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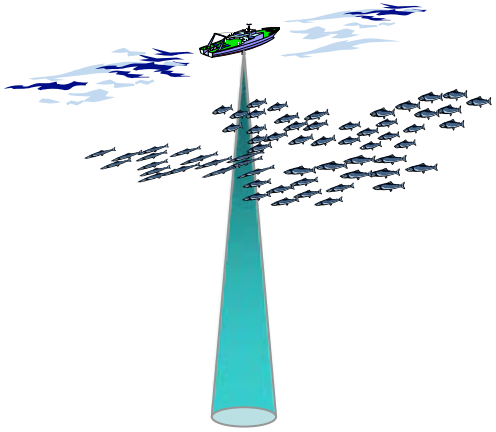
Measurement of fish school abundances in shallow sea using omnidirectional multi-beam sonar

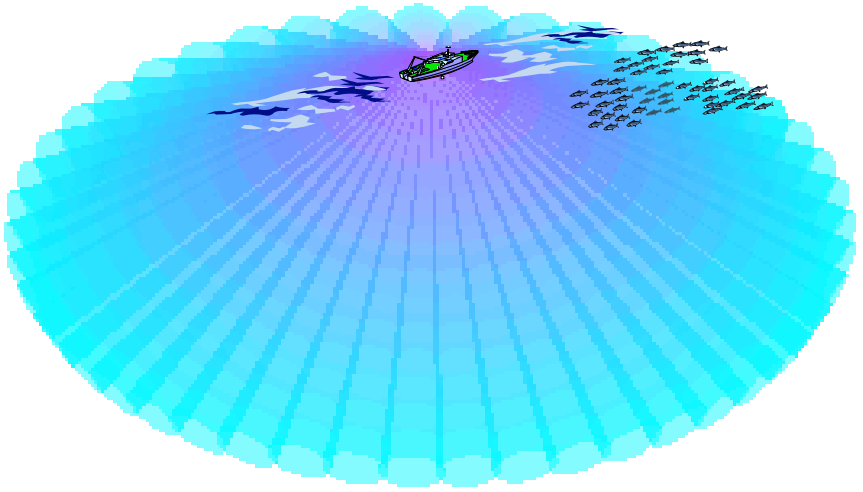
Yong TANG （Dalian Fisheries University）
Kohji IIDA, Tohru MUKAI （Hokkaido University）
Yashisi NISHIMORI （Furuno Electric CO., Ltd. ）

Introduction

Background

For pelagic fish school,
Echo sunder: small sampling, avoidance behavior
sonar: long range survey, variable tilt angle, surface survey



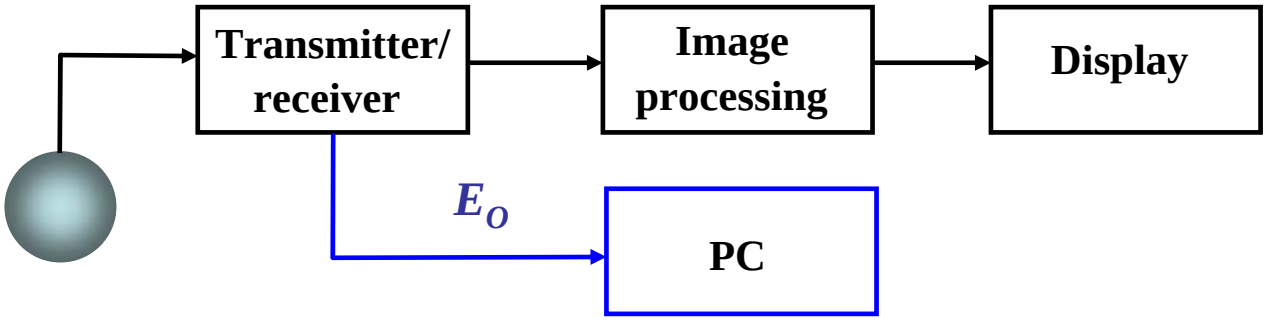


Echo sounder vs. Scanning Sonar

Quantitative Sonar

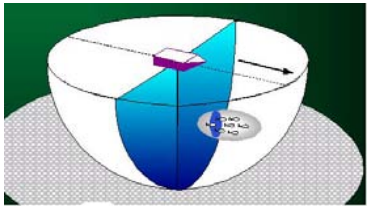
(Furuno FSV30 Research version, 24 kHz)

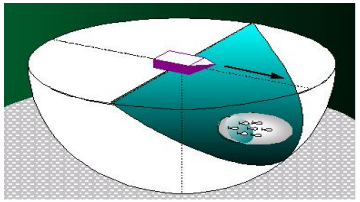
Sonar system

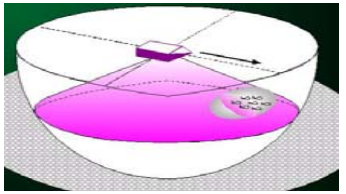


Detection modes

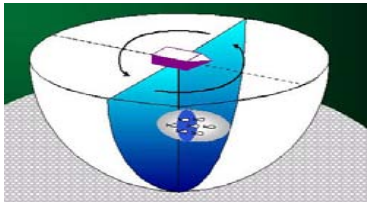
Cruise scanning modes

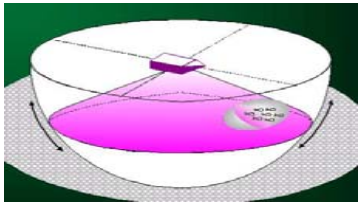


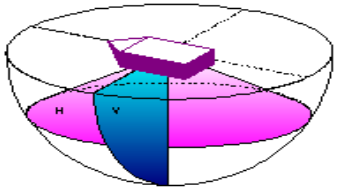




Instrument scanning modes







Biplane mode

Advantage:

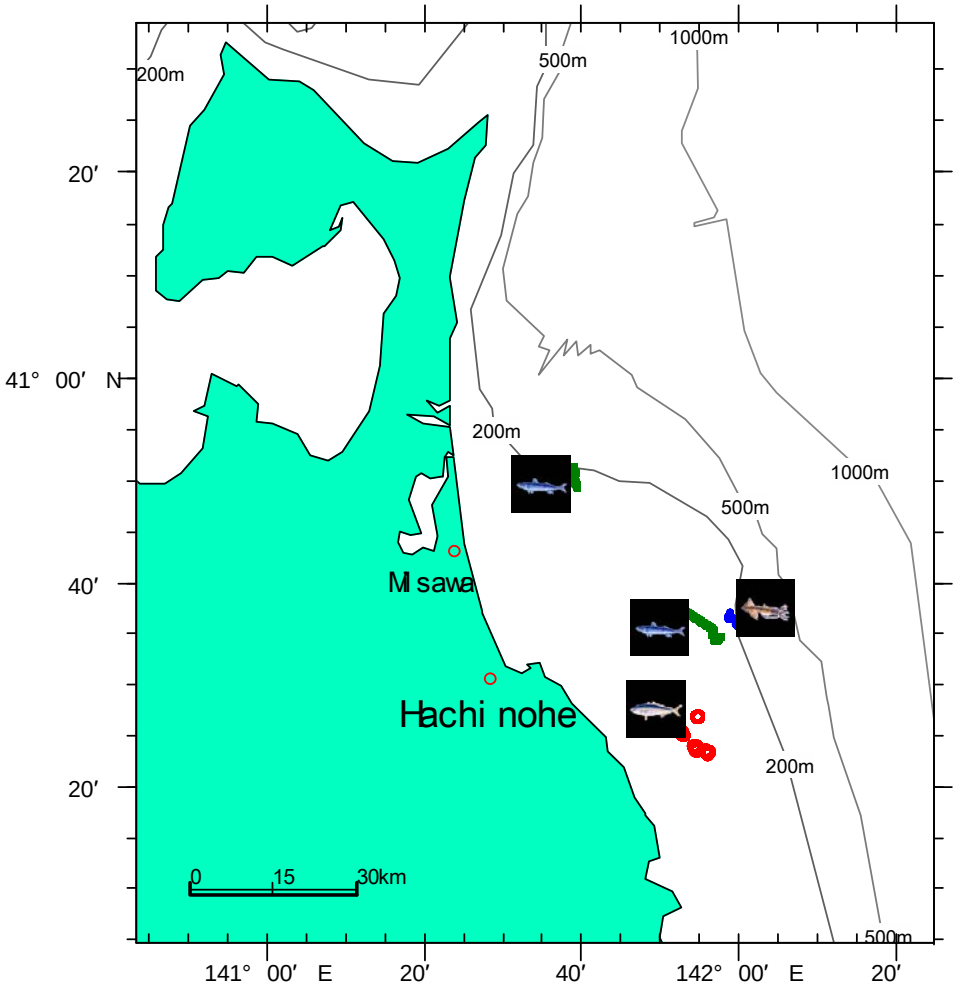
1. Beam stabilizing
2. Record the raw output signal and SV signal with a broad dynamic range

Content

- Measure fish school in shallow sea using a quantitative sonar.
- Investigate the relationship between the echo area and biomass of fish school.
- Investigate the relationship between the SV signal and biomass of fish school.
- The echo integrating method for sonar surveys
- How to average the fish target strength (TS) in three dimensions

Methods

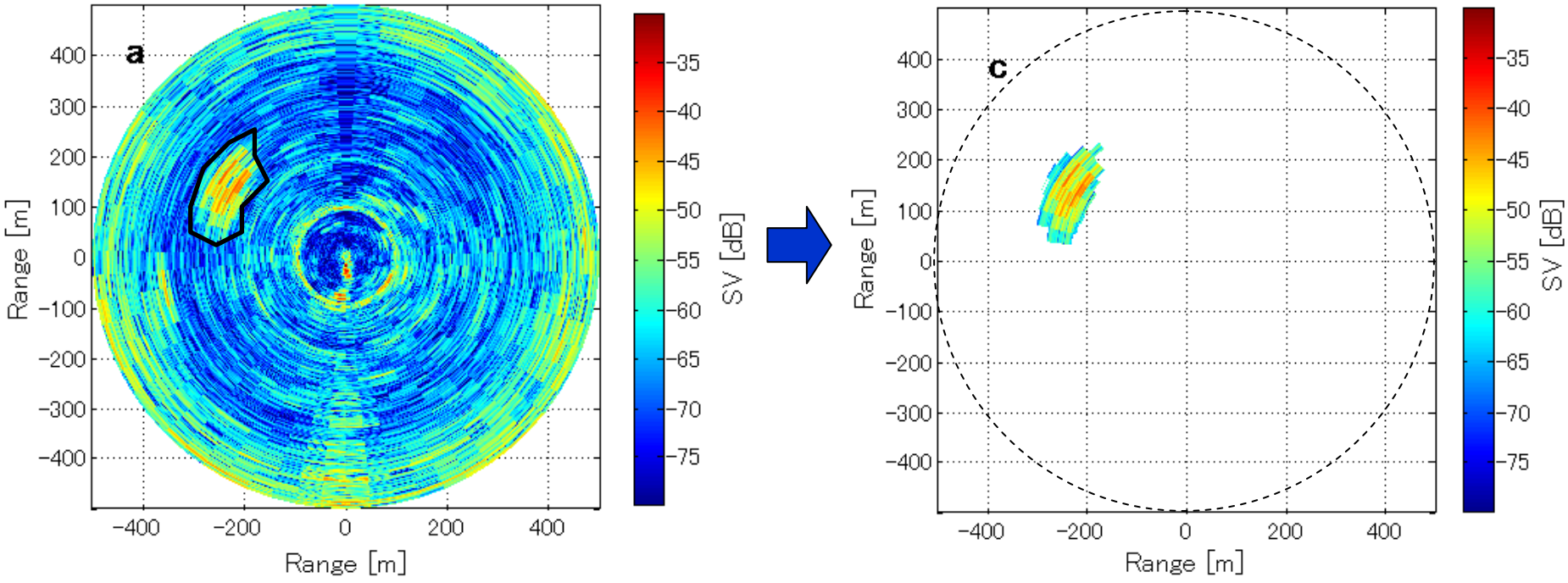
Field experiment in shallow sea near JAPAN



- Fishing ground near HACHINOHE
  Depth:80 ~ 200m
- Vessel: No.1 SOHO (90ton)
  Searching vessel in purse seine flotilla
- Quantitative Sonar (24kHz , Furuno) ,
  FSV30 Research Version
- 2005.9 : Mackerel + Squid
- 2005.11 : Yellow tail

Extract fish school echo

- Extract fish school echo using manual polygon method (Select fish school echo with multi angular lines)
- Contour processing with 2 dimensions low-pass filter



Calculate the area of fish school echo

- Area of fish school echo：

Area of echo：$S = \sum_i \sum_j \Delta S_{ij}$

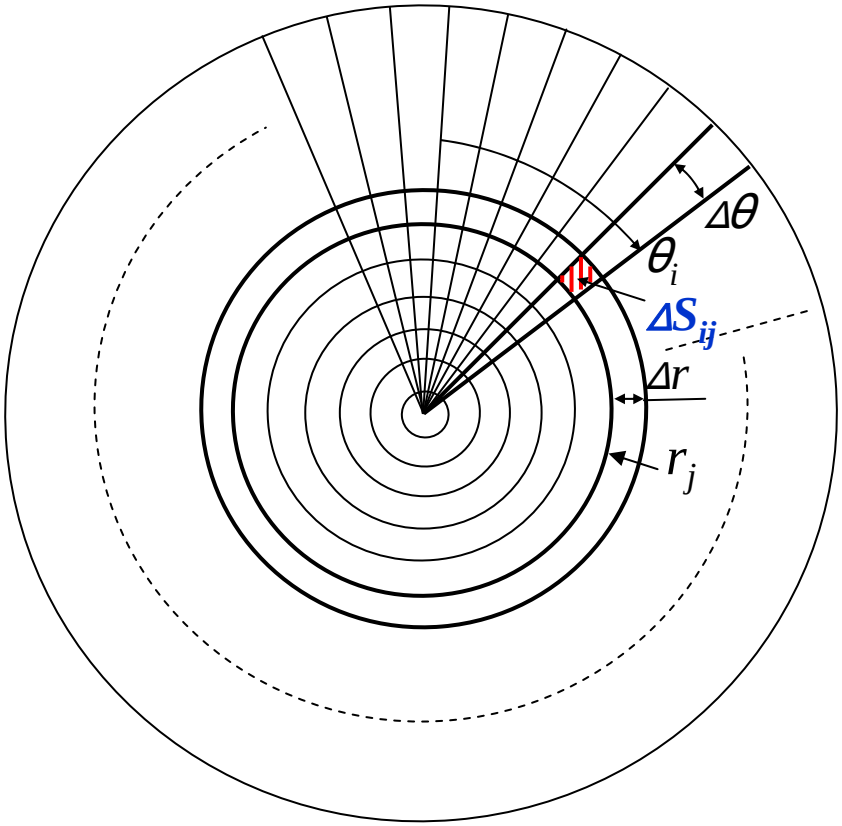
Area of one cell：$\Delta S_{ij} = \Delta\theta \Delta r (r_j + \frac{\Delta r}{2})$

- Azimuthal resolution：$\Delta\theta = 2\pi/64$
- Distance resolution ：$\Delta r = c/(2f_s)$
- Sound speed：c
- Sampling frequency：f_s

- Area compensation with pulse width and beam width

  Correct range with $c\tau/2$,
  Correct angle with θ_{-3dB}

Display method of echo at FSV30

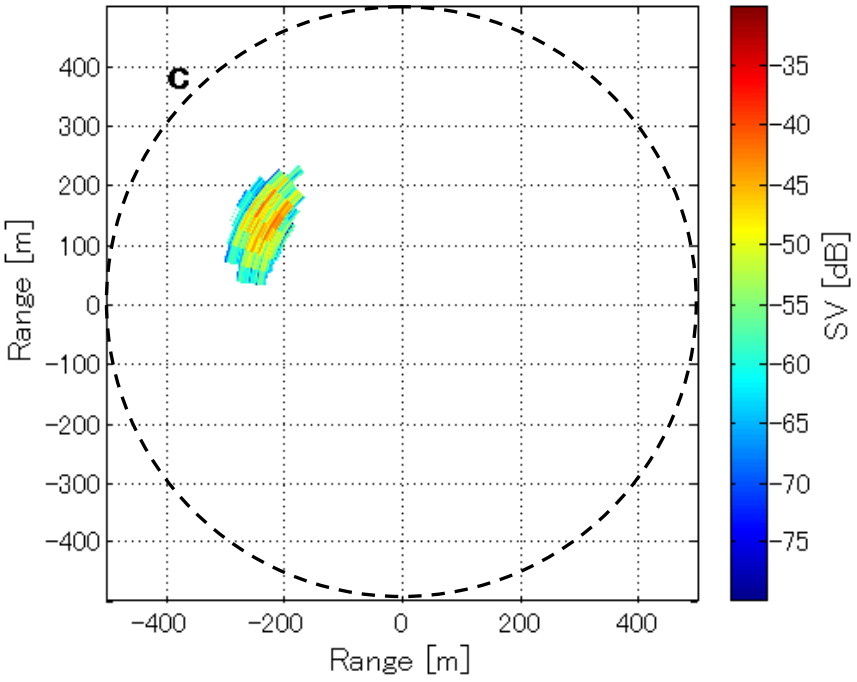


Maximum SV and ping average SV

- Maximum SV： the maximum of raw SV signal in fish school echo
- Ping average SV： the average of raw SV in total beams and range

$$< S_V >_p = \frac{1}{B_n} \sum_{i=1}^{B_n} \frac{1}{r_b - r_a} \sum_{j=r_a}^{r_b} S_{Vij}$$

- B_n ： the number of beam
- r ： radius of range



Results

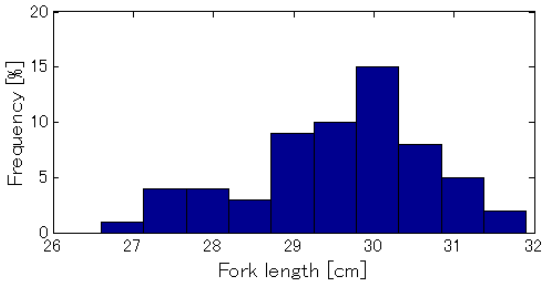
Length and weight of fish by purse seine

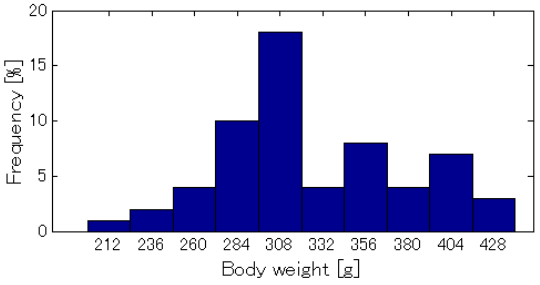
	Mean fork length	Mean body weight	Fish school catch Times	Fish catches weight [ton]
Mackerel	29.6 cm	327.0 g	6	328.7
Squid	22.6 cm		2	27.3
Yellow tail	61.2 cm	4000 g	4	63.6

Yellow tail

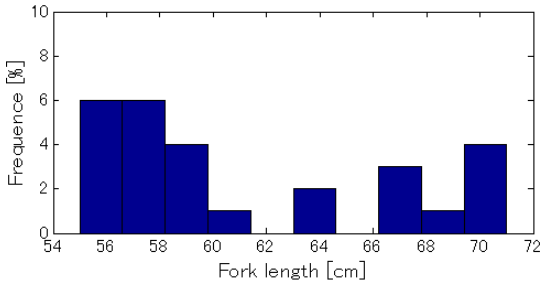
Mackerel

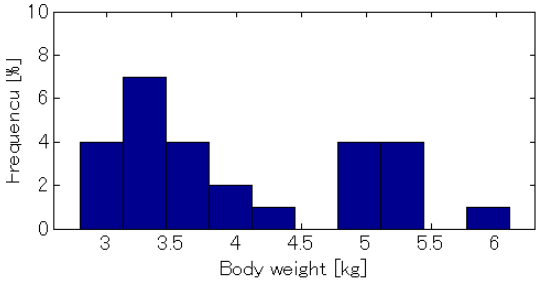
Mackerel





Yellow tail

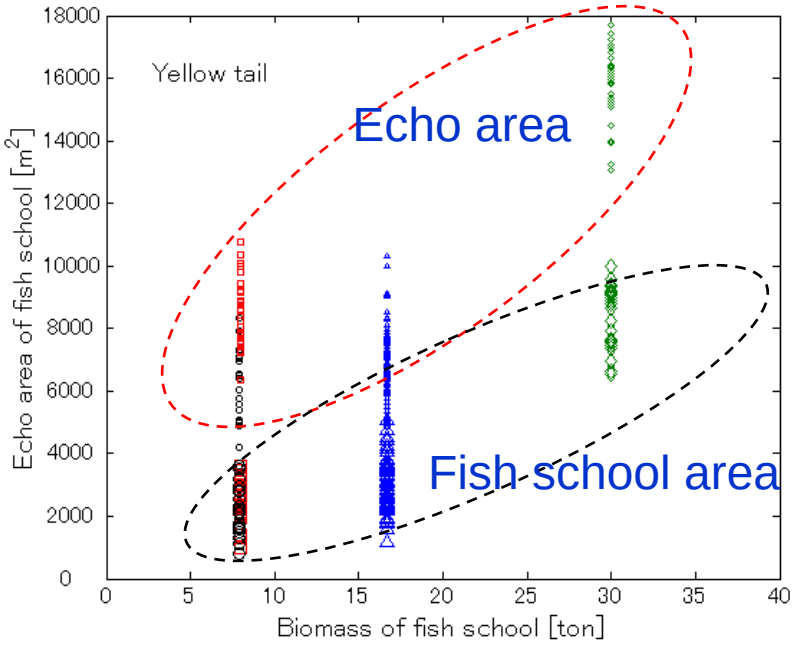




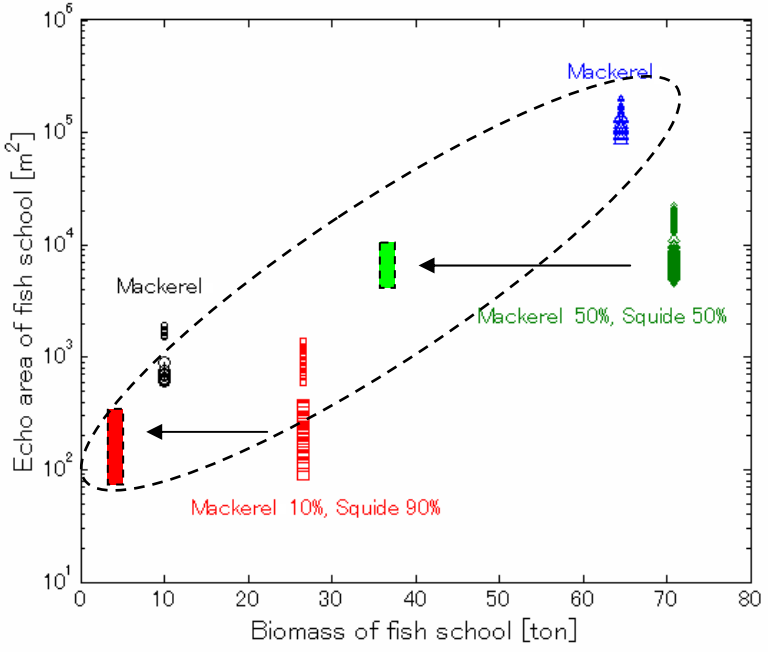
Relationship between the area and biomass

- Echo area of fish school： echo area with polygon processing
- Fish school area： after filter, azimuth and range compensate processing
- Biomass of fish school ： fish school weight with purse seine

Multi pings area of Yellow tail



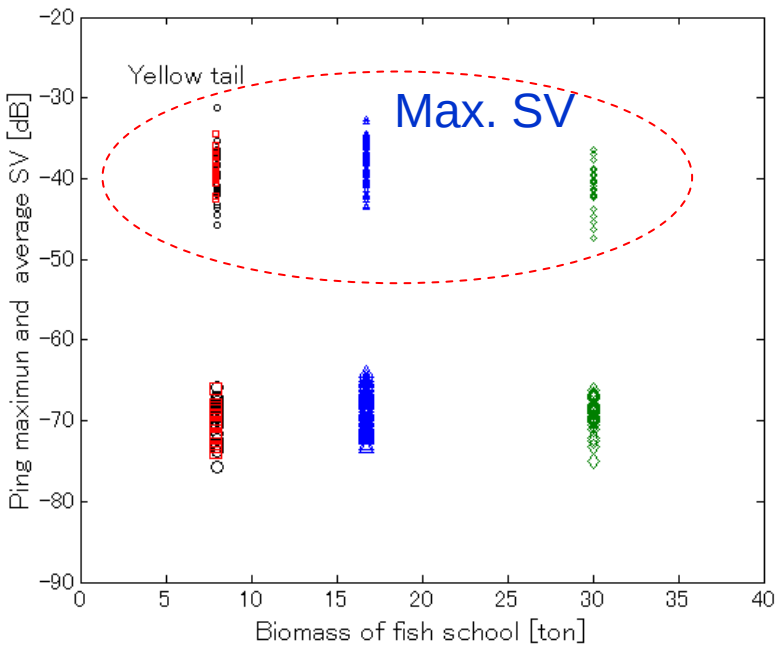
Multi pings area of mackerel and squid



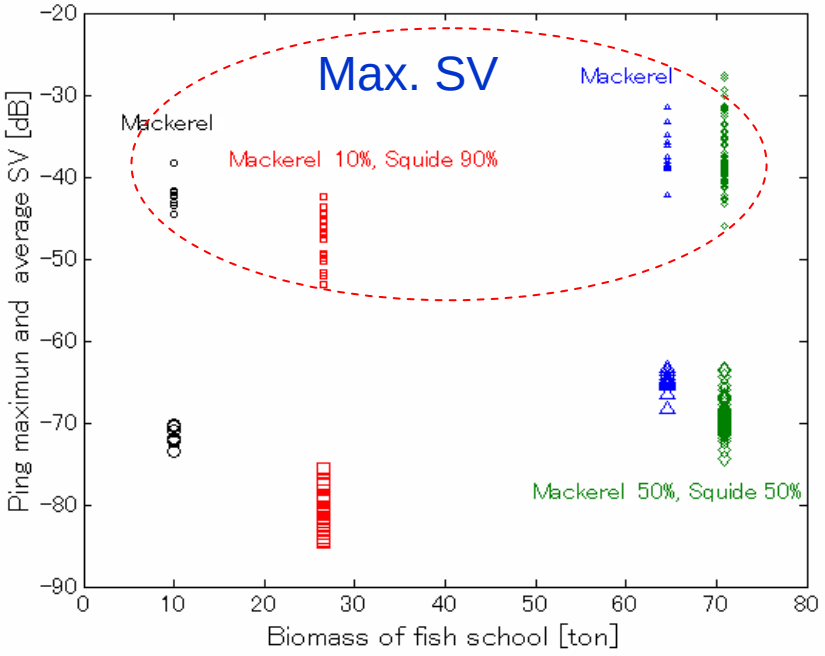
Relationship between the SV and biomass

- Compare multiple pings max. and average SV with the weight of fish school
- Threshold :　-70dB

SV of yellow tail



SV of Mackerel and squid

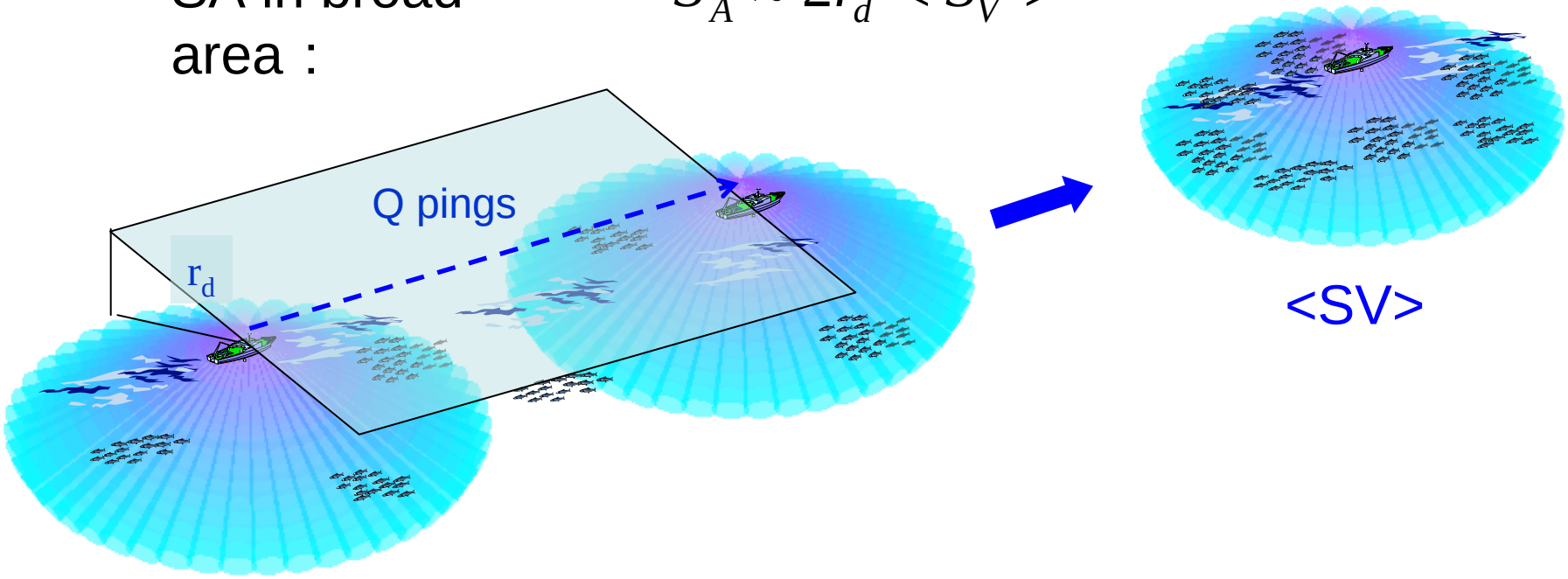


Echo integration method by circular mode

- Average density in broad area： $< n > = < S_V > / < T_S >$
- Average SV in broad area：

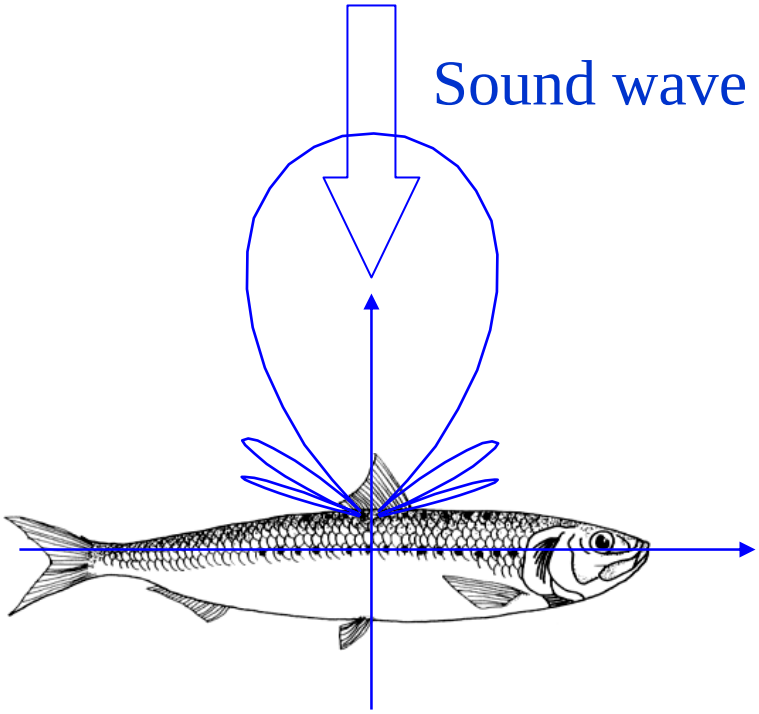
  Average raw SV signal of Q pings: $< S_V >= \frac{1}{Q} \sum_{p=1}^{Q} < S_V >_p$

- SA in broad area： $S_A \approx 2 r_d < S_V >$



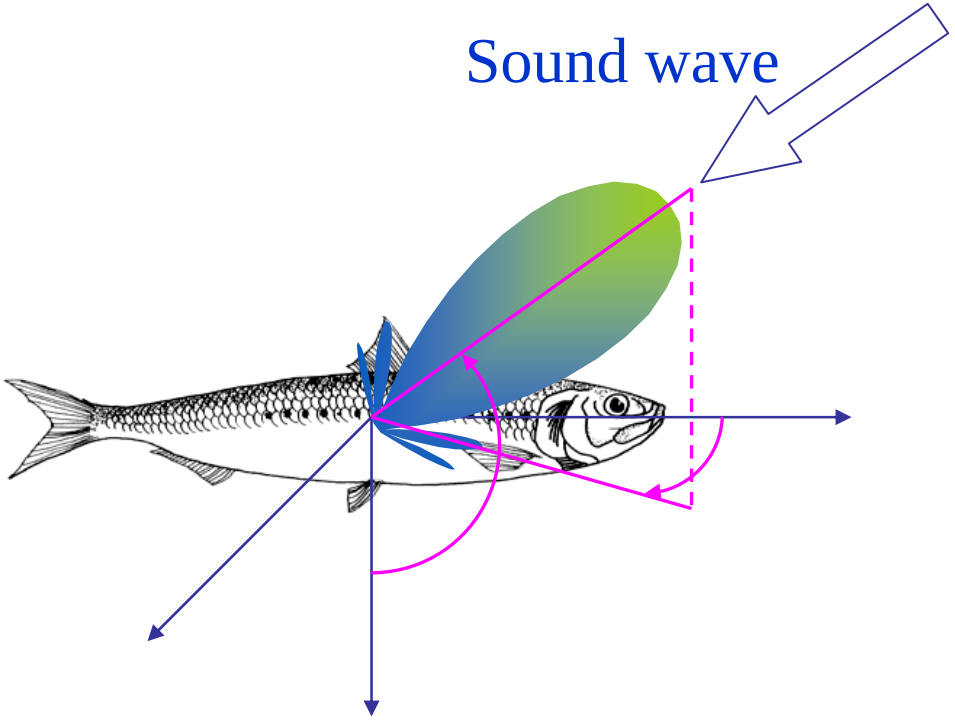
Concept of the 3 dimensions average Target Strength for sonar surveys

Quantitative echo sounder



The 2 dimensions average TS from dorsal aspect

Sonar



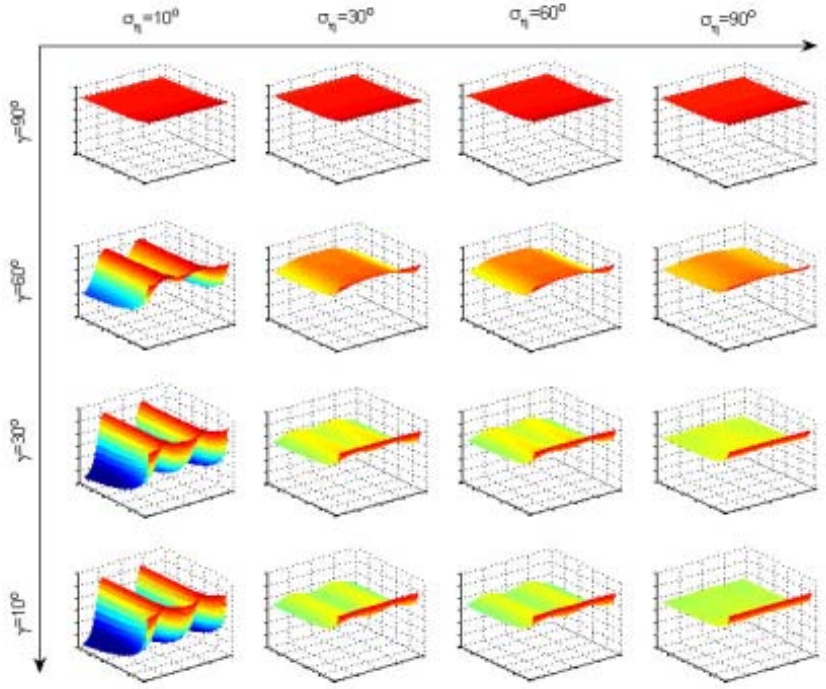
The 3 dimensions average TS from any aspect

3 dimensions average TS in broad area survey by sonar

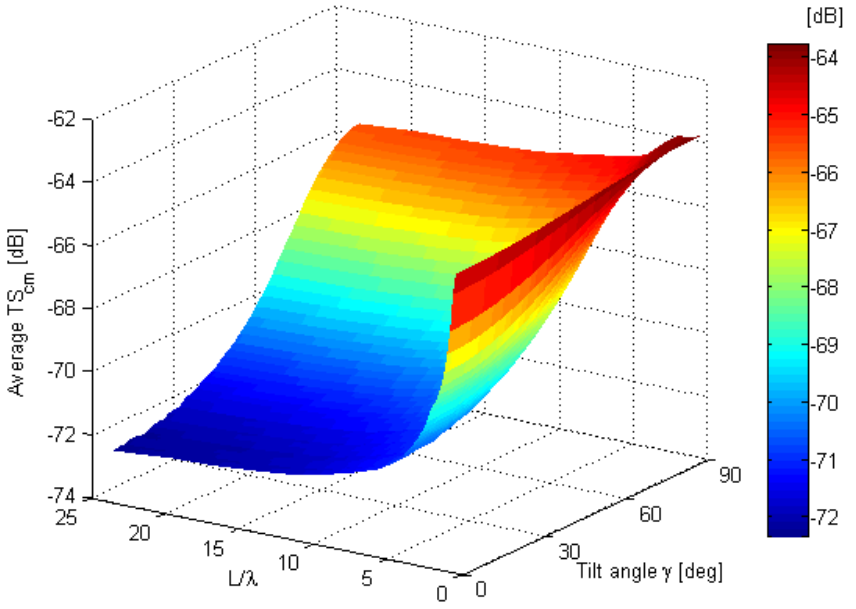
Targe Strength is a function of transducer tilt angle and attitudes of fish yaw angle:

$$\mathrm{TS}_{<3d>} \approx f(\gamma, \eta)$$

Vacant model for bladder fish



3D average TS of fish with tilt angle



Conclusion

- ✓ The area and SV of fish school can be measured using sonar in shallow sea.
- ✓ The fish school area indicate the biomass for the same species at the same fishing ground.
- ✓ The pings raw SV signal have near 10dB variation .
- ✓ The echo integration method for sonar surveys would be applied in near further.