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Incorporating experimentally derived estimates of survey trawl catchability into the stock assessment process

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During the course of the April, 1996, meeting of the Fishing Technology and Fish Behavior Working Group it became clear to many that the methodology for experimentally estimating the catchability of survey trawls might have progressed sufficiently to produce estimates useful for stock assessment. To determine whether the formation of a formal Study Group would be

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warranted to study the methodology and utility of experimentally derived estimates of trawl catchability, Steve Walsh, chairman of the FTFB, requested David Somerton to form an ad hoc group to consider the question and report its findings at the next FTFB meeting. The group included four members who have conducted experiments to measure trawl performance (Godo, Ramm, Somerton, Walsh,) and two members who have analyzed or fit stock assessment models to trawl survey data (Ianelli, Smith). The following report, which attempts to synthesize a rather brief e-mail discussion among the members of the ad hoc group, will consider the problem from the perspective of three questions: 1) What does the term “catchability” really mean?, 2) Are experimentally derived catchability estimates useful for stock assessment? and 3) Can experimentalists now produce good estimates of catchability?

1. What does catchability really mean?

Those who experimentally estimate trawl catchability (experimentalists) and those who might use these estimates in a stock assessment (modelers) view catchability from different perspectives. To modelers, the catchability coefficient, q, is the proportion of the stock removed by one unit of fishing effort, or, alternatively, it is the proportionality constant between stock size and survey CPUE. To experimentalists, catchability is the proportion of the animals within the area swept by the trawl that are captured. To avoid confusion, we follow the convention of Dickson (1993a) and consider the second interpretation as trawl efficiency or Q. For survey trawls, the two quantities are proportional:

$$q = Q\frac{a}{A}$$

where the proportionality constant is the ratio of the average area swept in one trawl haul, a, to the total area of the survey, A. Values of Q vary between 0 and 1 if the swept area is measured between the trawl doors and potentially up to about 3 if swept-area is measured between the wings. By comparison, values of q are quite small, because values of a/A are typically small. If the survey area does not encompass the entire geographic range of the stock, then the right side of the above equation is multiplied by an availability coefficient expressed as A / A^* where A^* is the area occupied by the stock. When availability is not unity, the relation beween q and Q will tend to be more complicated than a simple proportion. For example, an experimentalist may find that Q increases asymptotically with fish length, but q may increase to a maximum and then decline with fish length if large fish tend to occur at greater depths than those sampled by a survey. Thus the value of q needed by modelers is not necessarily estimable by experimental techniques focused solely on gear performance.

2) Are experimentally derived catchability estimates useful for stock assessment?

The state-of-the-art methodology for stock assessment is the catch-at-age model which in the Atlantic is primarily a tuned VPA model and in the Pacific is primarily a statistical catch-at-age model such as CAGEAN or Stock Synthesis (Hilborn and Walters 1992). These models typically require at least fishery catch data by age class, an estimate of natural mortality rate and survey CPUE values. Provided that the data are accurate, the time series are relative long and the population has experienced sufficient contrast in abundance, both types of catch-at-age models can estimate q as functions of both age and time. Experiments utilizing simulated data conducted by both ICES (ICES 1988) and the US National Research Council (Ianelli and Fournier 1996) have shown both approaches can produce unbiased estimates of q.

The primary need for independent estimates of survey Q therefore arises when the data available to catch-at-age modeling are insufficient to allow good estimates of q. Consider four examples of this. First, catch data are now unavailable for many Eastern Canadian stocks due to fishing moratoriums in response to low stock abundance. In the absence of catch data, current population estimates from VPA are unreliable and fisheries managers have turned to swept area abundance estimates produced by bottom trawl surveys. Second, Bering Sea snow crab cannot be aged. Since length-based models of snow crab dynamics have not been implemented, fisheries managers have likewise turned to swept area estimates of biomass. In both cases, biomass estimates are based on the assumption that Q = 1.0. Although in these cases an experimentally derived value of Q might provide a more accurate estimate of stock size, one could also argue that the use of a different modeling approach might be a better solution. Third, several stocks in the Northeast Pacific have the requisite types of data but, due to the short time series, model estimates of q are unreliable. Experimentally estimated values of Q could be used instead to constrain the model at more appropriate values of q or, alternatively, could be used to define a prior distribution on q in a Bayesian approach. Fourth, many developing fisheries have essentially no time series of catch data and are managed with swept area abundance estimates. In the last case, experimentally derived estimates of Q are critical to obtain unbiased estimates of abundance.

Another reason why experimentally derived estimates of Q may be useful to the stock assessment process is that q and natural mortality (M) are confounded in most stock assessment models (Thompson 1994). Since it is difficult to obtain independent estimates, M is typically assumed to be age independent and fixed at some reasonable value. Independent estimates of q, however, might allow M to be estimated better and perhaps provide a means to detect age dependency in M.

Estimates of the relative, rather than the absolute, value of Q are also important to stock assessment. Consider two cases. First, when survey CPUE data are used in multispecies models, relative values of Q are needed to scale the CPUE of each species to relative abundance. Second, hydroacoustic surveys need estimates of Q by size class for their sampling trawls to correctly estimate target strength.

In summary, the primary contribution of experimentally estimated values of trawl survey Q to the stock assessment process will be in cases where the data needed to support a stock assessment model are deficient. In some cases the deficiency could be rectified by using a different approach to modeling or data collection. In other cases, however, abundance estimates rely on survey catch per effort. In these cases, experimentally derived estimates of Q are needed to reduce the likelihood of large biases in the biomass estimates.

3. Can experimentalists now produce good estimates of Q?

Before considering this question, we examine the four approaches now used by experimentalists to estimate Q for trawls. The first type is essentially a gear comparison experiment where Q is estimated as the ratio of animal density (catch per area swept) from the trawl to density estimates from a gear type believed to be completely efficient, such as visual transects from an ROV (Adams et. al 1995) or minisub (Krieger and Sigler 1995). The second type of experiment utilizes a Leslie or DeLury depletion experiment in which a trawl is repeatedly used on a small closed population until the density has been substantially reduced (Joll and Penn 1990, Somerton and Otto, in prep). The third type utilizes acoustic transponding tags to determine the fate of individual fish initially positioned in the trawl path (Harden-Jones et. al

1977). The fourth type focuses on one of the three components of the trawl catching process: vertical herding, horizontal herding and escapement (Dickson 1993a).. The estimates of Q are then obtained by combining components in a mathematical model of the catching process (Dickson 1993b, Somerton and Munro in prep). The fourth approach, which is the most versatile, has received the most attention in recent years and will be considered in greater detail below.

Vertical herding, which increases the effective fishing height of a trawl, occurs when fish dive from mid-water into the trawl path in response to the sound produced by an approaching vessel. To be useful for estimating Q, experimentalists must be able to estimate either 1) a vertical herding coefficient equal to the proportion of fish in the water column that occur below the headrope at the moment of trawl passage or 2) the average distance that a fish will dive. Quantitative estimation of vertical herding is still in its infancy, but has been pursued by acoustically assessing changes in the vertical distribution of fish from a buoy mounted array as a ship passes nearby (Godo and Totland MS) or by comparing hydroacoustic and bottom trawl estimates of density (Aglen 1996).

Horizontal herding, which increases the effective fishing width of a trawl, occurs when fish avoid the trawl doors, mudclouds and bridles by swimming into the path of the trawl. To be useful for estimating Q, experimentalists must be able to estimate either 1) a horizontal herding coefficient equal to the proportion of fish between the doors and the wings that are herded into the path of the trawl or 2) the average horizontal distance a fish will swim to enter the trawl path. Quantitative estimation of horizontal herding has been accomplished by modeling changes in catch that occur when the bridles or sweeps are varied in length (Engas and Godo 1989a, Ramm and Xaio 1995, Somerton and Munro in prep).

Escapement occurs primarily when fish dive under the footrope (escapement through the net mesh is negligible on survey trawls with small-mesh liners and escapement over the headrope is another form of vertical herding). Experiments to estimate escapement have either attached auxiliary bags under the belly of a trawl to capture escaping fish (Engas and Godo 1989b, Walsh 1992, Munro et. al. in prep) or have attached video cameras on the trawl to count escaping fish (Weinberg et. al in prep, Somerton and Munro in prep).

Whether the experimental method measures Q in total or in parts, all of the approaches can lead to unbiased estimates under appropriate conditions. To be most useful, however, the conditions appropriate for the experiment must be representative of the conditions encountered on the survey. This is not always easy for the experimentalist to control. For example, trawl Q will differ between day and night, between deep and shallow water, and between smooth and rough bottom, yet video techniques to estimate escapement cannot be used at night and in deep water because of insufficient light and under-trawl bags cannot be used in rough bottom because they are too fragile. Even if non-representative sampling were not a problem, year-to-year variability in Q is likely to be sufficiently large so as to require repeated Q estimation experiments.

In summary, it is doubtful that any experiment has successfully estimated a value of Q that captures the spatial and temporal variability sufficiently well to allow precise, unbiased estimation of biomass from trawl CPUE data. Uncertainty about the relative importance of various potential sources of variability was a topic independently raised by nearly all members of the ad hoc group. The group recognized that such knowledge would allow better designed experiments to estimate Q and would have the potential of reducing the variance of survey CPUE data. Furthermore, if the process of Q variation could be understood sufficiently well it may be possible to control the sources of variation collectively known as the "vessel effect" in multi vessel surveys, thus eliminating the need for costly vessel comparison experiments. Most members of the group believed that further study of the spatial and temporal variability of Q is critical and that the use of Q estimates in management decisions without this knowledge may not be prudent.

Recommendations

It is unfortunate that in most fisheries research institutes the scientists we have referred to as experimentalists and modelers have little contact. Experimentalists may have the ability to estimate parameters or test assumptions crucial to model performance, but are unaware of the potential for their contributions because they lack the intimate knowledge of model structure and fitting procedures. Conversely, modelers may clearly see the tenuous aspects of the model, but are unaware of the help they might get from experimentation. Therefore, one of the real contributions of a new Study Group examining the incorporation of survey Q estimates in the stock assessment process is that it would create a forum for collaborative studies between the two disciplines. It is important that the experimentalists join forces with both survey scientists as well as stock assessment modelers so that survey data are improved in ways most beneficial to the stock assessment models and the fishery management process. This improvement might be derived from a better understanding of survey Q variation that would allow modelers to statistically correct for changing Q or allow survey scientists to reduce Q variability with appropriate changes to sampling protocol.

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