 year-class were not released in 2001, but were kept in captivity for use in a PIT tag migration experiment (Wyneken et al. 2010) then released in 2003 (Benjamin Higgins, pers. comm.). In addition, 100 Kemp's Ridley hatchlings collected from SPI in 2013 were captive-reared at the Galveston Laboratory, then survivors were

Table 5. Sources covering precautions taken to prevent clutches of Kemp's Ridley (*Lepidochelys kempii*) eggs, collected for the Padre Island National Seashore reintroduction experiment, from coming in contact with Rancho Nuevo sand.

Fontaine et al. (1985 1988b, 1989a, 1989b)
Fontaine and Shaver (2005)
Higgins (2003)
Klima and McVey (1982)
Shaver (2001, 2005, 2006, 2007)
Shaver and Caillouet (2015)
Wauer (1978, 2014)
Woody (1986)

used in TED tests and released offshore of SPI in 2014 (Benjamin Higgins, pers. comm.). The search for Kemp's Ridleys that were head-started or captive-reared by the Galveston Laboratory and released into the wild has continued (Shaver and Caillouet 2015), whether or not they were associated with the reintroduction experiment.

All KRREP activities proposed by NPS et al. (1978 *op. cit.*) were to be conducted for 11 y (1978–1988), including the work at RN, PAIS, and the Galveston Laboratory (Woody 1986, 1990, 1991). However, the emphasis on reintroduction was clear. Under heading "III. Program Activities" (NPS et al. 1978 *op. cit.*), items A and B were related to reintroduction; item C covered beach monitoring to protect nesters and eggs at RN, as well as collection of 2,000 eggs for PAIS reintroduction and up to 2,000 hatchlings for head-start; item D covered research at RN; and items E–G covered care of hatchlings at RN and PAIS, other operations at PAIS, transport of hatchlings to the Galveston Laboratory, head-start, release, and monitoring.

With regard to accomplishments and evaluations of head-start and reintroduction, our review focuses on activities carried out by the Galveston Laboratory and its collaborators. We also review captive breeding, because some head-started Kemp's Ridleys from year-classes 1978, 1979, 1982, and 1984 were distributed among marine aquaria for development of a captive brood stock (Table 6). Shaver and Caillouet (2015) cover Kemp's Ridley reintroduction, related conservation and research on the turtles imprinted at PAIS and RN, and the labor-intensive nester search and detection program on-going at PAIS and elsewhere along the Texas coast.

Table 6. Sources covering distribution of head-started Kemp's Ridleys (*Lepidochelys kempii*) from year-classes 1978, 1979, 1982, and 1984 among marine aquaria for development of a captive brood stock.

Balazs (1979)
Brongersma et al. (1979)
Caillouet (2000)
Caillouet and Revera (1985)
Caillouet et al. (1986b, 1986c, 1988)
Márquez-M et al. (2005)
Mrosovsky (1979)

Details of Early Planning

The first plan.—After we learned about Roland Wauer's involvement in the early planning, one of us (Caillouet) found out, serendipitously, that Wauer was scheduled to present a seminar on birds at a plant nursery (Martha's Bloomers) in Navasota, Texas on 14 August 2010. He contacted Wauer and attended the seminar to meet and interview Wauer, who graciously gave him a copy of Wauer (1999). Wauer (1999) described early planning of a project "to provide increased protection to nesting Atlantic Ridley turtles, and to restore a nesting population to Padre Island, Texas"; the Galveston Laboratory's participation in the project was also described, but not referred to as head-start. However, Wauer (1978) had already referred to it as head-start. Wauer (pers. comm.) indicated that a Resources Management Plan for PAIS contained a project statement relevant to reintroduction (Wauer 1978). Another of us (Shaver) located this plan (NPS 1974 *op. cit.*) in the PAIS headquarters archives; it contained Project No. 9 entitled Atlantic Ridley Turtle Reestablishment. She found out from Robert Whistler (Donna Shaver, pers. comm.) that he drafted NPS (1974 *op. cit.*), as Chief Naturalist for PAIS. Robert Whistler (pers. comm.) admitted that he knew little about sea turtles at the time, but learned from Henry Hildebrand who influenced development of Project No. 9, described as follows (verbatim from NPS 1974 *op. cit.*):

Project: Atlantic Ridley Turtle Reestablishment

"Padre Island was once a major nesting site of the Atlantic Ridley turtle. Accounts from old-time residents relate how they traveled by wagons along the beach and had to wait while turtles traveled from their nests to the water. This species is no longer known to nest within the United States. It does nest on the coast of Mexico where it is protected, but eggs are quickly collected and sold when authorities are absent. The species may be endangered and should be considered for reintroduction onto Padre Island which may be its only protected nesting site.

Action (Research): Initiate research, and proceed with actions deemed conducive to the reintroduction of the species. First, vehicles must be restricted from a section of beach; vehicles should not be permitted to drive over the nests and destroy the eggs. At the present time, there is no feasible section. However, the Master Plan proposes closing Little Shell Beach to vehicular traffic, and this beach could be used as a nesting area. Investigate the desirability of a cooperative agreement with Mexico for the collection and transportation of turtle eggs. Establish liaison with other agencies and individuals who have shown interest in the population dynamics of the Ridley turtle. Encourage the use of Padre Island as a natural laboratory.

Research: This study could best be undertaken by a Park Service biologist; investigations should be initiated soon if this species is to be saved from extirpation. Research activities should include: (1) comparative habitat evaluation, (2) feasibility of collection of turtle eggs from Mexican beaches and introduction on a protected beach of Padre Island National Seashore, and (3) a monitoring program."

Oddly, Robert Whistler was not mentioned in NPS (1974 *op. cit.*), but Roland Wauer (pers. comm.) confirmed that Robert Whistler drafted it. Project No. 9 appears to be the earliest written proposal for reintroduction of Kemp's Ridley to PAIS. It provided succinct rationale and explicit aims for reintroduction of Kemp's Ridley to PAIS and called for research that could be considered pre-monitoring, elements that were later thought to have been absent in the planning (Mrosovsky 2007). A chapter drafted by Robert Whistler (Whistler, R. 2005. Padre Island Administrative History Chapter Eight: Natural Resource Issues. Available from http://www.cr.nps.gov/history/online_books/pais/adhi8.htm [Accessed 6 December 2012]); Donna Shaver pers. comm.) explained that he and Henry Hildebrand "combined efforts to propose the turtle project in 1974" and sought support and possible funding from NPS and other federal agencies, but support and funding were not forthcoming. NPS (1974 *op. cit.*) scheduled the reintroduction project to begin in the fifth year of the plan; we assume that was to be 1979, but it was implemented one year earlier (NPS et al. 1978 *op. cit.*; Wauer 1978).

Wauer (1999) indicated that Clyde J. Jones (Director, National Fish and Wildlife Laboratory, National Museum of Natural History, Washington, D.C.) and he "...had developed the idea, initiated a feasibility study that was done by [Howard W.] Duke Campbell, and had invited several sea turtle scientists to participate" as members of "the initial advisory group" that included Drs. Archie Carr, Henry Hildebrand, and René Márquez. Roland Wauer (pers. comm.) clarified that "the idea" was the decision made in December 1976 to pursue further planning and implementation of Project No. 9 (NPS 1974 *op. cit.*). Woody (1989) also confirmed that "...NPS proposed discussions of a project whose goal would be to establish a nesting population of [Kemp's Ridley] sea turtles at the Seashore" (i.e., at PAIS); he also confirmed that "The possibilities of such a project were discussed in 1976 and 1977 between regional representatives of FWS and NPS..."

NPS et al. (1977 *op. cit.*) listed members of a Science Advisory Board (SAB), including Archie Carr (University of Florida), Henry Hildebrand (Texas A&I University), René Márquez-M. (University of Mexico), and Peter Pritchard (Florida Audubon Society), who would serve as consultants. Roland Wauer and Robert Whistler participated in further planning during 1977 and 1978, so it is surprising indeed that neither NPS (1974 *op. cit.*) nor its Project No. 9 were mentioned in any of the 1977–1978 planning documents we examined. It is also noteworthy that NPS (1974 *op. cit.*) did not mention head-start or enhanced protection at RN, both of which were later recommended by Campbell (1977 *op. cit.*) of FWS.

Resumed planning.—Interestingly, Pritchard (1976) recommended head-starting as well as perfection and wide spread adoption of a trawl net equipped with a wide-mesh guard that would keep turtles out, to improve survival prospects for Kemp's Ridley and to supplement ongoing Mexican beach protection in Tamaulipas. He recognized that captive-reared turtles might become dependent on artificial feeding, lose their proper fear of man, or fail to navigate properly to their nesting beach once they reached maturity; nevertheless, he considered head-start worth trying as an experiment. In May 1977, Carr (1977) called for drastic action to prevent Kemp's Ridley from disappearing:

> "The species is clearly on the skids, and if present conditions continue it will shortly - in two years perhaps, or three, or five - be gone. The dramatic drop during the 1950's was caused by over-exploitation combined with very heavy natural predation pressures. The terminal decline now in progress has been brought about by incidental trawler catch. When ridleys were many and shrimping was less intensive this factor was negligible. Today it is wiping out the species."

Table 7. Additional sources of information on early planning of the Kemp's Ridley (*Lepidochelys kempii*) Restoration and Enhancement Program.

Klima and McVey (1982)
Woody (1986, 1989)
Fletcher (1989)
Dodd and Seigel (1991)
Godfrey and Pedrono (2002)
Caillouet, C.W., Jr. circa 1999. Marine Turtle Newsletter articles on status of the Kemp's Ridley population and actions taken toward its recovery. Available from http://www.seaturtle.org/mtn/special/kemps.shtml [Accessed 4 December 2014].

This desperate situation apparently prompted NPS, FWS, NMFS, TPWD and Mexico's INP to begin planning the KRREP in 1977, and to implement it in 1978 (NPS et al. 1978 *op. cit.*; Wauer 1978). The KRREP's stated goals were restoration of Kemp's Ridley through enhancement of nesting success and survival at RN, and reestablishment of a breeding population at PAIS. Head-start was considered essential to the second goal. Early planning for the KRREP was also discussed by sources listed in Table 7.

Roland Wauer played the central role in guiding and facilitating the planning during 1977 and early 1978. He compiled the draft action plan (NPS et al. 1977 *op. cit.*) and the final Action Plan (NPS et al. 1978 *op. cit.*) with input provided by participating individuals and agencies (Wauer 1978). During the 1978 nesting season, he traveled to RN (Pritchard and Gicca 1978), assisted in collecting and packing eggs in PAIS sand for transfer to PAIS (Wauer 1978), and accompanied the resulting hatchlings on their flight from PAIS to Galveston (Roland Wauer, pers. comm.). We also learned that R. Bruce Bury accompanied Roland Wauer to RN in 1978 to participate in oversight and implementation of efforts to ensure that the eggs to be moved to PAIS did not contact RN beach sand (R. Bruce Bury, pers. comm.). According to Pritchard and Gicca (1978), scientific visitors that were present for various periods during the first season of work associated with the KRREP included Patrick Burchfield (Brownsville coordinator for the project), Bruce Bury, Howard Campbell, Thomas Fritts, Roland Wauer, and Jack Woody (Project Coordinator).

Feasibility study.—The feasibility study (Campbell 1977 *op. cit.*) provided rationale, explicit aims, and pre-monitoring for reintroduction (see Mrosovsky 2007). It encompassed biological justification as well as mechanical and political possibility for reintroduction. This study progressed in simultaneous phases including: (1) documentation of Kemp's Ridley as a native breeding species on the PAIS; (2) review of mechanical and biological problems associated with moving sea turtle eggs from the natal beach to establish new or reintroduced colonies; and (3) contacts with all agencies and individuals required for an operation of such complexity, to determine their willingness and potential to contribute to the effort.

The study began in May 1977 with a literature review and contacts with authorities expected to possess unpublished data, including Archie Carr, Henry Hildebrand, Frank Lund (University of Florida, Gainesville, Florida), Réne Márquez-M., and Peter Pritchard; all of them contributed collectively and significantly to this data gathering effort. Early participation by such highly respected sea turtle scientists who were particularly knowledgeable of Kemp's Ridley is noteworthy. Ila Loetscher (Sizemore 2002) and Earl Lippoldt also provided valuable unpublished data. In July-August 1977, physical suitability of the PAIS beach was examined by land and from the air and compared to that at RN. Contacts also were made with representatives of TPWD, NMFS, FWS (Office of Endangered Species), and various academic and conservation organizations to discuss their interest in and potential contributions to the program, and the challenges of the program.

Campbell (1977 *op. cit.*) contained results and recommendations for consideration in further planning and commitment of resources. His was the first planning document to mention head-start, among those we examined. Campbell (1977 *op. cit.* Appendix II) recommended that head-start be combined with transplanting eggs and hatchlings to reintroduce Kemp's Ridley to PAIS. Clearly, tagging of head-started turtles was needed to provide the essential means of linking them to head-start and reintroduction after their release. Otherwise, it would have been necessary to tag and release hatchlings to make it possible to evaluate reintroduction and head-start. At that time, the technology for mass-tagging Kemp's Ridley hatchlings had not been developed (Pritchard 1979; Allen 1981; Fontaine et al. 1993; Higgins et al. 1997).

The literature review and correspondence conducted by Campbell (1977 *op. cit.*) produced no evidence of large-scale breeding aggregations of Kemp's Ridley at PAIS, but indicated that individual nestings had occurred with some regularity at PAIS over the preceding decade, not only by Kemp's Ridley but also by other sea turtle species. Hatching success of Kemp's Ridley and other species showed that eggs were fertile and physical characteristics of the beach were suitable for incubation. No obvious physical problems were discovered regarding the PAIS beach, and strong similarities were revealed between nesting beaches at PAIS and RN. Beach slope and profile, sand grain size, and other physical characteristics were essentially the same. Differences in air and water temperatures at the two nesting sites were minimal during the nesting season and therefore considered unimportant. Mechanical and biological problems associated with transplanting sea turtle eggs were considered resolved over many preceding years, and the process of transplanting eggs was considered routine for experienced personnel. Moving and incubating eggs, hatching them, and rearing young sea turtles had been accomplished throughout the world and were continuing. The only area of uncertainty identified by the feasibility study was that of "actually establishing new colonies on new beaches." No clearly successful transplant had previously been achieved. Apparent failure of previous transplant attempts was attributed to poor understanding of imprinting of hatchlings to their natal beach, enormous first-year mortality of hatchlings, and lack of a suitable method for tagging hatchlings so they could be recognized later when they were adults. There also was concern that the population could not support any removal of eggs from RN for reintroduction to PAIS. Recognizing that this was subjective and difficult to assess, Campbell (1977 *op. cit.*) recommended an initial approach designed to be compensatory and minimize this potential problem. For reintroduction, 2,000 eggs would be transferred from RN to PAIS and the resulting hatchlings transferred to the Galveston Laboratory for head-start; in addition, 2,000 hatchlings would be transferred from RN to the Galveston Laboratory for head-start. Campbell (1977 *op. cit.*) expected that "captive rearing of as many hatchlings from the Mexican beach as are removed to Texas should return more adults to Mexico than would the natural recruitment from the eggs removed to Texas if the "head starting" concept has any validity at all." However, 2,000 eggs were not equivalent to 2,000 hatchlings (i.e., hatch rate was less than 100%). In any case, Campbell (1977 *op. cit.*) apparently expected hatch rate as well as survival rate during head-starting to be higher than had these eggs or hatchlings been left at RN. In retrospect, as long as enough head-started turtles survived and returned to reintroduce nesting to PAIS, it did not matter whether or not head-starting increased survival from hatchling to nester life stages to the extent expected by Campbell (1977 *op. cit.*). It is also possible that Campbell (1977 *op. cit.*) included such ambitious expectations to elicit agreement from all parties. A related question is whether Campbell (1977 *op. cit.*) expected higher survival rates in head-started Kemp's Ridleys after their release than those of wild counterparts of the same sizes and ages, but there is no way to answer this question. Regardless, head-starting was essential to grow the turtles to sizes at which they could be safely tagged, so they could be linked (by their tags, after release into the Gulf) to experimental reintroduction and head-start upon recapture or nesting. Interest in and concern for Kemp's Ridley was high among all individuals and agencies contacted by Campbell (1977 *op. cit.*), and support among the agencies for the proposed reintroduction was unanimous.

Campbell (1977 *op. cit.* Appendix II) listed five options (paraphrased, but in their original order) for recovery of the Kemp's Ridley population: (1) protection of the known nesting beach, (2) reduction in incidental kill by fisheries operations, (3) establishment of breeding populations in protected areas in Texas, (4) enhancement of recruitment into the Mexican population, and (5) establishment of a captive breeding population. Options (3) and (4) constituted the core of the report's recommendations. Interestingly, option (5) was considered highly desirable and perhaps critical for egg production if the natural breeding stock were lost before full recovery. Option (1) was recognized as ongoing and critical to long-term survival of Kemp's Ridley, but in need of emphasis. Option (2) was in progress and considered necessary for survival of most sea turtle species, but unlikely to be realized within the expected 2–10 y remaining for Kemp's Ridley. Campbell (1977 *op. cit.*) noted that PAIS represented a potentially secure breeding ground for Kemp's Ridley where disturbance to breeding and nesting could be controlled with minimum enforcement effort.

Campbell (1977 *op. cit.*) listed the following factors as the minimum necessary for potential success of the proposed reintroduction, recognizing that some of them were too new to be fully evaluated before they were attempted: (1) incubation of eggs in sand from PAIS to avoid possible chemical imprinting to RN sand, and essentially natural orientation exposure of hatchlings to the natal beach and offshore waters at

PAIS, (2) captive-rearing for 0.5–1 y to a size at which mortality due to predators is reduced, (3) adequate technique for marking young turtles to allow their recognition as adults, and (4) release of captive-reared turtles of a given year-class in an area and habitat consistent with their age, place, and time of naturally occurring (i.e., wild) young of the same year-class. All these factors considered necessary for potential success were operational, and much less stringent than the more elaborate evaluation criteria that were later added as reintroduction and head-start efforts progressed (see **EVALUATIONS**). The above list of factors also suggests that establishing more stringent evaluation criteria to measure success before reintroduction was attempted would have been premature, because the immediate and primary goal was saving the declining Kemp's Ridley population from extinction (see Mrosovsky 2007).

Roland Wauer, Howard Campbell, and John C. Smith (Non-Game Project Leader, TPWD, Rockport, Texas) presented results and recommendations of the feasibility study to the Joint Secretary's and Southwest Regional Advisory Boards at Padre Island on 26 September 1977 (Campbell 1977 *op. cit.* Appendix I). We assume these "Advisory Boards" represented the Secretaries of the U.S. Department of the Interior (for NPS and FWS) and the U.S. Department of Commerce (for NMFS, within the National Oceanic and Atmospheric Administration, NOAA), and the Southwest Regional Directors of NPS and FWS; however, the NMFS Southeast Regional Director was not mentioned. After the 26 September 1977 presentation, TPWD expressed interest in conducting negotiations with government agencies in Mexico. Appendix I in Campbell (1977 *op. cit.*) was a very important memorandum from Theodore R. Thompson (Deputy Regional Director, NPS Southwest Regional Office) to the Director of the NPS [whose name was not shown, but William J. Whalen held the position], dated 7 October 1977. Its subject was "Restoration of the Atlantic Ridley Turtle as a Cooperative Interagency Project"; it summarized the meeting of 26 September 1977 and stated that: "The State of Texas already has talked with Mexico about obtaining turtle eggs. The Texas Department of Parks and Wildlife will host a meeting in late November for agency personnel to develop a plan of attack and a timetable. I believe that this gathering should heavily involve Regional level personnel, who will follow through on activities already started. It is particularly important that the National Park Service, Fish and Wildlife Service, and the National Marine Fisheries Service cooperate fully. Each agency must play a significant role if the project is to be successful." This memorandum confirmed that the State of Texas negotiated the transfer of Kemp's Ridley eggs from RN to PAIS for reintroduction, and it also mentioned the meeting that TPWD would later host in Austin, Texas on 17 November 1977, as scheduled in Campbell (1977 *op. cit.*) and NPS et al. (1977 *op. cit.*).

Draft action plan.—A draft "Restoration Plan for the Atlantic Ridley Turtle" was distributed by letter dated 28 November 1977 from Roland Wauer to "all of the Austin participants" (Table 8); the reference to "Austin participants" apparently referred to the 17 November 1977 meeting held in Austin, Texas (Campbell 1977 *op. cit.*; NPS et al. 1977 *op. cit.*). Roland Wauer did not refer to this draft as an action plan, but he mentioned head-start. Interestingly, the "Austin participants" represented NPS, FWS, NMFS, and TPWD, but not Mexico. Roland Wauer indicated that he had corresponded with "Archie, Peter, Henry and Rene" (i.e., Carr, Pritchard, Hildebrand, and Márquez-M., respectively) asking them to serve on the "Science Board" (i.e., the SAB), but did not mention whether they were sent copies of the draft plan. We assume they were sent copies, because Wauer's letter requested that recipients of the draft plan add details on what was planned for the RN phase of the program so that he could prepare the final plan, and he expressed hope that the plan would

Table 8. List of all Austin participants to whom Roland Wauer sent copes of the Draft Restoration Plan for the Atlantic Ridley Turtle (*Lepidochelys kempii*) via his letter 28 November 1977.

Bill Brownlee, Texas Parks and Wildlife (TPWD), Austin, Texas, U.S.A.
Dr. Duke Campbell, U.S. Fish and Wildlife Service (FWS), Gainesville, Florida, U.S.A.
Ted Clark, TPWD, Austin, Texas, U.S.A.
John Dennis, National Park Service (NPS) Washington Support Office (WASO-550), Washington, D.C., U.S.A.
Dr. Don Eckberg, National Marine Fisheries Service (NMFS), St. Petersburg, Florida, U.S.A.
Hal Irby, TPWD, Austin, Texas, U.S.A.
Dr. Clyde Jones, FWS, Washington, D.C., U.S.A.
Carol Justice, FWS. Washington, D.C., U.S.A.
Dr. Ed Klima, NMFS, Galveston, Texas, U.S.A.
Dr. James P. McVey, NMFS, Galveston, Texas, U.S.A.
Floyd E. Potter, Jr., TPWD, Austin, Texas, U.S.A.
John Turney, NPS PAIS, Corpus Christi, Texas, U.S.A.
Robert G. Whistler, NPS PAIS, Corpus Christie, Texas, U.S.A.
Jack Woody, FWS, Albuquerque, New Mexico, U.S.A.

be finalized before mid-December 1977.

NPS et al. (1977 *op. cit.*) probably was the draft plan mentioned in Roland Wauer's letter of 28 November 1977 because it did not include details of "research to be conducted at Rancho Nuevo." Item C on p.14 of NPS et al. (1977 *op. cit.*) suggested that adding such research details would be the responsibility of Howard Campbell. The primary focus of this draft action plan (NPS et al. 1977 *op. cit.*) was reintroduction of Kemp's Ridley to PAIS. Although the section of NPS et al. (1977 *op. cit.*) entitled "Rancho Nuevo Beach Monitoring and Egg Collection" included protection of nesting turtles and their eggs from native and human predators during the nesting season at RN, it also included collection of eggs at RN for reintroduction to PAIS. NPS et al. (1977 *op. cit.*) named Jorge Carranza (Director of INP) as a member of the Agency Coordinating Committee (ACC), along with Don [Donald] Ekberg (Director, NMFS Southeast Regional Office, St. Petersburg, Florida), Hal [Harold] Irby (TPWD, Austin, Texas), Ro [Roland] Wauer, and Jack Woody. NPS et al. (1977 *op. cit.*) indicated that members of the SAB would serve as consultants throughout the course of the program, and that NPS would serve as coordinating agency for the SAB. Permit requirements were identified, including a permit from Mexico, a [U.S.] Endangered Species Permit and a Texas permit. This draft plan emphasized that "the key to the entire program is Mexico's participation and support" and that "Don Ekberg and a Texas representative will meet with Mexico's Jorge Carranza regarding the program on December 7–9, 1977." It stated that "Jack Woody will initiate a request for authorization to handle and transport eggs and turtles immediately upon completion of this plan," and that "Bill Brownlee [TPWD] will initiate a request for authorization of the State of Texas upon receipt of a copy of the Endangered Species Permit application." Agency responsibilities were designated as follows: (1) beach monitoring and egg collections at RN would be the responsibility of Mexico and the FWS, "with special assistance by National Park Service personnel," (2) incubation of eggs at PAIS and exposure of hatchings to the beach and surf at PAIS would be the responsibility of the PAIS Superintendent, and (3) rearing from hatchlings until the head-started turtles were tagged and released, as well as monitoring thereafter, would be the responsibility of NMFS.

This early assignment of responsibility to NMFS for monitoring the turtles following their release is important, especially in the context of its later reiteration by NMFS' National Sea Turtle Coordinator: "NMFS will place special emphasis on detecting tagged turtles in the wild" (Williams 1993). Beach monitoring at RN apparently referred to protection of nesting turtles, eggs, and hatchlings from natural predators and human take during the nesting season. However, it may also have encompassed counting nests, eggs, and hatchlings. Special assistance by NPS personnel referred to the collection of 2,000 eggs at RN, depositing them in PAIS sand within Styrofoam™ boxes, and transporting them to PAIS. Another 2,000 eggs were to be collected and incubated at RN. Descriptions of the "Rearing Project" and "Release and Monitoring" by the Galveston Laboratory were included. However, other than indicating that the turtles would be tagged with numbered tags and selected individuals would receive sonic tags for tracking, NPS et al. (1977 *op. cit.*) gave no additional details regarding monitoring of the turtles after release. Also absent from NPS et al. (1977 *op. cit.*) were planned activities aimed at documenting head-started Kemp's Ridley nestings at PAIS, RN, or elsewhere, although nestings were essential to accomplishing the stated goals of head-start and reintroduction (Shaver and Caillouet 2015). Documenting nestings of head-started Kemp's Ridleys remains essential to evaluating reintroduction and head-start, together as well as separately.

***Final action plan.*—**The finalized Action Plan (NPS et al. 1978 *op. cit.*) reiterated most of the draft action plan (NPS et al. 1977 *op. cit.*). With regard to the requirement that Jack Woody initiate a request for authorization to handle and transport eggs and turtles under an Endangered Species Permit, a "Convention Permit" was added, apparently referring to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). No mention was made of the need for personnel at the Galveston Laboratory to be permitted, but they certainly were required to carry copies of all necessary permits while engaged in head-starting and related activities. The same was true of all who collaborated with the Galveston Laboratory; e.g., NPS personnel also had permits from Texas and FWS. In addition, when head-started Kemp's Ridley releases took place off Florida, Florida Department of Natural Resources (FDNR) permits were required.

The following responsibilities and requirements were specified (they are paraphrased here) for the Galveston Laboratory within NPS et al. (1978 *op. cit.*): (1) hatchlings received from PAIS and RN will be placed in flow-through systems in tanks and raceways, (2) each group of hatchlings (PAIS and RN) will be maintained separately, (3) turtles will be fed a diet of chopped, boneless, scaleless fish, shrimp, and other marine foods available, at rates of 5–8% of body weight per day or at whatever volume of food they will consume in 3–4 h, (4) after November 15, turtles will be placed in special heated containers (with water temperature approximately 22° C) equipped with the best designs of water treatment facilities to handle wastes produced by the turtles, (5) water will be exchanged whenever it is determined to be below quality for the turtles, (6) turtles will be maintained for periods up to one year then released, (7) turtles imprinted at RN and those imprinted at PAIS will be released at periods up to one year, at locations and times determined to be the most logical for young turtles to occur, (8) turtles will be placed in Styrofoam™ transport boxes, kept moist, cool, and ventilated, and moved by boat to release locations, (9) turtles will be released on grass flats off Florida's west coast and lower Gulf of Mexico, and other areas where yearlings have been observed, (10) all turtles will be tagged with numbered tags and selected individuals will also be tagged with sonic tags and tracked, and (11) in the second year (i.e., 1979), some 1 y old turtles will be tagged with radio transmitters and tracked from aircraft and satellites. The Action Plan (NPS et al. 1978 *op. cit.*) gave no further details regarding monitoring head-started turtles after release, or searching for and documenting their nestings at PAIS, RN, or elsewhere.

The captive breeding option.—Establishment of a captive breeding colony was among options considered by Campbell (1977 *op. cit.* Appendix II), but it was not among the actions recommended by NPS et al. (1978 *op. cit.*). However, after NPS et al. (1978 *op. cit.*) was implemented, Brongersma et al. (1979) recommended establishment of a captive breeding colony of Kemp's Ridleys at Cayman Turtle Farm Ltd. (CAY), Cayman Island, British West Indies, "to ensure preservation of this genetic entity, if efforts to preserve the species in the wild should fail." They recommended using existing aquarium specimens, accidentally caught individuals, and hatchlings of the 1978 year-class at the Galveston Laboratory. Balazs (1979) recommended further that the reservoir of breeding Kemp's Ridleys be established through dissemination of hatchlings of the 1978 year-class to responsible and consenting aquaria, oceanaria, and appropriate zoological facilities in the U.S., Mexico, and other countries (Table 6).

The mysterious meeting.—Also mentioned in the literature (e.g., Klima and McVey 1982; Woody 1989), and by some of the early planners who were contacted in 2010 (by Caillouet), was a multi-agency planning meeting purportedly held in January 1977 in Austin, Texas. We were unable to corroborate that such a meeting took place at that time, based on the planning documents we examined. Perhaps the meeting in question was the one hosted by TPWD on 17 November 1977 (Campbell 1977 *op. cit.*; NPS et al. 1977 *op. cit.*), or the one held in January 1978 during which the Action Plan (NPS et al. 1978 *op. cit.*) was approved by attendees. We are unaware of any additional planning documents that might corroborate a January 1977 meeting. If it did take place, it may have been informal (Jack Woody, pers. comm.), and therefore not documented in a planning document or report.

Oversight.—We stress that agencies and individuals that participated in various components of reintroduction and head-start did not proceed without direction, approval, and oversight of their work. Each agency had internal procedures to approve, control, and evaluate its work. NPS et al. (1978 *op. cit.*) required annual reviews to evaluate past, current, and future phases of the KRREP. Initially, the ACC and SAB provided oversight and guidance to all agencies participating in the KRREP. Additional oversight and guidance were provided by a Sea Turtle Working Group established in 1977 within the MEXUS-Gulf Program, a formal fisheries agreement between INP and the NMFS Southeast Fisheries Science Center in Miami, Florida (Berry 1987). References to a Kemp's Ridley Working Group (KRWG) can also be found in the literature (e.g., NMFS et al. 2011; Burchfield and Peña 2013). In any case, after the KRREP was initiated, a consortium of representatives of NPS, FWS, NMFS, TPWD, and INP (or its successor agencies) met annually to review progress and discuss and approve plans for the next year's work. At these meetings, oral presentations and recommendations were made, proposals were distributed, results were evaluated, and proposed work was discussed, modified as needed, and approved. Scientists from non-government organizations (NGOs) and universities occasionally participated in these meetings. If agreement on a proposal was not unanimous, that did not necessarily prevent its implementation. However, participants were usually in agreement and worked cooperatively in making decisions and providing guidance. In some cases, annual reports were prepared and distributed (e.g., Pritchard and Gicca 1978; Pritchard 1980; Caillouet 1997; Shaver 2012; Burchfield and Peña 2013). All participating agencies involved in the KRREP had permitting

Table 9. Previous reviews of major accomplishments of Kemp's Ridley (*Lepidochelys kempii*) head-start, reintroduction, and research activities, and reviews of Kemp's Ridley head-start at the Galveston Laboratory.

Reviews of Major Accomplishments	Reviews of Head-start
Caillouet et al. (1995c)	Wauer (1978, 2014)
Caillouet (2000)	Woody (1981, 1986)
Shaver (2001, 2005, 2006, 2007)	Caillouet (1984, 1987)
Higgins (2003)	Caillouet and Koi (1985)
Fontaine and Shaver (2005)	Fontaine and Caillouet (1985)
Shaver and Wibbels (2007)	Fontaine et al. (1985, 1988b, 1989a, 1989b, 1990a)
	Caillouet et al. (1986b, 1986c, 1988, 1993, 1995c, 1997a)
	Manzella et al. (1988b)
	Duronslet et al. (1989)
	Leong et al. (1989)
	Shaver (2001, 2005, 2006, 2007)
	Shaver and Caillouet (2015)

authority over some aspect of the work. If something objectionable to a given agency was proposed, and that agency had authority to withhold a necessary permit, it could have prevented implementation simply by refusing to issue the permit. A good example is FWS' prevention of annual importation of 2,000 Kemp's Ridley hatchlings into the U.S. for head-start at the Galveston Laboratory in 1993, simply by not issuing the necessary FWS permit (Byles 1993; Williams 1993). Therefore, various controls were in place to reconsider and modify goals, objectives, and direction of the KRREP at any time.

***Public awareness.*—**High public profiles of reintroduction and head-start greatly enhanced awareness of the plight of Kemp's Ridley as well as the need for conservation of all sea turtles. Especially effective in this regard were Kemp's Ridley conservation advocacy efforts of Carole H. Allen (Allen 2013), Chairperson of the organization she founded and managed (Help Endangered Animals-Ridley Turtles; i.e., HEART), a standing committee of the non-profit Piney Woods Wildlife Society of Houston, Texas. Carole Allen and HEART not only had strong educational focus involving children and parents, but also advocated use of TEDs, raised funds, and provided funding and other support for Kemp's Ridley conservation, as well as head-start and related research at the Galveston Laboratory, PAIS, RN, and Texas A & M University in College Station and Galveston. Availability of sea turtles in captivity at the Galveston Laboratory provided opportunities for public viewing during scheduled tours and NOAA open houses in which Allen and others representing HEART sometimes participated (off site). Also effective was public exposure to releases of hatchlings produced from clutches laid by head-started and wild Kemp's Ridleys at PAIS (Shaver and Caillouet 2015).

Accomplishments

The challenges of rearing marine turtles in captivity are so great that Tonge (2010) considered them unsuitable even for laboratory usage and gave them little attention in his discussion of maintenance and husbandry of aquatic reptiles. Mass rearing Kemp's Ridleys for 7–15 mo in captivity was much more challenging and expensive than rearing laboratory specimens or rehabilitating live-stranded individuals that are injured or ill. Sources summarizing major accomplishments and contributions of the NMFS Galveston Laboratory, NPS Padre Island National Seashore, and their collaborators to head-start, reintroduction, and related research are listed in Table 9. Kemp's Ridley head-start at the Galveston Laboratory was also previously reviewed by sources that provided details about (1) housing, raceways, and rearing containers, (2) seawater source, storage, quality, heating, monitoring, and replacement, (3) hygiene, (4) yolk absorption in hatchlings, (5) measuring and weighing turtles, (6) natural foods and commercial feeds and feeding, (7) survival, (8) growth, and (9) prophylaxis, diagnosis and treatment of diseases, all of which improved over time (Table 9).

Collaborative research.—Availability of large numbers of Kemp's Ridleys in captivity, as well as fewer Loggerhead (*Caretta caretta*) and Olive Ridley (*L. olivacea*) turtles, afforded opportunities for collaborative research at the Galveston Laboratory (Caillouet et al. 1986b, 1988, 1995c; Fontaine et al. 1990a; Caillouet 1997, 2000). The Galveston Laboratory collaborated with individuals in federal and state agencies, universities, and NGOs, as well as with veterinarians including Drs. Joseph Flanagan (Houston Zoo, Houston, Texas), Richard Henderson (Galveston, Texas), and Elliott Jacobson (University of Florida, Gainesville, Florida). Collaboration provided part-time employment, research experience, and career development for graduate students, especially those associated with the Texas Sea Grant College Program, Texas A & M University, the University of Texas Medical Branch, and the Louisiana State University Sea Grant College Program. The Galveston Laboratory also participated in the Sea Turtle Stranding and Salvage Network (STSSN), providing additional part-time employment for graduate students. Collaborative research topics included hatchling yolk-absorption, natural foods and commercial feeds and feeding, wastes from sea turtles and excess feed in seawater, diseases and treatments, necropsy, behavior, growth, survival, morphometrics, composition of Rathke's gland secretions, genetics, swimming performance, physiology (reproductive, metabolic, and respiratory), tags and tagging, radio-, sonic-, and satellite-tracking, geographic distribution, strandings, rehabilitation, threats at sea, captive breeding, TED testing and certification, incubation temperature dependent sex-ratios, olfactory imprinting, and trace metals. Caillouet and Landry (1989) chaired the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management, held in October1985 at Texas A & M University at Galveston. For copies of Galveston Laboratory publications and reports related to head-start, reintroduction, and the KRREP, see Caillouet (1997) and (NOAA Fisheries, Galveston Laboratory, Galveston Publications. Available from http://www.galvestonlab.sefsc.noaa.gov/publications/ [Accessed 7 December 2014]).

Initial work with Loggerhead.—Klima (1978) clearly intended that the Galveston Laboratory test practicality of a rearing and release program as a viable conservation and management tool, not only for Kemp's Ridley but also for other sea turtle species including Loggerhead, Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricata*), and Green Turtle (see also Bullis 1978). However, consultation with Archie Carr, Peter Pritchard, Henry Hildebrand, and Galveston Laboratory staff led to a decision to conduct the initial head-start trial on Loggerhead, a threatened species (Klima 1978; Edward Klima, pers. comm.; Jack Woody, pers. comm.). Leong et al. (1980, 1989), Klima and McVey (1982), and Clary and Leong (1984) described captive-rearing of Loggerheads at the Galveston Laboratory during 1977. Loggerhead was classified as a threatened species, and its captive-rearing allowed the staff to gain experience before attempting to head-start Kemp's Ridleys.

In September 1977, 1,060 Loggerhead hatchlings were received from FDNR, Jensen Beach, Florida. They were reared in communal groups within large tanks and fed mostly raw fish that had been frozen. Initially, seawater was recycled, but recycling was replaced later on by continuous, gradual flow-through. Almost all the hatchlings became ill at one time or another. Sick turtles were removed from communal tanks, isolated individually in 10-liter plastic buckets containing seawater replaced daily, and provided experimental chemotherapy (Leong 1979; Leong et al. 1980, 1989; Clary and Leong 1984). When their condition improved they were returned to communal tanks. Overall survival was only 9% after 10 mo of rearing.

***Kemp's Ridley eggs and hatchlings for head-start.*—**In 1978, the number of live Kemp's Ridley hatchlings received by the Galveston Laboratory included 1,226 from RN and 1,854 from PAIS (an additional hatchling from PAIS was dead on arrival) (Caillouet et al. 1986b, 1987; Manzella et al. 1988b; Duronslet et al. 1989; Fontaine et al. 1989b, 1990a). Thereafter, fewer hatchlings were received annually (except for 2,025 received in 1990) by the Galveston Laboratory to be head-started (*ibid.*; Caillouet 1995b; Shaver and Wibbels 2007; Benjamin Higgins, pers. comm.). Within the period 1978–1992, the number of Kemp's Ridley eggs taken from RN for the reintroduction experiment (22,507 eggs), plus the estimated number (13,518 eggs) that produced hatchlings at RN for head-start, represented 2.8% (or 22,507 + 13,518 = 36,025 eggs) of the total production of 1,286,900 eggs at RN during same period (Caillouet 1995b). The annual take of eggs that produced hatchlings for head-start during 1993–2000 was ≈ 1/10 the annual take of eggs during 1978–1992. Hatchlings from year-classes 1978–1988 were received by the Galveston Laboratory from PAIS as part of the reintroduction experiment (Shaver and Caillouet 2015), and others were received directly from RN (year-classes 1978–1980, 1983, 1989–2000) and CAY (year-classes 1987–1988) (Caillouet 1995b; Caillouet et al. 1995b). Hatchlings from RN were transported by U.S. Coast Guard (USCG) or TPWD aircraft to Galveston. In retrospect, the takes of eggs and hatchlings from Rancho Nuevo for Kemp's Ridley head-start during 1978–1985 did not prevent the population decline from reversing in 1986, although it may have prevented an earlier reversal.

***Rearing turtles in groups.*—**During July-August 1978, Kemp's Ridley hatchlings received by the Galveston Laboratory were initially reared in communal groups in large fiberglass raceways with seawater replaced thrice weekly, and they were fed a commercial, pelletized feed (Clary and Leong 1984; Leong et al. 1989). Every turtle contracted one or more diseases or infections, some similar to those exhibited earlier by Loggerhead as well as other maladies that had not been observed in Loggerhead. Kemp's Ridley hatchlings were very aggressive and bit or scratched each other causing injuries that led to further complications (Leong 1979; Klima and McVey 1982; Clary and Leong 1984; Fontaine et al. 1985). Sick individuals were isolated and treated successfully in buckets by techniques developed for Loggerhead, but maladies recurred when successfully treated turtles were returned to communal rearing. Further details concerning diseases in Kemp's Ridleys reared at the Galveston Laboratory, as well as prophylaxis and treatment, can be found in sources listed in Table 10.

***Rearing turtles separately.*—**The practice of communal rearing of Kemp's Ridleys was stopped after six months and replaced by rearing individuals separately, one per container (initially in the same kind of buckets used earlier for isolation and treatment of sick turtles); multiple containers were suspended side by side, partially submerged, in seawater within the raceways. Bottoms of the buckets were perforated with holes that allowed seawater exchange and turtle excrement and debris from uneaten feed to escape. Various sizes of individual containers, all with perforated bottoms, were later used to accommodate the increase in size of turtles (Table 11). Some containers were purchased; plastic flower pots used for hatchlings and plastic buckets used after the turtles grew too large for the flower plots. Larger containers were fabricated from purchased materials, to accommodate further increase in size of the turtles. All containers were made of resilient, corrosion-resistant (except for some metal fasteners), non-toxic materials. The containers had smooth inside surfaces to protect the turtles from abrasion and to prevent their biting off pieces, since they would ingest non-feed items if available. The location of each container within the raceway was coded for purposes of record keeping. Suspension of containers in groups within raceways facilitated thrice-weekly draining of seawater, removing sea turtle wastes and debris from uneaten feed, cleaning raceways, containers, and turtles, and refilling raceways with clean seawater. When a raceway was drained, the turtles remained out of water on the bottoms of their suspended containers until the raceway was cleaned and refilled.

Isolation rearing was confining, but provided adequate space for the turtles to swim around, submerge completely, and rest on the bottom of their individual containers. However, there was early concern that such confinement reduced the turtles' physical fitness. Physical fitness of head-started juveniles was tested in captivity, by experimentally exposing a sample of turtles, one at a time, to a controlled-current exercise regimen within a laminar flow tank (Stabenau et al. 1988, 1992). Each turtle in the sample was subjected to this regimen 1 day each week over a six month period; the turtles swam against the current and their fitness showed signs of improvement over time (Stabenau et al. 1988, 1992; Valverde et al. 2007). However, this exercise regimen could not be adopted as a routine practice for all head-started turtles, because of limited personnel, equipment, and funds, as well as the large number of turtles being reared.

Seawater temperatures were maintained within an approximate range of 20–30C, mostly near 26–30C, and rarely fell below 20C (Caillouet et al. 1986b; Fontaine et al. 1988b, 1989b; Caillouet 2000; Higgins 2003). Forced-air heaters and heated seawater controlled air and seawater temperatures during winter. Forced-air ventilation controlled air and seawater temperatures during summer. Clean and warm seawater were essential to successful rearing and disease prevention.

Malone and Guarisco (1988) analyzed seawater containing Kemp's Ridleys, their wastes and uneaten feed, and results were used thereafter to guide seawater management during head-starting. They assessed seawater quality based on biochemical oxygen demand, total Kjeldahl nitrogen, ammonia nitrogen, nitrite nitrogen, suspended solids, volatile suspended solids, and settleable solids. Wang (2005)

Table 10. Sources covering diseases in Kemp's Ridleys (*Lepidochelys kempii*) reared at the Galveston Laboratory, as well as prophylaxis and treatment.

Leong (1979)
McLellan and Leong (1981, 1982)
Fontaine et al. (1983, 1985, 1990b)
Clary and Leong (1984)
Caillouet et al. (1986b)
Leong et al. (1989)
Robertson and Cannon (1997)
Higgins (2003)
Jacobson (2007)

Table 11. Sources covering containers used to head-start Kemp's Ridleys (*Lepidochelys kempii*) at the Galveston Laboratory.

Fontaine et al. (1985, 1988b, 1989b, 1990a)
Caillouet et al. (1986c, 1988)
Manzella et al. (1988b)
Caillouet (2000)
Higgins (2003)

studied trace metal accumulation in Kemp's Ridleys during head-starting. Various indicators of seawater quality were routinely monitored during head-starting (Caillouet et al. 1986b; Fontaine et al. 1988b, 1989b; Duronslet et al. 1989; Higgins 2003).

Artificialities of captive-rearing.—The turtles were reared out of view of each other, but were able to see their surroundings and caretakers above their containers. Rearing exposed them to additional artificialities of feeds, feeding, light, temperatures, sounds, and other physical and chemical characteristics of their captive environment that may have predisposed them to maladaptive post-release behaviors and survivability as compared to their wild counterparts. Post-release behaviors considered abnormal or aberrant were reported for some head-started Kemp's Ridleys observed after release into the Gulf of Mexico (Fontaine et al. 1989a; Meylan and Ehrenfeld 2000; Shaver 2007; Shaver and Wibbels 2007). Tag returns and short-term tracking by sonic, radio, and satellite methodologies made it possible to link post-release behaviors to head-start and reintroduction. However, the potential for such detrimental effects (Pritchard 1976; Woody 1990, 1991) did not dissuade the early planners or their agencies from approving and implementing head-start and reintroduction (NPS et al. 1978 *op. cit.*).

Conditions of captive care may also affect wild Kemp's Ridleys taken from their natural environment for medical treatment and rehabilitation after being found live-stranded, injured, or ill. Exposure of wild Kemp's Ridleys to extended human care and artificial conditions in captivity is not an issue when the turtles have permanent disabilities, infirmities, or infectious diseases that prevent their return to the wild. However, when wild Kemp's Ridleys are temporarily held in captivity for medical treatment and rehabilitation, human care may also predispose them to maladaptive, abnormal, or aberrant behaviors following their return to the wild. This potential apparently has not discouraged medical treatment, rehabilitation, and release of such turtles (Caillouet 2012b; NOAA, U.S. Department of Commerce. 2010. NOAA's Oil Spill Response: Rehabilitated Kemp's Ridley Sea Turtles Released. Available from http://www.noaa.gov/factsheets/new%20version/releasing_kemp's_ridley_turtles.pdf [Accessed 7 December 2014]; Wider Caribbean Sea Turtle Conservation Network. 2008. Sea Turtle Care & Medicine. Available from http://www.widecast.org/What/Regional/Medicine.html [Accessed 7 December 2014]). In fact, tag returns and satellite tracking of rehabilitated wild Kemp's Ridleys can be useful in determining their behavior following release (Lyn et al. 2012). Once released into the wild, head-started Kemp's Ridleys that survived to the calendar year following the one in which they were released were assumed to have adapted to living in the wild (Caillouet et al. 1995a, 1995b). However, such short term survival was not proof that their behavior and survivability in the wild had been or would be natural or normal for the species.

Duration of captive-rearing.—Caillouet et al. (1995a, 1995b, 1997a) considered Kemp's Ridleys reared in captivity for 7–15 mo before release into the wild to be typical head-started turtles. Typical head-started Kemp's Ridleys were referred to as yearlings (age group 1) because

Table 12. Sources covering sizes and putative ages of wild Kemp's Ridleys (*Lepidochelys kempii*) the surface-pelagic, post-hatchling-early juvenile life stage.

Zwinenberg (1977)
Ogren (1989)
Collard and Ogren (1990)
TEWG (1998, 2000)
Snover and Hohn (2004)
Snover et al. (2005, 2007)
Putman et al. (2010, 2013)
NMFS et al. (2011)
Witherington et al. (2012)

they were released in the calendar year following the calendar year in which they were received as hatchlings (age group 0). More than 80% of them were 9–11 mo old when released (*ibid*.). Their sizes and ages at release into the wild (Caillouet et al. 1995a, 1995b, 1997a) were within the size and putative age ranges of wild Kemp's Ridleys in the surface-pelagic, post-hatchling-early juvenile life stage (Table 12). Shaver and Wibbels (2007) indicated that sizes of head-started Kemp's Ridleys at release were comparable to those of the late pelagic stage or early post-pelagic stage of wild Kemp's Ridleys, attributing this to Ogren (1989), who also suggested that wild Kemp's Ridleys grow faster in the Gulf of Mexico than along the U.S. Atlantic coast. Witherington et al. (2012) estimated that the wild, surface-pelagic, juvenile Kemp's Ridleys they observed were 1 or 2 y old. Typical head-started Kemp's Ridley yearlings exhibited the distinctive coloration pattern described by Marquez-M. (1994) for 1 y old juveniles; viz. black carapace, almost white plastron and undersides of the neck, beak, upper eyelids, tail, and proximal parts of the tail, and a narrow, dorsal, white border along the periphery of the carapace.

The habitat of wild, surface-pelagic Kemp's Ridleys is near the ocean's surface, where the turtles drift passively, dive, feed, and apparently rest while being dispersed by surface circulation (Table 13). The wild, surface-pelagic Kemp's Ridleys observed by Witherington et al. (2012) were strongly associated with the surface-pelagic *Sargassum* macroalgae community. Manzella et al. (2001) observed two head-started Kemp's Ridleys of the 1987 year-class floating in *Sargassum* after release in 1988, one 4.8 mo after release and the other 14.8 mo after release. During an offshore study conducted in south Texas in October-November 1988 and February-June 1989, no sea turtles were observed by divers beneath Sargassum mats, and none were captured along with *Sargassum* in surface trawl hauls, nor did stomach contents of pelagic fishes caught near the mats contain hatchling turtles or parts thereof (Fontaine et al. 1990a).

Table 13. Sources covering the habitat of wild, surface-pelagic Kemp's Ridleys (*Lepidochelys kempii*).

Zwinenberg (1977)
Ogren (1989)
Collard and Ogren (1990)
TEWG (1998, 2000)
Snover and Hohn (2004)
Snover et al. (2005, 2007)
Putman et al. (2010, 2013)
NMFS et al. (2011)
Witherington et al. (2012)

***Feeds and feeding.*—**Experimentation with various feeds and feeding methods led to routine use of commercially produced, pelletized, dry, floating feed fed twice daily, in early morning and late afternoon (Fontaine et al. 1985; Caillouet et al. 1986b, 1989b). Initial feeding of hatchlings was delayed to allow time for absorption of yolk (Fontaine et al. 1985; Fontaine and Williams 1997). Thereafter, the daily total weight of feed received per turtle was adjusted monthly, based on its percentage of average (arithmetic or geometric) body mass of a monthly sample of turtles (Fontaine et al. 1985, 1988b; Caillouet et al. 1986b, 1988, 1989; Caillouet 2000; Higgins 2003). The twice-daily portions of feed were measured and distributed volumetrically, based on the volume-mass relationship of the feed. Under this feeding regimen, daily weight of feed per turtle increased exponentially during head-starting, while weight of feed as a percentage of body mass declined logarithmically (Higgins 2003). Problems with insect invasion of pelletized feed held in dry storage led to its routine frozen-storage (Fontaine et al. 1985).

***Growth and survival in captivity.*—**Growth in body weight and survival of Kemp's Ridleys during head-starting were examined by sources listed in Table 14. Caillouet and Koi (1985) showed that the range in body weight within samples of Kemp's Ridleys being head-started increased with age, based on year-classes 1981–1983 (i.e., variance in individual weight was heterogeneous). Therefore, they recommended application of the geometric mean as a measure of central tendency of weights of turtles of a given age during head-starting (see also Caillouet et al.1986b, 1989).

Caillouet et al. (1986c) determined survival and growth in weight year of turtles in year-classes 1978–1983, for PAIS and RN imprint groups, and by clutches, during head-starting. They characterized growth in weight with a linear regression of the natural logarithm of weight (in g) on the square root of age (in days). Manzella et al. (1988b) used the model to compare growth of turtles of the 1986 year-class reared in two different sizes of containers, and detected no significant difference in growth within the two sizes of containers. Caillouet et al. (1997a) modified this model for application in estimating growth in weight during head-starting of year-classes 1978–1992, by expressing weight (w) in kg and age (t) in years, and estimating slope d (the growth index) and intercept $\ln(c)$ using linear regression:

$$\ln(w) = \ln(c) + d(t^{1/2}) \quad (1)$$

Table 14. Sources covering growth in body weight and survival of Kemp's Ridleys (*Lepidochelys kempii*).

Klima and McVey (1982)
Caillouet et al. (1986b, 1987, 1989, 1997a)
Fontaine et al. (1985, 1990a)
Manzella et al. (1988b)
Duronslet et al. (1989)
Landry (1989)
Fontaine and Williams (1997)
Fontaine and Shaver (2005)
Shaver and Wibbels (2007)

Caillouet et al. (1997a) also estimated the relationship between variance, s^2, and arithmetic mean, $\bar{w}$, of the combined year-classes; a scatter plot of s^2 on $\bar{w}$ showed greater variability in w at t in year-classes 1978–1985 than in year-classes 1986–1992. Caillouet et al. (1997a) suggested that variability of w at t in year-classes 1986–1992 may have been lowered by controlling incubation temperature to produce female-dominated sex ratios (Shaver et al. 1988; Caillouet 1995a) and by improving rearing facilities and methods. The slope of the relationship between $\ln(s^2)$ and $\ln(\bar{w})$ was very close to 2, indicating that the distribution of w at t was ln-normal within the range of t for head-started Kemp's Ridleys.

The relationship between w and straight carapace length (SCL) was determined from paired w and SCL observations from year-classes 1978–1992 combined (Caillouet et al. 1997a):

$$w = a(\mathrm{SCL})^b \quad (2)$$

Parameters $\ln(a)$ and b were estimated by linear regression of $\ln(w)$ on ln(SCL), as follows:

$$\ln(w) = \ln(a) + b(\ln[\mathrm{SCL}]) \quad (3)$$

where $\ln(a) = 8.438$, $b = 2.920$, n = 53,317, and adjusted $r^2 = 0.994$. This large data set could have contained paired observations for some turtles weighed and measured more than once (i.e., at different ages) during head-starting. Equation (3) also was rearranged, without changing its parameter estimates, and used to estimate SCL from w (Caillouet et al. 1997a).

Rearing more than 15 mo.—Kemp's Ridleys transferred from the Galveston Laboratory to CAY and other marine aquaria to develop a captive breeding stock were reared in captivity for more than 15 mo, and were referred to as extended head-started or super head-started (Fontaine and Caillouet 1985; Fontaine et al. 1985, 1988b; Caillouet et al. 1995a, 1995b). This distinction from typical head-started Kemp's Ridleys is important, because the extended captive-rearing to which super head-started turtles were exposed may have conditioned them to greater dependency on human care than typical head-started turtles. Turtles of the 2000 year-class that were released in 2003 are considered super head-started. We assume that the longer head-started Kemp's Ridleys are exposed to human care and other artificial conditions of captivity, the greater the risk of their developing maladaptive, abnormal, or aberrant behaviors that could be detrimental to their performance and survival in the wild. The same may be true for sick or injured wild Kemp's Ridleys brought into captivity for treatment and rehabilitation, then released. Therefore, we believe that evaluation of head-start should not include super head-started individuals because of their extended exposure to potentially irreversible effects of captive-rearing. However, we would not exclude super head-started individuals from an evaluation of reintroduction; a nesting by a super head-started Kemp's Ridley has been documented at PAIS (Shaver and Caillouet 2015).

Over a period of almost 10 y, the growth-in-weight trend for 10 super head-started Kemp's Ridleys of the 1978 year-class, at Sea-Arama Marineworld in Galveston, was asymmetrically sigmoid (Caillouet et al. 1986b; Duronslet et al. 1989; Fontaine et al. 1989b). This indicated that the inflection point on the growth curve had been passed and that growth rate was declining with age, suggesting that the turtles were either approaching maturity or had reached maturity. McVey and Wibbels (1984) reported growth in carapace length and weight in super head-started Kemp's Ridleys at Sea-Arama Marineworld and Miami Seaquarium, Miami, Florida over a period less than 20 mo.

***Tags and tagging.*—**Witzell (1998) emphasized that tagging sea turtles should be based on a sound research plan and legitimate research goals, and these requirements were met by Campbell (1977 *op. cit.*) and NPS et al. (1978 *op. cit.*). Without tags, head-started Kemp's Ridleys released into the Gulf of Mexico could not have been distinguished from wild conspecifics (Table 15). Tags on head-started Kemp's Ridleys linked their recapture data to previously recorded information on year-class, imprint group, release location, and hatchling emergence dates (from which their age was calculated; see Caillouet et al. 2011).

Table 15. Some examples of sources emphasizing that tags were essential to distinguish head-started Kemp's Ridleys (*Lepidochelys kempii*) released into the Gulf of Mexico from wild conspecifics.

Campbell (1977 *op. cit.*)
NPS et al. (1978 *op. cit.*)
Klima and McVey (1982)
Caillouet (1984, 1987)
McVey and Wibbels (1984)
Fontaine and Caillouet (1985)
Fontaine et al. (1985, 1990a, 1993)
Caillouet et al. (1986b, 1987, 1995c, 1997b)
Manzella et al. (1988a)
Higgins et al. (1997)

In most cases, each type of tag was tested on small numbers of head-started Kemp's Ridleys while they were in captivity, to ensure the tag was safe for application to larger numbers to be released. Tags were applied to head-started Kemp's Ridleys well before their release to allow healing of wounds caused by tagging. Prior to release, each turtle was weighed and SCL was measured. Each was also examined to make sure its tags were properly applied and retained before release. An approach of applying more than one tag to head-started turtles was tested on samples of turtles of year-classes preceding the 1984 year-class (Fontaine et al. 1993; Benjamin Higgins, pers. comm.). Multiple-tagging was expected to increase chances that at least one tag would be retained and recognized when the turtles were recaptured.

External metal (Monel^{TM} or Inconel^{TM}) tags were applied to the trailing edge of a foreflipper (usually the right) of all turtles to be released from each year-class, about one month before their release (Fontaine et al. 1990a, 1993; Caillouet et al. 1995a; Fontaine and Shaver 2005; Shaver and Wibbels 2007). These tags were initially issued by the NMFS Miami Laboratory, Miami, Florida, then later by the Cooperative Marine Turtle Tagging Program (CMTTP) that coordinates the distribution of sea turtle tags, manages tagging data, and facilitates exchange of tag information for projects conducted in the Atlantic Region (Archie Carr Center for Sea Turtle Research, University of Florida. 2014. Cooperative Marine Turtle Tagging Program. Available from http://accstr.ufl.edu/resources/tagging-program-cmttp [Accessed 7 December 2014]; Peter Eliazar, pers. comm.). Each tag bore a unique alphanumeric code and inscription requesting reporting the turtle's recapture to the NMFS Miami Laboratory.

Living tags (Hendrickson and Hendrickson 1981, 1983; Bowman 1983) were first applied experimentally to samples of turtles of year-classes 1978 (only one turtle), 1980 (180 turtles) and 1982 (436 turtles), then to most or all surviving individuals of year-classes1983–2000 (Fontaine et al. 1993; Caillouet et al. 1997b; Fontaine and Shaver 2005; Shaver and Wibbels 2007; Benjamin Higgins, pers. comm.). The living tag is a permanent, light-colored mark (autograft) on the darker carapace. As applied to a head-started Kemp's Ridley, it was formed by excising a small piece of light-colored plastron tissue and implanting it into a darker-colored carapace scute chosen to identify the turtle's year-class (Bowman 1983; Fontaine et al. 1985; Caillouet et al. 1986a, 1997b; Fontaine et al. 1988a, 1993). Such scute tissue implants grow in size as the turtle grows. Living tags were applied 6–8 week prior to releasing turtles (Benjamin Higgins, pers. comm.).

We used internal coded-wire tags (Northwest Marine Technology Inc. 2014. Coded wire tags (CWT). Available from http://www.nmt.us/products/cwt/cwt.shtml [Accessed 7 December 2014]) experimentally to small numbers of turtles from year-classes 1978 (9 turtles) and 1982 (12 turtles; Fontaine et al. 1993; Fontaine and Shaver 2005; Benjamin Higgins, pers. comm.). They were applied to most turtles of year-classes 1984–1997, but to less than half of the turtles in year-classes 1998 and 1999 (*ibid*.). CWTs were applied to only four year-classes (1985–1988) of the eleven imprinted to PAIS. None were applied to turtles of year-class 2000. CWTs were magnetized either before or after being implanted, which was determined by the type of hypodermic injector used (Higgins et al., 1997; Benjamin Higgins, pers., comm.). They were implanted into the flesh in the phalanges area of a right or left foreflipper, and can be detected in X-ray images by trained personnel (Fontaine et al. 1993). Trained personnel can also detect them by scanning both foreflippers with a magnetometer, if they were magnetized before implantation. If they were not magnetized before implantation, they can be magnetized upon recapture by passing a magnet over both foreflippers, which can then be scanned with a magnetometer. Some turtles were also successfully tagged, experimentally, with CWTs in both the right and left hind flippers in 1991, but tagging in the foreflippers was the preferred routine (Benjamin Higgins, pers. comm.). In some cases, flippers of dead-stranded Kemp's Ridleys have been archived in frozen storage for later examination for CWTs.

Internal passive integrated transponder (PIT) tags, also called radio frequency identification (RFID) tags, were applied to samples of turtles in year-classes 1978, 1982, and 1984–1989, then to most turtles in the 1990–2000 year-classes (Fontaine et al. 1993; Fontaine and Shaver 2005; Benjamin Higgins, pers. comm.). PIT tags were inserted with a hypodermic injector into the flesh of the pectoral muscle in the axial area of a foreflipper of each turtle, around two months before turtles were released (Fontaine et al. 1993; Benjamin Higgins, pers. comm.). In turtles ≥ 30 cm SCL, PIT tags were inserted with a hypodermic injector into the flesh of a foreflipper, in a location posterior to the fibula (Benjamin Higgins, pers. comm.). In some cases, flippers of dead-stranded Kemp's Ridleys have been archived in frozen storage for later examination for PIT tags. PIT tag migration in Kemp's Ridley has been investigated by Wyneken et al. (2010).

Flipper tags were easily recognized, but not permanent. Living tags were permanent, but not always recognized as tags by untrained observers. CWTs were permanent but required a magnetometer or X-ray image for detection by trained personnel; their binary codes could be determined only after the tags were excised, which was prohibited on live animals but not on dead specimens (e.g., found stranded). PIT tags were permanent but required well trained and experienced personnel using compatible detectors to detect them and read their alphanumeric codes (Manzella 1988); X-ray images also can be used to detect them. PIT tag detection was sometimes prevented by incompatibilities between PIT tags and PIT tag readers from different manufacturers, or by use of PIT tag-compatible readers of different detection strengths from the same manufacturer (Donna Shaver, pers. comm.). Scars left by foreflipper tags that were lost for various reasons can indicate previous tagging, but they alone are not sufficient evidence to distinguish head-started Kemp's Ridleys from wild conspecifics when flipper tags are lost and tagging scars remain (Caillouet et al. 1997b). In our view, proof that a recaptured, stranded, nesting, or otherwise observed Kemp's Ridley was head-started can come only from detection of external or internal tags which clearly identify it as head-started. Unfortunately, some observers used unexpected locations, ease of capture, or other putatively aberrant behavior of Kemp's Ridleys in the wild, to conclude they were head-started, in the absence of proof from retained external or internal tags to confirm it (e.g., Woody 1991; Bowen et al. 1994).

In addition to the four types of tags already mentioned, radio- or sonic-tags were attached to limited numbers of head-started Kemp's Ridleys for purposes of tracking them following release (Timko and DeBlanc 1981; Klima and McVey 1982; Wibbels 1984; Manzella et al. 1990). Renaud et al. (1993) conducted an experiment in which they attached imitation satellite transmitters to carapaces of 12 Kemp's Ridleys that were 32-mo old (i.e., super head-started), to determine their retention over a 16 mo period in captivity. Shaver and Rubio (2008) tracked head-started nesters by satellite after attaching platform transmitter terminals to their carapaces.

Table 16. Sources of information on transporting head-started Kemp's Ridleys (*Lepidochelys kempii*).

NPS et al. (1978 *op. cit.*)
Fontaine et al. (1985, 1989a, 1989b)
Caillouet et al. (1986b, 1987)
Manzella et al. (1988a)
Duronslet et al. (1989)
Higgins (2003)

Table 17. Sources of information on head-started Kemp's Ridley (*Lepidochelys kempii*) release sites.

Klima and McVey (1982)
McVey and Wibbels (1984)
Wibbels (1984)
Fontaine and Caillouet (1985)
Manzella et al. (1988a, 1990)
Fontaine et al. (1990a)
Caillouet et al. (1995a)
Fontaine and Shaver (2005)
Shaver (2005)
Shaver and Wibbels (2007)

Transport and release.—Table 16 lists sources of information on transporting head-started Kemp's Ridleys, via ground vehicles, aircraft, and vessels. Release dates for year-classes 1978–1992 are given in Caillouet et al. (1995a). Most turtles of the 1978 and 1979 year-classes were released off the west coast of Florida. Only 113 turtles of the 1978 year-class and six of 1979 year-class were released along the Texas coast. Because of the threat of incidental capture in shrimp trawls, most releases in Texas were carried out during periods and in areas closed temporarily to shrimping. For example, release of some of the 1978 year-class turtles off Padre Island in 1979 took place during the period when Texas offshore territorial waters, from the 7.3 m depth contour out to nine nautical miles, were closed to shrimping (Griffin et al. 1993). After the 1979 year-class was released, releases along the Texas coast usually took place during the Texas Closure, an annually recurring and coordinated NMFS-TPWD closure to shrimp trawling in offshore federal and state waters during a period of varying duration in May-July, which allows Brown Shrimp (*Farfantepenaeus aztecus*) to grow to larger, more valuable sizes before harvest (Griffin et al. 1993; Matlock 2010). Depending on the release sites chosen (Table 17) and the availability of vessels each year, head-started Kemp's Ridleys were released from vessels operated by NOAA, USCG, University of Texas Marine Science Institute, Texas A & M University, TPWD, Florida Department of Environmental Protection (FDEP), or ARCO Oil and Gas Company. Yearlings were usually transported by vehicles to the docking locations of release vessels (Table 16). However, on occasion some were transported by vehicle to Galveston's Scholes Airfield, where they were loaded onto USCG aircraft that flew them to airports near vessel docking locations; they were then taken by vehicle to the docking locations. All turtles were released one to a few at a time from the stern of the vessel while it was underway at relatively slow speed.

Table 18 lists sources of numbers of head-started Kemp's Ridleys released annually into the Gulf of Mexico; the numbers released reflected variation in numbers of hatchlings received by year-class and imprint group (PAIS, RN, and CAY), as well as survival during head-starting. The overall total number released from year-classes 1978–2000 was 23,967, including 14,776 from year-classes 1978–1988 (i.e., those associated with the reintroduction experiment), 7,800 from year-classes 1989–1992, and 1,391 from year-classes 1993–2000 (Benjamin Higgins pers. comm.). Super head-started Kemp's Ridleys were included in these numbers (*ibid.*). We were unable to reconcile the 23,967 total with the 23,987 total reported by Shaver and Wibbels (2007), but the difference is only 20 turtles. Most turtles released from year-classes 1978–1988 were in the PAIS imprint group, with fewer in the RN and CAY imprint groups (Caillouet et al. 1995a; Fontaine and Shaver 2005; Shaver and Wibbels 2007). All turtles released from the 1989–2000 year-classes were in the RN imprint group (Shaver and Wibbels 2007; Benjamin Higgins pers. comm.). The major head-start effort involved the 1978–1992 year-classes, after which numbers were reduced by about 1/10 for year-classes 1993–2000 (Shaver and Wibbels 2007). Some head-started Kemp's Ridleys from the 1980 year-class (197 turtles) were released in Campeche Bay (Caillouet et al. 1995a; Shaver and Wibbels 2007). Most from the 1981–2000 year-classes were released along the coast of Texas. Although releases off west Florida were recommended by NPS et al. (1978 *op. cit.*), they were discontinued and replaced by releases in the western Gulf of Mexico to reduce the probability that the turtles would escape into the Atlantic (Fontaine et al. 1989a). An exception was the release of 29 head-started Kemp's Ridleys of

Table 18. Sources of information on numbers of head-started Kemp's Ridley (*Lepidochelys kempii*) released annually.

Caillouet et al. (1986b, 1995a, 1995b, 1997a)
Manzella et al. (1988a)
Duronslet et al. (1989)
Fontaine et al. (1989a)
Caillouet (1995b, 2000)
Shaver (2005, 2007)
Fontaine and Shaver (2005)
Shaver and Wibbels (2007)
Shaver and Caillouet (2015)

the 1992 year-class off Panama City, Florida in 1993, after their use in TED testing (Shaver and Wibbels 2007; Benjamin Higgins, pers. comm.).

Time lapse to nesting.—During years 1966–1977 that preceded reintroduction and head-start, 280,000 hatchlings were released through conservation efforts at RN (TEWG 2000). Young (i.e., putative neophyte) Kemp's Ridley nesters began appearing at RN in 1976, 10 y after hatchling recruitment was restored by INIBP (Marquez-M. 1994; Pritchard 1997). During 1978–1988, when eggs for reintroduction were being transferred from RN to PAIS, 548,420 hatchlings were released at RN (TEWG 2000). Annual numbers of nests at RN declined from 5,991 in 1966 to a low of 740 recorded in 1985 before the decline reversed in 1986 (TEWG 2000). In comparison, the first documented nesting of a PAIS-imprinted and head-started Kemp's Ridley occurred in 1996, 17 y after the first head-started turtles were released in 1979 (Shaver 1996; Shaver and Caillouet 2015). During the 23 y of head-starting, 2,106,641 hatchlings were released through conservation efforts in Tamaulipas (TEWG 2000; data for years 1999 and 2000 were provided by Jaime Peña pers. comm.); 1,558,221 of these hatchlings were released during 1989–2000, when only RN imprinted hatchlings were transferred to the Galveston Laboratory. Shaver and Caillouet (2015) reported the number of hatchlings released at PAIS from nestings by head-started Kemp's Ridleys, most of which came from eggs laid at PAIS.

Tag returns and tracking.—Tag returns were among the most important and essential data required for evaluation of head-start and reintroduction (Campbell 1977 *op. cit.*; NPS et al. 1978 *op. cit.*; Pritchard 1979; Allen 1981). Tag returns and tracking results were necessary to evaluate performance of head-started turtles following release and to determine overall effectiveness of reintroduction and head-start. Not only was it essential to the head-start and reintroduction experiments that significant numbers of head-started females survived to maturity and reproduced in the wild, but also that significant numbers were documented by tag returns as having nested (Shaver and Wibbels 2007; Caillouet et al. 2011; Shaver and Caillouet 2015). Tag returns provided biological information on age, survival, movements, dispersal, distribution, habitat utilization, growth, feeding ecology, trace metals in blood, adaptation, behavior, maturation, and reproduction of head-started Kemp's Ridleys recaptured or otherwise observed after release into the Gulf of Mexico.

Table 19. Sources of information on head-started Kemp's Ridley (*Lepidochelys kempii*) tag returns and tracking results.

Timko and DeBlanc (1981)
Klima and McVey (1982)
Wibbels (1983a, 1983b, 1984)
McVey and Wibbels (1984)
Manzella et al. (1988a, 1990, 1991)
Fontaine et al. (1989a)
Shaver (1991, 1998, 2007)
Manzella and Williams (1992a, 1992b)
Caillouet (1994)
Cannon et al. (1994)
Werner (1994)
Werner and Landry (1994)
Caillouet et al. (1995a, 1995b, 1997b, 2011)
Fontaine (1995)
Fontaine and Schexnayder (1995)
Schmid (1998)
Shaver and Caillouet (1998, 2015)
Kenyon et al. (2001)
Metz (2004)
Fontaine and Shaver (2005)
Landry et al. (2005)
Shaver and Wibbels (2007)
Seney and Landry (2008)
Shaver and Rubio (2008)
Snover et al. (2008)
Shaver and Caillouet (2015)

Table 19 lists sources of information on head-started Kemp's Ridley tag returns and tracking results. Tag returns were received through the STSSN, from deliberate searches for nesters at PAIS and other areas of Texas, and serendipitously (Caillouet et al. 1995a; Fontaine and Shaver 2005; Shaver and Wibbels 2007; Shaver and Caillouet 2015). The STSSN was the major source of tag returns for head-started Kemp's Ridleys; they were recorded incidentally to documentation of sea turtles strandings (Fontaine and Shaver 2005). Although conservation efforts in Tamaulipas required tagging and examination of nesters for tags (NPS et al. 1978 *op. cit.*; NMFS et al. 2011; Shaver and Caillouet 2015), only six head-started Kemp's Ridleys were reported to have nested in Mexico; one was PAIS-imprinted and the other five were RN-imprinted (Shaver and Wibbels 2007; Donna Shaver, pers. comm.).

Identification of a Kemp's Ridley as head-started can be challenging. A head-started Kemp's Ridley could be erroneously identified as wild if its foreflipper tag or tags were missing and if those who recaptured or found the turtle were unfamiliar with living tags and internal tags, did not have appropriate, functioning equipment to detect and decode internal tags, or were inadequately trained in proper use of such equipment. Nevertheless, overall tag return rate for head-started Kemp's Ridleys was about 4% (Shaver and Wibbels 2007). Interestingly, tag return rate was 4% for 1,859 wild nesters tagged at RN during 1966–1978, based on 82 tag returns reported during 1966–1979 (data from Table 2, p. 161 in Márquez, M. et al. 1982). Similarity between the overall tag return rates of head-started Kemp's Ridleys (yearlings through adults, including both sexes) and wild nesters at RN is surprising, because the estimated annual survival rates of wild subadults (85.0–93.5%, ages 6–11 y) and adults (85.0–93.5%, ages ≥ 12 y) are higher than those estimated for small wild juveniles (60.7–81.5%, ages 2–5 y) (NMFS et al. 2011). Estimated annual survival rates of head-started Kemp's Ridleys released into the wild (Caillouet et al. 1995a) were generally lower than those estimated for their wild counterparts over similar ranges in size and age (NMFS et al. 2011), but many factors influence tag returns besides survival. Therefore, a comparison of tag returns for head-started turtles with those of wild nesters at RN is not strictly valid.

Fontaine and Shaver (2005) reported 958 tag returns from head-started year-classes 1978–1992. For year-classes 1993–2000, the only tag returns reported by Shaver and Wibbels (2007) were from one individual from the 1993 year-class that nested twice in 2003. Since then, additional tag returns for head-started Kemp's Ridleys have been documented (Shaver and Caillouet 2015), and more may be documented in the future, but numbers of head-started survivors are diminishing. The most recent nesting by a head-started Kemp's Ridley was documented in 2013 (Donna Shaver, pers. comm.). Recovery methods were determined from tag returns by Caillouet et al. (1995a) and Fontaine and Shaver (2005), and showed that head-started Kemp's Ridleys were vulnerable to anthropogenic threats similar to those to which wild Kemp's Ridleys were exposed (see also Fontaine et al. 1989a; Manzella and Williams 1992a, 1992b; Shaver and Wibbels 2007; NMFS et al. 2011). We combined tag returns (data from Fontaine and Shaver 2005) for some of the recovery methods into fewer categories, and recalculated percentages after eliminating entries with unknown and not reported methods that together represented 115 tag returns. Based on the remaining 843 tag returns for which a method was reported, 420 strandings (live, dead, and floating dead) represented 49.8%, 161 incidental captures in shrimp trawls represented 19.1%, and 209 recaptures by all other fishing gears or methods combined (commercial, recreational, and sampling) represented 24.8%. For nesters tagged at RN, Marquez-M. (1994) reported that 71.2% of the tag returns were from shrimp trawling in the Gulf of Mexico.

The threat of incidental capture of Kemp's Ridleys in shrimp trawls was high (Yaninek 1995; Epperly 2003; Lewison et al. 2003) when reintroduction year-classes 1978–1988 were released in

1979–1989, respectively. Federal regulations requiring seasonal use of TEDs in shrimp trawls in offshore waters were first implemented in 1987, but they were not very effective in that year due to legal challenges and federal government suspensions of their enforcement (*ibid.*). Temporal-spatial coverage of federal TED regulations expanded thereafter, until TEDs were required in shrimp trawls at all times and in all areas of the southeast U.S. in 1994 (*ibid.*; Sheryan Epperly, pers. comm.). Even after TEDs were required in shrimp trawls at all times and in all areas, sea turtle strandings continued to be correlated with shrimp trawling in the Gulf of Mexico (Caillouet et al. 1996; Lewison et al. 2003; Finkbeiner et al. 2011; Caillouet 2012b). Only the 1993–2000 year-class turtles were released in an environment in which the threat of incidental capture in shrimp trawls was substantially reduced compared to years preceding 1993.

Releasing most head-started turtles along the Texas coast, and mostly during periods and in areas temporarily closed to shrimping, gave them short-term protection from interactions with shrimp trawling, but not during periods open to shrimping before or after such closures (Shaver 1998, 2005; Lewison et al. 2003). Interestingly, shrimp trawling effort in the northern Gulf of Mexico began to decline in the late 1980s or early 1990s (Caillouet et al. 2008; Nance et al. 2010), which could have contributed along with TEDs to reduction in the threat of incidental capture in shrimp trawls to head-started and wild Kemp's Ridleys (Caillouet 2010, 2014).

After release, head-started Kemp's Ridleys dispersed and some apparently adapted, survived, and grew (Caillouet et al. 1995a, 1995b, 2011). Some females also matured and produced viable offspring in the wild (Fontaine and Shaver 2005; Shaver and Wibbels 2007; Shaver and Caillouet 2015). This occurred, despite their exposure to artificial conditions and manipulations in captivity (from the egg stage to their release as yearlings) and to multiple anthropogenic and natural threats in the wild. A viable nesting colony of Kemp's Ridley now exists at PAIS (see Figure 2 in Shaver and Caillouet 2015), consisting of head-started and wild nesters (Fontaine and Shaver 2005; Shaver and Wibbels 2007; Shaver and Caillouet 2015), some of which may be offspring of head-started nesters (Caillouet 2005). Hatchlings produced from clutches laid by head-started Kemp's Ridley nesters have been indistinguishable (so far) from those produced from clutches laid by wild nesters, because hatchlings produced from clutches laid by head-started Kemp's Ridleys have not been marked or tagged at PAIS. However, it is possible that genetic studies conducted at PAIS (Frey et al. 2014) may eventually link some of the wild nesters to head-started mothers (Shaver and Caillouet 2015).

Growth and maturity after release.—Somatic growth and maturity in head-started Kemp's Ridleys in the wild have been estimated by Caillouet et al. (1995b, 2011) and Snover et al. (2008). The most definitive analysis of somatic growth in subadult and adult life stages of head-started Kemp's Ridleys was Caillouet et al. (2011). They fitted a von Bertalanffy growth curve to post-release SCL (cm) versus known age (t, in y) of 82 head-started Kemp's Ridley recaptures. The data set was limited to turtles ≥ 40 cm SCL at recapture, which included turtles in transition from subadults to adults, as well as 49 that were known nesters (i.e., known adult females); all were in the declining phase of growth. Juveniles < 40 cm in SCL, considered to be in the exponential phase of growth, were excluded. Use of this size-constrained data set avoided complications related to fitting the von Bertalanffy growth curve to data from juveniles growing exponentially (Snover et al. 2008; Caillouet et al. 2011). The resulting growth curve (Caillouet et al. 2011) was:

$$\widehat{\mathrm{SCL}} = \mathrm{SCL}_{\mathrm{asym}}[1 - e^{-k(t-t_0)}] \quad (4)$$

where the estimated asymptote SCL_{asym} =

64.08 cm, estimated $k = 0.1817$, estimated $t_0 = 3.7011$, and e is the base of natural logarithms; adjusted $r^2 = 0.898$, and n = 82. Applying equation (4) and assuming an SCL at maturity of 58 cm (Márquez M. 1994), we estimated age at maturity at $t = 9.2$ y. Assuming SCL at maturity is 60 cm (Snover et al. 2007), we estimated the time lapse to maturity at $t = 11.5$ y; recent demographic modeling of the wild Kemp's Ridley population assumed it to be 12 y (NMFS et al. 2011; Gallaway et al. 2013). Age at maturity estimated from somatic growth curves increases by increasing increments as the assumed size at maturity increases. Chaloupka and Musick (1997), Chaloupka and Zug (1997), and Snover et al. (2007; Bjorndal et al. 2014) reviewed age, growth, and maturity in wild and head-started Kemp's Ridleys.

Captive breeding.— To establish a captive brood stock, 264 head-started Kemp's Ridleys were distributed among CAY and numerous marine aquaria in the U.S. (Caillouet and Revera 1985; Caillouet et al. 1986b, 1988; Duronslet et al. 1989). The Kemp's Ridleys at CAY provided additional research opportunities (Rostal 2005, 2007; Holder and Holder 2007). Twelve Olive Ridley hatchlings were obtained from Ross Witham, FDNR, Jensen Beach, Florida in September 1984 and were head-started; the six survivors were transferred to Miami Seaquarium in May 1985 (Caillouet et al. 1986b).

CAY was successful in breeding Kemp's Ridleys in captivity (Wood and Wood 1984, 1988, 1989). Two 5 y olds produced eggs in 1984. One released seven eggs in a seawater tank but none developed, and the other deposited 62 eggs in a nest but only three hatchlings emerged and all died. Four 7 y olds nested in 1986, laying a total of 535 eggs from which 78 viable hatchlings were produced. The 184 hatchlings produced from nestings at CAY in 1987 and 1988 were transferred to the Galveston Laboratory and head-started (Caillouet et al. 1995b); 130 yearlings were released from year-class 1987, and 14 from year-class 1988 (Caillouet et al. 1995a). Production of Kemp's Ridley hatchlings through captive breeding at CAY was terminated after 1988 (Duronslet et al. 1989; Márquez-M. et al. 2005). Surviving super head-started adults that had been head-started at the Galveston Laboratory and sent to CAY were returned by FWS to the Galveston Laboratory and released into Galveston Bay in 1992. The remaining brood stock, including survivors originally sent as hatchlings to CAY from RN, and others produced by captive breeding, were transferred to XCaret Eco Park, Quintana Roo, Mexico (Caillouet 2000; Márquez-M. et al. 2004, 2005; Ana Cecilia Negrete, pers. comm.). Two viable hatchlings were produced in 1986 from a nesting named Little Fox at Miami Seaquarium (David Owens, pers. comm.). Little Fox was the only survivor among five Kemp's Ridley hatchlings from RN that were given to Ila Loetscher by Henry Hildebrand in 1971 (Sizemore 2002); this female had been reared in captivity by Ila Loetscher, Sea Turtle, Inc., and flown as an adult to Miami Seaquarium where she nested. Bentley (1989) described unsuccessful attempts in 1984 and 1985 at captive breeding Kemp's Ridleys at Miami Seaquarium; one of the three adult females involved was Little Fox.

Evaluations

The December 1981 issue (No. 19) of Marine Turtle Newsletter contained articles suggesting how head-start might be evaluated, including several that applied to Kemp's Ridley (Hendrickson and Hendrickson 1981; Pritchard 1981; Woody 1981). Table 20 lists additional evaluations of Kemp's Ridley head-start, and we may have overlooked others. It is noteworthy that most of these evaluations took place before the first documented nesting of a head-started Kemp's Ridley occurred in 1996 (Shaver 1996).

Two major evaluations of Kemp's Ridley head-start were initiated by NMFS, both of them external to this agency. The first was conducted by Wibbels et al. (1989. Blue Ribbon Panel Review

Table 20. Sources of additional evaluations of Kemp's Ridley (*Lepidochelys kempii*) head-start.

Pritchard (1979, 1997, 2006)
Ehrenfeld (1982)
Dodd (1985)
Mortimer (1988, 1995)
Allen (1990, 1992)
Magnuson et al. (1990)
Wibbels (1990, 1992)
Woody (1990, 1991)
Dodd and Seigel (1991)
Frazer (1992, 1997)
FWS and NMFS (1992)
Shaver and Fletcher (1992)
Taubes (1992a, 1992b)
Donnelly (1994)
Eckert et al. (1994)
Heppell and Crowder (1994, 1998)
Caillouet et al. (1995c)
Heppell et al. (1996, 2007)
Heppell (1997)
Ross (1999)
Seigel and Dodd (2000)
Godfrey and Pedrono (2002)
Spotila (2004)
Caillouet (2005, 2006)
Fontaine and Shaver (2005)
Mrosovsky (2007)
Shaver and Wibbels (2007)
Kemp's Ridley Recovery Team (2009)
NMFS et al. (2011)
Shaver and Caillouet (2015)

of the National Marine Fisheries Service Kemp's Ridley Headstart Program. Available from http://www.galvestonlab.sefsc.noaa.gov/publications/pdf/930.pdf [Accessed 8 December 2014]); see also Wibbels 1990). The second was conducted in September 1992 (Eckert et al. 1994).

Blue ribbon panel review.—Wibbels et al. (1989 *op. cit.*) and Wibbels (1990) evaluated head-start based on its potential to contribute significantly to Kemp's Ridley recovery, rather than on its originally planned role as part of reintroduction (NPS et al.1978 o*p. cit.*). They recognized that considering head-start as a potential conservation method was controversial among scientists. However, such an evaluation was consistent with the expectations for head-start expressed by Klima (1978). FWS' termination of PAIS imprinting after 1988 (Woody 1990; Jack Woody, pers. comm.) had already disconnected head-start from reintroduction, leaving head-start to be evaluated on its own merits and performance. The panel concurred with the decision to end what it referred to as artificial imprinting at PAIS, noting that imprinting was simply one unproven hypothesis to explain how sea turtles choose nesting beaches. Moreover, the panel stated that artificial imprinting to PAIS added extra variables to the head-start experiment, all with potential to interfere with its effectiveness. This view was especially ironic, because head-start was essential to tagging turtles of year-classes 1978–1988 to provide the means for evaluating the reintroduction experiment. Likewise, it was essential to tagging turtles of year-classes 1989–2000 to provide the means for evaluating the head-start experiment. The panel did not describe the extra variables or how they might interfere with effectiveness of head-start.

After 1988, hatchlings for continued head-starting were putatively imprinted in Tamaulipas, as using procedures similar to those employed at PAIS during 1978–1988. Standard procedures for collecting, transplanting, and incubating eggs as well as releasing emergent hatchlings into the Gulf of Mexico from Tamaulipas beaches were similarly manipulative, even though most of the hatchlings were released (i.e., not collected for head-starting). The major difference was that hatchlings for head-start, whether putatively imprinted at RN or PAIS, were collected from the surf and sent to the Galveston Laboratory. In Tamaulipas, most naturally laid clutches were collected and transplanted into artificial (prepared by humans) nest cavities within beach corral hatcheries, but some were also placed in local sand within Styrofoam^{TM} boxes (NMFS et al. 2011). Hatchlings that emerged were retrieved, transferred in containers to release locations, placed on the beach, and protected during their crawl to the surf (Márquez-M. et al. 2005; Heppell et al. 2007). Hatchlings produced in nests left *in situ* (*ibid.*; Gallaway et al. 2013; Bevan et al. 2014) were not protected during their crawl to the surf. Shaver and Wibbels (2007) reported an overall hatching success of 77.1% for eggs obtained from RN and incubated in Styrofoam^{TM} boxes at PAIS (i.e., the 1978–1988 year-classes), as compared to an overall hatching success of 63.1% for eggs incubated in corrals at RN (Shaver 2005). The main differences between operations in Tamaulipas and PAIS were the numbers of clutches transplanted and hatchlings released, although there may have been other differences involving methods of transporting eggs, transporting emergent hatchlings, and distances crawled by the hatchlings to the surf. For head-start, hatchlings taken from Tamaulipas in 1978 and after 1988 were collected from the surf and transported to the Galveston Laboratory, just as were those produced from eggs incubated at PAIS. In other words, putative imprinting of head-started Kemp's ridleys as hatchlings was artificial in Tamaulipas as well as at PAIS.

Wibbels et al. (1989 *op. cit.*) lauded the Galveston Laboratory for its refinement of first-year captive-rearing into what they called an exact science, its having better facilities and staff than elsewhere in the world for such purpose, and for its having increased public awareness of the status of sea turtles through the efforts of Carole Allen and HEART. They noted that long term tag returns showed that head-started Kemp's Ridleys could adapt and grow in the wild, and that captive breeding studies indicated they could successfully reproduce in captivity. Wibbels et al. (1989 *op. cit.*) justified the cost of head-start by the unprecedented opportunity to address its effectiveness as a sea turtle conservation technique. In addition, peripheral research associated with head-start was considered to have potential for providing technologies and data that could enhance sea turtle conservation in general (e.g., development of permanent tagging techniques) and provide life history information. Costs of reintroduction and head-start did not appear to be major concerns of the early planners (NPS et al. 1978 *op. cit.*), but they did not plan continuation of head-start beyond 11 y.

Wibbels et al. (1989 *op. cit.*) established the following new criteria (paraphrased) for assessing success of head-start: Provisional Criteria. (a) apparent competence of head-started turtles at and after release, measured by their survival, growth, body weight, feeding behavior, orientation, and reactions, as compared to those of wild Kemp's Ridleys, (b) ratio of recoveries (tag returns and strandings) of head-started to those of naturally occurring Kemp's Ridleys, taking into account the number of hatchlings produced at RN and the number of hatchlings head-started (i.e., produced at PAIS), as well as possible biased sampling due to presence of tags on head-started turtles, and (c) comparison of recovery locations of head-started and wild Kemp's Ridleys; and Ultimate Criterion. The proportion of nesting head-started females should increase gradually over a 5-y period relative to the proportion of wild nesting females. Recommendations by Wibbels et al. (1989 *op. cit.*) included (1) limiting head-starting to 2,000 hatchlings per year and ≤ 1 y, and releasing all healthy and normally developed individuals (i.e., without obvious genetic defects) after about 8–12 mo of captive-rearing, with the exception of captive-rearing a minimal number for ≤ 2 y for use in TED testing, (2) using tag returns and stranding data from head-started and wild Kemp's Ridleys to provide insight regarding competence of head-started turtles in the wild as compared to wild counterparts, (3) continuing development of practical means of assessing turtle fitness, using controlled feeding to prevent them from becoming too fat, and using physical and physiological data to guide such procedures, (4) continuing research on tagging with conventional tags, living tags, CWTs, and PITs, (5) continuing research to develop a practical and non-lethal sexing technique, especially for hatchlings, (6) continuing research on sex ratios of head-started turtles with the aim of achieving a 50F:50M ratio or one with a slight female bias, but certainly not one > 70% female, by changing nest location or choosing eggs early or late during the nesting season at RN, (7) continuing research toward developing radio- and sonic-tracking technology on both head-started and wild Kemp's Ridleys, to generate baseline data on ecology, behavior, and competence of the head-started turtles in the wild, (8) continuing recording and compiling strandings and sightings of head-started and wild Kemp's Ridleys, (9) subjecting internal and external research proposals concerning head-start to external review, and developing a specific protocol for submitting research proposals regarding head-started Kemp's Ridleys, and (10) requiring that the entire head-start staff emphasize to the public that head-start is an experiment, that it should not be viewed as the means of saving Kemp's Ridley, and that the primary element of Kemp's Ridley recovery is protection in the natural habitat (e.g., with TEDs).

Wibbels et al. (1989 *op. cit.*) concluded that it was impossible at that time to determine if head-started Kemp's Ridleys recruited into the natural breeding pool, because shrimping-induced mortality rate of both wild and head-started Kemp's Ridleys was so high that few head-started turtles were expected to reach sexual maturity. They emphasized that head-start should not be viewed as a panacea for sea turtle conservation or a means of restoring the population. Otherwise, they warned, protection of the species in its natural habitat could be jeopardized. The panel recommended that head-start be continued but not expanded for 10 y following installation of TEDs on all shrimping vessels in U.S. waters of the Gulf of Mexico and Atlantic. That recommendation was based on estimates of the time required to reach sexual maturity.

Eckert et al. (1994) panel review.—In August 1992, three years after the Blue Ribbon Panel Review, Eckert et al. (1994) reviewed the experimental design of head-start. Although imprinting at PAIS was mentioned as having been concurrent with head-starting through 1988, after which it was discontinued, it was given no further attention except to state that the imprinting program was subsequently focused on monitoring at PAIS for head-started nesters. In reality, putative imprinting associated with head-start continued; its location was simply shifted from PAIS to Tamaulipas. Like Wibbels et al. (1989 *op. cit.*), Eckert et al. (1994) characterized head-starting as "controversial among sea turtle biologists almost from its inception," and cited numerous papers supporting this characterization. They indicated that criticisms of head-starting tended to revolve around concerns that head-started Kemp's Ridleys would not nest or integrate into the wild population due to their confinement during the first year of life, and that head-starting acted to mollify resource policy makers into believing that the causes of the dramatic decline in the Kemp's Ridley population did not need to be addressed. They pointed out that proponents of head-starting generally responded to such criticisms by claiming not enough time had elapsed for the turtles to reach maturity and nest, that marking techniques in the early years were inadequate, and that tagged turtles did not remain tagged long enough to be recognized as head-started when mature and encountered on the nesting beach.

Eckert et al. (1994) emphasized that head-starting was an experiment and not a mitigation measure or technique. Their review focused instead on whether the experimental design was appropriate, and on recommendations they thought would improve it. Eckert et al. (1994) indicated that head-starting should be judged on economic and policy bases if and when proven feasible. Their stated goal was to improve the experimental design so that it would provide scientific information needed to determine whether or not head-starting should be continued. They examined head-starting based on four questions: (1) Is there a testable hypothesis?; (2) Are sample sizes adequate and unbiased?; (3) Does the experiment have a control and an experimental group?; and (4) Does the project have an end point or final goal?

Eckert et al. (1994) concluded that, at its inception, head-starting had no experimental hypothesis that could be tested to determine its effectiveness in supporting the wild population. They attributed this alleged lack to a focus on challenges of captive-rearing, to the extent that consideration of an experimental design was overlooked, and to an apparent assumption "that survival in the marine environment was assured after hatchlings were raised for a year." They acknowledged that captive-rearing had become very successful, and that an experimental hypothesis or set of goals had emerged (i.e., Wibbels et al. 1989 *op. cit.*) because of outside pressure. Eckert et al. (1994) generally agreed with and applauded the provisional criteria proposed by Wibbels et al. (1989 *op. cit.*) to guide head-starting, but considered the ultimate criterion to be flawed. In 1992, the number of nestings by wild turtles was increasing, but no nestings by head-started turtles had been documented. The panel accurately concluded that the only way the proportion of nestings by head-started turtles could increase relative to that of wild turtles would be for nestings by head-started turtles to increase more rapidly than those of wild turtles. Furthermore, the annual number of head-started Kemp's Ridleys released into the Gulf of Mexico decreased after 1993, and releases were sporadic after 2001, while wild hatchling releases increased exponentially (Gallaway et al. 2013; Caillouet 2014). Eckert et al. (1994) suggested a revised goal for the head-start experiment, expressed in a two-part hypothesis: head-starting can produce Kemp's Ridley juveniles that are able to join the natural, wild populations, find their way to nesting beaches, procreate, and hatch viable offspring of their own, and head-started turtles demonstrate equivalent or superior biological fitness (defined as equal or better survival rates from egg to reproductive adult, and equivalent or better fecundity) when compared to those of wild Kemp's Ridleys. They did not specify particular nesting beaches under the first part, which implied that they were more concerned with whether head-started Kemp's Ridleys would find any nesting beach and procreate, than with which beach the turtles might choose for nesting. The first part of their hypothesis has evidence to support it (Caillouet 1998; Fontaine and Shaver 2005; Shaver and Wibbels 2007; Shaver and Caillouet 2015). The second part has not been fully supported, although fecundity of head-started nesters has been shown to be similar to that of wild nesters (Shaver and Wibbels 2007; Shaver and Caillouet 2015).

With regard to the second part of the Eckert et al. (1994) hypothesis, we believe it is unrealistic to evaluate head-starting on a basis of its producing nesters of biological fitness superior to that of wild Kemp's Ridleys. A more appropriate, alternate hypothesis would expect head-starting of a given number of hatchlings to return more nesters to Tamaulipas than the same number of hatchlings released there (see Campbell 1977 *op. cit.*). Expecting superior biological fitness of head-started turtles implies that captive-rearing could somehow improve them in ways other than simply increasing short term survival in captivity, as compared to their wild counterparts of similar sizes and ages. Efforts directed toward maintaining physiological fitness during head-starting were not fully successful. Although survival rate during head-starting (Fontaine et al. 1989b; Fontaine and Shaver 2005; Shaver and Wibbels 2007) was higher than that estimated for wild Kemp's Ridleys of similar sizes and ages (NMFS et al. 2011), other factors related to head-start may have offset this initial advantage after the turtles were released. Equivalent biological fitness in head-started and wild turtles would be a more reasonable null hypothesis for evaluating success, performance, or effectiveness of head-start as a potential recovery method. We are unaware that any other Kemp's Ridley conservation or management method has been expected to produce turtles of superior biological fitness as a criterion for declaring it effective. Regardless, the second part has been partially fulfilled by determining the number of eggs per clutch for head-started Kemp's Ridley nesters (Shaver and Caillouet 2015). Head-start by itself, disconnected from its important role in reintroduction of Kemp's Ridley to PAIS, has not been demonstrated to be successful as a mitigation technique or conservation method. The likelihood that it might eventually be considered successful diminishes as the number of head-started Kemp's Ridleys in the population declines, even though additional head-started nesters (ones not previously documented) may be found in the future. This likelihood is further reduced by the apparently limited efforts directed toward searching for head-started Kemp's Ridley nesters anywhere except at PAIS and other beaches in Texas (Shaver and Caillouet 2015). However, if offspring of head-started nesters can eventually be distinguished genetically from those produced by wild nesters, their contributions to the Kemp's Ridley population may be estimable in the future.

Eckert et al. (1994) concluded that the control group representing wild Kemp's Ridleys had been overlooked, leaving no comparison by which to measure the head-start experiment. They pointed out that stranding data used to describe distribution of the species in the Gulf of Mexico were biased by representing only turtles that died near the coast and washed ashore, while tagged turtles were more readily reported. Therefore, they recommended a rigorous mark-recapture program based on archival tagging of wild Kemp's Ridley hatchlings, and maintenance of previously attached or implanted tags on head-started Kemp's Ridleys, for purposes of determining rates of growth, survival, tag retention, and a host of important life history characteristics in both groups. They emphasized that valid comparisons could only be based on turtles recaptured during the proposed tag-recapture program, to avoid biases associated with comparisons of recaptures in pre-TED years with those in years in which TEDs were required.

Eckert et al. (1994) defined head-started turtles as the experimental group and wild turtles as the control group, then addressed the topic of sample size required to detect effects of introducing head-started turtles into the population. For the control group, they proposed mass-tagging hatchlings at RN with the same types of archival tags (CWTs or PIT tags) that had been applied to head-started Kemp's Ridleys, so the two groups could be distinguished from one another, especially on nesting beaches. By contrast, although NPS et al. (1978 *op. cit.*) called for continued tagging of Kemp's Ridley nesters at RN, this tagging was not intended to evaluate success of reintroduction or head-starting. Instead, permanent tagging of wild females nesting at RN was proposed as a continuation of ongoing work conducted by INP during years prior to initiation of the KRREP (Márquez M. et al. 1982). Interestingly, Marquez-M. (1994) noted that very little tagging of Kemp's Ridleys had been done outside of RN, and indicated that the increase in tagging following implementation of the KRREP was especially that of head-started turtles. In any case, a control group of wild adult females tagged at RN had already been established and enhanced over the years. In addition, tagging of wild Kemp's Ridleys of any life stage from hatchlings to adults was not necessary to distinguish them from multi-tagged, head-started Kemp's Ridleys, unless all external and internal (archival) tags applied to head-started turtles were lost, even when tagging scars remained. Assuming that a head-started Kemp's Ridley lost its foreflipper tag(s) but retained a living tag, PIT, or CWT, it probably would have been identified erroneously as wild if not examined for living tags, PITs, or CWTs. Therefore, the implant locations, codes, or other characteristics of internal archival tags implanted into wild Kemp's Ridleys of any life stage had to be different from those for internal archival tags applied to head-started turtles, so that internally tagged turtles in these two groups could be distinguished by their tags (Fontaine et al. 1993; Caillouet et al. 1997b; Higgins et al. 1997). Nevertheless, it was potentially very useful to tag large numbers of wild hatchlings at RN with archival tags that could link them by year-class to their RN origin, and to hatch dates from which their ages could be determined upon recapture. Interestingly, this was similar to the expected utility of archival living tags applied to hatchling turtles, as envisioned by John and Lupe Hendrickson in the 1980s (Hendrickson and Hendrickson 1981, 1983; Mrosovsky and Godfrey 2003; Kishinami, C. 2003. John Roscoe Hendrickson biography: A daughter's memories. Available from http://www.cedointercultural.org/JRHtext.htm [Accessed 8 December 2014]).

Use of PIT tags on large numbers of hatchlings was considered cost-prohibitive by the Galveston Laboratory, so only CWTs were considered and used for mass-tagging hatchlings at RN, as recommended by Eckert et al. (1994). Prior to the mass-tagging, three laboratory studies were conducted to determine the effects of tagging hatchlings with CWTs, the first on Loggerhead in 1993, and the other two on Kemp's Ridleys in 1994 and 1995 (Higgins et al. 1997). Mass-tagging of Kemp's Ridley hatchlings with CWTs at RN took place in 1996 (3,336), 1997 (10,002), 1999 (10,010), and 2000 (20,537), for a total of 43,885 hatchlings (Caillouet 1998; Snover and Hohn 2004; Snover et al. 2007; Benjamin Higgins, pers. comm.). This 4-y total was more than twice the 23-y total for head-started Kemp's Ridleys tagged and released, but not all of these head-started turtles were tagged with CWTs (see ***Tags and tagging***).

Fontaine et al. (1993) and Higgins et al. (1997) explained the proper protocols required to detect and decode CWTs, whether magnetized or not before release of the turtles. If these protocols are not carefully followed, CWTs will not be detected (Fontaine et al. 1993; Caillouet et al. 1997b; Higgins et al. 1997; Benjamin Higgins, pers. comm.). More importantly, tagging of head-started year-classes had already been conducted in ways that distinguished them from the mass-tagged hatchling year-classes, making it essential that the established detection and decoding protocols be followed (*ibid*.).

Eckert et al. (1994) acknowledged that their recommendations included some protocols that would be considered impossible for most sea turtle species, but believed them possible for Kemp's Ridley because of its small population that nested on a single primary beach. The ambitious, large-scale mark-recapture program they recommended for NMFS was aimed at gathering the following information on head-started and wild Kemp's Ridleys: (1) survival rate of hatchlings to maturity, (2) average survival rate of juveniles to maturity, (3) growth rates of juveniles, (4) behavior, including habitat selection, movement, and migration patterns, (5) physiology, comparing physical fitness of head-started and wild caught turtles, (6) sex ratios of *in situ* populations, (7) size frequency distributions of juvenile populations, and (8) age at maturity. They recommended further that NMFS: (1) establish a large number of netting and capture areas around the Gulf of Mexico and U.S. east coast for purposes of capturing and archival tagging Kemp's Ridleys, and gathering data on size, sex, habitat characteristics, physiological parameters, and food preferences, (2) demonstrate that magnetized CWTs or PIT tags do not adversely impact hatchlings, (3) tag (during two consecutive nesting seasons) a large number of wild hatchlings with archival tags that identified their year-classes, and release them at RN for the purpose of determining survival rates from hatchling to maturity, (4) assess tag retention rates for wild and head-started turtles at different life stages, (5) double-tag all head-started and wild-captured turtles with visible tags, and at least single-tag them with archival tags, and (6) organize and support the tagging program to ensure its longevity and provide means to detect archival tags by the wide range of groups that might encounter tagged turtles.

Eckert et al. (1994) recognized that detection of tagged turtles (head-started or wild) on nesting beaches depended upon levels of searching for nesters and checking them for tags, as well as the numbers of marked turtles available to be detected; i.e., the smaller the numbers the greater the detection effort required and vice versa. Eckert et al. (1994) considered the relatively small numbers of head-started turtles disadvantageous because they required a high level of effort to be detected, yet they also considered the relatively small numbers advantageous because of what they indicated were fewer turtles that were impacted by the experimental technique of head-starting. We reiterate that annual numbers of eggs and hatchlings for reintroduction and head-start (Caillouet 1995b) were purposefully limited from the onset by NPS et al. (1978 *op. cit.*), and these limits were controlled by the participating agencies. Eckert et al. (1994) acknowledged that the level of effort aimed at detecting head-started Kemp's Ridley nesters at RN was not high, and cited Pritchard (1990) who estimated that only 48.4% of Kemp's Ridleys nesting at RN in 1989 were seen during beach monitoring. This 48.4% detection rate is comparable to that in Texas (Shaver and Caillouet 2015), and it may be as high as can be expected given that it takes only about 45 min from the time a nester leaves the water to the time she returns after nesting. Moreover, Eckert et al. (1994) stated that tagging techniques applied to head-started Kemp's Ridleys virtually guaranteed they would not be detected. However, tag returns reported prior to the Eckert et al. (1994) review and thereafter indicated that head-started Kemp's Ridleys could indeed be found when sufficient effort was directed toward searching for, finding them, and examining them for tags (Shaver and Caillouet 1998; Fontaine and Shaver 2005; Shaver and Wibbels 2007). Nevertheless, we concur with Eckert et al. (1994) that the probability of detecting head-started Kemp's Ridley nesters was and continues to be much lower than that of wild nesters (whether tagged or not). This is an expected result of the much larger and increasing (through 2009) numbers of wild Kemp's Ridley females in the population as compared to the much lower and declining numbers of head-started Kemp's Ridley females, combined with relatively low efforts toward searching for and detecting head-started nesters outside of Texas.

The search for Kemp's Ridley nesters in Texas, head-started and wild, has been much more intense at PAIS, SPI, and Boca Chica Beach (near the mouth of the Rio Grande river) than elsewhere in Texas (Shaver and Wibbels 2007; Shaver and Caillouet 2015). Coupled with the fact that most head-started Kemp's Ridleys were released along the Texas coast, the greater effort in searching for them as nesters on Texas beaches probably increases the likelihood of finding them there than elsewhere in the Gulf of Mexico or North Atlantic Ocean. In addition, PAIS was the only area of the Texas coast selected the Kemp's Ridley reintroduction experiment (NPS et al. 1978 *op. cit.*); it continues to be the epicenter of nesting in Texas (Shaver and Caillouet 2015).

Eckert et al. (1994) apparently did not anticipate that their proposed tagging of wild hatchlings with archival tags at RN, if implemented, would provide a means of measuring the effort directed toward their detection and documentation. Because the hatchlings were tagged and released at RN, it was expected that surviving females would return as adults to nest at RN, assuming homing and fidelity to the natal beach. To our knowledge, there have been no documented nestings by survivors of this control group at RN or elsewhere. If some females from each of the four year-classes in this group survived through the 2014 nesting season, they would be 14, 15, 17, and 18 y old adults capable of nesting. Yet, there have been relatively few documented tag returns from any life stage in this group (Snover and Hohn 2004; Snover et al. 2005, 2007; Dodge et al. 2008), suggesting that efforts to detect them have been limited at best. This paucity of tag returns could also be due in part to inadequacy of training of personnel to search for Kemp's Ridleys in this control group, lack of required detection equipment, or both (Higgins et al. 1997;

Benjamin Higgins, pers. comm.). In addition, it is time-consuming to locate these tags, using recommended procedures (Fontaine et al. 1993; see ***Tags and Tagging***), and the detection equipment is very expensive. Nevertheless, assuming that some survivors from this control group remain in the population, they represent a highly valuable resource that could provide the kinds of information envisioned by Hendrickson and Hendrickson (1981, 1983) and Eckert et al. (1994), if they could be found and their tags detected (Caillouet et al. 1997b). At the very least, archived flippers of dead specimens can be examined for CWTs as well as other tags.

Eckert et al. (1994) commented on the relevance of the Blue Ribbon Panel's (Wibbels et al. 1989 *op. cit.*) suggestion that few if any head-started Kemp's Ridleys were expected to reach maturity because shrimping-induced mortality rates were so high. Eckert et al. (1994) agreed that mortality rates associated with trawling were likely high, and that TEDs should be required on all shrimping vessels, but suggested that coverage of the nesting beach was probably not adequate to detect any head-started turtles even if mortality due to shrimping were nil. They proposed that beach coverage at RN be increased to observe all turtles that nest there and that all field teams be outfitted to detect head-started turtles. They suggested that increased beach coverage should be able to determine whether any head-started turtles were currently nesting there. They also were uncomfortable with relying on living tags to detect head-started turtles, suggesting these tags could be easily misinterpreted and that research on their retention and detection rate in the wild had been inadequate. We disagree with their assessment of the living tag, which has proven especially useful in documenting head-started Kemp's Ridley nestings, whether by itself or in combination with other retained tags (Shaver and Caillouet 2015).

Despite their detailed discussion of factors that reduced the probability of documenting head-started Kemp's Ridley nesters, Eckert et al. (1994) suggested that numbers of head-started turtles already tagged with CWTs, PIT tags, or both, and released were adequate to represent the experimental group, and that it was unnecessary to release any more head-started turtles. However, the Galveston Laboratory continued to head-start and tag Kemp's Ridleys (year-classes 1993–2000) with foreflipper tags, living tags, CWTs, and PIT tags, and release them off Galveston, albeit based on about 200 hatchlings received per y. The mass-tagging of hatchlings at RN provided a large and very valuable resource of tagged, wild Kemp's Ridleys of known natal beach origin and approximate age, calculable from hatch and recapture dates. Unless greater efforts are directed toward searching for, detecting, and documenting tag returns of survivors in this control group, this important resource will have been wasted. In our view, survivors from these releases are potentially more valuable toward providing important biological information about the wild population of Kemp's Ridleys, than as a control group to test head-start. Recommendations by Eckert et al. (1994) would also be applicable to mass-tagging (with CWTs or PIT tags) of wild Kemp's Ridleys along the U.S. Atlantic coast, to provide a means of determining the proportion that returns to nest at RN or other Gulf of Mexico beaches. It can safely be assumed that most Kemp's Ridleys along the U.S. Atlantic coast originated from nestings on beaches in the western Gulf of Mexico, especially those in Tamaulipas (NMFS et al. 2011). One Kemp's Ridley that nested at PAIS had been rehabilitated in Massachusetts, tagged, and released. Published records documenting Kemp's Ridley returns from the Atlantic to the Gulf of Mexico appear to be fewer than 20, and all were reported nesting at or near RN (Schmid 1995; Chaloupka and Zug 1997; Schmid and Witzell 1997; Witzell 1998; Schmid and Woodhead 2000). Until substantially more evidence is amassed to the contrary, it will continue to appear that most Kemp's Ridleys that nest in the Gulf of Mexico have not spent time in the Atlantic.

Evaluations via demographic modeling.— Heppell et al. (1996) emphasized that survival and growth rates for both head-started and wild Kemp's Ridleys must be known before head-start can be evaluated. Survival rate of head-started Kemp's Ridleys from egg to reproductive adult has not been determined per se. However, survival rates from eggs to hatchlings (Shaver 2005; Shaver and Wibbels 2007; Shaver and Caillouet 2015) and hatchling to yearlings (Fontaine and Shaver 2005) in captivity, and following release of yearlings into the Gulf of Mexico (Caillouet et al. 1995a) have been estimated. For comparison, survival rates of various life stages of wild Kemp's Ridleys have been estimated (TEWG 1998, 2000; Heppell et al. 2005, 2007; NMFS et al. 2011; Gallaway et al. 2013). Based on matrix modeling, Heppell and Crowder (1994) predicted that head-starting could not contribute significantly to the Kemp's Ridley population, even if head-started juveniles had the same survival and growth rates as wild juveniles. Crowder et al. (1998) stated that the best use of this type of analysis was to eliminate management alternatives unlikely to lead to population recovery, and gave Kemp's Ridley head-start as an example. Using a series of hypothetical matrix models, each with a different age at maturity, Heppell and Crowder (1998) showed that only slight increases in the number of nesting Kemp's Ridley females might be expected from a head-start program, but these increases were inconsequential compared to the potential benefits of TEDs.

Discussion

Meylan and Ehrenfeld (2000) reviewed active intervention and management approaches that promote sea turtle conservation and prevent sea turtle populations from declining. They suggested that Bjorndal (1982) remains a useful guide that advocates least-manipulative techniques. Meylan and Ehrenfeld (2000) explained that an inherent problem with manipulative management techniques is that once one is chosen, many decisions are required to implement it, and in most cases the information needed to guide the decisions is inadequate. Nevertheless, Meylan and Ehrenfeld (2000) characterized Kemp's Ridley head-start as the world's premier head-start project, and indicated that it complemented efforts to protect nests and release hatchlings at the nesting beach in Mexico.

There can be no doubt that reintroduction and head-start were highly manipulative. The early planners were focused on reestablishing Kemp's Ridley nesting at PAIS, and proposed methods they thought would accomplish this goal, based on limited information available at the time. The existing nesting colony at PAIS (Plotkin 1999; Lewison et al. 2003; Shaver and Caillouet 2015) is evidence that the early planning was sufficient. In December 2000, TPWD implemented regulations prohibiting shrimp trawling within 5 mi of the southern Texas coast from 1 December each year through 15 July of the next year (Lewison et al. 2003). Lewison et al. (2003) implied that the second nesting population on Padre Island was worthy of protection by this seasonal closure to shrimping. They estimated that this closure would likely reduce mortality of adult Kemp's Ridleys by as much as 39%, and "protect a second Kemp's ridley nesting beach to safeguard the population should a catastrophe affect the primary nesting beach in Rancho Nuevo, Mexico."

Inadequacy of information was also evident in the decision to terminate imprinting at PAIS in 1989, while allowing head-start to continue with hatchlings imprinted at RN. However, timing of this termination was consistent with the schedule proposed by NPS et al. (1978 *op. cit.*). In addition, there was concern that the reintroduction and head-start experiments were giving a false impression, within the U.S. and elsewhere, that they were proven sea turtle conservation methods, and this impression might undermine protection of the wild stock (Jack Woody, pers. comm.). Regardless, this decision not only reduced the probability that reintroduction would achieve its goal, but it also separated head-start from reintroduction, thereby raising the bar for evaluation of head-start as a potential stand-alone conservation measure. In retrospect, this decision did not prevent reintroduction of Kemp's Ridley to PAIS, and it allowed head-start to be evaluated separately, on its own merit and performance.

Although Kemp's Ridley head-start involved manipulation of egg through yearling life stages, once the surviving yearlings were released into the Gulf of Mexico they were left to fend for themselves (Eckert et al. 1994; Caillouet et al. 1995a, 1995b; Caillouet 2005; Fontaine and Shaver 2005; Shaver and Wibbels 2007). The methods used at RN and PAIS to supply hatchlings for head-start, combined with head-start methods used at the Galveston Laboratory, boosted survival rates of life stages from egg through yearling (Fontaine and Shaver 2005; Shaver and Wibbels 2007; Shaver and Caillouet 2015) as compared to survival rates of wild Kemp's Ridleys of similar life stages. Operations in Tamaulipas and PAIS that produced hatchlings for head-start were short-term compared to those that extended human control and manipulation at the Galveston Laboratory.

It is important, especially in the context of the current situation facing Kemp's Ridley (Caillouet 2014), to consider that reintroduction of Kemp's Ridley to PAIS might have been accomplished without head-start, by annually transplanting eggs to PAIS from RN, and releasing emergent hatchlings at PAIS instead of head-starting them. However, had hatchlings been released at PAIS instead of being head-started, reintroduction might have taken longer than it did when combined with head-starting, because hatchling mortality is naturally high. Conversely, head-starting may have decreased survival and performance after release as compared to wild Kemp's Ridleys of similar ages and sizes. Turtles that died during head-starting were the source of sex ratio information that was used to determine pivotal incubation temperature; without this information, it would have taken longer to determine pivotal temperature for Kemp's Ridleys. As it was, only four year-classes (1985–1988) of PAIS-imprinted hatchlings were female-biased (Shaver and Caillouet 2015).

Finally, determining success of releasing hatchlings at PAIS (instead of head-starting them), as an alternative means of reintroducing nesting to PAIS, would not have been possible without tagging hatchlings. Without head-start and tagging, any increased nesting at PAIS that might have resulted from releasing hatchlings at PAIS probably would have been attributed to other conservation efforts and not to reintroduction efforts. This underscores the need for better methods for mass-tagging hatchlings (Allen 1981).

Manipulative management techniques were and still are employed in Tamaulipas on a very large scale (Burchfield and Peña 2013). During 1978–1992, 1,286,900 eggs were produced at RN as compared to an estimated 36,025 eggs taken for reintroduction and head-start during the same period (Caillouet 1995b), a ratio of about 36:1. During 2009 alone, 1,089,452 hatchlings were released from Tamaulipas beaches (Burchfield 2009). The manipulative management procedures employed in Tamaulipas gave eggs and hatchlings the substantial boosts in terrestrial survival rate that saved Kemp's Ridley from extinction and helped put it on an exponential trajectory (through 2009) toward recovery (Table 21). It is also possible that such procedures applied toward increasing the Kemp's Ridley population might have had some negative effects (Burke 1991; Dodd and Seigel 1991; Meylan and Ehrenfeld 2000; Mrosovsky 2007).

Reintroduction was not planned as a means of testing the imprinting hypothesis, but its operations were designed with the intention of imprinting Kemp's Ridleys to PAIS before head-starting them (NPS et al. 1978 *op. cit.*). Imprinting was seen as necessary to reintroduction and head-start. However, even though most wild Kemp's Ridleys

Table 21. Sources covering the manipulative management procedures employed in Tamaulipas, and the reductions in at-sea mortality due to use of turtle excluder devices (TEDs) and declining shrimp trawling effort, that helped put the Kemp's Ridley (*Lepidochelys kempii*)population on an exponential trajectory (through year 2009) toward recovery.

Heppell and Crowder (1994, 1998)
Heppell et al. (1996, 2005, 2007)
Heppell (1997)
TEWG (1998, 2000)
Epperly (2003)
Lewison et al. (2003)
Caillouet (2005, 2006, 2010, 2011, 2014)
Márquez-M. (2001)
Márquez-M. et al. (2005)
Crowder and Heppell (2011)
NMFS et al. (2011)
Gallaway et al. (2013)
Caillouet (2014)

nest on Gulf of Mexico beaches of Mexico (especially at RN), significant numbers nest in Texas, and some individuals have been documented to nest both in Mexico and Texas, suggesting that natal beach imprinting is not absolute (Shaver and Caillouet 2015). Nevertheless, reintroduction and head-start can both be evaluated indirectly in the context of the imprinting hypothesis (Shaver and Caillouet 2015).

Putman and Lohmann (2008) hypothesized that Kemp's Ridleys detect two elements of the magnetic field, inclination angle and total intensity, as Loggerhead turtles are known to do (Lohmann and Lohmann 1994, 1996). Putman and Lohmann (2008) examined the hypothesis that Kemp's Ridley hatchlings at RN imprint on one of these elements of RN's magnetic field and use this information to navigate and return there as adults to reproduce. As a first step, they conducted modeling under assumptions of 10 y and 15 y at sexual maturity, and an inability of the turtles to compensate for gradual drift in magnetic signatures of RN over time. Theoretically, if the turtles imprinted on inclination angle at RN, they could return within an average distance of 23 km from RN if absent 10 y, or within an average distance of 32 km if absent 15 y. If they imprinted on magnetic field intensity, they could return within an average distance of 89 km from RN if absent 10 y, and within an average distance of 132 km if absent 15 y. These results were consistent with the known precision of natal homing in Kemp's Ridleys, and indicated that magnetic imprinting could return turtles sufficiently close to their natal region where they could then use other local cues to pinpoint particular nesting areas. Simply stated, if turtles learn the magnetic signature of their home area before hatching, or acquire this information during their crawl to the surf, and if magnetic navigation is primary in guiding sea turtles to their natal beach as adults, then head-started Kemp's Ridley imprinted at PAIS should have homed on PAIS as adults and those imprinted at RN should have homed on RN as adults, unless other factors prevented or disrupted the effects of magnetic imprinting.

According to David Owens (pers. comm.), a similar case can made for homing based on olfactory imprinting to geological and faunal cues. However, a limitation of olfactory imprinting is that odorants typically do not extend long distances through the sea, and turtles approaching from directions that are not down-current presumably cannot detect odorants from the natal area until they are very near the target (Lohmann et al. 1999, 2013). For this reason, adult turtles have been hypothesized to use two different sets of cues sequentially as they navigate to their natal beaches: magnetic information may be used over long distances to guide turtles into the general vicinity of their nesting areas, and local cues (e.g., olfactory, visual, or both) may be involved in selecting the final nesting sites (Lohmann et al. 2008a, 2008b).

Putman et al. (2010) investigated the hypothesis that relative abundance of Kemp's Ridley nests on beaches in seven coastal regions of the western Gulf of Mexico can be explained by the location and characteristics of surface currents that facilitate passive transport of pelagic hatchlings and early juveniles (≤ 2 y old) to coastal foraging grounds in the Gulf and western North Atlantic. The seven regions were Texas, North of RN, RN, South of RN, Veracruz, South Campeche, and North Campeche. Computer simulated particles (hypothetical hatchlings) were released 45–55 km offshore from each region during 1 June–20 July in 2004–2007, and their pattern of passive dispersal over two years was simulated. Annual results were averaged and the averages used to rank the seven regions according to overall favorability of surface circulation in dispersing the turtles. Surface circulation was most favorable to turtles originating at RN where most nests occur, followed by South Campeche, Veracruz, North of RN, Texas, North Campeche, and South of RN. Highest to lowest rankings by estimated nest abundance were RN, Veracruz, South of RN, Texas, and South Campeche, with North Campeche and North of RN tied at zero nests. It is interesting that Texas placed fifth in ranking by favorability of surface circulation, but fourth in ranking by estimated abundance of nests. In other words, Texas ranked higher in estimated abundance of nests than did South Campeche, North Campeche, and North of RN, two of which (South Campeche and North of RN) outranked Texas in favorability of surface circulation. Especially significant is that Texas' estimated nest abundance outranked that for North of RN (i.e., between RN and Texas) as well as South Campeche, which had the second most favorable surface circulation ranking. In addition, Texas' estimated nest abundance outranked that of North Campeche. Since most nesting in Texas occurs at PAIS, this suggests that reintroduction of Kemp's Ridley to PAIS took place despite Texas' less favorable surface circulation ranking.

Because exponential growth in the Kemp's Ridley population was interrupted in 2010, and nests numbers declined in 2013 and 2014 (Caillouet 2014), it may be necessary to intensify the manipulative conservation approaches in Tamaulipas that contributed to exponential increase in the population through 2009. We will not make specific recommendations in this regard. However, although not necessary for restoration of population growth, an improved lifetime tag, applicable to large samples of hatchlings, would be useful to identify their year-class and beach of origin (Hendrickson and Hendrickson 1981, 1983; Eckert et al. 1994), as a means of evaluating these approaches. We suggest that a less invasive, non-surgical, living tag be developed for this purpose, one applicable to marking more than one scute per hatchling, since marking combinations of scutes increases the number of year-classes that can be distinguished from one another. We also recommend that greater attention be paid to searching for and documenting recaptures of tagged Kemp's Ridleys, especially on nesting beaches.

How Should Success be Judged?

Ultimately, the general question arises as to how success of Kemp's Ridley head-start and reintroduction should be judged (Burke 1991; Dodd and Seigel 1991). According to Dodd and Seigel (1991), the goal of any conservation program is establishment (or enhancement) of a viable, self-sustaining population that is at least stable. This implies that the KRREP and related conservation efforts would have to establish or enhance such a Kemp's Ridley population to prove their success. Burke (1991) responded to Dodd and Seigel (1991), indicating that (1) it is difficult to determine at what point a population becomes self-sustaining and stable, (2) such population characteristics are subject to variability, and (3) there are no guarantees they are sustainable with or without human intervention. The bi-national recovery plan (NMFS et al. 2011) provides criteria for assessing when the Kemp's Ridley population has recovered and can be removed from the list of endangered species (i.e., delisted, after first being down-listed to threatened status). These criteria represent very high standards for evaluating success of Kemp's Ridley conservation efforts. Since Kemp's Ridley has not yet been down-listed to threatened status, neither the KRREP nor any other conservation measures aimed at Kemp's Ridley recovery have singly or in combination proven successful by the standards of Dodd and Seigel (1991). However, it is safe to say that conservation efforts within the KRREP and those outside the KRREP (e.g., TED regulations and enforcement), as well as declining shrimp trawling effort, helped set the Kemp's Ridley population on an exponential trajectory toward recovery (Table 21) that lasted until it was interrupted in 2010 (Caillouet 2011; Crowder and Heppell 2011; Gallaway et al. 2013; Caillouet 2014). The exponential increase (through 2009) in numbers of clutches laid on Tamaulipas beaches certainly was a highly positive outcome, because it indicated that conservation efforts and some exogenous factors (e.g., declining shrimping effort) worked in positive ways toward Kemp's Ridley recovery. Protecting nesters, eggs, and hatchlings in Tamaulipas definitely had a positive effect on the Kemp's Ridley population (*ibid.*). Use of TEDs in shrimp trawls and declining shrimping effort in the Gulf of Mexico increased survival of post-pelagic Kemp's Ridleys at sea (Table 21).

Kemp's Ridley nesting has been reintroduced to PAIS (Shaver and Caillouet 2015), and the nesting colony there was also growing exponentially through 2009. Some of the wild nesters at PAIS could be offspring of head-started nesters, but others could have been produced by nestings of wild Kemp's Ridleys in Texas, Mexico, and elsewhere. No doubt head-starting had a positive effect by allowing tagging of yearlings so they could be identified as part of Kemp's Ridley reintroduction to PAIS. However, it may be impossible to determine whether head-starting by itself, outside its context as part of the reintroduction experiment, had a positive effect on the population, since numbers of head-started individuals in the population are declining. Nevertheless, head-starting and reintroduction were successful in producing a considerable body of useful biological information about Kemp's Ridleys that otherwise would not have been produced.

Cost-effectiveness of reintroduction and head-start eventually became a consideration in their evaluation (Woody 1990; Shaver and Fletcher 1992; Taubes 1992a, 1992b; Wibbels 1992; Eckert et al. 1994). NPS et al. (1978 *op. cit.*) did not call for collection and archival of cost data or assessment of cost-effectiveness of any part of the KRREP. As far as we are aware, none of the participating agencies imposed such requirements later on, to assure that data were available for quantitative assessments of cost-effectiveness of the KRREP as a whole or in its separate parts. Neither of the two Kemp's Ridley recovery plans (FWS and NMFS 1992; NMFS et al. 2011) called for cost-effectiveness assessments of any conservation effort applied to date. Wibbels et al. (1989 *op. cit.*) justified the costs of head-starting simply by invoking the worldwide interest in possible effectiveness of head-starting as a conservation technique, and the unprecedented opportunity afforded by the Galveston Laboratory to address this issue. Cost per hatchling released at RN and cost per head-started yearling released into the Gulf of Mexico were compared by Woody (1991), but he did not provide details regarding how his cost estimates were derived. Shaver and Fletcher (1992) noted that costs of incubation and imprinting at PAIS were significantly lower than those of head-starting. This was to be expected, if for no other reason than shorter duration of operations, simpler and smaller facilities, and smaller sizes of eggs and hatchlings at PAIS, as compared to longer duration of operations, more complex and larger facilities, and larger turtles associated with head-starting. A further complicating factor in evaluating cost-effectiveness of head-start and reintroduction is that actual costs included "in kind contributions" made by a variety of agencies, organizations, institutions, and industries, the values of which were not determined. In addition, there is a question whether costs of research conducted in support of reintroduction and head-start should be included in their evaluation.

Any future assessment of cost-effectiveness of reintroduction and head-start should include comparable assessments of cost-effectiveness of protecting nesters, eggs, and hatchlings in Tamaulipas, the requirement for TEDs in shrimp trawls, and any other conservation methods aimed at Kemp's Ridley recovery. Such comparable assessments have not been conducted to our knowledge, with one exception. During 2000–2002, the National Center for Ecological Analysis and Synthesis (NCEAS) conducted a study (NCEAS, Biggest Bang for the Buck: Really Melding Demographic Theory with Economics. Available from https://www.nceas.ucsb.edu/projects/3560 [Accessed 16 August 2014]) that attempted to determine cost-effectiveness of various Kemp's Ridley conservation methods including experimental head-start (see Caillouet 2005, 2006, 2009, 2010). Its results have not been published as far as we are aware. However, the fact that the study was conducted suggests that cost data were available and used. If in the future a cost-effectiveness study is conducted to compare Kemp's Ridley conservation methods, we believe it should include costs in relation to all life stages from egg through reproductive adult, as recommended by Eckert et al. (1994); it should also include costs of demographic modeling (see Heppell and Crowder 1994, 1998; Heppell et al. 1996, 2005, 2007; Crowder et al. 1998). Because research has been associated with all conservation methods applied to date, the value of these research contributions should logically be integrated into any future cost-effectiveness analysis. However, considering the complexities of determining and tracking cost-effectiveness of conservation and research over time, and the paucity of available cost data, we believe an accurate evaluation of cost-effectiveness of Kemp's Ridley conservation approaches is not possible at this time.

Epilogue

Robert Whistler drafted NPS (1974 *op. cit.*), which contains the earliest recommendation to reintroduce Kemp's Ridley to PAIS, and Roland Wauer and other NPS officials approved it. Clyde Jones and Roland Wauer initiated further planning in 1977 (Wauer 1999), beginning with Howard Campbell's feasibility study (Campbell 1977 *op. cit.*), and they established a board of professional advisors (i.e., the SAB) who provided valuable input and oversight during the planning. Reintroduction of Kemp's Ridley to PAIS was the primary focus of early planning (NPS 1974 *op. cit.*; Campbell 1977 *op. cit.*; NPS et al. 1977 *op. cit.*; NPS et al. 1978 *op. cit.*; Wauer 1978). Roland Wauer and NPS played leadership and coordinating roles in the early planning with input from participating individuals and agencies. Reintroduction, head-start, and protection and enhancement at RN were incorporated into the Action Plan (NPS et al. 1978 *op. cit.*) that was implemented in 1978 as the KRREP. Wauer (1978) and Woody (1986) elucidated the original importance of reintroduction of Kemp's Ridley to PAIS, and Woody (1991) reinforced it:

"The original concept was to attempt to establish a second nesting population at Padre Island as insurance against the possibility that the Rancho Nuevo core group might be lost, as well as to develop the techniques necessary to maintain the species in captivity should all else fail. The concept made sense in 1978, and I supported the idea then."

This concept still makes sense, especially in contexts that a nesting colony now exists at PAIS, and pre-2010 expectations regarding population recovery (NMFS et al. 2011) have changed (Caillouet 2010, 2011, 2014; Crowder and Heppell 2011; Gallaway et al. 2013).

The KRREP went as planned for 11 y, during which many unanticipated problems were identified and attempts made to solve them. For example, the problem of male-biased sex-ratios was solved in 1985, when sufficient data had accumulated to determine pivotal incubation temperature; incubation temperatures were then controlled in ways that produced female-biased sex ratios in the 1985–1988 year-classes imprinted at PAIS (Mrosovsky and Godfrey 2010; Caillouet 2012a; Shaver and Caillouet 2015). In Tamaulipas and elsewhere, incubation temperatures during the nesting season must also be generally favorable to producing females, because sex ratios in the Kemp's Ridley population are female-biased (Coyne and Landry 2007; Wibbels 2007; Mrosovsky and Godfrey 2010; Caillouet 2012a). PAIS imprinting was terminated in 1989 (Wibbels et al. 1989 *op. cit.*; Wibbels 1990), but head-starting continued with 1989–2000 year-class hatchlings imprinted at RN. In 1993, the number of hatchlings received annually from RN was reduced to about 200 or fewer; in 1994, the turtles from the 1993 year-class were used in TED testing and certification, and year-classes thereafter were used for research on tags and tagging until year-class 2000 was released. Searches for and documentation of head-started nesters and compilation of tag-returns continue to this day, especially in Texas and mainly at PAIS. Despite all changes and challenges associated with reintroduction and head-start, nesting of Kemp's Ridleys was reintroduced to PAIS.

Putman and Lohmann (2008) indicated that magnetic imprinting occurs in hatchlings on their natal beach, and that adults use this information to guide them sufficiently close to their natal beach so that additional local cues can help them find it. This implies that hatchlings also sense, store, and use information about magnetic fields they experience during dispersal to pelagic habitats as hatchlings and during long and repetitive migrations to and from foraging grounds as they survive and grow toward maturity. If similar imprinting occurred in hatchlings that were head-started, and if their captivity and locations of release as yearlings did not interfere with their ability to navigate and return as adults to their natal (i.e., imprinting) beach, then survivors imprinted at PAIS should have returned as adults to PAIS and those imprinted at RN should have returned to RN. If head-starting altered the magnetic memory, survivors might be expected to home as adults to Galveston beaches; head-started Kemp's Ridleys have nested there (Shaver and Caillouet 2015). Head-started yearlings were exposed to different magnetic fields at their release sites and during dispersal from those sites. If, as Putman et al. (2010, 2013) suggest, surface circulation influences distribution and survival of young Kemp's Ridleys and where they eventually return to nest, and if this applies as well to head-started yearlings, they might be expected to return to nest near their release sites. It is also possible that moving eggs and hatchlings, head-starting, and releasing yearlings in various locations disrupts natural, magnetic memory mechanisms to the extent that most if not all such turtles are destined to unnatural, aimless wanderings, thus reducing their chances of ever reproducing. Yet, head-started Kemp's Ridley females found beaches, nested on them, and produced viable eggs and hatchlings in Texas and Mexico (Shaver and Caillouet 2015). Therefore, some head-started Kemp's Ridleys survived to maturity, found mates, copulated, nested, and their eggs produced viable hatchlings. Apparently, nesting at PAIS was sufficient to reestablish a nesting colony there. It remains to be determined whether this colony will continue to grow and become sustainable. It continues to be supported by manipulative conservation methods, as are the nesting colonies in Mexico (NMFS et al. 2011). The combined influences that reduced the probability of reintroducing Kemp's Ridley nesting to PAIS were insufficient to prevent it, and this makes the reintroduction all the more remarkable.

Clearly, the amounts of effort applied in searching for head-started and wild nesters on beaches in the U.S. and Mexico influence numbers of nesters found and documented (Byles 1993;

Williams 1993; Eckert et al. 1994; NMFS et al. 2011; Shaver and Caillouet 2015). The number of nesters examined also influences the chance of finding a head-started Kemp's Ridley. The fact that relatively few head-started Kemp's Ridley nestings have been documented on beaches anywhere other than PAIS implies that reintroduction worked, but it also could have been affected by the high level of searching for nesters, both head-started and wild, at PAIS. More nestings of head-started Kemp's Ridleys may have occurred than have been documented anywhere. Had search and tag detection efforts aimed at documenting head-started Kemp's Ridley nesters been equally intense in Tamaulipas and Texas, then a valid comparison could be made between nestings of PAIS and RN imprint groups. If, on the other hand, the location of release of head-started Kemp's Ridleys played a dominant role in where they returned to nest, a completely different distribution of their nesting might be expected (Shaver and Caillouet 2015). No nestings by wild Kemp's Ridleys tagged with CWTs as hatchlings at RN have been documented anywhere despite the 43,885 released during 1996–2000 at RN.

In our opinion, the results of reintroduction are very promising. The current level of nesting at PAIS greatly exceeds that documented historically (Hildebrand 1963; NPS 1974 *op. cit.*), although nesting levels were poorly documented before 1996 (Shaver and Caillouet 2015). The goal of reintroducing Kemp's Ridleys to PAIS was achieved, but there are no guarantees the colony will continue to increase and become sustainable. Incidentally, the same is true for nesting colonies in Tamaulipas and elsewhere on Mexico's coast of the Gulf of Mexico, and interruption of the exponential increase after 2009 is of great concern in this regard. The need for a secondary nesting colony has not ended, and the Kemp's Ridley population is still endangered (NMFS et al. 2011). Further efforts will be needed to monitor, sustain, and enhance nesting colonies in Tamaulipas and Texas until Kemp's Ridley is delisted (NMFS et al. 2011).

Head-starting contributed to reintroduction, because it provided tagged turtles from year-classes 1978–1988 that could be linked to reintroduction. It also increased survival during the first year of life. However, reintroduction through transplantation of eggs and release of hatchlings might have worked had it been tried, but mass-tagging of hatchlings would have been required to provide a means of assessing success of such an approach.

One rationale given in NPS et al. (1978 *op. cit.*) for head-starting hatchlings from RN in 1978 was that it was expected to compensate for taking eggs for reintroduction. This could be interpreted as an expectation on the part of the planners that head-starting would be an effective conservation or management tool in and of itself (Klima 1978; NPS et al. 1978 *op. cit.*). However, we would not recommend it for this purpose. Head-starting of Kemp's Ridley has not shown promise as a management tool outside its connection to reintroduction. Perhaps head-starting worked to the degree it did because the turtles were in their pelagic phase, after which they were ready physiologically and behaviorally for a new diet and a benthic life style (David Owens pers. comm.). Most were reared 9–11 mo before release, and the pelagic phase has been assumed to last two years (TEWG 1998, 2000; Heppell et al. 2005, 2007; NMFS et al. 2011; Witherington et al. 2012).

Recommendations made by Eckert et al. (1994), that NMFS initiate a major effort to search for wild Kemp's Ridleys CWT-tagged as hatchlings at RN, did not materialize. Although 43,885 hatchlings were tagged with CWTs at RN, few tag returns have resulted, suggesting that efforts aimed at detecting these turtles were inadequate. Without the required effort to find these CWT-tagged turtles as nesters in Tamaulipas or elsewhere, we cannot determine whether release of head-started Kemp's Ridleys returned more nesters to RN than would have been returned had the hatchlings been released at RN, even though head-started nesters have been documented nesting at RN, PAIS, and elsewhere. Another obvious question is why some head-started Kemp's Ridleys imprinted to RN have nested in Texas and elsewhere outside of RN (Shaver and Caillouet 2015). It is possible that they nested in Tamaulipas in greater numbers but were not examined for tags (external and internal) and therefore were not documented.

The numbers of nesters (head-started and wild) at PAIS are significant and were increasing through 2009. Also important to consider is that some of the thousands of female hatchlings produced by head-started nesters at PAIS likely survived, nested, and produced more offspring. Therefore, over time, reintroduction and head-start may have had, and may continue to have, multiplicative effects on the nesting colony at PAIS as well as nesting elsewhere (Caillouet 2005). Although hatchlings produced by head-started nesters have not been tagged before release, ongoing genetics work might be able to link some of them to head-started nesters (Shaver and Caillouet 2015).

Continued head-starting of Kemp's Ridleys was recommended by Wibbels et al. (1989 *op. cit.*), Wibbels (1990), and Eckert et al. (1994). Unfortunately, the mass-tagging and releases of hatchlings at RN, recommended by Eckert et al. (1994), produced few returns, none of which were documented nesting at RN. However, mass-tagging of hatchlings with CWTs was shown to be practicable. The lack of documented nestings at RN from these releases suggests that little if any effort was expended toward their detection. However, if none survived to maturity, the result would be similar.

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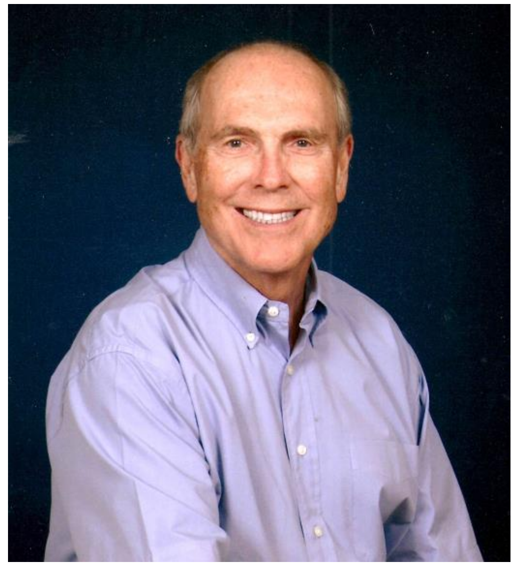

Charles W. Caillouet, Jr. has a B.S. in Forestry (1959) and M.S. in Game (Wildlife) Management (1960) from Louisiana State University, and Ph.D. in Fishery Biology (1964; minors Statistics and Physiology) from Iowa State University. His doctoral research focused on the relationship between forced exercise and blood lactic acid in Channel Catfish (*Ictalurus punctatus*). During 1964–1967, while an Assistant Professor at University of Southwestern Louisiana (now University of Louisiana Lafayette), he investigated abundance and distribution of postlarval Brown Shrimp (*Farfantepenaeus aztecus*) and White Shrimp (*Litopenaeus setiferus*) in Vermilion Bay, Louisiana. During 1967–1972, as Associate Professor at Rosenstiel School of Marine and Atmospheric Science, University of Miami, he helped establish a commercial marine fisheries statistics collection program for Puerto Rico's Department of Agriculture, conducted statistical analyses and evaluation of sport fishery catch rates in Everglades National Park, and directed and conducted Sea Grant aquaculture research on Pink Shrimp (*F. duorarum*). He was to first to induce maturation in female pink shrimp by eyestalk ablation. As Supervisory Fishery Biologist (Research) and Chief of various divisions and branches at the Galveston Laboratory during 1972–1998, he supervised and conducted research related to biology, population dynamics, and aquaculture of Penaeid shrimp, and head-starting Kemp's Ridley; he also managed environmental impact studies related to petroleum exploration and production, and Strategic Petroleum Reserve salt dome brine disposal. In October 1985, he and Dr. André Landry chaired the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management, at Texas A&M University Galveston. In 1988, Dr. Caillouet assisted in drafting IUCN guidelines for use by CITES in reviewing and evaluating sea turtle ranching proposals. In November 1995, he and his staff received a U.S. Department of Commerce Bronze Medal Award for superior federal service related to sea turtle research and related activities. He served on the TEWG (1998), and peer reviewed the draft 5-Yr Review for Kemp's Ridley published in 2007. In 2004, he participated in Stakeholders meetings associated with development of NMFS et al. (2011), peer reviewed an early draft, and commented on a later draft during the public comment period. To date, Dr. Caillouet has authored or coauthored 137 publications and reports. He is an Emeritus Member/Fellow of the American Institute of Fishery Research Biologists, and a member of the IUCN/SCC Marine Turtle Specialist Group. Following retirement in June 1998, he remained engaged in Kemp's Ridley and Penaeid shrimp research as a volunteer. http://www.gulfbase.org/person/view.php?uid=ccaillouet. Photographed by Olan Mills.

Donna J. Shaver received her B.S. in Wildlife Biology (1981) from Cornell University, M.S. in Biology (1984) from Texas A&I University, and Ph.D. (2000) in Zoology from Texas A&M University in College Station, Texas. Her doctoral research focused on the distribution, residency, and seasonal movements of the Green Sea Turtle in Texas. Dr. Shaver has worked with sea turtles since 1980. She worked with the National Park Service at Padre Island National Seashore from 1980–1993. From 1993–2003, she was Director of the U.S. Geological Survey Padre Island Field Research Station. Since 2003, she has been Chief of the Division of Sea Turtle Science and Recovery for the National Park Service at Padre Island National Seashore. Dr. Shaver is the Texas Coordinator of the U.S. Sea Turtle Stranding and Salvage Network. She is a member of the Kemp's Ridley Sea Turtle Recovery Team, KRWG, and IUCN Species Survival Committee Marine Turtle Specialist Group. Dr. Shaver oversees a variety of sea turtle research and conservation projects conducted in Texas, collaborates with other researchers in the U.S. and Mexico, and provides training and leadership to biologists and volunteers working with sea turtles in Texas and Mexico. Her largest and most long-term effort has been the Kemp's Ridley Sea Turtle Restoration and Enhancement Project at Padre Island National Seashore. She has conducted research on unhatched Kemp's Ridley eggs, sex ratios and incubation temperatures for Kemp's Ridley, sea turtle nesting and strandings in Texas, Kemp's Ridley foraging ecology, and movements and habitat use by adult Kemp's Ridley and juvenile Green turtles. Her work has been recognized with awards from several organizations including most recently the U.S. Fish and Wildlife Service 2013 Endangered Species Recovery Champion Award for Agency Partner, and Harte's Heroes 2014 Legends of the Gulf Award. To date, she has authored or co-authored more than 110 publications and reports dealing with sea turtles. She has been interviewed by numerous media outlets, was featured as ABC World News Tonight's Person of the Week on July 29, 2005, and was named the Corpus Christi Caller Times Newspaper 2011 Newsmaker of the Year on January 1, 2012. http://www.gulfbase.org/person/view.php?uid=dshaver. Photographed by National Park Service.

André M. Landry, Jr. holds a Ph.D. degree in Wildlife and Fisheries Sciences from Texas A&M University and has been involved in sea turtle research since 1984. He served as Director of the Sea Turtle and Fisheries Ecology Research Laboratory at Texas A&M University where he taught sea turtle courses and conducted sea turtle research. Dr. Landry's initial sea turtle research efforts began in 1984 by first collaborating with the NMFS Galveston Laboratory in research related to Kemp's Ridley head-start, then shifting in 1985 to documenting sea turtle stranding dynamics along the Louisiana and Texas coasts. He developed a standardized stranding survey protocol carried out by his graduate students working as NMFS surveyors. Landry and his students necropsied over 250 stranded sea turtle carcasses to document possible cause of death and generate natural history data on species composition, length-frequency, sex ratios, reproductive condition, and food habits. Landry's work on stranding dynamics enabled federal contracts to assess mortalities in sea turtles unrelated to shrimping and characterize toxicology of sea turtles comprising a mass stranding event along the upper Texas coast in July 1991. His involvement with head-starting Kemp's Ridley sea turtles at the NMFS Galveston Laboratory assessed the effect of different feeding regimens on growth of head-started hatchling and juvenile Kemp's Ridleys and the effect of exercise on swimming performance and stamina of captive-reared Kemp's Ridleys. Dr. Landry's live-animal work involved numerous state, federal and private grants/contracts to document various aspects of natural history of sea turtles and anthropogenic impacts on these organisms through in-water capture and nesting-beach patrol operations in the northwestern Gulf of Mexico. As a result of this research, Landry's capture of 1,026 sea turtles (including 660 Kemp's Ridleys) from waters of Texas and Louisiana facilitated (1) an in-water Kemp's Ridley monitoring program at Sabine Pass during 1992–2002, (2) the largest program of directed in-water capture of sea turtles (80% being Kemp's Ridley) in the Gulf of Mexico for research and stock assessment purposes, (3) release of 972 tagged (with flipper tags and PITs) individuals available for subsequent recapture and study, and (4) development of a multidisciplinary faculty team whose access to these in-water capture and recapture data produced new findings, research initiatives and biotechnology critical to sea turtle recovery. Landry's patrols of upper Texas coast beaches during 2007-2012 provided invaluable data on Kemp's Ridley nesting dynamics and migration behaviors. The aforementioned activities afforded Landry, his research collaborators, 30 graduate students, dozens of undergraduate interns and hundreds of citizen volunteers unprecedented opportunities to describe Kemp's Ridley population dynamics based on abundance, size composition, ecology, sex ratio, physiology, reproduction, nesting activity, migration, food habits, health, pollutant bioaccumulation, and fate of wild and head-started conspecifics. Landry was a member of NMFS' TED Certification Advisory Panel, and a regular contributor to the Kemp's Ridley Working Group. In 2004, he participated in Stakeholders meetings associated with development of the second revision of the bi-national Kemp's Ridley Recovery Plan (NMFS et al. 2011) and provided comments and input to the Kemp's Ridley Recovery Team. Dr. Landry retired in August 2012. http://www.gulfbase.org/person/view.php?uid=landry (Photographed by Lee Ann Day Landry)