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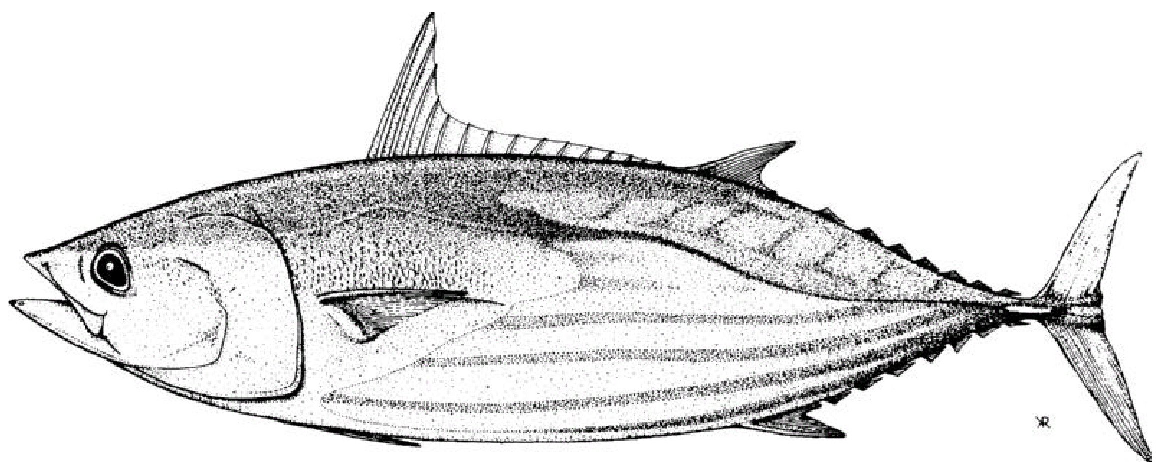

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Development and application of generalized additive models to correct incidental catch rates in the Hawaii-based longline fishery[1]

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Abstract

The Hawaii-based longline fishery primarily targets bigeye tuna, *Thunnus obesus*; yellowfin tuna, *Thunnus albacares*;and albacore, *Thunnus alalunga*, but several other pelagic species (e.g., blue shark, *Prionace glauca*; blue marlin, *Makaira mazara*; dolphin (i.e. 'mahimahi'), *Coryphaena hippurus*; opah, *Lampris guttatus*; and wahoo, *Acanthocybium solandri*) are taken incidentally and together comprise a large fraction of the total catch. Therefore, a series of statistical studies has been conducted at the Honolulu Laboratory of the U.S. National Marine Fisheries Service (NMFS) to assess the quality of the relevant data. The objectives have been increased accuracy of logbook reports, the principal monitoring tool used in this fishery, and improved understanding of logbook reporting behavior on individual and fishery-wide scales.

The approach employed by the Honolulu Laboratory for the analysis of incidental catch rates involves fitting one or more generalized additive models (GAMs) to fishery observer data, evaluating and interpreting the effects of the predictors, and then applying the model coefficients fishery-wide to estimate catch rates on unobserved trips. The response variable in the GAM is the catch per set and the underlying probability distribution is assumed to be the Poisson. The forward entry fitting procedure entails minimizing the Akaike Information Criterion (AIC) and residual deviance, maximizing the pseudocoefficient of determination, and computing sequential *F*-tests. Fishery-wide application of the GAM is intended to reveal instances of under- and nonreporting and other logbook inaccuracies, to identify and permit characterization of trends in specific sectors of the fishery, and to improve understanding of logbook reporting behavior. It is also used to estimate total catches and underreporting and to recreate the catch history.

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The currently used GAM procedures are expected to be enhanced by inclusion of remotely sensed oceanographic variables as predictors. Work to date has been characterized by use of the date of fishing to describe temporal variation. Because this is probably a proxy for physical processes, it is expected that reparameterization with oceanographic factors as predictors should yield more meaningful and useful models. Future work will also emphasize investigation of released fish because data from observed sets revealed that releases accounted for substantial fractions of the apparent underreporting in logbooks relative to the observers for five incidentally caught species.

We recommend that GAM analyses of incidental fish catch rates be preceded by preliminary data quality assessments. For example, both captains and observers sometimes misidentify fish. We have also required clear indications that data are inaccurate or false before deleting them from development or application sets. We have sought parsimony in modeling, requiring all predictors to be statistically significant and limiting the degrees of freedom so as to ensure parameter comprehensibility. While this approach has undoubtedly sacrificed some accuracy and overlooked some instances of under- or nonreporting, we nonetheless suggest that these methods and approach could be adopted or adapted for use elsewhere.

Introduction

The Hawaii-based longline fishery primarily targets bigeye tuna, *Thunnus obesus*; yellowfin tuna, *Thunnus albacares*;and albacore, *Thunnus alalunga*, but several other pelagic species (e.g., blue shark, *Prionace glauca*; blue marlin, *Makaira mazara*; dolphin (i.e. 'mahimahi'), *Coryphaena hippurus*; opah, *Lampris guttatus*; and wahoo, *Acanthocybium solandri*) are taken incidentally and together comprise a large fraction of the total catch. Because of the magnitude of this composite catch and the ecological, economic, or recreational importance of the individual species, a series of statistical studies has been conducted at the Honolulu Laboratory of the U.S. National Marine Fisheries Service (NMFS) with funding support from the Pelagic Fisheries Research Program (PFRP) at the University of Hawai'i to assess the quality of the relevant data. The data sources are records from the NMFS Hawai'i Longline Observer program, commercial logbooks from the Hawai'i-based fleet, and public auction sales records from the United Fishing Agency, Ltd., (UFA) in Honolulu. The objectives have been increased accuracy of logbook reports, the principal monitoring tool used in this fishery, and improved understanding of logbook reporting behavior on individual and fisherywide scales.

The Honolulu Laboratory is in very favorable circumstances to conduct its monitoring responsibilities. Location of the longline fleet in Honolulu facilitates deployment of observers and permits daily observations of presence in or absence from port, which in turn promotes prompt compliance with logbook requirements. In addition, the preponderance of the landings of this fleet is sold through the UFA public auction. These records can serve as approximate checks on trip catch totals since numbers of fish sold should not exceed numbers kept.

The approach employed by the Honolulu Laboratory for the analysis of incidental catch rates involves fitting one or more statistical models to fishery observer data, evaluating and interpreting the effects of the predictors, and then applying the model coefficients fisherywide to estimate catch rates on unobserved trips. Walsh and Kleiber (2001) fitted a generalized additive model (GAM) to blue shark catch rates with observer measurements of environmental, operational, and spatiotemporal variables as predictors. Walsh et al. (in press) then applied a GAM to unobserved sets fisherywide, which permitted identification of under- and nonreporting of blue shark catches, characterization of reporting patterns in different sectors of the fishery (i.e., tuna-directed or swordfish-directed effort), and estimation of total underreporting, demonstrating that a GAM could serve as a 'surrogate observer.'

GAMs are presently being developed and used with other incidentally caught species. Walsh (2002) presented GAM-corrected estimates of blue marlin catches. The sales data provided by the United Fishing Agency, Ltd. public fish auction were particularly useful in this case because the sales totals demonstrated that certain outliers from the preliminary analyses resulted from misidentification and reporting of other istiophorids as blue marlin. As such, the analytical framework for this fishery includes development (fishery observer), application (commercial logbook), and verification (auction) data sets.

The aforementioned studies were complemented by a study of logbook reporting patterns for 15 fish species (or species groups) taken on observed sets by this fishery (Walsh 2000). Results demonstrated that all species were underreported in the logbooks, with the greatest negative bias associated with species that were very numerous, of little economic value, or both (Walsh 2000). This work was useful because it provided estimates of 'optimal' reporting behavior (i.e., reporting in the presence of and possibly after conferring with an observer) to facilitate interpretation of logbook reports from unobserved sets relative to GAM predictions.

We present herein a detailed description of methods employed in studies of fishery observer and commercial logbook data conducted at the NMFS Honolulu Laboratory with incidentally caught species. We also describe planned enhancements to analytical procedures for incidental catches and present recommendations for evaluation and use of both fishery observer and logbook data.

Statistical Methods

Data Sources

The Hawai'i Longline Observer Program, which was developed to monitor interactions between the longline fishery and protected species, particularly marine turtles (DiNardo 1993), initiated activities in March 1994. In addition to the primary monitoring responsibilities, the observers were to record species-specific tallies of the catch and environmental and operational details from each set (Fisheries Observer Management 1998). Approximately 6,200 longline sets had been observed by program personnel as of January 1, 2002.

Mandatory commercial logbook reports have been collected and archived in their original and electronic forms at the Honolulu Laboratory since November 1990, with over 133,000 sets summarized as of January 1, 2002. Although considerably less detailed than the observer reports, these also provide species-specific tallies of the catch, along with environmental and operational details for each set.

Auction sales records have been provided electronically by the UFA with the cooperation of the Hawai'i Division of Aquatic Resources (HDAR) since January 2000. These data include numbers sold, weights, and value by species, for each trip by each vessel.

GAM Development

The initial stage in model development entails plotting logbook catches on the observer data from the corresponding sets in the expectation that this trajectory would approximate 45°. Any seeming outliers are then examined for possible errors. Sets with demonstrably incorrect data are deleted, and the initial GAM fitting proceeds by forward entry. The response variable is the catch per set and the underlying probability distribution is assumed to be the Poisson; as such, logarithms are the appropriate link function. The forward entry fitting procedure involves minimizing the Akaike Information Criterion (AIC) and residual deviance, maximizing the pseudocoefficient of determination, and computing sequential F-tests with a 0.05 significance criterion (Walsh and Kleiber 2001). Fitting is depicted by plotting the residual deviance, pseudocoefficient of determination, or both, against the number of predictors. The partial residual plots are carefully examined for errors and as indicators of highly influential observations. After examining these plots, the observer data may have values deleted as necessary, and the GAM is refitted to obtain the usable coefficients. All statistical procedures are conducted in S-PLUS.

GAM Application

The initial stage in fishery-wide application of a GAM entails application of the coefficients to the entire archive of unobserved logbook data to identify predictor scale problems. The latter refers to a tendency toward extreme inaccuracies in estimated catches if the development and application data sets exhibit markedly different predictor scales. Because the logbook predictor ranges almost always exceed those in the observer data, truncation of the logbook data on one or more variables is usually necessary to approximate the predictor ranges in the development set. This initial step is followed by computation of a log-log linear regression of logbook catches on GAM predictions from unobserved sets. The studentized residuals (Cook and Weisberg 1982; Draper and Smith 1981; Hoaglin et al. 1983) from this regression are then used in an effort to identify outliers. The archived original logbook forms from all sets with "significant" studentized residuals (i.e., $|SR \geq 2|$) are examined for indications of errors. Data deemed inaccurate or false on the basis of these examinations are deleted from the application set. A series of species-specific criteria predicated upon typical catch rates, location, and patterns in the residuals can also be constructed and used to identify unusual or aberrant observations (Walsh et al., in press; Walsh 2002). Sequential editing of this sort leaves a further reduced data set to which the GAM coefficients are again applied. A log-log regression of the logbook catch rates on GAM predictions is computed and evaluated in terms of its coefficient of determination, *F*-test, variance estimate, and residuals plots. This regression is interpreted as the best estimate of the typical relationship between logbook reports and expected catch rates.

Categorical effects not explicitly included in the model (e.g., type of fishing effort) are assessed by sorting the application data on the variable of interest and then plotting the predicted and reported values appropriately. For example, a time series plot of monthly mean catch rates from tuna-directed effort with the corresponding monthly mean GAM predictions could reflect a trend of improving, deteriorating, or stable reporting behavior in this sector of the fishery. Similarly, the monthly mean residuals from the aforementioned log-log regression, pooled or sorted on some variable of interest and some measure of effort (e.g., monthly set totals) as a second response axis, can also be plotted against time. These trajectories may reveal seasonal or other systematic patterns that permit model refinement, improved monitoring efforts, or increased understanding of logbook reporting behavior. The residuals can also be used to assess other issues of special interest, such as possible effects of the presence of an observer on subsequent reporting behavior for an individual who may previously have underreported or effects of instruction for an individual who may previously have tended to misidentify certain species. GAM predictions are summed to estimate total catches and underreporting after adjusting for the effects of data editing and observed sets on effort. Total underreporting is presented with 95% Bonferroni prediction limits estimated by a bootstrapping algorithm (Walsh et al., in press). In addition, the GAM predictions from any given locale can be used to reconstruct the catch history after standardizing as catch-per-unit-effort (i.e., catch per 1000 hooks).

Planned Enhancements to Currently Used Statistical Methods

The principal enhancement of the currently used and previously described GAM procedures will entail inclusion of remotely sensed oceanographic variables as predictors. Previous work (Walsh 2002; Walsh and Kleiber 2001; Walsh et al., in press) has been characterized by use of the date of fishing (month and year, as a numerical variable) as a predictor to describe temporal variation. Because the date is probably a proxy for physical processes, it is expected that reparameterization with oceanographic factors as predictors should yield more meaningful and useful models.

The second enhancement will entail examination of logbook data for releases to evaluate underreporting. The reason is that comparison of logbook and observer reports for five of these incidentally caught species on observed sets revealed that releases accounted for 31%-67% of the differences in catch totals, and this primarily resulted from non- rather than underreporting of releases in the logbooks (Walsh, unpublished data). The appropriateness of evaluating the releases patterns became apparent when the auction data became available because the latter suggested that many captains appear to regard the logbook as a landings report, rather than a total catch report (Walsh, unpublished data).

Recommendations for Analysis of Incidental Catches

It is necessary to recognize that GAM analyses of incidental fish catch rates may require preliminary data quality assessments from several perspectives. For example, it cannot be assumed that observers, particularly newly hired individuals, always identify fish correctly. If it is suspected that an observer may have misidentified similar fish, such as two congeners, a plot of numbers of fish from the logbook report on numbers from the observer report with separate plotting characters can reveal misidentifications as roughly 'mirror image' outliers above and below 45°. The plot of logbook on observer data for any single species can also reveal other concerns. Logbook reports of zero catches when the observer reports list positive catches may indicate that the captains involved are not conscientious even in the presence of an observer, in which case ongoing data checks or continued deployments of an observer may be required. Logbook values from observed sets that fall above the 45° line may reflect misunderstanding and misuse of the logbook form; there have been instances in this fishery when captains logged blue sharks as finned and released, although these categories should be treated as mutually exclusive (Walsh, unpublished data). Finally, logbook reports from unobserved trips submitted by captains who have been shown to misidentify fish by discrepancies with observer or auction data may need to be reviewed historically to determine whether there has been a pattern of error.

The second principal recommendation is concerned with the philosophy underlying the GAM analyses. We have consistently employed conservative data editing techniques, requiring clear indications that data are inaccurate or false before deleting them from development or application sets. Similarly, we have sought parsimony in modeling, requiring all predictors to be statistically significant and limiting the degrees of freedom so as to ensure parameter comprehensibility. While this approach has undoubtedly sacrificed some accuracy and overlooked some problems, most notably failing to detect under- or nonreporting of species that typically are not numerous in the catch, we nonetheless suggest that these methods and approach are appropriate and could be adopted or adapted for use elsewhere.

Literature Cited

Cook, R.C. and S. Weisberg. 1982. Residuals and Influence in Regression. Chapman and Hall, London.

DiNardo, G.T. 1993. Statistical guidelines for a pilot observer program to estimate turtle takes in the Hawaii longline fishery. NOAA Technical Memorandum NMFS (NOAA-TM-NMFS-SWFSC-190).

Draper, N.R. and H. Smith. 1980. Applied Regression Analysis. Second Edition. John Wiley & Sons, Inc. New York.

Fisheries Observer Management. 1998. Hawaii Longline Observer Program Field Manual. Southwest Region, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, United States Department of Commerce.

Hoaglin, D.C., F. Mosteller, and J.W. Tukey. 1983. Understanding Robust and Exploratory Data Analysis. John Wiley & Sons, Inc. New York.

Walsh, W.A. 2000. Comparisons of fish catches reported by fishery observers and in logbooks of Hawaii-based commercial longline vessels. Southwest Fisheries Science Center Administrative Report H-00-07.

Walsh, W.A. 2002. Incidental catches of fishes by Hawai'i longliners. Pelagic Fisheries Research Program Newsletter 7:1-4.

Walsh, W.A. and P. Kleiber. 2001. Generalized additive model and regression tree analyses of blue shark (*Prionace glauca*) catch rates by the Hawaii-based longline fishery. *Fisheries Research* 53:115-131.

Walsh, W.A., P. Kleiber, and M. McCracken. In press. Comparison of logbook reports of incidental blue shark catch rates by Hawaii-based longline vessels to fishery observer data by application of a generalized additive model. *Fisheries Research.*