JIMAR, PFRP ANNUAL PROGRESS REPORT: FY 2004

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Project Proposal Title: Development of a hierarchical model to estimate sea turtle rookery contributions to mixed stocks in foraging habitats

Funding Agency: JIMAR

1 Purpose of the project and indicative results:

The purpose of the project is to develop general methods for incorporating ecological covariates in genetic stock analysis models. Stock analysis attempts to estimate the proportion of the individuals in a mixed population that come from each of a number of possible source populations: for example, comparing data from breeding grounds and an open-ocean population that combines individuals from many breeding grounds to figure out the importance of particular breeding grounds to the overall population. In the past, stock analysis has been based only on individual morphological or genetic measurements, such as the mitochondrial DNA haplotypes of individuals found in rookeries and in mixed-stock foraging grounds. Other ecological information such as the size of the breeding population or the distance from the breeding population to the foraging ground is often available (and ignored). We are using stock analysis of Atlantic sea turtle populations (loggerhead and green turtles) to test and develop models that include ecological covariates such as rookery size and location, and drawing initial conclusions about the more powerful or different conclusions that come from incorporating this information. In particular, we are developing hierarchical Bayesian models, which are a flexible but rigorous way to add rookery size and geographic location to stock analysis methods that have traditionally used only genetic data to try to infer the contributions from each rookery. We are also developing important auxiliary statistical tools, such as model selection methods that can determine whether adding particular ecological covariates to an analysis actually increases the precision and accuracy of our estimates, or whether (if we mistakenly try to add irrelevant information to the model) it actually dilutes the power of the analysis; these tools are necessary before one can confidently start using hierarchical Bayesian methods as a general tool to add information to stock analyses. We are building soft-

ware tools that implement these methods and that can be used by a broader audience of researchers. Finally, we hope to apply these general methods to some broader questions in stock analysis: for example, where should we define boundaries between populations for the purpose of stock analysis? How do we know when we have enough information to justify analysis at a very fine spatial scale or using very detailed genetic differences, and when should we be satisfied with analyses on a coarser scale?

2 Progress during FY 2004.

- A ms. which we submitted last year, "Combining genetic and ecological data to estimate sea turtle origins", by Okuyama and Bolker, details the construction of hierarchical Bayesian models for sea turtle stock analysis, the testing of such models with a broad range of simulated data to see what conditions favor the use of such models over other (non-hierarchical) stock analysis tools, and the application of hierarchical Bayesian models to existing data on mitochondrial DNA haplotypes of green and loggerhead turtles in the Atlantic Ocean. This is one of the first uses of hierarchical Bayesian models in an ecological context, and is unique in its emphasis on using these models to incorporate additional ecological covariates in a flexible way.

  This ms. was accepted by *Ecological Applications* subject to moderate revision: we have made the revisions, and another round of editorial changes, and are preparing to submit the paper in its final "in press" form.

- We have continued to work on the model selection problem, which is the next one we had set for ourselves. We have continued to work on applying the *Deviance Information Criterion* (DIC) (a metric recently developed by researchers in Bayesian statistics, and described in our last progress report) to hierarchical models for sea turtle populations. We have found that hierarchical models are most valuable when small amounts of data are available from large numbers of sources (e.g., rookeries or feeding grounds); it is in this case that the hierarchical structure can provide the most additional information. Our ms. on the subject is in progress.

- We have pioneered methods for estimating contributions in a "many-to-many" stock analysis situation, where data are available from many sources (rookeries) and many destinations. In this case, we can incorporate rookery and feeding-ground size directly (rather than hierarchically, although we are also exploring hierarchical versions of this model), and we can express contributions in either a "rookery-centric" way — percentages of individuals leaving each rookery for different foraging grounds — or in the more traditional "foraging ground-centric" way — percentages of individuals in each foraging ground coming from different rookeries. We have found that approaching this problem naively, by running a series of separate stock analyses for each foraging ground, give misleading answers.

These methods have been briefly described and incorporated in a manuscript submitted to *Molecular Ecology* by Brian Bowen et al.(with 20 authors: BMB, TO, KAB, and ABB are all co-authors) on "Natal homing in juvenile loggerhead turtles (*Caretta caretta*)", which shows for the first time (on the basis of stranding data) that juvenile sea turtles actually preferentially remain in the general vicinity of their natal rookeries, rather than forming a single completely mixed stock.

We are also preparing a more general ms. on many-to-many stock analysis using the large quantity of green turtle genetic data that KAB and ABB have amassed.

3 Plans for the remainder of the year (18 April – 31 December 2004

- We will finish our DIC and "many-to-many" stock-analysis mss.
- We will follow up contacts made at the PFRP meeting last December to work on applying our methods to Pacific sea turtle stocks.
- We will continue to work to make the procedures we have developed robust and to incorporate them into a relatively user-friendly package running on top of the R programming environment (and possibly tying in the BUGS statistical estimation package as well). (An initial version of the package is available at `http://www.zoo.ufl.edu/bolker/turtle`.)
- We will implement geographic hierarchical models, that take location (at a finer scale than presence in one gyre or another) into account. We have intended from the beginning to implement these models, and the many-to-many analyses we have begun to do have made the utility of these types of models clearer.
- Finally, we will use these tools to tackle the broader question of model aggregation. Hierarchical models were designed with complex spatial data sets in mind, and should be ideally suited to asking questions about the spatial and genetic resolution at which we should characterize our data to get the most accurate estimates of rookery contributions to stocks.

4 Papers published in refereed journals

B. Bolker, T. Okuyama, K. Bjorndal, and A. Bolten (2003) Stock estimation for sea turtle populations using genetic markers: accounting for sampling error of rare genotypes. Ecological Applications, 13(3):763-775.

5 Other papers and presentations

B. Bolker, T. Okuyama, K. Bjorndal, and A. Bolten (2003) Accounting for sampling error of rare genotypes in sea turtle stock estimation. Page 252 in: J.A. Seminoff, compiler. Proceedings of the 22nd Annual Symposium on Sea Turtle

Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-503.

Principal investigators' meeting, Pelagic Fisheries Research Program, JIMAR/NOAA, University of Hawai'i, Manoa, HI, 5 December 2004. "Bayesian hierarchical methods for mixed stock analysis of sea turtles."

24th Annual Symposium on Sea Turtle Biology and Conservation, San Jose, Costa Rica 22-29 February 2004. "Using ecological covariates to strengthen sea turtle mixed stock analysis." (presented by Toshinori Okuyama and Ben Bolker) [runner-up student prize awarded to Toshinori Okuyama]

6 Students graduating

None

7 Budget for next fiscal year:

None: grant ends at the end of this fiscal year (31 December 2004).