Akustikk og fiskeåtferd: korleis kan vi observera åtferd og kva finn vi ut?

Nils Olav Handegard

INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET

Ting eg har lurt på

- Korleis oppfører fisken seg i høve til det fysiske miljøet?
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- Korleis reagerer fisk på ulike støykjelder?

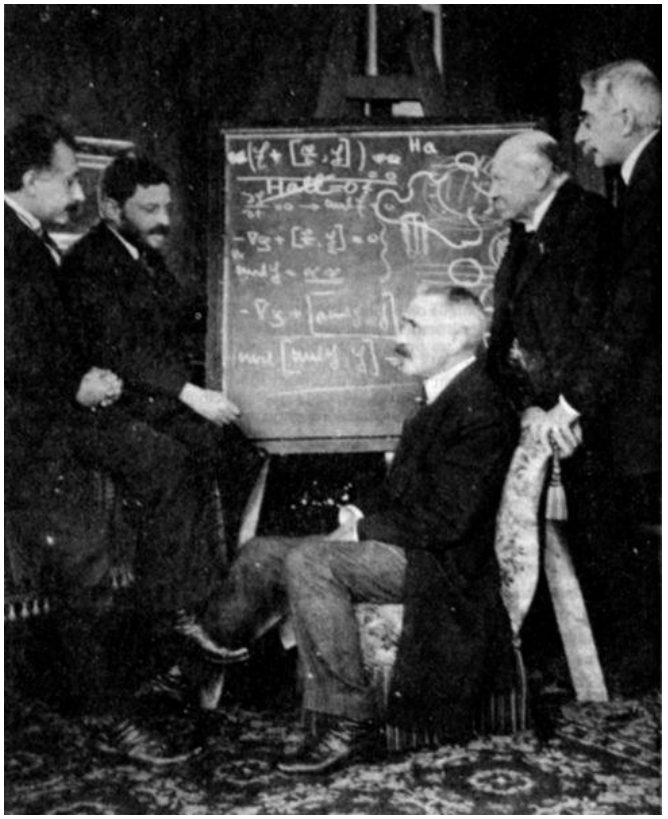
The beginning

- In 1490 Leonardo Da Vinci wrote:

  "If you cause your ship to stop and place the head of a long tube in the water and place the outer extremity to your ear, you will hear ships at a great distance from you.“

Paul Langevin (1872-1946),
French physicist

His most famous work was in the use of ultrasound using Pierre Curie's piezoelectric effect. During World War I, he began working on the use of these sounds to detect submarines through echo location. However the war was over by the time he had it operational (wikipedia).



Albert Einstein, Paul Ehrenfest, Paul Langevin, Heike Kamerlingh Onnes, and Pierre Weiss at Ehrenfest's home in Leiden

”Echo Sounding”

Nature, 1925, *115*, p689-690

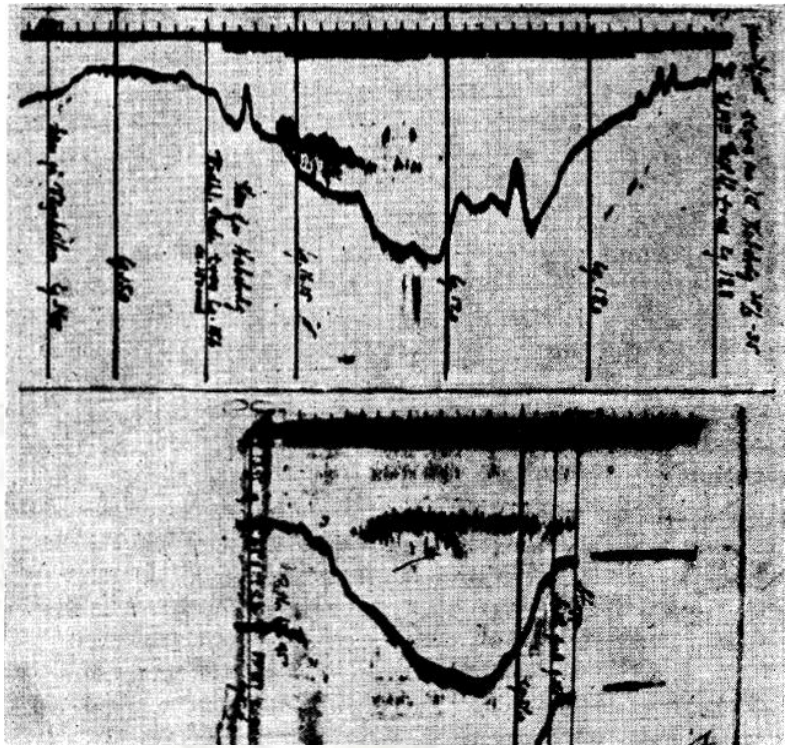
Whatever may be the limitations of the present device, there is no doubt that, as in many other instances, simplification of design and operation will follow further research, and an aid to navigation of inestimable value will eventually be at the disposal of all who take ships to sea. By the use of the

Further progress

- 1927 The French navigator Railley du Baty reported unexpected sounder signals midwater
- 1933 Skipper Ronnie Balls experimented with echo sounders
- 1934 First schools detected by echo sounders published by skipper Reinert Bokn using British echo sounders (Admirality sounder, wrote on paper)

“Echo Sounding in Fishery Research”

O.Sund, Nature, 1935, Vol 135, p 953



It is interesting to note that this spawning concentration of cod has apparently no relation to the bottom. This was well known before, but no one could have imagined the fish to be limited to such a sharply defined layer of only 10–12 metres in thickness, extending widely above deep water and shallow, always at the same distance from the water surface.

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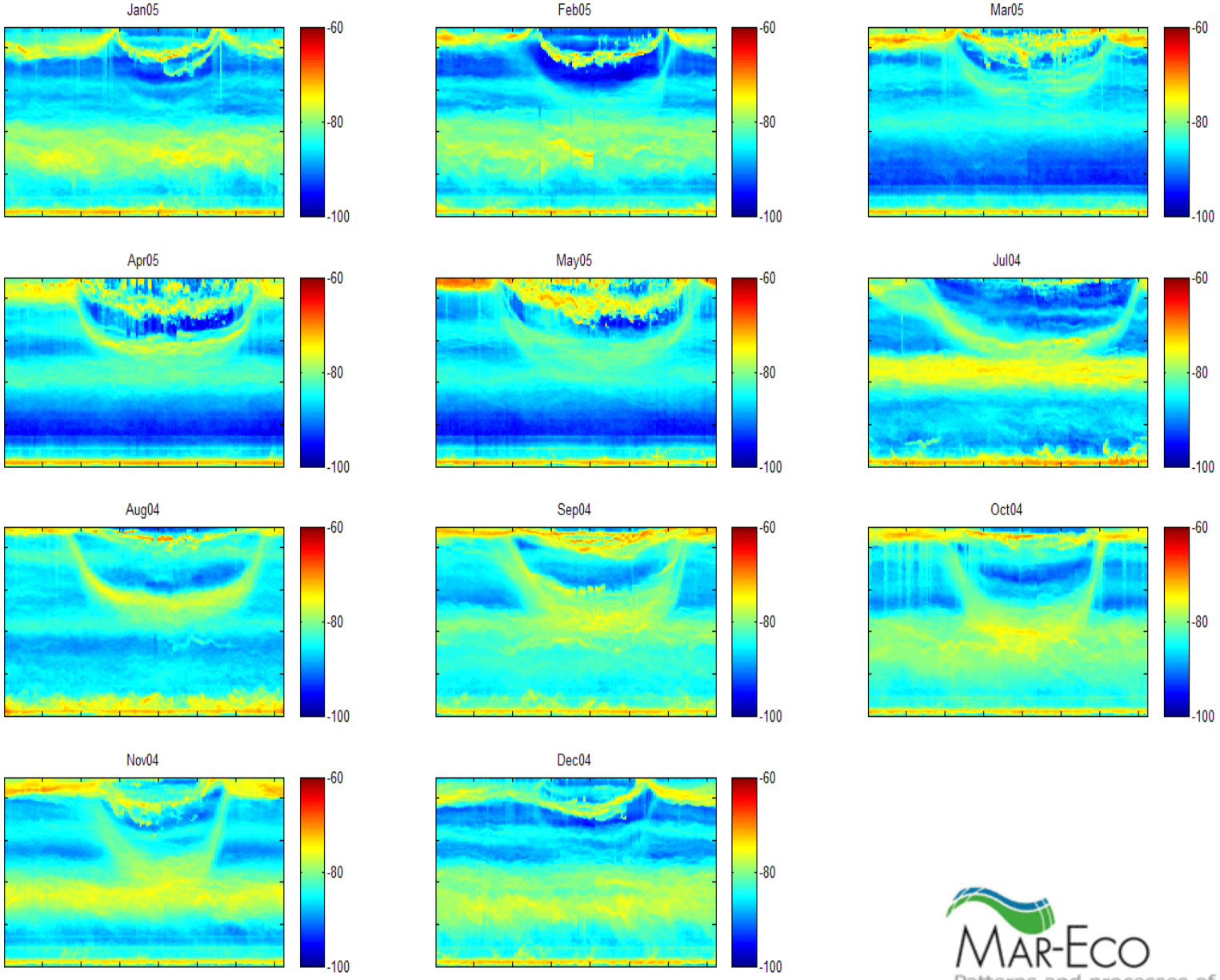
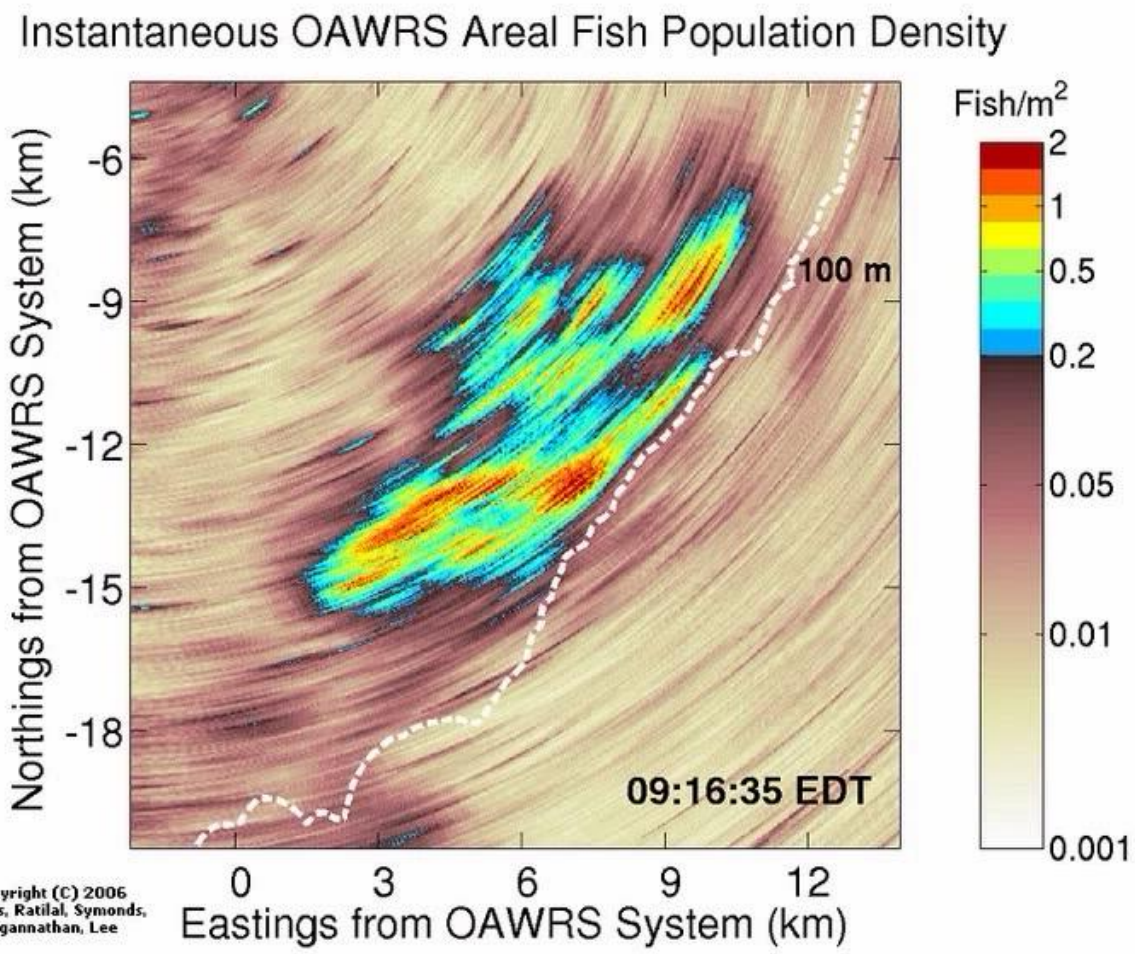


MAR-ECO

Patterns and processes of the eco-systems of the northern mid-Atlantic

CENSUS OF MARINE LIFE



Fish Population and Behavior Revealed by Instantaneous Continental Shelf–Scale Imaging

Nicholas C. Makris,[1*] Purnima Ratilal,[2] Deanelle T. Symonds,[1] Srinivasan Jagannathan,[1] Sunwoong Lee,[1] Redwood W. Nero[3]

3 FEBRUARY 2006 VOL 311 **SCIENCE** www.sciencemag.org

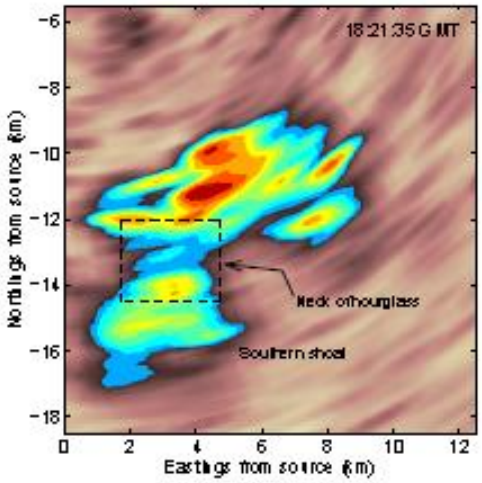
Critical Population Density Triggers Rapid Formation of Vast Oceanic Fish Shoals

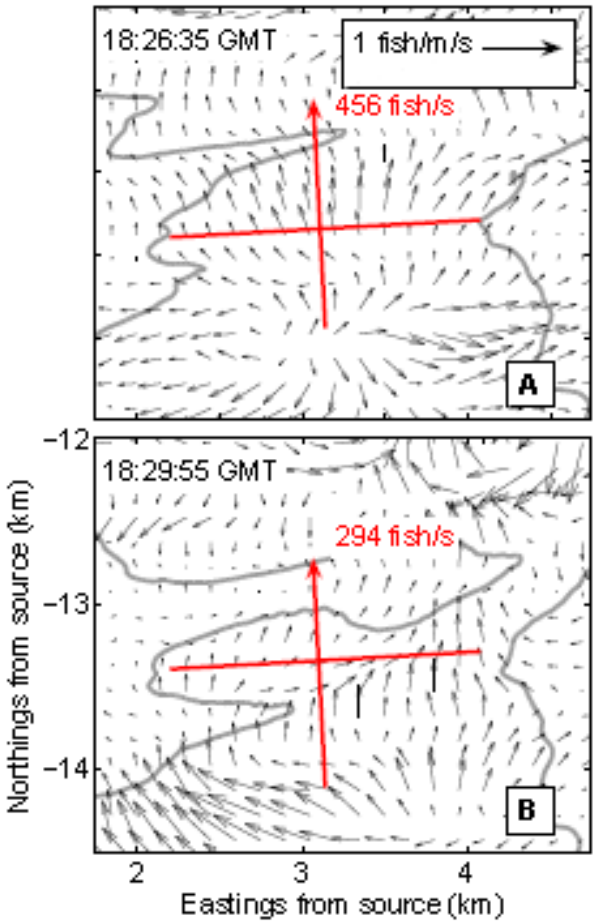
Nicholas C. Makris,[1*] Purnima Ratilal,[2] Srinivasan Jagannathan,[1] Zheng Gong,[2] Mark Andrews,[2] Ioannis Bertsatos,[1] Olav Rune Godø,[3] Redwood W. Nero,[4] J. Michael Jech[5]

27 MARCH 2009 VOL 323 SCIENCE www.sciencemag.org

- Frequencies: 390-440Hz
- Spatial scales: ~100 km
- Requires ocean waveguide

Fish schools (Jagannathan et al, 2010)





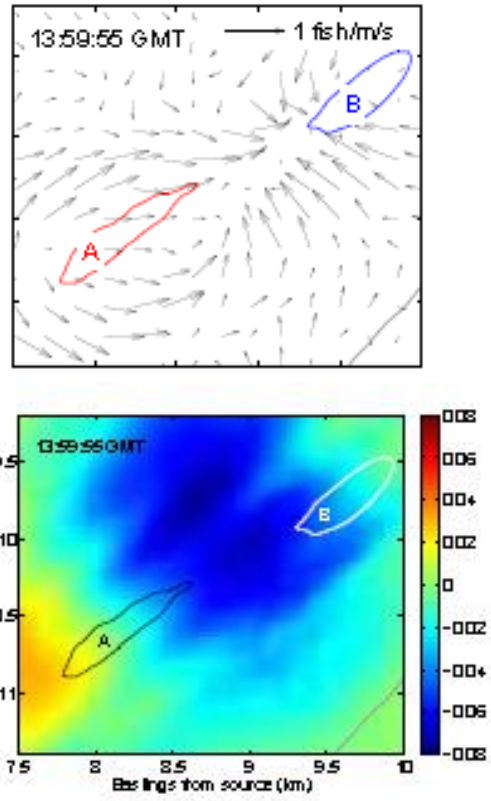
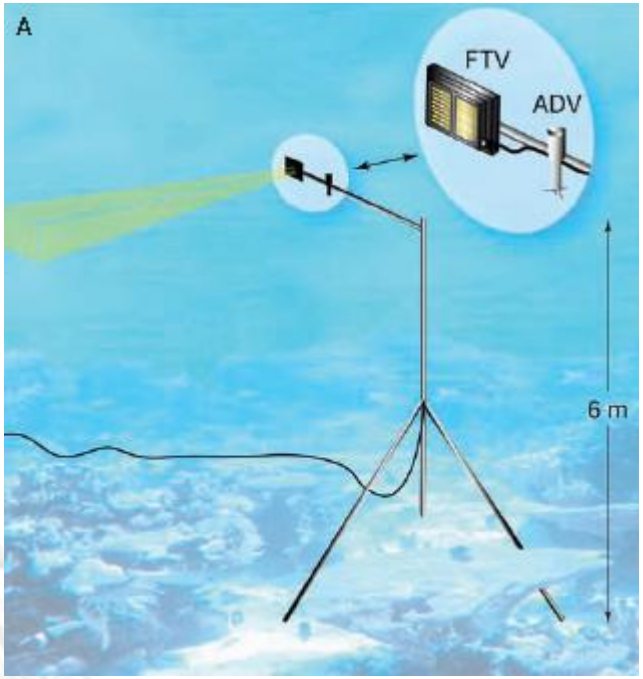


Fig. 9. Pressure (N/m^2 per unit fish mass) distribution within large fish shoal showing formation of a low pressure region that attracts schools A and B. Black and white lines both represent the 1.5 fish/m^2 population density contours. Gray line represents the 0.2 fish/m^2 population density contour. Same zoom area as Figure 8.

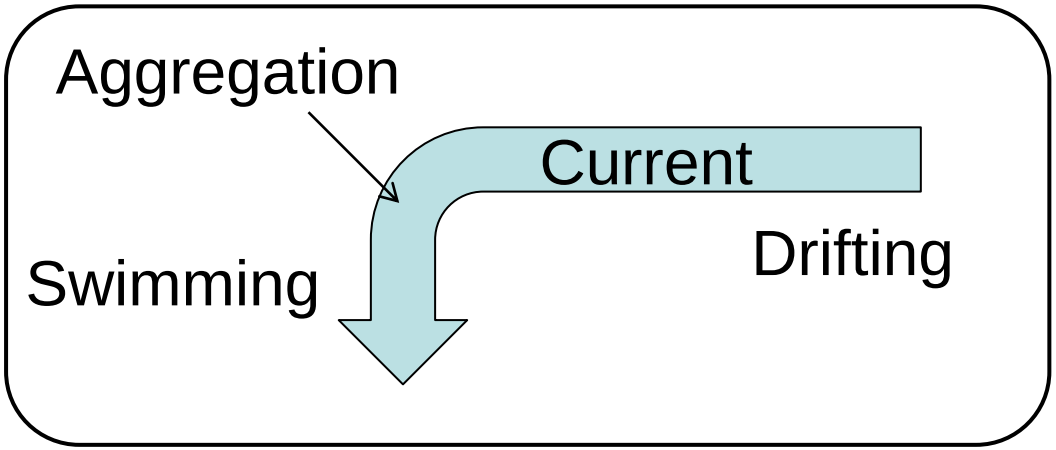
Swimming against the flow

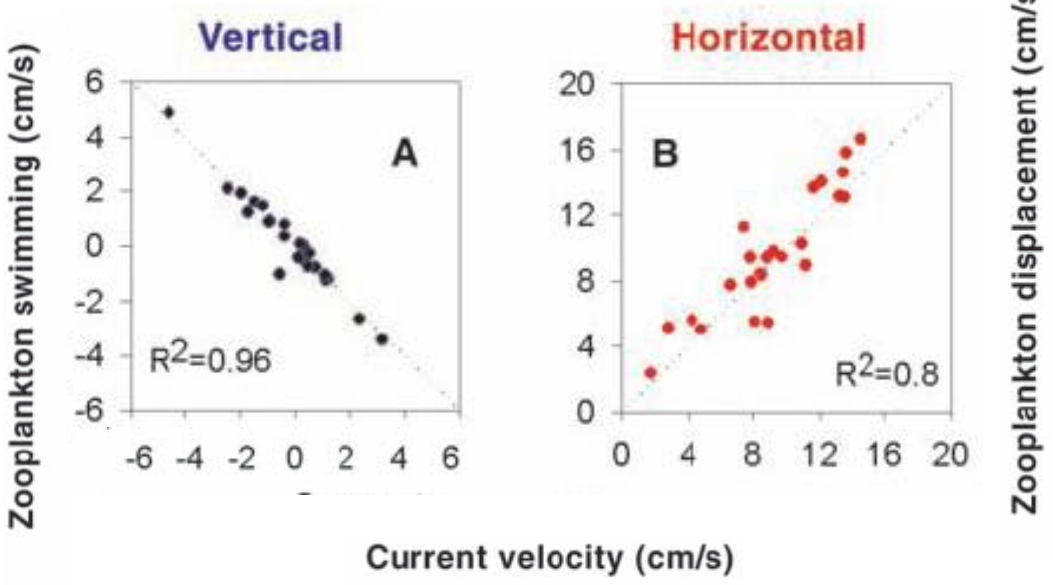


Swimming Against the Flow: A Mechanism of Zooplankton Aggregation

Amatzia Genin,[1*] Jules S. Jaffe,[2] Ruth Reef,[1] Claudio Richter,[3] Peter J. S. Franks[2]

6 MAY 2005 VOL 308 SCIENCE





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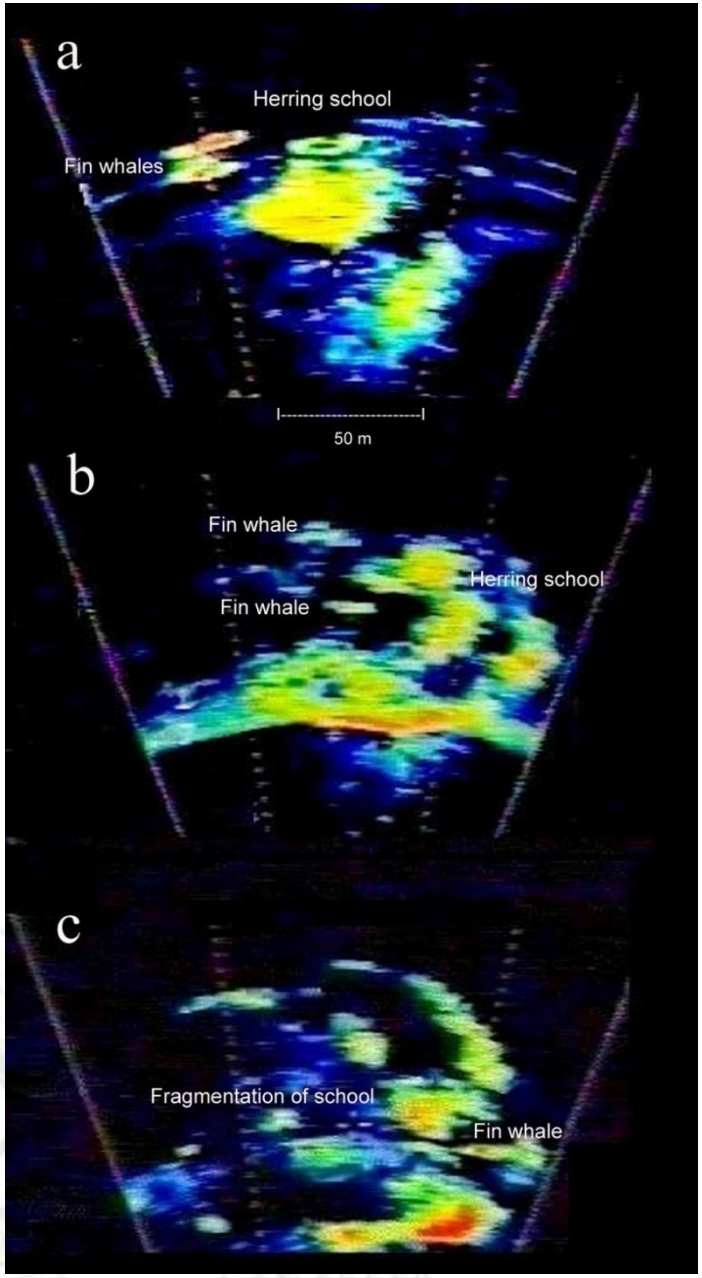
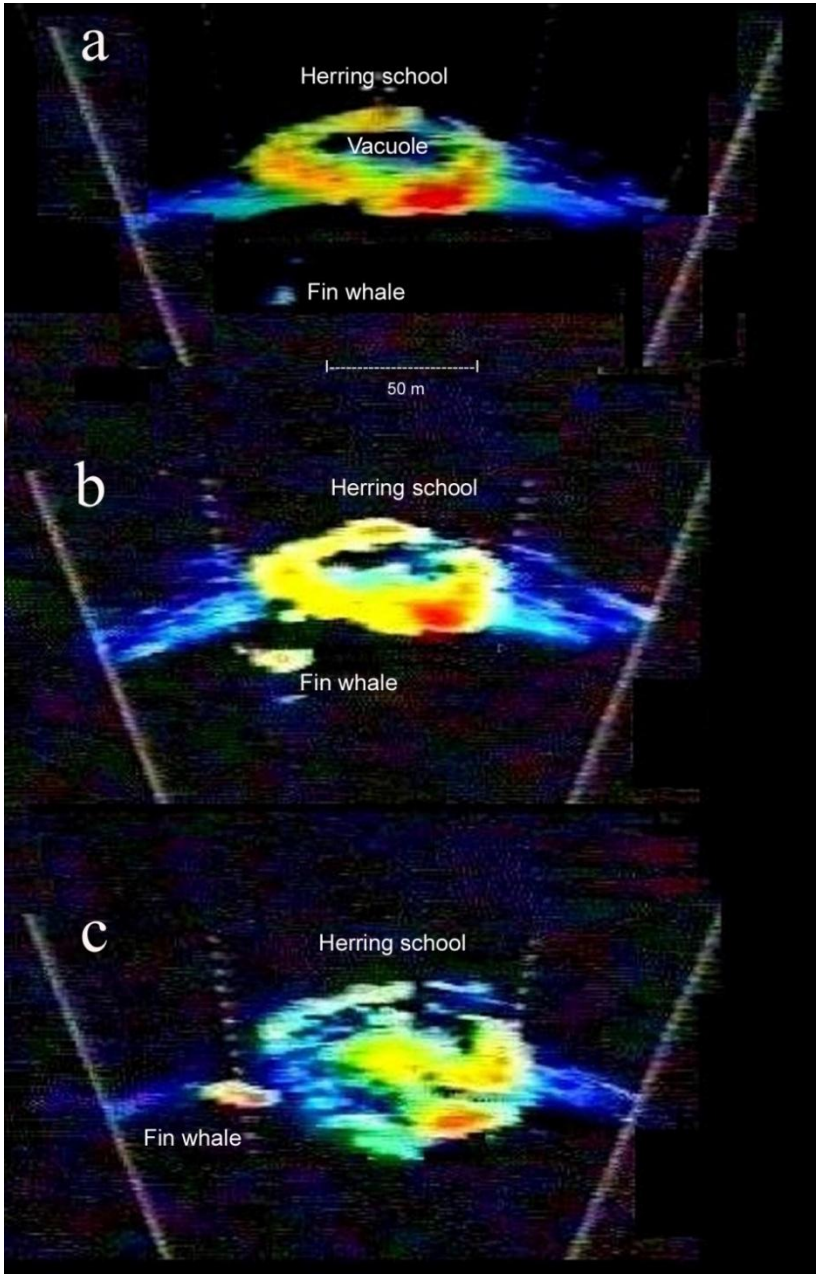
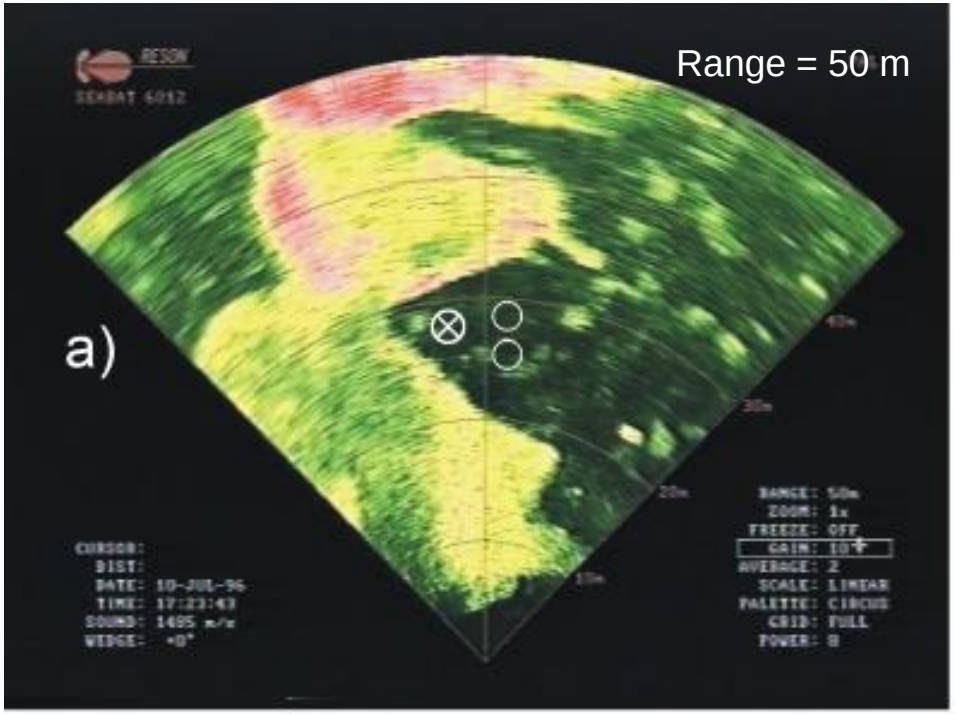
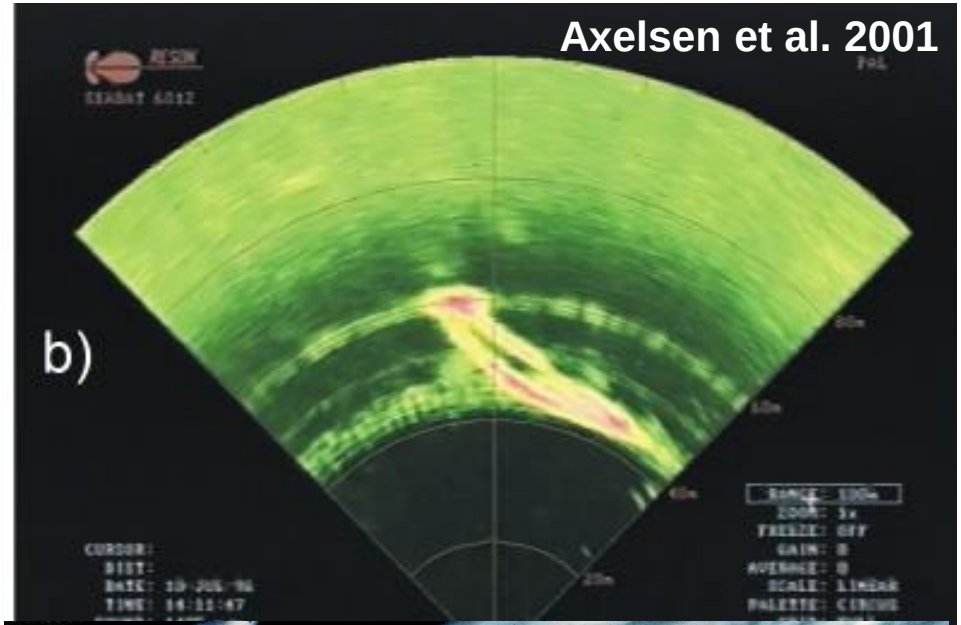
Fin whales pursuing herring at night

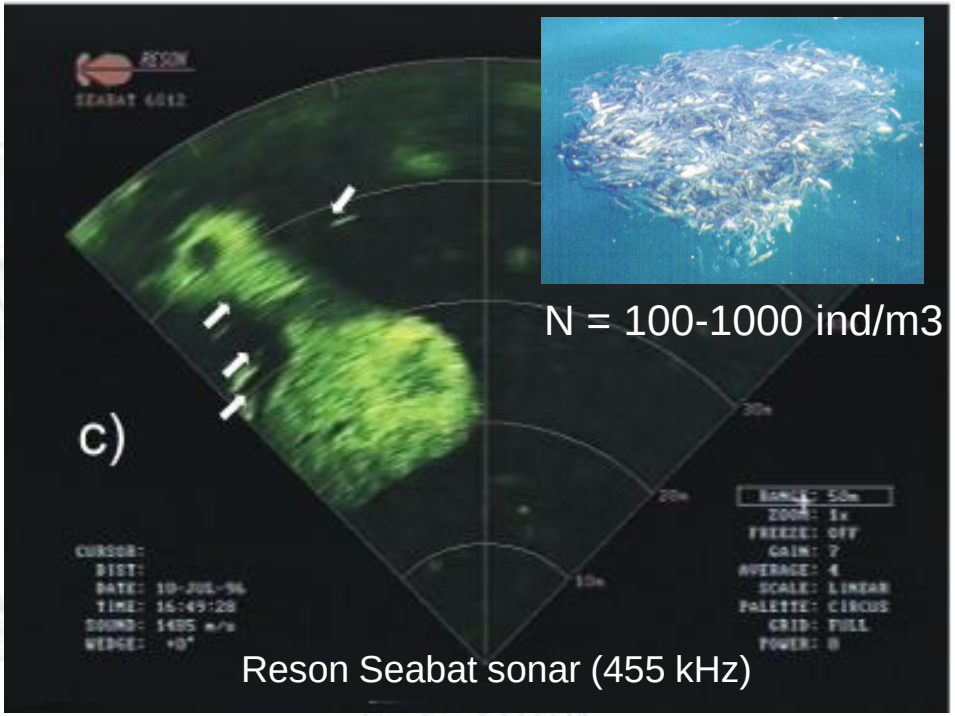




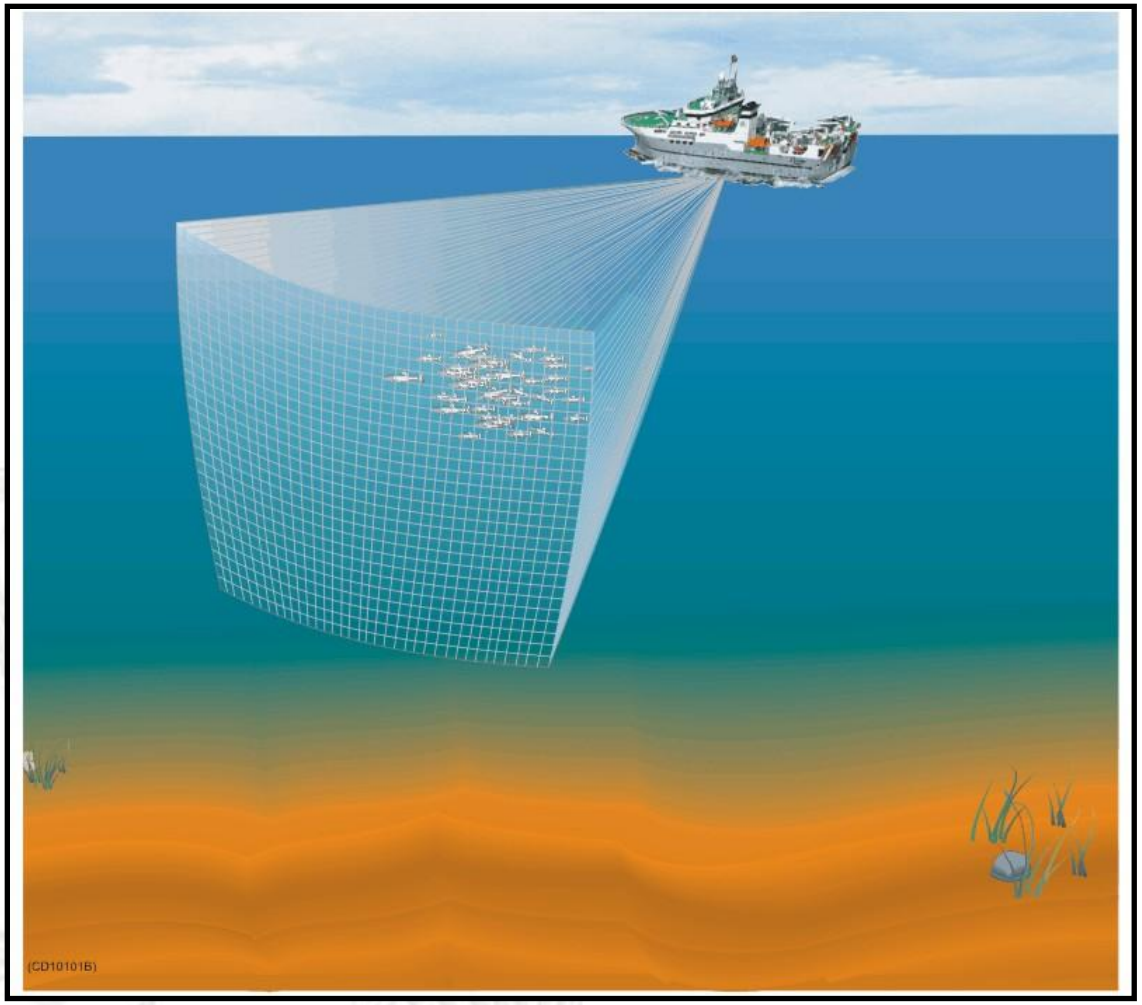
From Leif Nøttestad


Range = 50 m
a)

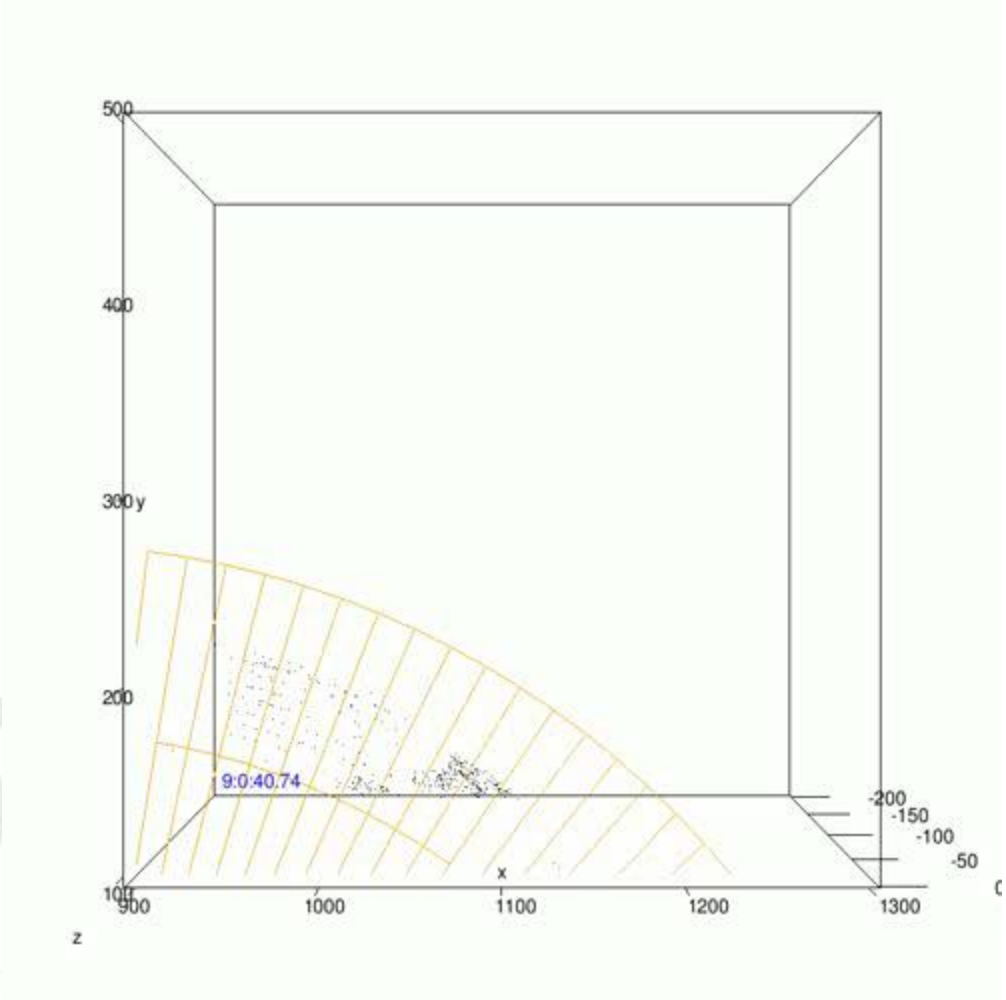

Axelsen et al. 2001
b)


N = 100-1000 ind/m3
c)
Reson Seabat sonar (455 kHz)

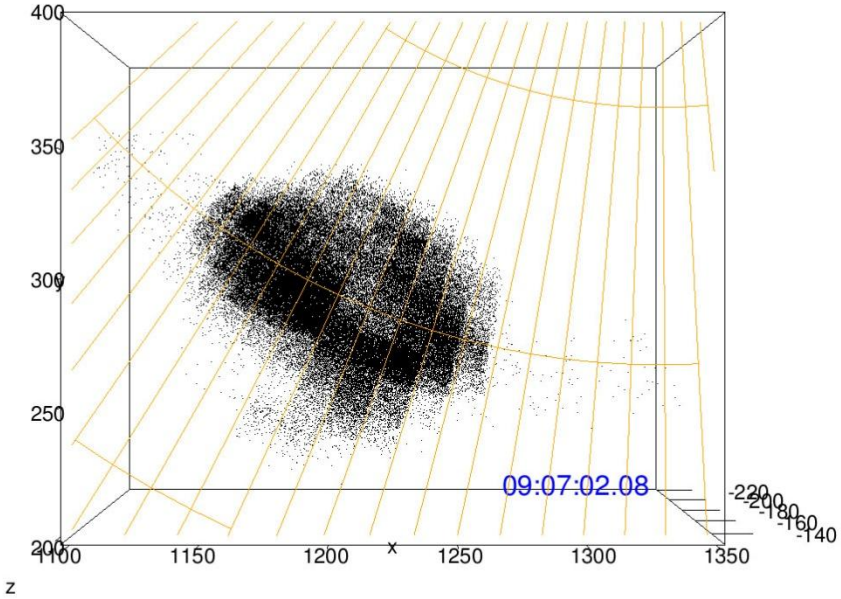
Multi beam sonars

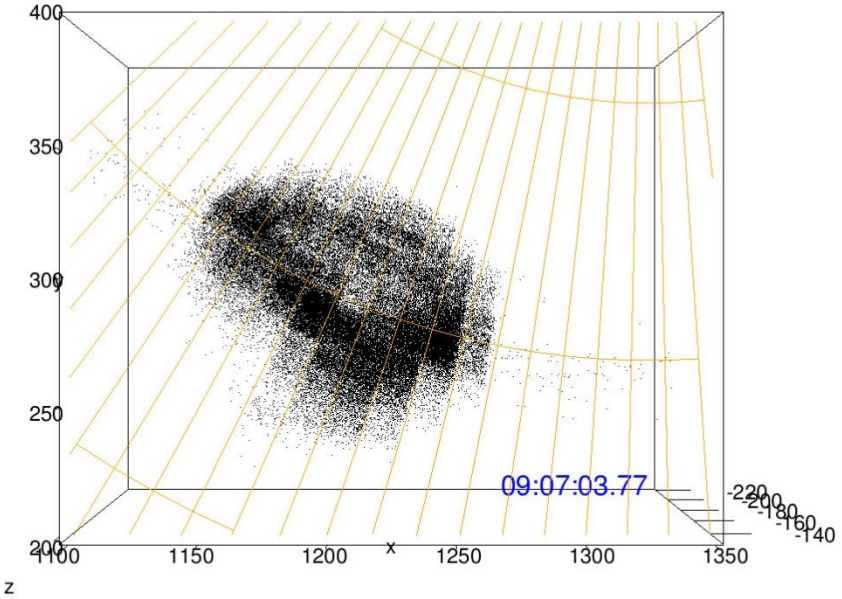


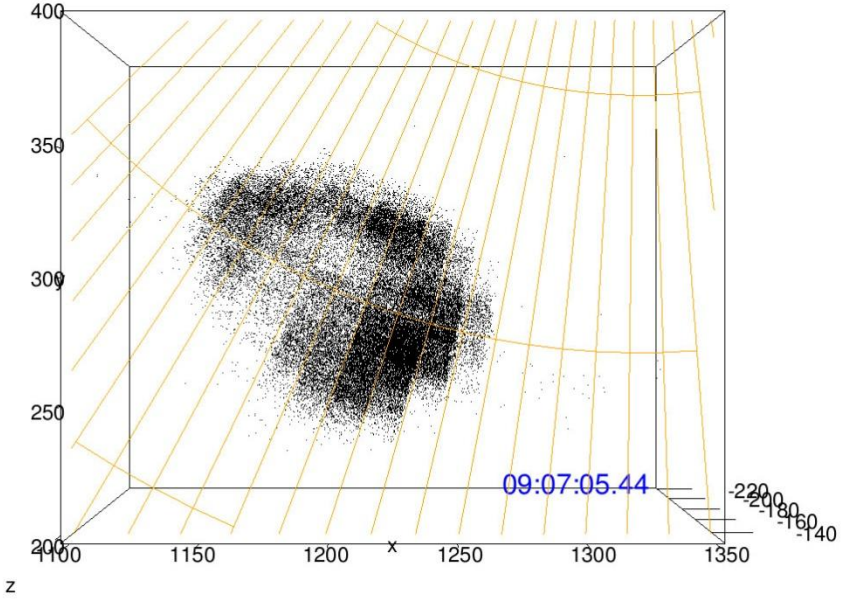
- Multiple beams
- School size and structure
- Typical range is 500m
- Simrad MS70:
- 500 individual beams

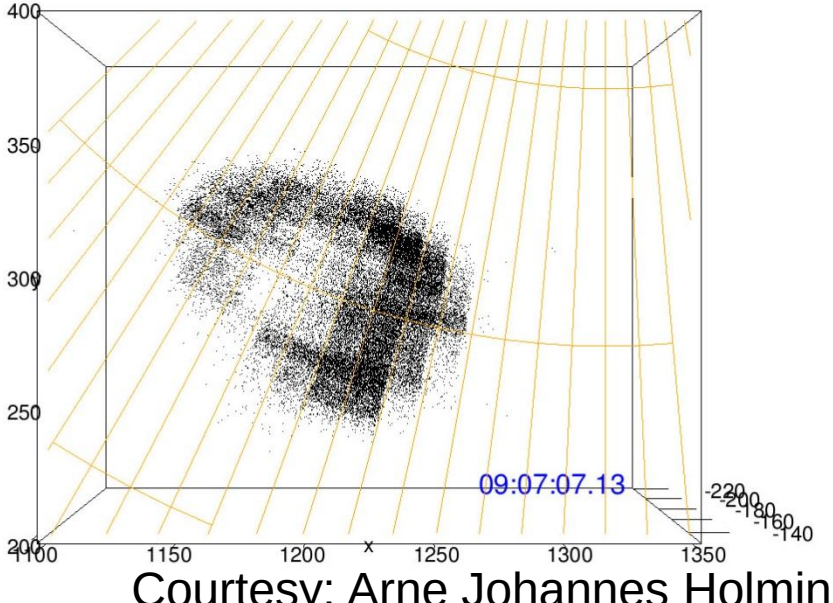


Courtesy: Arne Johannes Holmin









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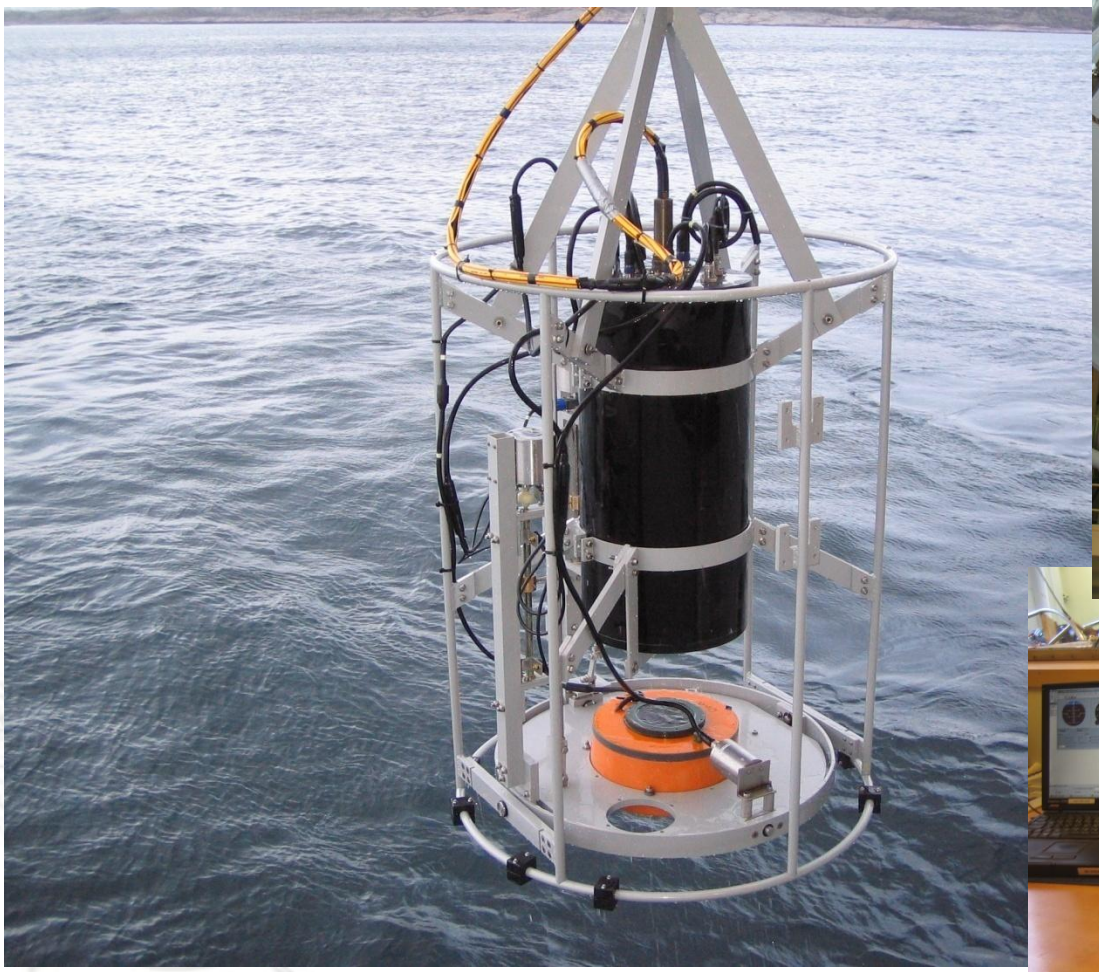
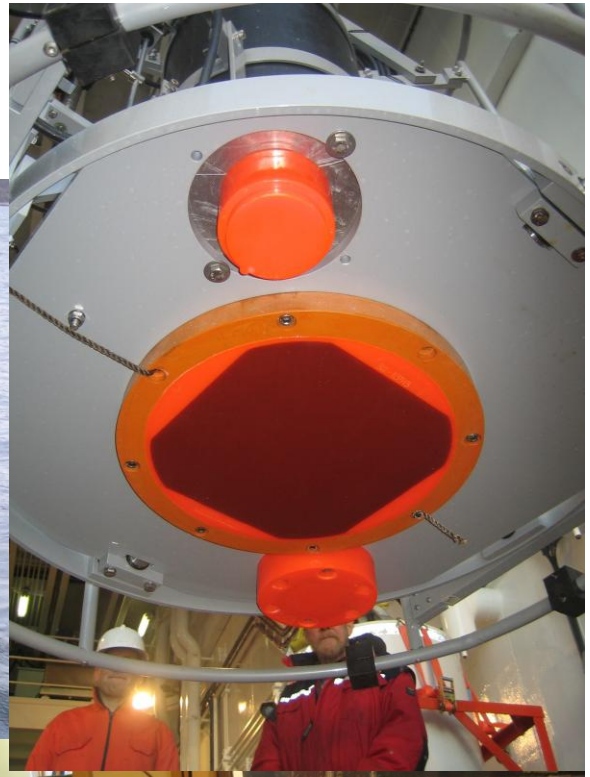
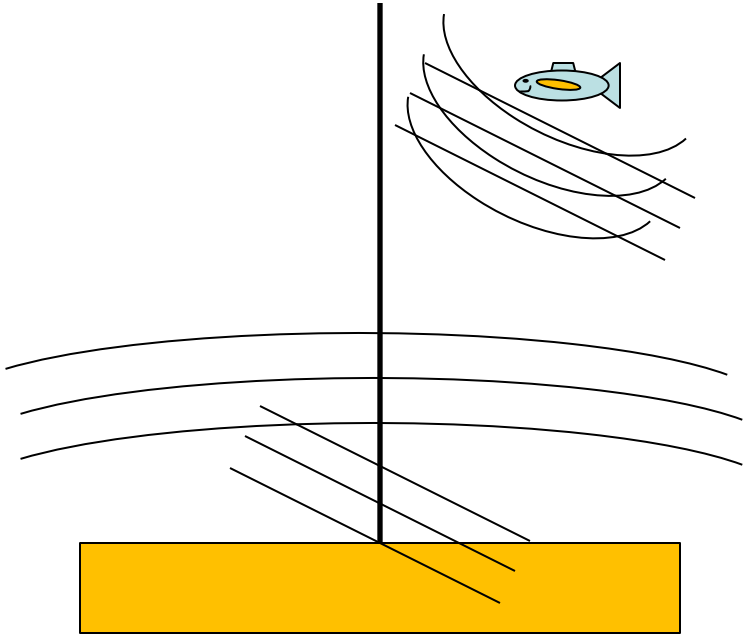
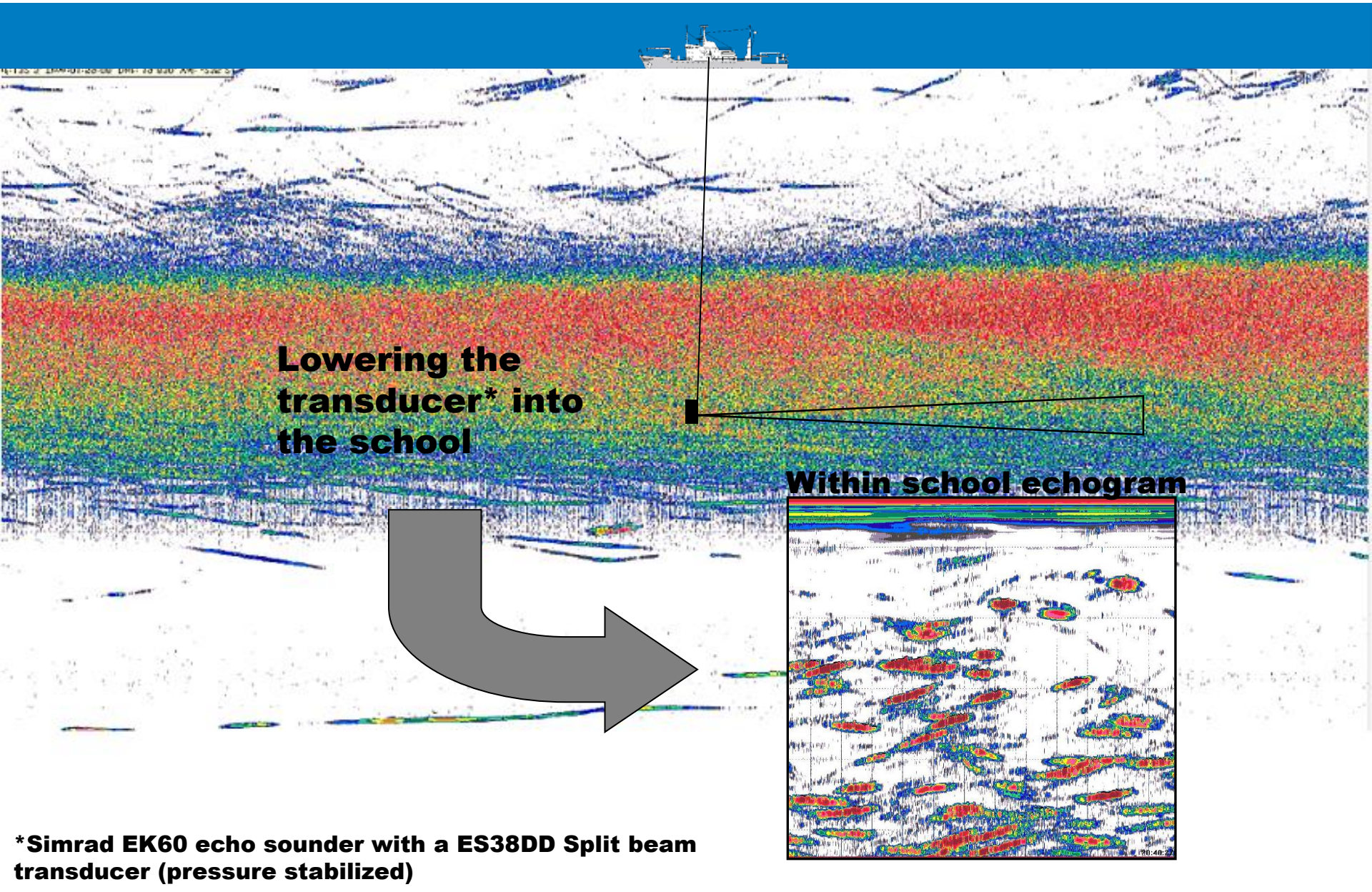
Drop sonde





The split-beam echosounder



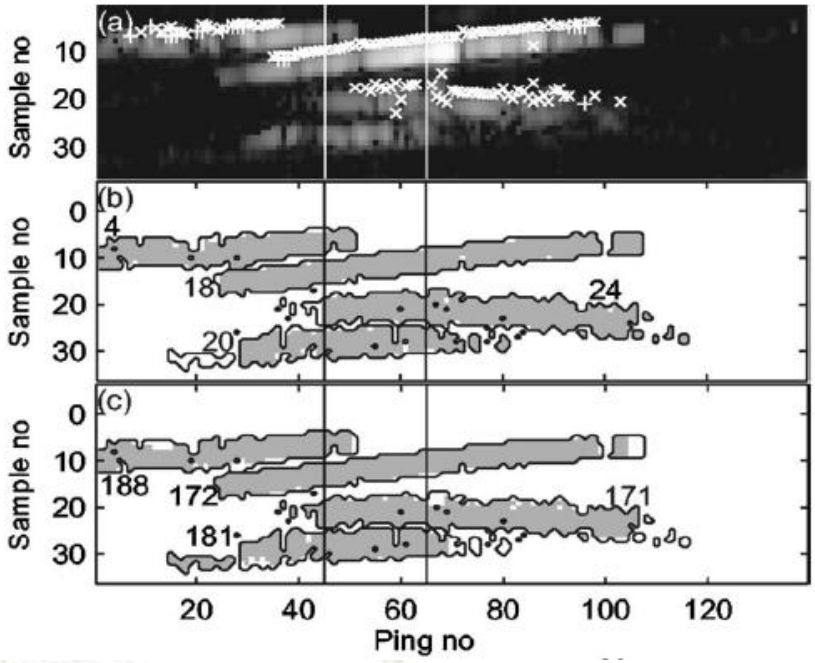


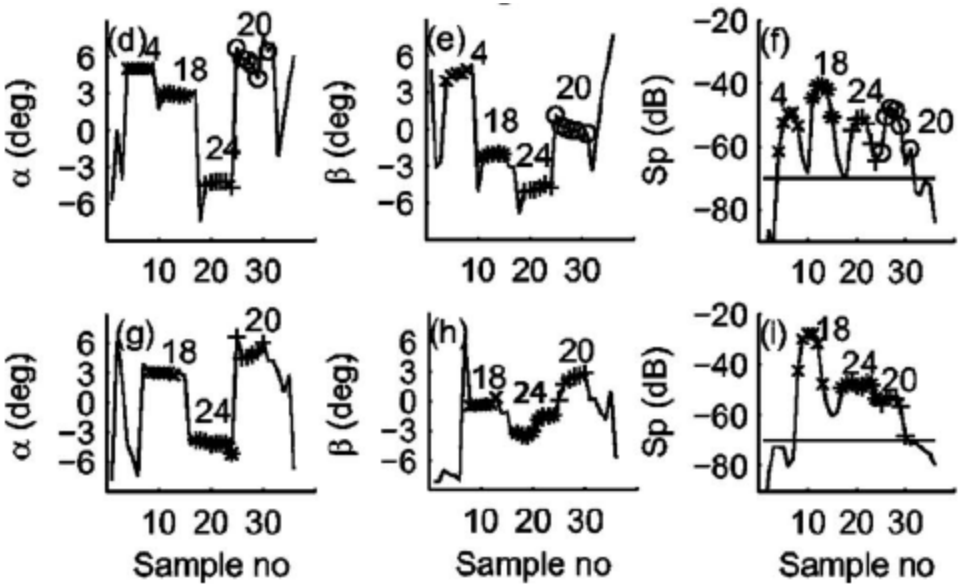
*Simrad EK60 echo sounder with a ES38DD Split beam transducer (pressure stabilized)

Observing individual fish behavior in fish aggregations: Tracking in dense fish aggregations using a split-beam echosounder

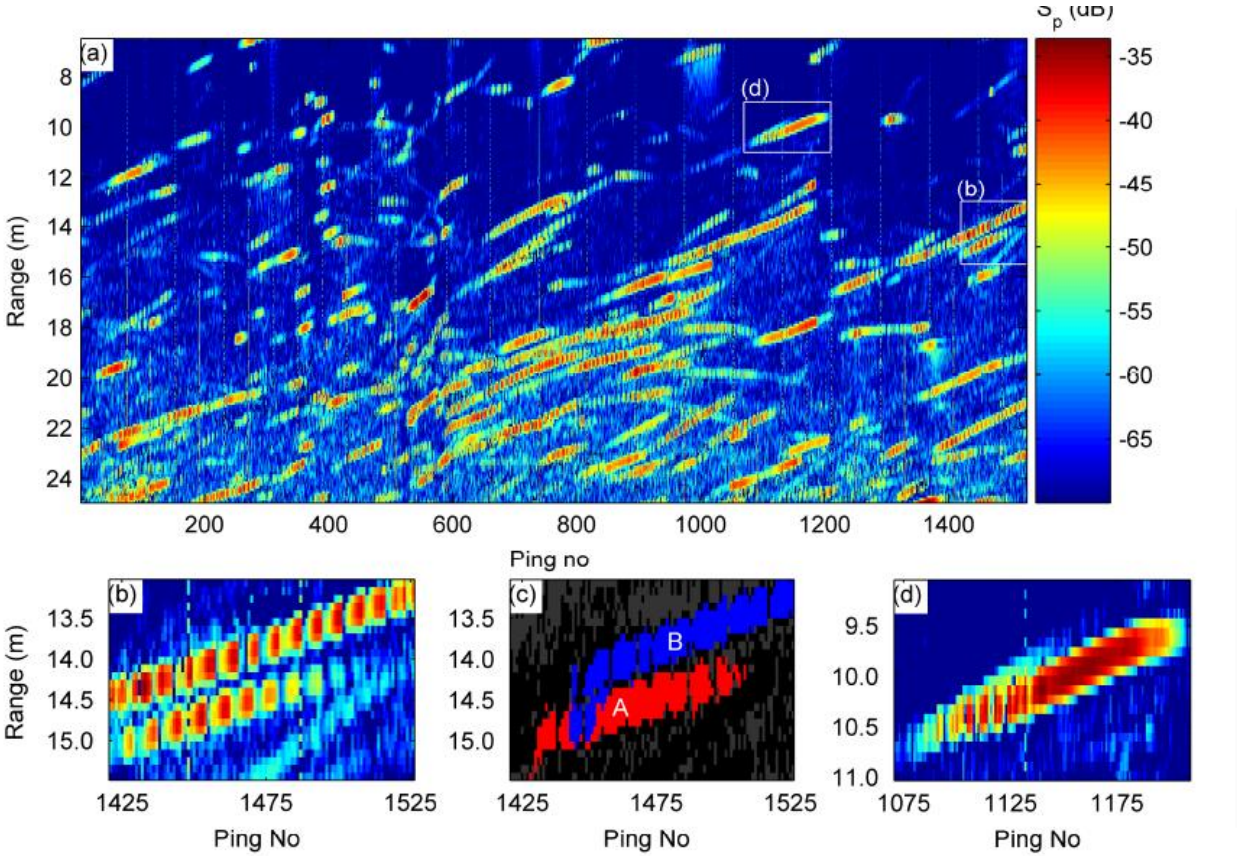
Nils Olav Handegard[a)]
Institute of Marine Research, Bergen, Norway

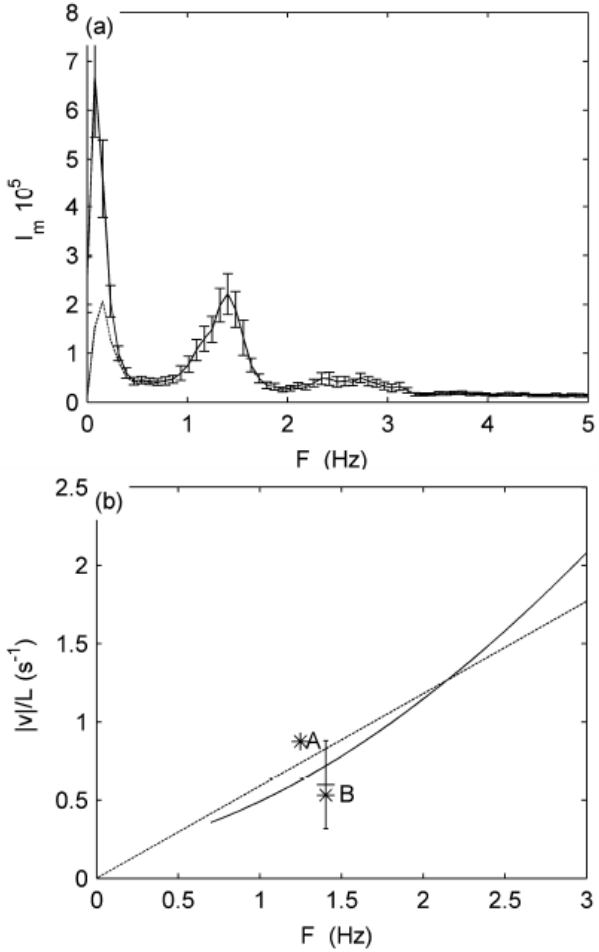
J. Acoust. Soc. Am. **122** (1), July 2007





Estimating tailbeat frequency

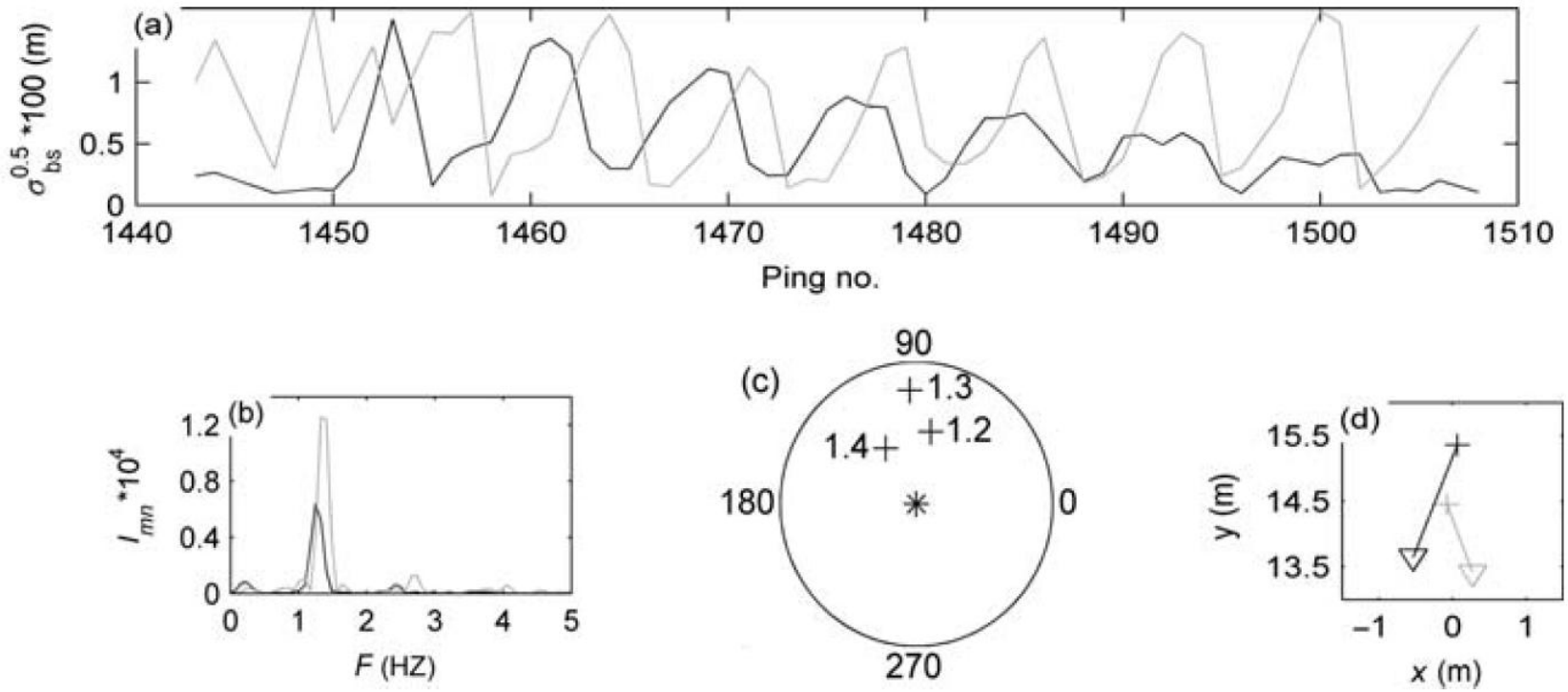


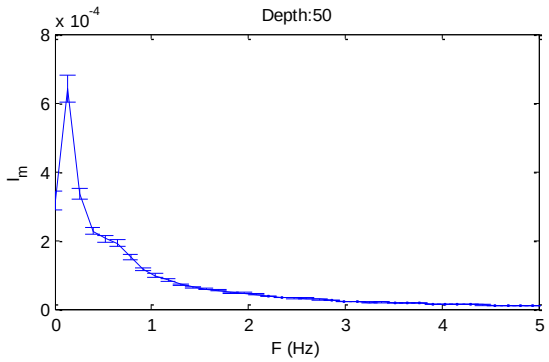


Handegard et al. (in press)

Estimating Tail-beat Frequency using split-beam echosounders

ICES Journal of Marine Science, in press


(a)
$\sigma_{bs}^{0.5}$ *100 (m)
1
0.5
0
1440
1450
1460
1470
1480
1490
1500
1510
Ping no.
(b)
I_{mn} *10^4
1.2
0.8
0.4
0
0
1
2
3
4
5
F (HZ)
(c)
90
+1.3
+1.2
1.4+
180
0
270
(d)
y (m)
15.5
14.5
13.5
−1
0
1
x (m)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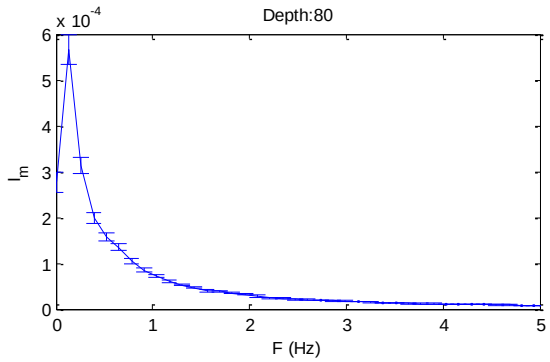
I_m
F (Hz)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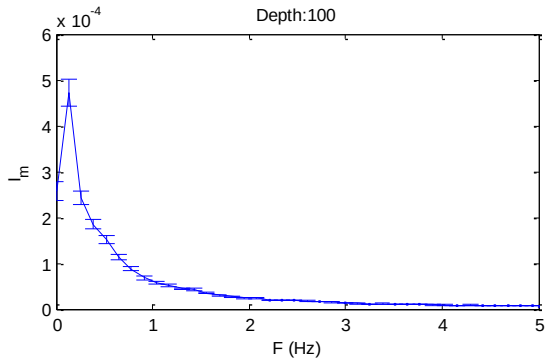
F (Hz)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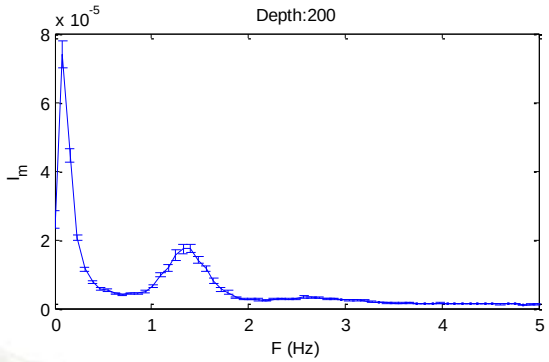
F (Hz)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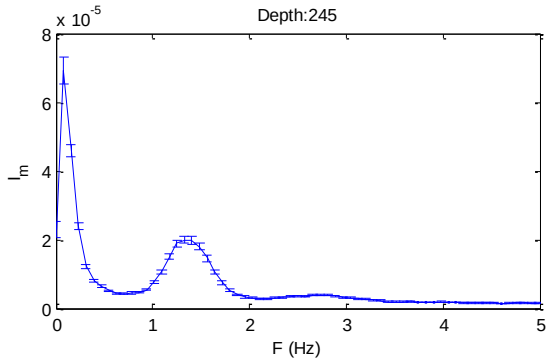
I_m
F (Hz)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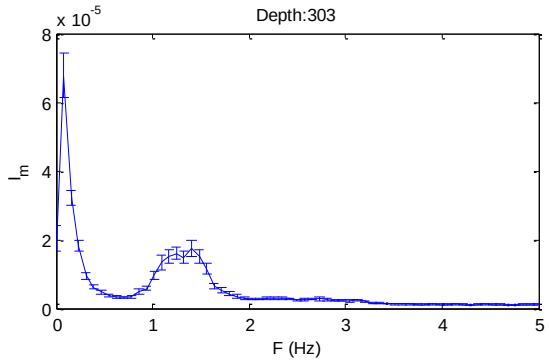
I_m
F (Hz)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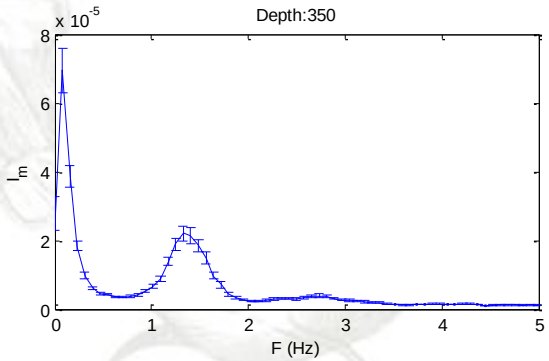
x 10^-5
I_m
F (Hz)


Depth:350
x 10^-5
I_m
F (Hz)

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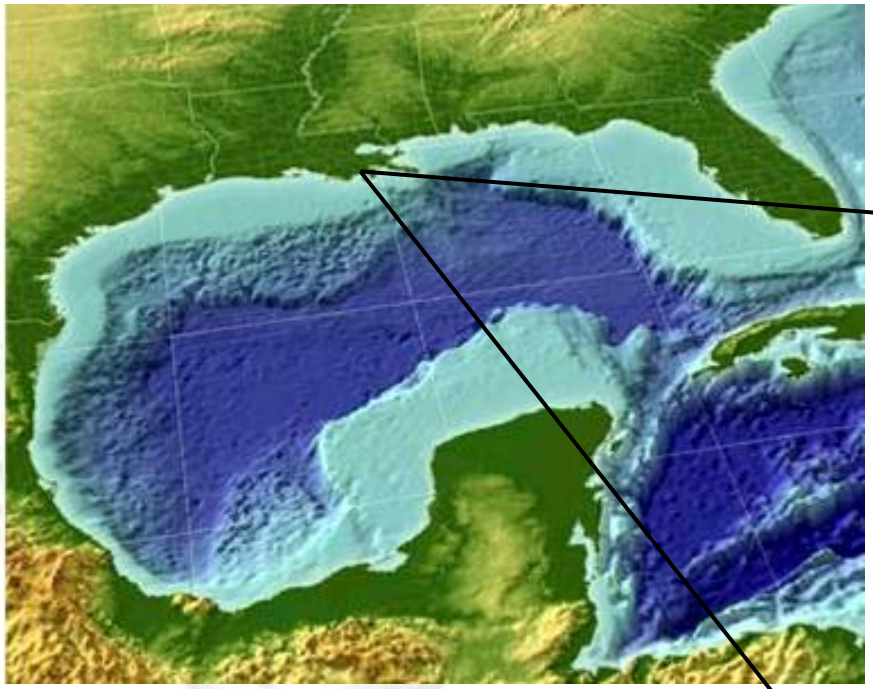
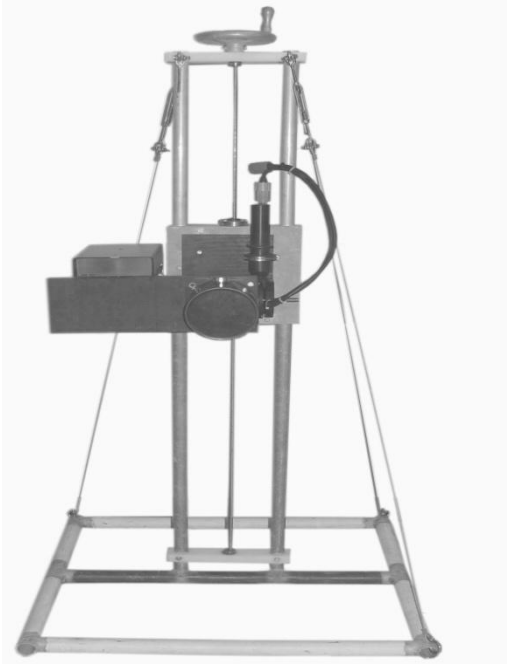
Observations

Sonar was deployed in shallow coastal waters (<2m depth) in Gulf of Mexico.



Observations

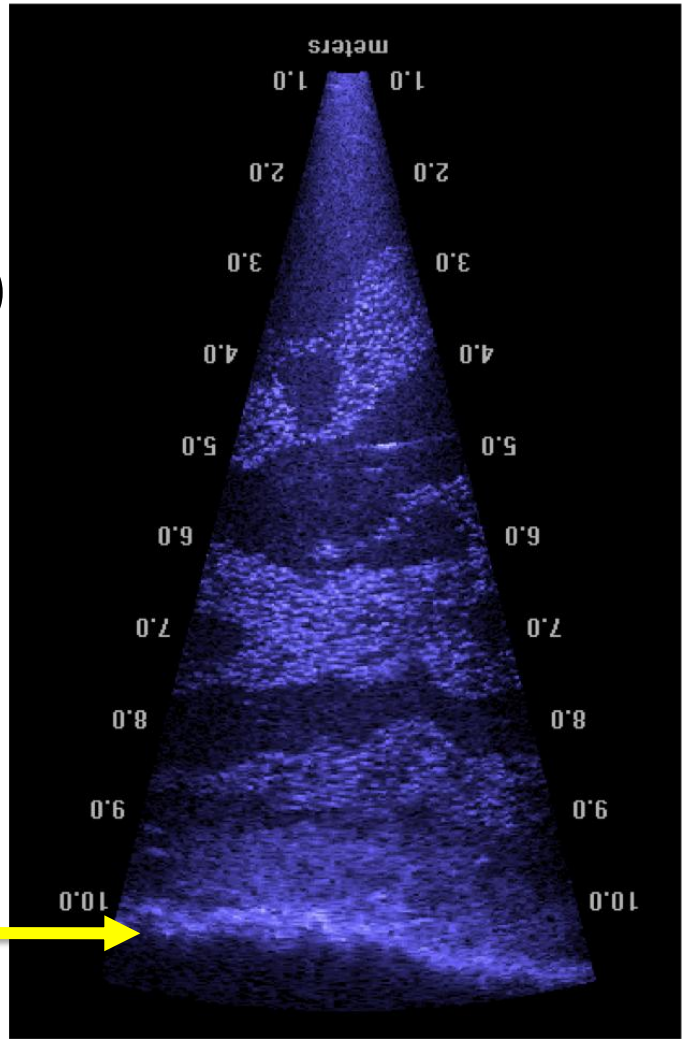
DIDSON sonar positioned 12 m from marsh edge



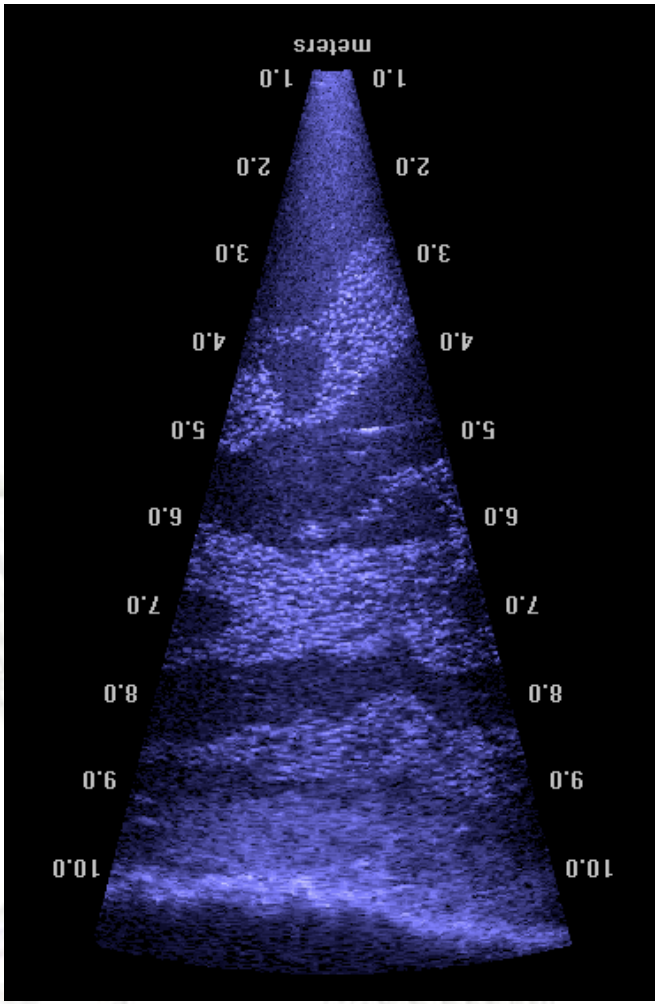
DIDSON sonar

High-frequency mode (1.8 MHz)
Collected at ~7 frames per second
Range ~10 m
Beam configuration (~-3dB):

- Across: 96x0,3 deg (5 cm @ 10m)
- Vertical : 14 deg (140 cm @ 10m)
- Range: 2 cm



Marsh Edge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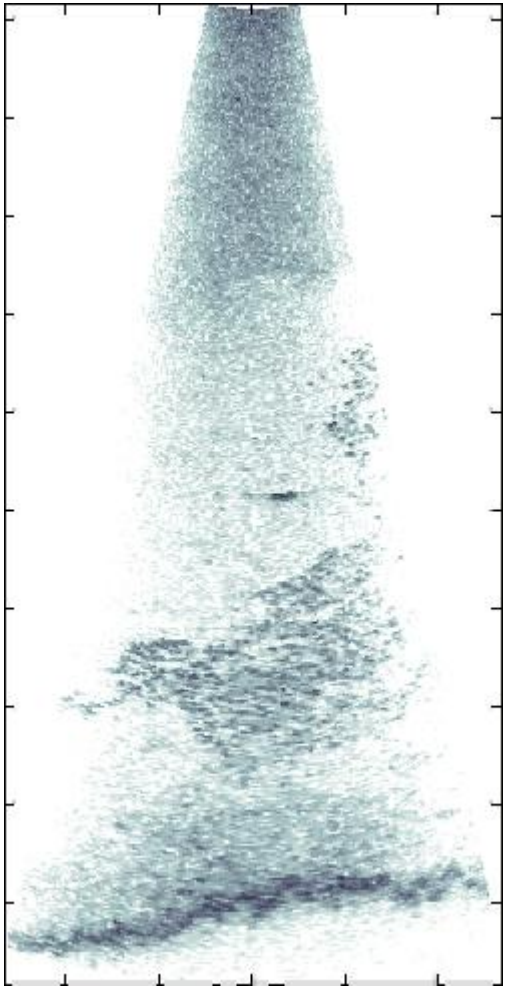
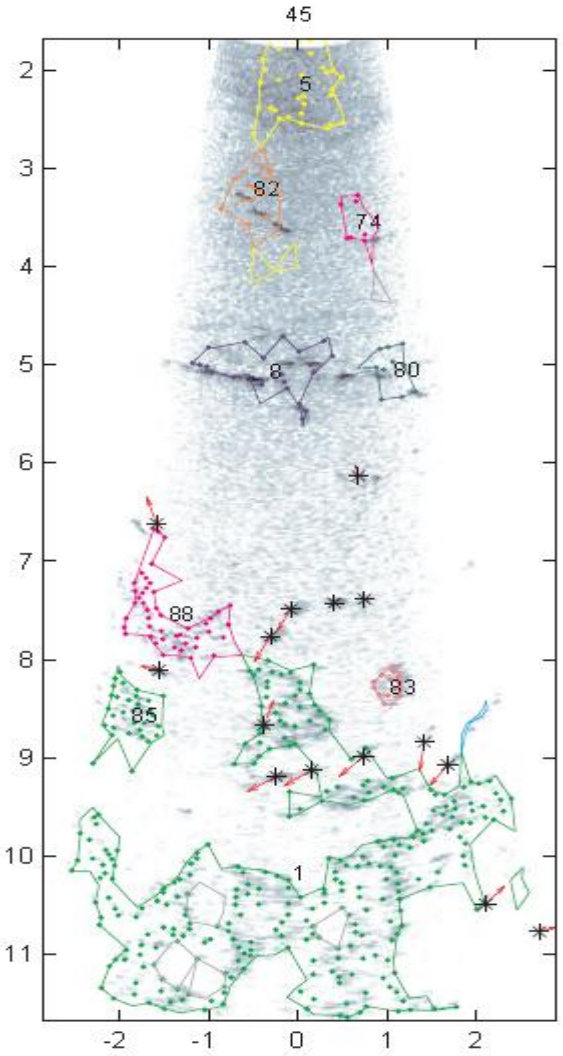
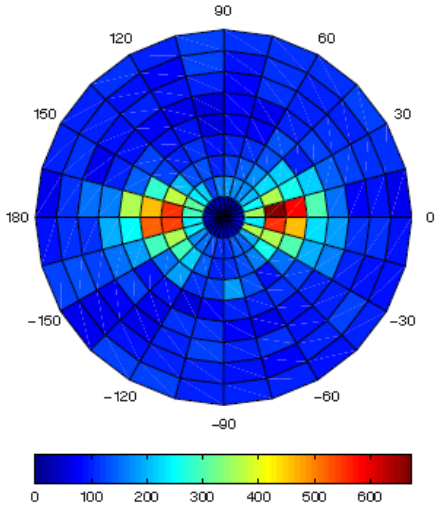
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0



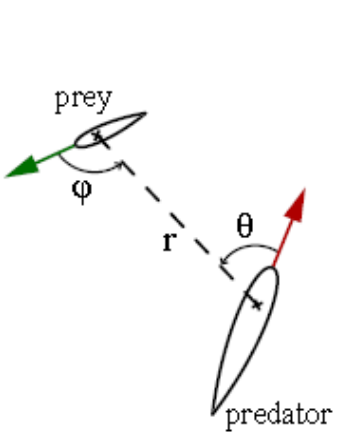

45
5
82
74
8
80
88
83
85
1
2
3
4
5
6
7
8
9
10
11
-2
-1
0
1
2

Results

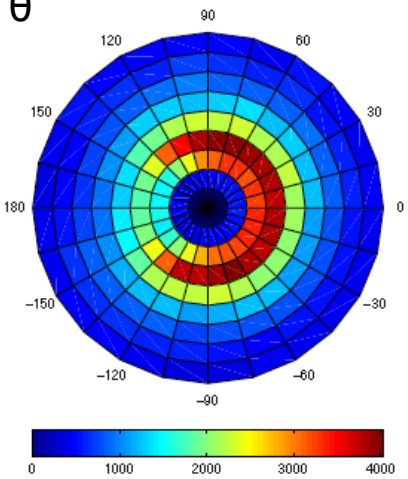
Predator-predator interaksjonar



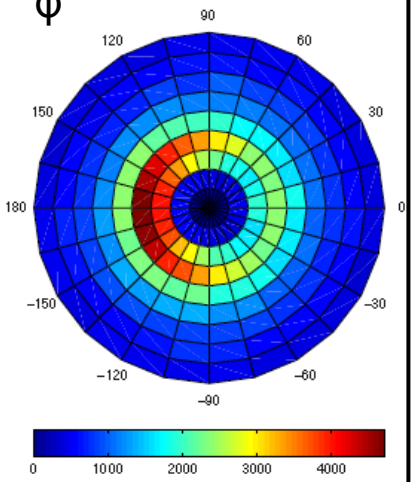
Predator-byttedyr interaksjonar

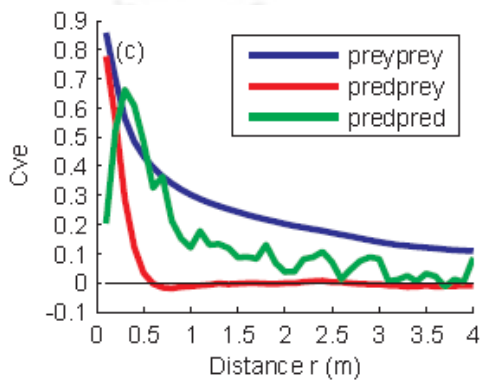


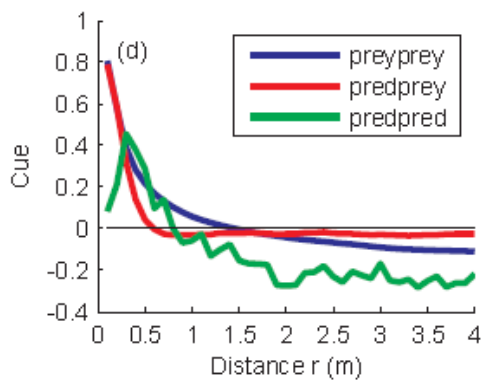
θ



φ





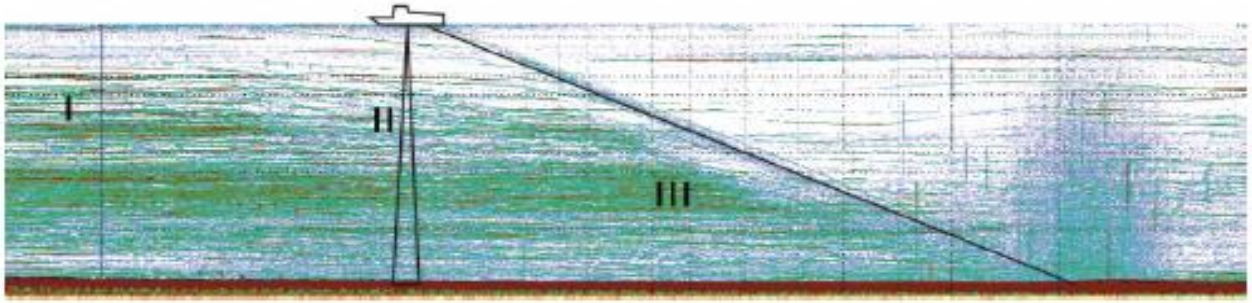


Korrelasjonslengder

Ting eg har lurt på

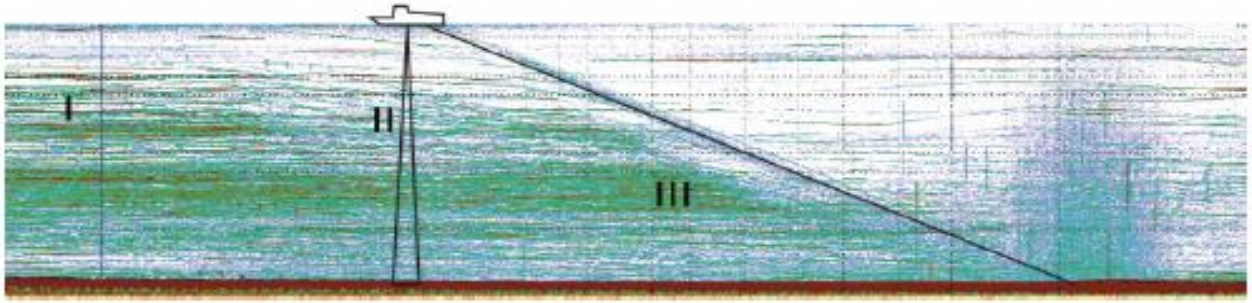
- Korleis oppfører fisken seg i høve til det fysiske miljøet?
- Kor dynamisk er ein fiskestim?
- Kva skjer med symjemønsteret når symjeblæra vert trykt saman?
- Kva er dynamikken mellom predatorar og byttedyr?
- Korleis oppfører fisk når eit fartøy nærmar seg og kvifor bør vi bry oss om det?

Fish behaviour and sampling

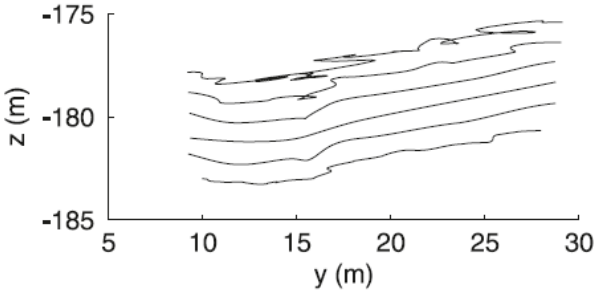


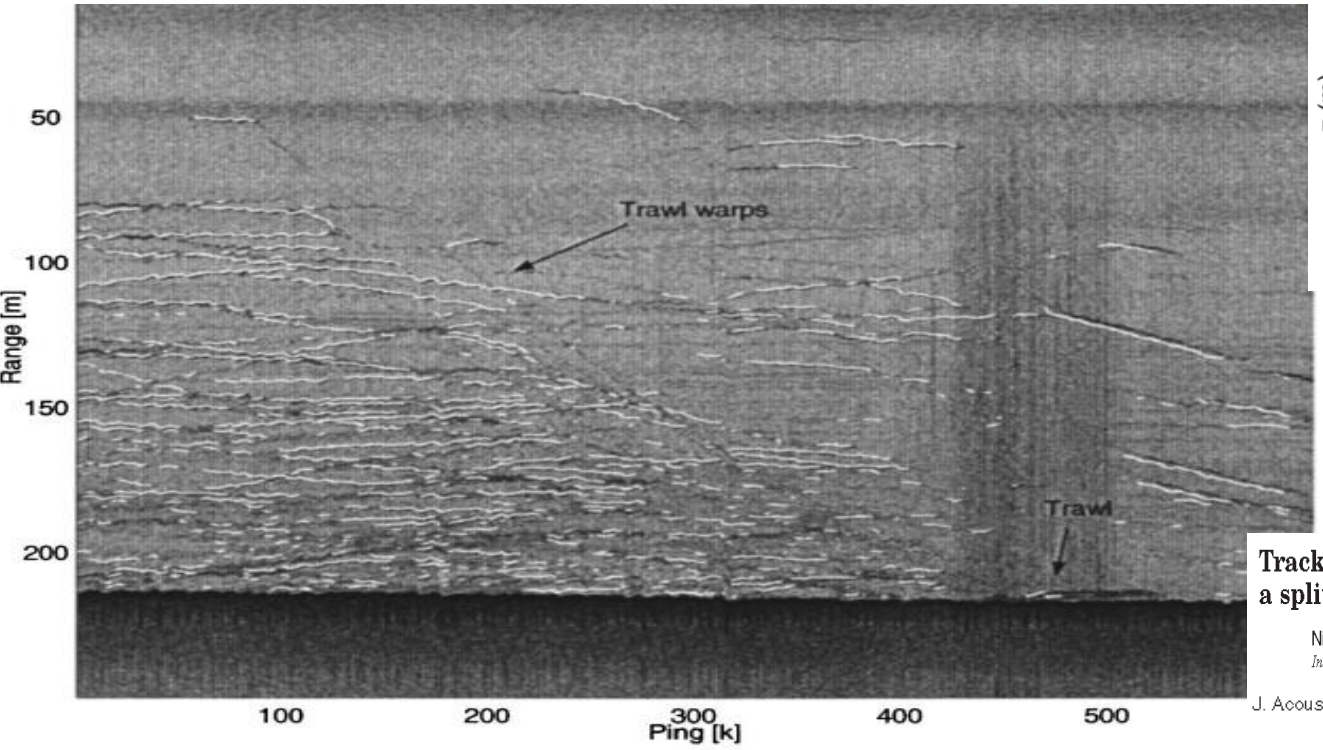
- The behaviour
  - I Behaviour before the arrival of the vessel
  - II Reaction close to the vessel
  - III Reaction to the gear
  - IV Selectivity to trawl (net, gear, mesh, etc)
- How does it affect the surveys?

Observing fish behaviour



54 passings
23k tracks



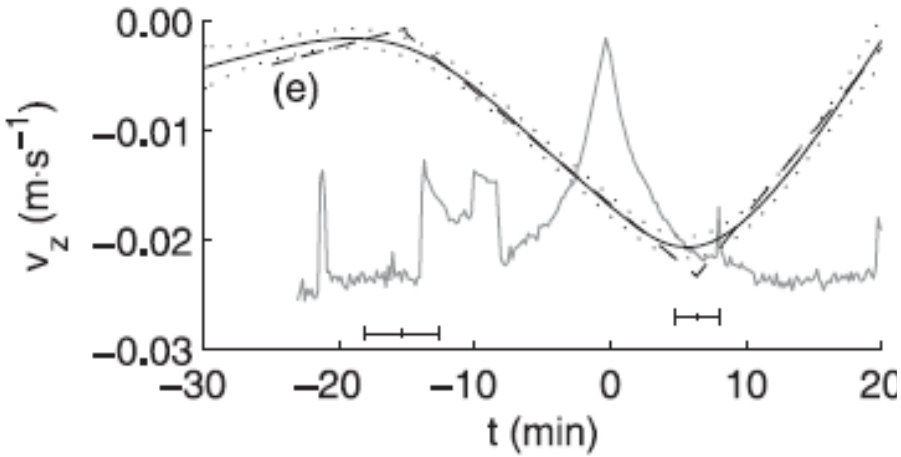


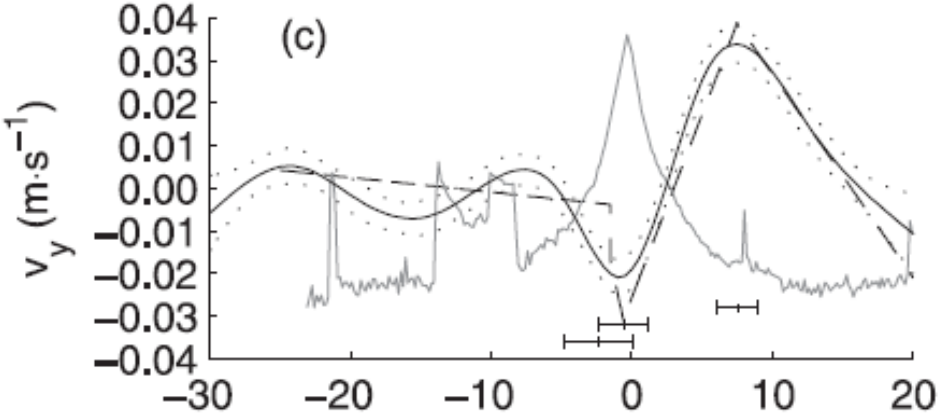
Tracking individual fish from a moving platform using a split-beam transducer

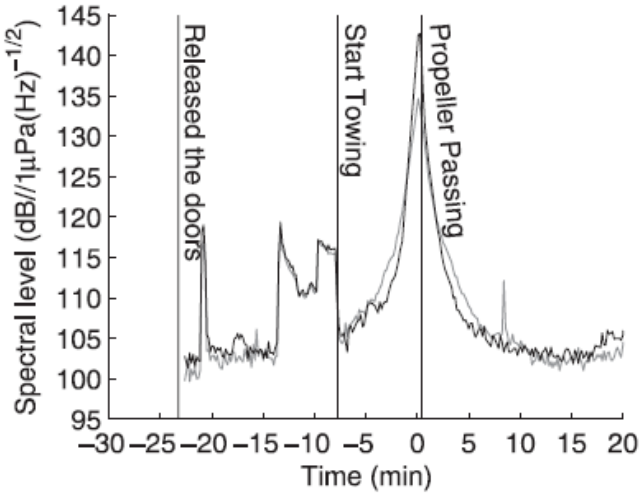
Nils Olav Handegard,[a)] Ruben Patel, and Vidar Hjellvik
Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway

J. Acoust. Soc. Am. **118** (4), October 2005

Observing fish behaviour



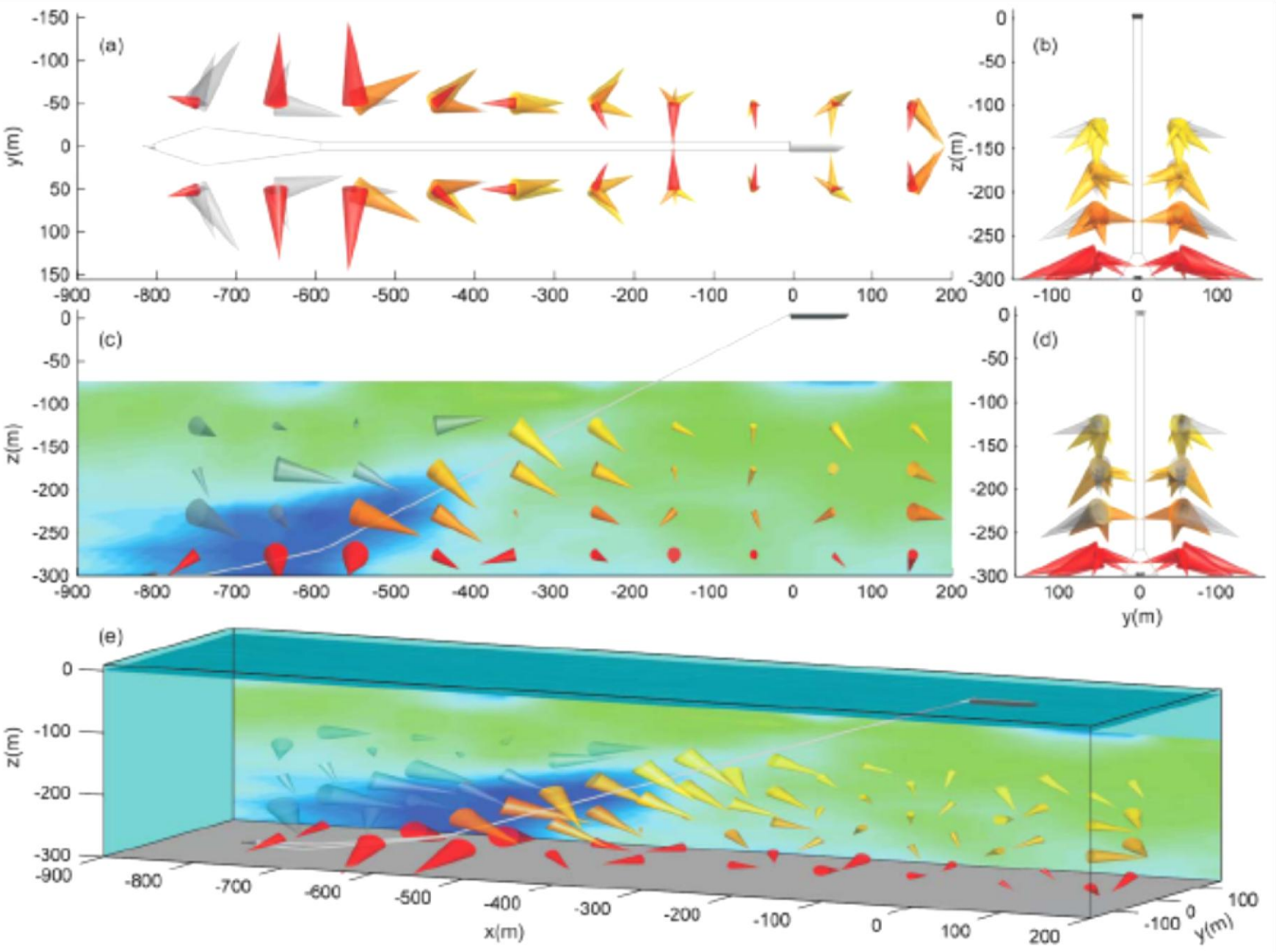


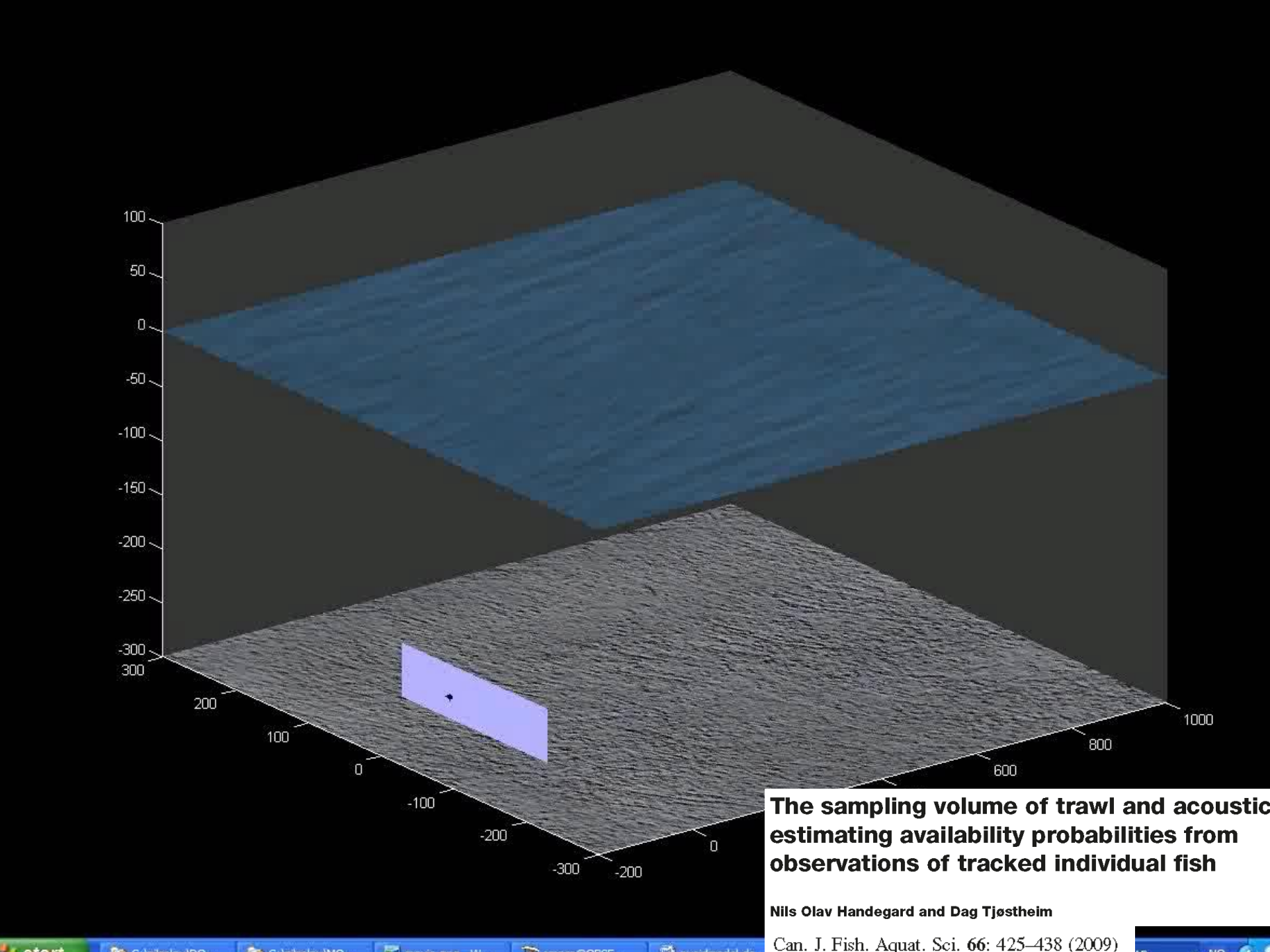


When fish meet a trawling vessel: examining the behaviour of gadoids using a free-floating buoy and acoustic split-beam tracking

Nils Olav Handegard and Dag Tjøstheim

Can. J. Fish. Aquat. Sci. 62: 2409–2422 (2005)


(a)
y(m)
-150
-100
-50
0
50
100
150
-900
-800
-700
-600
-500
-400
-300
-200
-100
0
100
200
(b)
z(m)
0
-50
-100
-150
-200
-250
-300
-100
0
100
(c)
z(m)
0
-50
-100
-150
-200
-250
-300
-900
-800
-700
-600
-500
-400
-300
-200
-100
0
100
200
(d)
0
-50
-100
-150
-200
-250
-300
100
0
-100
y(m)
(e)
z(m)
0
-100
-200
-300
-900
-800
-700
-600
-500
-400
-300
-200
-100
0
100
200
x(m)
-100
0
100
y(m)

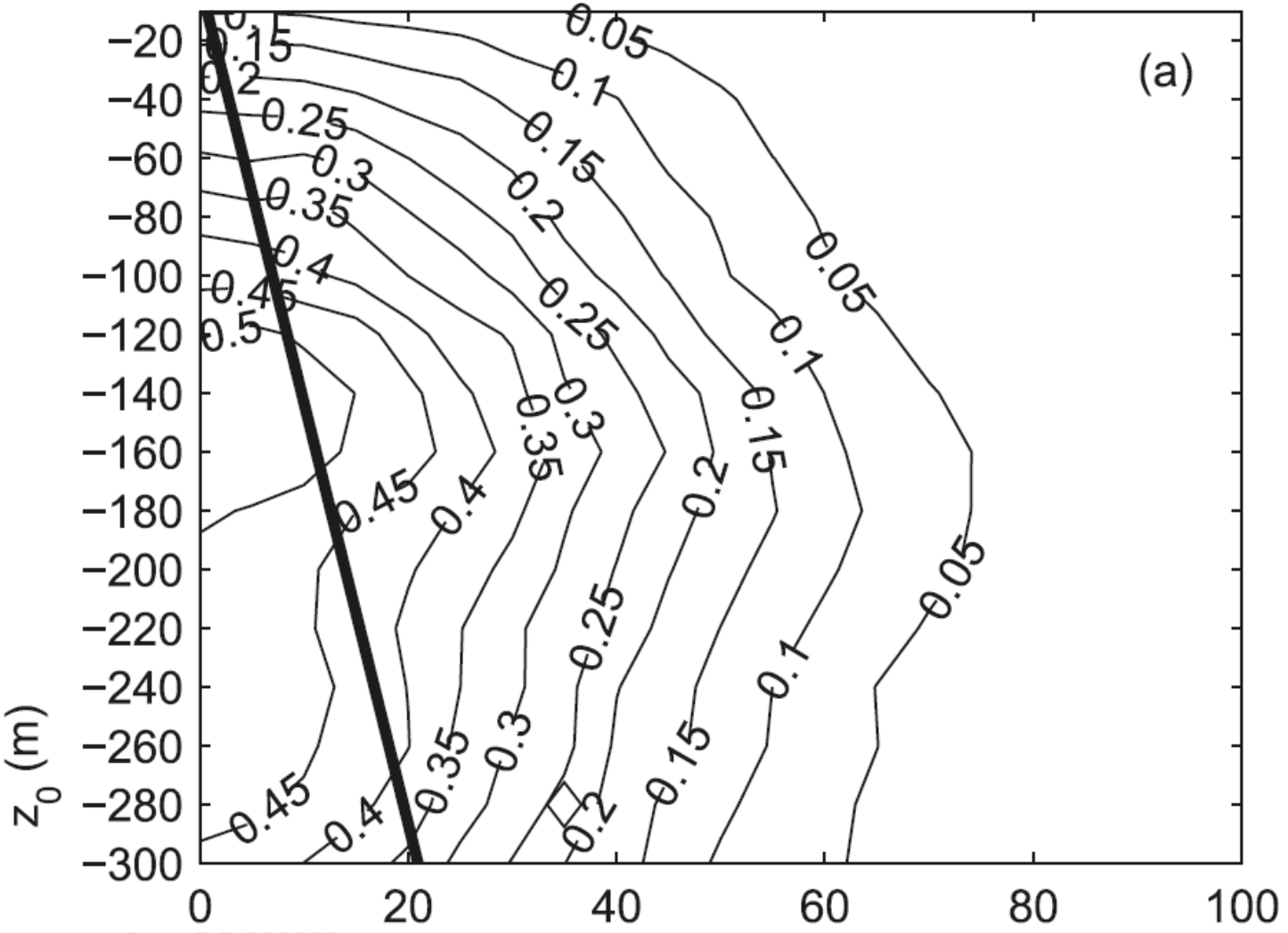


The sampling volume of trawl and acoustic estimating availability probabilities from observations of tracked individual fish

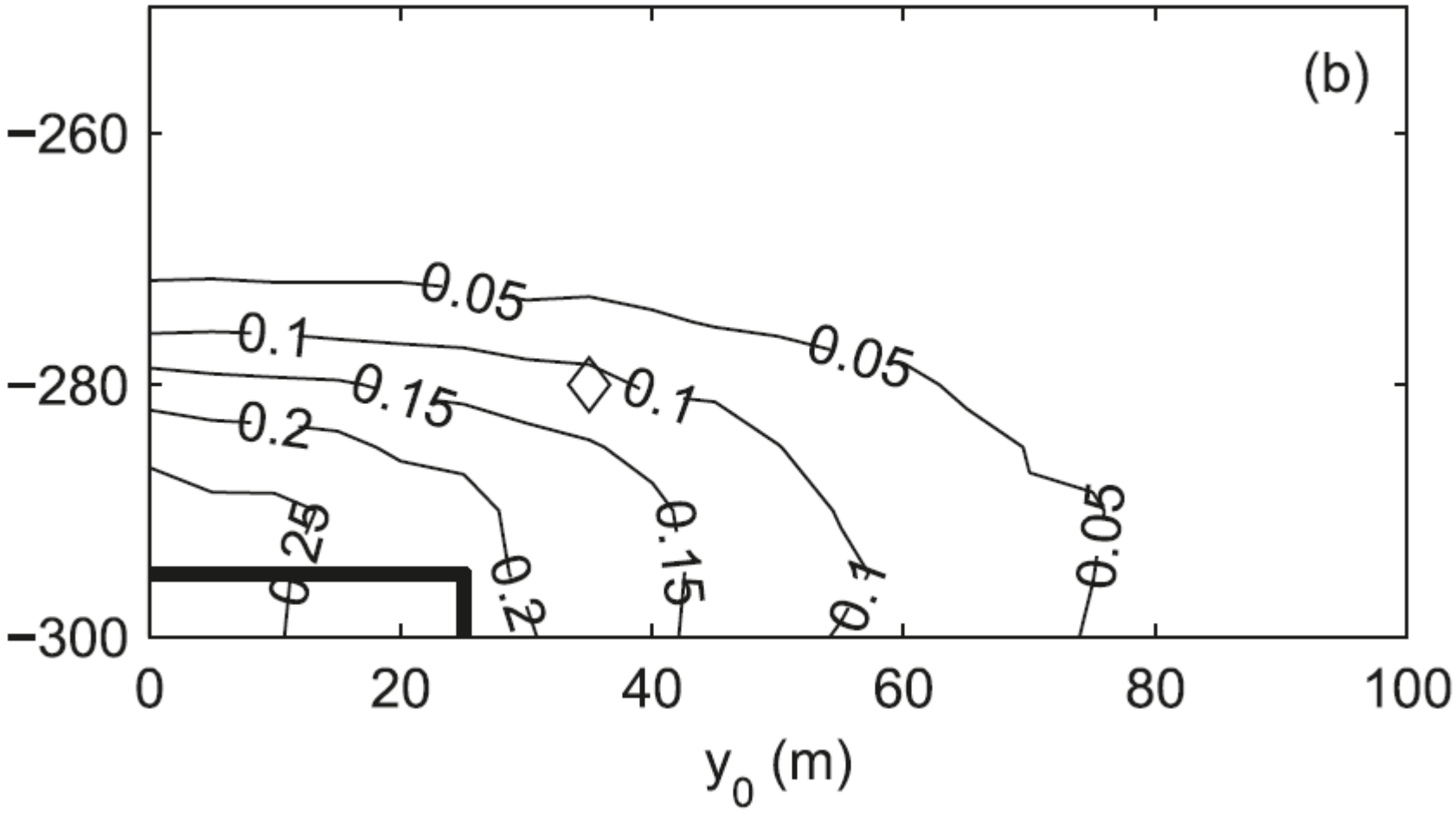
Nils Olav Handegard and Dag Tjøstheim

Can. J. Fish. Aquat. Sci. **66**: 425–438 (2009)

P(within echo beam)



P(available to trawl)



Avoidance

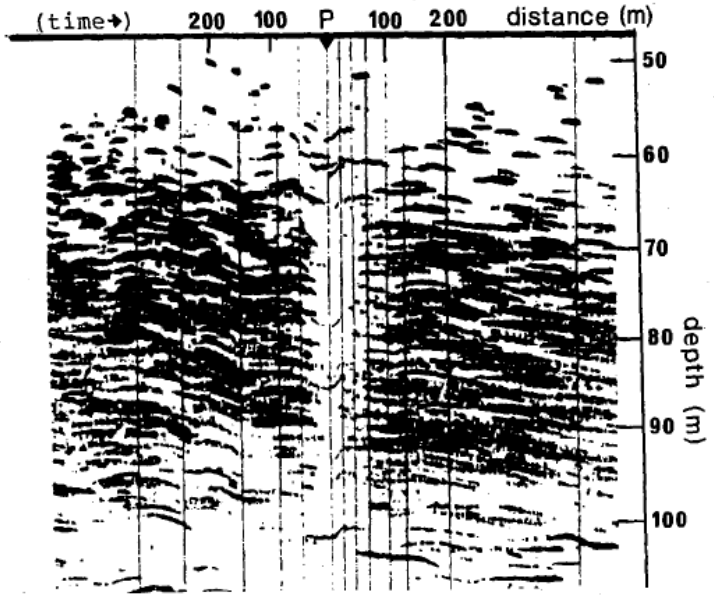
OBSERVED FISH REACTIONS TO A SURVEYING VESSEL WITH SPECIAL REFERENCE TO HERRING, COD, CAPELIN AND POLAR COD

by

Kjell Olsen, Jostein Angell and Fritz Pettersen,
Institute of Fisheries, University of Tromsø,
P.O. Box 3083 Guleng, 9001 TROMSØ, Norway

and

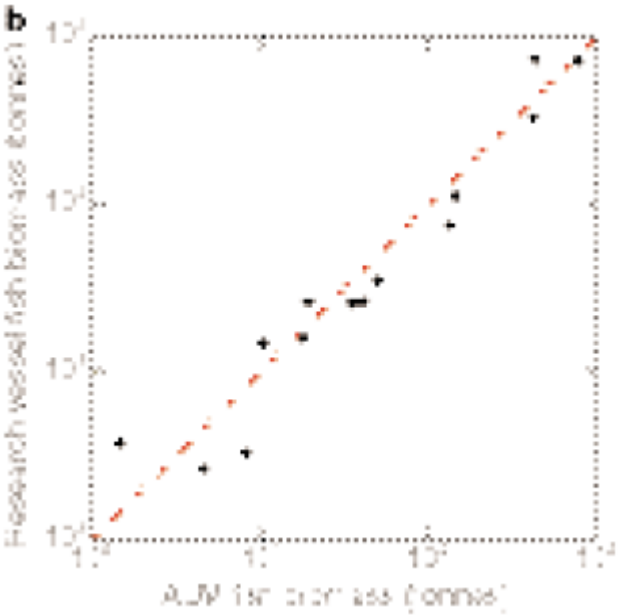
Arne Løvik
Electr. Res. Lab. (ELAB), University of Trondheim,
7034 TRONDHEIM - NTH, Norway



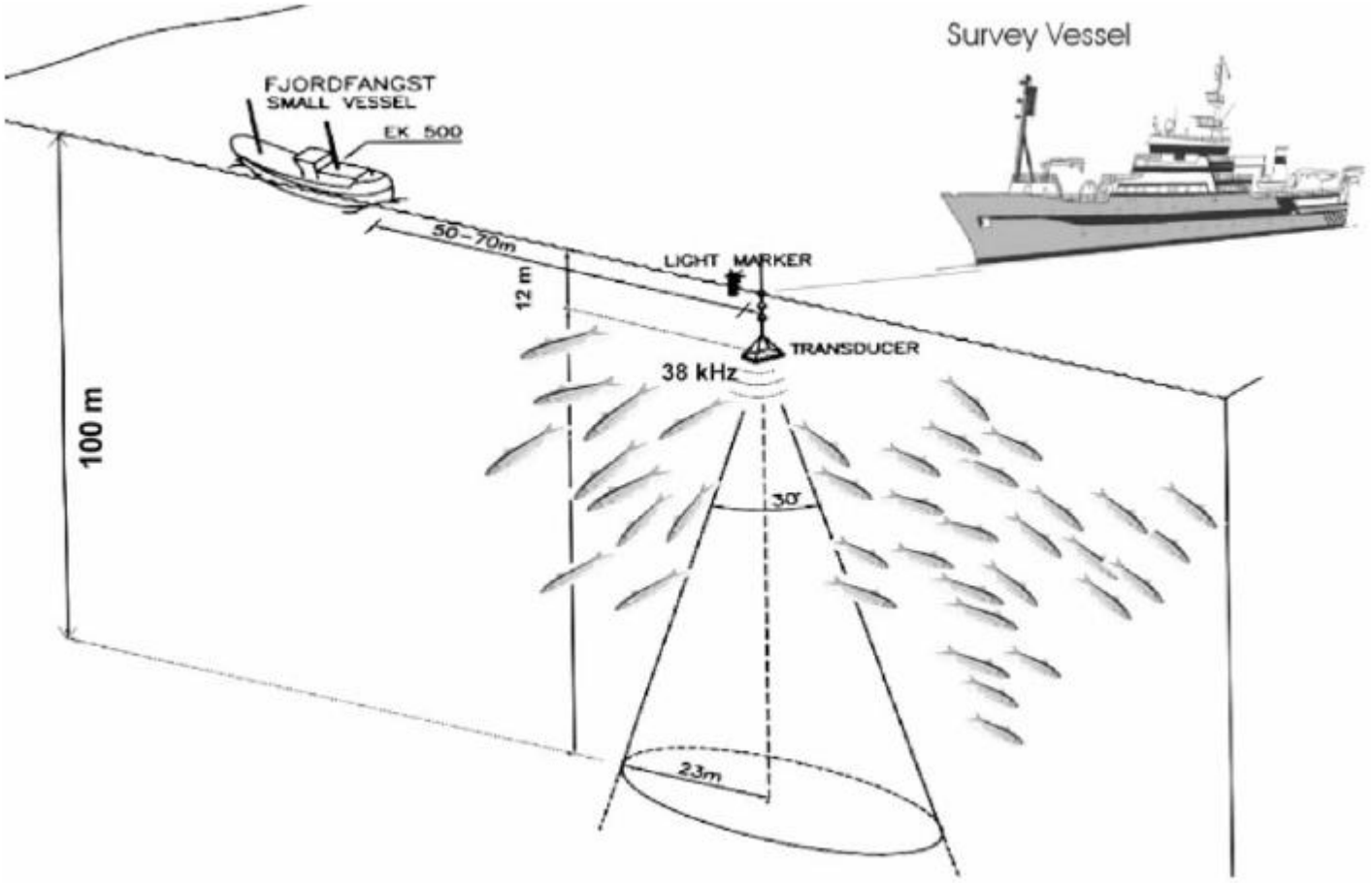
Fish do not avoid survey vessels

NATURE | VOL 404 | 2 MARCH 2000 | www.nature.com

P. G. Fernandes*, A. S. Brierley†,
E. J. Simmonds*, N. W. Millard‡,
S. D. McPhail‡, F. Armstrong*,
P. Stevenson‡, M. Squires‡

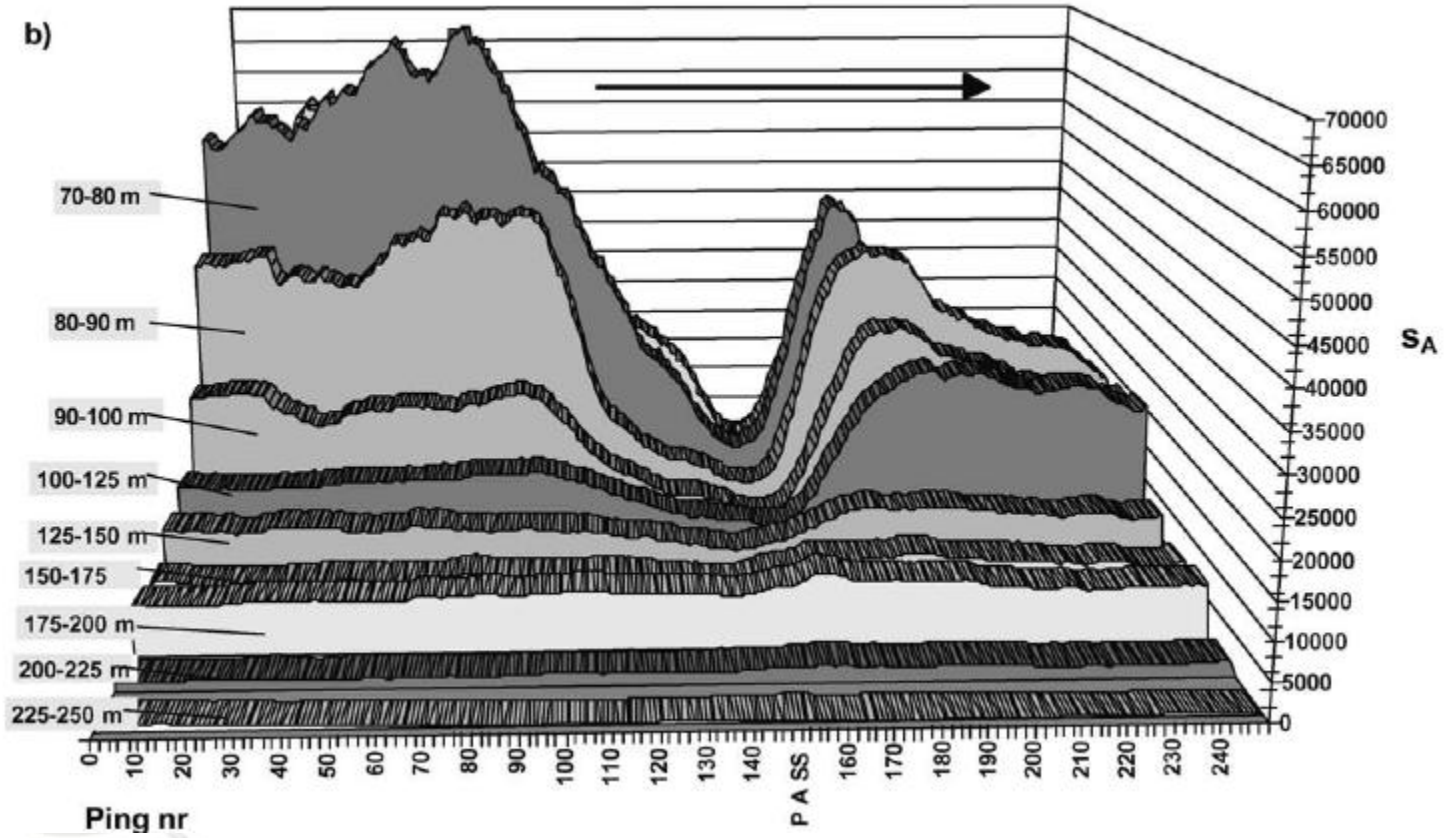


Avoidance



Vabø et al. (2001)

Avoidance



Vabø et al. (2001)

Avoidance

- Noise reduced vessel seemed to help
- Recommended by ICES

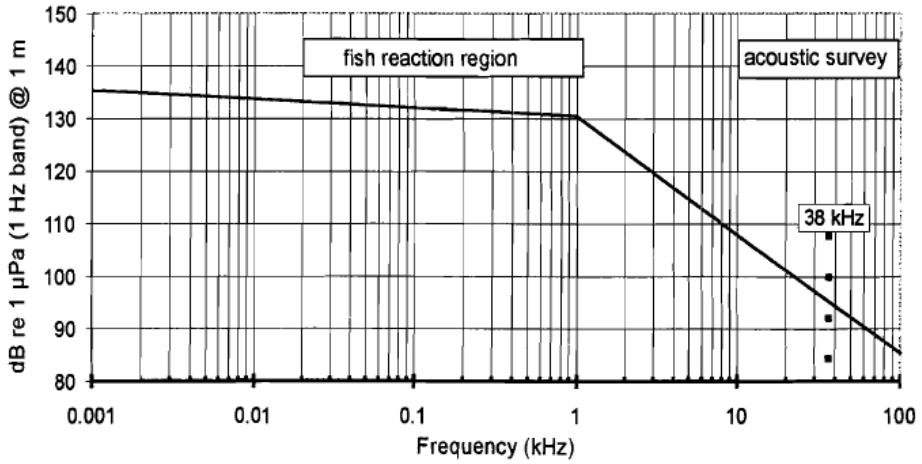


Figure 22. Proposed underwater radiated noise specification at 11 knots free-running for all vessels used in fisheries research.

UNDERWATER NOISE OF RESEARCH VESSELS
Review and Recommendations

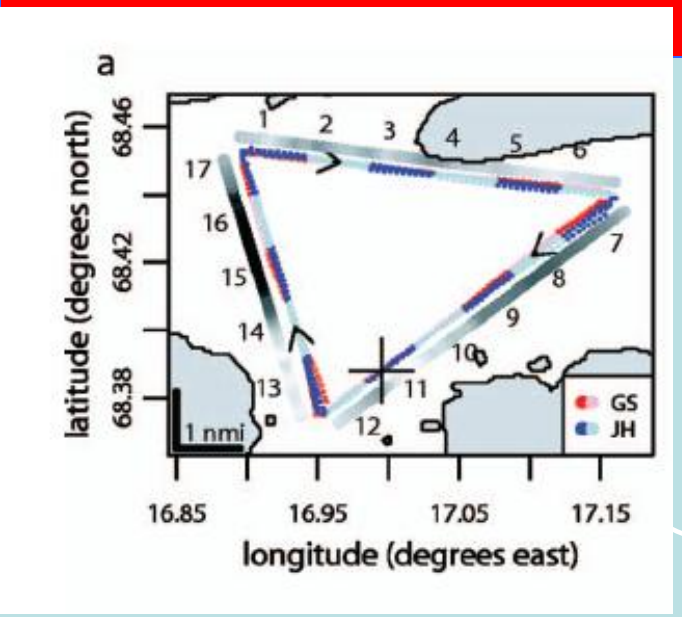
edited by

R. B. Mitson

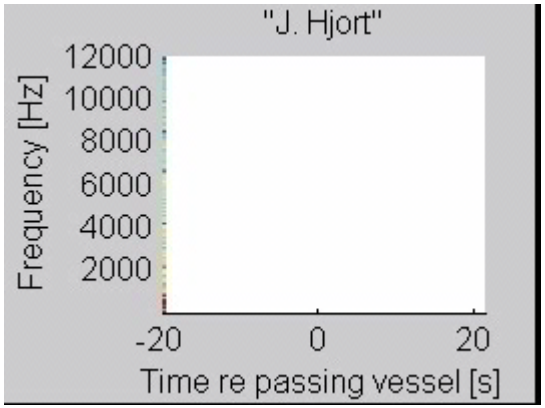
ACOUSTEC
Swiss Cottage
5 Gunton Avenue
Lowestoft, Suffolk NR32 5DA, UK

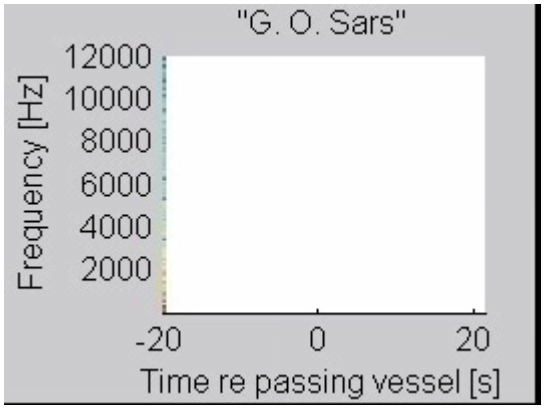
Avoidance

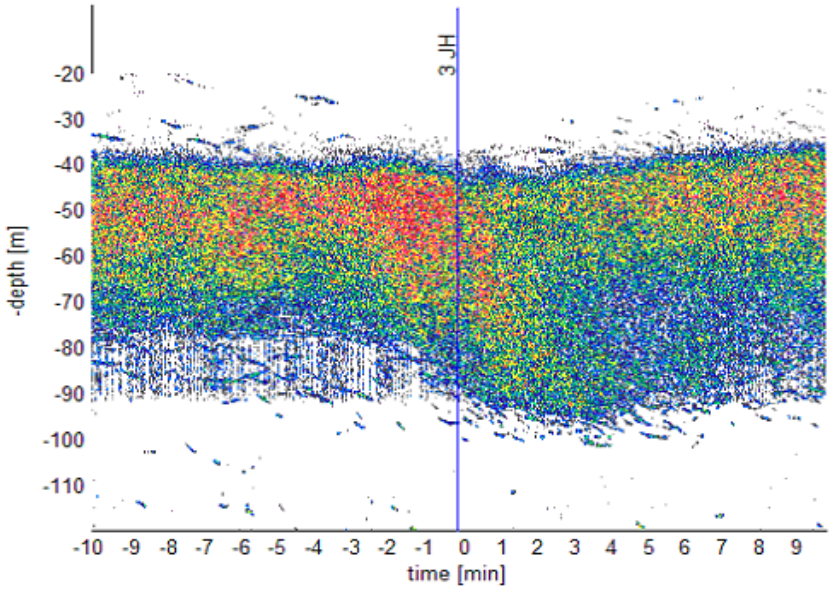
R/V G.O.Sars
R/V Johan Hjort

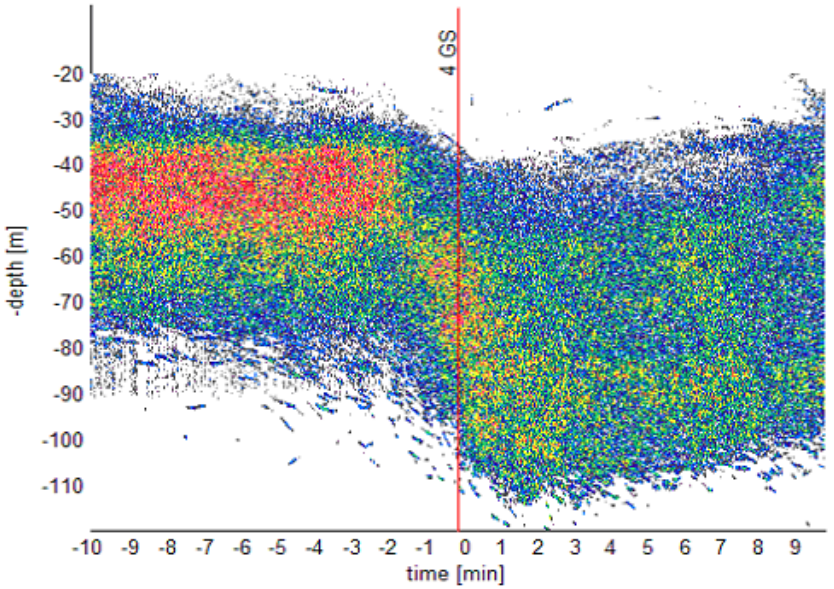


EK60 / ADCP / Hydrophone









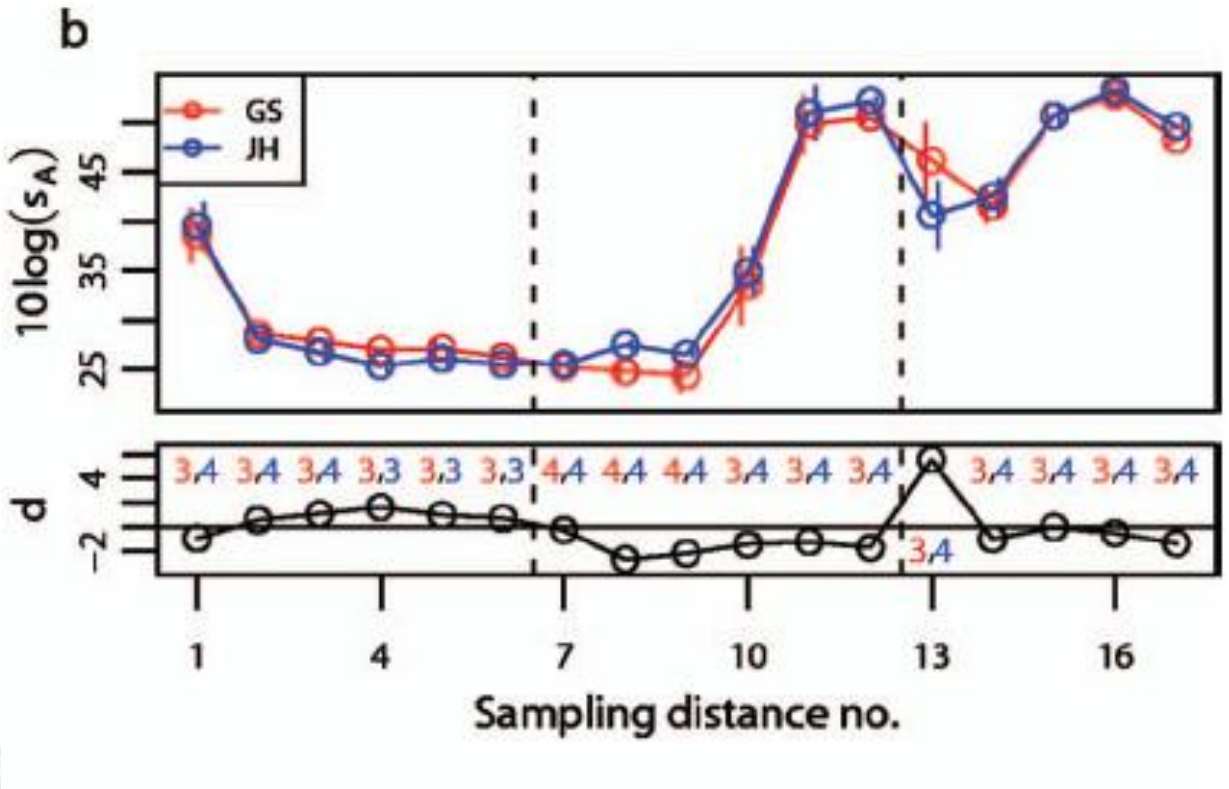
Ona et al. (2007)

Silent research vessels are not quiet

JASA Express Letters

J. Acoust. Soc. Am. **121** (4), April 2007

Vessel comparisons

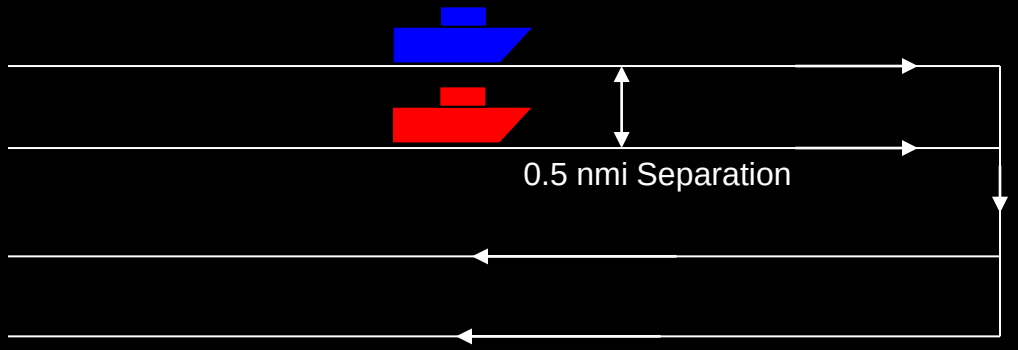


- End of story?...

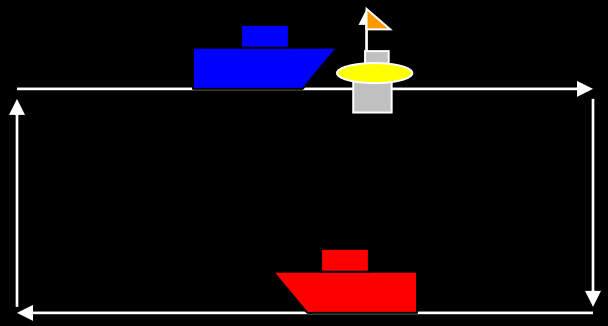
NOAA Fisheries vessel comparison

Side by side

(entire survey)



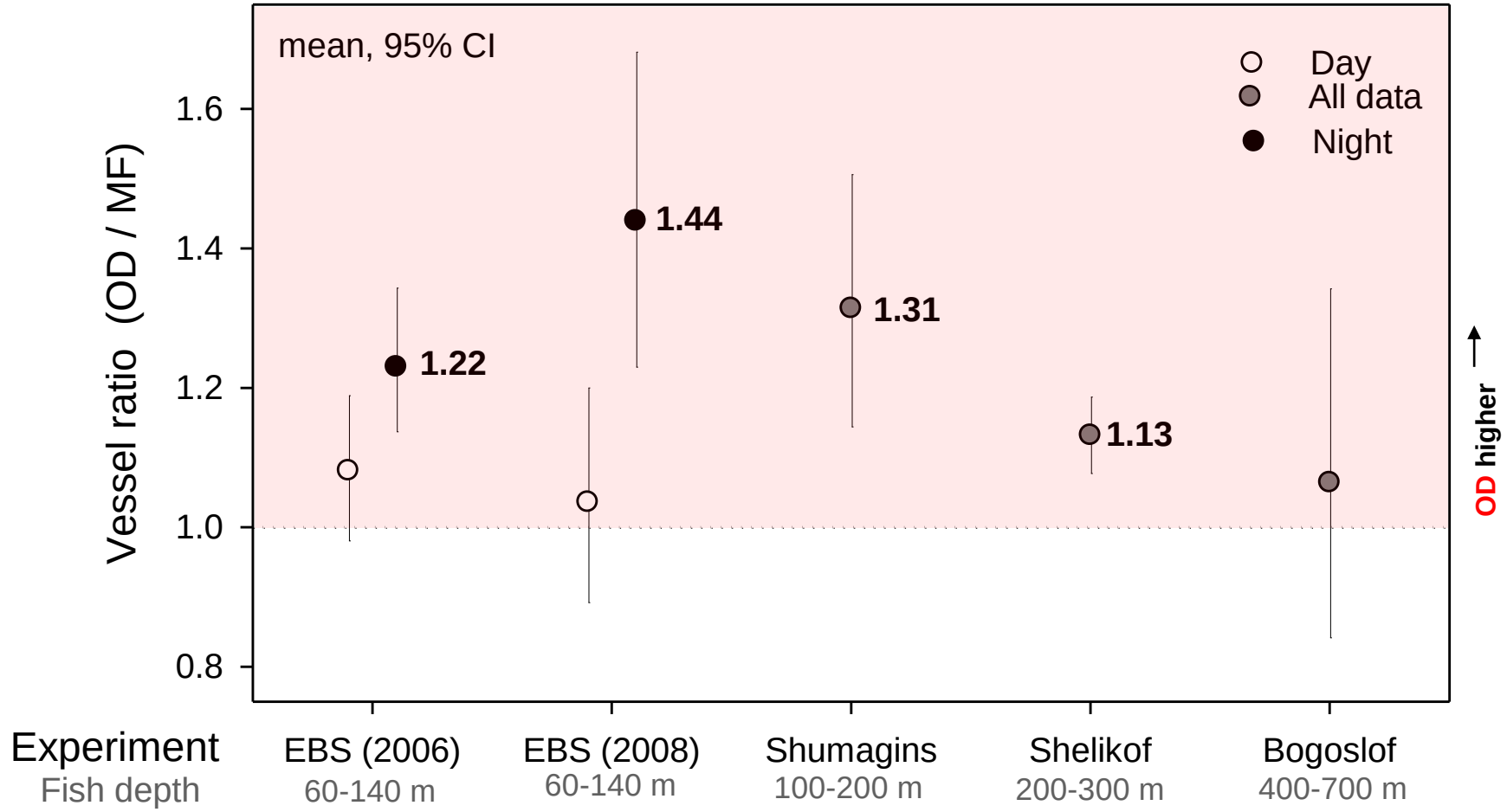
Echosounder buoy



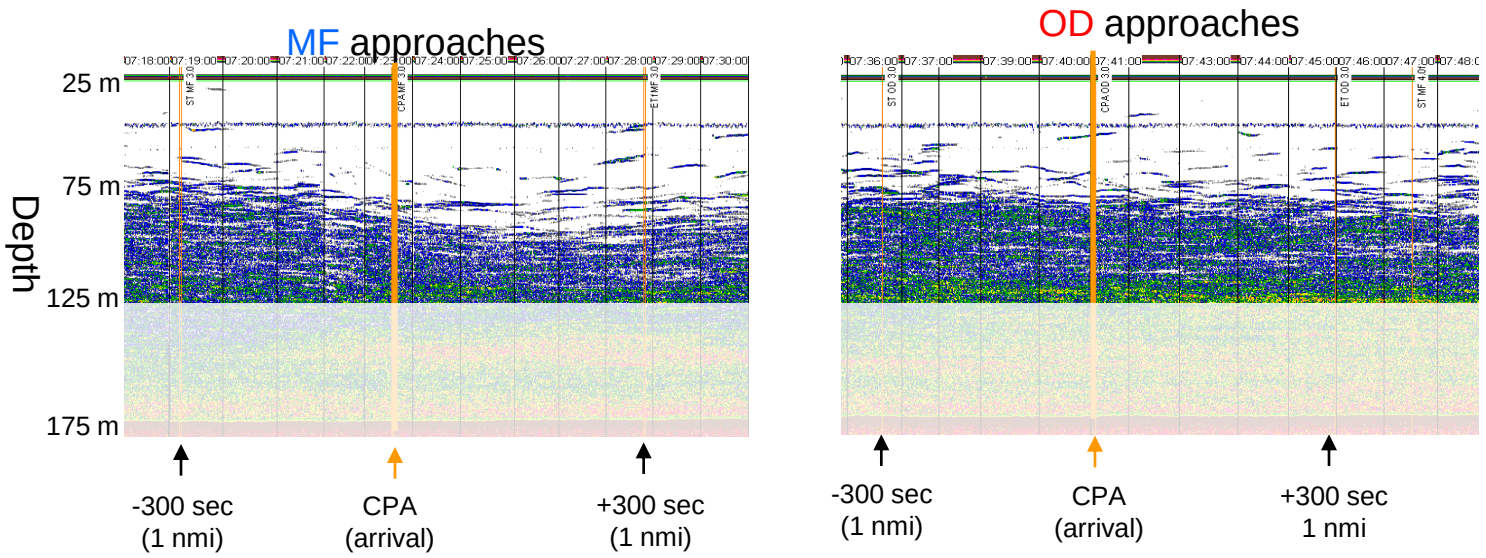
NOAA Fisheries
Alaska Fisheries Science Center
Seattle, USA

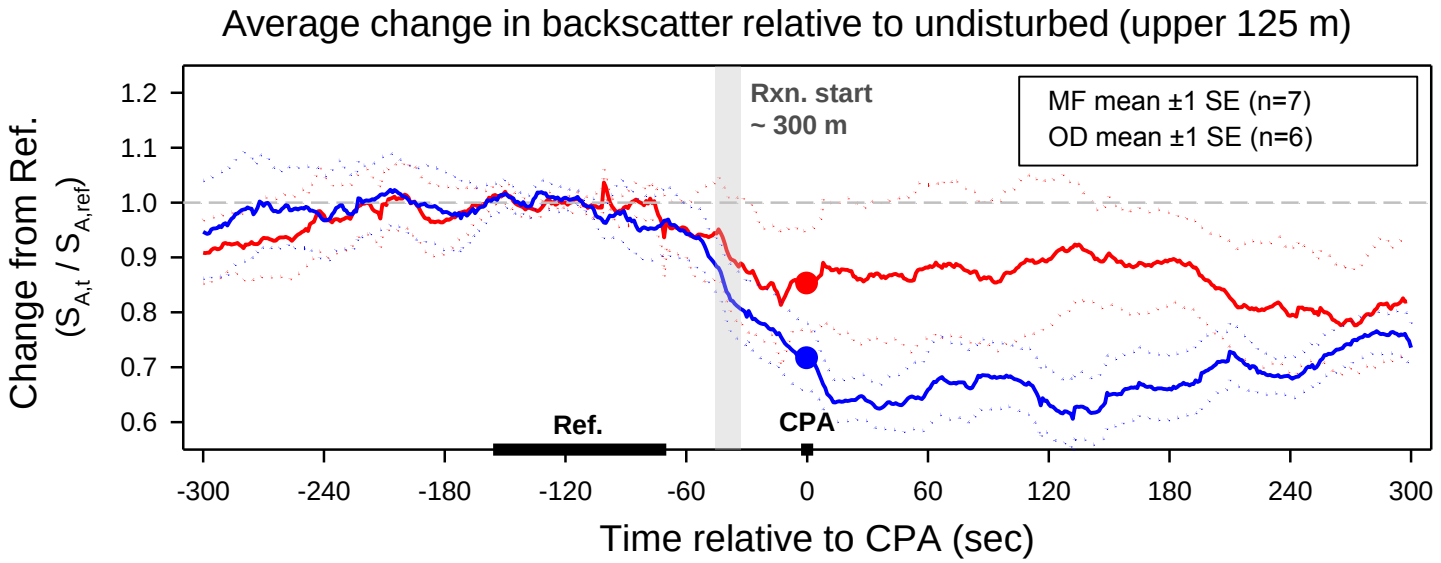
Alex De Robertis, Christopher Wilson and Neal Williamson

Side-by-side vessel backscatter ratio (OD/MF)



Buoy confirmation: pollock react differentially to OD and MF (Sh





Change at CPA

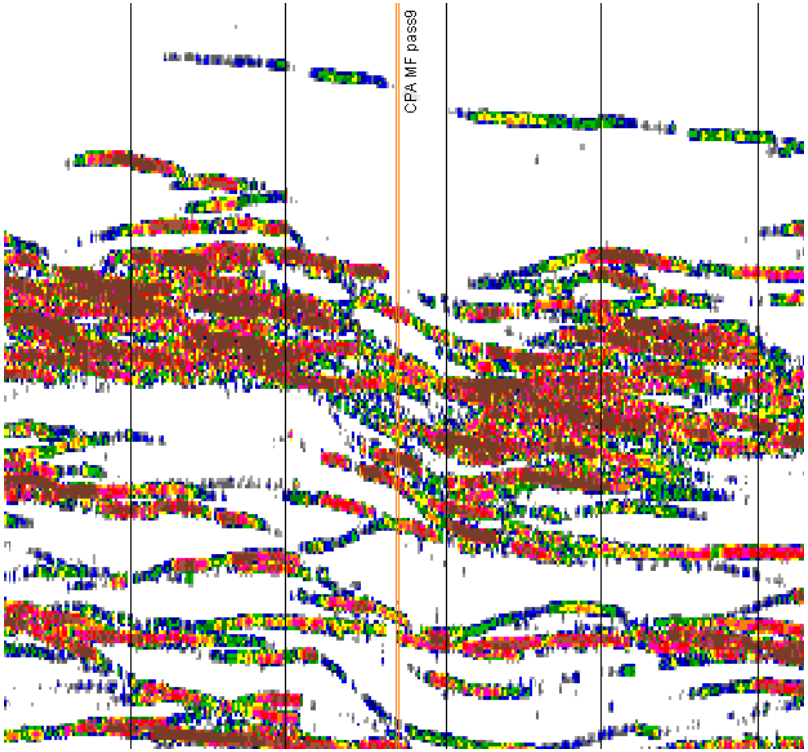
OD=0.85 (n.s)

MF=0.71 (p<0.01)

Analysis following Vabø et al. (2002)

TS drops during vessel reaction: OD TS >> MF TS

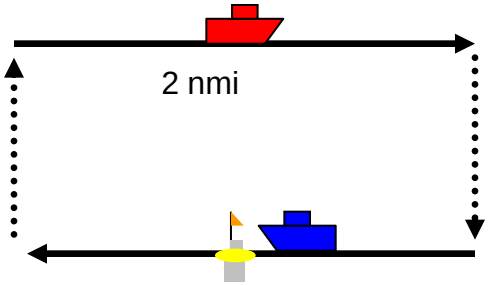
Buoy Echosounder



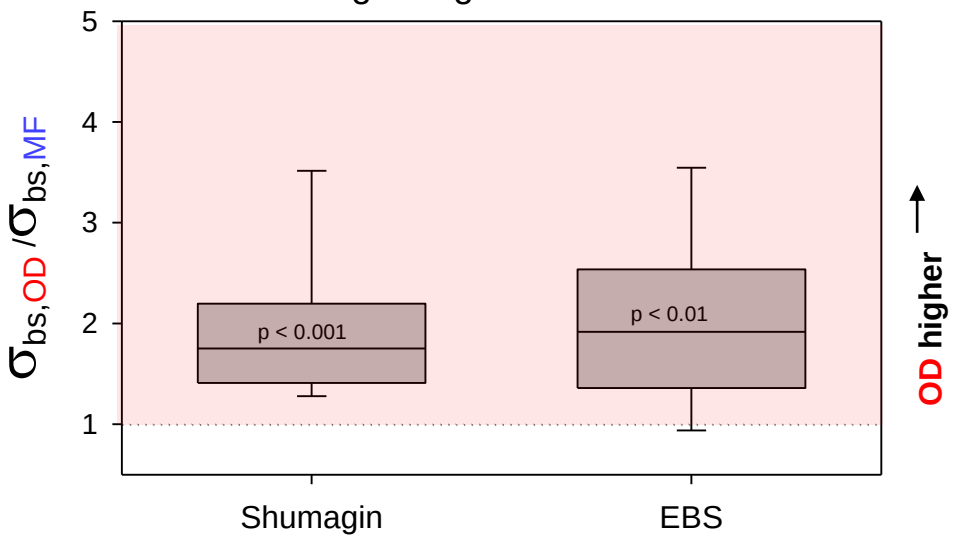
TS drop during MF passag

(40 log R echogram)

Vessel Echosounders



Single targets - 18 kHz



Avoidance

- Nature of vessel stimuli and fish responses remain poorly understood
- Expect vessel differences
- Measurement of vessel avoidance is much easier than predicting fish decision-making
- Observe bias indicators on a routine basis:
  - Vertical distribution, avoidance, gear performance
- This is also relevant when using survey indices!

Ting eg lurer på

Exploiting bandwidth
From individual to population

Herring behaviour at sub population scale

Makris et al. 2009

Krill behaviour at cm scale

Klevjer & Kaartvedt, University of Oslo.