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Improving the catch efficiency for cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) during bottom trawling in the Barents Sea

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Objectives: Compare two types of ground ropes, i.e. the conventional rock-hopper versus a semi-circle spreading gear to answer questions:

- 1) Is efficiency dependent on species, size of fish and fish density?
- 2) Is area and time of year (i.e. depth, ambient light and temperature) affecting the efficiency?
- 3) (Effect on fish behaviour and escape rate with artificial light).
- 4) Which of the two ground ropes is most efficient?



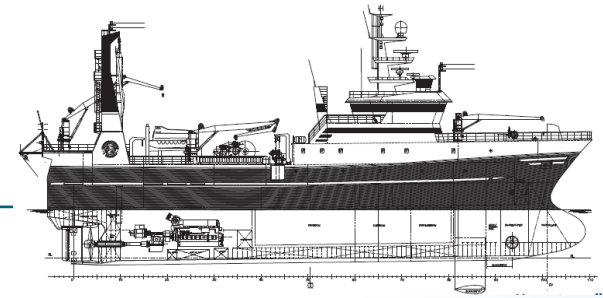
Rock-hopper (spaced round discs)



Semi-circle (dense elements)

All trials were made on board the 64 m RV «Helmer Hanssen» and we applied two trawl methods:

- 1) Semi-pelagic trawling (November 2014)
- 2) Bottom trawling (February 2015)



Setup of the Alfredo No 3 fish trawl during trials February-March 2014 & 2015

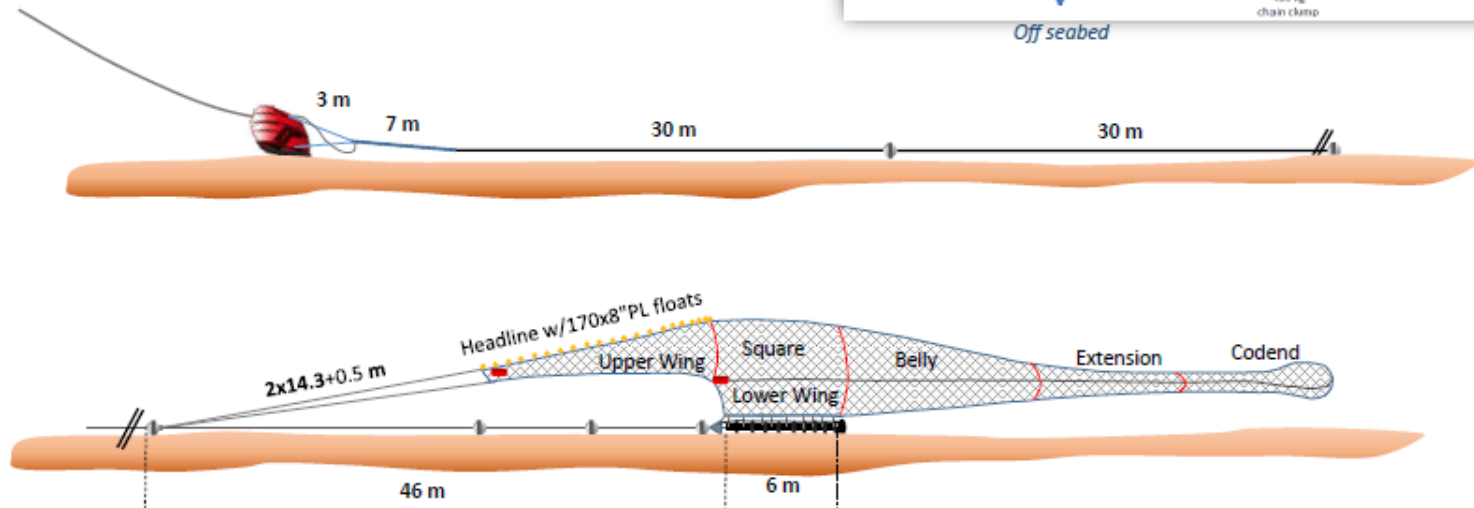
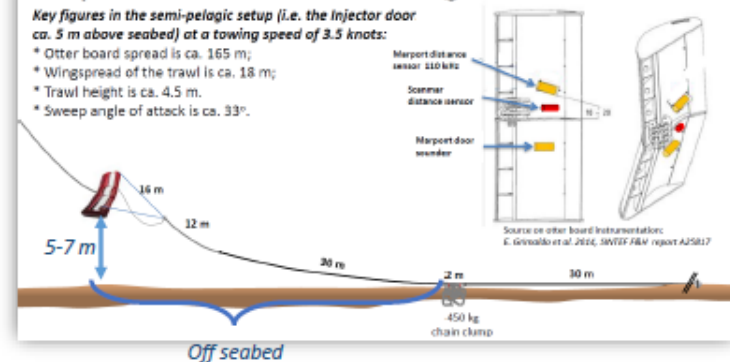
Key figures in this gear-rig at a towing speed of 3.5 knots:

- * Otter board spread is ca. 130 m;
- * Wingspread of the trawl is ca. 14,5 m;
- * Trawl height is ca. 4.5 m.
- * Sweep angle of attack is ca. 30°.

Setup of the Alfredo No 3 fish trawl during trials November 2014

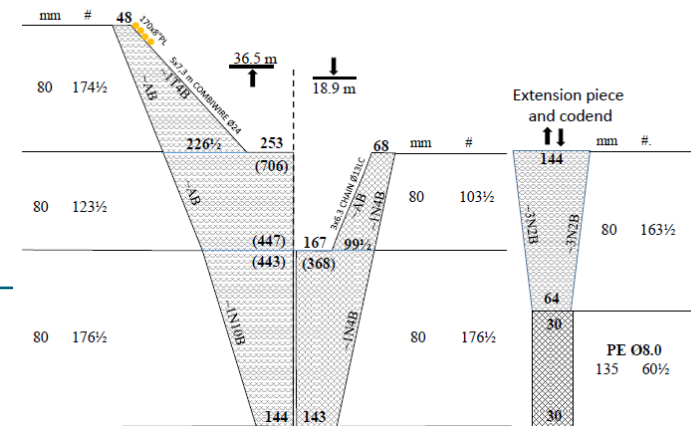
Key figures in the semi-pelagic setup (i.e. the injector door ca. 5 m above seabed) at a towing speed of 3.5 knots:

- * Otter board spread is ca. 165 m;
- * Wingspread of the trawl is ca. 18 m;
- * Trawl height is ca. 4.5 m.
- * Sweep angle of attack is ca. 33°.



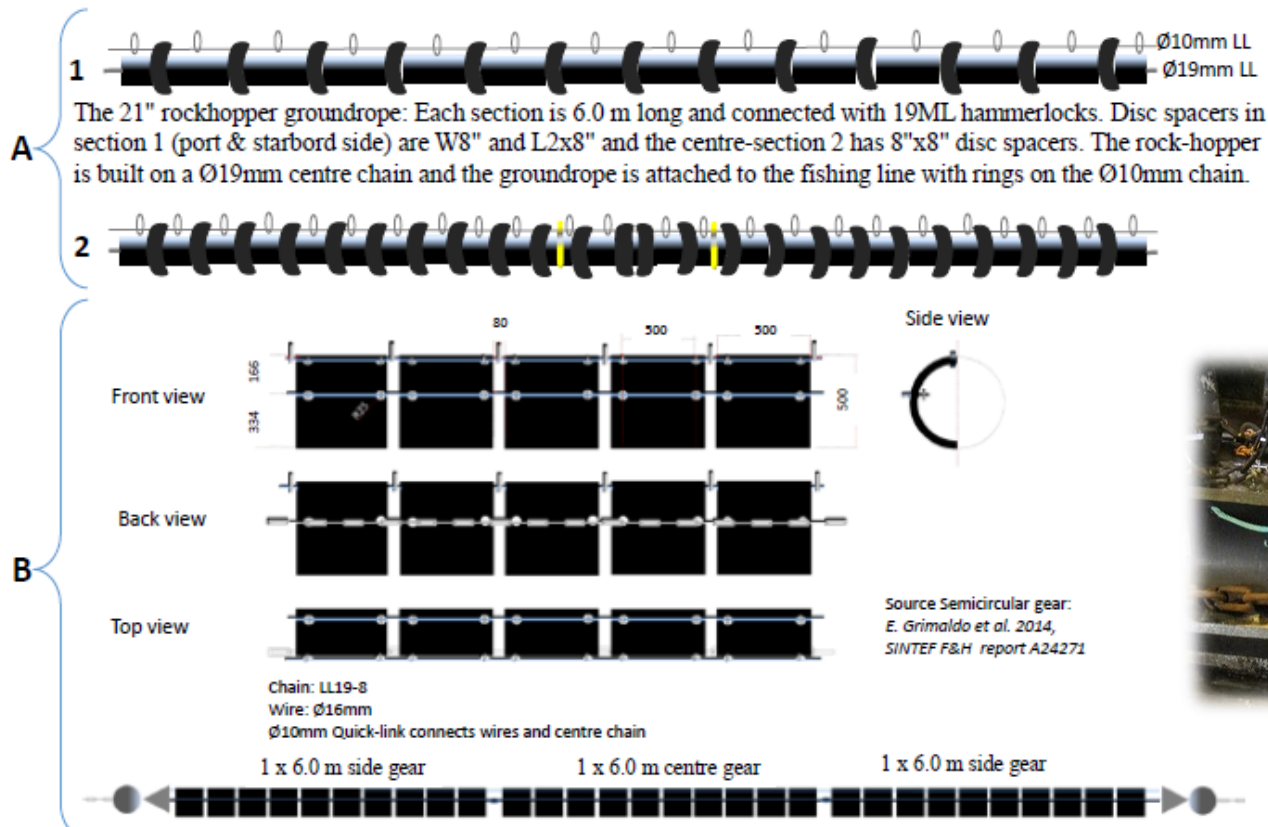
The experiments were made with an Alfredo No. 3 trawl and 2 types of ground ropes:

- 1) Rock-hopper ground rope (RHG)
- 2) Semi-circle spreading gear (SCSG)



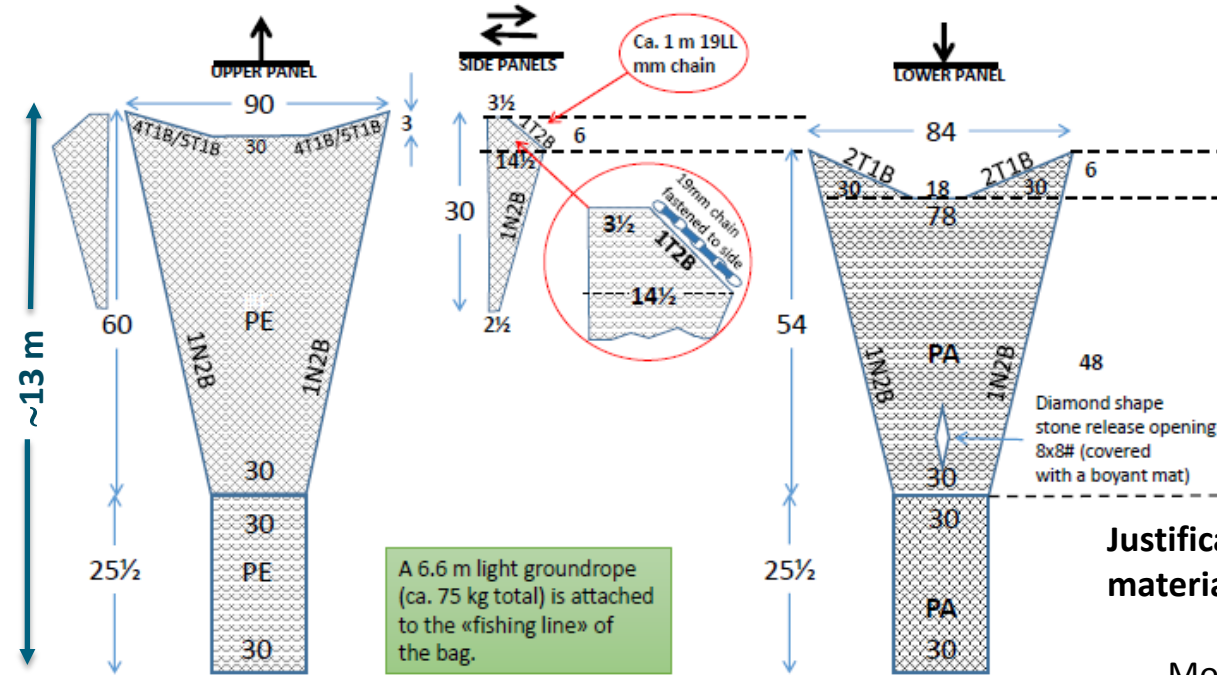
Groundropes for Alfredo No 3 fish trawl used during November 2014 and February-March 2014 & 2015 trials;

A) The 21" rockhopper gear and B) The 20" Semicircular spreading gear



Bag for retaining fish/crabs escaping below the fishing line

Upper panel and sidepanels made from dbl. Ø5mm by 155 mm meshes (135 mm inside) PE.
Lower panel made from dbl. Ø6mm 155 mm meshes (135 mm inside) PA.



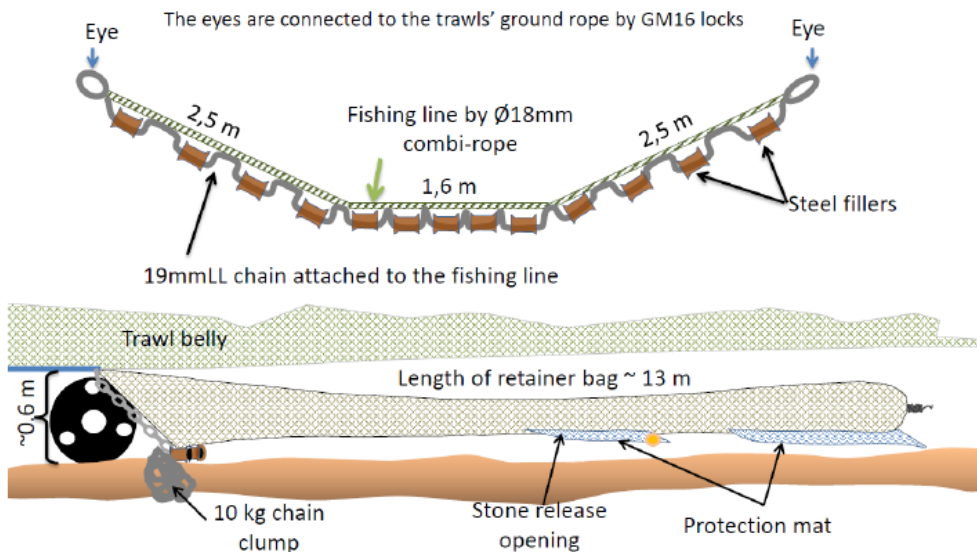
Modified version of sketch in Ingolfsson & Jørgensen 2006; Fish. Res. 79. (RB Larsen UIT 10.09. 2014)



Retainer bag and RHG

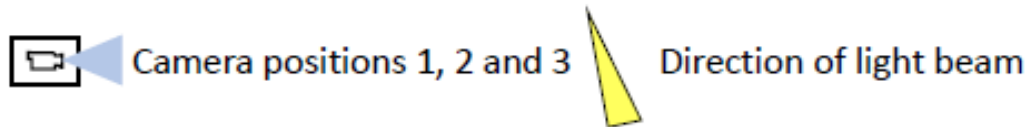
Justification for choice of design (mesh size, material and twine thickness) for the escapee bag:

- Most fish are in the centre of the trawl mouth.
- 135 mm mesh size will retain cod >65 cm TL and most snow crab sizes.
- We expected stones of various sizes and collection of clay/mud in the bag.



Underwater observations February 2014-2015 and November 2014 confirming fish behaviour, function of the retainer bag and escape under the fishing line

Underwater observations on the Alfredo No 3 fish trawl during trials November 2014

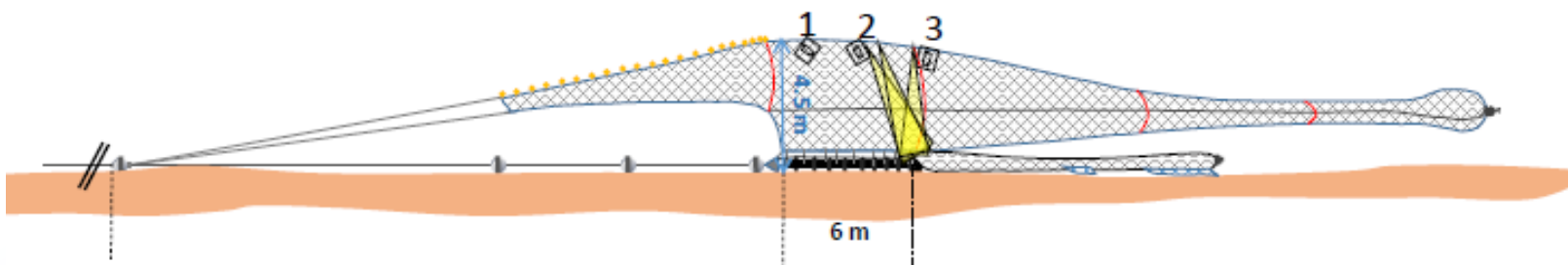
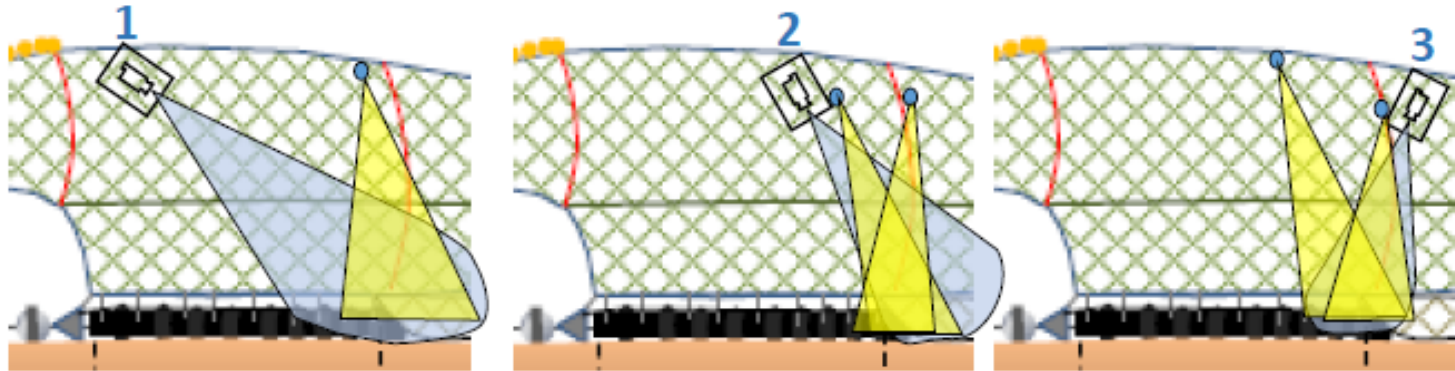


Position 1: SIMRAD OE-1434 facing aft/down at a ca. 6 m distance to the ground rope + 2 x 9W lamps

Position 2: GoPro H2/H3 facing down/aft at a ca. 4 m distance to the ground rope + 2/4 LED/halogen lamps

Position 3: GoPro H2/H3 facing down/forward at a ca. 3 m distance to the ground rope + 4 LED lamps

Position 3: TrawlCam facing down/forward at a ca. 3 m distance to the ground rope + inbuilt LED lamp



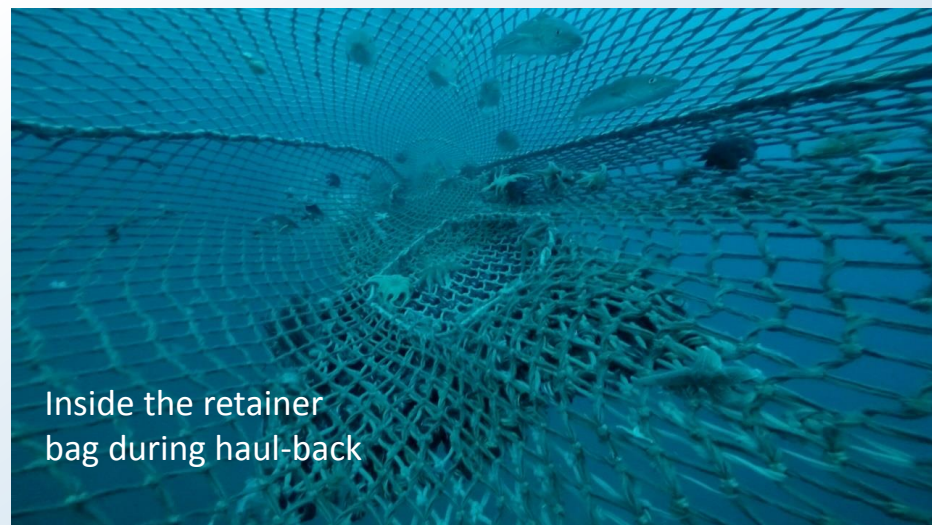
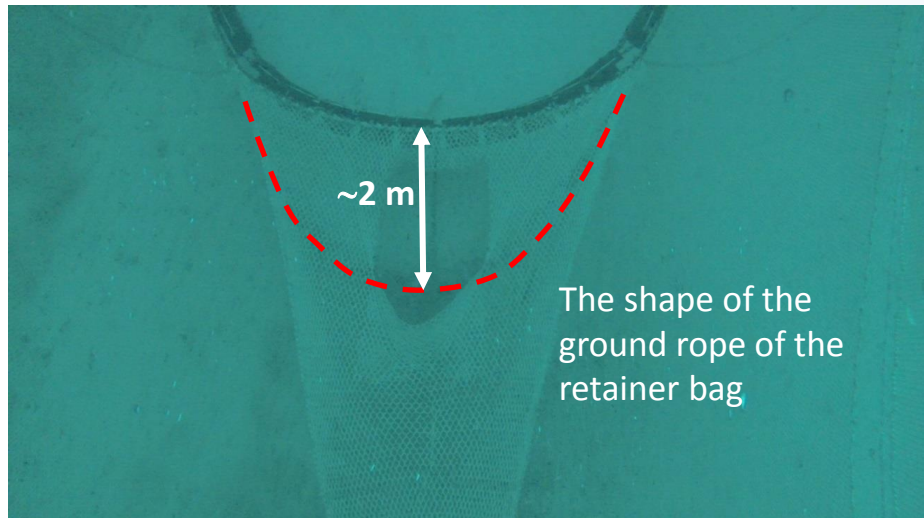
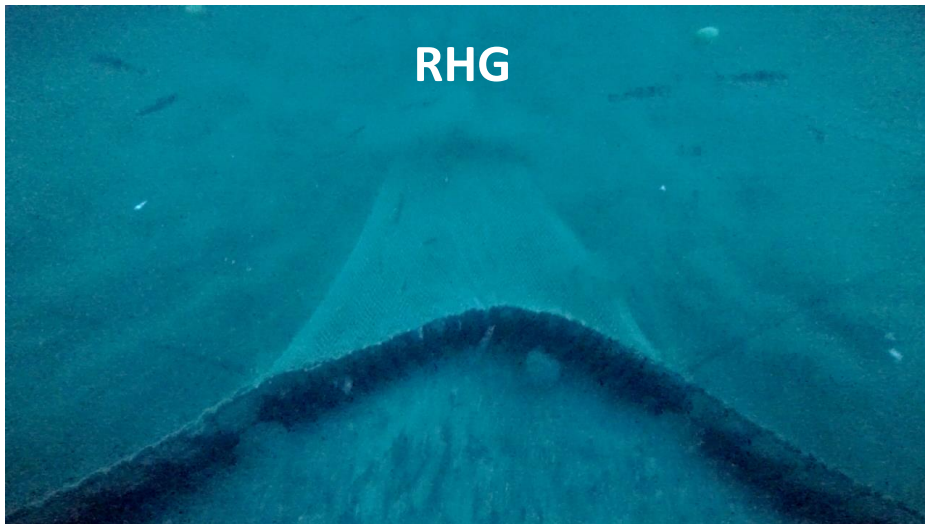
Underwater observations February 2014 & 2015:

Behaviour of cod and haddock in natural light; depth 60-70 m showing that fish line up in the centre of the trawl mouth



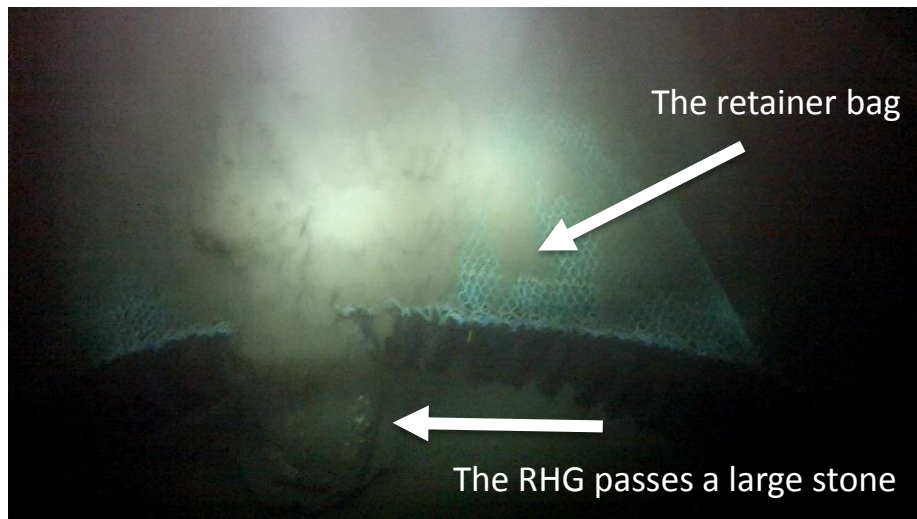
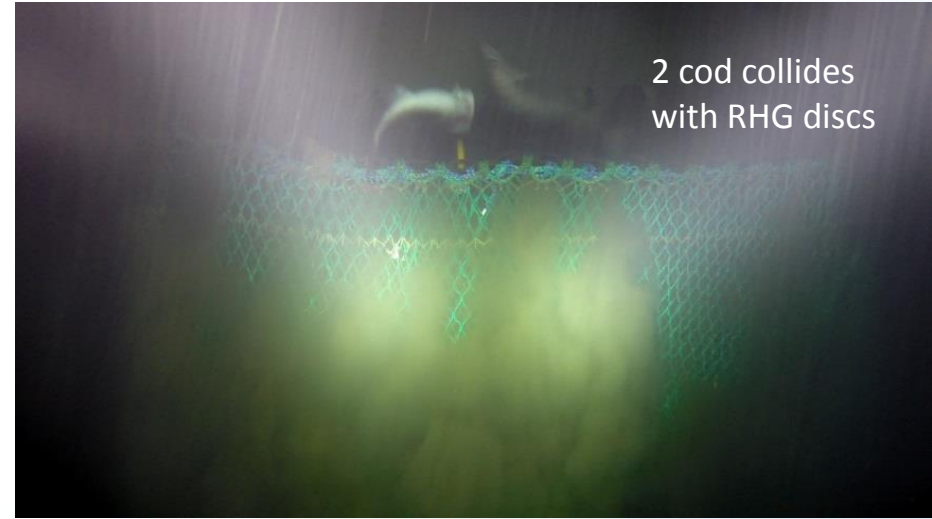
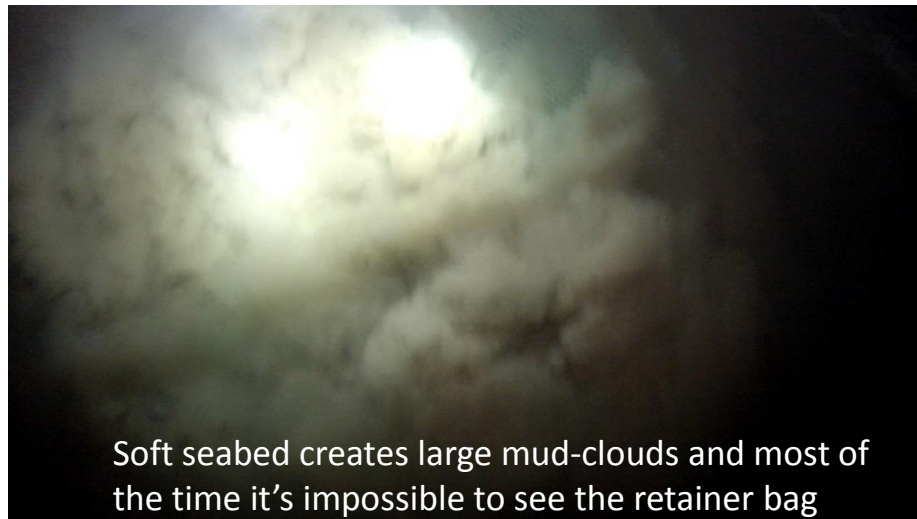
Underwater observations February 2015 (natural light):

Observations of the function of the retainer bag (55-70 m depth)



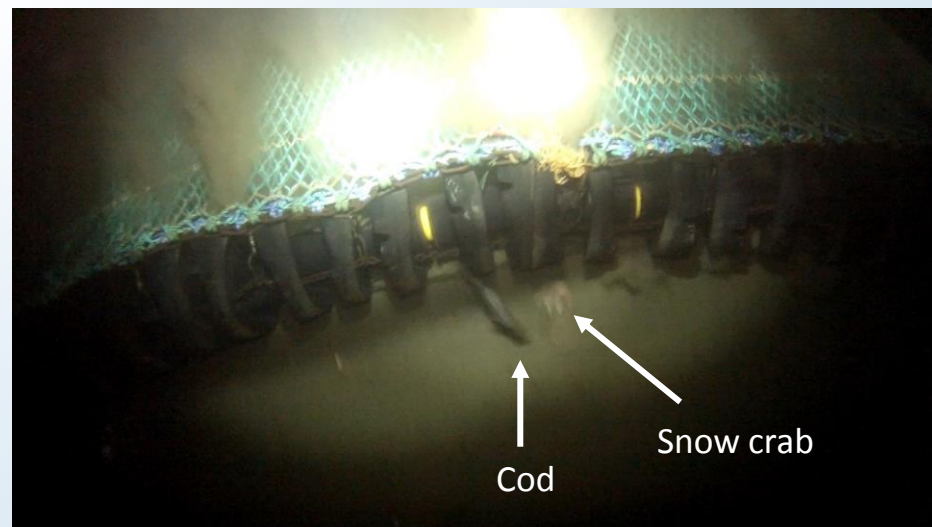
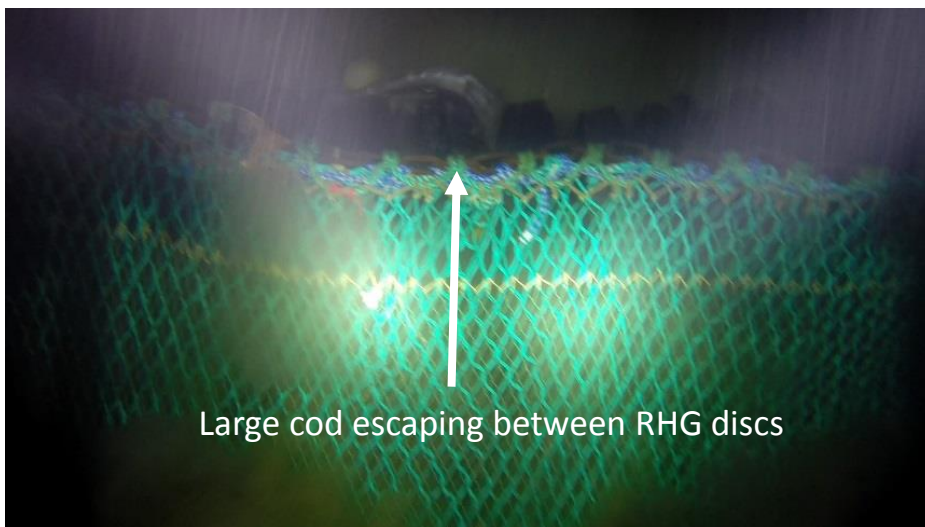
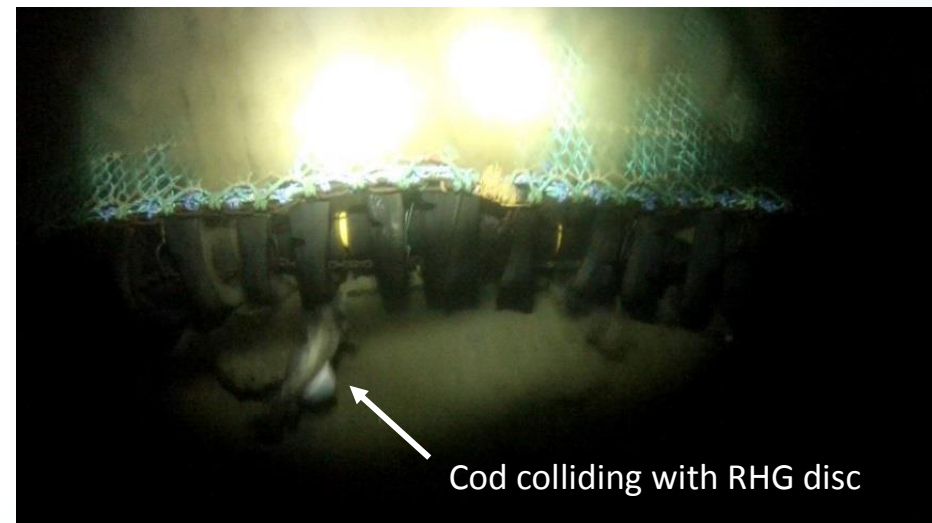
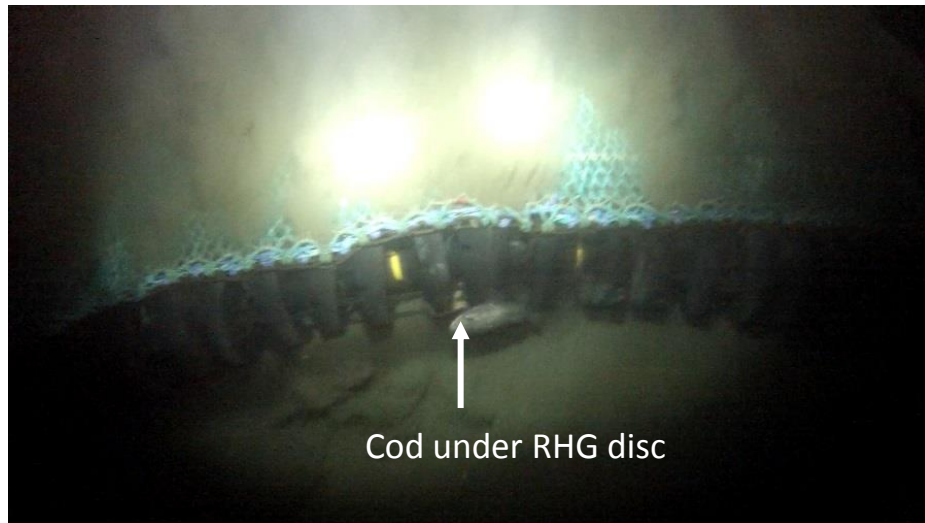
Underwater observations November 2014:

Behaviour of large cod with strong artificial light; depth ca. 250 m showing that fish many fish collide with the ground rope and several escape under the fishing line

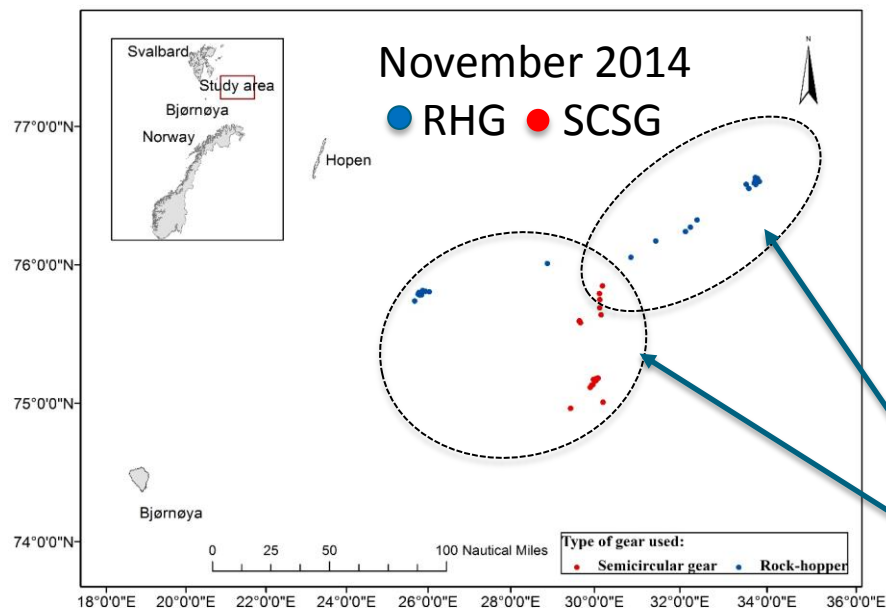


Underwater observations November 2014:

Behaviour of large cod with strong artificial light; depth ca. 250 m showing that fish many fish collide with the ground rope and several escape under the fishing line



Geographical areas for the experiments in Nov. 2014 - Feb. 2015 and research designs. Valid hauls marked (●●).

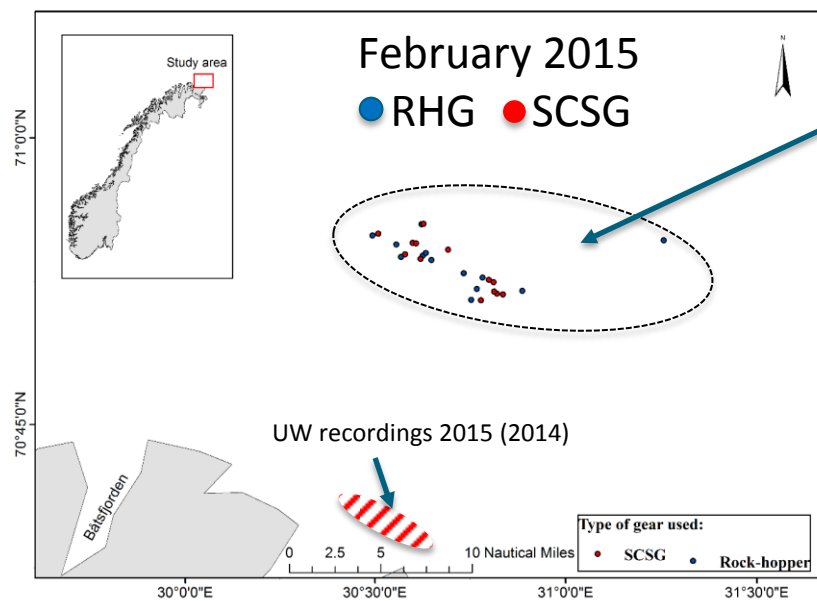


November 2014: 16 (RHG) + 16 (SCSG) hauls

Separate ground rope series: For practical reasons only 1 trawl could be rigged and first part of the trials were also covering snow crab encounters by the RHG. Unfortunately, this area gradually closed by drift-ice

Area with large cod and snow crab, depth 200-300 m

Area with large cod, depth 200-300 m



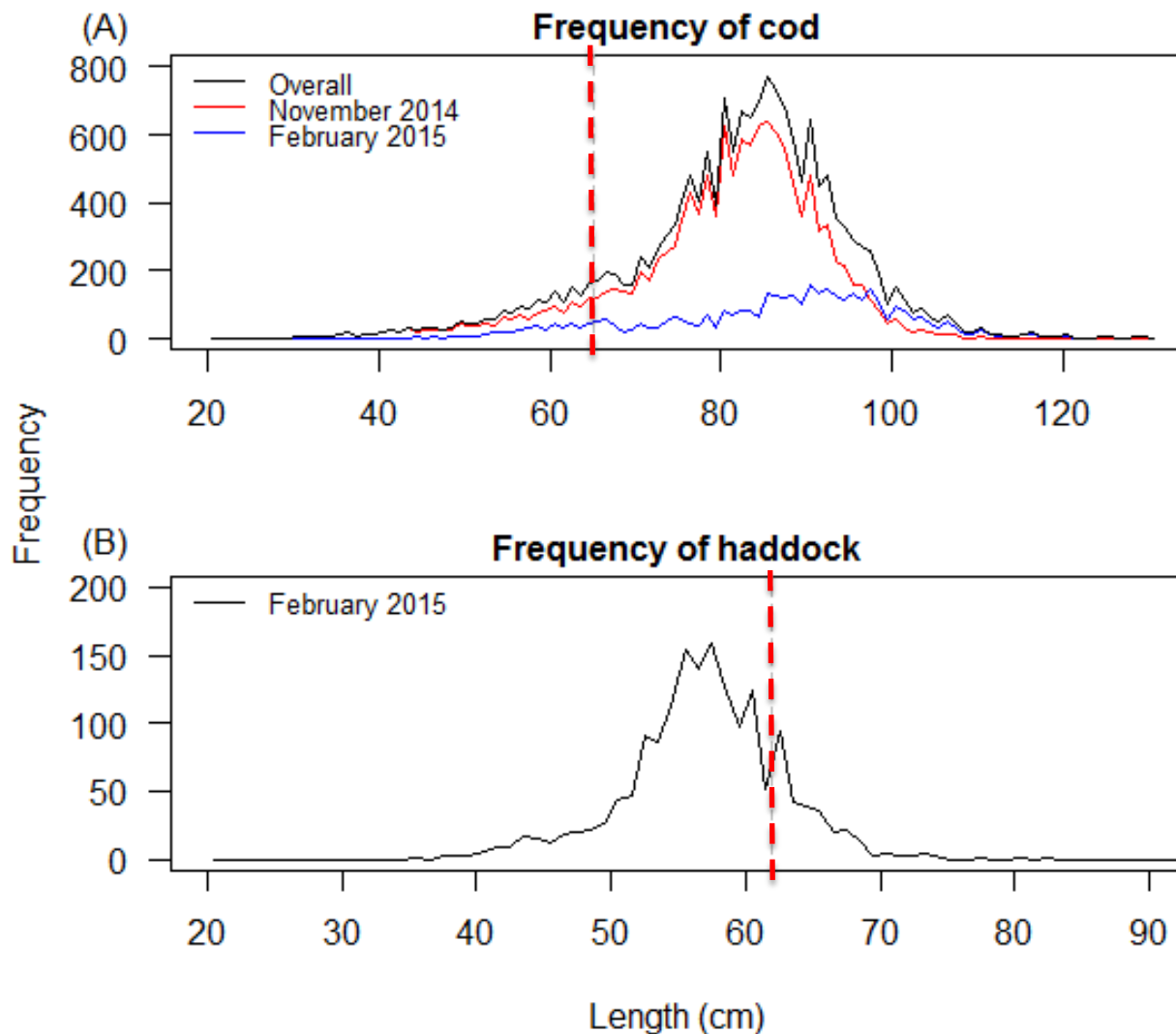
Area with large cod and haddock, depth 300 m

February 2015: 13 (RHG) + 13 (SCSG) hauls:

It was used an alternate ground rope set-up (pair-wise hauls)

Size distributions for cod and haddock during surveys in November 2014 and February 2015

(Note: Codend & retainer bag mesh sizes were 135 mm)



Average length of cod:

-Nov-14: **80.14 cm** (sd \pm 12.12)

-Feb-15: **86.56 cm** (sd \pm 15.06)

Dashed red line mark upper fish length of possible escape through 135mm mesh size

Average length of haddock:

Feb-15: **55.89 cm** (sd \pm 5.63)

Results: Number of valid hauls and numbers of cod and haddock in codend and retainer bag

	Rock-hopper ground rope; RHG				Semi-circle spreading gear; SCSG			
N (hauls/fish)	Hauls	Codend	Retainer	Total	Hauls	Codend	Retainer	Total
Cod (Nov. 14)	16	2887	872	3759	16	7127	485	7612
Cod (Feb. 15)	13	1656	128	1784	13	2133	70	2203
SUM cod (14&15)	29	4543	1000	5543	29	9260	555	9815
Haddock (Feb. 14)	13	836	64	900	13	766	16	782

Rock-hopper gear RHG:

Escape (N) of cod

- a) Nov-14: 23,2%
- b) Feb-15: 7.2%

Escape (N) of haddock

- Feb-15: 7.1%

Semi-c. spread. gear SCSG

Escape (N) of cod

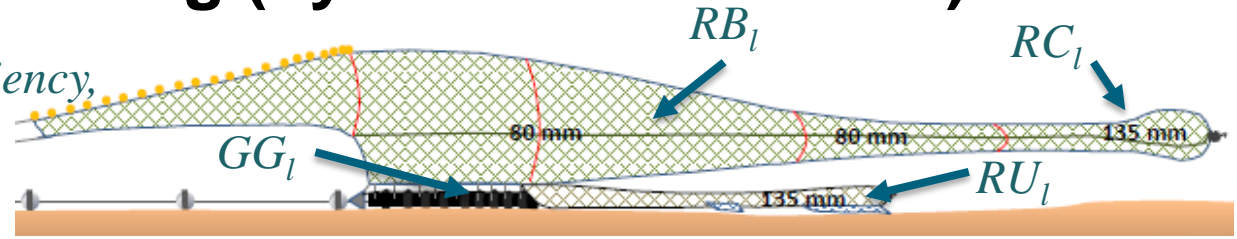
- a) Nov-14: 6,4%
- b) Feb-15: 3.2%

Escape (N) of haddock

- Feb-15: 2,0%

Statistical modelling (by SELNET software)

The experimental efficiency, EG_l , is affected by



The experimental efficiency of the ground gear, EG_l :

$$EG_l = \frac{nc_l}{nc_l + nu_l}$$

Was modelled by:

$$EEG(l, v) = \frac{\exp(f(l, v))}{1.0 + \exp(f(l, v))}$$

Where f is polynomial on the form :

$$f(l, v) = \sum_{i=0}^k v_k x \left(\frac{l}{100} \right)^k = v_0 + v_1 \frac{l}{100} + v_2 \frac{l^2}{100^2} + \dots + v_k \frac{l^k}{100^k}$$

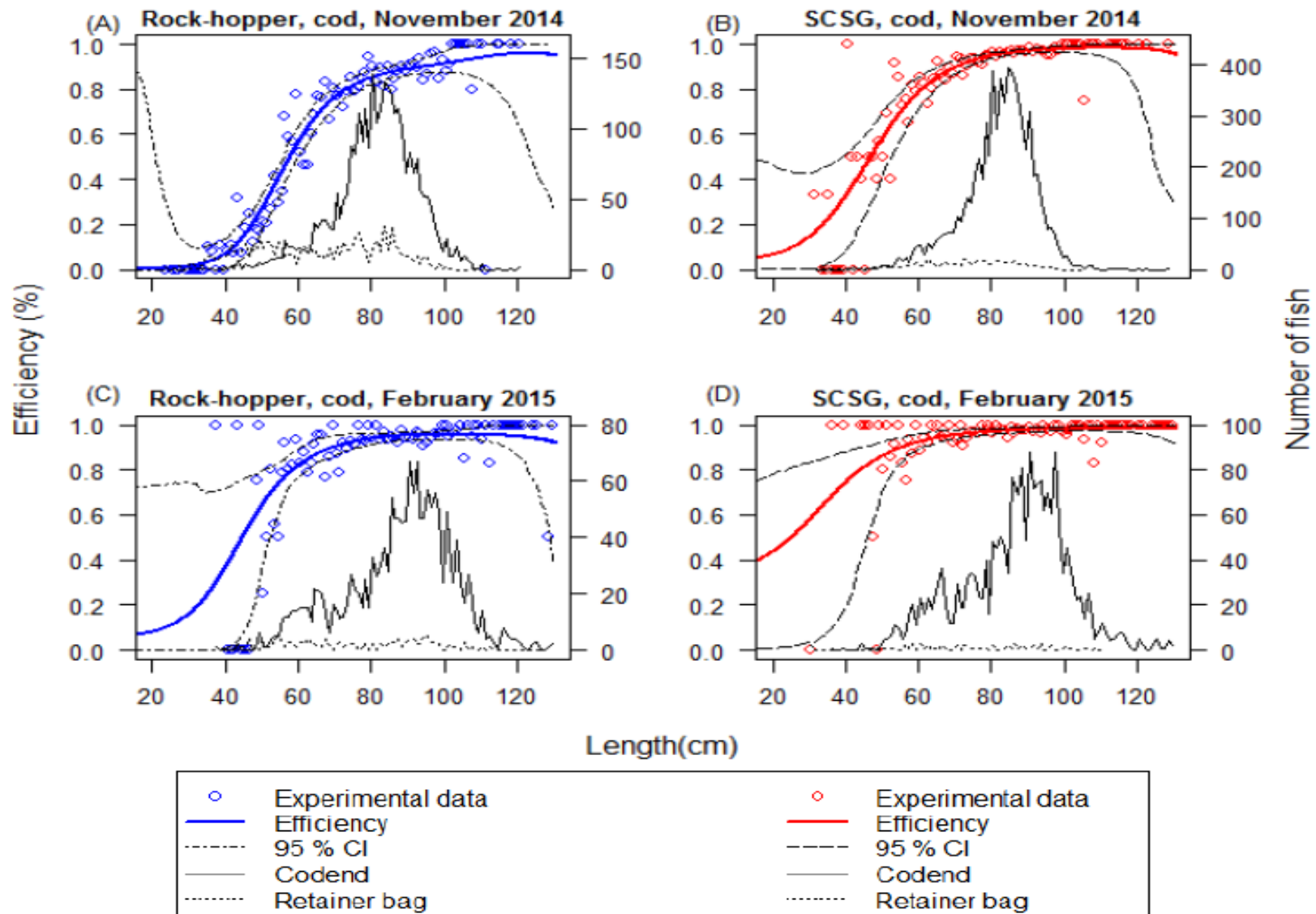
Model parameters values were obtained based on maximum likelihood estimation by minimizing:

$$- \sum_l \sum_{i=1}^h \{ nc_{li} x \ln(EEG(l, v)) + nu_{li} x \ln(1 - EEG(l, v)) \}$$

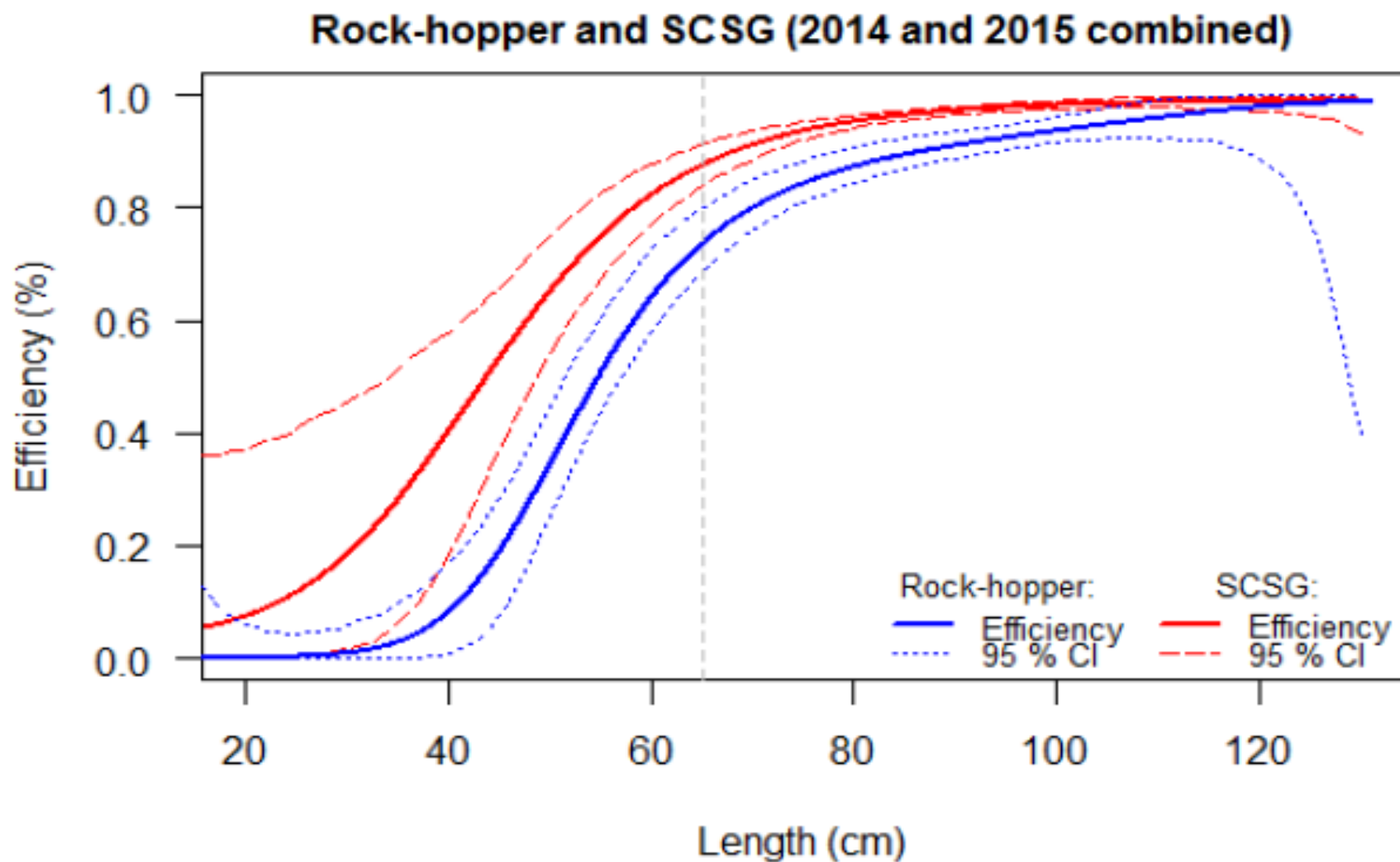
However the experimental EG can be biased by size selectivity in collecting bag (RU), codend (RC) and trawl body (RB) since theoretically we have:

$$EG(l) = \frac{GG(l) x RB(l) x RC(l)}{GG(l) x RB(l) x RC(l) + (1 - GG(l)) x RU(l)}$$

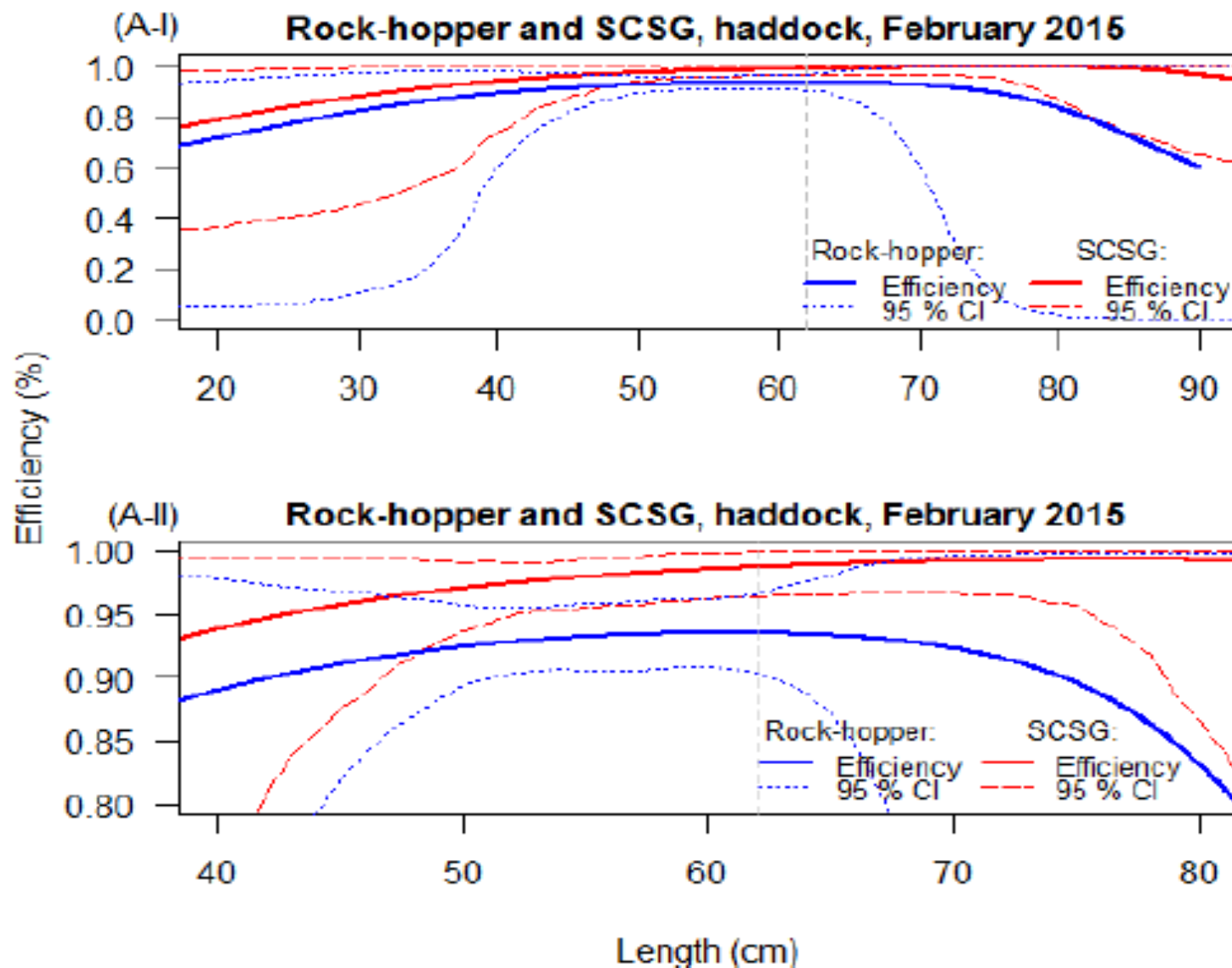
Therefore we can only use the experimental efficiency (EEG) as estimate for GG for sizes of fish above where size selection may occur in collecting bag, codend or trawl body!



DATA ON COD: Catch efficiency, i.e. escapement rate for cod (with conf. limits) for RHG and SCSG November-14 and February-15. Frequency of fish in codend and retainer bag show the length distribution of fish and the distribution of power in data.



DATA ON COD: The overall difference in the catch efficiency for cod between hauls with RHG and SCSG for combined data (November-14 and February-15).



DATA ON HADDOCK: Catch efficiency for haddock for hauls with the RHG and the SCSG during February-15 (A-I). A-II show expanded area of interest.

Results: Calculated efficiency for the RHG and SCSG and improved efficiency/reduction in escape by the SCSG compared to the RHG

Cod > 65 cm	Efficiency (%) (95 % CI)	Escapement (%) (95 % CI)	Improved efficiency (%)	Reduced escape (%)
RHG (Nov. 2014)	85.7 (83.9 - 87.9)	14.3 (12.1 - 16.1)	11.1	66.7
SCSG (Nov. 2014)	95.2 (94.2 - 96.4)	4.8 (3.6 - 5.8)		
RHG (Feb. 2015)	94.8 (93.9 - 95.7)	5.2 (4.3 - 6.1)	3.1	56.7
SCSG (Feb. 2015)	97.7 (96.9 - 98.6)	2.3 (1.4 - 3.1)		
RHG (Nov. -14 & Feb. -15)	88.7 (86.5 - 91.3)	11.3 (8.7 - 13.5)	8.0	63.0
SCSG (Nov.-14 & Feb.-15)	95.8 (94.9 - 96.8)	4.2 (3.2 - 5.1)		
Haddock > 62 cm				
RHG (Feb. 2015)	93.2 (88.4 - 97.7)	6.83 (2.3 - 11.6)	6.2	85.2
SCSG (Feb. 2015)	99.0 (96.8 - 100)	1.0 (0.0 - 3.16)		

- Engås & Godø (1989) found (in September 1986) escape on cod close to 23% for cod and 5% for haddock in the centre bag
- Ingolfsson & Jørgensen (2006) found (in March/April 2003) escape on cod of 22% for cod and 15% for haddock in the centre bag.
- In both papers the length dependent escape is evident (and their fish sizes are smaller than ours) and the experiments were done in different areas and periods.

$$\text{Improved efficiency} = \frac{SCSG - RHG}{RHG}$$

$$\text{Reduced escape} = \frac{RHG - SCSG}{RHG}$$

Summing up the story and our conclusions

- Despite several weaknesses identified in our research designs we do believe the results reflects a good comparison to a commercial fishery.

- The relative difference in efficiency between the RHG and the SCSG ground ropes is significant for cod 39-105 cm. (Non-significant for haddock due to overlapping confidence limits and few numbers of fish > 62 cm).
- Our estimates of trawl efficiency are conservative (i.e. we didn't cover the sides of the ground rope).
- The use of the conventional rock-hopper ground rope should be reconsidered by the commercial fleet, i.e. more time and fuel is spent to catch fish compared to the lighter semi-circular spreading gear.
- We will continue to investigate this topic in new trials coming up in November 2015 (and onwards) with improved research designs.

Thanks for your attention