Observing school dynamics in situ using acoustics

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Outline

- Collective behaviour
- Sonar observations
- Analysis methods
- Results

Collective behaviour

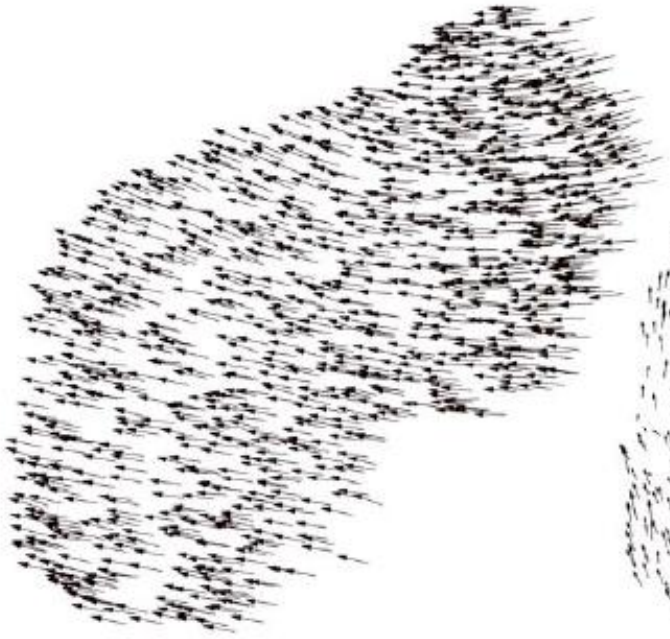
- Parr 1927. ”A contribution to the theoretical analysis of the schooling behaviour of fishes”.
- Breder 1954. “Equations Descriptive of Fish Schools and Other Animal Aggregations “

Modelling

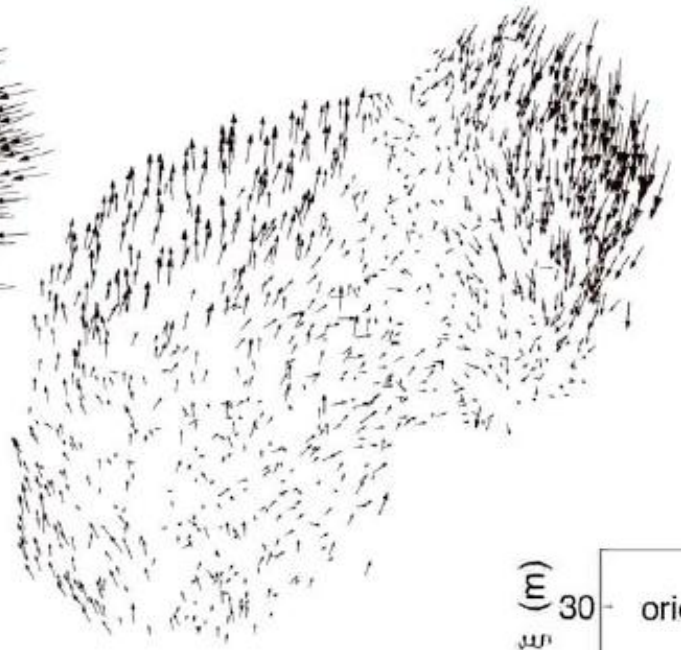
- From
  - Aoki 1982 ” A Simulation Study on the Schooling Mechanism in Fish “
  - to Nvidia Labs
- Validation…

Starling work (Cavagna et al, 2010)

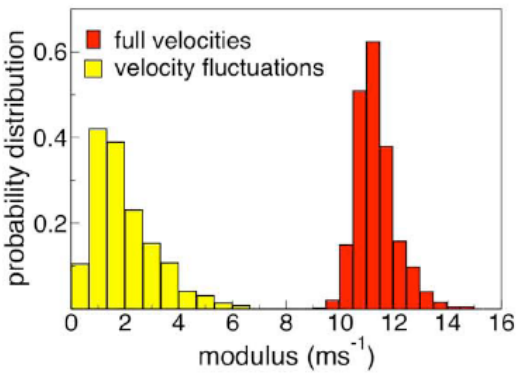
A: full velocities



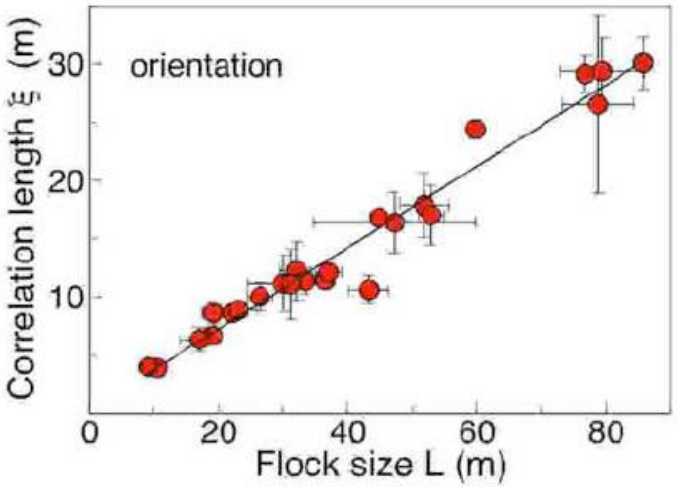
B: velocity fluctuations



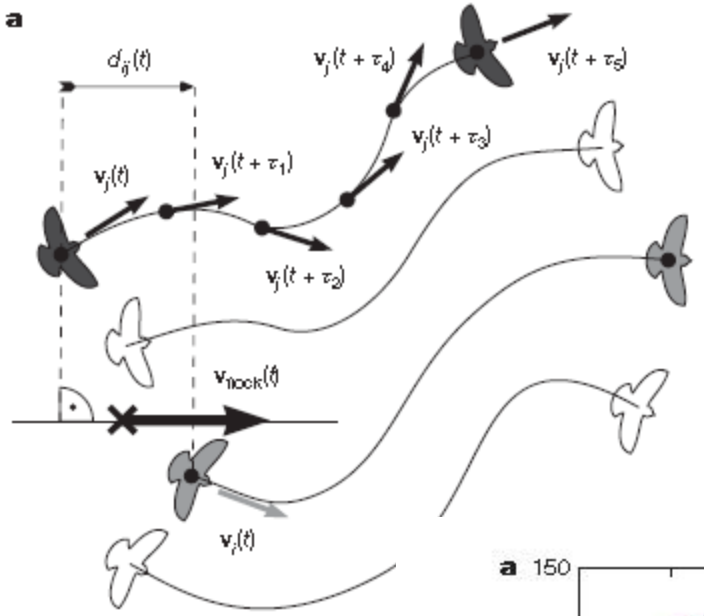
C

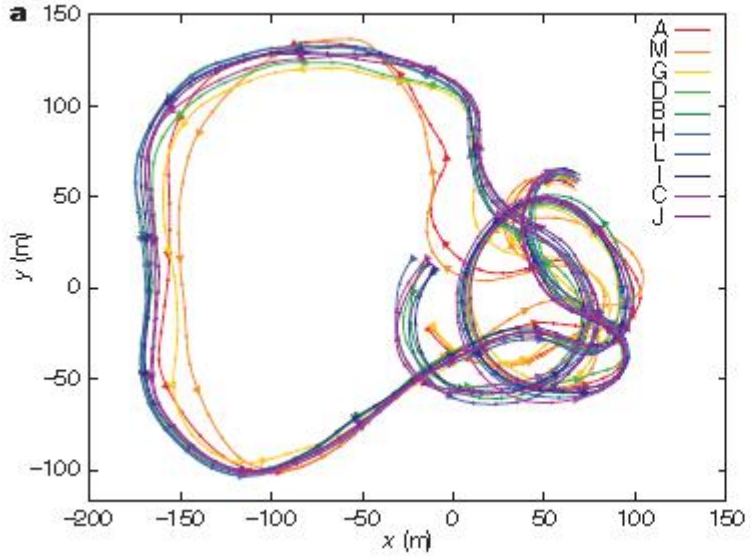


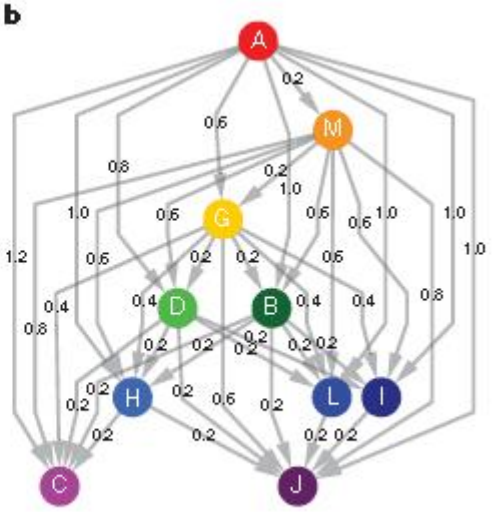
$$C(r) = \frac{\sum_{ij} \vec{u}_i \cdot \vec{u}_j \, \delta(r - r_{ij})}{\sum_{ij} \delta(r - r_{ij})}$$



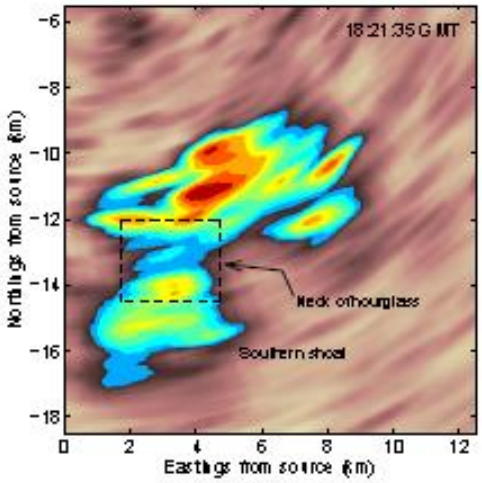
Pigeons, Nagy et al 2010

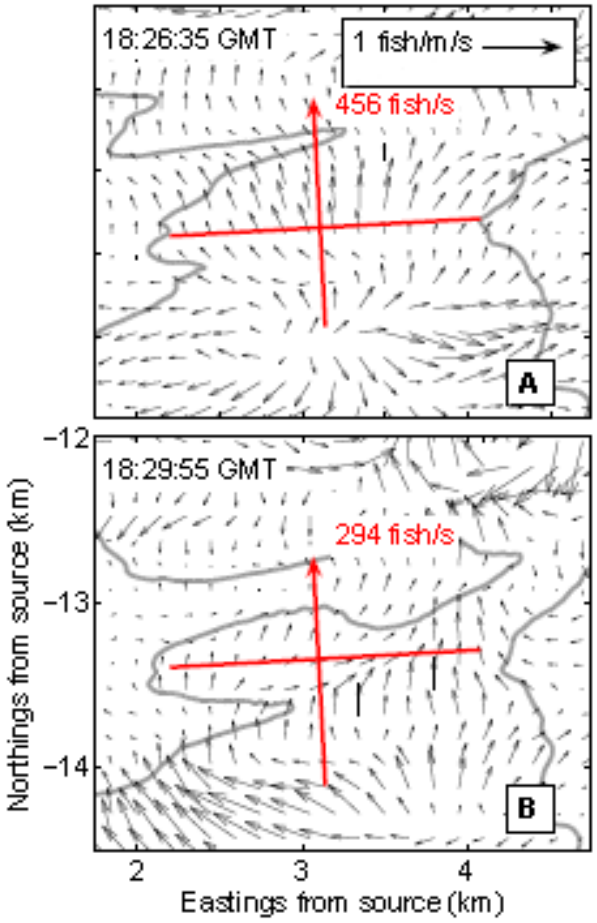






Fish schools (Jagannathan et al, 2010)





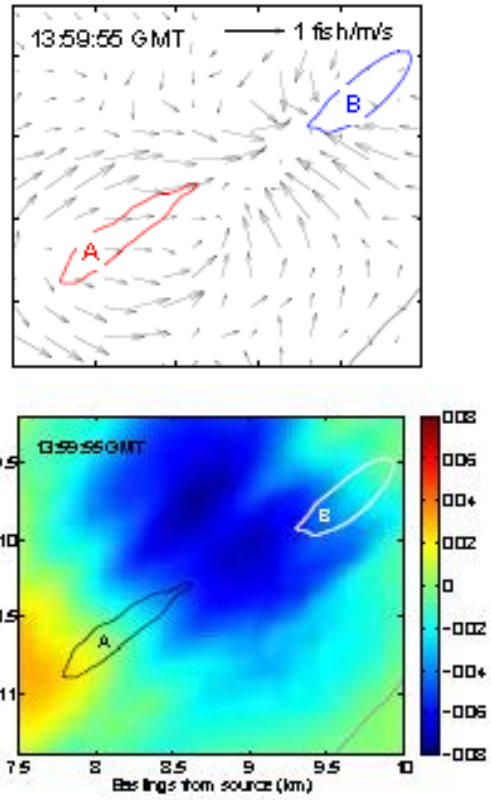


Fig. 9. Pressure (N/m^2 per unit fish mass) distribution within large fish shoal showing formation of a low pressure region that attracts schools A and B. Black and white lines both represent the 1.5 $fish/m^2$ population density contours. Gray line represents the 0.2 $fish/m^2$ population density contour.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

- Collective behaviour
- Sonar observations
- Analysis methods
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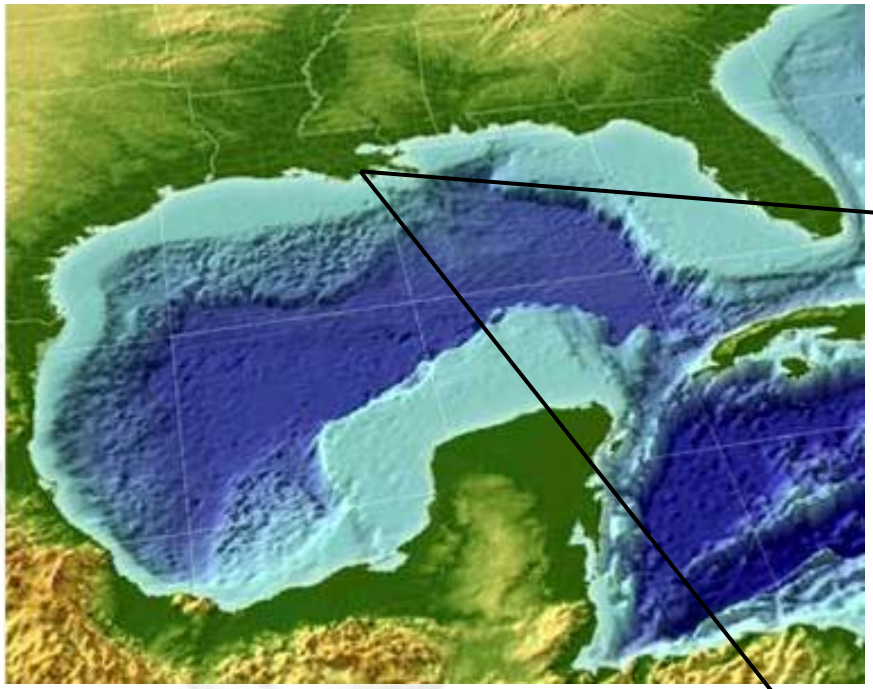
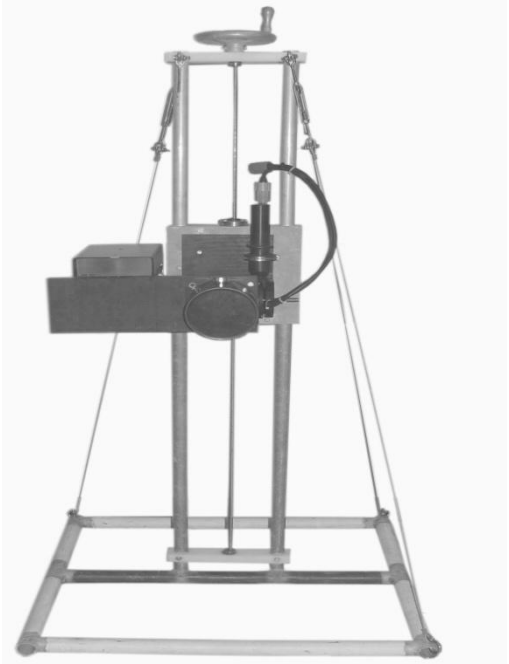
Observations

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



Observations

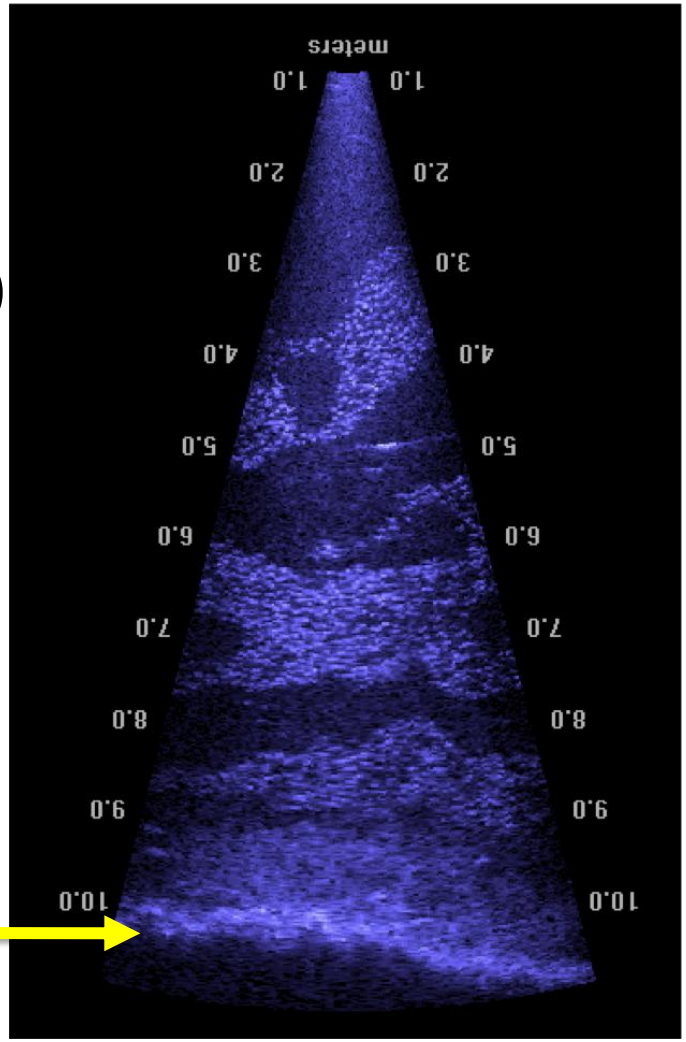
DIDSON sonar positioned 12 m from marsh edge



DIDSON sonar

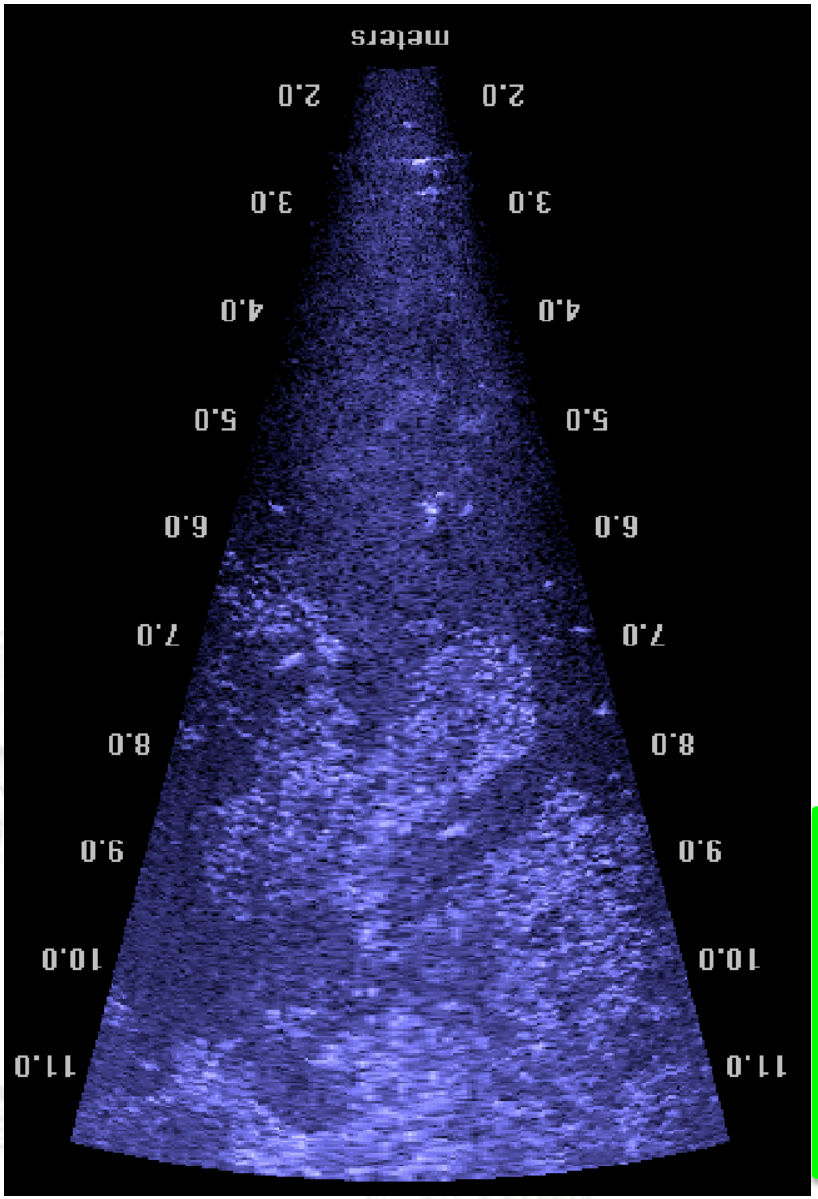
High-frequency mode (1.8 MHz)
Collected at ~7 frames per second
Range ~10 m
Beam configuration (~-3dB):

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

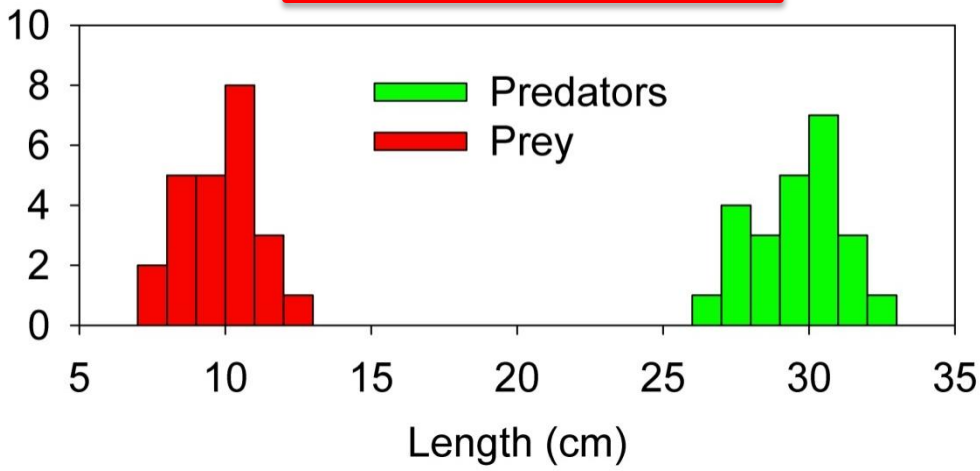


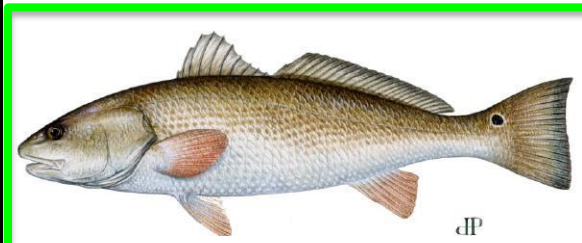
Marsh Edge

Species: Predators and Prey

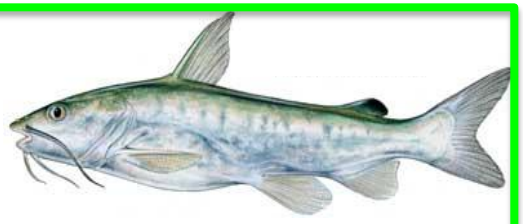


Gulf menhaden
(*Brevoortia patronus*)

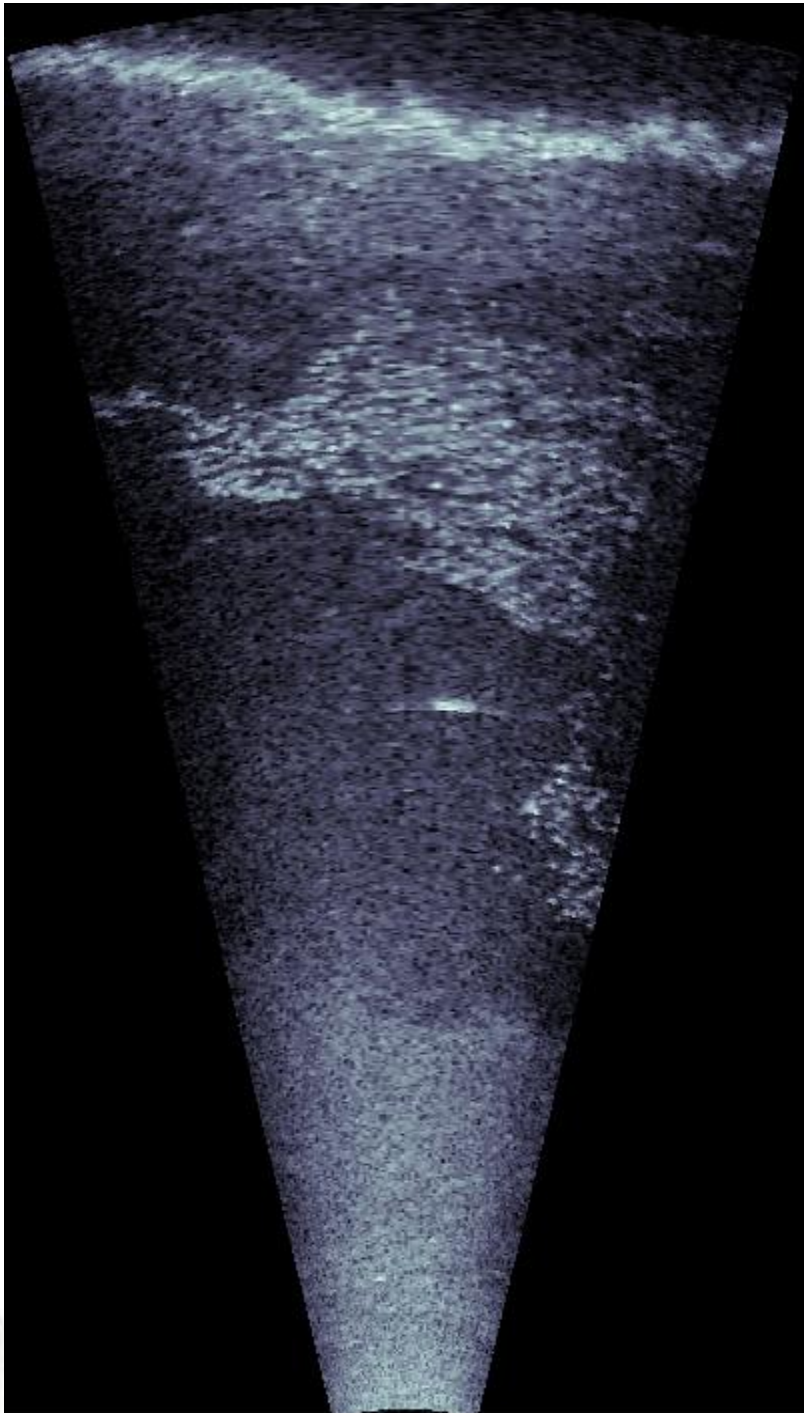




Red drum
(*Sciaenops ocellatus*)



Hardhead catfish
(*Arius felis*)



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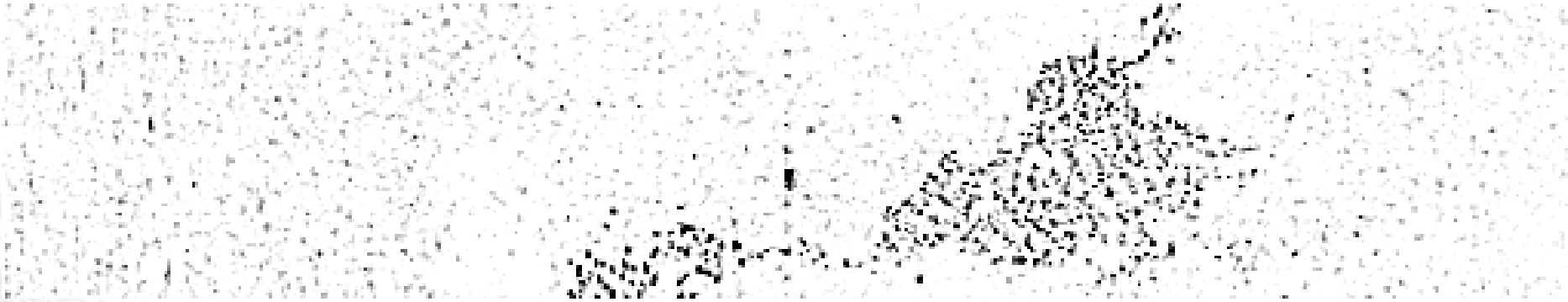
Pre filtering

- Background removal
- Wavelet filtering
- Average between frames



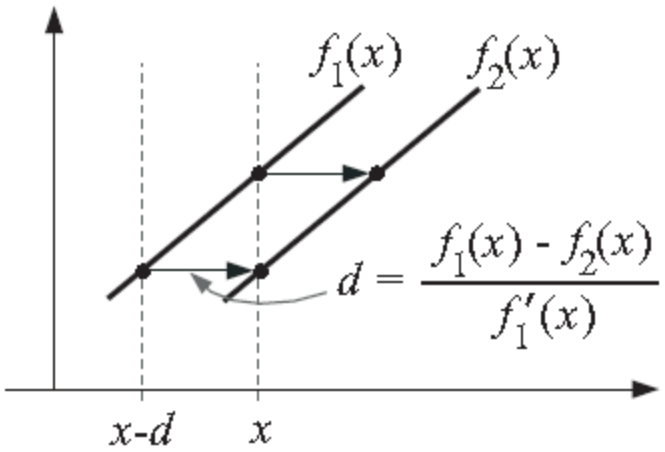
Flow field tracking

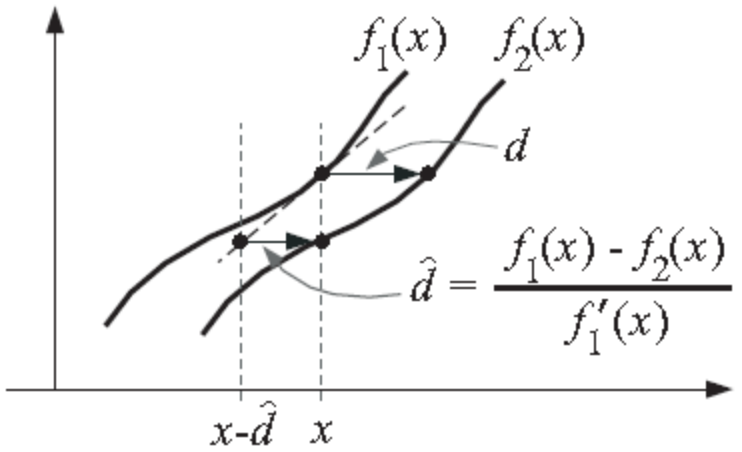
- Estimates the flow in the image

Optical Flow Estimation

David J. Fleet, Yair Weiss

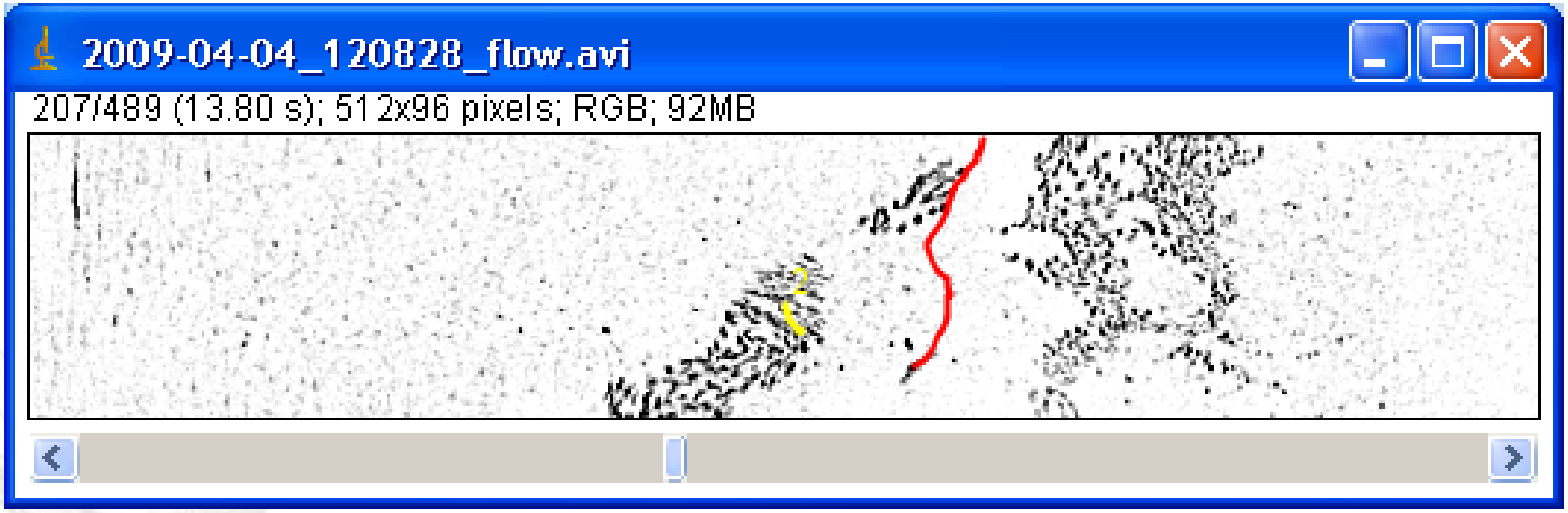
$$I(\vec{x}, t) = I(\vec{x} + \vec{u}, t + 1) ,$$





Manual tracking of predators

- ImageJ (ver. 1.42q), National Institute of Health, USA
- MtrackJ plugin (ver. 1.3.0), Erik Meijering, Erasmus MC-University Medical Center Rotterdam, Netherlands



SED

- SED based on Sbalzarini & Koumoutsakos
  - Dilation operator
  - Select local maxima - match the original image with the dilated image
  - Choose upper p*th* precentile of the candidates
  - Adjusted by the brightness weigthed centroid

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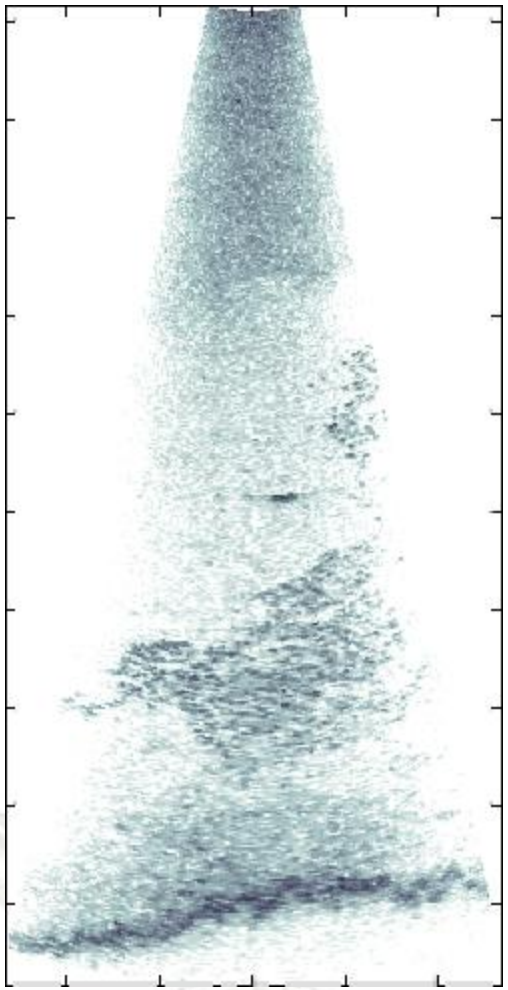
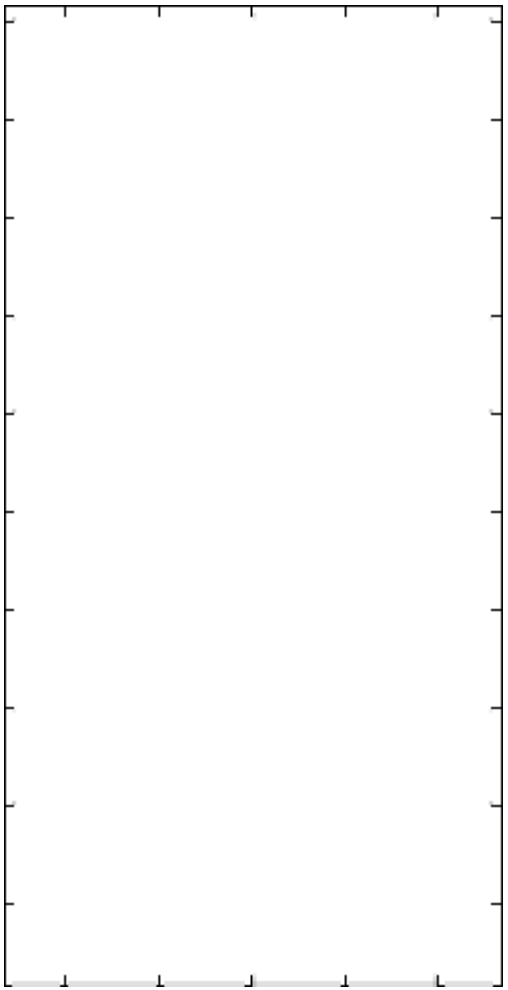
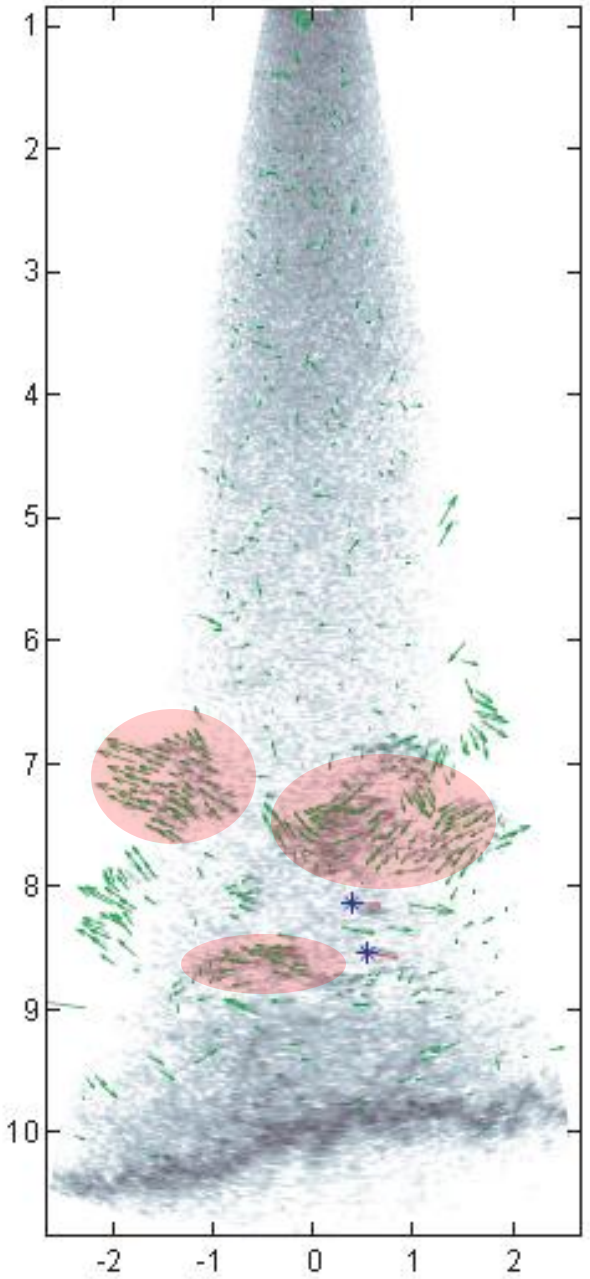
The resulting data set



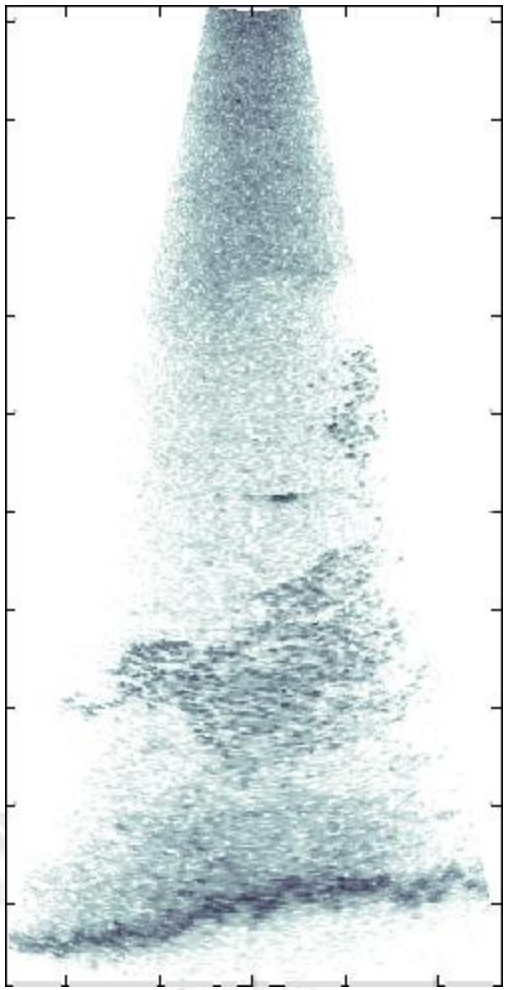


Further work

- Define connected regions and label the targets
  - Lots of false targets
  - ”ordfilt2” works well
- Density measures
  - Based on the SED
  - Range dependent
- Spatial correlation in direction



Thank you



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