A hierarchical model to estimate relative catchability at size

Tim Miller

NEFSC, Woods Hole, MA

Annual trawl surveys supply important information on relative abundance to stock assessment models. Sometimes the vessel or gear changes due to new technology or aging equipment and the new vessel/gear configuration will sample populations differently from the old one. To use both sources of information, we must measure the differences in catchability of the old and new survey gear/vessel configurations. The catchability of a survey is often thought of as a constant value across all tows made with a particular gear/vessel configuration, but it can vary from tow to tow due to random variation in the environment and towing procedures. In most cases, the problem will be further complicated by differences in catchability across sizes of individuals. At the Northeast Fisheries Science Center, the *Henry B. Bigelow* replaced the *Albatross IV* in 2009 as the bottom trawl survey vessel and new gear and fishing protocols were also implemented. Over the course of 2008, a paired-tow study was conducted to provide conversion factor estimates for catches made by the two vessels. We present a beta-binomial model that allows estimation of size-specific conversion factors and illustrate the method with an example.

Mixture distribution models of Pacific rockfish schooling behavior

James T. Thorson[1]* and Ian J. Stewart[2]

[1]University of Washington, School of Aquatic and Fisheries Sciences, Seattle, WA; [2]NWFSC, Seattle, WA

Seven Pacific rockfish (*Sebastes* spp.) are currently listed as overfished. These and other rockfish species are constraining to fisheries management owing to target and nontarget catch limits. Indices of abundance for rockfish are frequently derived from a bottom trawl survey that occasionally yields extraordinary catch events (ECEs), in which catch per unit area is much greater than usual. ECEs strongly violate index standardization model assumptions, and removing or including them can cause considerable changes in the indices of abundance used in stock assessments and potentially affect stock assessment results. We hypothesize that ECEs result from trawl catches of fish schools. In this study, we develop models for positive catch rates of rockfish from the bottom trawl survey using a mixture distribution composed of two generalized linear models (GLMs): one for low catches (i.e. solitary individuals) and one for ECEs (i.e. schools). These models can incorporate spatial covariates within both GLMs, and can select a parsimonious model using Akaike's information criterion. Bayesian hierarchical analysis can also be applied to multispecies data to estimate the distribution of differences in density between schooling and solitary individuals among rockfish. Preliminary exploration shows that mixture distributions often fit catch data better than single-distribution GLMs. Bayesian hierarchical analysis can also determine the ratio of densities among solitary and schooling individuals and this information may be especially valuable for infrequently encountered species. Use of mixture-GLM methods for positive catch rates will improve existing survey standardization methods by providing results that are more robust to the occurrence of ECEs.

Acoustical-optical surveys of coastal pelagic species, with emphasis on Pacific sardine, using improved allocation of effort, multifrequency acoustic methods, and a towed stereo camera system

Juan P. Zwolinski*, George R. Cutter, Jr., and David A. Demer

SWFSC, La Jolla, CA

Acoustic surveys are currently used for wide-scale monitoring of many coastal pelagic species and are the primary source of fisheries-independent information used in their assessments. The recent decreasing trend in the abundance of Pacific sardine stock in the California Current Ecosystem (CCE) triggered the need for detailed monitoring of its spatial distribution and demography. In 2006, the Southwest Fisheries Science Center initiated a series of coast-wide acoustic-trawl surveys in

the CCE, and the preliminary results were encouragingly similar to those from relevant stock assessments. To improve the efficiencies of the acoustic surveys, and the accuracies and precisions of their estimates of fish distribution and abundance, efforts were made to optimize the sampling timing and design based on the remotely-sensed distribution of essential oceanographic habitat for the Pacific sardine. Based on historical information of essential habitat, the survey timing can be selected to match the timing of condensed habitat or to include the spatial location of the seasonal commercial fishery to improve species classification and the gathering of biological data. Immediately prior to the survey, the track lines are allocated based on a remotely-sensed distribution of essential oceanographic habitat for optimal sardine surveying. The echo energy is apportioned to the various species present using a combination of probabilistic classification including a variety of information such as essential habitat, acoustic scattering spectra and intensity, and aggregation depth. The classifications are validated and the models refined using independent observations from a net, egg pump, and a new towed stereo camera system. The foundation for these methods and some example results from recent surveys are presented.

Trawl survey designs for reducing uncertainty in biomass estimates for patchily-distributed species

Paul Spencer[1]*, Dana H. Hanselman[2], and Denise McKelvey[1]

[1]AFSC, Seattle, WA; [2]AFSC, Juneau, AK

'Patchiness' in the spatial distributions of marine populations such as Alaska rockfish can arise from heterogeneous habitat characteristics, and can result in errors in survey biomass estimates when high-density patches are either over-represented or under-represented in survey trawls. In this study, we developed a spatial survey simulation model to evaluate the influence of spatial aggregation on biomass estimation, and considered alternative trawl survey designs intended to reduce the variability of biomass estimates. Variants of double sampling procedures were simulated in which high-density areas identified from acoustic data in the first sampling phase were then assigned increased trawl sampling densities in the second sampling phase. Geostatistical analyses of hydroacoustic data collected in Alaskan trawl surveys were used to simulate spatial distributions of fish populations. Simulated survey biomass estimates and sampling variability were evaluated as functions of several factors, including the spatial aggregation of the population and sampling density. When the relationship between the hydroacoustic data and fish density was strong, the double sampling procedure resulted in reduced variance in estimated biomass relative to simple random sampling with equivalent sample size. However, the variance in estimated biomass from the double sampling design was not substantially reduced when the relationship between hydroacoustic data and fish density was weak. The potential improvement in variance when a strong relationship exists between hydroacoustic data and rockfish density offers motivation to continue to refine analyses of hydroacoustic data and rockfish spatial patterns.

Theme E: Developing a Comprehensive Approach for Characterizing Uncertainty

Calculating the uncertainty in fishery assessment forecasts

Richard D. Methot, Jr.

Office of Science and Technology, Seattle, WA

Fishery forecasting models are used to project future catch and stock abundance levels expected from a specified harvest policy. These projections are central to determination of acceptable biological catch (ABC) for one to several years into the future, and to evaluation of longer-term rebuilding plans. The simplest of these projections use a point estimate of the stock abundance at the end of the assessment time series and a point estimate of the target fishing mortality rate (F) for the period of the forecast. Typically, future recruitment is treated as a random process so a probability distribution of future catch and abundance is forecast. More complete implementations also take into account uncertainty around the estimates of current abundance and target fishing mortality rates. Where fisheries are managed to achieve a specified target catch, it is important to also take into account the fact that future F levels resulting from this catch will depend upon current and future recruitment levels, which are not known at the time of setting the target catch level. There can be a several year time lag between

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Jane Lubchenco, Ph.D.
Administrator of NOAA

National Marine Fisheries Service
Eric C. Schwaab
Assistant Administrator for Fisheries

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Office of Science and Technology, F/ST
National Marine Fisheries Service, NOAA
1315 East West Highway
Silver Spring, MD 20910

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