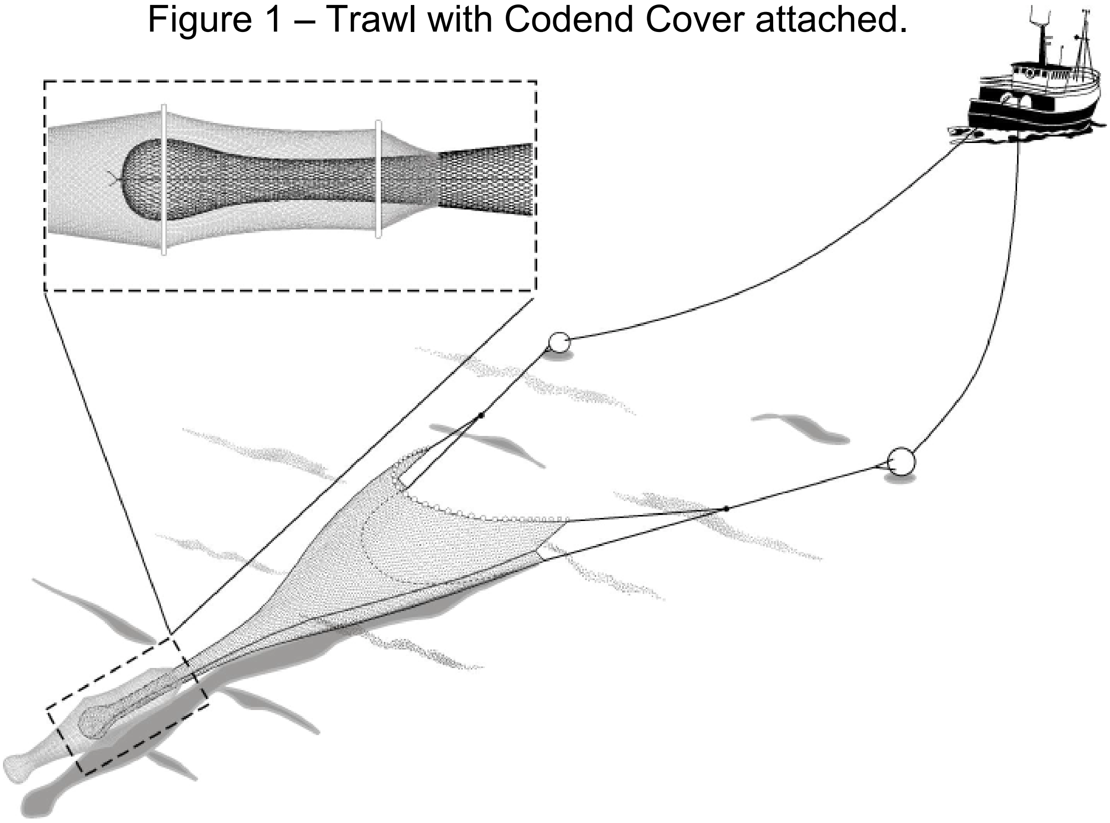
Evidence of sampling induced biases in mortality estimates from experiments investigating mortality in fish escaping from towed fishing gears

Mike Breen, Graham Sangster*, Barry O'Neill*, Rob Kynoch*, Emma Jones* and Aud Soldal[§]. (* Marine Laboratory, Aberdeen, Scotland, UK and [§] IMR, Bergen, Norway)*

Extended Abstract
When studying escapes from trawl codends and other selective devices, the most common method of capturing or 'sampling' escaping fish is using a codend cover (Figure 1). This paper will summarise a programme of work providing evidence for two potential problems with codend covers, when sampling fish for use in survival experiments.

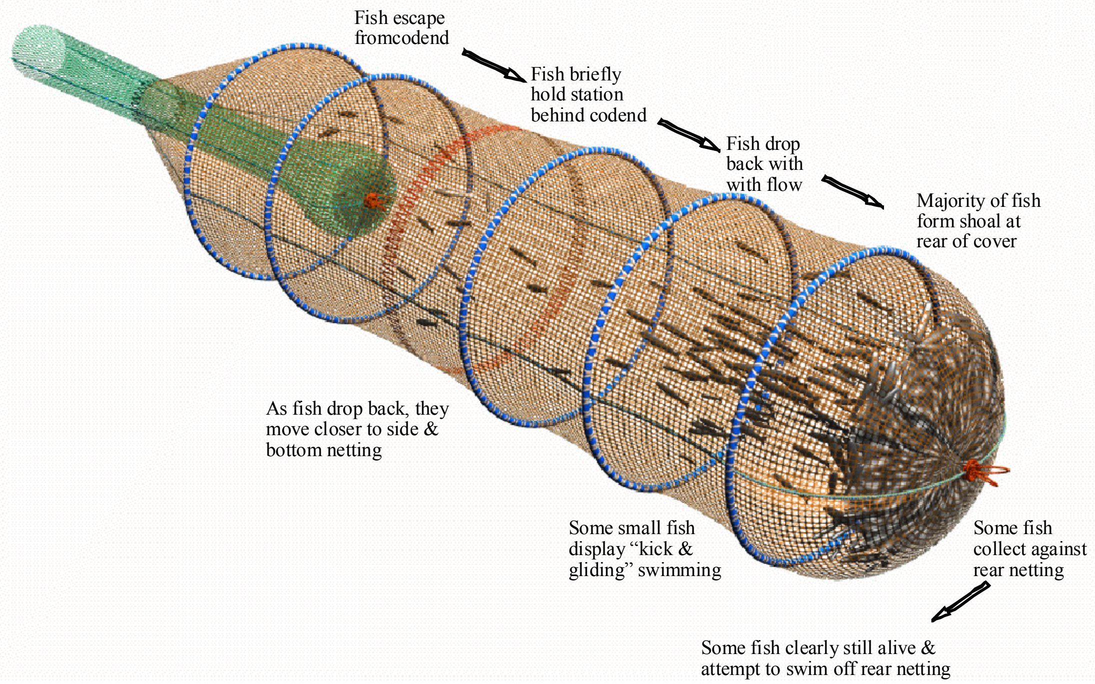
Figure 1 – Trawl with Codend Cover attached.



<u>Direct observations</u>
A series of direct observations, using divers and remote underwater cameras, were made of the behaviour of gadoid fish (in particular haddock) escaping from a trawl codend into a 'survival' cover during a research cruise aboard FRV Clupea. The 'survival' cover was the same as that used in escape survival experiments undertaken by FRS Marine Laboratory and partners (Main & Sangster, 1988, 1990 & 1991 Sangster et al, 1996, Lowry et al, 1996 and Wileman et al, 1999). The cover had originally been designed with the protection of the captive sample in mind. It was constructed of a small, square mesh (30mm), knot-less, nylon netting which was

thought to minimise abrasive contact with the captive fish and restrict water-flow within the cover. The observed behaviour of the fish captive within this cover is summarised in figure 2. The most relevant observation was that a significant number of fish were seen collecting on the netting at the rear of the cover, after only a few minutes of sampling time. It had been assumed that these fish had been killed or were close to death following their passage through the trawl and codend. However, closer inspection by divers revealed that many of these fish were in-fact alive, some repeatedly attempting to swim off the netting, but were trapped there by a substantial flow of water. What was unclear was whether or not these fish were trapped because of injuries or exhaustion received as a result of their passage through the trawl and codend.

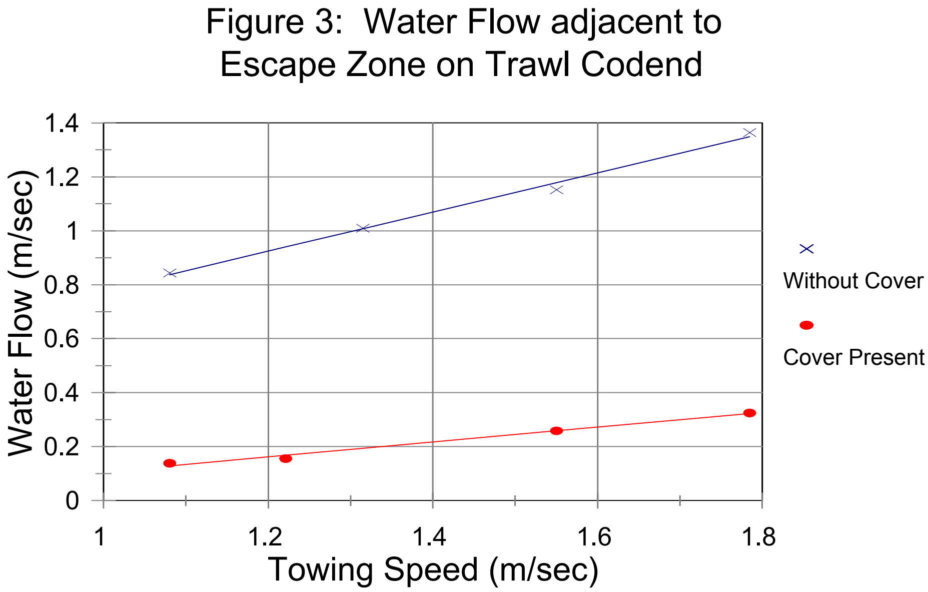
Figure 2: Behaviour of Captive Fish in Codend Cover



Flow measurement

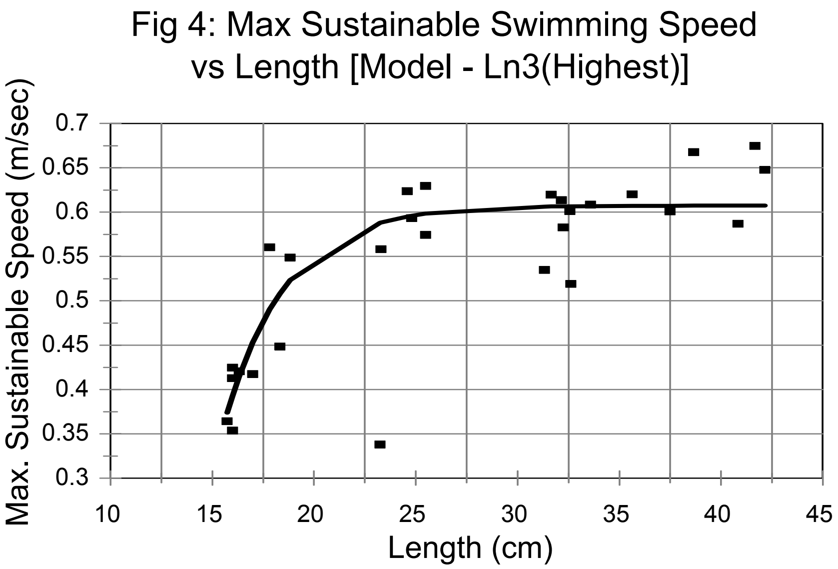
Detailed measurements were made of the water-flow (relative to the cover and codend) within the 'survival' cover both on half scale models, in a flume tank, and on the full scale cover at sea. It was revealed that while flow within the main body of the cover was indeed reduced, at operational towing speeds a substantial flow of water was still present (~0.45 m/sec for a trawl towing at ~1.4 m/sec). The likely impact of the water-flow upon the captive sample of fish was unknown.

In addition, it was shown that the water flow around the covered codend was significantly reduced (by ~80%) in comparison to that observed around a normal, uncovered codend (figure 3). This has important implications for the behaviour of escaping fish and their likelihood of receiving an injury during their passage through the codend meshes. Firstly, the reduced flow will mean the codend experiences less drag and therefore the twine forming the codend meshes will be under less tension. Passage through these meshes by escaping fish will, as a result, be easier and less injurious. Secondly, the passage from within the codend to the fast flowing water mass outside (relative to the codend and escaping fish) would be less hazardous because of reduced cross-flows. Again resulting in a less injurious exit from the codend. In essence, the presence of the 'survival' cover around the trawl codend will protect escaping fish from injurious forces normally experienced during passage through a trawl codend. This would suggest that this method of sampling escaping fish may underestimate the true escape mortality.



Swimming experiments

An experiment was undertaken to investigate the prolonged swimming performance of haddock and estimate maximum sustainable swimming speeds. The method used to measure swimming endurance is based on the technique pioneered by He & Wardle (1986, 1988) using a rotating gantry with light array to stimulate the fish, via the optomotor response, to swim around a circular swimming path in the annular tank at the Marine Laboratory, Aberdeen. Individual haddock and groups of haddock were entrained to swim at a range of speeds (0.5 – 0.8m/sec) at a constant temperature (10 ± 0.5°C).

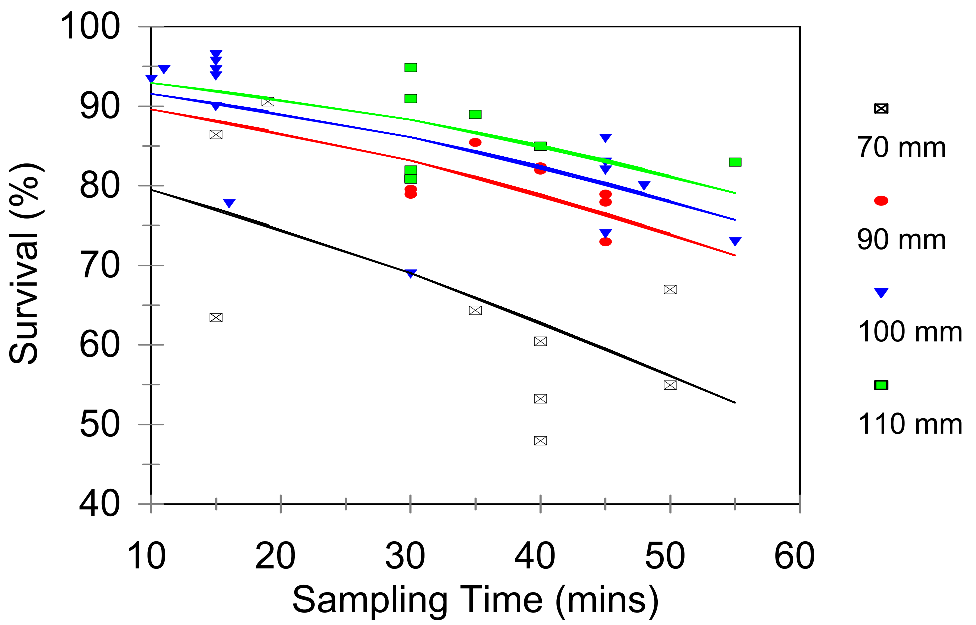


Endurance was shown to be highly dependent upon the swimming speed and size of individual fish. Maximum sustainable swimming speeds were estimated for individual fish from their endurance data and shown to be related to length, particularly among smaller fish (figure 4). Comparison of this relationship with the water flows experienced in the main body of the cover at operational speeds (~0.45 m/sec), suggests that the majority of smaller haddock (<18cm) would be unable to sustain the swimming speeds necessary to maintain position within the cover. These fish would be forced against the rear of the cover were they may receive a number of life threatening injuries, including skin abrasion and suffocation.

<u>Reviewing Historic Data</u>

The evidence from the swimming performance trials would suggest that water flow conditions within the 'survival' cover have induced a significant biasing mortality, particularly among smaller fish, in previous escape mortality investigations. If this were true, examination of past work should reveal two distinct trends. Firstly, it would be expected that escape mortality in haddock would be inversely proportional to length. This has been demonstrated in three separate experiments (Sangster et al 1996, Lowry et al 1996 and Wileman et al, 1999). Secondly, mortality would be expected to increase with increasing sampling time (ie. the period of time from when fish start to be collected in the cover to when it is released from the trawl). This relationship was confirmed by Breen et al (1999) when data from previous FRS escape survival investigations was modelled with respect to 15 potential explanatory variables (figure 5), of which sampling time and mesh size proved to be the most significant factors.

Figure 5: Relationship between Escape Survival, Sampling Time and Mesh Size for Haddock



Summary
This paper has demonstrated that, for haddock at least, current designs of codend cover are inappropriate for sampling fish escaping from towed fishing gears for use in survival experiments. Two confounding biases have been highlighted. Firstly, the presence of a cover significantly reduces the water flow around the codend (by ~80%), which is likely to affect escape behaviour and reduce the likelihood of injury during escape. Secondly, while the flow around the codend is reduced, there is still a substantial flow of water in the main body of the cover (~0.45 m/sec for a trawl towing at ~1.4 m/sec). From swimming endurance experiments on haddock, it is clear that the majority of smaller fish (<18cm) captive in the cover would not be able to sustain the swimming speeds demanded by these observed water flows. These fish are likely to receive life threatening injuries as a result of their captivity in the cover.

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