RAPPORT FRA HAVFORSKNINGEN

Nr. 5–2016

ISSN 1893-4536 (online)

Flume tank testing of a multiple inner-paneled trawl to reduce loss and clogging of small organisms

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Background:

Trawl catch data from surveys is used towards stock assessments and ecological studies with the general assumption that the trawl efficiency is the same between hauls and between years. In 2012, trials conducted with the Deep Vision stereo camera system mounted in the Harstad survey trawl indicated that individuals were meshed prior to the codend, with high numbers of previously meshed individuals entering the codend at the surface during haul back (Underwood *et al*, 2014). The trawl is constantly changing between tight and slack during the surface phase of haul back, causing the meshes to open and close. This action likely shakes enmeshed individuals free. Hauling procedures and/or weather conditions can alter the duration and rate at which these meshes open and close. If the escapement or entering of the codend differs from haul to haul, the assumption that the trawl has a constant efficiency is not valid, affecting the assessment and advice.

Small mesh liners, sized slightly smaller than an outer “frame” of large meshes are presently used in the commercial krill fishery. These liners are constructed as a series of overlapping cones, resulting in a wave movement that undulates gently with the flow of water and prevents small organisms from becoming enmeshed. This design was adapted for the Harstad trawl and first tested in 2013 (Engås *et al*., 2013). Initially, four 6 m inner panels of 8mm mesh were tested in the aftmost 21 m of the trawl. Subsequent investigations increased this to six panels lining the final 31 m of the trawl (Engås *et al.*, 2014). Though the catch rates were low, the inner panels were observed to move in a wave motion towards the condend, preventing individuals from becoming caught in the meshes.

In 2014, video observations were made of the IMR krill trawl with attached multisampler. High numbers of small individuals were caught in folds of excess netting in the inner panels of the trawl and in front of the multisampler. These individuals were released during haul back and entered the last codend which was activated at the surface (Engås. Personal communication).

As similar problems were observed with both the Harstad and the IMR krill trawl, flume tank testing was undertaken in 2015 to investigate the performance of the small mesh inner panels as well as options to improve the trawl’s taper into the rigid frame of the multisampler. Different tapers, mesh orientation, and circumferences were tested to arrive at a design to both maximize the wave like movement of the liner panels and minimize excess netting and pockets ahead of the multisampler.

Model:

A 1:3 model of a trawl with nine 4.5 m inner panels (Fig. 1) was used for the flume tank tests. Each inner panel was attached to the outer frame at the forward seam and the aft of the inner panel was not attached allowing for the inner panel to move in a wave motion towards the codend. The model was designed with different tapering of the inner panels from no tapering (inner panels #2 and #8) to 60 % tapering (inner panel # 9). Two extra panels were also made for testing; an inner panel #8 with a reduced circumference and an inner panel #9 with a tapering of 77%. The multisampler was simulated using a rigid steel frame also produced in 1:3 scale model. As with the full scale multisampler, the steel frame was mounted at a 45 degree angle and brought to neutral buoyancy using three air-filled buoys.

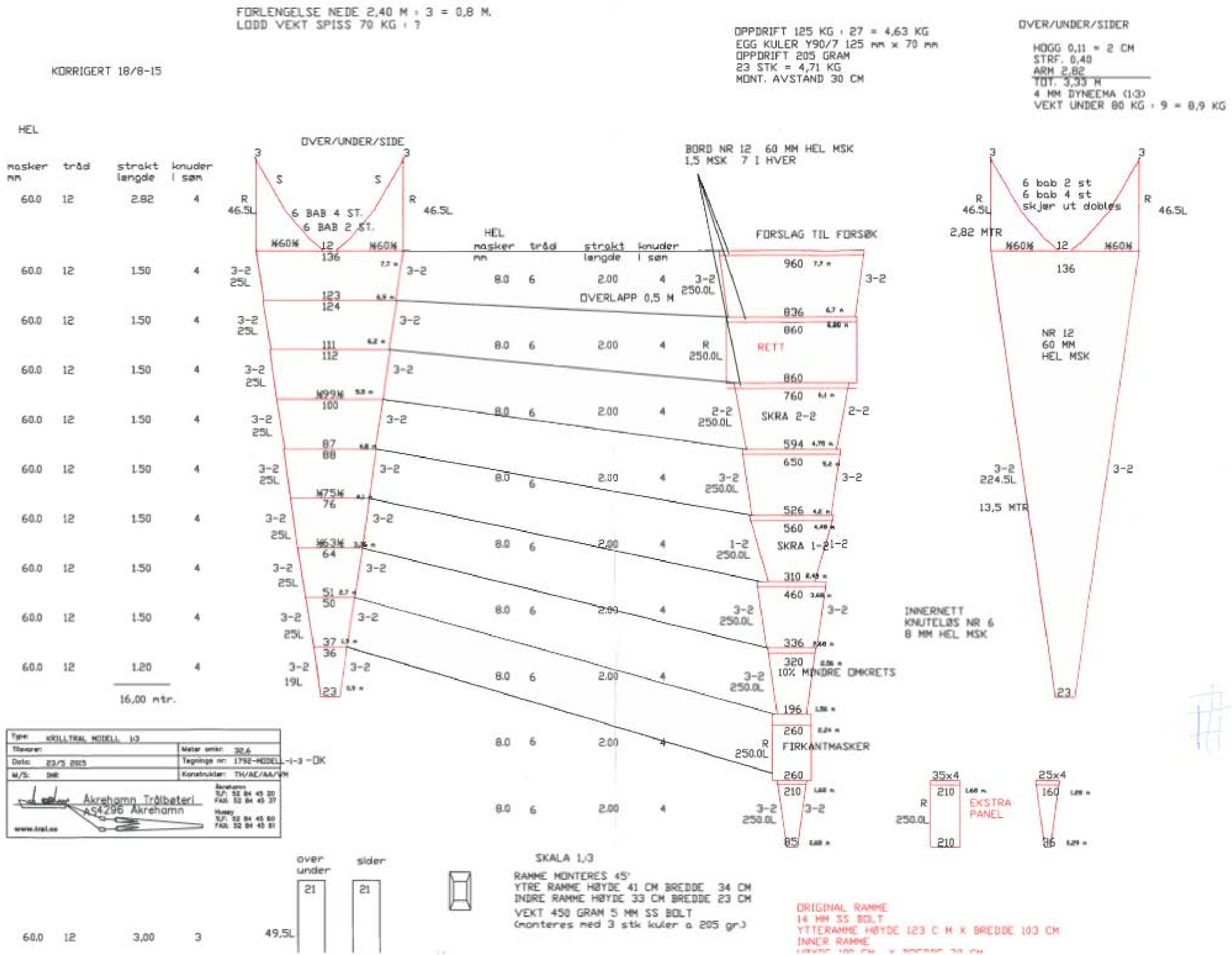

Figure 1: *Drawing of the trawl with the outer frame and the nine inner panels (In Norwegian). Mounting positions of the inner panels to the outer frames are indicated in black. The two extra panels for inner panels #8-9 are in the lower right corner. Note that the majority of panels are diamond orientation and tapered, while panels 2, and 8 are untapered and panel 8 is constructed with meshes in square orientation.*

Flume tank testing:

Flume tank testing was carried out at the SINTEF flume tank in Hirtshals, Denmark on the 15th September, 2015. Initial observations of the model indicated there were two main areas of concern. Firstly, excess netting led to a lot of folds in the inner panels of the trawl and the inner panels #1-4 were not moving as much as previously observed on the cruises. Secondly, excess netting combined with the flow of water inside the trawl created a pocket in front of the multisampler. These two areas were the main influence on the seven tests of the model and the alterations of the model (Table 1).

Table 2: *Description of the seven flume tank tests conducted and comments on the observations of each test.*

Test	Water Speed (scaled)	Wing Spread (scaled)	Rigging/Alteration	Comment
#1	2.5 knots	6m	Original model	Excess folds in inner panels #1-4
#2	2.5 knots	8.2m	increase wing spread to 8.2m	
#3	2.5 knots	8.2m	Inserted flow meter in section 7	No reduction in flow: 0.76 m/sec flow in tank, 0.85 m/sec inside trawl from flow meter (this is within measurement error)
#4	2.5 knots	12m	increase wing spread to 12m	Improvement in inner panel #4, little change in first 3 inner panels
#5	2.5 knots	12m	Reduce inner panel #2 circumference by 20% Replace inner panel #9 with one with greater taper (160 meshes to 36 meshes over 6 m).	There is some improvement to the second inner panel, particularly in the bottom panel (compare with test #4), but folds in the panels are still present. Results entering multisampler frame are a bit problematic because of the untapered inner panel #8 which has numerous folds in the panel netting.
#6	2.5 knots	12m	Reduce inner panel #2 circumference by additional 10% (now 30% smaller than outer net) Replaced inner panel #8 with 210 x 210 extra panel (this is 35% smaller than the outer frame).	There is now much more motion in inner panel #2, but seemingly less in #8 (perhaps because it is square while outer frame is tapered).
#7	2.5 knots	8m	Decreased wingspread back to 8 m.	Makes little difference in movement, if anything maybe a bit less than with 12 m wingspread.

To decrease the amount of folds in inner panels # 1-4, the wing spread was increased. After increasing the wing spread from 6m to 12m, the number of folds was reduced in inner panel #4 (Fig. 2 a-b), however, there was little improvement in inner panels #1-3. The water flow inside the trawl was also tested to see if a reduction in flow could be a contributing factor but this was not the case. It was decided that the circumference of the inner panels was too large in comparison with the outer frames and inner panel #2 (a panel originally having no taper) was reduced to test the difference in circumferences. The inner panel circumference was reduced to 20 % then 30 % of the circumference of the connecting seam of the outer frame. The reduction of 30 % led to an improvement in the movement of the inner panel #2 (Figure 2 c-d).

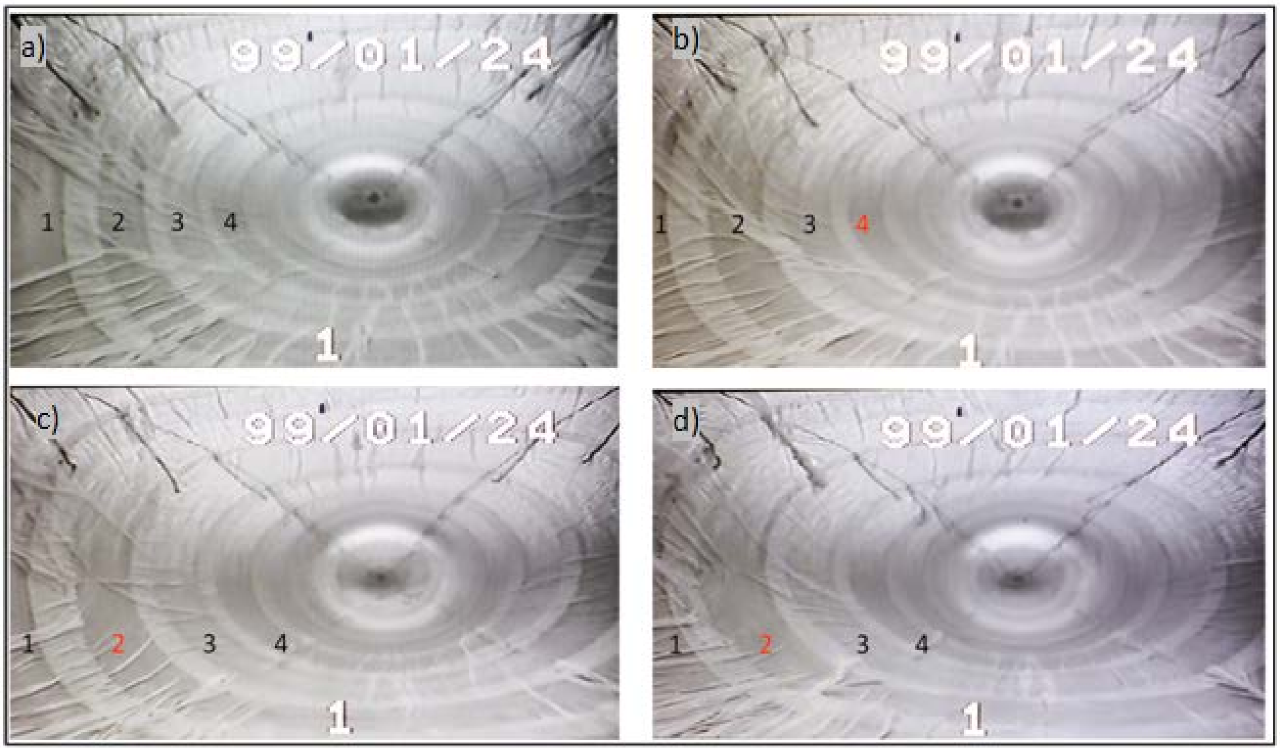

Figure 2: *View of inner panels, looking back to the codend, during four of the flume tank tests. a) the original model at 6m wing spread, b) the original model at 12m wing spread, c) a 20% reduction in inner panel #2 circumference and d) a 30% reduction in inner panel #2 circumference. The inner panels #1-4 are labeled in each picture. Red numbers indicate the panels with an improvement in the trawl performance.*

To reduce the pocket due from too much netting connected to the multisampler, inner panel #9 (60 % taper) was replaced with a more tapered panel (77 %). The new panel helped with the transition into the multisampler frame, but it did not fully solve the problem. It was thought that since inner panel #8 had a lot of folds (indicating excess netting), it might have also added to the problem. The inner panel #8 was then replaced with a non tapered panel with a circumference of 35 % less than the circumference at the connecting seam of the outer frame. The reduction in circumference of inner panel # 8 improved the shape of the trawl and the transition to the multisampler (Fig. 3).

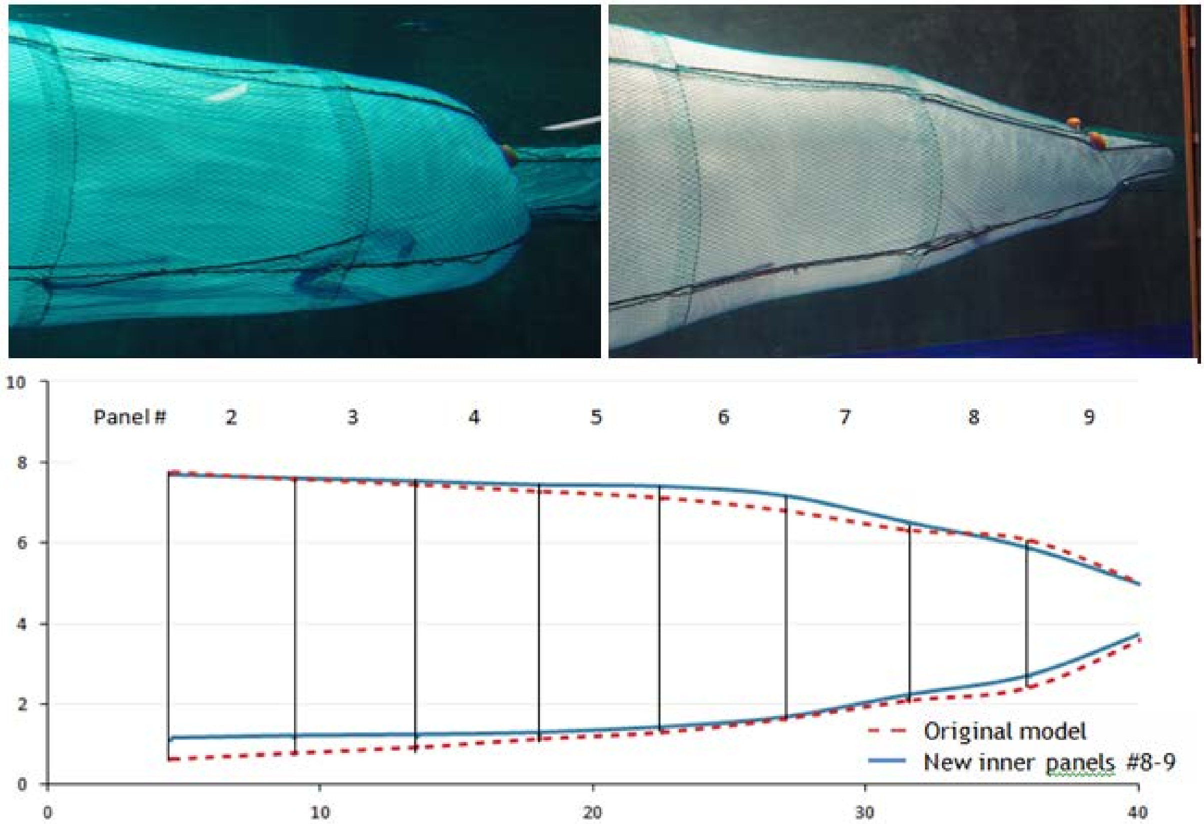

Figure 3. *Change in the shape of the trawl. Before (upper left) and after (upper right) the inner panels # 8-9 were altered, and the cross-section view of inner panels #2-9 (lower; plotted from measurements made from rail-camera rig outside the tank). The inner panels # 2-9 are indicated at the top. The red dashed line is the original shape (test 3) and the solid blue line is with the altered inner panels # 8-9 (test 6).*

Conclusions

Overall, the inner panels moved similar as observed previously in the cruises. The wave like movement of the inner panels towards the codend is due to the hydrodynamic forces/turbulence. The tapering and circumference of the forward part of the inner panels affected the amount of movement in the inner panels. It was agreed that a trawl designed with a low tapering of the outer frame and inner panels that have a) no tapering, and b) a circumference of at least 30 % less than the seam where the inner panel is attached to the outer frame should be tested in sea trials.

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