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# The Ecology and Migrations of Sea Turtles, 1 Results of Field Work in Florida, 1955

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The information presented here was gathered in the Cedar Key-Crystal River area (Levy and Citrus counties) of the Gulf coast of peninsular Florida (fig. 1), mostly between April and November, 1955. Operations there were a phase of a general study of the natural history of sea turtles in the Florida and Caribbean areas, a three-year project supported by a grant (G-1684) from the National Science Foundation. Results of the first season's work in the Caribbean will be published in the near future (Carr and Giovannoli, MS).

While the main goal of the program is an understanding of the migratory habits of the Atlantic Green turtle, *Chelonia mydas mydas* (Linnaeus), it was foreseen from the start that the work with that species would inevitably turn up information on the other sea turtles, and as all are really quite poorly known, such data will be organized and published as the time seems proper. Thus, in the present paper we give early tagging results, measurements, counts, and general observations on two kinds of turtles: the Green turtle and the Atlantic Ridley, *Lepidochelys kempi* (Garman). While the data are admittedly scant and inconclusive, the conspicuous lack of reliable information on any phase of the biology of the two interesting and puzzling animals makes the publishing of the results at hand, incomplete as they are, seem desirable.

The two forms are considered together here because our investigation

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leans heavily on the Gulf Coast turtle fishery, which in the same net settings takes the much sought Green turtle and the less favored Ridley. The turtles are caught in tangle nets 100 to 200 yards long, 8 to 10 feet deep, and with an 8- to 12-inch-bar mesh. It is worthy of note that these two kinds of turtles, belonging to different genera, and, from the evidence at hand, with very different feeding habits, should be so regularly taken in the same fishing operation. However, it is possible that the fisherman's

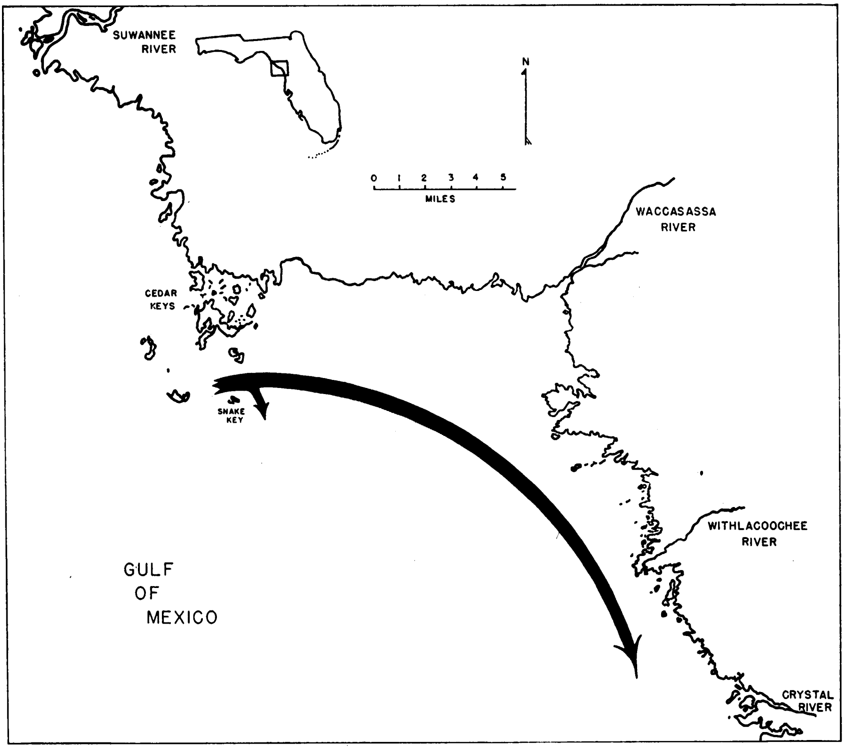


FIG. 1. Map showing Cedar Key and Crystal River-Withlacoochee fishing grounds. Large arrows indicate probable general course taken by tagged turtles before recapture.

custom of setting the nets across "sloughs" or channels among the flats merely results in an intercepting of the two forms as they move along the most favorable highway in the area—perhaps towards very divergent goals. The fishermen say that the Green turtles are in the area because the grass flats (turtle grass, *Thalassia,* and manatee grass, *Cymodocea*) are especially extensive there. Why the Ridleys are there is not fully known, though it is possible that they feed on the crabs and other invertebrates found on the flats as well as in the channels. Other points of similarity and contrast between the two animals are noted below. While it is not unusual for a single night's turtling on the flats to yield Ridleys and Green turtles in equal numbers, turtle fishermen of the area rarely catch Loggerheads, *Caretta caretta caretta* (Linnaeus), although in deeper water just offshore they are frequently seen, as is an occasional Hawksbill, *Eretmochelys imbricata imbricata* (Linnaeus).

## TAGGING METHODS

Three kinds of tags have been used since the beginning of the program, and turtles bearing all three are presumably now at large. The tag first used was a 1-inch circular disk of monel metal stamped on both sides. Only Loggerheads were marked with this type (see Caldwell, Carr, and Hellier, 1956), and it was soon abandoned in favor of a 2- by 1½-inch oval of monel metal with the legend all on one side. Both these disks were perforated at opposite poles and were wired on through corresponding holes in the caudal laminae of the turtles, just to the right or left of the midline, and on either the upper or the lower surface of the shell. The fastening was 50-pound-test monel trolling wire. In earlier stages the wire was passed from one hole to another across the face of the tag and under the shell, but later it was doubled and threaded separately through each hole and twisted fast at the hind edge of the shell, the twisted ends then being jammed forward between the tag and the shell surface to protect them from untwisting. A still later development, and one that may replace the others in future work, was a 2-inch cow-ear tag of monel metal fastened by means of a special pincer to the hind edge of the fore flipper, through a hole punched to receive it. On this the legend is on the upper side and the number on the lower. All three tags bear the address of the University of Florida and an offer, in Spanish and English, of a reward for their return.

Of the three styles of tags the cow-ear tag is by far the easiest to apply. Ours is a modification of the method used by Tom Harrisson in his study of Pacific Green turtle nesting on islands off Sarawak (as described by him at the 1955 meeting of the American Society of Ichthyologists and Herpetologists). With a sharp quarter-inch chisel, a hole is punched in the required place on the thin part of the fin, and the tag is easily clamped through this incision. There is little or no bleeding if the proper place is chosen, and there seems to be no impairment of the swimming function of the flipper. A turtle can be tagged this way in about a third of the time required by the shell-tag method. We have durability tests of the various types of tags under way at the Gulfarium, The Living Sea, at Fort Walton Beach, Florida, and if these turn up no unexpected disadvantages in the fin-tagging method it will probably be adopted for the remainder of the study. Its one obvious disadvantage is the increased puzzlement the finder may feel at the problem of sending a three-dimensional object of irregular shape through international mails. It can of course be easily unbent and sent as flat as the others, but the psychological hazard is important in tagging programs, and we can only hope that the shape of the fin tag does not augment this hazard appreciably.

## METHODS OF TAKING MEASUREMENTS

Weights of commercial-sized turtles were taken, in the fish houses on a platform balance, to the nearest pound. The length of the carapace was measured in inches (to the nearest quarter of an inch) either with a pair of large wooden dividers and a rule or by laying the rule across the top of the carapace and measuring between perpendiculars from the center of the anterior end of the carapace and the greatest posterior projection of the carapace. The width of the carapace was measured in the same manner, at its widest point. The curve of the shell was *not* measured.

## SEASONAL VARIATION IN MEAN SIZE IN THE TWO SPECIES

Our size data for the whole season can be divided roughly into three groups, separated by periods when no turtles were seen. There is an apparent, though not statistically significant, change in the mean size of turtles taken on the Crystal River-Withlacoochee grounds at these different times, with larger animals (24.9 inches mean carapace length for Greens and 21.6 inches mean carapace length for Ridleys) making up most of the early season catch and smaller sizes (22.5 inches in mid-season and 23.3 inches in late season for the Greens and 19.8 inches in mid-season and 20.5 inches in late season for Ridleys) predominating in the two later groups. It should be noted that the size range for each species is about the same in all three sections of the season, but that the means and modes vary, the latter approaching the mean in each case. One possible explanation for this variation might be that the big early-season turtles have "laid up" over the winter (see section below on Green turtles) and thus represent an older (and in mean size, larger—having grown while "laid up") group that arrived on the fishing grounds the year before, while the smaller mid-season individuals represent new groups of migrants just arriving, and are thus younger than the others (again see section on Green turtles). On the other hand, the changes in mean size of the individuals in the catch may be due to unknown selective sampling by the netting operation, such as a greater susceptibility to entanglement on the part of bigger turtles, resulting in their being the first to be taken from the population and leaving the smaller ones for the mid-season catch, with these in turn showing growth by late season. It is also possible that if the population does actually migrate into the area each season, and none "lay up" over the winter, the larger ones may swim faster or more continuously and arrive on the grounds somewhat ahead of the smaller members of the fleet.

In the remainder of this paper we deal with the Green turtle and the Ridley separately and, unless otherwise noted, data presented under each species heading refer only to that species.

## GREEN TURTLE

Study of the Green turtle in Florida is limited by the fact that the local population is composed almost entirely of non-breeding, juvenile individuals. The minimum weight for sexually active adults seems to be about 130 pounds (the approximate weight of the smallest females found on the Costa Rican rookery). We have seen no Florida Greens heavier than 115 pounds, and the modal weight is much less. Thus, the work in Florida has not had the advantage of a near-by rookery affording a large supply of readily available hatchlings and mature females for marking and study. While repeated rumors indicate that an occasional isolated female may nest on the lower East Coast beaches of Florida, these have not been seen by us during many nights and miles of Loggerhead tagging, nor have they been substantiated through definite records by any zoologist of the last 50 years. The cases must be rare to the point of aberrancy.

Evidence that the Florida *Chelonia* population is indeed an immature, and thus itinerant, one can be summarized as follows:

1. Non-professional but often well-qualified observers in widely scattered places share a belief that Green turtles make long-range mass migrations for nesting purposes and perhaps at other times.

2. Of the hundreds of individuals examined by us, no gravid females were found, and, as is mentioned above, no specimens as heavy as the minimum for sexual maturity in other places have been seen. That the small size of Florida *Chelonia* does not simply imply a dwarfed geographic or ecologic race seems indicated by the fact that the secondary sex characters are not even evident.

3. Hatchlings are never found, on the beaches or elsewhere. The smallest turtle examined by us was 13.5 inches long and weighed 12

pounds. The smallest that any fisherman questioned claimed to have seen was a three-pound one allegedly taken at Crystal River several years ago. While baby turtles are everywhere astonishingly hard to trace, they do turn up once in a while in tropical waters and should be seen along the heavily netted Florida coast if present there.

4. The nesting season for American stocks of the Atlantic Green turtle, as far as known, is the period from May to October. This coincides closely with the turtle fishing season in Florida, which begins in April and ends with the first cold of fall. Thus, the population is being sampled at a proper time for shelled eggs to be found in the females if there were any, and for hatchlings to be taken.

5. The West Coast fishery, as stated in making the preceding point, is a seasonal one. The disappearance of the turtles in early fall and their reappearance in late spring probably imply mass seasonal movements of a magnitude sufficient to warrant the term "migration." Most local fishermen make this interpretation of the facts, saying confidently that with the first freeze the West Coast schools assemble in large bands and leave the area completely, to return only when the water starts to warm up in April. It is of some interest that a small percentage of the Gulf Coast turtlers are vehemently sure that this is wrong and that the fall assembling is the prelude to a "burying up" in the mud bottom of holes on the flats where the turtles stay throughout the winter. This alternative explanation for the observed "bunching" at the beginning and end of the season, which is apparently fact, seems to take support from the occasional occurrence of mud-covered turtles among the spring catches.

6. A study of old accounts and observations shows clearly that marked changes in the character and condition of the Florida *Chelonia* population have occurred. Thus, while detailed data on the Cedar Key fishery of a hundred years ago are lacking, there seems little reason to doubt published statements (see Carr, 1952, p. 347) that large mature Green turtles were formerly taken there up until around the turn of the century. True's statements (1884), however, that Greens of between 600 and 800 pounds were not rare and that top weights reached 1000 pounds should probably be given cautious scrutiny, although they are widely accepted by zoologists. Another change is the obliteration of a rather well-documented mass nesting ground on the Dry Tortugas, once a populous rookery and now rarely if ever visited by Green turtles. It may be that this Tortugas nesting ground was the main source of supply for Florida waters and that since its exhaustion the origin, and thus the character, of the population here has changed. Today, the only American *Chelonia* rookeries definitely known are those off the coast of Quintana Roo, on the

Yucatan Peninsula; at Tortuguero, Costa Rica; and on Aves Island in the eastern Caribbean.

While the selective nature of the Florida Green turtle contingent restricts study to small individuals caught in nets, it at the same time contributes evidence towards a case for migration. Because the age groups involved are never sexually mature, they can neither have been born in home waters nor be destined to breed here. In other words, they move in from elsewhere.

A considerable amount of reconnaissance seems to show that the breeding area nearest Florida is Isla de Mujeres off the northeast coast of the Yucatan Peninsula. The important Costa Rican grounds are farther away. There is of course a steady current (the Gulf Stream) flowing from both these points to the Florida Peninsula, and it could be that Florida Green turtles come in on this current, perhaps growing to the approximately 10-pound minimum size for Florida specimens on the way, and then exploiting the local feeding resources while attaining a size and strength that would permit a return to tropical waters by some other route. There is, however, no recorded precedent for such a conjecture, and no turtle anywhere is known to follow the great ocean currents in connection with a seasonal or developmental migration, unless it be that the big nesting assemblages at Ascension Island are aided on their trip west from the West African mainland coast by the Equatorial Current; and if so, what they do about it on the return journey would be interesting to know.

Off the south-central coast of Cuba there is a long archipelago of uninhabited keys that once were heavily visited by nesting Green turtles but that were virtually exhausted by the turtle hunters of the nineteenth century. There are indications that a recent limited resurgence of this rookery may have occurred, and, if so, it is possible that these keys are the home ground of Florida *Chelonia*. As regards current relations, however, such an origin seems much less likely than the geographically more distant Yucatan or Central American localities, as any direct course taken by the hatchlings would involve a crossing of the Gulf Stream. It is likely that the Florida population consists of waifs and strays from the main Caribbean population and that they are forever lost to that population.

## Results of Tagging Project

Homing: Forty-three Green turtles 16¼ to 22¾ inches long, taken during the regular fishing season on the Withlacoochee-Crystal River grounds (fig. 1) were tagged and released at Cedar Key (except for six released at Crystal Beach, Pinellas County, about 60 shoreline miles south of the fishing grounds). Six tags have come back to us, and two tagged individuals were recovered with the tags gone but the two tag holes clearly evident in the back shell margin. Of the latter two, one was individually identifiable because of a recorded shell deformity, while the other was recognizable only as one of the group released at Cedar Key. Beside these, two subadult females, shipped to Tampa from the Nicaraguan Mosquito Cays, by way of Grand Cayman, where they remained for a time in a crawl, were tagged and released at Cedar Key.

The 18.6 per cent recovery was surprising. It is perhaps pure coincidence that the only previous marking experiments with Atlantic Green turtles, those of Schmidt (1916) in the Danish West Indies, involved almost identical figures (65 released, 9 recovered). Two salient facts in our results are these: Every recovery but one involved a return to the site of original capture; and one turtle made the return trip twice. The one recovery not involving a complete "homing" trip occurred when a turtle was retaken only a few hours after being released, and it is interesting that the site lay directly on the homeward course and may well have been an interruption of a homing journey. A more detailed history of the tag returns is presented in table 1.

At first glance these data seem clearly to suggest homing behavior, especially when seen against the background of almost universal belief among turtlemen that Green turtles have a strong homing instinct. On the other hand, the case may be argued differently, and it is even possible that the data have no validity at all as evidence for actual homing.

All the turtles that "went home" were released at one place—Cedar Key, between the town on the mainland and Seahorse Island, some 4 miles off shore. The site of recovery lies 25 miles southeast by direct measurement, although considerably farther along the coastal shallows over which the turtles probably traveled. If random radiation from the point of release could be assumed, and if the radiating animals had been sampled by randomly distributed agents, it would be necessary only to calculate the proper quota of turtles for each quadrant about the point of release to determine the significance of the number of actual recoveries. Obviously, however, neither the movements nor the sampling of the freed turtles can be regarded as random. The land back of the site of release reduces the field of radiation roughly to a semicircle and the deep water off shore is probably shunned by the turtles, as the turtle-grass flats extend only a few miles out to sea and the food supply is thus not there. Thus, the assumed spreading is perhaps strongly channeled into, if not confined to, linear paths northward and southward of Cedar

Key, through the flats and shallows that support turtle and manatee grass pasture.

Thus, as a first step in determining the value of the recovery data as evidence for homing, as opposed to random spreading, half of the released turtles, the potential recoveries, should be assigned to the peninsular shoreline northwest of Cedar Key and half to that to the southeast, and the nine returns should be appraised against that background. However, even this more refined operation involves three probably unjustifiable assumptions: (1) that all the turtles left the Cedar Key area, where no turtle nets are set; (2) that even if the spreading were not homing, half would go north and half south, which is not necessarily true at all, as the spreading could be a one-directional migration; and (3) that turtle fishing is equally heavy and effective all along the zone of possible recovery, which is also untrue.

TABLE 1

RÉSUMÉ OF TAG RETURNS OF TURTLES ORIGINALLY CAUGHT ON THE CRYSTAL RIVER-WITHLACOOCHEE GROUNDS AND TAGGED AND RELEASED AT CEDAR KEY

| Species | Where Recaptured | Date Released (1955) | Date Retaken (1955) | Days Out |
|---|---|---|---|---|
| Green | Crystal River-Withlacoochee | July 21 | Aug. 9 | 16 |
| Green | Crystal River-Withlacoochee | July 21 | Oct. 13 | 85 |
| Green[a] | Crystal River-Withlacoochee | July 29 | Aug. 27 | 29 |
| Green | Cedar Key[b] | Aug. 11 | Aug. 11 | <1 |
| Green | Crystal River-Withlacoochee | Aug. 11 | Sept. 30 | 50 |
| Green | Crystal River-Withlacoochee | Aug. 11 | Nov. 9 | 90 |
| Green[a] | Crystal River-Withlacoochee | Sept. 5 | Nov. 9 | 65 |
| Green | Crystal River-Withlacoochee | Unknown[c] | Oct. 31 | — |
| Ridley | Crystal River-Withlacoochee | July 29 | Sept. 10 | 43 |
| Ridley | Crystal River-Withlacoochee | Unknown[c] | Nov. 10 | — |

[a] The same turtle. It was originally caught on the fishing ground off Crystal River, carried by boat to Cedar Key, tagged and released, recaught 29 days later off Crystal River, returned by boat to Cedar Key, kept in the crawl several days, released again, and was caught at Crystal River a third time 65 days after its second release. Then it was butchered.

[b] Caught near Snake Key, less than 1 mile from point of release, between release point and Crystal River-Withlacoochee grounds.

[c] Tag gone but holes remaining.

If Green turtles were regularly taken by other than specialized turtling (in mullet nets, say, which are used pretty evenly from Appalachicola to Tampa Bay) the sampling would be trustworthy. But even the small sizes released by us are only rarely caught in anything other than the big-meshed tangle nets of the turtle fishermen (one such rare occurrence was the lone tagged Green turtle not taken at the site of original capture mentioned above, which was accidentally taken by a mullet fisherman). While turtle fishing is carried on to varying degrees all the way from Cape San Blas to the Florida Keys, there is a strong concentration of activity off the mouths of the Withlacoochee and Crystal rivers where our returns all came from. It might be argued that this fact only seemingly distorts the case and that actually the concentration of turtling off the two rivers means that there is superior Green turtle habitat there—habitat to which expatriate animals would understandably return. Then it could be countered that, though perhaps the goodness of the habitat was involved, it was merely as an attractive stopover station in a southward migration in which the tagged turtles were engaged when first caught and which they resumed when let go. A number of other points of view might be taken, but these are sufficient to show how misplaced any confidence in a statistical test of the significance of our "homing" data would be. On the other hand, the consonance of our preliminary results with the almost universal belief among Gulf and Caribbean turtle fishermen in the homing instinct of the Green turtle is noteworthy.

The reality of the apparent homing tendency receives additional support from the stories, widespread among the West Coast turtle fishermen, of homing journeys made in past decades by branded individuals accidently released, usually by storms, from crawls at Cedar Key. Through the middle and late 1800's especially, Cedar Key was far more active as a center of Green turtle fishing and export than now. Apparently since the early days of the fishery the Crystal River area has been the principal site of Green turtle aggregation, and thus of turtling activity, and there are numerous old tales still afloat of returns across the same tract of water traversed by the animals in our own tagging experiments.

Still another bit of evidence supporting the "homing" assumption is found in the results of Schmidt (1916) in the Danish West Indies. In this case, one of the turtles that he released was recaptured 11 months later in the same area. Though it is not clear whether the turtle was originally caught there, the long stay in a restricted area could be regarded as the maintenance of a home range.

Migration: As is implied above, if the tag-return data are taken as evidence of homing, then obviously they contribute nothing in the question of seasonal mass migration (and vice versa). A point seeming to favor the homing interpretation is the fact that individuals that have gone home are stationary and more susceptible to recapture than individuals in a migration stream. Future tagging experiments will be designed to permit a distinction between the two kinds of movements, as fragmentary circumstantial evidence shows that both probably occur.

POPULATION SIZE: Any clear idea of the size of Green turtle populations on the West Coast of Florida must await experiments more elaborate than our simple tagging operation. The possibility that a population in unidirectional motion is involved, and that the movement may be continuous, periodic, or sporadic and either individual or massed, makes the use of such arithmetical proportions as the Lincoln Index almost pointless. Moreover, even the volume of the total catch is hard to determine, because in many places turtling is sporadic, and everywhere a large part of the catch is consumed locally. A very rough estimate of the catch on the Crystal River-Withlacoochee grounds is a thousand per year. We actually examined 207 and estimate that five times that many may have been caught. With the use of this estimate and the known numbers of tagged turtles released and tagged turtles recaptured, the following simple proportion may give a very rough estimate of the total population of the area:

$$\frac{\text{Number of marked turtles recaptured}}{\text{Total number of turtles captured}} = \frac{\text{Total number of marked turtles released in the general area}}{\text{Total turtle population in the area}}$$

thus,

$$\frac{8}{1000} = \frac{43}{x}.$$

The figure thus obtained is 5600 turtles. Several factors which may actually considerably alter even this very rough calculation should be considered:

1. It is based only on the turtles caught commercially. Fishermen believe that numerous small turtles (10 to 20 pounds) are in the area but are rarely taken commercially owing to the selectivity of the net mesh size. The number of these may be as much as several hundred.

2. Though the numbers of turtles tagged and recaptured is accurately known, it must be remembered that none of the tagged turtles were released on the fishing grounds (see section on Green turtle tagging), and possibly only half of these reached the fishing grounds to enter the

area of possible recapture (see section on Green turtle homing). If this were the case, the total calculated population on the grounds would be 2750 individuals.

3. We are assuming that all tagged turtles retaken were reported to us. With such a small sample, our failure to receive only one or two tags would appreciably alter the calculation. While all tags were probably reported, several turtles with only holes in the shell (see section on tagging) may have slipped by the fishermen and the fish houses unnoticed.

4. The calculation is based on the assumption that the population to be sampled is confined and is not replenished from outside sources or by the growth of individuals from the small non-commercial size to commercial size. It also assumes that the marking and fishing operations were carried out at one time, and does not take into account the fact that if the population was not replenished, the constant removal of numbers of unmarked turtles through the two-month season increased the probability of the later capture of a marked individual.

However, with all its drawbacks, the estimate at least indicates the order of magnitude of the numbers of Green turtles on the grounds. Incidentally, the calculation is based on a tag-return percentage of a size usually considered successful in programs involving other marine animals.

Growth: In most of our returns only the tag was seen by us, the turtle having been butchered or shipped away immediately after capture. In only one case were we able to get measurements of a recaptured individual, and this was one retaken after only 13 days. It showed no change in weight or shell length not attributable to normal error in measuring under field conditions.

However, one of the two turtles mentioned above as having been recaptured with the tag gone but with the wire holes remaining was seen. While it was not individually recognizable from our tagging records, it was significantly bigger than any turtle released by us and thus furnishes basis for an estimate of minimal growth rate. Because Green turtles show some variation and asymmetry in postocular scale number, a count of these scales was included in our standard record of each specimen. If it be assumed that the tagless return was the largest, originally, of its postocular group, then it was an individual released on July 21—102 days before recapture on October 31. The increase over the original length (22¾ inches) was 1 inch; over the original width (17½ inches), ½ inch; and over the original weight (44 pounds), 6 pounds. Gains were thus 0.0098 inch per day in length, 0.0049 inch per day in width, and 0.059 pound per day in weight. As there is little real reason to assume that this was actually the biggest tagged turtle of its group, much greater gains may have occurred. For instance, assuming that the tagless turtle was originally the smallest of its group instead of the largest, we have a period between captures of 94 days for an animal originally 17¼ inches long, 13½ inches wide, and 24 pounds in weight; and an increase of 6½ inches (0.069 inch per day) in length, of 4½ inches (0.048 inch per day) in width, and of 26 pounds (0.28 pound per day) in weight.

The only other information on growth rates of Atlantic Green turtles in the natural state is that of Schmidt (1916) who among nine marked and recovered turtles of from 5 to 44 pounds in weight found weight increases of from 0.3 to 0.95 pound per month (approximately 0.010 to 0.032 pound per day).

## Carapace Measurements

In view of the frequency with which the proportions and shape of the shell have been used in attempts to define species and races of sea turtles, the extreme variability of the ratios in our material, the first adequate sample ever appraised in print, is of particular significance.

Carapace Length-Width Ratio: The small number of measurements to be found in the literature have seemed to indicate the expected strong sexual difference in length-width relationship between wide-shelled females and narrow-shelled males, but taxonomically useful data grouped by sex and developmental stage have not been available. Figure 2 summarizes values for all the sexually immature individuals that we have measured.

Shell Depth: The determining of shell depth, by any accurate method, proved so slow and awkward an operation that we were unable to include this measurement. There is, however, an obvious disparity in the dorsoventral dimensions of Green turtles of the same length, in all size groups, which was not only repeatedly noted by us but was often called to our attention by fishermen. Even in narrowly delimited ontogenetic groups it seems probable that individual variation of this sort will prove greater than the differences between isolated populations.

## Length-Weight Relationship

Despite the above-mentioned marked variation in length-width and length-depth ratios, what appears to be a useful relationship between shell length and body weight is expressed by the equation:

$$\log W = -2.195 + 2.87 \log L$$

where $L$ is carapace length and $W$ is weight.

The sample, 208 specimens, consists of mostly young (12 to 115 pounds) turtles from the Crystal River-Withlacoochee fishing grounds. In the determination of the mathematical expression of the relationship, a single hatchling from Costa Rica and a few adult and subadult specimens from Costa Rica and Nicaragua were included. The actual length-weight data are presented in table 2, while the theoretical weights calculated with the above formula are presented in table 3 for comparison. It might be expected that homogeneity of the length-weight samples would decrease as maturity is approached and as the adult sexual disparity in length-width ratio develops. On the other hand, a subadult male (length 33½ inches,

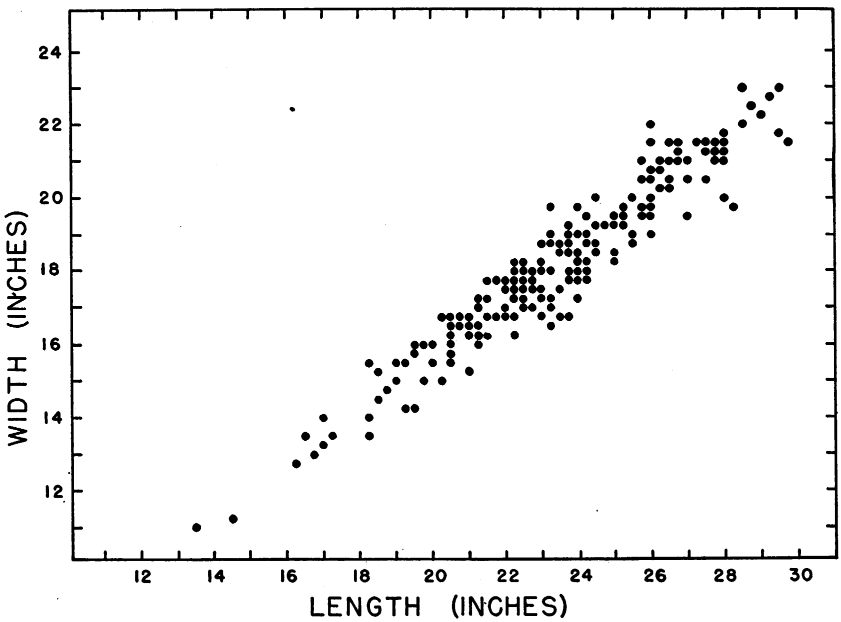


FIG. 2. Empirical length-width relationship of the carapace in Atlantic Green turtles. Each dot represents one or more individuals.

weight 145 pounds) and a subadult female (length 34 inches, weight 142 pounds) from Mosquito Cays showed surprisingly close agreement in length and weight. It may be that normal variation in the length-weight relationship within a sex overshadows intersexual variation and that the length-weight relationship on a mean basis, for a number of individuals, may be a smooth curve.

The 800-pound Green turtles reported from Cedar Key and elsewhere in the late 1800's (see Carr, 1952, p. 347) would, according to this formula, have a carapace length of approximately 60 inches.

TABLE 2

EMPIRICAL VALUES FOR LENGTH-WEIGHT RELATIONSHIP OF THE ATLANTIC GREEN TURTLE

(Unless otherwise noted, the turtles are from the Gulf coast of Florida and the sex is undetermined.)

| Carapace Length (Inches) | Mean Weight (Pounds) | Range of Weights (Pounds) | Number of Specimens |
|---|---|---|---|
| 2 | 0.05 | — | 1[a] |
| 13½ | 12.0 | — | 1 |
| 14½ | 14.0 | — | 1 |
| 16¼ | 15.0 | — | 1 |
| 16½ | 18.0 | — | 1 |
| 16¾ | 23.0 | — | 1 |
| 17 | 20.5 | 20–21 | 2 |
| 17¼ | 24.0 | — | 1 |
| 18¼ | 22.3 | 21–24 | 3 |
| 18½ | 27.5 | 27–28 | 2 |
| 18¾ | 27.0 | 26–28 | 2 |
| 19 | 28.0 | — | 1 |
| 19¼ | 30.0 | — | 2 |
| 19½ | 29.8 | 28–31 | 4 |
| 19¾ | 28.0 | — | 1 |
| 20 | 34.5 | 32–37 | 2 |
| 20¼ | 37.8 | 34–40 | 4 |
| 20½ | 37.2 | 34–45 | 9 |
| 20¾ | 40.5 | 38–43 | 2 |
| 21 | 39.0 | 35–45 | 6 |
| 21¼ | 43.0 | 38–50 | 5 |
| 21½ | 43.3 | 42–45 | 4 |
| 21¾ | 41.3 | 40–43 | 3 |
| 22 | 46.1 | 43–50 | 7 |
| 22¼ | 44.4 | 41–52 | 7 |
| 22½ | 50.3 | 49–55 | 8 |
| 22¾ | 49.5 | 44–55 | 4 |
| 23 | 50.6 | 46–57 | 9 |
| 23¼ | 51.8 | 47–60 | 10 |
| 23½ | 53.8 | 51–59 | 5 |
| 23¾ | 55.9 | 49–61 | 9 |
| 24 | 58.1 | 52–63 | 11 |
| 24¼ | 57.2 | 52–63 | 6 |
| 24½ | 63.6 | 57–70 | 7 |
| 24¾ | 58.0 | — | 1 |
| 25 | 62.3 | 54–68 | 7 |
| 25¼ | 68.3 | 63–76 | 3 |
| 25½ | 64.7 | 61–70 | 3 |

TABLE 2—(*continued*)

| Carapace Length (Inches) | Mean Weight (Pounds) | Range of Weights (Pounds) | Number of Specimens |
|---|---|---|---|
| 25¾ | 72.5 | 68–76 | 4 |
| 26 | 76.0 | 62–91 | 11 |
| 26¼ | 81.3 | 79–83 | 3 |
| 26½ | 75.0 | 66–82 | 5 |
| 26¾ | 82.2 | 71–90 | 5 |
| 27 | 83.7 | 76–97 | 3 |
| 27¼ | 87.0 | — | 1 |
| 27½ | 85.0 | 72–96 | 3 |
| 27¾ | 88.3 | 83–93 | 3 |
| 28 | 90.6 | 76–102 | 5 |
| 28¼ | 84.0 | — | 1 |
| 28½ | 91.5 | 90–93 | 2 |
| 28¾ | 96.0 | — | 1 |
| 29 | 99.0 | 95–103 | 2 |
| 29¼ | 115.0 | — | 1 |
| 29½ | 101.5 | 94–109 | 2 |
| 29¾ | 99.0 | — | 1 |
| 31½ | 135.0 | — | 1[b] |
| 31¾ | 138.0 | — | 1[c] |
| 33½ | 145.0 | — | 1[d] |
| 33¾ | 167.0 | — | 1[c] |
| 34 | 142.0 | — | 1[b] |
| 34¼ | 176.0 | — | 1[c] |
| 35¼ | 157.0 | — | 1[b] |
| 37¼ | 223.0 | — | 1[c] |
| 41 | 304.0 | — | 1[c] |
| 42¼ | 341.0 | — | 1[c] |

[a] Hatchling from Turtle Bogue (Tortuguero), Costa Rica.
[b] Female from Mosquito Cays, Nicaragua.
[c] Female from Turtle Bogue (Tortuguero), Costa Rica.
[d] Male from Mosquito Cays, Nicaragua.

## Postocular Scale Count

In a few places throughout the range of *Chelonia* there seems to be slight geographic correlation in the limited variability in number of scales entering the posterior border of the orbit. The scales range in number from three to five and may be unequal on the two sides. The greatly predominating count for the Atlantic Green turtle in American waters is four on both sides. In spite of the relative stability of the character,

TABLE 3

COMPARISON OF EMPIRICAL AND CALCULATED WEIGHTS OF SELECTED SIZES OF ATLANTIC GREEN TURTLES

| Carapace Length (Inches) | Mean, Empirical Weight (Pounds) | Range, Empirical Weight (Pounds) | Calculated[a] Weight (Pounds) |
|---|---|---|---|
| 2 | 0.05 | — | 0.046 |
| 5 | — | — | 0.65 |
| 10 | — | — | 4.73 |
| 14½ | 14.0 | — | 13.7 |
| 18½ | 27.5 | 27–28 | 27.7 |
| 21 | 39.0 | 35–45 | 39.8 |
| 23¼ | 51.8 | 47–60 | 53.6 |
| 26 | 76.0 | 62–91 | 73.5 |
| 28 | 90.6 | 76–102 | 90.9 |
| 29½ | 101.5 | 94–109 | 105.5 |
| 33½ | 145.0 | — | 151.97 |
| 41 | 304.0 | — | 271.4 |
| 42¼ | 341.0 | — | 296.8 |
| 44 | — | — | 332.5 |

[a] By means of formula given in text.

we made scale counts for all specimens that came to hand, for it seemed possible that if the turtles brought in to Cedar Key are really samples of itinerant migration streams, waves of clumped character-frequencies might occur, as representatives of partly isolated, slightly different populations, originating in different parts of the Caribbean, moved along the coast of the peninsula. Such an occurrence might have been detected statistically as chronological clumping of scale count numbers. It was not. The counts will be continued in seasons to come, however, and with more material and more accurate segregation of arrival-time groups, some slight correlation may well show up. A summary of the results of the postocular tallies, which, if nothing else, should be of use in zoogeographic studies of *Chelonia* of the world, is given in table 4.

## ATLANTIC RIDLEY TURTLE

Florida populations of Ridleys, like those of the Green turtle, comprise only sexually immature (or at least small, sexually inactive) individuals. Also like the Green turtle, the Ridley is of strongly seasonal occurrence in the Gulf coastal waters of the Florida Peninsula, and the period and methods of the fishery are the same for the two. Despite the parallels, however, the life histories of the two must be quite different, and the history of the Ridley, especially, presents unique and stubbornly puzzling aspects. These have been described elsewhere (Carr, 1952, 1955, 1956) and can be summarized as follows:

1. The Atlantic Ridley is not known to breed (mate, lay, form shelled eggs, appear in hatchling stages) anywhere, and is known *not* to nest in many places where the other species of sea turtles all show up, occasionally or abundantly.

TABLE 4

VARIATION IN POSTOCULAR SCALE COUNT IN 205 ATLANTIC GREEN TURTLES FROM THE CRYSTAL RIVER-WITHLACOOCHEE GROUNDS

| Number of Scales: Right side | Number of Scales: Left side | Frequency | | Per Cent of total[a] | |
|---|---|---|---|---|---|
| 4 | 4 | 157 | | 76.6 | |
| 4 | 5 | 15 | 24 | 7.3 | 11.7 |
| 5 | 4 | 9 | | 4.4 | |
| 5 | 5 | 7 | | 3.4 | |
| 3 | 3 | 5 | | 2.4 | |
| 3 | 4 | 6 | 8 | 2.9 | 3.9 |
| 4 | 3 | 2 | | 0.97 | |
| 4 | 3½[b] | 2 | | 0.97 | |
| 3 | 3½ | 1 | | 0.49 | |
| 4 | 4½ | 1 | | 0.49 | |

[a] 93.7 per cent have four on at least one side.

[b] ½ means that the scale was partly split and would have been counted as 4 if completely split.

2. An intensive search of all parts of the Caribbean has failed to produce Ridleys, or any knowledge of the existence of Ridleys anywhere in these waters in which all the other sea turtles occur.

Although the present study involved the examination of some 96 Ridleys, much the largest body of material ever available to a zoologist, we are able to contribute only the following note towards the filling of the most fundamental gap in our understanding of the animal—the mystery surrounding its reproductive habits.

A striking feature of the Ridley problem has been the failure to find ovarian eggs in an advanced stage of development. This is a point of clear-cut contrast with the other species and one recognized as noteworthy by most of the more observant fishermen with whom we have talked. Until recently none of these has claimed to have seen a Ridley with eggs. Since the beginning of the Cedar Key work, reports of two examples of "gravid" Ridleys have come to us.

The first was a rumor, widespread among the fish houses in 1954, that during the summer of 1953 a "Ridley with eggs" had been butchered locally by someone. We were unable to trace the rumor to its source. The second report was more arresting, and there can be little doubt of its authenticity, although here again we were unable to corroborate it by direct observation. On October 27, 1955, we got word that an unprecedentedly large Ridley (93 pounds), caught at Crystal River and butchered at Cedar Key, had been found with yellow (i.e., with yolks but no white) ovarian eggs "the size of marbles" and between 100 and 150 in number. Unfortunately, the shell and eggs had been discarded (dumped in the tidal channel with the fish-house offal), and we were unable to recover them to get accurate measurements.[1] The weight was greater than that of any Ridley seen by us outside captivity, and most of the fishermen said it was the biggest Ridley they had seen. The man who cut up the turtle said that it was excessively fat, abnormally so, and that only 13 pounds of salable meat was obtained from the 93-pound animal, whereas usually a third of the live weight is yielded. A witness to the butchering, a turtle fisherman for over 50 years, commented that the eggs looked like "next year's" and were the most advanced he had ever seen. The largest eggs previously seen by us have been those the size of BB shot, to be found in the small individuals (40 to 50 pounds) brought in during the summer fishing period.

## Tagging Results

Twenty-five Ridleys caught on the Withlacoochee-Crystal River grounds during the summer of 1955 were tagged and released, most of them in batches including tagged Green turtles. Of these, 18 were tagged with the disk tag and seven with the flipper tag. Only two recoveries were made (table 1), and in neither instance were complete data available. A turtle tagged July 29 was retaken at the site of initial capture, after an interval of 43 days. It was butchered immediately after capture, and we were unable to make measurements upon which to base growth calculations. Another recovery, even less satisfactory, involved the taking, by a Cedar Key fisherman, on about November 10, of one of our Ridleys with the tag holes in the hind shell edge but the tag missing. This turtle was also killed and cut up before we heard about it, and we

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[1] By the use of the formula given below, the calculated length for this specimen is 29½ inches.

thus got no measurements from which to calculate growth, even on the minimal-maximal basis as was done for a Green turtle (see section on Green turtle growth). However, the last batch of tagged Ridleys was released on August 11, thus giving a minimum period between tagging and recovery of 91 days for this turtle.

Though these two records alone are of little statistical value, the fact that the two cases parallel so markedly the more trustworthy Green turtle data, and the long interval between release and recapture, perhaps implying resumption of a home range, lend stature to the observations and at least suggest that homing occurred, or suggest that more than they suggest anything else.

Population Size: By the use of the very scant data at hand, on the same basis and with the same drawbacks as for the Green turtle above (plus the factor of even poorer returns), an order of magnitude estimate for the size of the Ridley population on the fishing grounds is 3750, with 300 as an estimate of the total catch.

## Shell Measurements

Although the volume of our morphometric data seems reassuring, its value may be questioned on the basis of our failure to segregate sexes and ontogenetic groups. As our sample comprised only individuals with undeveloped secondary sex characters, the distinguishing of the sexes would have required a dissection of the animal, which was not possible in the cases of most of the Ridleys measured. Thus, we not only have not separated the sexes in our data, but are not able to say with certainty which, if any, of the specimens were of breeding age. However, these uncertainties seem no grounds for withholding the data; and in fact, the most probable interpretation seems to be that the sample is wholly composed of juvenile, and thus comparable, individuals.

Length-Width Relationship: The considerable variation in this ratio can be seen in figure 3. The Ridley is the only marine turtle in which the shell is so nearly circular in outline and in which the width may sometimes actually exceed the length.

## Length-Weight Relationship

This relationship may be expressed by the formula:

$$\log W = -1.69 + 2.49 \log L$$

where $L$ is carapace length and $W$ is weight. The actual range of weight versus length is shown in figure 4, while various weights calculated by this formula are presented in table 5. The great variation in the length-width proportion makes for correspondingly wide ranges in the length-weight ratios, because the Ridleys that are as wide as, or even wider than, long are heavier than those of more usual widths for the length class.

## LATERAL LAMINA COUNTS

Because the number of lateral laminae of the carapace seems to be of considerable taxonomic importance in *Lepidochelys*, and a character that

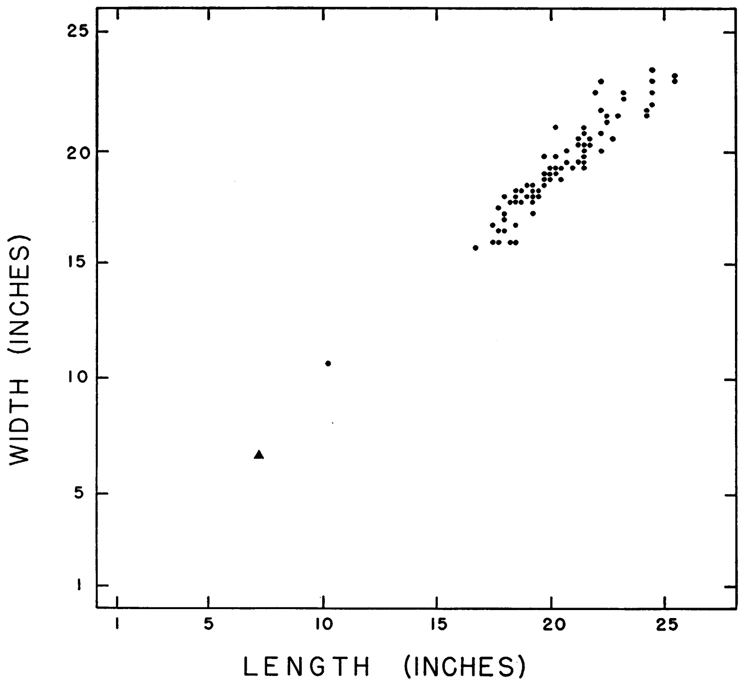


FIG. 3. Empirical length-width relationship of the carapace of Atlantic Ridley turtles from Gulf Coast of Florida. Each circle represents one or more individuals. A single individual cited by Carr (1952, p. 401) from an unnamed locality is included and is represented by the triangle.

may help clear up some of the peculiar zoogeographic problems presented by the genus, bilateral laminal counts were made for all specimens examined. The resulting data, representing 96 specimens from a circumscribed locality, furnish a hitherto unavailable basis for comparison and statistical evaluation of samples taken elsewhere. The Crystal River-Withlacoochee population seems remarkably stable with respect to this feature. Out of the entire lot no specimen was found with other than the

5–5 count for the two sides except for one with 6–5. In this individual the extra scale was on the left side.

## ACKNOWLEDGMENTS

The present study has leaned heavily on the facilities of the University of Florida's Seahorse Key Marine Laboratory, placed at our disposal by the director, Dr. E. Lowe Pierce. Mr. Charles Crevasse, Sr., has furnished enthusiastic cooperation in many ways, both as a member of the

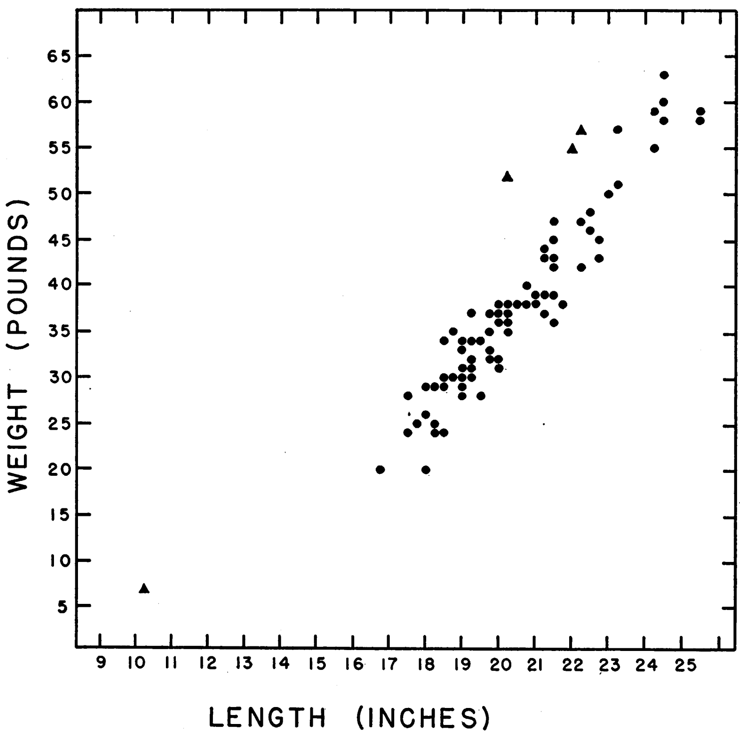


FIG. 4. Empirical length-weight ratio of Atlantic Ridley turtles from Gulf Coast of Florida. Each circle represents one or more individuals, and the specimens that are wider than long are shown as triangles.

staff of the Laboratory and since leaving that post. His brother Mr. John H. Crevasse brought in returned tags and contributed much from his knowledge as the most experienced turtle fisherman in the area. Other sources of tag returns, information, and constructive advice were Mr. H. J. Brown, Mr. R. B. Davis, Jr., Mr. and Mrs. R. B. Davis, Sr., and Mr. John Gibson.

The people around the Davis Seafood and Cedar Key Fish and Oyster Co. platforms, with cheerful patience, put up with our repeated intru-

TABLE 5

COMPARISON OF EMPIRICAL AND CALCULATED WEIGHTS OF SELECTED SIZES OF ATLANTIC RIDLEY TURTLES

| Carapace Length (Inches) | Mean, Empirical Weight (Pounds) | Range, Empirical Weight (Pounds) | Calculated[a] Weight (Pounds) |
|---|---|---|---|
| 10¼ | 7.0[b] | — | 2.596 |
| 16¾ | 20.0 | — | 22.8 |
| 18½ | 29.2 | 24–34 | 29.2 |
| 20 | 35.3 | 31–38 | 35.4 |
| 21½ | 41.6 | 36–47 | 42.4 |
| 22¾ | 44.0 | 43–45 | 48.8 |
| 23¼ | 54.0 | 51–57 | 51.6 |
| 24½ | 59.8 | 58–63 | 58.8 |
| 25½ | 58.5 | 58–59 | 64.9 |

[a] By means of formula given in text.

[b] This individual, the only one of its size seen, was one in which the shell was wider than long. Thus, this weight would normally be expected to be associated with a greater shell length, and a smaller weight might normally be expected for this 10¼-inch shell length.

sions and with our machinations with the turtles in their charge.

To Mr. W. A. Campbell of Bronson we are indebted for cypress poles donated for a turtle crawl. The County Commission, Levy County, generously made a special ruling to allow the convenient placing of the pen beside a road bridge at Cedar Key.

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