Translocating turtles: trials, tribulations and triumphs

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ABSTRACT

This paper reviews attempts to translocate sea turtle eggs or hatchlings from their normal natal beaches to currently unoccupied potential nesting beaches, in the hope of establishing colonies in those places. Among topics considered are sex ratio, imprinting, headstarting, and the use of living tags.

The trouble is nobody knows how a new resident colony is formed.

Carr (1984).

One of the most urgent limitations which have frustrated students of sea turtle ecology... has been the inability to affix a permanent mark on the animals... The problem has been one of finding a tag which will serve on a growing (from 20 or 30g to 100 kg), developing animal.

Hendrickson and Hendrickson (1986).

INTRODUCTION

A workshop held in December 2002 in Fuerteventura, Spain, considered the possibility of introducing or reintroducing nesting sea turtles to beaches on the Canary Islands by moving eggs or hatchlings from currently used beaches in the Cape Verde Islands. I am in favour of experimentation if carefully carried out and designed in a way permitting evaluation. We need more information on when and why turtles return to their natal beaches, and on what factors influence the strength of philopatry. Testing whether turtles can be induced to nest on beaches other than their natal ones might provide guidance in advance of global warming and sea level rise.

In this context, there follow brief accounts of some past attempts at reintroduction and translocation of turtles. We can learn from these endeavors. “Today is yesterday’s pupil” (Thomas Fuller).

Transplanting green turtle eggs

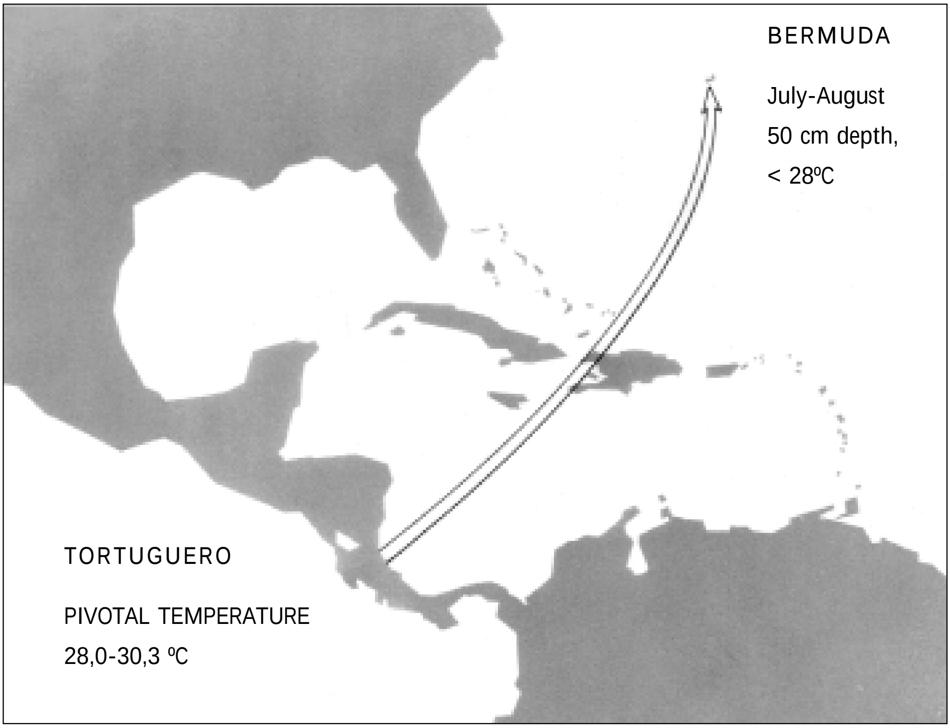

Figure 1. Illustration of the need to consider thermal effects on sex ratio when transplanting eggs.

BERMUDA

Between 1967 and 1977, more than 24,000 green turtles eggs were taken from Tortuguero, Costa Rica, and placed in hatcheries in Bermuda. The eggs were buried at about the same depth as green turtle clutches in nature. The great majority of the resulting hatchlings were released; a small percent were kept for headstarting (BURNETT-HERKES, 1974). The hope was that exposure to Bermudan sand during a sensitive early stage of development would create a lasting preference for stimuli (presumably chemical but possibly magnetic) characteristic of that location, ie that they would become imprinted to those stimuli, causing them to return to their natal area when it came to laying. To the best of my knowledge, these actions have not resulted in restoration of nesting turtles on Bermuda. If that had occurred, the event would surely have been reported and heralded as important.

Quite apart from whether imprinting to Bermudan sand was effective or not, there is a good reason for the failure to establish nesting females on beaches there: probably all or nearly all the turtles hatched on Bermuda were males. It is estimated from field studies of Tortuguero green turtles that their pivotal temperature, the constant temperature producing 50% of each sex (MROSOVSKY AND PIEAU, 1991), lies between 28.0 and 30.3ºC (STANDORA AND SPOTILA, 1985). From what readings were taken in Bermuda, it would seem that the sand temperature at 50 cm depth in the hatcheries there did not exceed 28ºC, and was therefore on the male side of the pivotal temperature.

The basis for the information given above on translocations to Bermuda comes from personal communications in 1982 from D.B.Wingate to the present author. Temperature was not measured over many seasons. Moreover, perhaps some of the eggs ended up shallower than 50 cm (top of clutches); greater daily cycles of temperature at shallower depths could have had some feminizing influence (GEORGES ET AL., 1994). Therefore, it is not asserted that no female turtles were produced. Nor is it asserted that warmer places in Bermuda could not be found. However, from what information I have been able to glean, it seems likely, even though most of the eggs were buried in August, among the warmest months of the year in Bermuda, that the sand temperatures would have generally been in the male producing range. Mean incubation times in excess of 70 days for most of the years are consistent with this, because incubation takes longer when it is cool (cf Figure 12 in MROSOVSKY ET AL., 1984; Figure 7 in STANDORA AND SPOTILA, 1985).

In addition, in 1981, 3048 green turtle eggs from Suriname were taken to Bermuda and buried there on 12 June at which time the sand was 21ºC; even in early August it was still only 25ºC (ANON, 1982). Low temperatures probably contributed to the poor hatch rate (11.4%). Almost certainly all the turtles that did hatch were males.

LESSONS

(1) The first lesson that can be learned from the Bermuda project is that sex ratio needs to be taken into account in transplantation attempts (Figure 1). Although the influence of temperature on sex ratio was documented in freshwater turtles by PIEAU (1971) soon after the start of the Bermudan project, the phenomenon

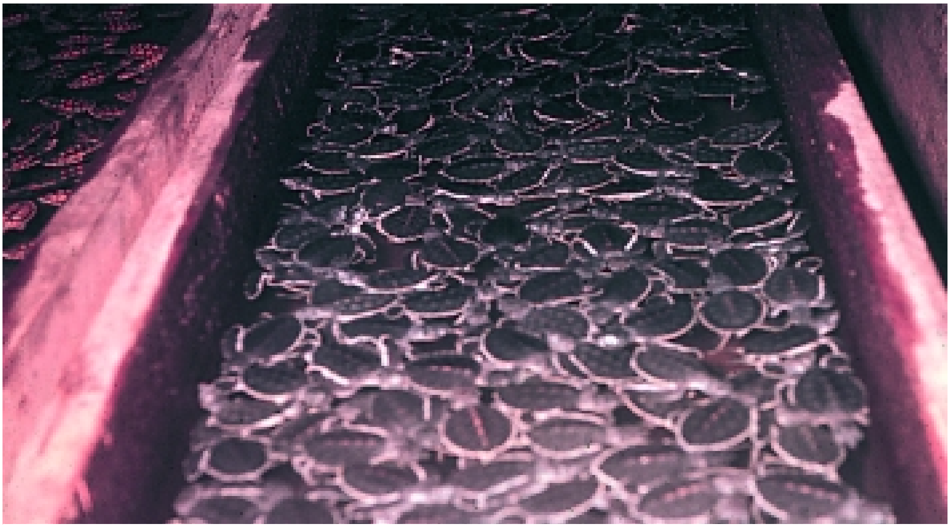

Figure 2. Hatchling green turtles, Tortuguero, Costa Rica, 1965, awaiting translocation to elsewhere in the Caribbean as part of Operation Green Turtle. The exact ages of different batches of turtles, and the stimuli they experienced, have not been published.

was not widely known in the sea turtle community at that time, and was not demonstrated in sea turtles until 1979 (YNTEMA AND MROSOVSKY, 1979).

(2) The second lesson is that failure to publish and disseminate the results of what few investigations of temperature were done makes it hard to assess the negative result. Information on conditions before and during transport are also lacking, as are accounts of what patrolling of the Bermudan beaches was undertaken. The absence of details in the public domain becomes an even more salient deficiency when considering Operation Green Turtle from which the transplantations to Bermuda were an outgrowth.

OPERATION GREEN TURTLE

Green turtle hatchlings were taken from Tortuguero, Costa Rica, and released at a number of beaches in the Caribbean where turtles were thought to be currently absent (for a popular account, see CARR, 1984).

A critique of this experiment has been given elsewhere (MROSOVSKY, 1983). Details of the apparent inconsistencies and gaps will not be repeated here. If the imprinting hypothesis is to be taken seriously, then information on what stimuli the turtles were exposed to, and at what ages, should be provided (Figure 2). The general point about Operation Green Turtle is that "its failure as science is not that the results are negative but something quite different: the lack of adequately reported details of what actually was done. It is like a scientific paper with no methods section" (MROSOVSKY, 1983). Had turtles appeared on some of these beaches since, even that would have been hard to assess without provision of evidence that none were nesting there previously. As the saying goes, absence of evidence is not evidence of absence.

An abstract on Operation Green Turtle has appeared since (ELIAZAR ET AL., 1998). The number of hatchlings released is given at over 130,000, distributed to 17 different countries. Despite no known nesting resulting from this effort, it was considered a success in that it raised awareness about sea turtles.

LESSONS

(1) The main lesson to be learned from Operation Green Turtle is that little can be learned from it because of inadequate documentation. This is an extremely important point, especially for any long-term project. If this lesson is learned, perhaps Operation Green Turtle can be considered a success on that basis, as well as being a "venture in public relations" (CARR, 1984).

PADRE ISLAND AND KEMP'S RIDLEY

Eggs of Kemp's ridleys (Figure 3) have been taken from what was then the only known major nesting beach for the species, that at Rancho Nuevo, in Tamaulipas, Mexico, and sent to Padre Island, Texas, USA. The transport of these eggs to Padre Island took place at various stages of development. In an attempt to maximize the possible chances of imprinting to Padre Island stimuli, no contact with Mexican sand was permitted: the eggs were incubated in sand from Padre Island only.

After hatching, the turtles were released on Padre Island, allowed to crawl into the surf, and then retrieved (a few escaped). Most were taken to Galveston, Texas, for head-starting, that is rearing them in captivity and then releasing them at a size greater than

Figure 3. Kemp's ridley nesting at Rancho Nuevo, Mexico, in 1985, the year when numbers there reached their lowest level. No other turtles were nesting within sight of this one.

that of hatchlings. Thus the project had two main components, imprinting and headstarting; these two were combined for most of the turtles. A detailed account of the work on Kemp's Ridley at Padre Island appears in Shaver (this volume). However, as there is more information about this turtle translocation than any other, its findings merit commentary and scrutiny by those considering attempts to establish new nesting colonies.

Headstarting: Kemp's ridleys released as yearlings have returned to nest. This establishes that headstarting does not necessarily prevent turtles from surviving and reproducing. Whether headstarting is superior to other conservation measures, and whether it is the most cost effective, are much harder matters to assess.

The pendulum has swung back and forth about the merits of headstarting. Originally it was considered by many as a recommended and needed measure. From that early enthusiasm opinion generally has become negative, an extreme form of which is exemplified in the statement:

"Headstarting should not be utilized in any circumstance as a means of conserving sea turtles. Headstarted turtles are in no better position than their "natural" counterparts. They are not capable of escaping predators. They become accustomed to humans which can be fatal when in the wild. Even more it is not confirmed that they eventually return to their natal beach and succeed to reproduce" Anon (1996).

Ironically, this appeared in the year when the first return of a headstarted turtle to nest was reported — from the Kemp's ridley programme (Shaver, 1996). But the author of the words quoted above is in good company. Headstarting receives hardly any mention in an IUCN/SSC manual of techniques for conservation of turtles (Eckert et al., 1999).

The demonstration that headstarted turtles can reproduce should perhaps swing opinion back somewhere toward the middle ground of reserving judgement. After all, there is an attractive rationale for headstarting. As Carr (1984) put it:

"Theoretically, it ought to be possible to reduce natural predation on young sea turtles by artificially incubating eggs and rearing the hatchlings to a size too big for the enemies to eat. This seems a promising thing to try, but it will take a great deal of experimentation to show whether it really accomplishes the purpose".

My own doubts about headstarting have concerned not so much the amount of work that might be required but the difficulty in evaluating the attempts made so far (Mrosovsky, 1983; see also Buitrago, 1981; Pritchard, 1981). Definition of the aims at the start of projects has been inadequate; precise formulation of criteria for success has been delayed in coming (Wibbels et al., 1989a; Eckert et al., 1992).

Imprinting: turtles exposed as embryos to Padre Island sand have returned to nest there. We must distinguish between the imprinting manipulations made (exposure to sand at early stages of life history, etc.) and the assumptions about their effects (that there is a biological process whereby such manipulations result in a tendency to return to beach with that sand). The return of a turtle that was subjected to imprinting manipulations does not prove that imprinting as a biological process was responsible.

Some problems with imprinting as an explanation for the results from Padre Island project are:

(1) Two turtles that had nested at or near Rancho Nuevo were also seen either subsequently or previously on the beach at Padre Island (Shaver and Caillouet, 1998). These turtles were not linked to the imprinting or headstarting procedures, although this cannot be ruled out if the possibility of tag loss is kept in mind. In any case, these 2 cases show that choice of nest site is not ineluctably determined by experiences at an early stage of development.

(2) In 2002, among the nesters on Padre Island, there were 2 headstarted turtles that had not been exposed to Padre Island sand but to Mexican sand (Shaver, this volume). A third turtle exposed to Mexican sand nested at Galveston, Texas. If imprinting as a biological process had occurred, these turtles should have nested in Mexico.

(3) Nesting Kemp's ridleys have recently been seen along the coast of Florida (review in Johnson et al., 1999; there may be some more recent instances). Nests have also be laid in North and in South Carolina (Palmatier, 1993). The Atlantic coast of the USA is outside the known historical nesting range of this species. Johnson et al. (1999) propose that we may be witnessing the initial stages of the formation of a new colony of this species in Florida. They argue that with daylight nesting, Kemp's ridleys emerging on these beaches in the past would not have been totally missed. The nesting at Padre Island might, however, in part reflect increased monitoring. The number of ridleys seen on Padre Island shows some positive relationship with the amount of patrolling (Shaver, this volume).

Even if sampling artefacts at Padre Island are discounted, that does not mean that imprinting must have been responsible. An alternative explanation to imprinting for the nesting at Padre Island is that it results from a general increase in the number of Kemp's ridleys and an associated expansion of nesting range (JOHNSON ET AL., 1999; MROSOVSKY, 2000).

Against this explanation must be set the point that out of 47 turtles that were actually seen on Texan beaches, 40.4% had tags linking them to the Padre Island imprinting; 6.4% had experienced Mexican sand as embryos and hatchlings (SHAVER, this volume). This suggests that there is something more than expansion of range at work. However, it is also conceivable that the high percentage of project turtles among the Padre Island nesters comes about through a quasi random wandering. Turtles released at or near Padre Island might disperse somewhat on entering the sea. Some might get as far as Florida, but if movements were not directed in any particular direction in the Gulf of Mexico or Atlantic, more might find themselves still in the general vicinity of Padre Island when they became mature enough for breeding. This suggestion is not negated by a more widely dispersed pattern of tag returns because whether a turtle is caught and a tag noticed and returned is not an unbiased way of determining distribution. So it remains possible that when ready to lay, the turtles from this project might have tended to nest on the nearest available shore, that is the higher percentage of headstarted turtles out of those at Padre Island may reflect a breakdown in orientation more than imprinting. That would still be satisfactory for those who are concerned only that there be more Kemp's ridleys on Padre Island. For those who want to understand the underlying mechanisms, with a view to applications in other areas, it is unsatisfactory.

Unfortunately it is not easy to test for the existence of imprinting of this kind in turtles, and actual data on the topic are few. An experiment by GRASSMAN ET AL. (1984) is sometimes cited as supportive. They took 9- to 12-month-old Kemp's ridleys from the Galveston headstarting operation and presented them with a choice of 4 compartments, one containing a solution of Padre Island sand and seawater, one with a Galveston sand solution, and two with untreated seawater. Time spent in the compartments per entry, total time spent in the compartments, and number of entries were measured. Only on the first of these was there a significant preference for the Padre Island sand solution. Even if one discounts the data from the other 2 measures, the design of the experiment does not leave imprinting as the only possible explanation. There might simply have been a preference for a particular type of water. Imprinting manipulations should have been made with different sand types to ascertain if the behaviour reflected the animals'

Figure 4. Moving eggs from high risk places on the beach in Suriname in the 1970s and 1980s. The eggs are lightly rinsed, and placed in styrofoam boxes.

early experience or a preference by all groups for a solution with particular olfactory and chemical characteristics. Also, it is questionable whether behaviour of juveniles in a tank resembles homing of reproductive adults to natal beaches in the wild.

Altogether, although there is talk of imprinting, the actual evidence for this process is thin. Even if imprinting exists, nothing is known about what stimuli are essential, when the critical periods are, and whether it is totally irreversible. It is, of course, possible that various factors are at work. The results might stem from a combination of expansion of range, random wandering and some imprinting.

Sex ratio: initially, eggs for imprinting and headstarting experienced masculinizing temperatures. Without additional measures, eggs incubated in styrofoam boxes above ground (Figs 4 and 5) tend to be cooler with longer incubation times than those in the sand. So the use of styrofoam boxes might well increase production of male hatchlings. The sea turtle community was warned about this possibility in 1978 (Mrosovsky, 1978) and again verbally at a conference in 1979 (Mrosovsky and Yntema, 1981) and in writing in 1979 (Yntema and Mrosovsky, 1979). Attention was specifically drawn to the longer incubation times of Kemp's ridley eggs (Marquez, 1978; Mrosovsky, 1978; Mrosovsky and Yntema, 1981). That the method of incubating eggs in styrofoam boxes has masculinizing effects on sex ratio was subsequently demonstrated (Morreale et al., 1982; Mrosovsky, 1982; Dutton et al., 1985). That the eggs taken to Padre Island had been similarly affected is supported by the study of tissues from animals that died: in the first 7 years of the translocation project (up to 1985, discounting 1981 for which only 4 specimens were sexed) there were male biased sex ratios (Shaver et al., 1988; Wibbels et al., 1989b, Caillouet, 1995). From 1985-1992, steps were taken to reduce and probably eliminate the male bias (Caillouet, 1995). These modifications appeared effective in that 77.5% of the samples examined for the 1985-1988 year classes were

Figure 5. Simple above ground hatchery in Suriname for protecting styrofoam boxes containing eggs.

females. Considering the 1978-1988 year classes as a whole, it was estimated that 59.6% were females (SHAVER, in press).

In fact, the authorities in the USA and Mexico reacted rapidly when the possibility of sex ratio biases arose. Tissue was sent to Yntema and Mrosovsky in 1979. Unfortunately, adequate comparison groups from hatchlings from styrofoam boxes and nests in the sand, matched for time in a thermally changing nesting season, were not constituted. Compounded with small sample sizes and some tissue being too far deteriorated to enable reliable histological diagnosis of sex, definitive results were not obtained.

In my opinion it would have been preferable to take one or two hundred eggs and estimate the pivotal temperature and range of temperatures over which both sexes are produced in a controlled laboratory experiment. If this had been done in the late 1970s when this matter first came up, it would have sped up recognition that the Padre Island hatchery was producing male biased sex ratios. However, Yntema and Mrosovsky were allowed tissue only from turtles that had died. In contrast, transport to Padre Island, application of living tags, and headstarting, all of which entailed some mortality, were permitted. Such is the ambivalence of attitudes toward experiments involving endangered species.

Notwithstanding all deficiencies, difficulties, and irrationalities, much has been learned in this project about Kemp's ridley. This includes knowledge about rearing in captivity, disease, movements, growth, and years to maturity. An extensive list of papers and reports from the Galveston laboratory has been compiled by CAILLOUET (1997) and there have been some more since then. Here I concentrate on points that might inform future attempts to establish turtle colonies.

LESSONS

(1) Premonitoring. To assess the success of a translocation, one needs to know about nesting on the host beach before the experiment starts, or failing that, in the years from its inception up to the earliest possible date for maturation of the introduced turtles. This can be called premonitoring.

(2) Control group. The return of a single or a number of headstarted turtles is insufficient in itself to show that this method is better than other measures in boosting the population, or in causing it to expand its range to new areas. I cannot agree with statements such as: "When a nesting Kemp's ridley can be identified as a head-started animal, the overall project will be considered a complete success (MANZELLA ET AL., 1988)". The same authors also say: "The purpose of the program is to increase the wild population of Kemp's ridleys...." What if the nesting of the headstarted turtle was achieved at the cost of a decrease in the population? Clearly, complete success cannot be established by the occurrence of a single nesting. What would be helpful is a comparison with some control group that was not headstarted. For example, a large group of non-headstarted turtles, released into the water at Padre Island, would have been one approach. Turtles in both groups would have had to have undergone the same tagging procedure, and have the same initial sex ratio.

(3) Experimental design. In this project, most of the turtles experienced imprinting, headstarting, and incubation temperatures potentially distorting natural sex ratios, at least in particular years. Had these turtles done better (or worse), in terms of contributing offspring to the next generation, than a comparably sized group from eggs remaining at Rancho Nuevo, it would have been difficult or

impossible to disentangle the cause of the difference. It should however be recalled that in the 1970s the numbers of Kemp's ridleys were still falling, reaching a record low of 740 nests in 1985 (MARQUEZ ET AL., 1999; a figure of 702 is given by the TURTLE EXPERT WORKING GROUP, 1998). Sometimes conservation imperatives lead to a number of different measures being tried simultaneously, thus sacrificing understanding in a welter of confounded variables in the hope that one of them will work.

(4) Marking. Tagging is key in assessing translocations. What type of tag or tags should be used? With Kemp's ridleys, for demonstration of nesting turtles originating from the Padre Island and Galveston projects, the living tag method is the one that has given the most data (SHAVER, this volume). In this method, a sliver of pale tissue is taken from the plastron and transplanted to a particular scute on the darker carapace; this can be done in under 2 minutes (HENDRICKSON AND HENDRICKSON, 1981b). As this is an autograft, there is no immune response (HENDRICKSON AND HENDRICKSON, 1981a; for photographs see WOOD AND WOOD, 1993; MROSOVSKY, 1982; BELL AND PARSONS, 2002; Figure 6).

Figure 6. Living tag of pale tissue taken from the plastron and transplanted to the carapace of a juvenile green turtle at the Cayman Turtle Farm. The photograph was taken 2 years after the transplant. There is some overgrowth of the transplant, but the paler tissue is still clearly visible (from Mrosovsky, 1982).

(5) Covert aims. It appears that for some of those involved, the translocations to the USA may have been valued primarily as a device for shunting funds to protection on the beach at Rancho Nuevo (TAUBES, 1992; see also MROSOVSKY, 1983). That is arguably more important for the survival of this species. In their review of the Kemp's ridley headstart program, WIBBELS ET AL. (1989a) emphasized that the primary element was the protection of the turtles in their natural habitat. Earlier on, KLIMA AND MCVEY (1981) listed 3 components: enhanced survival at Rancho Nuevo, establishing a second breeding population at Padre Island, and an experimental study to evaluate headstarting. The latter was identified as a "major component of the overall recovery plan."

If there was some covert disagreement about the primary aim, it may have distracted attention from the imprinting and headstarting projects in Texas. If — which is hard to believe — those costly and high profile endeavors were truly the only way to get support for the enhanced efforts on the beaches in Mexico, then perhaps they could be justified on that basis alone. As a general rule for the future, explicit statements of all the aims of a project and their rankings would seem the most desirable and least divisive.

CAYMAN TURTLE FARM RELEASES OF GREEN TURTLES

Sea turtles, especially green turtles, used to nest in huge numbers on the Cayman Islands. These populations have been virtually though not totally wiped out (AIKEN ET AL., 2001). Possibly thriving nesting colonies could be re-established in the Cayman Islands.

Between 1980 and 1991, 26,995 green turtles were released from the Cayman Turtle Farm; 39% of these were yearlings and 61% hatchlings (WOOD AND WOOD, 1993). In the 20-year period of 1980-2000, more than 29,000 turtles were released around the Cayman Islands (UK, 2002). In addition, some animals have escaped back to the sea; major losses, including 88% of the adult breeding herd, occurred in 2001 during Hurricane Michelle (UK, 2002).

Green turtles are now found in areas such as North Sound, Grand Cayman, where many of releases were made (WOOD AND WOOD, 1993). They are growing and appear healthy other than those with fibropapillomas which afflict wild turtles also. Although deliberate premonitoring of these areas was not done, the presence of tagged turtles shows that some of the animals there are from the Cayman Farm. Anecdotal reports indicate that following releases more turtles were seen in North Sound (Wood, 1982). As Wood and Wood said in 1993, “there is no reason to believe that once the animals reach sexual maturity they will not become reproductively successful as well.”

Recent events have borne this out, with the bonus that nesting turtles from these releases have been found on the Cayman Islands themselves. In 2002, 3 females, of which 2 were actually nesting, were seen on Seven Mile Beach, Grand Cayman. In addition, 1 male was captured offshore while mating. All of these 4 animals were identified from their living tags (Bell and Parsons, 2002).

These are small numbers but it should be mentioned that the discovery of these animals was probably more the result of chance than of any systematic monitoring which has been lacking (Parsons, pers comm). More beach patrols might well reveal higher numbers nesting on the Cayman Islands. But that would not mean that some of the turtles from these releases will not nest elsewhere. The tag returns for the released turtles did not all come from Cayman Island waters. Some 42% came from other countries, especially from Cuba (Wood and Wood, 1993), perhaps reflecting the amount of fishing there. When it comes to reproduction, released turtles might nest in a variety of places. If they do, the ratio of numbers nesting on the Cayman Islands to nesting elsewhere will be of great interest.

A point of potential relevance here is the diverse origins of the turtles released by the Cayman farm. The stock at the farm is indeed heterogeneous. It comprises turtles and their offspring from Suriname, Costa Rica, Mexico, Ascension Island, and a few from Guyana and Nicaragua. Fosdick and Fosdick (1994) describe collections from some of these places. The turtles that have been released had various origins and environmental experiences during development. Details of these are not always known, or if recorded somewhere, not readily available. From a scientific point of view, this diminishes the value of information obtained when tagged turtles are recaptured. Perhaps most of the recaptured turtles have a particular genetic background, or sex, or early history. Perhaps further details will be forthcoming.

This is not the place to go into the vicissitudes suffered by the Cayman Farm (see Fosdick and Fosdick, 1994). Suffice it to say here that their main biological aim has been to breed and raise turtles in captivity, and in this they have succeeded. The releases are secondary for them, and are “part of a continuing study to assess turtle survival and the establishment of a resident turtle population" (Wood and Wood, 1993). In some cases releases also served to get rid of excess stock in times of financial pressure.

Of course, biologists will wish there was more information available and that experiments had been more extensive and controlled. Nevertheless, as it is, there are a number of points arising that may be useful in designing future attempts to establish or re-establish colonies.

LESSONS

(1) Headstarted green turtles can survive to reproduce; this extends the previous demonstrations with Kemp's ridleys. If this applies to two species of marine turtle, it probably applies to all.

(2) Living tags have provided important data. This is not to say this type of tag is problem free. Eckert et al. (1992) wrote:

"We are not comfortable with relying on living tags as a means to detect headstarted turtles. Living tags are too easily misinterpreted, and there has not been adequate research to determine the retention and detection rate of those tags after release".

Since then, some limited information has become available on retention of living tags. A useful feature of the Cayman Farm releases was that a number of turtles were double tagged. In particular, 243 turtles, originally given external titanium tags before release as yearlings, were later recaptured. Of these 243, 40 "were noted" as having had a living tag visible at release. At recapture, however, only 26 of these 40 "were noted" as having a living tag (Wood and Wood, 1993). It is not clear if the cautious wording implies there is some observer bias or difficulty in detecting a living tag. The average time between release and recapture of a larger number of turtles, including these 40 given living tags, was 795 days, with 50.2% having 3 or more years between release and recapture. It is assumed here that in the subset of 40 turtles there was a comparable percent with long intervals between release and recapture, though this is not specifically stated by Wood and Wood (1993).

At face value, these data indicate that there is tag loss with living tags, as with external tags. Nevertheless, the 65% retention is not bad for early use of a tech-

Figure 7. Nesting beach at the Cayman Turtle Farm, 1982. Clutches laid here were moved into an indoor hatchery. Eggs were exposed to sand from the Cayman Islands only.

nique that could doubtless be improved with further work. So further research and data are indeed needed.

But the criticism about research not being adequate applies also to internal wire tags, and Passive Integrated Transponder (PIT) tags even. The fact is that in both the Kemp's ridley project and in the Cayman Island releases, the living tag was the one that came through best. Moreover, there are already other ways that yearlings can be tagged. With hatchlings, options are much more limited. What would be really valuable is some idea of retention/detection rates for living tags applied to hatchlings. The recent returns of living tags show retention from the hatchling stage to maturity is possible (Bell and Parsons, 2002), but do not tell one if it is probable. Studies of captive turtles, tagged with transplants as hatchlings and kept for a year or two, could provide a survival curve for such tags.

(3) None of the turtles released were from a population nesting on the Cayman Islands (other than on the beach at the Cayman Farm, Figure 7). This makes the nesting on the Cayman Islands of turtles released in its waters encouraging for

further translocations. Whether these turtles had imprinted to Cayman Island stimuli while in the Farm, or whether they were simply nesting near to release sites, it has been shown that turtles whose ancestors nested elsewhere have now nested on the Cayman Islands.

This suggests another option for having turtles nest in the Canary Islands: borrow breeders from elsewhere, allow them to lay in captivity, direct into local sand on an artificial beach, and release offspring at some later time. The expense of this method would be partly compensated for by avoiding the costs and logistics of taking Canary Islands sand to the Cape Verde Islands, and then bringing the eggs back again. There is also the potential for revenue from tourists, judged by the success of the Cayman Farm. And there are also scientific grounds for at least considering this option. After all, even assuming that some kind of attachment to cues in the natal area is responsible for fidelity to that area when it comes to breeding, at what stage that attachment occurs remains a speculation. Experiences after the hatchlings enter the surf might be contributory or even essential. Experience in seawater with particular characteristics might override the influence of cues that impinged on the embryos in the sand. Whatever the case, the initial data from the Cayman Islands (Bell and Parsons, 2002) are worth pondering.

OTHER TRANSLOCATIONS

In 1976, 100 green turtle and 10 olive ridley hatchlings were taken from Bigisanti, Suriname, and, after a 10-day stopover in Curaçao, released at Spaans Lagoon, Aruba (Rooze and Kristensen, 1977). A small artificial beach had been constructed for the occasion, the aim of which was not primarily to augment turtle populations but to attract attention and publicity for turtle conservation. The release took place by day, and in the heat most of the turtles were unable to reach the water without help.

As part of an experiment on sea-finding orientation, in 1957-1958, 22 green turtle hatchlings were taken from Tortuguero on the Atlantic coast of Costa Rica and released on its Pacific coast (Carr and Ogren, 1960).

There have probably been been other small-scale translocations that have escaped publicity. The low survival rate of hatchlings and juveniles, and slim chances of recognizing these turtles without tags, make it unlikely that much will be learned from releases comprising few animals. The best that can be hoped is that they do no harm.

SELF-TRANSLOCATIONS: WEAK NEST-SITE FIDELITY

There are several reports of individual female turtles having nested on widely separated beaches. These instances indicate that nest-site fidelity is not the absolute rule. How else would turtles come to nest on newly formed volcanic islands? In the Guianas, beaches are destroyed in one place and built up in another over the course of a few years; in such dynamic areas, turtles move from one beach to another (SCHULZ, 1975). Translocating turtles might then be only hastening a process of colonization of unoccupied areas that could have eventually occurred naturally.

Data on mitochondrial (mt) DNA tend to be overinterpreted. When it is said that populations using different nesting beaches are genetically distinct, this does not mean there is no gene transfer, but that it is limited. It means that there are statistically significant differences in haplotype frequency between the samples from different nesting beaches. Nevertheless, even though on average the various haplotype frequencies differ among geographical areas, often some of the individuals in the samples from the different beaches still have the same haplotypes.

Moreover, most of the work on molecular genetics has been based on mtDNA rather than nuclear (n) DNA. However, for green turtles, it has been found that differentiation between populations is less when nDNA rather than mtDNA is studied. This greater gene flow may be mediated by movements of the males (KARL ET AL., 1992).

Populations of turtles nesting on beaches even separated by some distance, and each having different haplotype frequencies of mtDNA, need not necessarily be thought of as neatly isolated genetic packets. In any case, regardless of interpretation of studies of mtDNA, there is some support for movements between different nest sites from tagging data. The list that follows is probably not inclusive.

A loggerhead has been documented nesting on both the west and on the east coast of Florida (LEBUFF, 1974); the sites were separated by about 600 kms. Another loggerhead nested both in North Carolina and in Florida at sites separated by 725 km (STONEBURNER AND EHRHART, 1981).

In the Indian Ocean, a green turtle tagged while nesting on Tromelin was seen almost 9 years later on Europa Island, some 2200 kms away (LeGall and Hughes, 1987). Another green turtle nested on both Mona Island, Puerto Rica, and some 560 km away on Aves Island, Venezuela (Kontos et al., 1988).

Individual leatherbacks have laid eggs on beaches as much as 110 km apart in the Caribbean (Eckert et al., 1989). Movements of this species for nesting are also known between Trinidad and Suriname, that is >500 km (Hilterman and Goverse, 2002). The longest distance to date between nests of the same leatherback is >1000 kms, from Playa Grande, Costa Rica, to Tierra Colorado, Mexico (Sarti, pers comm).

The 2 Kemp's ridleys that nested at both Padre Island and Rancho Nuevo (see above) should also be included in this list, for a distance of approximately 250 km.

A green turtle encountered on the beach at Tortuguero in July 2000 carried a tag with a different type of letter and number combination from that used in tagging at Tortuguero but similar to that used in Mexico (Mangel and Troeng, 2001; Troeng, pers comm). The vast majority of tags in Mexico have been attached to turtles when on land for nesting. Presumably this turtle nested in Mexico and then later in Costa Rica. There is a problem with this explanation: it requires not only lack of nest-site fidelity but also lack of species fidelity! The Mexican records had this tag being attached to a Kemp's ridley.

This little mystery exemplifies something that must arise not infrequently with so much tagging going on in so many places: errors of transcription, errors of reading tag numbers from worn tags or in the dark. Such errors are more common in the hours after than before midnight (Godfrey, pers comm), as might be expected from a chronobiological perspective. It all makes one wonder how much weight should be attached to findings based on single tag returns. In the case of the change of nest site in the Indian Ocean, it is somewhat reassuring that the authors state that there was no doubt about the identification of the turtle on Europa. It was seen onshore there on two successive nights (Le Gall and Hughes, 1987).

RECOMMENDATIONS FOR THE CANARY ISLANDS PROJECT

These recommendations for what is desirable may well assume an idealized choice of options. They are one person's opinion, after watching what has happened in other translocations. Those in the Canary Islands concerned with this project are wisely seeking input from a variety of sources.

1. Premonitoring. Inspections of beaches in the Canary Islands for signs of nesting before any potential returns of translocated turtles is essential for evaluation. This may sound simple, but since turtles will not necessarily return to the exact beach of release, and since there are many beaches in this archipelago, monitoring may be expensive and arduous. Moreover, eggs/turtles should probably be translocated to several beaches. On theoretical grounds, arising from a survey of translocations of 93 species of bird and mammal, there is a higher chance of success if available animals are split between two or more release sites, unless very few are involved. This is because the chance of success at a given site does not increase linearly with the number of animals released, but asymptotes (GRIFFITH ET AL., 1989).

   However, all beaches need not be inspected every day. What is more important is that there be something systematic to which comparisons can be made in the future. Protocols should not be so demanding as to make it unfeasible to keep them going over many years. Information on how long tracks remain visible in windy conditions in this region might be collected as a preliminary step. Perhaps a combination of helicopter surveys with some ground truthing on accessible beaches would be possible. But some form of premonitoring is essential, for reasons given above.

   This is obviously an unglamorous task because the expectation is that turtles will not been seen. However, as Dr Margaritoulis has pointed out at this meeting, there could be some surprises in the Canary Islands. In fact there is already at least one recent record worth noting: a juvenile loggerhead (ca 50 cm curved carapace length) has been seen on Cofete beach, Fuerteventura, though in the unusual circumstances of daytime and winter (CEJUDO, 2000). Altogether, it is essential that premonitoring be undertaken — if this is to be a scientific as well as a conservation exercise.

2. Marking. For assessment, it is imperative that turtles are marked in a way that will still be present when they mature. If turtles do not come up on the Canary Islands in the future but go elsewhere, marking will help learn what did happen to those

turtles. Omission of marking prevents the discovery of unexpected outcomes. If, however, as hoped, turtles are found nesting on the Canary Islands, marking will indicate how many are part of the translocation experiment, and whether from particular years of that endeavor with particular conditions pertaining.

Marking might seem a simple demand, but the problem of tagging hatchling turtles has not been satisfactorily solved. PIT tags or other inserted devices may migrate within the body as the animal grows, and so not be readily detectable. Validation of internal tagging for hatchlings is needed. Moreover, such tags cannot be detected without special equipment. People likely to come into contact with a turtle, perhaps fishermen, or tourists on a beach, may not have this equipment. Therefore, an additional external tag is desirable. The living tag would seem to be a good candidate on the basis of the results from the Padre Island project and from the Cayman Farm.

However, there are potential drawbacks. In some of the work on the Kemp's ridley, there was a higher mortality rate in hatchlings given the living tag (32%) than in those not treated (16%) (CAILLOUET ET AL., 1986). This was reported for the 1984 year class. Probably the hatchlings brought to Texas that year were in sub-optimal health anyway, or experienced sub-optimal conditions after arrival (SHAVER, pers comm). In some other cases, survival of hatchling turtles after application of living tags has been excellent and essentially indistinguishable from untagged controls (HENDRICKSON AND HENDRICKSON, 1981b, 1986). It might be decided that a certain mortality rate in animals given living tags is acceptable in the interests of being able to detect animals from this project.

Another potential problem is that although the living tag method can be successful with green turtles and Kemp's ridleys, it is conceivable, as pointed out in this meeting, that it may be less effective with species such as loggerheads whose carapace tends to attract barnacles.

If living tags do not work out for loggerhead hatchlings, and no other method is found, then it may be necessary to consider headstarting simply for the purpose of being able to tag the animal (cf KLIMA AND MCVEY, 1981). A yearling has a higher chance than a hatchling of retaining an external tag; conventional external tags could be combined with PIT tags and with living tags. Also, if the latter are applied to yearlings, time afterwards in tanks can be allowed to make sure the transplant has taken. There would not be the concern, as there might be with hatchlings, to complete the transplant and subsequent release of the animals rapidly, before the juvenile frenzy had waned.

Because the logistic demands of the project would be very different if head-starting were required, simply as means of tagging the turtles, it seems essential for this reason also that evaluation of the suitability of living tags for the present project be undertaken soon. Someone involved with the Canary Islands project should learn as much as possible about living tags and if necessary initiate further research with loggerhead hatchlings. In fact, extensive and carefully designed experiments with loggerhead hatchlings have already been carried out at the Miami Seaquarium by HENDRICKSON AND HENDRICKSON (1981b, 1986). Among their findings were that the percentage of transplant "takes" is higher with pocket grafts than with two other methods, and that it makes little difference whether the graft is done within 24 hours of emergence or 7 days later, and whether the graft is put on a nuchal or costal scute. However, success was influenced by who performed the surgery: procedural details such as how long the glue is left to dry before the turtle is returned to water might be responsible. Data were also provided on evaluation of the clarity of the graft, on a scale from clear to very faint and overgrown with carapacial keratin; there was an 86% consistency in categorization between two observers. The work of the Hendricksons should be studied in detail. "Those who cannot remember the past are condemned to repeat it" (SANTAYANA).

Another point that should be ascertained before using living tags in Macaronesia is what scutes have already received such tags in other projects. In the early 1990s, a few loggerhead hatchlings in Quintana Roo, Mexico, were given living tags, with plans to tag many more in the future (ZURITA ET AL., 1994). It appears that coordination between different groups using living tags has not been adequate, increasing the possibility that different projects will use the same scute (BJORNDAL ET AL., 2003). The need for preserving the integrity of the coding systems with living tags was recognized right away (HENDRICKSON AND HENDRICKSON, 1981b, 1986) and the desirability of announcing which scutes were being used, preferably in advance of tagging, was urged on a wider audience (MROSOVSKY, 1982). Failure to do so would be irresponsible (cf BJORNDAL ET AL., 2003).

3. Public records. Suppose the problems of tagging are satisfactorily addressed, this would be only a part of being able to determine the origin of an individual when a tagged turtle was found. A tag is useless unless there are records of when and where that tag was applied. The organizations and people who find a tagged turtle, perhaps 20 years after the tag was applied, may not be the same as those who did the tagging in the first place. It is recommended that each year it be insisted on, with iron-fisted inflexibility, that details of the project be put into the public domain. This should be a condition of any financial support, or permits (GRIFFITH ET AL., 1989). Such a requirement will force participants to undertake the often time-consuming writing up of procedures and results, even though they might prefer to be walking the beach. Records put on the web can be labelled as preliminary, and when checked can be re-labelled as checked, or "final report" for a given year.

   It is recommended that the Canary Island translocation project, if that eventuates, builds rigorous checking routines and redundancy into their tag numbering system. In my laboratory, we find that the most common source of error is in transcription of numbers from one piece of paper to another. Transcriptions should be checked — preferably later and preferably by someone else.

   Annual accounting and open presentation of data, especially for a long-term project, helps avoid lost data and wasted effort. And it opens up the project explicitly to outside scrutiny. In contrast, there are unfortunately some turtle programmes that are either incapable or unwilling to provide information to interested parties.

4. Risk and mitigation. Should experimental procedures be tried on populations that are threatened? It is notable that the taking of risks is sometimes thought justifiable precisely in circumstances when particular populations are considered imperiled. For Operation Green Turtle, "a major impetus for this effort was the excessive harvest of female green turtles at Tortuguero .... and the bleak survival outlook of the population if the harvest continued" (ELIAZAR ET AL., 1998). For the Padre Island project, it has been said that "the ridley situation was so desperate that the agencies decided to take the risk of failure" (CARR, 1979). Such attitudes apply of course to species other than sea turtles. It was only when the situation for the California condor became truly bleak that priorities shifted from a hands-

off policy to experimentation aimed at determining causes of mortality and at breeding in captivity (SNYDER AND SNYDER, 2000).

If experiments and risk taking are acceptable in desperate situations, then surely they are all the more, not less, justified when populations are apparently healthy. In such cases, rather than ask whether the situation is dire enough to demand desperate measures, the more appropriate question might be whether the experiment is likely to do any harm. The take of hatchlings in Operation Green Turtle and the dispatch of ridley eggs sent to Padre Island have not prevented the dramatic increases in the number of nesting females in those areas (BJORNDAL ET AL., 1999; MARQUEZ ET AL., 1999).

Where there is high natural mortality, and relatively dense nesting, there seems no reason why a take of some eggs —it depends of course on the number involved— for a translocation project need have much impact. But there is a way to insure that it does not: build mitigation measures into the project from the start. The essentials are to identify causes of natural mortality, and then reduce those causes, thus compensating for the take of eggs or hatchlings —for whatever purpose those are needed (MROSOVSKY, 1983). In the case of the Cape Verde Islands, use of hatcheries has already protected some eggs from predators and inundation (GARCIA ET AL., in press). All that is needed is to link particular new and extra conservation efforts to the number of eggs taken to the Canary Islands, so that an equal or greater number are saved on the Cape Verde Islands. To reduce the chance of misconceptions arising, mitigation measures should be agreed upon with the authorities in the Cape Verde Islands, and made public there. Any additional conservation benefits coming from increased presence of rangers or biologists on the beach, and increased public awareness about turtles, can be considered as gravy.

The IUCN/SSC (1995) has produced a useful and comprehensive set of guidelines for re-introductions; these raise a number of general issues that should be thought about. It should be remembered, however, that these are guidelines, not requirements, and should not be used to stifle innovation and experimentation.

5. Control group. Without explicit formulation of the aims of the endeavor, it is difficult to comment other than tentatively on what control groups should be considered. It would be nice to have turtles nesting on the Canary Islands where so

many inviting beaches exist; turtles may well have nested there in the past (LOPEZ-JURADO, pers comm). Promotion or restoration of biodiversity is in general desirable. It seems unlikely that attempts to establish turtles on the Canary Islands would do harm. However, at present the survival prospects of the loggerhead turtle are not so dire as to demand that every possible measure be thrown into action. That leaves one of the main attractions of this project as the chance of obtaining the knowledge and understanding of sea turtle biology that could be so important for conservation in the future in a warming world. Therefore, it would seem appropriate to reduce the number of manipulations in the interests of making outcomes more instructive.

If the only aim is to establish nesting turtles on the Canary Islands, then it could be argued that, with the proviso that premonitoring is well done and reveals little or no nesting, there is no need for groups other than the translocated turtles. Success will be evident simply by increases over the premonitoring baseline levels. If tags last that long, they would provide direct evidence that the newly arriving turtles were translocated animals, and not part of some expansion in range.

However, a project kept to the essentials above seems unduly lacking in ambition. It would be much more interesting if one could learn not only if translocation worked, but how it compared quantitatively to what would have happened to these turtles had they not been moved. A group of turtles untranslocated but otherwise treated in the same way would offer a way of assessing the effectiveness of translocation. Such a group would have to be treated in exactly the same way, with the same amount of time in captivity and the same tagging procedures down to such details, if possible, of the person doing the tagging.

Having an untreated group of turtles at the Cape Verde Islands — untreated except for interventions necessary to tag the hatchlings — could in itself be exciting. It could potentially provide direct data on survival rates of hatchlings, one of the big unknowns in turtle life history. These would be minimal survival rates because some turtles would be missed at nesting, either on account of tag loss or for other reasons. Sex ratio of this group would need consideration. It could be matched to that of the translocated animals by constituting the two groups at the same time of the season. Other hatchlings could be taken for direct specification of sex ratio at that time. Also maturation period would become evident, empirically from data, rather than from extrapolations and modelling. Sometimes what is learned from control groups is more valuable than what is learned from experimental groups!

If either imprinting or headstarting are to be included in the translocation protocol, then additional control groups for those manipulations are wanted. For imprinting, some of the translocated eggs/hatchlings could be kept in Cape Verde Islands sand and water. Beaches on the Cape Verde Islands would have to monitored when these turtles were due to mature.

If headstarting is included, the matter of appropriate control procedures probably becomes more complicated. Tags applied to hatchlings and headstarted yearlings may not have the same retention rates. Probably all tagging would have to be done at the same stage. But if headstarting were being done precisely to facilitate tag retention (see above), this would be contradictory and counterproductive. Another (very expensive) approach would be to headstart animals both in the Canary and the Cape Verde Islands, leaving translocation as the only treatment differing between comparison groups.

In summary, the following are recommended: premonitoring, marking (especially experimentation with living tags), record keeping and publication, mitigation, and a control group. A tall order indeed! But the Canary Islands project has the benefit of being able to build upon past experiences. It has the opportunity to do things right! Buena Suerte!

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REFERENCES

AIKEN, J.J.; GODLEY, B.J.; BRODERICK, A.C.; AUSTIN, T.; EBANKS-PETRIE, G.; HAYS, G.C. (2001). Two hundred years after a commercial marine turtle fishery: the current status of marine turtles nesting in the Cayman Islands. Oryx, 35, 145-151.

ANON. (1982). Report on U.S. FWS and NMFS sea turtle permit activities during 1981. East & Gulf Coast News, 2, 4-13.

ANON. (1996). Headstarting... to what? Turtle Tracks Newsletter of the Sea Turtle Protection Society of Greece, 13, 3.

BELL, C.D.L.; PARSONS, J. (2002). Cayman turtle farm head-starting project yields tangible success. Marine Turtle Newsletter, 98, 5-6.

BJORNDAL, K.A.; BOLTEN, A.B.; ARENAS, A.; ZURITA, J.; D'AMIANO, A.; CALDERÓN, C.; PARSONS, J.; SEMINOFF, J.A. (2003). Green turtle with living tag captured in the southern Bahamas. Marine Turtle Newsletter, 101, 26.

BJORNDAL, K.A.; WETHERALL, J.A.; BOLTEN, A.B.; MORTIMER, J.A. (1999). Twenty-six years of green turtle nesting at Tortuguero, Costa Rica: an encouraging trend. Conserv. Biol., 13, 126-134.

BURNETT-HERKES, J. (1974). Returns of green sea turtles (Chelonia mydas Linnaeus) tagged at Bermuda. Biol. Conserv., 6, 307-308.

BUITRAGO, J. (1981). Percentage of head-started turtles in a population as a criterion. Marine Turtle Newsletter, 19, 3.

CAILLOUET, C.W. (1995). An update of sample sex composition data for head started Kemp's ridley sea turtles. Marine Turtle Newsletter, 69, 11-14.

CAILLOUET, C.W. (1997). Publications and reports on sea turtle research by the National Marine Fisheries Service, Southeast Fisheries Science Center, Galveston Laboratory, 1979-1996. NOAA Technical Memorandum NMFS-SEFSC-397, ii plus 21 p.

CAILLOUET, C.W.; FONTAINE, C.T.; WILLIAMS, T.D.; MANZELLA, S.A.; REVERA, D.B.; KOI, D.B.; INDELICATO, K.L.W.; TYREE, M.G.; LEONG, J.K.; DURONSLET, M.J.; MARVIN, K.T. (1986). The Kemp's ridley sea turtle head start research project: an annual report for fiscal year 1985. NOAA Technical Memorandum NMFS-SEFC-174 ii plus 37 pp, 29 tables, 1 figure and 5 appendices.

CARR, A. (1979). The Windward Road. Adventures of a naturalist on remote Caribbean shores. University Presses of Florida, Tallahassee, FL.

CARR, A. (1984). So excellent a fishe. Revised edition. Charles Scribner's Sons, U.S.

CARR, A.; OGREN, L. (1960). The ecology and migrations of sea turtles, 4. Bulletin of the American Museum of Natural History, 121, 1-48.

CEJUDO, D. (2000). Caretta caretta (tortuga boba), en la playa de Cofete, Fuerteventura (Islas Canarias). Bol. Asoc. Herpetol. Esp., 11, 26-27.

DUTTON, P.H.; WHITMORE, C.P.; MROSOVSKY, N. 1985. Masculinisation of leatherback turtle Dermochelys coriacea hatchlings from eggs incubated in styrofoam boxes. Biol. Conserv., 31, 249-264.

ECKERT, K.L.; BJORNDAL, K.A.; ABREU-GROBOIS, F.A.; DONNELLY, M. (Editors). (1999). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

ECKERT, S.A.; CROUSE, D.T.; CROWDER, L.B.; MACEINA, M.; SHAH, A. (1992). Review of the Kemp's ridley sea trutle headstart experiment. Galveston, Texas. 10 pp.

ECKERT, K.L.; ECKERT, S.A.; ADAMS, T.W.; TUCKER, A.D. (1989). Inter-nesting migrations by leatherback sea turtles (Dermochelys coriacea) in the West Indies. Herpetologica, 45, 190-194.

ELIAZAR, P.J.; BJORNDAL, K.A.; BOLTEN, A.B. (1998). Operation Green Turtle revisited. Proceedings of the 16th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-412, p. 43.

Fosdick, P.; Fosdick, S. (1994). Last Chance Lost? Irvin S. Naylor, York, Pennsylvania.

García, M.; Peña, B.; Abella, E.; Ballell, L.; Madariaga, B.; Lozano, M.; Díaz-Merry, A.; Del Ordi, D.; González, M.; Borrás, S.; Ruiz, X.; López, O.; Nuez, m.; Hidalgo, J.; Pérez, N.; Varo, N.; Cejudo, D.; López-Jurado, L. (in press). Hatching success in natural and relocated nests of loggerhead in the island of Boavista (Cape Verde, Western Africa). In 21st Annual Symposium on Sea Turtle Biology and Conservation.

Georges, A.; Limpus C.; Stoutjesdijk, R. (1994). Hatchling sex in the marine turtle Caretta caretta is determined by proportion of development at a temperature, not daily duration of exposure. J. Exp. Zool., 270, 432-444.

Grassman, M.A.; Owens, D.W.; McVey, J.P.; Márquez, R. (1984). Olfactory-based orientation in artificially imprinted sea turtles. Science, 224, 83-84.

Griffith, B.; Scott, J.M.; Carpenter, J.W.; Reed, C. (1989). Translocation as a species conservation tool: status and strategy. Science, 245, 477-480.

Hendrickson, L.P.; Hendrickson, J.R. (1981a). A new method for marking sea turtles? Marine Turtle Newsletter, 19, 6-7.

Hendrickson, J.R.; Hendrickson, L.P. (1981b). "Living tags" for sea turtles. Final Report to U.S. Fish and Wildlife Service, 25 pp.

Hendrickson, L.P.; Hendrickson, J.R. (1986). Experimental evaluation of graft-marking procedures for sea turtles. Final Report to U.S. Fish and Wildlife Service, 27 pp.

Hilterman, M.L.; Goverse, E. (2002). The Sea Turtles of Suriname 2001 Project: Aspects of Nesting and Nest Success of the Leatherback Turtle (Dermochelys coriacea) in Suriname, 2001. Report to the World Wildlife Fund, Guianas Forests and Environmental Conservation Project.34 pp.

IUCN/SSC. Guidelines for re-introductions. Retrieved March 3, 2003, from http://www.iucn.org/themes/ssc/pubs/policy/reinte.htm.

Johnson, S.A.; Bass, A.L.; Libert, B.; Marshall, M.; Fulk, D. (1999). Kemp's ridley (*Lepidochelys kempi*) nesting in Florida. Florida Scientist, 62, 194-204.

Karl, S.A.; Bowen, B.W.; Avise, J.C. (1992). Global population genetic structure and male-mediated gene flow in the green turtle (Chelonia mydas): RFLP analyses of anonymous nuclear loci. Genetics, 131, 163-173.

Klima, E.F.; McVey, J.P. (1981). Headstarting the Kemp's ridley turtle, Lepidochelys kempi. In Biology and Conservation of Sea Turtles. Bjorndal, K.A. (ed). Smithsonian Institution Press, Washington & London. pp. 481-487.

Kontos, A.; Eckert, S.; Eckert, K.; Gomez, J.L.; Lee, R.; Van Dam, R. (1988). Inter-island migration of nesting green turtle, Chelonia mydas. Marine Turtle Newsletter, 42, 10-11.

Le Gall, J.-Y.; Hughes, G.R. (1987). Migrations de la tortue verte Chelonia mydas dans l'Océan Indien Sud-Ouest observées à partir des marquages sur les sites de ponte Europa et Tromelin (1970-1985). Amphibia-Reptilia, 8, 277-282.

LeBuff, C.R. (1974). Unusual nesting relocation in the loggerhead turtle, Caretta caretta. Herpetologica, 30, 29-31.

Mangel, J.; Troëng, S. (2001). Report on the 2000 Green Turtle Program at Tortuguero, Costa Rica. Caribbean Conservation Corporation, San Pedro, Costa Rica, 58 pp.

Manzella, S.A.; Caillouet, C.W.; Fontaine, C.T. (1988). Kemp's ridley, Lepidochelys kempi, sea turtle head start tag recoveries: Distribution, habitat, and method of recovery. Marine Fisheries Review, 50, 24-32.

MÁRQUEZ, R. (1978). The Atlantic ridley in Mexico: 1978 season and conservation programme. Marine Turtle Newsletter, 9, 2.

MÁRQUEZ, R.; DÍAZ, J.; SÁNCHEZ, M.; BURCHFIELD, P.; LEO, A.; CARRASCO, M.; PEÑA, J.; JIMÉNEZ, C.; BRAVO, R. (1999). Results of the Kemp's ridley nesting beach conservation efforts in México. Marine Turtle Newsletter, 85, 2-4.

MORREALE, S.J.; RUIZ, G.J.; SPOTILA, J.R.; STANDORA, E.A. (1982). Temperature-dependent sex determination: current practices threaten conservation of sea turtles. Science, 216, 1245-1247.

MROSOVSKY, N. (1978). Editorial. Marine Turtle Newsletter, 9, 1-2.

MROSOVSKY, N. (1982). Sex ratio bias in hatchling sea turtles from artificially incubated eggs. Biol. Conserv., 23, 309-314.

MROSOVSKY, N. (1982). Editorial. Marine Turtle Newsletter, 22, 1-2.

MROSOVSKY, N. (1983). Conserving Sea Turtles. British Herpetological Society, London.

MROSOVSKY, N. (2000). Sustainable Use of Hawksbill Turtles: Contemporary Issues in Conservation. Key Centre for Tropical Wildlife Management. Northern Territory University, Darwin.

MROSOVSKY, N.; DUTTON, P.H.; WHITMORE, C.P. (1984). Sex ratios of two species of sea turtle nesting in Suriname. Can. J. Zool., 62, 2227-2239.

MROSOVSKY, N.; PIEAU, C. (1991). Transitional range of temperature, pivotal temperatures and thermosensitive stages for sex determination in reptiles. Amphibia-Reptilia, 12, 169-179.

MROSOVSKY, N.; YNTEMA, C.L. (1981). Temperature dependence of sexual differentiation in sea turtles: Implications for conservation practices. In Biology and Conservation of Sea Turtles. Bjorndal, K.A. (ed). Smithsonian Institution Press, Washington, D.C. pp. 59-65.

PALMATIER, R. (1993). Lepidochelys kempii (Kemp's ridley) nesting. Herpetological Review, 24, 149-150.

PIEAU, C. (1971). Sur la proportion sexuelle chez les embryons de deux Chéloniens (Testudo graeca L. et Emys orbicularis L.) issus d'oeufs incubés artificiellement. C.R. Acad. Sc. Paris, 272, Série D, 3071-3074.

PRITCHARD, P.C.H. (1981). Criteria for scientific evaluation of head-starting. Marine Turtle Newsletter, 19, 3-4.

ROOZE, V.; KRISTENSEN, I. (1977). Onze schildpadden verdwijnen. Stinapa, 14, 43-48.

SCHULZ, J.P. (1975). Sea turtles nesting in Surinam. Stichting Natuurbehoud Suriname (Stinasu), Verhandeling Nr. 3.

SHAVER, D.J. (1996). Head-started Kemp's ridley turtles nest in Texas. Marine Turtle Newsletter, 74, 5-7.

SHAVER, D.J. (in press). The Kemp's ridley imprinting project at Padre Island National Seashore and Kemp's ridley nestings on the Texas coast. Chelonian Conservation and Biology.

SHAVER, D.J. (this volume). Efforts to establish a nesting colony of Kemp's ridley sea turtles (Lepidochelys kempii) in south Texas through experimental imprinting and headstarting.

SHAVER, D.J.; CAILLOUET, C.W. (1998). More Kemp's ridley turtles return to South Texas to nest. Marine Turtle Newsletter, 82, 1-5.

SHAVER, D.J.; OWENS, D.W.; CHANEY, A.H.; CAILLOUET, C.W.; BURCHFIELD, P.; MÁRQUEZ, R. (1988). Styrofoam box and beach temperatures in relation to incubation and sex ratios of Kemp's ridley sea turtles. In Proceedings of the Eighth Annual Conference on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-214. Schroeder, B.A. (compiler). pp. 103-108.

SNYDER, N.; SNYDER, H. (2000). The California Condor. Academic Press, San Diego, CA, USA.

STANDORA, E.A.; SPOTILA, J.R. (1985). Temperature dependent sex determination in sea turtles. Copeia, 1985, 711-722.

STONEBURNER, D.L.; EHRHART, L.M. (1981). Observations on Caretta c. caretta: A record internesting migration in the Atlantic. Herp. Review, 12, 66.

TAUBES, G. (1992). A dubious battle to save the Kemp's ridley sea turtle. Science, 256, 614-616.

TURTLE EXPERT WORKING GROUP. (1998). An assessment of the Kemp's ridley (Lepidochelys kempii) and loggerhead (Caretta caretta) sea turtle populations in the western north Atlantic. NOAA Technical Memorandum NMFS-SEFSC-409. 96 pp.

U.K. CITES MANAGEMENT AUTHORITY. (2002). Application to register a captive breeding operation involving Chelonia mydas on Grand Cayman, Cayman Islands.

WIBBELS, T.; FRAZER, N.; GRASSMAN, M.; HENDRICKSON, J.; PRITCHARD, P. (1989a). Report to the National Marine Fisheries Service: Blue ribbon panel review of the National Marine Fisheries Service Kemp's Ridley Headstart Program. National Marine Fisheries Service, 12 pp.

WIBBELS, T.; MORRIS, Y.A.; OWENS, D.W.; DIENBERG, G.A.; NOELL, J.; LEONG, J.K.; KING, R.E.; MÁRQUEZ, R. (1989b). Predicted sex ratios from the international Kemp's ridley sea turtle head start research project. In Proceedings of the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management. Caillouet, C.W.; Landry, A.M. (eds). Galveston, Texas.

WOOD, F.; WOOD, J. (1993). Release and recapture of captive-reared green sea turtles, Chelonia mydas, in the waters surrounding the Cayman Islands. Herpetological Journal, 3, 84-89.

WOOD, J.R. (1982). Release of captive-bred green sea turtles by Cayman Turtle Farm Ltd. Marine Turtle Newsletter, 20, 6-7.

YNTEMA, C.L.; MROSOVSKY, N. (1979). Incubation temperature and sex ratio in hatchling loggerhead turtles: A preliminary report. Marine Turtle Newsletter, 11, 9-10.

ZURITA, J.C.; HERRERA, R.; PREZAS, B. (1994). Living tags in three species of sea turtle hatchlings in the Mexican Caribbean. In Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-341. Schroeder, B.A.; Witherington, B.E. (compilers). pp. 273-277.

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