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PROCEEDINGS OF THE SECOND WESTERN ATLANTIC TURTLE SYMPOSIUM

W.A.T.S. II

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Editorial Committee

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June 1989

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Center
Panama City Laboratory
3500 Delwood Beach Road
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Management Options

A Philosophical Approach to Population Models

By Nathaniel B. Frazer

Before I begin my discussion of management options, let me take just a few minutes to put some things into perspective. You've come to this symposium for many different reasons and from many different walks of life. We've spent the last few days discussing virtually every aspect of sea turtle management, biology and conservation. Let me assure you that it is not my intent to review or to repeat all that has been said. But before we decide what our management options are, we must decide what our management objectives are, and why we think it's important to manage sea turtles in the larger context of things.

I will limit my remarks to a consideration of management options only insofar as they relate to developing and caring for sea turtle populations as potentially renewable natural resources, for it seems to me that most of the national representatives gathered here today are looking for guidance concerning this approach to sea turtle management and conservation.

The manager of any natural resource must be concerned with several aspects of management. None of us operates in a vacuum, and each of us attempts to respond to the many, often conflicting, demands of society and of the natural world. The manager's concerns include, but are not limited to, the political, social, and economic needs of people as well as the biological requirements of the resource base.

Natural resource management requires many talents, and managers must display great patience and exercise skilled judgment. It's not a job for the weak-willed or for the fainthearted. In attempting to manage a resource, we must make rules and regulations that are directed at our fellow human beings. We usually would not attempt to legislate behavioral changes in the resource itself. In the case of sea turtles, I would borrow a phrase from fisheries management and say that "Management plans manage people, not turtles."

Anyone who has been involved in policy analysis or implementation knows clearly that managing people requires compromise. Fishermen – both artisanal and commercial – perceive that they need to catch fish (or turtles). From the standpoint of the resource manager, fishermen may view that the fish (or turtles) exist only for their use, and that there should be no limit to the degree to which they can utilize the resource. Even when this is not the case, there are other considerations to be faced. A fisherman in Belize, for example, told me that he understood the need for closed seasons on the lobsters and conchs that his government had written, but that these regulations were actually harmful to him if fishermen from neighboring states continued to enter Belizean waters to catch the lobster in the closed season. He perceived his government's regulations as giving someone else an unfair advantage.

To the government resource manager, the environmentalists must, at times, seem to be akin to religious fanatics and to exemplify the most uncompromising aspects of the environmental movement. I know that some of us take very strong stands on these issues – because we believe so firmly in our convictions.

Governmental officials may lean toward resource development and conservation but can find themselves working for a government that has other political interests as well. Sometimes one set of interests conflicts with another, causing internal strife within the government. I have seen this in my own country.

With focus on these social, political and economic concerns, biological realities are often ignored. There is a great danger here, because the resource manager is caught in the middle of a paradox: managing people requires compromise but biological reality defies compromise.

Let me explain what I mean by giving you a somewhat oversimplified example. Let us say that a turtle population produces 3,000 turtles/yr, that the fishermen want to take 6,000/yr and the environmentalists want to limit the catch to 2,000/yr. A political management compromise might be somewhere in between what the fishermen want and what the environmentalists want, say 4,000 turtles/yr. But if this political compromise violates the biological reality, the resource is not sustainable at the compromise level of exploitation.

Of course, economists may tell us that to deplete a potentially renewable resource is sometimes economically justifiable if calculations of short-term monetary profit outweigh the estimated long-term monetary return. However, this kind of reasoning seems to imply that another resource will always take the place of the one depleted. I don't believe that this is always true.

Nevertheless, whatever the political compromises are, clearly the biology of a species cannot be a party to these compromises if the species is to survive. In the time scale in which management decisions are made, biological realities do not change. If the demands we place upon a species are too great, it will not be able to adjust, and we risk losing the resource.

Thus, although we may become preoccupied with political compromise, the wise management of renewable living resources such as sea turtles clearly cannot ignore the basic biology of the species in question. I repeat that the biological realities cannot be compromised without risk of losing the resource for everyone.

In attempting to arrive at a reasonable management plan for the recovery and controlled exploittation of sea turtles, we must do the following: reduce natural mortality; reduce incidental catch and regulate intentional take, which will require us to conduct stock assessment and determine the sustainable yield. That is, we must ask "how many are there?" and "how many can we take?" Much of what you have heard at this symposium thus far concerns various methods which have been proposed to bring about one or more of these objectives. All of them constitute management options that are available to us in our attempts to accomplish these three tasks. In preparing to address these tasks, two points become obvious after a little consideration. First, management options depend upon the biology of the species and second, management decisions are based upon population models.

The first of these is clear from what I have said before. If management options are not derived from biological realities, then all of our political compromises vanish in the wake of resource depletion. The second statement may not be as clear. Note that I have chosen my words very carefully here. I do not say that management decisions should be based on population models. I maintain that management decisions are based on population models. They were based on population models in the past, are now, and will continue to be in the future.

For some of you, this may seem to be a strange thing for me to say. Each of you probably has his or her own favorite management scheme. You may be saying to yourselves right now, "I don't base my management decisions on a population model." I'd like to argue that all of us do base our management decisions on population models, even if those models are hidden, tacit or somewhat inexplicit. I'll use headstarting as an example of what I am talking about, since the general idea is familiar to most of you. Please note that I do not intend to single out headstarting as being in any way especially wrong, misguided or inferior to any other management scheme. I am simply using it to illustrate a point.

If one is an advocate of headstarting, then I maintain that one bases management decisions on a population model, even though the model may not have been developed intentionally as a model or with the degree of explicitness that we usually associate with mathematical demographic computer models. There are several assumptions that are inherent in the underlying headstart model, just as there are in any other model. At some level, the decision for headstarting is based upon the following three mathematical relationships. Survivorship of captive turtles during the first year of life (that is, from the time the eggs are gathered on the beach until the time the yearling headstarted turtles are released) is greater than or equal to the survivorship of wild turtles during the first year of their lives. This is the basis of headstarting programs, and it does express a mathematical relationship even though the survivorship is usually not expressed as any particular quantitative measure. A second assumption is that survivorship of captive turtles after their release is greater than or equal to the survivorship of wild turtles after their first year of life. And finally, the third assumption is that the fecundity of headstarted turtles upon reaching adulthood is equal to the fecundity of wild turtles.

The first of these three model statements, that survivorship from egg to release of yearlings is greater than or equal to survival in the wild, might be easily shown to be true. However, I do not know of any study that has compared natural mortality (from the time eggs are laid to the end of the first year 'of life) to mortality of headstarted turtles-reared from eggs gathered on the same beach.

The third statement, that fecundity of headstarted turtles upon reaching adulthood is equal to the fecundity of natural turtles from the same population, might reasonably be assumed to be true. (Although one must be aware of possible effects of temperature on the incubation of the eggs, imprinting, and other possible, but as yet unknown, effects].

About the relationship expressed in the second statement, that survivorship of headstarted yearlings released into the wild is equal to or greater than survivorship of wild yearling turtles, we know very little. We do know that headstarted turtles can survive in the wild after their release. But do they survive as well or better than their wild counterparts? We do not know. If they do not survive as well, does the presumed increased survival during the first year of life in captivity make up for the decrease in survival later on? Again, we do not know.

Yet those who headstart turtles rely on these mathematical relationships, or some combination of them, when selecting this management option. Even if such mathematical relationships are not stated explicitly when the decision is made to select headstarting as the management option of choice, this population model lies hidden within the assertion that headstarting is better than not headstarting. The important point that I want to make here is that headstarting is based on an underlying mathematical population model whether or not those who headstart turtles are aware of this or are willing to admit it.

As I said, my purpose is not to criticize headstarting projects or those who run them. My purpose is to show that any management effort we are using is based, even if unknowingly, upon a mathematical population model. The same argument could easily be shown to apply to hatcheries, the implementation of TEDs, the setting of size limits on harvests, or any other management decision that has been made.

In the past, when some of us have called for the development and implementation of explicit mathematical population computer models to help determine management options, opponents have said things like: We don't have enough information to develop population models or it's too early to base management on population models.

Well, as I have shown, current management practices are already based on (tacit) population models. To those who say "We don't have enough information to develop population models," I find myself asking "Why do current (tacit) models ignore information that is available?" To those who say, "It's too early to base management on population models," I ask, is it too late to base management decisions on more explicit population models?

Some of the current, informal models guiding our present management decisions may not be based on the best information available, or may be based on only a portion of the information available. We must base our management decisions on explicit population models that incorporate all we know about a particular species. Where specific information is lacking, well constructed models that incorporate general knowledge about sea turtle population attributes can be used to determine just how critical the missing information is and how sensitive the predictions of the model are to inaccurate information.

Inexplicit, vaguely constructed models, put into use by those who do not recognize or admit that they are using models, are potentially counterproductive and will continue to limit our ability to assess which management practices should receive credit for any observed increase in sea turtle populations and which should receive blame for any decline.

It is possible to incorporate all we know about a species or a given population into a model. This is not to say that we now know everything we need to know. – But by being explicit in spelling out our models and the values we incorporate into them, we can continue to build better models as more information becomes available.

As I see it, our main decision in addressing the question of management options at this point is this: do we continue to use implicit, unspecified population models in making management decisions, or do we begin to use explicit, clearly-specified population models in attempting to make management decisions?

The formal models require explicit quantitative input values. In order to make mathematical computer models, assumptions must be clarified and stated. Investigators in this field are usually required to-state just how the input values were derived so that others who disagree can modify the scheme to incorporate their own methods of assessing the quantitative biology of the species.

Incorporating all known information into a complete model makes it possible to conduct sensitivity analyses to determine how sensitive predictions are to inaccurate or unavailable data. The models generate testable hypotheses in the best scientific tradition. And finally, new information is easily added to such a model.

In short, explicitly constructed mathematical models serve to clarify our thinking. As you can imagine, the explicitness of the formal models and the requirement that we divulge our thoughts about how things fit together and where all the values come from makes them easy to criticize (and easier to correct, I might add). But clear, constructive criticism is not to be shunned or hidden. It is the strength of science, and we should welcome the scrutiny of others.

On the other hand, the implicitness and subjectivity of the current informal models make them more difficult to criticize in any productive way, since builders of this type of model do not have to tell us the specific assumptions they make or the particular values, if any, that they place into the underlying mathematical relationships upon which such models rest.

Two very explicit, carefully constructed formal models of the new type are available.

One has been used to carry out stock assessment based on nesting female surveys. Karen Eckert provided a modification of the classical Jolley-Sever method for population estimation specifically to incorporate the peculiarities and irregularities of sea turtle reproductive behavior. The other model has been used to assess the probable effects of various management options (hatcheries, TEDs, protecting adult females, protecting subadults, etc.) on a loggerhead population. Debbie Crouse (also here on the panel) has provided a modification of the classical model of population dynamics. Crouse's model will appear soon in the scientific journal Ecology, after having received constructive critical review by some of the leading ecologists in North America, and I believe that Eckert is preparing her model for publication as well. I know she has presented it at the 50th anniversary meeting of the Association of Southeastern Biologists and has sought constructive criticism and input from colleagues. We must look in the future to investigators like these to achieve any real progress in the assessment of management options for sea turtle conservation.

In closing, let me "get out on a limb" and say that I believe that we know enough about sea turtle biology in general to make certain recommendations concerning management options for their exploitation. For example, we know that all sea turtle species are relatively long-lived, late-maturing animals with high fecundity, high juvenile (and egg) mortality and low (natural) adult mortality. We also know that each of the species is iteroparous both within and between years. (For those of you who don't speak biological Greek, that means they reproduce more than once.) The different sea turtle species may vary somewhat, but all of them exhibit these traits in their basic life histories. For some species, such as loggerheads, we have pretty good data concerning numerical values for each of these aspects of their biology.

I'd like to share with you the results of a population model based on data gathered over the last 25 years on loggerheads off the Atlantic coast of the United States. In Figure 1, I have attempted to incorporate all we know about loggerhead population biology. I want to stress one thing here and I'm sure that this statement will be controversial and that some (or perhaps alll) of the panel members may disagree. Nevertheless, all I intend to say about Figure 1 and about loggerheads pertains to other sea turtle species as well, because even though their population ecology differs in minor ways, they all have basically the same life history strategy, and this enables us to make certain generalizations about them.

First, I'd like to tell you what this figure says to me about management options, and then I'd like to throw it open to a discussion of management options by the panel. The figure illustrates a concept called "Reproductive Value," which is a measure of the value to the population of an individual female turtle of a particular age. Reproductive value represents the present value of any future offspring that she is likely to have, given her chances of surviving, and the number of offspring she is likely to have if she does survive.

Simply stated, the V(x) or vertical axis from 0 to 500 represents an index of how valuable an individual is based on her future reproductive contribution to the population. The upper and lower curves represent two different models. The lower curve is for a population that is stationary (that is, neither growing nor declining). The upper curve is for a population that is declining.

For both populations, the figure tells us that an individual of age 5 is not very valuable, whereas an individual of age 30 is very valuable. A five-year old has little chance of surviving to adulthood to reproduce. A thirty-year old has already survived to adulthood and is reproducing. Hence, her value is greater. Also, one egg is not very valuable. An egg has only one chance in 1,000 of surviving to adulthood.

Note how the value increases rapidly for older juveniles just before they become adults, since they've already survived the high juvenile mortality stage and are very likely to achieve adulthood.

The exact values upon which these models are based will change as our knowledge of survival rates, fecundity, and age at maturity improves, but the general shape of the curve is not likely to change. For example, these models are based on an age of maturity of about 23 years old. If it is actually younger than that, the curves will shift to the left, but retain the same shape. If the age is actually older, the curves would shift to the right, but still retain the same shape. That is, older turtles will still be much more valuable than younger turtles.

These curves allow me to make certain recommendations concerning management options for sea turtles. Let's assume for the moment that we are absolutely determined to harvest this resource. What does the slide tell us? It tells us that our management options are limited. We clearly should harvest eggs instead of turtles, since an individual egg is not very valuable to the population. Of course, we would then want to reduce natural mortality of eggs and also reduce any incidental take or accidental destruction of eggs, so that we could maximize the harvest and minimize the impact on the population. After all, even though an individual egg is not very valuable to the population, turtles can come only from eggs, and more eggs can come only from turtles, so we don't want to overharvest in any case. Since turtles are "designed" for low juvenile and egg survival, we might be able to take eggs without destroying a population by substituting human predation for the natural predation, with which the turtles have evolved to cope. Also, due to environmental effects, there are those "doomed" eggs that Nicholas Mrosovsky keeps talking about eggs that are laid in places where they are in danger of being washed away by high tides, etc. We might be able to take all "doomed" eggs, which presumably represent "extra" eggs that would not become turtles anyway.

In terms of the turtles themselves, the slide tells us that we must leave the larger juveniles and adults alone. Each of them is extremely valuable to the population, and every one we remove takes a lot of value from the population. Even if we are headstarting and releasing turtles into the population, we'd better not harvest any large juveniles or adults unless we are absolutely certain that the headstarting is working.

Finally, if we are absolutely unwilling to stop taking the turtles themselves, then the figure directs us to another management option to minimize the impact of our harvesting. We must establish size limits. But the figure tells us that we've been doing this incorrectly for over 350 years. We should not set a minimum size limit to protect small turtles. We should set a maximum size limit to ensure that large turtles are not taken. We must restrict our fishermen to taking the smaller turtles of lesser value to the population. Unfortunately, these small turtles are likely to be of lesser value to our fishermen, as well. I stress that these answers are based on the biology of sea turtles. The questions assume that we are unwilling or unable to resist harvesting sea turtles or their eggs.

Please do not misunderstand me. I am not advocating any of these harvests. Sea turtles are declining, and if we continue to harvest them and to destroy their habitat, they will disappear, and the potential for the resource will be lost. The wisest move to ensure the presence of the resource base in the future would probably be to institute a moratorium immediately until their populations recover.

If turtles must be harvested then following the dictates of the best models we now have will minimize, although not eliminate, the impact of your harvest on the continued existence of the turtle populations. That is, the models may enable us to destroy the resource base a little more slowly.

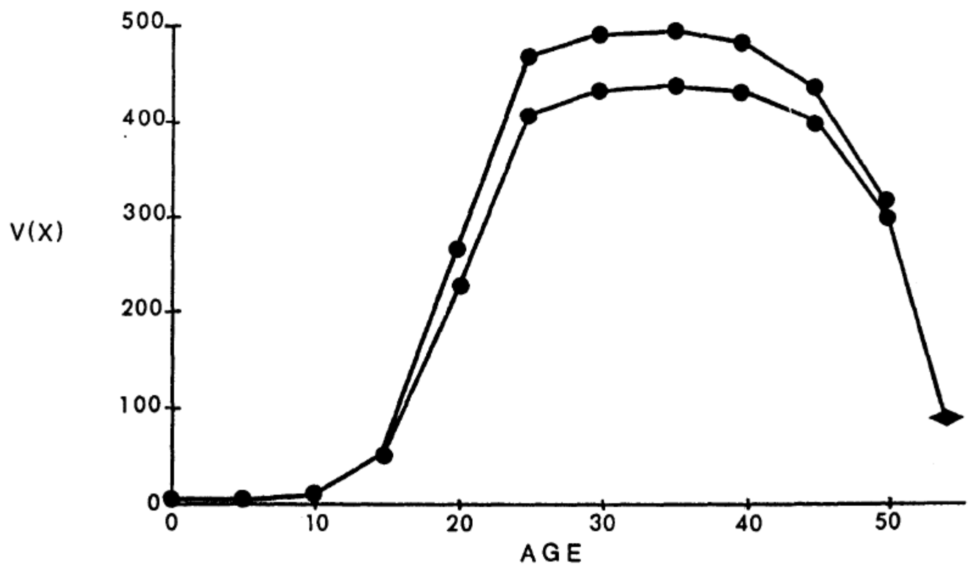

Figure 1. Loggerhead (Caretta caretta) population biology model.