Estimating Trawl Catchability

By Dave Somerton

Swept-area estimates of groundfish biomass, the primary product of Alaska Fisheries Science Center (AFSC) bottom trawl surveys, require knowledge of the proportion of fish captured within the swept area of a trawl (***Q***). Until recently, ***Q***, also known as catchability, had never been estimated for any species sampled by bottom trawl surveys and was assumed to equal 1.0 in the calculation of biomass. Recent studies by both Norwegian and Canadian investigators, however, have shown that the processes of fish herding and escapement often lead to values of ***Q*** that are quite different from unity. Because departures of ***Q*** from unity can result in biased estimates of biomass and possibly faulty advice for fishery management, the Groundfish Assessment Task of the AFSC Resource Assessment and Conservation Engineering (RACE) Division initiated a study designed to experimentally estimate the value of ***Q*** for several species sampled with the 83-112 bottom trawl (Fig. 1) used on the annual National Marine Fisheries Service (NMFS) surveys of the eastern Bering Sea.

To conduct the study, we used a highly simplified model of how a bottom trawl catches fish. We considered two distinct areas influenced by the trawling process: 1) the area bounded by the wings of the trawl--the net area and 2) the area bounded by the wingtips and the doors--the bridle area (Fig. 2). We also considered the trawling process as consisting of two components: 1) the herding of fish into the net path by the action of the bridles and the mudclouds that form in the wake of the doors and 2) the escapement or avoidance of the net. Using these simple parameters, we then defined a bottom trawl catch as made up of 1) fish originally in the net path that failed to escape and 2) fish originally in the bridle path that were herded into the net path and likewise failed to escape. Algebraically, this is expressed as

$$C = (eA_n + ehA_b)\,D$$

Where

C = catch
A_n = net area
A_b = bridle area
D = fish density
h = proportion of fish in the bridle area herded in to net area
e = proportion of fish in net area caught.

Expressed in terms of these parameters, ***Q*** is estimated as

$$Q = e + eh\frac{A_b}{A_n}$$

Because A_b and A_n can be measured, the problem of estimating ***Q*** is reduced to the problem of estimating two independent parameters: net efficiency (***e***) and herding (***h***). We estimated each of these parameters using the field experiments described below.

BOTTOM TRAWL

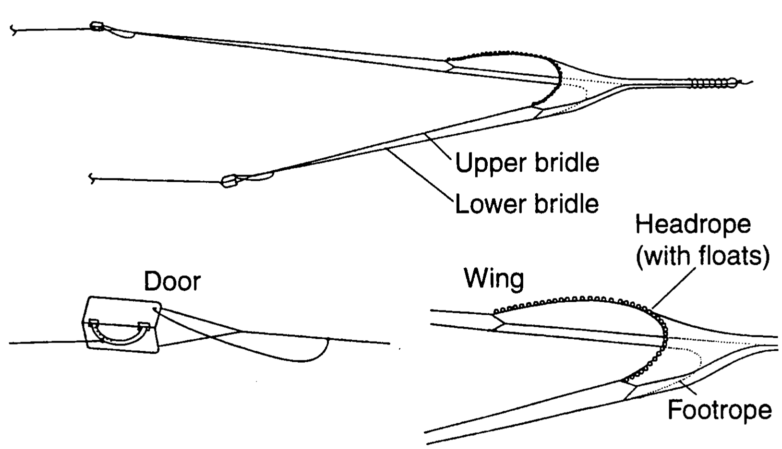

Figure 1. Components of the 83-112 bottom trawl.

Herding experiments

Our experimental approach to estimate the herding parameter was to repeatedly trawl in an area in such a way that A_n was held constant while A_b was varied in three increments by changing the length of the bridles. We reasoned

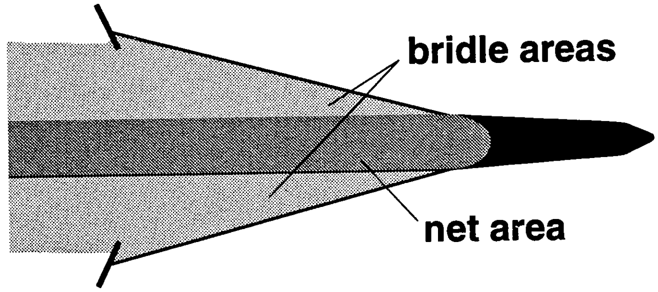

Figure 2. Fishing areas of a trawl.

that if herded fish comprised a significant part of the catch, then the catch should increase as the area exposed to herding, A_b, increased. The first of three herding experiments was conducted in September 1993 near Kodiak, Alaska, aboard the NOAA research vessel *Miller Freeman*. The experiment was primarily a pilot study to develop sampling methodology and to determine if the target species, arrowtooth flounder, displayed any tendency to herd. The second herding experiment, conducted in July 1994 in the eastern Bering Sea aboard the chartered fishing vessel *Aldebaran*, applied the methodology to Pacific cod, snow crab, and three species of flatfish. The third experiment, conducted in September 1994 aboard the research vessel *Alaska* off the Washington coast, applied the methodology to five species of flatfish. All three experiments followed a blocked sampling design of repeated, nearby but non-overlapping trawl hauls with each of three bridle lengths (27, 55, and 82 m). On all tows, both the wing spread and the door spread were measured with an acoustic net mensuration system, and the tow length was measured by monitoring a global positioning system between the first and last contact of the footrope with the bottom.

One complication we encountered was that the process of herding differs among species. Roundfish, such as Pacific cod, appear to be herded by the mudclouds created by the doors, whereas flatfish appear to be herded by direct contact with the lower bridles. Since the lower bridles are not in contact with the bottom over their entire length (Fig. 1), the effective bridle area for flatfish is smaller than it is for roundfish. Thus, to correct A_b for this effect, we conducted an experiment to measure the length of the bridle that was not in contact with the bottom. To do so, we tethered a videorecorder to the upper bridle to record contact of the lower bridle with the bottom from 15 to 35 m behind the doors at 5-m increments. Analysis of resulting video images demonstrated that the lower bridle's degree of contact with the bottom increased with increasing distance behind the doors and that at 28 m, contact was estimated to be maintained 50% of the time. This distance between the door and the point of 50% bottom contact was assumed constant for all bridle lengths and, after converting to the equivalent width of bridle area, was used to reduce A_b for flatfish.

Estimates of h were obtained by regressing catch-per-swept-area (C/A_n) against the ratio of A_b to A_n (Table 1). For flatfish species, h typically varied between 0.20 and 0.30 (i.e., 20%-30% of the fish within the uncorrected A_b were herded) but ranged from 0.10 for Pacific sanddab to 0.47 for slender sole. To put this in perspective, an h estimate of 0.30 would indicate that 38% of the catch was herded into the net path from the bridle path. If there were no escapement under the footrope, the effect of such herding would lead to a 60% overestimate in biomass.

Snow crab and Pacific cod both had h estimates of 0.0—in other words, neither species displayed any tendency to herd. This is not surprising for snow crab, because they are fairly sluggish at the temperatures in which they are usually found. However, the apparent lack of herding of Pacific cod is noteworthy because several European studies have reported that Atlantic cod is quite effectively herded by their survey trawls. This difference could be related to differences between Pacific and Atlantic cod or differences in trawl design.

Net efficiency experiment

The net efficiency of the 83-112 trawl was estimated for four species of flatfish (flathead sole, yellowfin sole, rock sole, Alaska plaice) by directly observing fish behavior with an underwater video system. Our experiment, conducted in August 1995 in the Bering Sea aboard the *Aldebaran*, consisted of mounting a low-light, videorecorder to the trawl pointing

Table 1. Estimates of the proportion of fish herded into the 83-112 bottom trawl in experiments conducted off the coast of Washington and in the eastern Bering Sea.

Washington		Bering Sea	
Species	**h**	**Species**	**h**
Rock sole	0.30	Dover sole	0.27
Yellowfin sole	0.22	English sole	0.19
Flathead sole	0.20	Pacific sanddab	0.10
Pacific cod	0.00	Rex sole	0.23
Snow crab	0.00	Slender sole	0.47

directly downward to view the footrope. The videotapes were later viewed for counting fish that went into the net or under the footrope. Efficiency was then estimated as the number of fish that entered the net divided by the number of fish encountering the footrope. The mean efficiency, 0.78, was considerably lower than previously estimated by stock assessment scientists.

Our experiment had two weaknessess. First, the effective maximum depth for videorecording was limited by the use of ambient light to about 40 m, too shallow to include the total habitat of the target species. As a consequence, only 7 of 25 tows had sufficient light for a reliable count of the fish. Second, because neither the species identity nor the size of flatfish could be reliably determined, we were forced to combine all flatfish species and count only individuals longer than about 25 cm, the size at which previous studies have shown maximum net efficiency is reached for flatfish.

To circumvent these problems, members of the Groundfish Assessment Task plan to estimate net efficiency by using a method pioneered in Europe that consists of attaching an auxiliary net under the belly of the trawl so that fish escaping under the footrope are captured by the auxiliary net. This experiment was applied to the Poly Nor'eastern trawl during the 1996 Gulf of Alaska triennial groundfish survey. Results of that work are now being analyzed.

Catchability

At present, values of ***Q*** can be calculated only for the three species of Bering Sea flatfish that have been the subjects of both herding and escapement experiments—1.2 for yellowfin sole, 1.3 for rock sole, and 1.1 for flathead sole. Since all of the ***Q*** values are greater than 1.0, the effects of herding exceed the effects of escapement and result in estimates of fish density that are greater than the actual density. Considering yellowfin sole, for example, such an overestimation in density has led to a 20% overestimate in biomass.

Members of the Groundfish Task will continue to experimentally estimate ***Q*** for a variety of species sampled by each of the three distinct trawls used in NMFS groundfish surveys—the 83-112 trawl, the Poly Nor'eastern trawl with a bobbin footrope, and Poly Nor'eastern trawl with a disk footrope—with the objective of providing more accurate estimates of biomass for use in assessment models. In doing so, we hope to gain more information on the process of how fish are caught by trawls so that we can define better sampling proceedures to minimize the variability in ***Q*** among survey vessels and years.