Generating Fisheries Management Advice in Data-limited Situations: Examples from the U.S. South Atlantic and Caribbean

Generando Recomendaciones para el Manejo de la Pesca en Casos de Datos Limitados: Ejemplos del Atlántico sur de los Estados Unidos y del Caribe

Produire des Avis de Gestion pour les Pêcheries en Situations de Données Limitées: Examples de la Façade Atlantique-Sud des États-Unis et des Caraïbes

MANDY KARNAUSKAS[1], NICK FARMER[2], BETH BABCOCK[3], MARGARET MILLER[1], DAVE MCCLELLAN[1], and JEAN WIENER[4]

[1]Southeast Fisheries Science Center, National Marine Fisheries Service NOAA, 75 Virginia Beach Drive, Miami, Florida 33149 USA. [2]Southeast Regional Office, National Marine Fisheries Service NOAA, 263 13th Ave S, St. Petersburg, Florida 33701 USA. [3]Rosenstiel School of Marine and Atmospheric Science, Department of Marine Biology and Fisheries, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33149 USA. [4]Fondation pour la Protection de la Biodiversité Marine (FoProBiM), B.P. 642, Port-au-Prince, Haiti, and 6011 Henning Street, Bethesda, Maryland 20817 USA.

ABSTRACT

While the southeastern United States and Caribbean generally suffer from a paucity of fisheries data with which to carry out formal stock assessments, management advice can sometimes be obtained with limited data, provided they contain sufficient resolution over space or time. Here we present two case studies, which were originally motivated by the need to generate management advice under severe data limitations. The first example focuses on the impact of the Haitian fishery at Navassa Island, where a SCUBA fish monitoring survey was carried out over the span of a decade (Karnauskas et al. 2011). Species-level and community-level indicators of ecosystem status were estimated using a framework which accounted for the artifacts of sampling. Despite the small sample size and the relatively short time series, significant trends emerged and these were in agreement with anecdotal observations of the level of fishing pressure. The second example relates to the spatial management of two rarely-encountered grouper species in the South Atlantic. While a plethora of data sources are available for this region, these data sets are largely incoherent in both space and time, and detection rates of the study species are extremely low. By incorporating all data into a generalized linear modeling framework, we were able to produce a map of probability of occurrence across the entire South Atlantic (Farmer and Karnauskas 2013). These results are being used to guide the design of marine reserves intended to protect these species. Both of the methodologies presented here could be applied to other fisheries in the region where similar data limitations exist.

KEY WORDS: Data-limited fisheries, size spectra, marine reserve, Bayesian statistics, SCUBA survey

NAVASSA ISLAND CASE STUDY

For the Navassa Island study, a stationary point count method was used to visually assess reef fish abundance (Bohnsack and Bannerot 1986). The total number of sites surveyed in the four cruises was as follows: 110 in 2002, 123 in 2004, 150 in 2006, and 140 in 2009. SCUBA divers, at designated randomly-selected survey points, identified all species within 5 min in an imaginary 7.5 m cylinder, with fishes appearing after five minutes recorded separately (McClellan and Miller 2003, Brandt et al. 2009). For each species, divers estimated the number of fishes, as well as the minimum, maximum, and average size observed. Eight different habitat types were surveyed in the four periods, but coverage varied from year to year. The specific divers who carried out the surveys also differed from year to year, and thus both habitat effects and diver biases had to be incorporated in the calculation of indicators. The list of indicators calculated in this study, and the method for incorporating these habitat and diver effects in each indicator calculation, is detailed in Table 1.

Table 1. List of indicators calculated in Karnauskas et al. (2011).

Indicator	*Method for incorporating habitat effects and diver biases into indicator estimates*
Mean length by species	three-way mixed-effects analysis of variance (ANOVA) with habitat type and diver as random effects and year as a fixed effect
Mean density by species	three-way mixed-effects analysis of variance (ANOVA) with habitat type and diver as random effects and year as a fixed effect
Mean density by target group	three-way mixed-effects analysis of variance (ANOVA) with habitat type and diver as random effects and year as a fixed effect
Slope of the log transformed size spectrum	Bayesian hierarchical model framework in which diver and habitat effects were modeled as random effects and year was a fixed effect
L_{max} spectrum	three-way mixed-effects analysis of variance (ANOVA) with habitat type and diver as random effects and year as a fixed effect

Anecdotal evidence – mainly, observations of fishing gear during each of the four cruises – suggested that fishing pressure escalated rapidly from 2002 – 2004, followed by declining fishing pressure in both 2006 and 2009. Also, the use of triple-mesh nets was observed in 2004, but they were not observed (in fishing boats nor as ghost fishing gear in the bottom of the sea) in other years. Trends in the indicators considered also suggested that maximum fishing pressure occurred in 2004, followed by some recovery in the community in 2006 and further recovery in 2009. The results of this study suggest that simple density-based and length-based indicators may accurately track trends in the overall community status. While these indicators are not associated with specific management reference points, they can provide measures of reference direction (i.e., whether the community is become increasingly overfished or not). A number of other studies corroborate the Navassa Island study and suggest that these simple metrics may track fish community status (Graham et al. 2005, Daan et al. 2005).

U.S. SOUTH ATLANTIC CASE STUDY

The U.S. South Atlantic case study on the spatial distributions of Warsaw grouper and speckled hind came about by a need to better understand the potential effects of marine reserve protection on these threatened stocks. For this region, a plethora of data sources are available, including fishery-dependent data, fishery-independent surveys, volunteer reef fish monitoring efforts, remote-operated vehicle surveys, and fisher reports. This data sources differ widely in both their geographical range and their ability to detect certain species. To make use of all these data sources, a logistic regression analysis was used to model the probability of detecting a target fish species as a function of gear type, depth, latitude, and habitat. Once the gear effects were estimated via this logistic regression, the probability of presence of a target species could then be calculated across the entire study domain, based on the depth, latitude, and habitat at any given point. Through this approach, we created maps of the probability of presence for the two target grouper species, for the entire South Atlantic (Farmer and Karnauskas, 2013).

The model performed reasonably well considering the scarcity of positive observations for these species and the spatial incoherence of the data sources. For speckled hind, the best fit model explained 36.8% of the total variation in occurrence. For Warsaw grouper, model performance was much worse due to extremely low occurrence rates – only 10.92% of the variation in occurrence was explained. Despite the relatively low proportion of variation explained, these models offer at least some information on the predicted spatial distributions of these grouper species, on which spatial management decisions can be based. Because the modeling approach produced a relative abundance index which could be applied across the entire region, we were actually able to estimate the percentage of the stock that would be protected by any given no-take marine reserve configuration.

CONCLUSIONS

These two case studies represent examples of how sparse data sets were employed to inform management, where little other quantitative management advice was available. In such extreme data-limited situations, however, extreme caution must be taken with regards to model imbalance. With such sparse data sets, models may be highly unbalanced, which can potentially cause spurious model fits to occur. In the studies presented here, care was taken to statistically show that model imbalance did not affect the integrity of the results. In the Navassa Island case study, we reran the entire set of analyses with a smaller balanced subset of the original data, such that the habitat type coverage was equal in all years. The results from this rerun were very similar to those from the complete data set, indicating that there was little bias introduced to the results from the unbalanced survey design. For the South Atlantic case study, imbalance in the modeling approach was caused by the different gears covering different geographical locations, often with very little overlap. To assess the potential for spurious model results, we ran a simple simulation analysis whereby a population was sampled with a highly unbalanced sample design; the same logistic regression modeling approach was able to produce estimates of abundance across space that were well-correlated with the known population. We also employed k-fold validation to ensure that the modeling approach could be used to accurately predict a subset of the real data. Such statistical procedures should be used to validate results, particularly when dealing with sparse data sets such as those often available for our region.

Investigators interested in acquiring the codes used for these analyses (available in WinBUGS and R) should contact Mandy Karnauskas: mandy.karnauskas@noaa.gov.

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