MIGRATION AND HABITAT USE

OF SEA TURTLES IN THE BAHAMAS

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Objectives:

1. Evaluate movement and distribution patterns of sea turtles in our series of study sites in The Bahamas. This objective includes the questions of where do the turtles come from, how long are they resident in these sites, and where do they go when they leave.

2. Collect data that will allow us to develop techniques to compare habitat quality and to serve as a foundation for studies of the role of green turtles in seagrass ecosystems.

3. Evaluate models for estimating growth rates and carrying capacities for sea turtles based on our data from a long-term study of immature green turtles in the southern Bahamas.

Results:

All of the project objectives were met. Many results have been analyzed and presented in the publications listed below. The results of this project have also been presented at many international meetings, some of which are indicated below as publications in proceedings from those meetings. The success of this project is evident in the quality of the publications that are based on data collected during the completion of the objectives of this project. These manuscripts are either published, in press, or in review. The cover page and abstract of the manuscript that is in review are enclosed.

Many of the results of Objective #1 have been analyzed and published (see below). However, some of results have not been analyzed because of the long lag times involved. Many green turtles, hawksbills, and loggerheads were tagged with standard flipper tags throughout The Bahamas Archipelago during this study, and we must await the recapture of these tagged animals before we can determine long-term residence times and movement patterns. Results of genetic analyses are not yet complete. When the genetic haplotypes for all sampled sea turtles have been determined, these results will be analyzed and published.

Objective #2 has been successfully completed. We have developed techniques to mimic green turtle grazing in pastures of the seagrass *Thalassia testudinum* and to monitor changes in biodiversity and *Thalassia* productivity in these grazed plots. One of our graduate students, Kate Moran, will use these techniques for her doctoral research on the effects of green turtle grazing on the structure, function, and biodiversity of *Thalassia* ecosystems.

The results of Objective #3 are contained in the manuscript now in review (cover page and abstract attached). We not only evaluated growth rates of immature green turtles in the southern Bahamas with a nonparametric regression model with five covariates, but we also estimated the carrying capacity of the Caribbean seagrass beds for green turtles based on our rates of seagrass intake in the southern Bahamas.

Publications Based on Results from RWO 166

Bjorndal, K.A. 1998. Model of the nutritional ecology of the green turtle. Page 13, C. Kirk (compiler), Proceedings of the Second Comparative Nutrition Society Symposium. CNS, Silver Spring, Maryland.

Bjorndal, K.A. In press. Quantitative models of nutritional ecology. Proceedings of the International Conference on Turtles and Tortoises. California State University, Dominguez Hills, 30 July - 2 August 1998.

Bjorndal, K.A. In press. Roles of sea turtles in marine ecosystems: nutritional ecology and productivity. In Proceedings of the 18th International Symposium on Sea Turtle Biology and Conservation, Mazatlan, Mexico. NOAA Technical Memorandum.

Bjorndal, K.A. and A.B. Bolten. 1996. Developmental migrations of juvenile green turtles in the Bahamas. Pages 38-39 in J.A. Keinath, D.E. Barnard, J.A. Musick and B.A. Bell (compilers), Proceedings of the Fifteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-387.

Bjorndal, K.A. and A.B. Bolten. 1998. Hawksbill tagged in The Bahamas recaptured in Cuba. Marine Turtle Newsletter 79:18-19.

Bjorndal, K.A. and A.B. Bolten. 1998. Hawksbill tagged in The Bahamas recaptured in Cuba. Bahamas Journal of Science 5:33.

Bjorndal, K.A., A.B. Bolten, R.A. Bennett, E.R. Jacobson, T.J. Wronski, J.J. Valeski and P.J. Eliazar. 1998. Age and growth in sea turtles: limitations of skeletochronology for demographic studies. Copeia 1998:23-30.

Bjorndal, K.A., A.B. Bolten, R.A. Bennett, E.R. Jacobson, T.J. Wronski, J.J. Valeski and P.J. Eliazar. In press. Limitations of skeletochronology for demographic studies in sea turtles. In Proceedings of the Seventeenth Annual Symposium on Sea Turtle Biology and Conservation, Orlando, Florida. NOAA Technical Memorandum.

Bjorndal, K.A., A.B. Bolten and M.Y. Chaloupka. In press. Green turtle somatic growth: density dependence, regulation of developmental migrations, and regional differences. In Proceedings of the 18th International Symposium on Sea Turtle Biology and Conservation, Mazatlan, Mexico. NOAA Technical Memorandum.

Bjorndal, K.A., A.B. Bolten and M.Y. Chaloupka. In review. Green turtle somatic growth model: evidence for density dependence.

Bowen, B.W., A.L. Bass, A. Garcia-Rodriguez, C.E. Diez, R. van Dam, A.B. Bolten, K.A. Bjorndal, M.M. Miyamoto and R.J. Ferl. 1996. Origin of hawksbill turtles in a Caribbean feeding area as indicated by genetic markers. Ecological Applications 6:566-572.

Encalada, S.E., P.N. Lahanas, K.A. Bjorndal, A.B. Bolten, M.M. Miyamoto and B.W. Bowen. 1996. Phylogeography and population structure of the Atlantic and Mediterranean green turtle *Chelonia mydas*: a mitochondrial DNA control region sequence assessment. Molecular Ecology 5:473-483.

Lahanas, P.N, K.A. Bjorndal, A.B. Bolten, S.E. Encalada, M.M. Miyamoto, R.A. Valverde and B.W. Bowen. 1998. Genetic composition of a green turtle (*Chelonia mydas*) feeding ground population: evidence for multiple origins. Marine Biology 130:345-352.

In Review

Running Head: Green Turtle Growth Model

Green Turtle Somatic Growth Model: Evidence for Density Dependence

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ABSTRACT

The green turtle, *Chelonia mydas*, is a circumglobal species and a primary herbivore in marine ecosystems. Over-exploitation as a food resource for human populations has resulted in drastic declines or extinction of green turtle populations in the Greater Caribbean. Attempts to manage the remaining populations on a sustainable basis are hampered by insufficient knowledge of demographic parameters. In particular, compensatory responses resulting from density-dependent effects have not been evaluated for any sea turtle population and thus have not been explicitly included in any population models.

Growth rates of immature green turtles were measured during an 18-year study in Union Creek, a wildlife reserve in the southern Bahamas. We have evaluated the growth data for both straight carapace length (SCL) and body mass with nonparametric regression models that had one response variable (absolute growth rate) and five potential covariates: sex, site, year, mean size, and recapture interval. The SCL model of size-specific growth rates was a good fit to the data and accounted for 59% of the variance. The body-mass model was not a good fit to the data, accounting for only 26% of the variance. In the SCL model, sex, site, year, and mean size all had significant effects, whereas recapture interval did not.

We used results of the SCL model to evaluate a density-dependent effect on somatic growth rates. Over the 18 years of our study, relative population density underwent a 6-fold increase followed by a 3-fold decrease in Union Creek as a result of natural immigration and emigration. Three lines of evidence support a density-dependent effect. First, there is a significant inverse correlation between population density and mean annual growth rate. Second, the condition index (mass/SCL^3) of green turtles in Union Creek is positively correlated with mean annual growth rates and was negatively correlated with population density indicating that the green turtles were nutrient limited during periods of low growth and high population densities.

Third, the population in Union Creek fluctuated around carrying capacity during our study and thus was at levels likely to experience density-dependent effects that could be measured.

We estimate the carrying capacity of pastures of the seagrass *Thalassia testudinum*, the major diet plant of the green turtle, as a range from 122 - 4439 kg green turtles/ha or 16 - 586 million 50-kg green turtles in the Caribbean. Because green turtle populations are probably regulated by food limitation under natural conditions, carrying capacity can serve as a baseline to estimate changes in green turtle populations in the Caribbean since pre-Columbian times and to set a goal for recovery for these depleted populations.

Finally, we compare the growth functions for green turtle populations in the Atlantic and Pacific oceans. Not only does the form of the size-specific growth functions differ between the two regions (monotonic declining in the Atlantic and nonmonotonic in the Pacific), but also small juvenile green turtles in the Atlantic have substantially higher growth rates than those in the Pacific. Research is needed to evaluate the causes of these differences, but our results indicate that demographic parameters should only be extrapolated with great caution between ocean basins.

Key words: Australia; Bahamas; Chelonia mydas; *carrying capacity; demography; density-dependent effect; growth models; growth rate; marine turtles; nonparametric regression; sustainable use.*

Key phrases: density-dependent effects on demographic processes; comparison of growth rates of green turtles in the Caribbean and Pacific Ocean; estimation of carrying capacity; management of long-lived species; nonparametric regression model to evaluate continuous and nominal covariates; sources of variation in somatic growth rates; sustainable utilization of wildlife.