Quantification of cod-end selectivity is primarily achieved by experimental trials at sea which often require large numbers of tows to obtain valid results. The ability to model and predict cod-end selectivity in different scenarios could potentially be a complimentary ‘on-shore’ tool to improve the process of assessing different cod-end designs. Such a modelling tool requires an understanding of the behaviour of fish inside the cod-end. The aim of this study was to provide a quantitative description of haddock behaviour inside the cod-end of a commercial trawl.

**Methods**

Underwater CCD cameras (ROS) were fitted to a circular metal hoop, 1m diameter, tied into the cod-end of a Scottish commercial whitefish trawl: one outside the net on the topsheet of the cod-end and one inside, mounted on a cross bar, angled upwards at 45° to the direction of tow. This inside camera allowed fish swimming in the top half of the cod-end ahead of the catch to be viewed (Figure 1).

In the first approach, the general behaviour of fish inside the cod-end was observed from video of a single haul (120mm mesh size). The first 3 speed blocks were analyzed, with one block divided into two sections of different densities. At very low densities, all fish that came into view could be observed. As numbers in view increased, a series of “start frames” were sampled and all fish present were followed from when they originally entered the camera view (prior to the start frame) until leaving. The duration in view of the camera, sequence and duration of the different behavioural categories observed (see table 1) were recorded.

The second approach focused on analyzing when and where fish attacked the net and tried to escape. Inside camera footage from the four hauls was used. For one of these three hauls the video was also available from outside the top sheet. Outside footage from a further 4 hauls was also viewed.

**Results – Non escape behaviour**

Catch composition was dominated by haddock with a few whiting. It was not always possible to distinguish between the two species and the data presented refers to all “gadoid” observations.

Figure 1 summarises the observed behaviour of gadoid fish in the cod-end of a trawl. Short (<2s) and long (>2s) observations are presented separately. Initial density was very low with a high number of short (<2s) sequences of behaviour. Steady swimming in the direction of the low ahead of the catch accounted for 60% of the observation time in these short sequences. Fish appeared to move forward, backwards or hold station in relation to the camera in a cyclic pattern caused by the pulsing action of the cod-end, to which the camera itself was attached. Fish were also observed orientated side-on, drifting backwards, turning and/or swimming in the opposite direction to the trawl along with a small number of escape attempts. The mean duration of individual behaviours was less than 1 second.

Figure 3 Position of escapes (left) and attempted escapes (right) for 4 hauls.

Figure 4 Variation in rate of escapes at different towing speeds observed from inside (a) and outside (b) camera footage. Rate of approaches, relative to density of fish present aggregated by towing speed (c) and density (d).

**Results - Escape behaviour**

A grid overlaying the video was used to quantify where fish approached the net and attempted to escape. The netting in view moved over the course of each video, but approaches were generally concentrated in the areas where meshes were most open. (Figure 3, left).

The rate of escape success ranged from 19-35% of all approaches. A small number of fish (4%) made two successive escape attempts. Just under 1/3 of these second attempts resulted in an escape.

The escape rates recorded from the inside and outside cameras were similar (Figure 4a & b), with higher mean escape rates at higher speeds. The rate of approaches to the net, both successful and unsuccessful, tended to be higher for blocks with a higher density of fish present, but expressed as a proportion of the mean number of fish in view, in that speed block, the approach rate was lower at higher densities (4d). This proportional approach rate also tended to be higher at higher towing speeds (Figure 4c).

At low densities, before the build up of catch, fish behaviour was more “territorial”, with more fish observed to turn, drift or swim against the direction of tow. No successful escapes were observed.

Once the catch has built up, steady swimming (the optomotor response) is the dominant behaviour in the zone ahead of the catch, especially at high densities and/or lower towing speeds. If fish are surrounded by others and able to swim comfortably, they seem to be less inclined to attempt active escape.

At higher speeds, escape rates were higher.

Fish attempting escape target open meshes, with a 19-35% success rate.