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New Perspectives on the Pelagic Stage of Sea Turtle Development

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Caribbean Conservation Corporation

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
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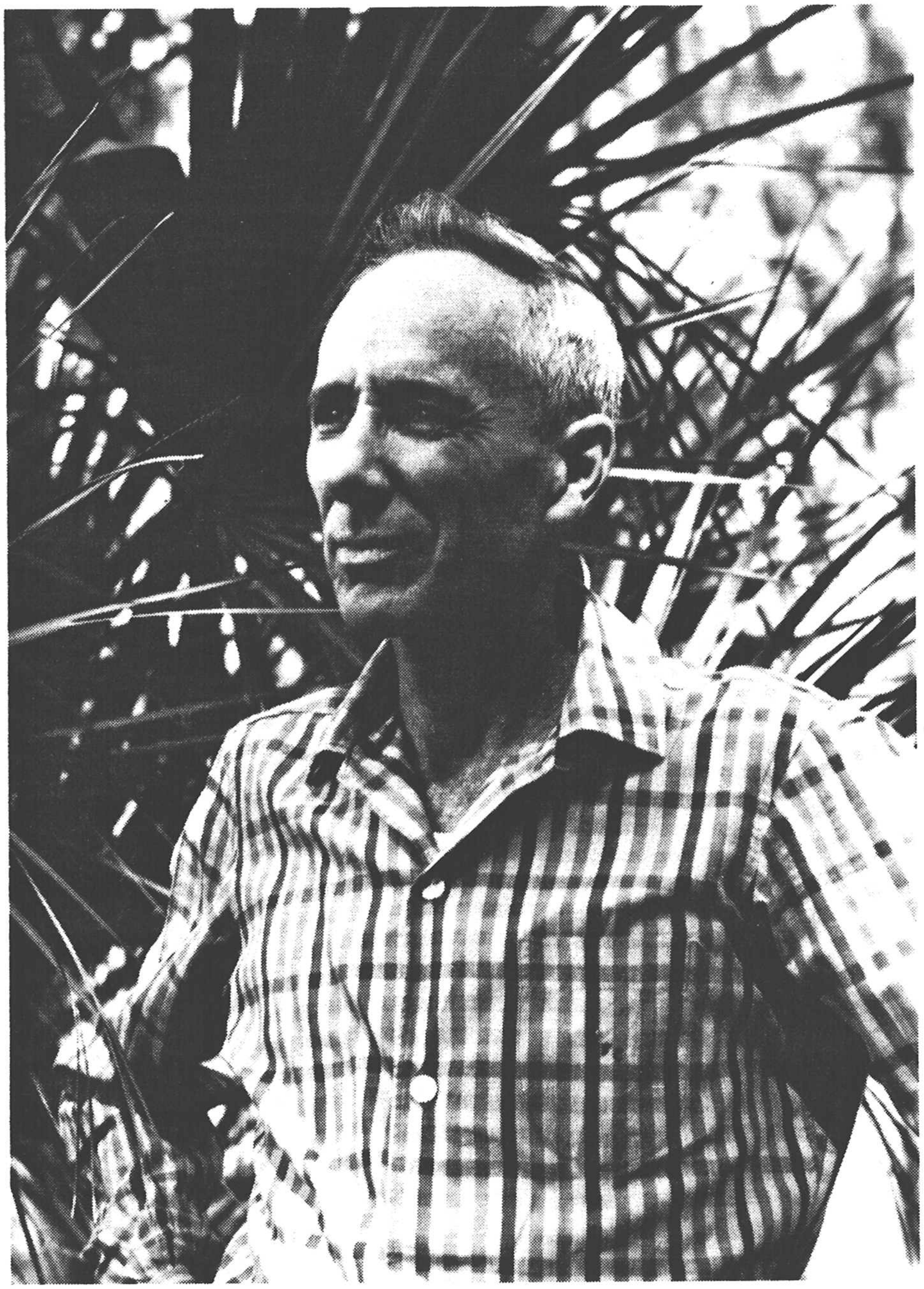

Archie Fairly Carr, Jr.

1909-1987

INTRODUCTION

Thirty years ago when interest in sea turtles was beginning to spread, the habitat of the post-hatchlings for all the species was unknown. After they left the nest and made their way through the surf, they simply disappeared. Very slowly, data to suggest a pelagic life in a sargassum weed habitat accumulated, and eventually I received support to investigate that idea intensively. By the end of that research period it was clear that when sargassum rafts are present in longshore arrays within the swimming range of the hatchlings, they do in fact enter them (Carr 1982). It followed that the early developmental stages are pelagic, with the corollary that, because sargassum accumulates along convergences, the adjacent currents may carry the rafts and their occupants on journeys of either local or oceanic extent or both.

Until lately the so-called lost-year puzzle has seemed mainly an academic concern. It has now become clear, however, that the missing pelagic stage is more protracted than was initially believed, and that during this time the turtles are brought into intimate contact with concentrated marine pollution. Growing awareness of the steady spread of marine debris and pollutants, of the tendency of these to collect along frontal driftlines, and of the habit of hatchlings to eat virtually any small object within reach, made closer investigation of this phase of sea turtle life seem urgent. Cruises and aerial searches for sargassum lines were made, and hundreds of interviews with seamen and commercial and sports fishermen were carried out. As understanding of the aims of the investigation spread, reports from sea-going people and volunteer collaborators began to lend substance to the sargassum theory of hatchling ecology. Besides the numerous specific records obtained, there were many other occasions when, in casual or group conversations, it was heard that "at some times of the year you see little turtles in the berry grass." Table 1 provides substantial (though partial) documentation of the case for a pelagic and driftline habitat for young sea turtles.

Thus, it is now well established that hatchling sea turtles go into sargassum driftlines if there are any within their initial locomotor reach (Carr 1985). Proof that they remain in the rafts has come more slowly, but juveniles showing weeks or months of growth have been recorded from many localities (Table 1). It is to be expected that the recovery sites for advanced post-hatchlings may be far from any known breeding grounds. Because sargassum lines regularly form at the shoreward walls of major currents, young turtles that enter them are likely to be quickly taken away from their place of origin. The advanced juvenile loggerhead found by R/V Geronimo in the edge of the Sargasso Sea (Fig. 1) very likely came from a Florida breeding beach, where the Gulf Stream comes close to shores on which heavy nesting occurs. As another example, during a Woods Hole cruise of R/V Cape Florida, Lisa Bibko photographed a saucer-size green turtle resting on top of rafts of dense sargassum up to four feet thick off Matanilla Reef at the northern tip of Little Bahama Bank. The turtle was one of two seen there. It was not taken aboard, but Bibko photographed it from several views, and her pictures (Figs. 2 and 3) clearly show it to be a green turtle, probably five to eight months old.

The site of the latter observation is near a place at which well-grown post-hatchlings have consistently been reported by swordfishermen. Before the recent failure of the swordfish fishery, long-liners in Fort Pierce and Fort Lauderdale repeatedly told us that in the area northwest of Little Bahama Bank, "where the current flows east and west instead of north and south," massive driftlines of sargassum form, especially in February and March. When this occurs, the fishermen say, little turtles "the size of your hand" can often be seen on and among the mats in the weedline along which the swordfish long-lines are set. On three occasions we visited this locality, and each time we found the driftline broken up by wave action. Nevertheless, the many independent reports from Gulf Stream fishermen based between Palm Beach and Port Canaveral indicate that an important station in the passive migration of *Chelonia*--and perhaps of *Caretta* also--is located just north of *Matanilla Reef*; and that whenever massive driftlines form in the area, months-old young turtles are likely to be found in them.

Not many such stations, where young turtles can predictably be found at great distances from their places of origin and long after hatching, are known; and it is not logistically feasible to make special cruises looking for them. Nevertheless, the reports that have accumulated clearly indicate that hatchlings not only go into sargassum rafts but remain in them for long periods of time. This is circumstantially corroborated by the repeated instances in which advanced post-hatchlings have washed up in storm-driven sargassum wrack on the same nesting beach on which they might have hatched several weeks or even months before (Fig. 4). In these cases the turtles must have passed the time since they hatched drifting in local eddies of the offshore currents (Carr and Meylan 1980, Carr 1986). Like the larvae of benthic invertebrates and some inshore fishes, the hatchlings are planktonic, with no control over their geographic displacement. After their brief initial swim away from land, off most nesting shores they are picked up and carried away by a current. If this is a major border current it may take them straightaway on a global circuit. When the current adjacent to the nesting beach is a local gyre, however, the migration of the hatchlings may, for a time, be confined to the vicinity of the hatching site (Carr and Meylan 1980, Carr 1986). Such short--circuiting has been suggested for the larvae of the calico scallop of Cape Canaveral, Florida (Bullis and Cummins 1961), which might simply circulate indefinitely in the eddy between Cape Canaveral and Cape Florida. This must be of frequent occurrence in the development of other sessile benthic organisms. Ample evidence that some post-hatchling sea turtles spend time in home- shore eddies is the repeated stranding of post-hatchlings a few weeks old on rookery beaches in Florida and Costa Rica, long after hatching. Such local eddies are usually shifting or ephemeral, however, and it is obviously unlikely that hatchlings ever pass their entire developmental periods in them. Most are evidently taken away on high-ocean journeys, and the difficulty of tracing these routes complicates the study of post-hatchling ecology.

Table 1.--Some Records and Reports of Neonate and Juvenile Sea Turtles Associated with Sargassum or from Pelagic Habitats

Genus and Stage	Locality & Circumstances	Date	Observer, Collector, or Informant
Caretta Hatchlings, marked in Tongaland	Edge of Agulhas Current, Indian Ocean; regularly recovered southward along coast of Natal and around Cape Peninsula	Various	G. Hughes (1978)
Caretta Hatchlings	Two found in stomach of white tip shark; 135 mi E of Cumberland Is., GA	27 Aug. 1957	R. Backus
Caretta Hatchlings	Nine found in sargassum raft "in Gulf Stream off Florida"	1965	Fisherman's report; Carr (1967)
Caretta Post-hatchling; SCL 6.4 cm	Netted in sargassum, 90 mi off Savannah River Mouth, GA	1968	Smith (1968)
	Two, others together 28 mi NE Daytona Beach, FL	25 July 1967	Same
	Another 18 mi NE Cape Canaveral, FL	25 Oct. 1967	Same
Caretta Neonate	Dipnetted 15 mi SE Key Largo, FL	26 July 1957	Caldwell *et al.* (1959)
Caretta "Apparently neonate"	Two seen in separate sargassum mats, Gulf of Mexico, 27°92'N; 85°22'W (about 300 mi WSW of Tampa	16 May 1982	(Observer?) R/V Bellows Cruise
Caretta SCL "approx. 6-7 cm"	From sargassum mat in "eddy at western end of Santa Rosa Island, FL, Gulf of Mexico"	28 July 1981	M. Holman (W. Valentine letter)
Caretta Neonate	Merritt Is. Refuge, Brevard Co., FL, in sargassum, after east wind	24 Oct. 1981	S. Vehrs
Caretta Neonate	Northeast Florida, several washed ashore, encrusted with sargassum bryozoans	Oct. 1968	Caldwell (1968)

Table 1.--Continued

Genus and Stage	Locality & Circumstances	Date	Observer, Collector, or Informant
Caretta Post-hatchling 5.7 cm SCL	Beach at Matanzas Inlet, St. Johns Co., FL; in sargassum after strong northeast wind	7 Sept. 1985	L. Alexander
Caretta Advanced post-hatchling; 6 cm SCL	New Smyrna Beach, FL, washed up in NE storm	3 Nov. 1983	D. Cring
Caretta Advanced post-hatchling; SCL approx. 6 cm	Gulf of Mexico, 26°45'N, 84°08'W, just east of Loop Current, sargassum and many Physalia	17 March 1984	R/V Delaware, Capt. D. Adams
Caretta Hatchlings	Fort Pierce, FL. Saw 20-30 in heavy sargassum 1-3 mi off Whistling Buoy. Picked up one in sargassum on shore	10 Oct. 1980	J. W. Jones
Caretta Advanced post-hatchling	Gulf Stream, west border off Miami	Spring, 1983	Capt. A. Dillard of Sea Hawk; twice saw young turtles. Said grouper main predator there.
Caretta 5.5 cm	Canaveral National Seashore. Washed up in sargassum	10 Oct. 1982	D. Whitman
Caretta Neonate	Western front of Gulf Stream, 93 km E of St. Augustine, FL. At least 20 seen in line of sargassum patches	22 Aug. 1981	P. McGillivary, Cruise of R/V Cape FL for Skidaway Oceanographic Inst.
Caretta Advanced post-hatchling (21 g)	John V. Loyd State Park, Broward Co., FL	5 Jan. 1982	J. Fletemeyer
Caretta Three post-hatchlings	Gulf of Mexico, approx. 120 mi WSW of Tampa. Just west of shelf in Loop water	25 May 1982	S. Collard, R/V Bellows cruise

Table 1.--Continued

Genus and Stage	Locality & Circumstances	Date	Observer, Collector, or Informant
Caretta Advanced hatchling; SCL 5.2 cm	St. Johns Co., FL, washed up in sargassum	Late Oct., 1968	Fla. State Museum 27019
Caretta SCL 12.4 cm	Bermuda, outer reef, in sargassum	17 May 1985	J. N. Burnett-Herkes
Caretta Carapace 3.5 cm wide	Gulf of Mexico 200-300 mi S of Galveston, TX, 26°30'N; 90°50'W	31 Apr. 1982	R. Trok; R/V, MAR Inc.
Caretta Two, advanced pelagic stage, one measured, carapace 13.5 cm	NW sargassum sea, 300 mi SSE Nantucket, 37°2'N; 66°23'W. Two 5 mi apart	28 June 1982	R/V Geronimo, St. Georges School
Caretta Neonate	South Melbourne Beach, Brevard Co., FL. Continuous sargassum wrack after Huricane Isidore. Four turtles found in weed in 100 yd walk, "Hundreds more surely killed."	30 Sept. 1984	D. Hopkins, S. Melbourne Beach
Caretta Neonate and weeks-old hatchlings	Flagler Co., FL. Many washed up with weed-wrack during Hurricane Isidore; some dead, some brought to Marineland	28-30 Sept. 1984	Rehabilitated by J. Lowenstein Marineland Research Lab.
Caretta Neonate	About 30 mi SE Port Canaveral, many turtles in numerous short sargassum lines	1982	T. Ferrence gave A. Carr photo, taken from boat, of hatchling sleeping in sargassum
Caretta Neonate and slightly advanced	24 mi SE Port Canaveral. Saw "about 20" in one raft about 75' x 100', moving south. Much other sargassum; many jellyfish	5 Sept. 1984	J. Dorman

Table 1.--Continued

Genus and Stage	Locality & Circumstances	Date	Observer, Collector, or Informant
Caretta Neonate, in sargassum after storm	Brevard Co., FL, Cocoa Beach, between 1st St. and Patrick Air Force Base	5 Sept. 1979	One hundred collected dead or moribund by B. Schroeder; sent by L. Ehrhart
Caretta Several wks old; SCL 7.9 cm	Gulf of Mexico, off mouth of Homossassa River	22 Feb. 1965	J. Miller
Caretta Neonate	Eight taken from stomach of dolphin caught beside sargassum raft, off St. Lucie Inlet, 19 km E of Stuart, FL	9 Sept. 1972	Fish caught by L. Barker; data recorded by R. Witham (1974)
Caretta Advanced pelagic post-hatchlings	Bermuda, various localities; stranded or drifting with sargassum	Various 1980-1985	J. Burnett-Herkes
Caretta Advanced pelagic stage, 18 cm	Mustang Island, TX; stranded	1984	A. Amos
Caretta One neonate, another weeks old	26 mi ENE of Sebastian Inlet, FL	8 Aug. 1966	E. M. Coon
Caretta 4 hatchlings	Mustang I. (NE end of Padre I.) Texas	Late Sept., 1986	A. Amos Strong offshore (NE) wind for several days surf up to bern, with storm pools.
"Probably Caretta"; hand-size pelagic stage	Edge of Little Bahama Bank N of Matanilla; Light at edge of E-W current. Advanced pelagic turtles "usually seen in weed line there in February and March" while working long-line for swordfish along weed lines	Feb. - Apr. various yrs prior to 1981	Capt. G. Buffkin, swordfish longliner (Same report from numerous swordfishermen in Fort Pierce and elsewhere along E coast)

Table 1.--Continued

Genus and Stage	Locality & Circumstances	Date	Observer, Collector, or Informant
Probably *Caretta* Hand-size, in sargassum patch about 125 ft long over 1900 ft depth	Volusia Co., FL off Ponce de Leon Inlet	24 May 1986	Fishermen in Daytona Striking Fish Tournament *fide* J. B. Miller
Probably *Caretta* Hand-size in sargassum over 1500 ft depth	Volusia Co., FL off Ponce de Leon Inlet	24 May 1986	Fishermen in Daytona Striking Fish Tournament *fide* J. B. Miller
Probably *Caretta* Two "small brown sea turtles" in weed line just south of "The Steeples" over 1000 ft depth	Volusia Co., FL ESE of Ponce de Leon Inlet	25 May 1986	Fishermen in Daytona Striking Fish Tournament *fide* J. B. Miller
Probably *Caretta* One saucer-sized brown turtle in driftline	Off St. Augustine, FL over 1000 ft of water	25 May 1986	Fishermen in Daytona Striking Fish Tournament *fide* J. B. Miller
Chelonia Hatchlings	Many netted by G. Furuya 50 mi SE Manzanillo, Michoacan, Pacific coast of Mexico. "There regularly."	Various dates	Caldwell (1969)
Chelonia Hatchlings	At sea near Revillagigedo Islands	June 1963	Caldwell (1969)
Chelonia Two, 10-15 cm	8 mi east of Marquesas Keys, FL; moving among sargassum rafts	Aug. 1983	T. and N. Carr
Chelonia Five, 10-20 cm	Mustang Island, TX; stranded	Various dates 1984	A. Amos
Chelonia Neonate and early advanced	22 mi off Colon, Panama, in driftline of sargassum	Sept. 1979	R/V Alpha Helix Carr and Meylan (1980)

Table 1.--Continued

Genus and Stage	Locality & Circumstances	Date	Observer, Collector, or Informant
Chelonia Advanced pelagic	Edge of Gulf Stream off Bahama Bank, north of Matanilla Shoal; on sargassum drift 4' thick	4 March 1983	Woods Hole Cruise, R/V Cape Florida, L. Bibko, Informant
Chelonia Neonate	Banco Colon, 26 mi off Colon, Panama	Sept. 1977	W. A. Rankin, dolphin fishermen
Chelonia Neonate	One taken from stomach of dolphin caught beside sargassum raft 19 km E of St. Lucie Inlet, Stuart, FL		Fish caught by L. Barker; data recorded by R. Witham
Chelonia Two "small" post-hatchlings	Vella Gulf; on log in driftlines		Vaughan (1981)
Eretmochelys Early to late post-hatchlings and older 5.3 to 20.7 cm	Bermuda, various localities. Drifting in weeds, stranded in beach and washed in over 20' wall by storm waves	1982, 1985, and 11 Sept. 1983 (the hatchling)	J. Burnett-Herkes
Eretmochelys Advanced to late stages and just beyond; shell lengths: less than 10 cm, 3; 10-20 cm, 2; 20-30 cm, 7	Mustang Island, TX	1983-1984	A. Amos
Eretmochelys Advanced pelagic	Broward Co., FL stranded with tar smeared sargassum		J. Fletemeyer
Eretmochelys Transitional stage 20.2 cm	Hutchison Island, FL stranded with tar smeared sargassum		R. Witham
Eretmochelys Advanced pelagic; 14.0 cm	Brevard Co., FL; dead, had ingested tar	6 Feb. 1981	J. Fletemeyer

Table 1.--Continued

Genus and Stage	Locality & Circumstances	Date	Observer, Collector, or Informant
Eretmochelys 23.1 cm SCL	Jupiter Is., Palm Beach Co., FL	16 Jan. 1981	Fla. State Museum 50028. Collector Unknown
Eretmochelys 14.0 cm SCL	Jensen Beach, Martin Co., FL	16 Feb. 1981	J. Dietjen, Fla. State Museum 50027
Eretmochelys Advanced pelagic 15.1 cm	Gulf of Siam, Thailand, 07°22'N; 100°43.5'E	9 Aug. 1980	Dipnetted, Scripps NAGA Expedition, T. Matsui, collector
Eretmochelys "Hatchling and slightly larger"	Various localities; both coasts of Choiseul, in sargassum driftlines, singly and in groups	Various dates	Vaughan (1981)
Eretmochelys 20 hatchlings and post hatchlings SCL 5-8 cm	Mustang I. (NE end of Padre I.) Texas	Sept. 15 - Oct 5, 1986 (ten in one day)	A. Amos Strong SE (offshore) wind for several days, with surf up onto berm and storm pools formed.
Lepidochelys 20.9 cm	30 mi E. of St. Augustine, FL, with another same size. Taken with cast net. This ridley is apparently the smallest ever recorded from FL	1 March 1961	Collector for Fla. State Museum 57983
Not Identified "Small Turtles"	W. Pacific; around barnacle-covered drift logs in open ocean	Various	Miller (1978)
Not Identified	19 mi SE St. Lucie Inlet, Stuart, FL, two hatchlings on floating board near sargassum raft	9 Sept. 1972	Observed by L. Barkes (reported in Witham 1974)

THE ROLE OF FRONTS

An original difficulty in accepting the idea of a pelagic developmental period for sea turtles was to explain how food could be found in reliable supply in the open ocean (Carr 1967). Once a little air-breathing carnivore had moved out of the productive waters of the continental shelf how could it possibly support itself? A partial answer emerged when post-hatchlings were found in rafts of sargassum. The mats have a diverse biota of adapted inquilines and could provide food as well as shelter, so this seemed an attractive solution to the puzzle of the disappearing turtles. Although the sargassum refuge is now proven reality, it cannot account for the missing interlude in the ecology of all populations of marine turtles because many of them breed where no sargassum is present. So, as important as sargassum is as refuge and feeding habitat, it is clearly not indispensible.

The uncertainty that this introduced was removed when I belatedly came to appreciate the prevalence and diversity of convergences where downwelling gathers and aligns buoyant material, including the dispersed food resources of the surface waters. Galt (1985) enumerated the many ways in which fronts of all dimensions and configurations may originate. They range in magnitude from driftlines along the walls of major border currents down to local rips over reefs and sea mounts, off capes and river mouths, and at the downcurrent ends of bars. The sinking and advection that they generate also occurs at the borders of the warm- and cold-core Gulf Stream rings, and it builds the fields of raggedly parallel multiple bands generated by wind-action in Langmuir circulation. In all these and many other kinds and sizes of fronts, the mobilization of flotsam by the vertical component generated by the horizontal collision of water bodies gathers in both the hatchlings and the resources that they require. If sargassum occurs in the region the same process builds the mats into rafts, rebuilds them when storms break them up, and strings them out in the driftlines that ease the hatchlings' problem of locating their pelagic frontal habitat. If no brown algae are present, offshore fronts nevertheless sustain the hatchlings by concentrating food resources, and by aligning debris that provides concealment.

Thus, it now seems clear that an essential factor in the survival of young sea turtles--and of other elements of the epipelagic, open-ocean fauna as well--is the accessibility of a front, where inanimate debris and any floating animal or plant--or any planktonic organism able to hold to a preferred depth either by its locomotion or by buoyancy control--will be gathered in. The marked increase in biological activity along rips, or Siome, as the Japanese call them, is widely recognized by sea-faring people; and the dynamics and surface manifestations of advection along the line between two water bodies in opposing motion has long been a familiar concept to oceanographers (Uda, 1938). The idea is a lot less familiar to other people, however; and this has held back understanding of the ecological organization of the marine environment.

Sea turtles share their ecologic dependence on fronts not just with holopelagic species, but also with littoral fishes and benthic invertebrates that release eggs or larvae to be carried by currents on planktonic developmental journeys--and so, are drawn into the driftlines. Although it is the overt swimming of these animals that takes them away from shore and out to the weedlines, it is downwelling that keeps them in the fronts--and these gather flotsam of any size, from pollen grains to drifting wrecks.

This effect is not restricted to material that floats on the surface. When plankton or nekton which by any mechanism are able to control their buoyancy and maintain a preferred depth are drawn in, they resist the sinking action, accumulate at their preferred depth, and give to the ecologic organization at the front a vertical dimension (Olson and Backus 1985).

In _The Arcturus Adventure_, William Beebe (1926) described the spectacular biological diversity in an oceanic rip between Easter Island and the Galapagos without mentioning the role of downwelling in creating the imposing factor. Lamb (1959-63) recorded a biologically rich front on May, 1963, in the open ocean 340 miles east of New York (41°N 66.30°W), at the convergence of the Gulf Stream and Labrador Current. No mention of the role of downwelling and advection was made. The confluence was marked by a wall of "sea smoke" up to 150 feet high. There was a profusion of marine life at the surface which the observer attributed to upwelling, and great numbers of sea birds of twelve different species and various stages of maturity were diving and feeding along the line. An unusual feature of the gathering were numerous flocks of grey phalaropes, each consisting of hundreds of birds, wheeling over the dense lane of sea life. The phalaropes seen were probably en route to Great Lakes and Canadian breeding grounds, and their presence suggests the possible importance of high-seas rips in the oceanic migrations of birds other than the dedicated divers. A few animal-oriented zoologists--notably sea-bird ecologists (Ashmole and Ashmole 1967, Ashmole 1971) and tuna and billfish specialists (Murphy and Shomura 1972)--have understood the bearing of downwelling on animal ecology. In most discussions of marine productivity and faunal abundance, however, upwelling (divergence) is stressed, and the role of convergence--the more immediate agent in concentrating biological activity--is not given due emphasis. Its action is fundamentally important to the ecologic organization of the epipelagic. I have elsewhere suggested (Carr 1986) that there would be no sea turtles of the kinds we know if there were no fronts.

THE DEVELOPMENTAL TRAVEL OF ATLANTIC _CARETTA_

After a period of pelagic developmental migration had been shown to be a stage in the sea turtle life cycle, an assessment was made of our ability to piece together the overall developmental habitat-shifts of any of the species. Little or nothing could be done with the Pacific turtles, because of the almost total lack of information on the immature stages. In the Atlantic the most inviting species seemed to be _Caretta_. It has major nesting grounds in U.S. waters, and is represented on the east coast of Florida by four different age classes as follows: (1) newly emerged hatchlings; (2) advanced hatchlings and juveniles in the Gulf Stream and its eddies in the area between Florida, Little Bahama Bank, and Bermuda; (3) colonies of subadults in Indian River, Mosquito Lagoon, and the Canaveral Nuclear Submarine Channel and along the southeastern Atlantic coast; and (4) major nesting colonies of adults along the east coast between Cape Canaveral and Cape Florida. The subadult colonies of the Indian River Lagoons and Canaveral Channel are the biggest aggregations of subadult Caretta known in American waters, or anywhere else for that matter (Carr, Ogren, and McVea 1980; Ehrhart 1983).

I have recently called attention to the fact that when size distribution in these groups is plotted, a conspicuous gap appears between the largest of the pelagic U.S. juveniles and the smallest subadults of the Lagoon and Channel colonies (Carr 1986). To bring these two classes together would clearly require several years' growth by the "lost-year" group. Loggerheads of these intermediate sizes (20 cm to 40 cm, straight carapace length) are virtually never found anywhere in U.S. waters. It has long been known, however, that juveniles of these sizes turn up in the eastern Atlantic from time to time. Dr. Leo Brongersma has assembled the records in his book, European Atlantic Turtles (1972). It has often been conjectured that the European turtles may come from American breeding grounds and Dr. Brongersma has repeatedly suggested the possibility that those that appear in southern European coasts come from and might in some cases eventually return to western Atlantic waters. On the whole, however, little zoogeographic importance has been attached to their occurrence, on the grounds that they are probably irretrievably lost to their parent population. The most attention has been given them by scientists and the news media in the United Kingdom, where the strays that arrive are in the grip of the North Atlantic Drift, and so are unlikely to survive the next winter. Sir Alistair Hardy (1958) during a cruise of the RRS Discovery II, observed a surprising concentration of young turtles in the North Atlantic Drift. In early September, 1952, when cruising from the Azores to Cornwall, the ship passed turtles--which Hardy considered to be loggerheads--all afternoon and evening, at an average rate of 10 per hour. A few days later Hardy examined a little loggerhead that had stranded at Bude, North Cornwall, and found the American alga Ectocarpus mitchellae to be growing on its shell.

A western Atlantic derivation has also been logically assumed for the infrequent green turtles that appear on the European coast; and for the more frequent arrivals of Kemp's ridleys (Lepidochelys kempi), which breeds only on a shore of the Gulf of Mexico and clearly presupposes a transatlantic crossing.

Virtually all of the sea turtles that strand on the European coast, and those observed at sea in the Gulf Stream circulation from England to the Canary Islands are immature. In the Azores we have for some years been collaborating with Dalberto Pombo of Santa Maria in a tagging project. The turtles that he tags there are loggerheads. They are consistently small but have not been abundant enough to confirm the presence of a regular itinerant developmental colony in the area. By coincidence, however, during the winter of 1984, Helen Martins, Senior Research Officer in Oceanography at the University of the Azores, wrote me that little loggerheads were being caught regularly by tuna fishermen on Princesse Alice Bank, an important fishing ground near Faial. She said that the fishermen were in the habit of making soup of the turtles, and suggested that we organize a tagging project, buying the turtles, tagging them and letting them go.

We accordingly embarked on a collaborative tagging program, and even before any tag-return data have come in, results of the project have been very interesting. When shell-length data for the 82 turtles tagged during the first two seasons (1984 and 1985) were received they represented a size class never seen in Eastern Atlantic waters (Table 2) and the measurements fit neatly into the space in our western Atlantic histogram (Fig. 5). Inasmuch as Princesse Alice Bank is located where the main flow of the Gulf Stream system begins its southward swing, the Faial loggerheads are well placed for eventual transportation back to American waters. Moreover, they are in sound physical condition, still pelagic, and feeding on pelagic forage (Fig. 6).

TABLE 2.--Straight carapace length (cm) in juvenile pelagic loggerheads taken by tuna fishermen on and near Princesse Alice Bank, The Azores, during summer months of 1984 and 1985.

1984		1985		1984 + 1985	
Number:	40	Number:	42	Number:	82
Average:	20.6	Average:	25.2	Average:	22.9
Median:	19.4	Median:	24.5	Median:	21.7
Range:	15.2-38.0	Range:	11.0-38.0	Range:	11.0-38.0

Assessment of the possibility that the developmental migrations of American loggerheads regularly involve transatlantic travel in the Gulf Stream system has until now been hindered by two factors. One has been our failure to appreciate the significance of the absence of the 20-40 cm age group in U.S. waters. The other has been the prevalent tendency to dismiss as non-viable derelicts the members of that size class when they turn up in the eastern Atlantic--especially in the United Kingdom, where the usual fate of flotsam is to drift on toward the Arctic into water of lethal temperature. Much less attention has been given the more numerous turtles that reach the eastern Atlantic in the southerly branch of the Gulf Stream system, which is both warm and likely to transport flotsam eventually back to America.

It seems reasonable to discard the occasionally mentioned possibility that the Mediterranean might be the source of the juvenile sea turtles of eastern Atlantic waters. Although *Caretta* nests in several parts of the eastern Mediterranean, the colonies there are not large, and the possibility that the Azores juveniles might be derived from them would seem to be precluded by a strong current, around 200 meters deep, that moves over the sill into the Mediterranean at the Straits of Gibraltar. To suppose that the many young loggerheads reported from the eastern Atlantic have travelled upstream and out of the Mediterranean goes against what is known of post-hatchling movements elsewhere.

Instead of contributing turtles to the Atlantic population, the Mediterranean more probably receives strays from the trans-Atlantic migrations of American turtles. Recent interviews along the coast of the Spanish Mediterranean suggest that some of the Azores loggerheads may drift out of the main Canary Current and into the branch that moves across the Gibraltar sill, where adult loggerheads occasionally appear to move through in both directions. This possibility is supported by conversations with fishermen along the coast of the Spanish Mediterranean, and with Joan Mayol of the Balearic Islands. Mayol's data (Fig. 7) indicate the presence of numerous immature loggerheads in Spanish Mediterranean waters that are consistently a little larger than those of the Azores size class. This assemblage of juvenile loggerheads may reflect the abundance of food resources along a recently discovered permanent front, extending across the western Mediterranean from Almeria, Spain to Oran, Morocco and through the Baleares (LaViolette 1986).

Mayol has reported heavy mortality of these turtles, which are taken incidentally by shark fishermen. According to his estimate, around 16,000 a year are caught on 4-inch hooks baited with squid. He believes that most of these die of injuries incurred in the process of release. Mayol is trying to devise a hook that will catch sharks but do less damage to the turtles and he is sending an observer aboard some of the boats to work out ways to minimize the effects of the surgery. I have arranged with his office to carry out a collaborative tagging project, with the aim of learning whether any of the Baleares loggerheads do emerge from the Mediterranean, and whether any of those tagged at Faial arrive there.

Although consanguinity of the young loggerheads of the eastern and western Atlantic now seems probable, much remains to be learned about the ecology and developmental travel of the migrants before they leave their pelagic stage and take up adult life along the American continental shelf. As any generalized chart of the surface currents of the Atlantic shows, a drift bottle released on Princesse Alice Bank and washed up on a Florida beach may have travelled by any of several downstream paths. If the Azores population does indeed come from America, and does eventually return there--and both now seem probable--the turtles have made both crossings of the Atlantic as passive Gulf Stream migrants. Whether adult *Caretta* has a capacity for long range, open-sea navigation, and if so, at what ontogenetic stage this appears, are unknown. Because mature loggerheads show breeding site fidelity, after ranging widely between nesting seasons (Limpus 1985, Ehrhart 1983), the adults must share at least some of the bi-coordinate open-sea travel-guidance sense that *Chelonia* evidently employs in commuting between its feeding pastures and nesting shores. It seems likely, however, that when the young pelagic loggerheads leave European waters they still travel as passive migrants in currents.

On Princesse Alice Bank they are obviously at a station where currents can take them home, but a problem with the timing of the return arises. As Figure 8 shows, by any bifurcation of the direct, main-axis Gulf Stream route they would get back too soon, arriving in Florida long before they had reached shell-lengths of even the smallest of the Canaveral Channel and Indian River population or any other subadult colony of American *Caretta*. By rough calculation, if they drifted in the main Gulf Stream system--the Canary Current, South Equatorial Current and Florida Current--the trip from Princesse Alice Bank to Canaveral would require only around a year or less--whether the final stage of the trip went through the Gulf of Mexico, or went directly to Florida through the Antilles. This is obviously not long enough to allow the growth necessary to fill out the graph in Figure 5.

The time required for *Caretta* to reach sexual maturity has been calculated by several different methods and has ranged from 10 to 50 years. Limpus (1985), who has measurements from a broad range of developmental stages of Queensland loggerheads, calculated the mean time required to grow from 75 cm curved carapace length to breeding maturity as 27 years, and the overall maturation time to be about 50 years. With measurements from the loggerhead colony of the Indian River lagoons, Mendonca (1981) derived a maturation age of 10-15 years. Bjorndal and Bolten (in prep) found that juvenile loggerheads on their natural foraging grounds in the southern Bahamas take three to four years to grow from a straight line carapace length of 25 cm to one of 75 cm. Other estimates based on data from naturally developing populations are 26 years (Henwood unpublished data), and 14.3-19.3 years (Zug *et al.* 1983). The period calculated with data from captive turtles by Frazer and Schwartz (1984) was 19-20 years.

Limpus (1985) pointed out that the rate of development very likely varies widely from one population of *Caretta* to another, and Balazs (1982) found this to be the case with *Chelonia* in the Hawaiian Archipelago. In any case, to date nobody appears to have estimated a developmental rate fast enough to allow the Azores loggerheads to reach the 40-cm straight-carapace-length of the Florida subadult colony within the travel time of the main-stream, direct drift-bottle routes available. By any of these they would arrive in America too small to join any known western Atlantic size class. Where they pass the time required for the necessary growth is not clear.

What appears to be significant evidence of continued post-Azores travel in the Gulf Stream system is the fact that wherever loggerheads turn up in the Macronesian area or in the Spanish Mediterranean (Fig. 7) they are usually small. Brongersma (1982) found shell lengths of loggerheads from Macronesian waters (the Azores, Madeira, Canary Islands, Selvagens Islands) to range from about 25 cm to about 50 cm. Five young loggerheads (approximately 26 cm SCL) were recently sighted by Ron Gilmer on a Woods Hole Cruise (Oceanus 176) between Cadiz and the Canary Islands (33°12'N 15°00'W; 30°01'N 14°21'W; 30°01'N 13°43'W; 29°15'N 12°56'W; 27°41'N 15°46'W). The juveniles taken on Princesse Alice Bank colony, however, are consistently the smallest of the lot. It might be assumed that their somewhat larger sizes in downstream localities reflect periods of stop-over in those localities. In most cases, however, loggerheads in the down-current stations have not been recorded in benthic habitats but in the open sea, where they are obviously being passively transported by the current.

That they are feeding at the surface over deep water is clearly indicated by the flotsam and pelagic food consistently found in the stomachs. In the stomachs of three loggerheads from off Madeira, Brongersma (1968) found salps, the shell of a pteropod, probable medusa nematocysts, a piece of plastic, and many goose barnacles with wood attached--evidently having been bitten off floating logs. Brongersma (1972) listed the following items of pelagic origin from stomachs examined by Pouchet and de Guerne (1940) taken during a cruise by Albert I of Monaco: many pteropods, *Hyalaea tridentata*; pieces of medusae; amphipods; the pelagic crab *Nautilograpsus minutus*; bunches of the goose barnacle *Lepas anatifera*; a cinder, straw, and wood chips. More recently van Nierop and den Hartog (1984) examined the gut contents of five little loggerheads, also from islands of the Macronesian area, and found--besides plastic debris--pelagic tunicates, pelagic snails, gooseneck barnacles--which regularly are found attached to solid flotsam --and nematocysts of a number of different species of coelenterates.

Results of recent oceanographic research make it somewhat easier to understand how the long period of time separating the Azores loggerheads from the age class they will join when they move into benthic West Atlantic habitats is passed. The report of Scully-Power (1986) on observations made during space shuttle Challenger Mission 41-G shows that the oceans of the world teem with fronts of all dimensions and configurations. Papers in a recent issue of the Journal of Physical Oceanography (Vol. 16, No. 3, March, 1986) reveal that in the North Atlantic small eddies, usually less than 50 km across, are far more numerous and long-lived than has been believed. In the words of McDowell (1986) "reanalysis has revealed a number of features . . . so anomalous that a sample or two from a Nansen bottle cast would have been considered suspect and most likely discarded, because it was presumed that water properties were smoothly varying on horizontal scales of tens to hundreds of kilometers." Meaning, as nearly as I can make out, that the numerous new eddies have been discovered because hydrographic procedures are more discriminating today than they used to be. In 1978 an intensive survey was carried out as a part of the POLYMODE Local Dynamics Experiment in the Sargasso Sea southwest of Bermuda (near 31°N, 70°W). Data from this work clearly have important bearing on the ecology and passive transport of planktonic animals, including juvenile turtles, in the North Atlantic. The shallow eddies detected by the survey had different and in some cases distant origins (Kerr 1985, McDowell 1986). Two were from the eastern Atlantic, three from the Gulf Stream, two from the central Sargasso Sea, and two from places not determinable from the data. A number of deeper (mid- and lower thermocline) eddies had also originated at long distances from the experimental site. McDowell concluded from these experiments that "the distinct origins of these features and their inferred trajectories contribute to our understanding of the general circulation within the North Atlantic and suggest that discrete eddies may represent an important mechanism for the large-scale exchange of properties in the ocean." I would go farther and suggest that the multiplicity of such features now coming to light helps bring new understanding of the ecology of epipelagic organisms and of the food resources and transport facilities available to them.

The eddies are not only rings derived from Gulf Stream meanders. They are itinerant vortices of varied origins and are not just surficial features but are cylinders, some of which extend down to or even below the thermocline. The rotation of those that reach the surface must generate downwelling, and this is bound to mobilize both flotsam and depth-keeping macroplankton. Thus their contribution goes far beyond the mixing of water properties. These small travelling eddies become both habitat and transport medium for any pelagic plankton grazer, planktonic or cursorial.

It must be somehow significant that the juvenile sea turtles that have been observed at sea have often been associated in groups. Observations of turtles are most often reported from just west of the Azores (Fig. 8), and from there southwestward to Gibraltar and Madeira (Brongersma 1972). They are often described by voyagers in terms of numbers seen in given periods of travel along a course. Thus, there is a question whether the groups are social aggregations or migrants aligned passively along a convergence. Linear grouping of loggerheads observed in the North Atlantic Drift (Hardy 1958) and by Richard Backus (*in litt.*) suggest the latter. However, other reports of "small, brown turtles" seen in "patches" or schools, suggest overt, social aggregation.

A recent example of such a sighting was recorded by Maigret (1983) who reported that in May, 1982 thousands of turtles, 30 cm or so in shell length, had been observed by a lobster boat at 33°N, 74°W -- coordinates corresponding to a point in the western Atlantic between Bermuda and North Carolina. Seventy-five of the turtles were captured, and the species was later identified as *Lepidochelys kempi*. When the basis for this astounding record was investigated by Peter Pritchard (in press) it was found that the western Atlantic position given was a typographic error, longitude 74°W having been a misprint for longitude 14°W. The locality was thus not off America but in the eastern Atlantic, near the island of Madeira. In continuing his investigation of this arresting record Dr. Pritchard asked and received permission to look at photographs of one of the specimens involved and found it to be a young loggerhead.

This, then, would appear to represent the largest travel aggregation of *Caretta* ever reported anywhere. Even more recently, a less well-documented case has been reported to me by Sam Sadove of OKEANOS (Ocean Research Foundation), in which a big school of young "brown sea turtles the size of basketballs" was seen by people on a yacht cruising off Madeira. Still another apparently reliable recent report tells of the sighting of "a whole bunch of little turtles" by the crew of a sailboat just south of Bermuda (Allan Meyer pers. comm.).

How frequent such seeming aggregations are, and what the adaptive utility of the association may be, deserves more attention. The only species in which migratory aggregation is known to be a regularly occurring trait is the olive ridley *Lepidochelys olivacea*. It was the sighting of a flotilla of massed olive ridleys from the air in the open sea off Costa Rica that led Hughes and Richard (1974) to discover the huge nesting *arribadas* of the olive ridley at Nancite in Guanacaste. During a two-year residence in Costa Rica, I heard repeated verbal reports from tuna and sailfish fishermen, and from commercial airline pilots, that thousands of sea turtles traveling in schools could sometimes be seen off the Pacific coast at points between Guanacaste and Panama Bay. I long ago suggested the possibility that a secretion of the unique marginal pores of *Lepidochelys* might serve to draw the migrants together (Carr 1963). This, however, has little bearing on the question of why and how immature planktonic migrants of other species aggregate, especially in view of the fact that they more often appear to travel separately.

Another important unknown in the developmental ecology of sea turtles is the mechanism that times and guides the shift of the migrants from passive epipelagic travel to the inshore, bottom-feeding life and habitat of the adults. Around the little reefs on the southernmost coast of Costa Rica where there is no nesting by *Caretta* I have occasionally seen young loggerheads, under the Indian River average size (Fig. 9), and have taken these for accidental strays out of the offshore current. More regularly, immature loggerheads, mostly smaller than those seen in U.S. waters, appear in driftlines among the smaller islands of the West Indies, and along the windward coasts of the big islands (Meylan 1983a, Carr *et al*. 1982). None within the Azores size-range have been recorded there, but juveniles smaller than those of the Florida colony turn up often. In the Bahamas, Cuba, the Windward Islands, the Cayman Islands, and the San Andres Archipelago local people say that they occasionally take loggerheads of these sizes, "most often in weedlines," where mature loggerheads and green turtles also sometimes forage (Meylan 1983a, Carr *et al*. 1982, Carr 1986). These loggerheads are evidently of distant origin and are too big to have come directly down-current from the Azores. Where they have passed the intervening time remains unknown. However, by the time young loggerheads arrive in Florida waters, they regularly have reached shell lengths greater than 40 cm, they turn up in large numbers, and they have established themselves as bottom feeders in benthic habitats.

It thus appears that from the time U.S. loggerhead hatchlings enter the sea, both before and after they join the Azores developmental colony and until they show up again as members of the subadult group of the Indian River lagoons and Canaveral Channel, they either are making repeated transatlantic crossings in the main Gulf Stream system, or are circling in rings and minor eddies, feeding at and near the surface along fronts.

Until recently our attention had been so closely fixed on the search for the early post-hatchlings that even after these began to turn up in numbers, due attention was not given the significance of the lack of American records of loggerheads of the 20 to 40 cm size and the presence of this age class in eastern Atlantic waters (Carr 1985). The Azores data provide strong evidence that young loggerheads are oceanic migrants not just as post-hatchlings, but for a protracted period of their early development. It seems necessary, therefore, to give serious consideration to the liklihood that the initial developmental regimen of western Atlantic loggerhead hatchlings is--as Hughes (1978) suggested for the Natal loggerheads of the colony he worked with--a period of three years or longer, and that during this time the Atlantic juveniles drift in the Gulf Stream system and feed on pelagic forage along the frontal walls of eddies and gyres. Knowing this indicates that the time has come for the old term "lost year" to be replaced by the designation "pelagic stage," and for this, in the case of Atlantic Caretta, at least, to include juveniles of straight-line carapace lengths of up to 30 cm and more.

THE PELAGIC STAGE AND PROBLEMS OF CONSERVATION AND MANAGEMENT

The new evidence of complexity in the lost-year ecology of sea turtles has important implications for their conservation and management, presenting helpful insights and revealing fundamental problems for nursery and head starting projects. Also indicated is a clear need for research in the neglected field of convergence ecology.

It is now obvious that when young cultured sea turtles are released in so-called head-starting projects, the release sites ought to be chosen with the greatest care. Shores located at a distance from any major current or its eddy ought to be avoided, no matter how great the convenience or public-relations value of other localities may be. The adaptive utility of the neonatal swimming urge and open-sea guidance sense of hatchlings is that it takes them out of shelf waters, where predation is at maximum, and into an offshore convergence habitat. The farther they swim seaward, the deeper the water becomes and the less likely they are to be found by aggregated predators, aquatic or aerial. Once away from longshore waters, however, when the pods have scattered widely and predation has slackened, the hatchlings face the problem of finding food. The adaptive response to this need is to continue travelling seaward until a rip is intercepted. The neonatal swimming urge, the residual yolk supply that hatchlings have, and their remarkable open-sea guidance sense (Frick 1976) are adaptations for finding a driftline after leaving the shore. It thus stands to reason that head starting and hatchling relocation should be undertaken only where a front is likely to be accessable within their travel-range.

It is obviously necessary to avoid release localities where the convergence habitat may carry heavy loads of pollutants. There seems at present to be no way in which the pelagic-stage young can be kept out of polluted fronts at some stage of their long period of drifting with currents, but it clearly makes no sense to release them where longshore petroleum drift is known to occur. At the recent Workshop on the Fate and Impact of Marine Debris in Honolulu, the impact of plastic flotsam on marine turtles was exhaustively documented by Balazs (1985), while Galt (1985) detailed the diversity, origin and unpredictable shiftings of the convergences along which pollutants collect. Galt's account of the changing positions of the fronts, and thus the routes of spread of pollutants does not simplify the problem of selecting appropriate release sites. In a given locality, however, it is usually possible to know what major current regimen is likely to prevail offshore at a given time, and to avoid releases at beaches where the probability of encountering heavy pollution is high.

In Florida, where the heaviest loggerhead nesting in the Atlantic system occurs, the adjacent sections of the Gulf Stream at times carry oil from both European sources and the heavily burdened Gulf of Mexico. Petroleum in one form or another has been found there in the guts of numerous hatchlings and juvenile sea turtles--usually loggerheads, but also hawksbills and green turtles--that have washed ashore in sargassum. On the Caribbean coast of Costa Rica, advanced juveniles that had ingested oil or tar have washed in on Tortuguero beach, evidently after one or more circuits in the West Caribbean Gyre (Carr and Meylan 1980, and verbal reports to Carr). In the guts of young loggerheads of the pelagic stage from around San Miguel (Azores), Madeira, and the Selvagens Islands, Brongersma (1968) and van Nierop and den Hartog (1984) found polyethylene sheet plastic, bits of solid plastic, pieces of paper, and nylon line; and all the stomachs contained semi-solid clots of oil. In 1983, after the 1982 year-class of head-start Kemp's ridleys were released off Mustang and Padre Islands, Texas, 91 of these were later found stranded. All had ingested oil or tar pellets, which had been picked up when the turtles went into offshore sargassum mats. The beaches of Bermuda and the sargassum rafts that drift by them are frequently smeared with tar. Meylan (1983b) called attention to the threat to the ecology of the southwest Caribbean gyre and South Equatorial Current, which receive the entire output of hatchlings from the Tortuguero nesting ground of Chelonia, from the pipeline and oil port being constructed at Chiriqui Grande on the shore of Chiriqui Lagoon.

For the present the problem of the coming together of hatchlings and pollutants in fronts is without a solution. One important tactical rule-of-thumb, however, is to refrain from releasing hatchlings or head-start turtles on any shore off which no convergence is available, where an onshore drift prevails in the season of release, or where a longshore driftline is likely to be loaded with pollution.

EPILOGUE

Results of the present work reveal an urgent need for further study of sea turtle life cycles, with special attention to their developmental ecology. The growing evidence for a more protracted pelagic stage, during which the juvenile turtles are passive migrants in fronts that are increasingly invaded by debris and toxic wastes, emphasizes the need for a better understanding, by marine biologists, of the organization of the driftline habitat and the behavioral ecology of its occupants. In the case of sea turtles our faulty understanding of the sites and schedules of transition from the pelagic stage to life on the continental shelf is a further fundamental obstacle to conservation and management.

Why the concentrated biological activity at fronts has had so little impact on the thinking of marine ecologists is an abiding puzzle. I became aware of it only when I began to consider the sargassum refuge as an answer to the "lost year" puzzle. What seemed a serious weakness in that theory was the tendency of the rafts to break up in heavy seas. The more generalized, mobile inhabitants could simply cruise around till they came upon another mat; but how about such wholly committed species as the sargassum fish? Its specialized adaptations would seem to make life impossible anywhere else. How did any of the adaptively committed sargassum species ever get back into a reassembled weed habitat after a storm had churned it up?

To get an answer, three ideas had to be put together, as follows: (1) the rafts are assembled by advection, caused by sinking, at fronts; (2) after heavy weather the same force both reassembles the mats and gathers and reinstalls the dislodged occupants when the sea calms down again, and (3) fronts, and thus, advection, are not confined to edges of major currents; they occur as semi-stable or recurrent features throughout the epipelagic; they are of all kinds and sizes (Uda 1938; Galt 1985); and they are able to assemble all kinds and sizes of flotsam, from salps and copepods to drifting trees or ships (Beebe 1926).

For quite a while I remained ignorant of these ideas and as a result found it impossible to understand how sargassum could ever have acquired a fauna of evolved, obligate occupants, unable to live elsewhere, and incapable of the active, oriented travel necessary for searching out another mat or driftline.

Then one day I looked out of a little airplane and saw the whole surface of the sea banded with narrow weedlines, spaced across the water with unaccountable regularity. When I got home and talked with an oceanographic colleague I learned that the multiple driftlines were made by advection between opposing horizontal vortices generated by steady wind, that they are called Langmuir bands, and that the phenomenon is common. For me, this eased the way toward understanding how epipelagic life can be lived by an organism unable to photosynthesize, or to sweep in plankton, or to cruise away to the Gulf of Guinea when its rip disintegrates.

If you tell a physical oceanographer about that problem, and can persuade him or her to speak English and to tell you why, and how regularly, convergent downwelling occurs in the surface water, and how this assembles flotsam in lanes and bands, you will learn that the process is common wherever there is differential horizontal movement in the upper water of the sea.

In a river you see this in miniature wherever the current washes around a snag or over a submerged boulder and makes a swirl on the downstream side. A gang of gyrinid beetles will probably be there, picking up stuff that collects along the edges of the swirl; and a baited hook cast into the curve of the little rip is likely to be taken by a fish. At the downstream end of a bar where the separated current comes together, or in the roil of water over a sunken boulder, it is the same. Then later on, when the river meets the sea the horizontal meeting generates vertical response, and because the water can't rise against gravity the vertical component is only downward; and since the flotsam that is drawn in can't sink, it accumulates along the line. Resources are mobilized along it, and it is a good place to fish.

In their admirable paper on the accumulation of small depth-keeping, cold-water fishes in warm-core Gulf Stream rings Olson and Backus (1985) said this:

> More sophisticated time/space sampling of both physical and biological parameters is needed in the future in order to provide better insight into the paradigm of increased biotic activity at fronts.

Until that sampling is done we are bound to remain peculiarly ignorant of the ecologic organization of three-fifths of the surface of the earth.

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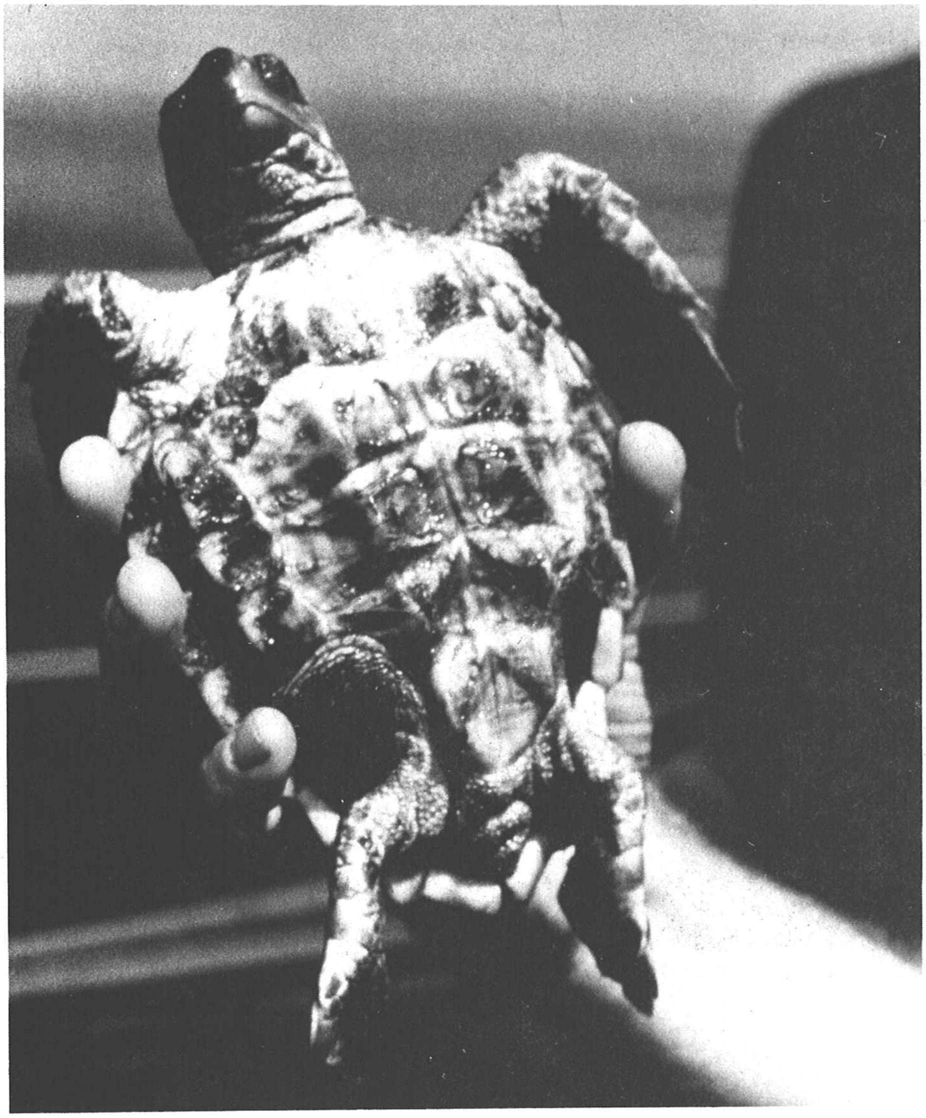

Figure 1. Pelagic stage juvenile loggerhead from edge of Sargasso Sea. (R/V Geronimo photo.)

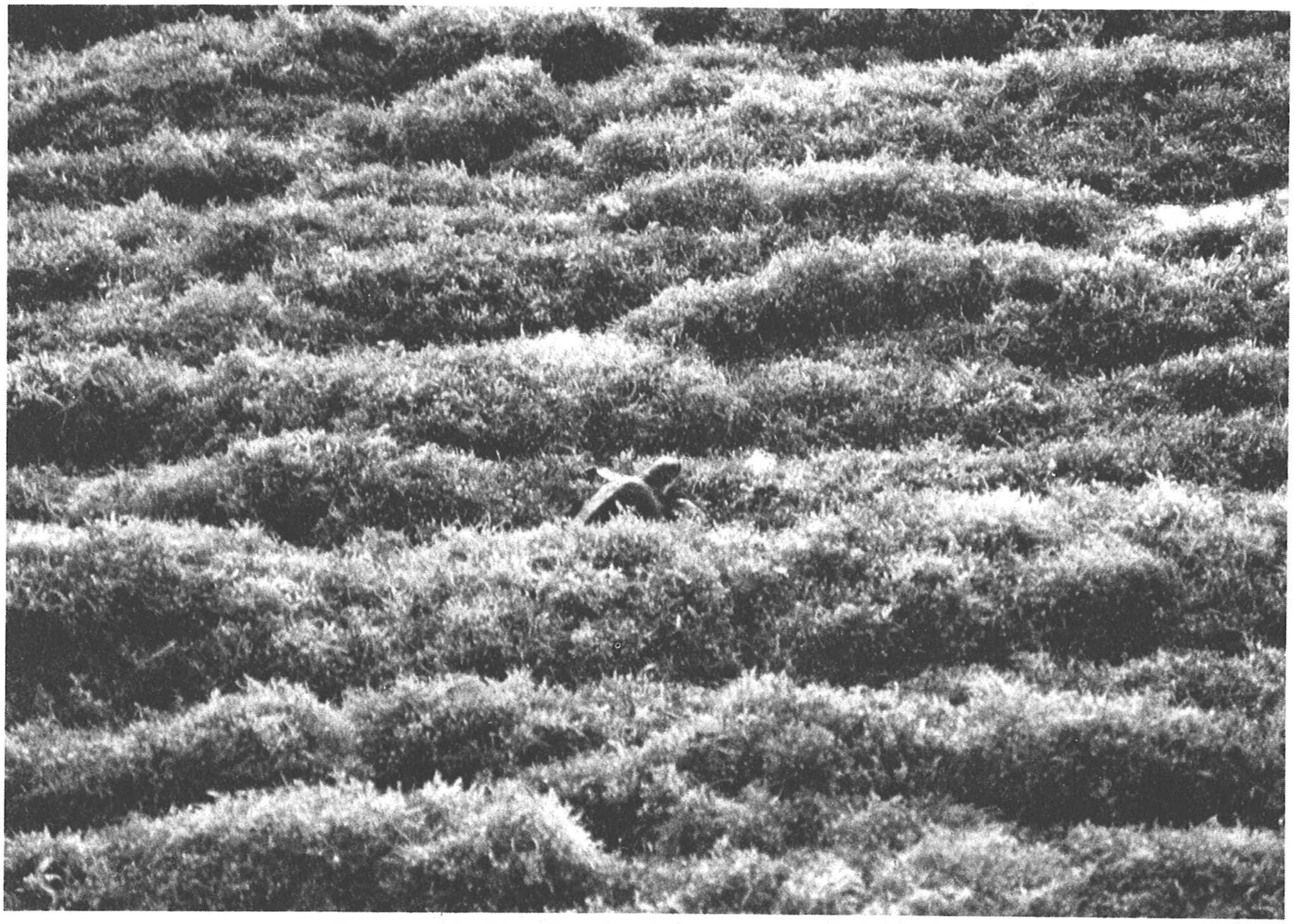

Figure 2. Pelagic stage green turtle in exceptionally dense sargassum driftline off the tip of Little Bahama Bank. (Lisa Bibko photo, R/V Cape Florida cruise.)

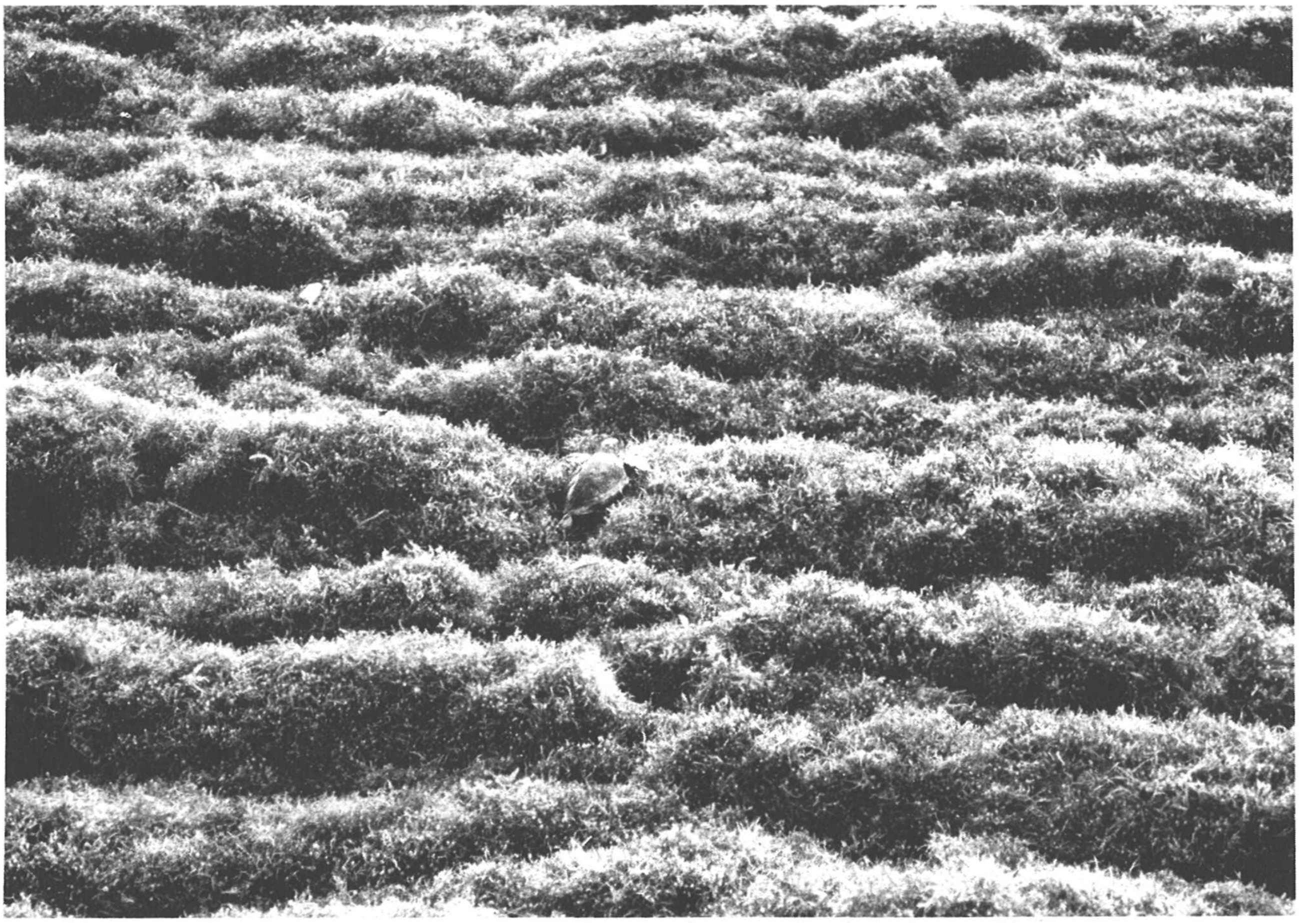

Figure 3. Pelagic stage green turtle, possibly the same as in Fig. 2 moving across sargassum raft off tip of Little Bahama Bank. (Lisa Bibko photo, R/V Cape Florida cruise.)

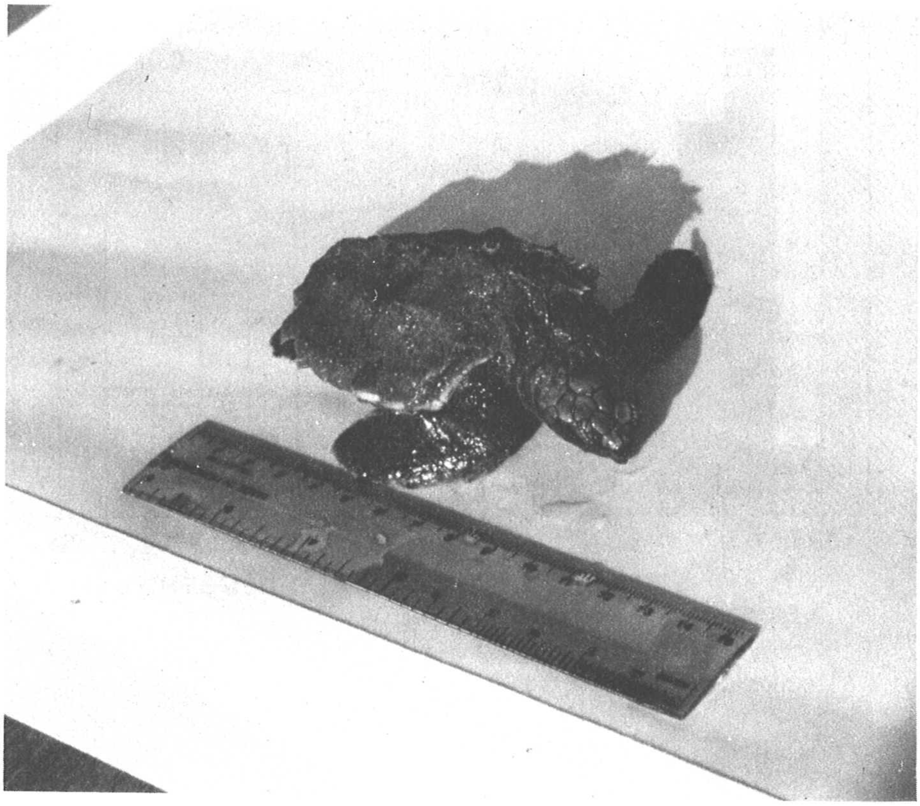

Figure 4. Advanced loggerhead post-hatchling, thrown ashore in sargassum by heavy seas, Flagler County, Florida, and rehabilitated by Marineland Research Lab.

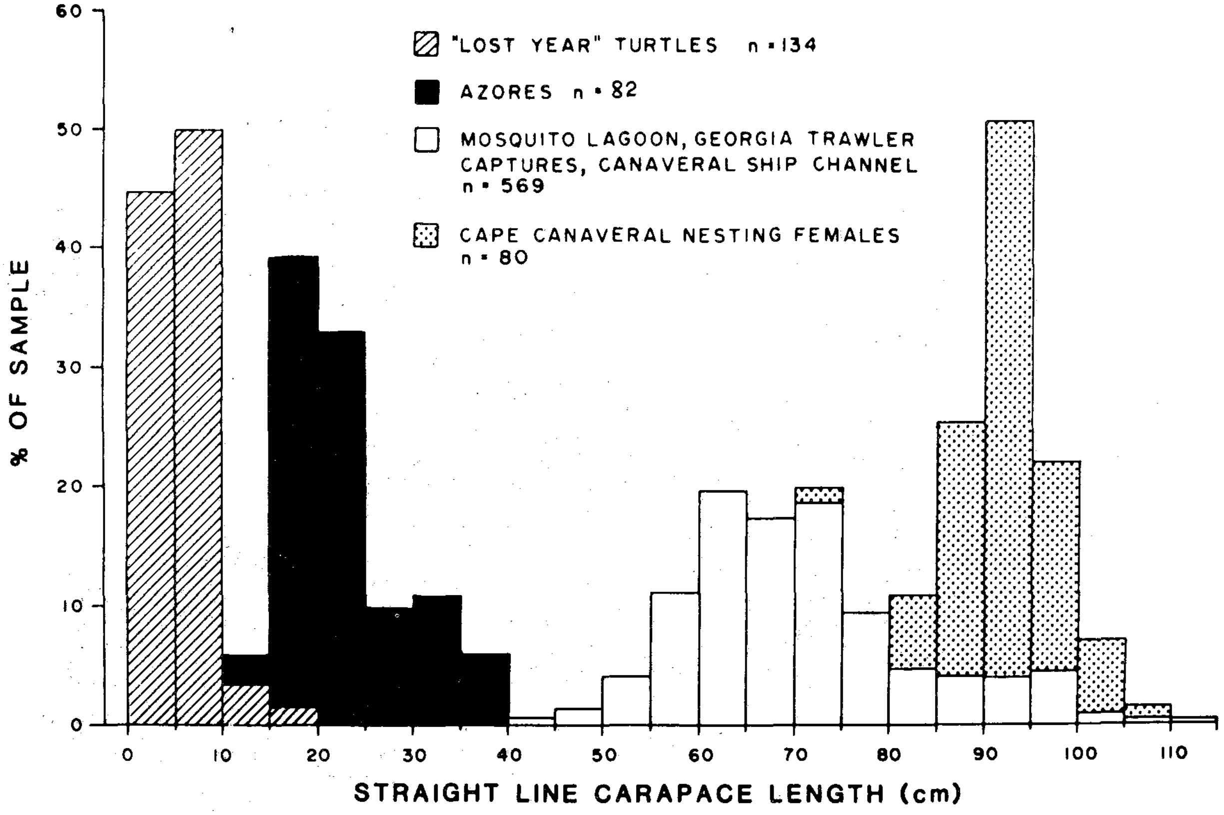

Figure 5. Comparative size distribution in three age groups of *Caretta* from the western Atlantic (Hillestad et al. 1977, Ehrhart 1980, Mendonca and Ehrhart 1982, Ogren and McVea 1982) and one from the Azores. (Unpublished data from the Department of Oceanography and Fisheries, University of the Azores.)

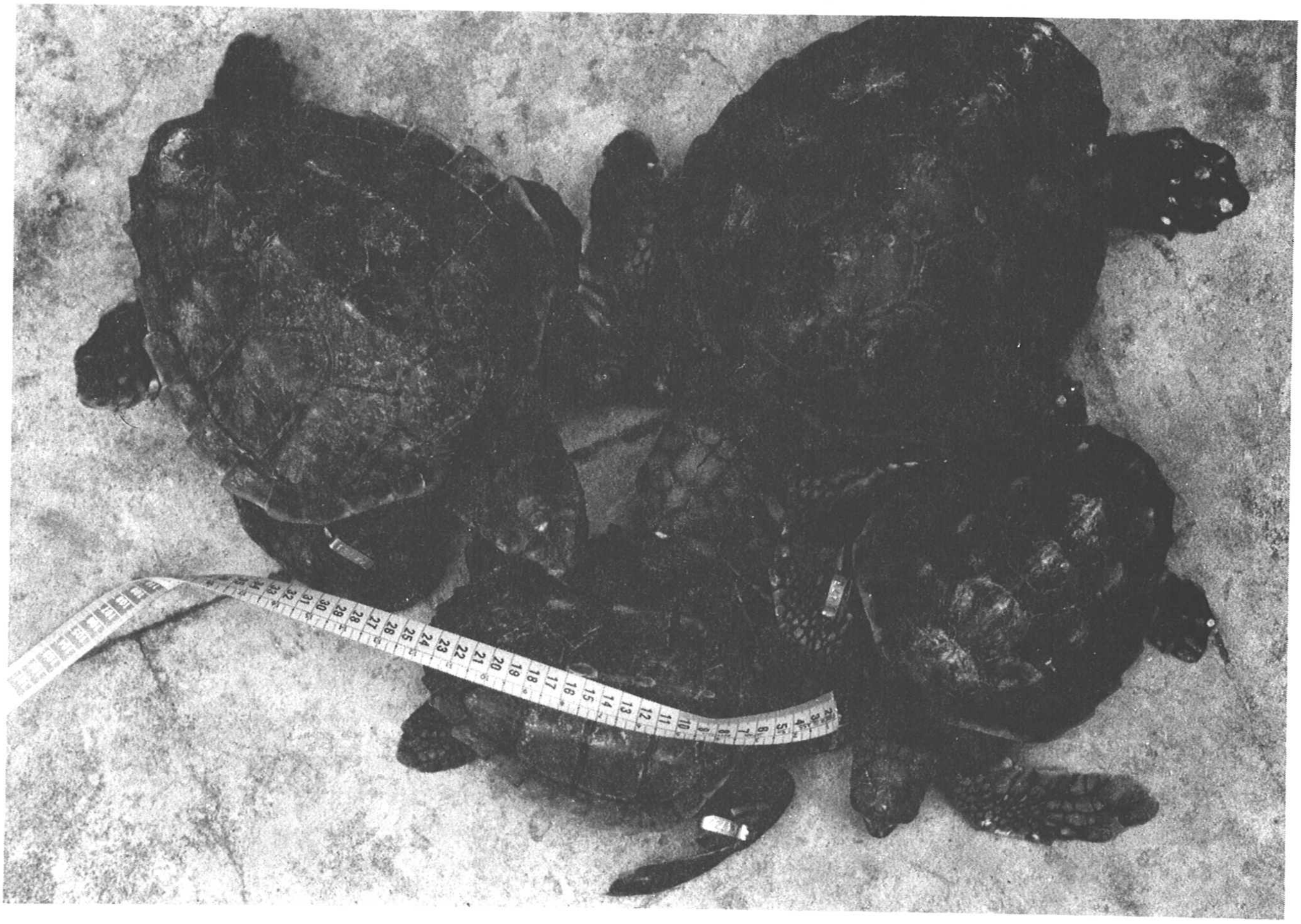

Figure 6. Pelagic stage loggerheads in the series of 82 represented in Fig. 5, from Princesse Alice Bank, Azores. (Photograph by Helen Martins, Department of Oceanography and Fisheries, University of the Azores.)

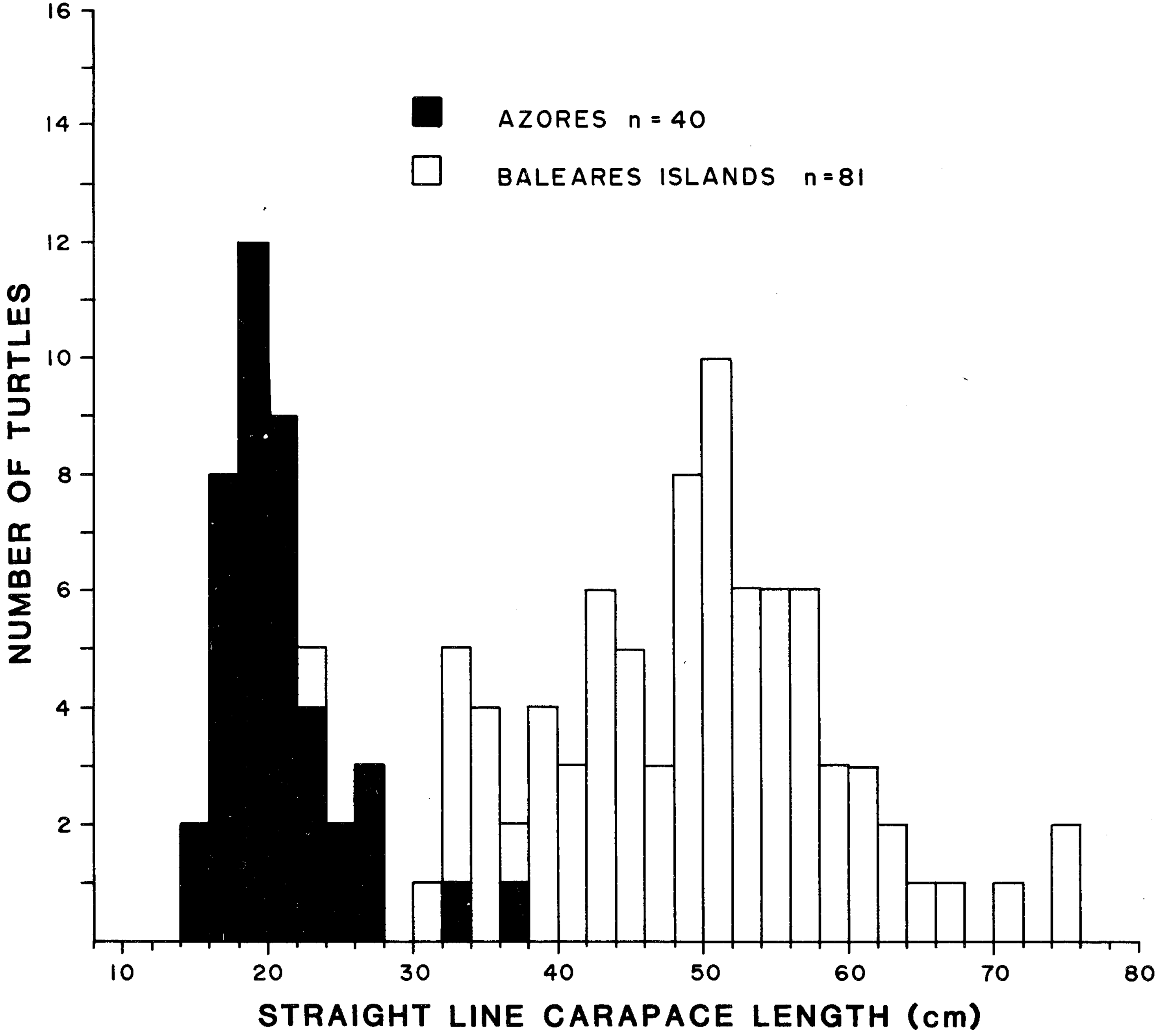

Figure 7. Size distribution in loggerheads in the East Atlantic and Spanish Mediterranean. (Azores data from Helen Martins; Beleares data from Joan Mayol.)

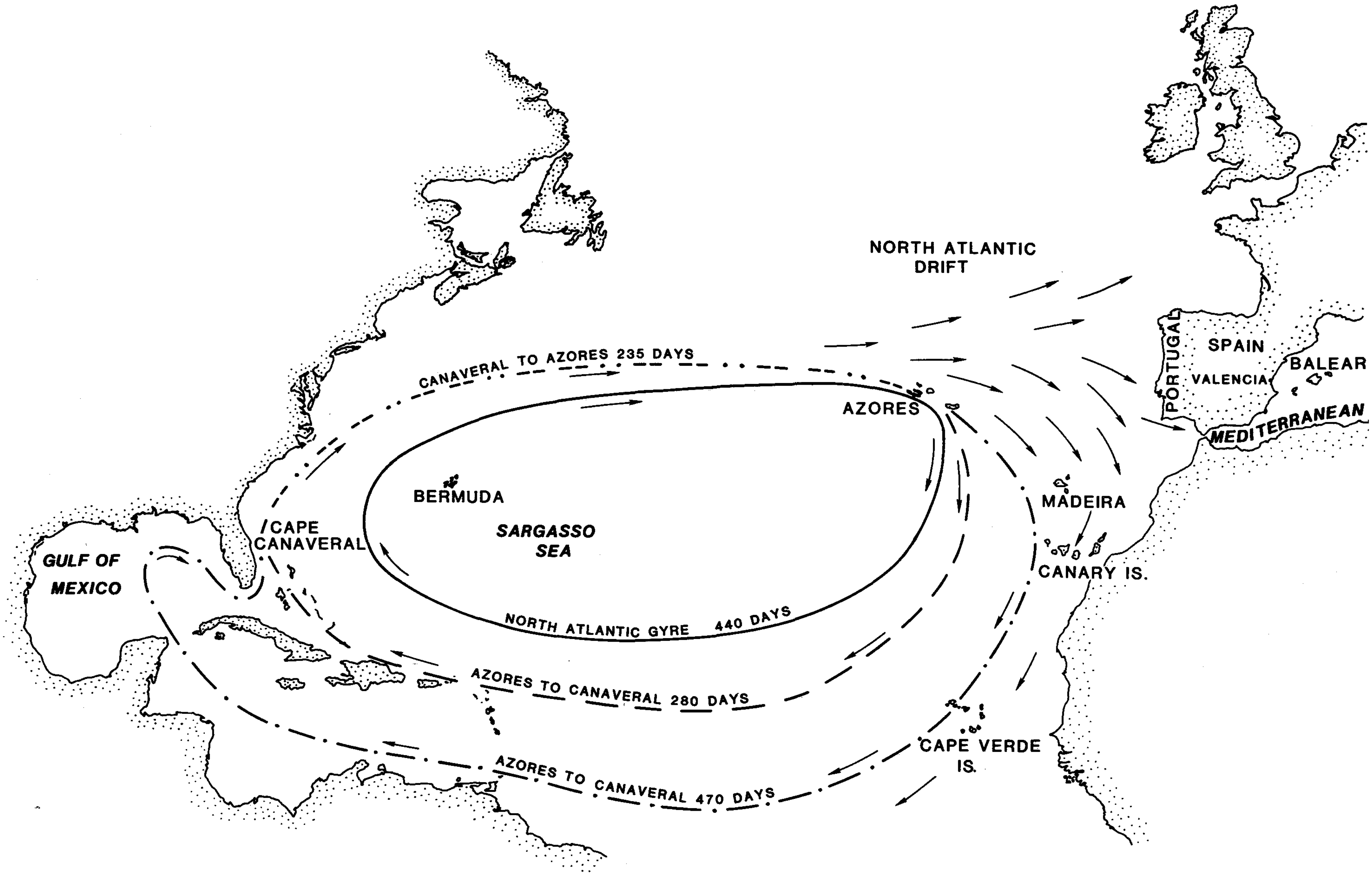

Figure 8. Travel-time estimates, at drift speed of 1/2 knot for three routes of passive migration from the Azores to Florida, and one from Florida to the Azores. This figure shows the need to postulate long residence in gyres, large or small, in order to account for growth of migrants between developmental stations.

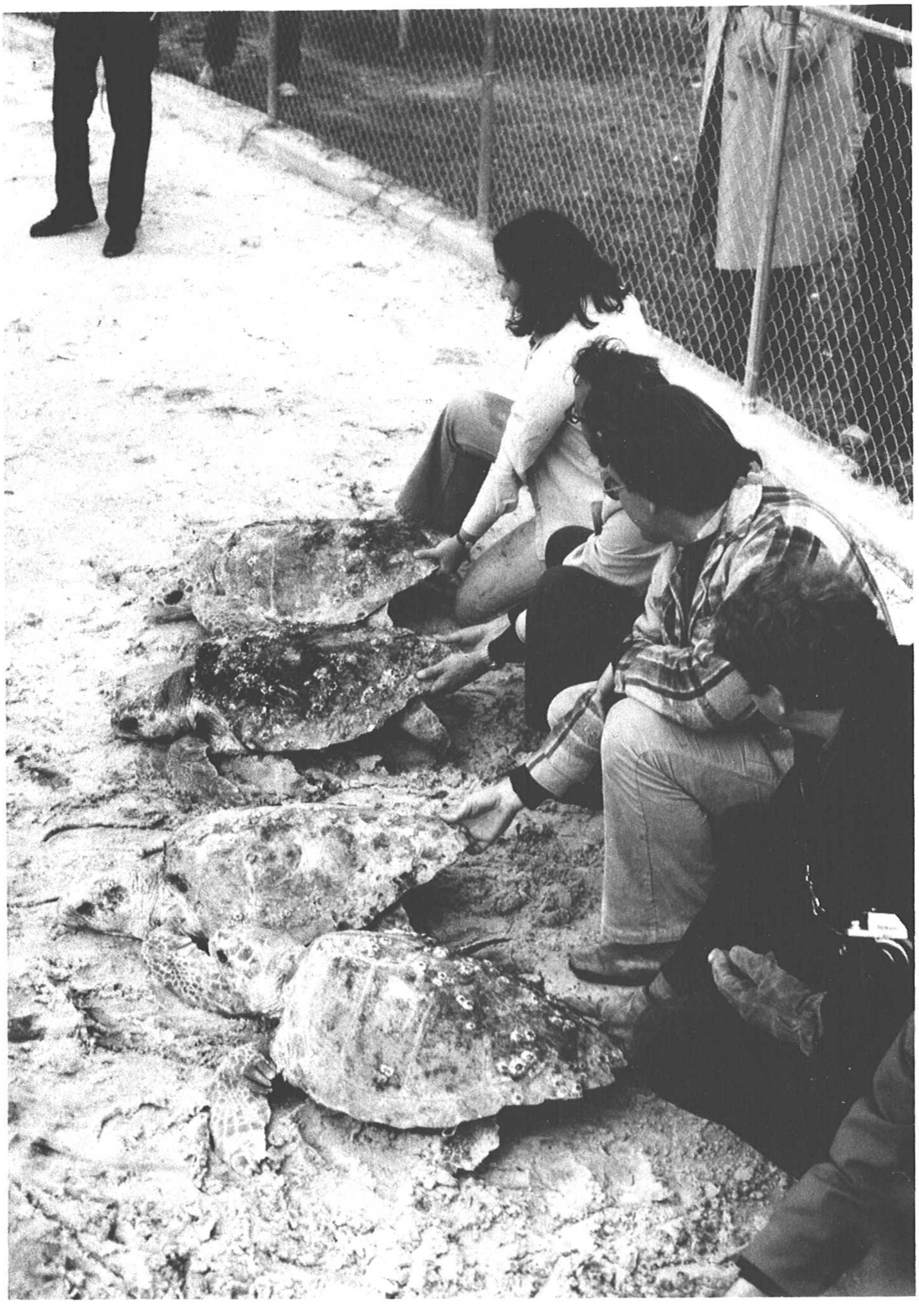

Figure 9. Subadult loggerheads of the size group in the Indian River Lagoon System. (Lew Ehrhart photo.)

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