

# **Bioacoustic Absorption Spectroscopy (BAS) for long term observation of fish**

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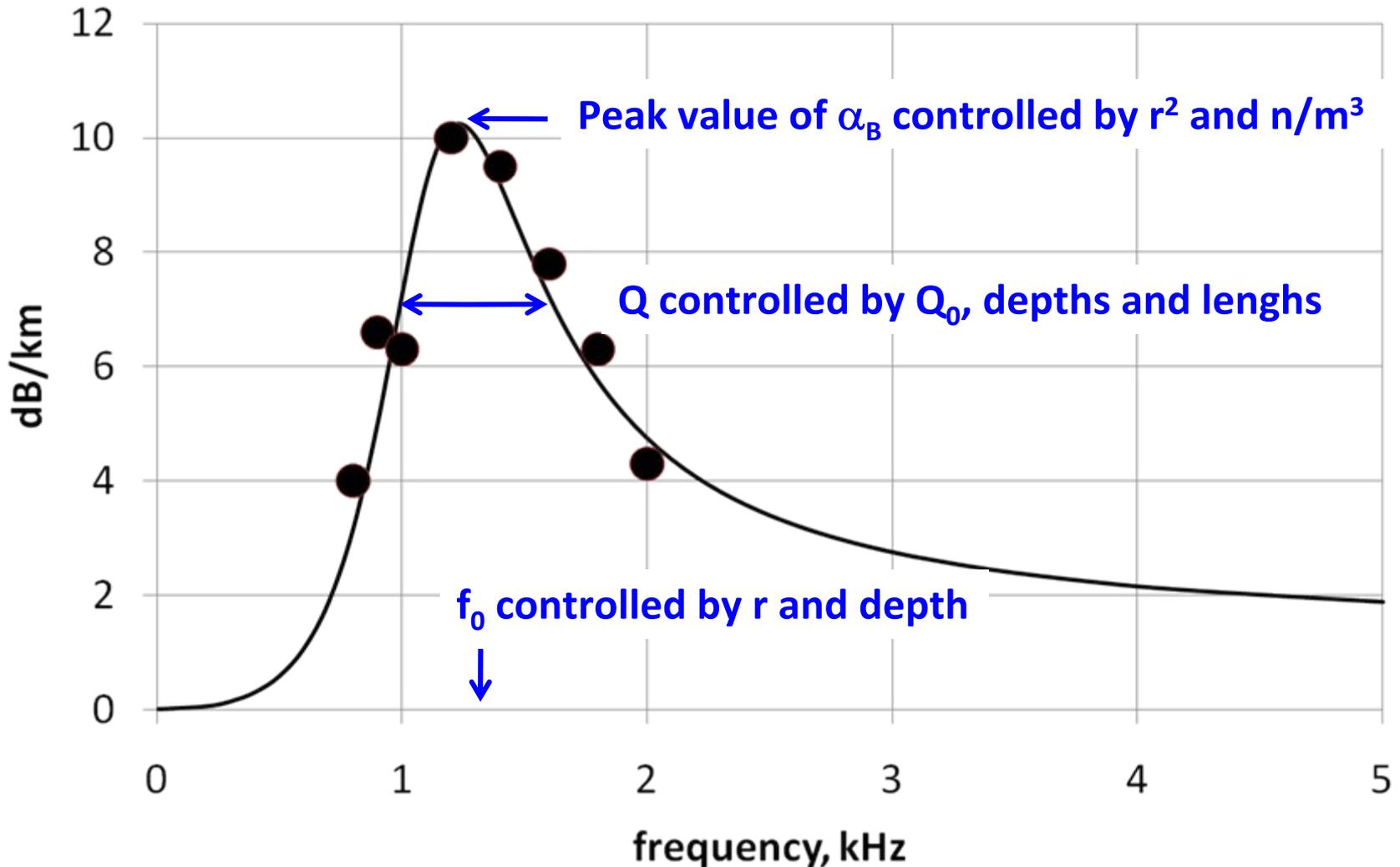
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## The vision

- **A network of BAS Observatories can provide continuous information on the number densities, diurnal behavior, *associations with fronts and eddies*, and annual migrations of the dominant species of fish in Ocean Observatory settings**

**Attenuation coefficient,  $\alpha_B$ , due to fish with swim bladders of radius,  $r$ , resonance frequency,  $f_0$ , and  $Q$  ( $\Delta f/f_0$ )**



## Acoustic absorption lines due to fish with swim bladders

Transmission of broadband acoustic energy through the ocean results in *absorption lines* due to resonance absorption by fish swim bladders

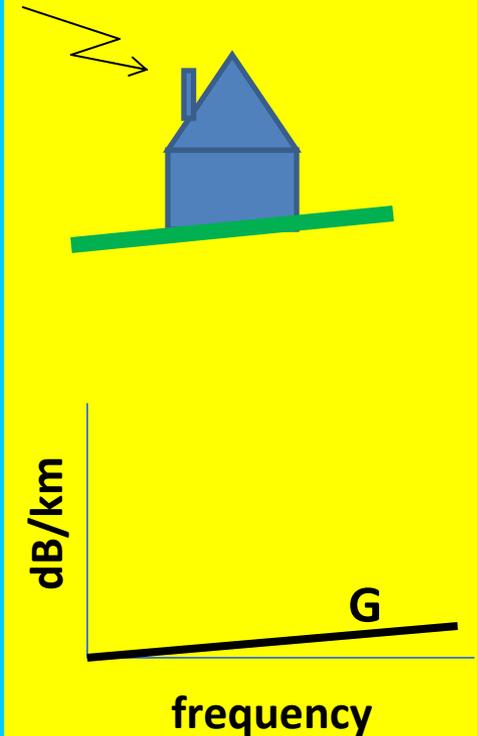
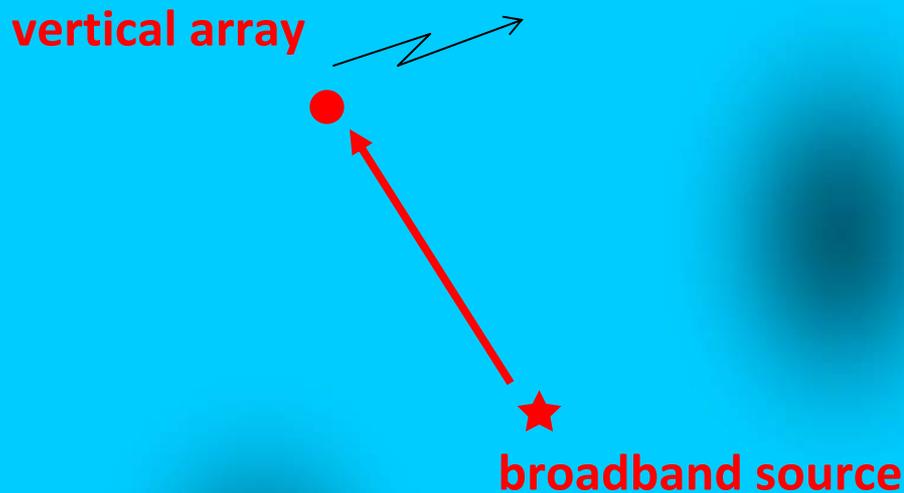
**Analogy:**

**Electromagnetic absorption lines due to CO<sub>2</sub> and H<sub>2</sub>O**

Transmission of broadband electromagnetic radiation (from the sun) through the atmosphere results in *absorption lines* due to CO<sub>2</sub> and H<sub>2</sub>O *relaxations*

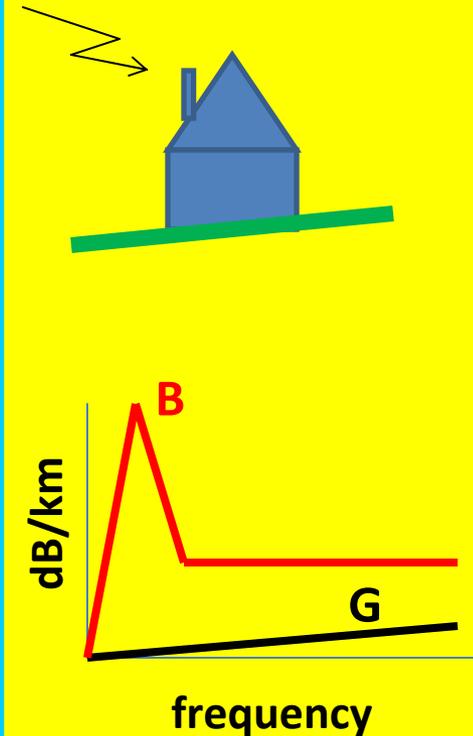
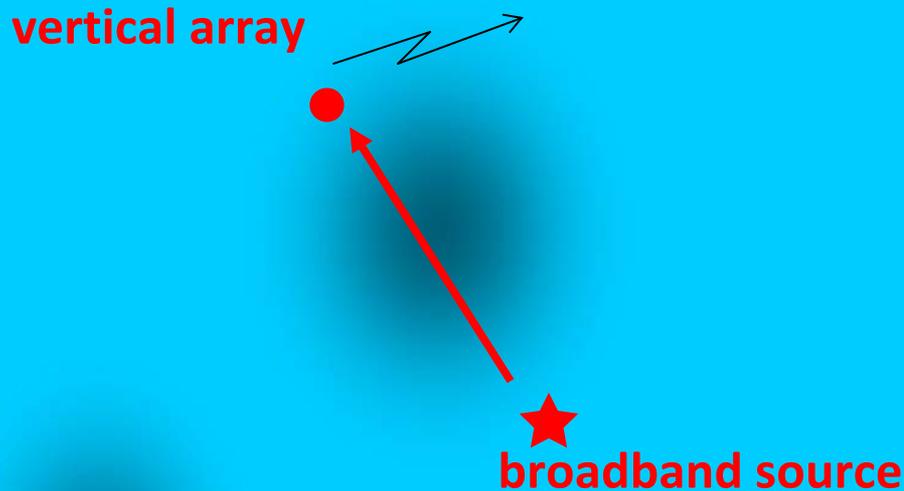
# Measure attenuation (dB/km) due geo-alpha (G) *when fish are absent*

High concentrations of fish are generally believed to be associated with fronts and eddies



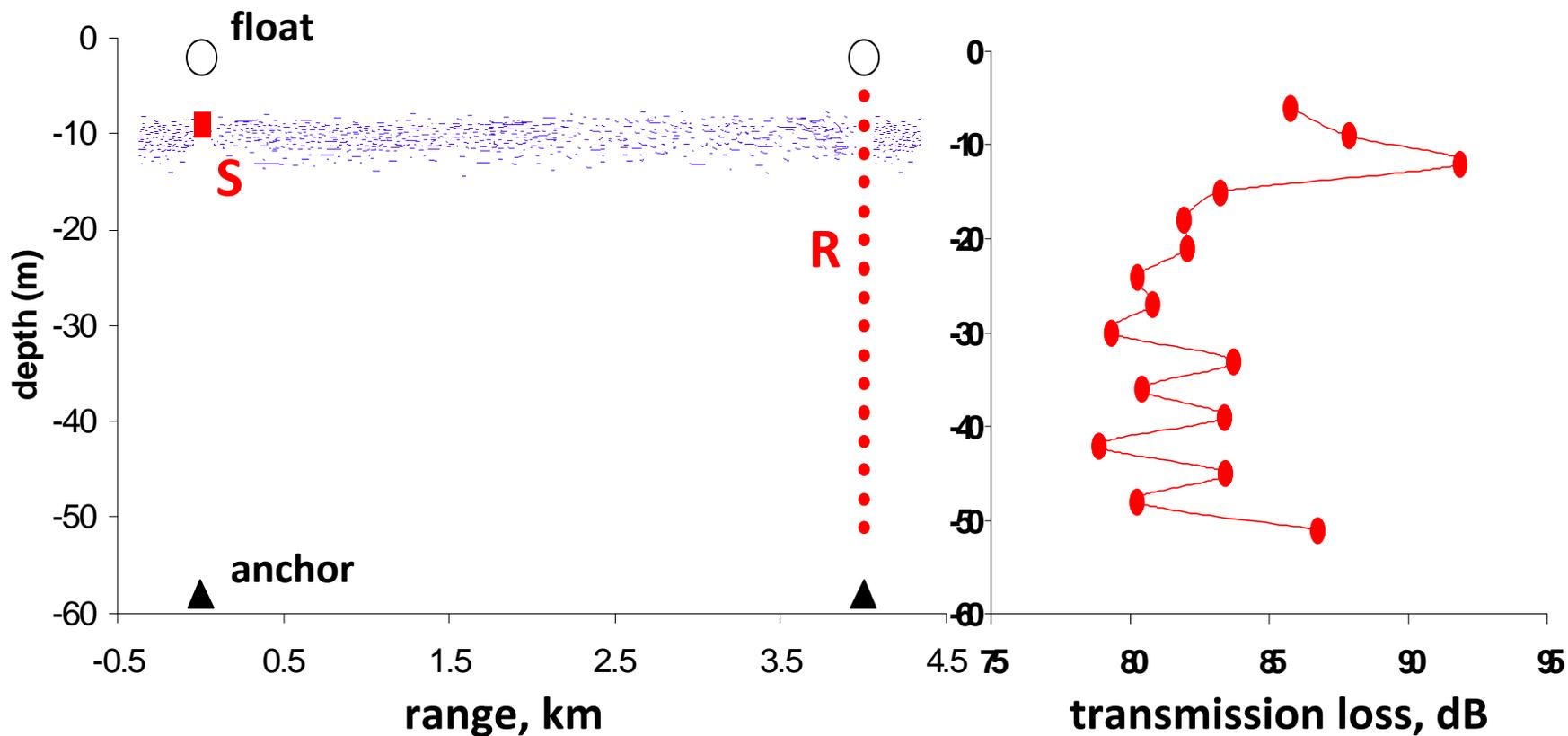
# Measure attenuation (dB/km) due to bio-alpha (B) and geo-alpha (G) when fish are present

High concentrations of fish are generally believed to be associated with fronts and eddies



**Left:** broadband source (S), receiving array (R) and absorbing layer of fish with swim bladders

**Right:** Transmission Loss, TL, vs depth at 1.2 kHz, resonance frequency of 15 cm sardines at 14 m



# Outline

- **Advantages**
- **Environmental impact**
- **Technology**
- **Examples of results**

Bio-alpha and estimation of number density

Scintillation Index of absorption lines and fish dynamics

- **Proposed Plan**
- **Cost**

## Advantages of BAS

- **Provides number density vs. fish length**  
(species with ancillary information)
- **Environmentally friendly: SL < 175 dB**  
(SL of echo sounders: > 220 dB)
- **Not biased by avoidance**  
(Fish avoid ships with echo sounders)
- **Sensitive to fish throughout ocean & near boundaries**  
(Fish within about 6 m of boundaries are not detectable with echo sounders)

# Environmental impact

- **None**

# BAS Technology

- ***Unique* ultra-broadband, ultra-lightweight source**
- ***Readily available* vertical hydrophone arrays**

# Deployment of ultra-broadband, ultra-lightweight source\*, Santa Barbara Channel

250 Hz <  $f$  < 10 kHz

SL: 170 dB (0.4-10 kHz)

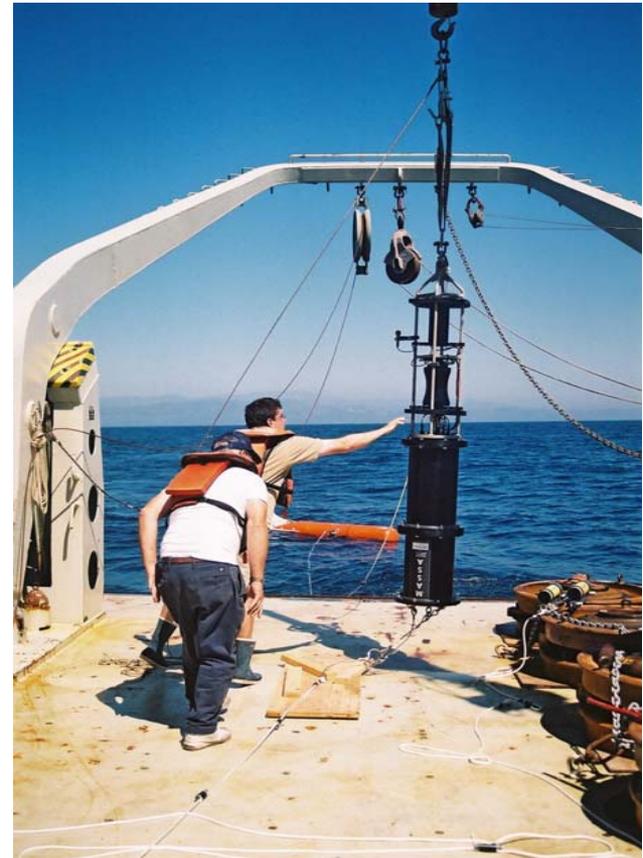
number of frequencies: 65

waveform: cw

duration: 0.5-10 sec

weight: 290 lb

battery life: 2 days



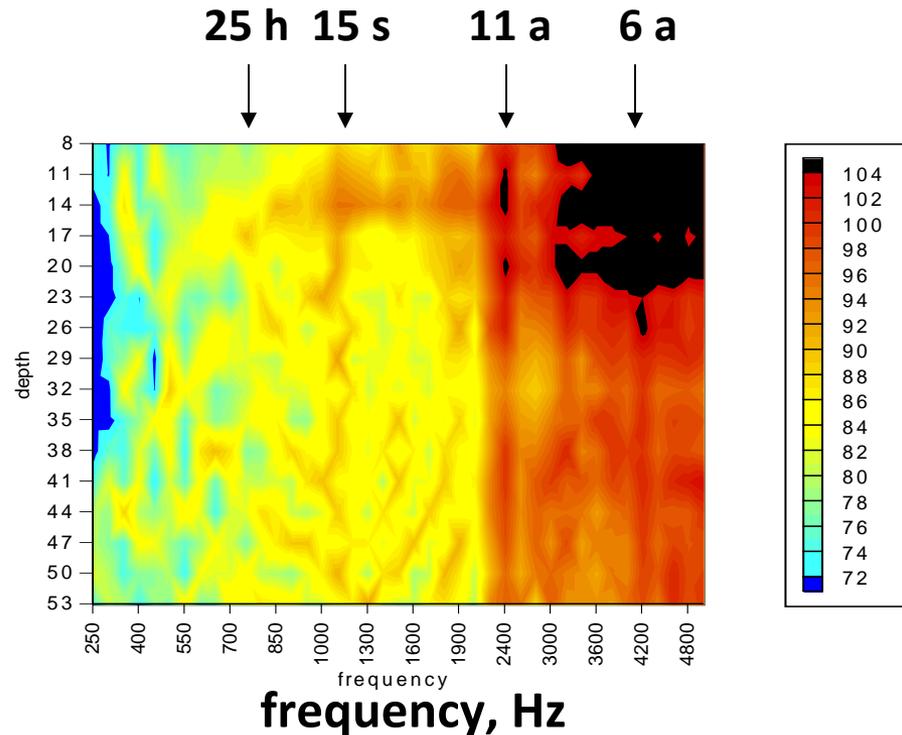
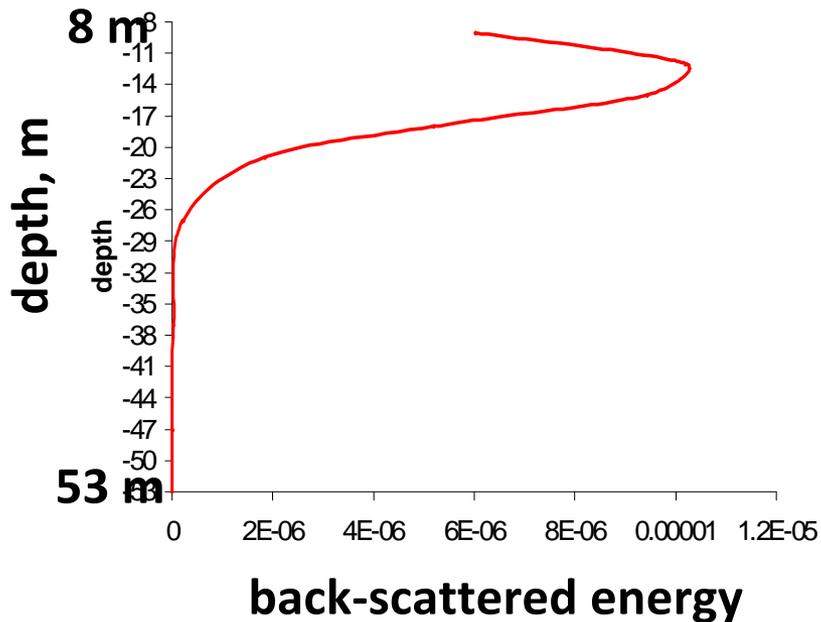
\* successfully employed in the BAS II experiment in 2002

# BAS experiments

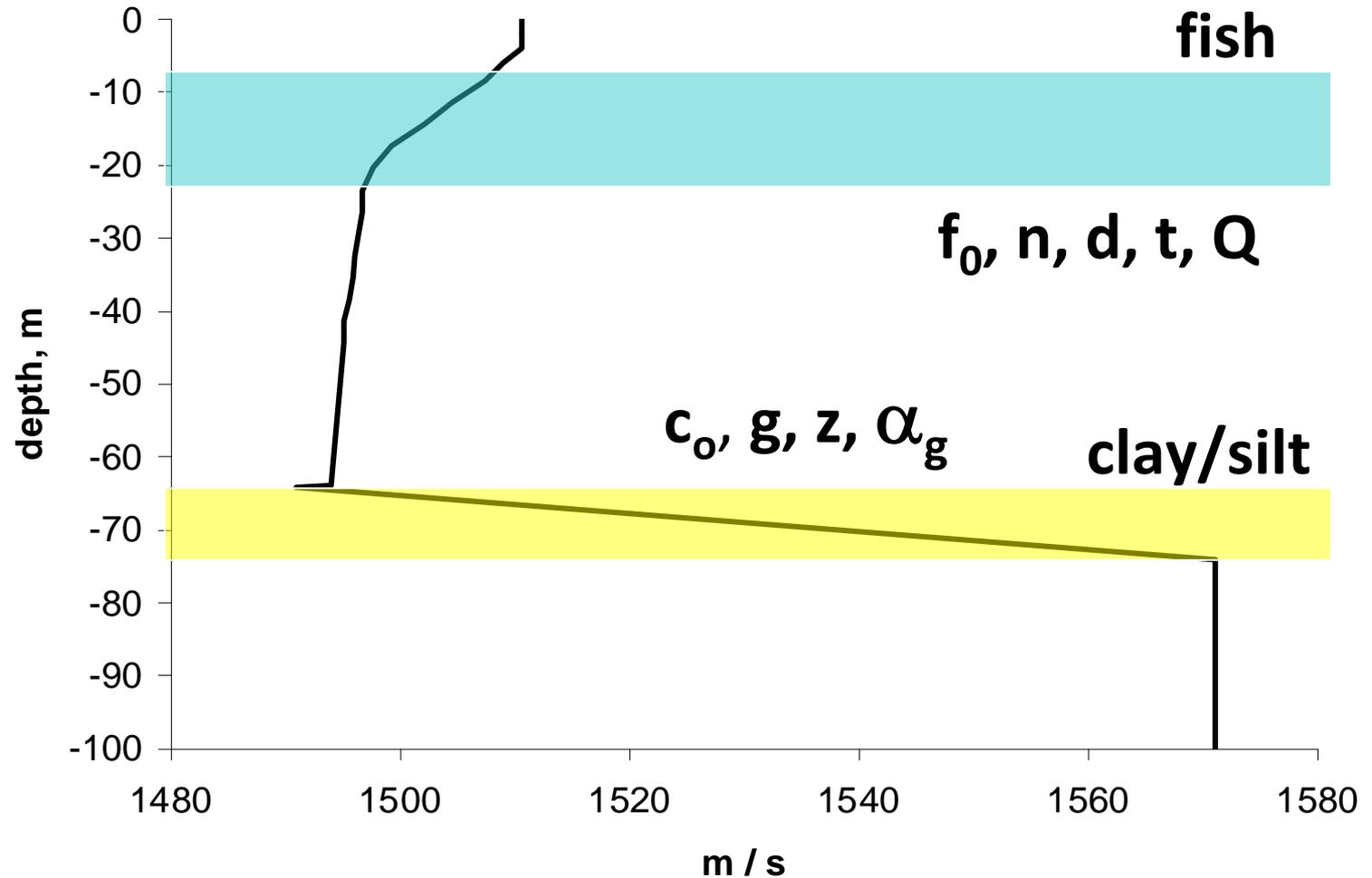
- **Weston, Bristol Channel, 1963-66**  
3 years, bottom mounted hydrophones, cabled to shore
- **Diachok, Gulf of Lion, 1995**  
2 days, vertical array, autonomous
- **Qiu, Yellow Sea, 1995**  
4 hours, 2 hydrophones, cabled to ship
- **Diachok, Santa Barbara Channel, 2002**  
2 days, vertical array, autonomous

**Left: Echo sounder, 38 kHz**

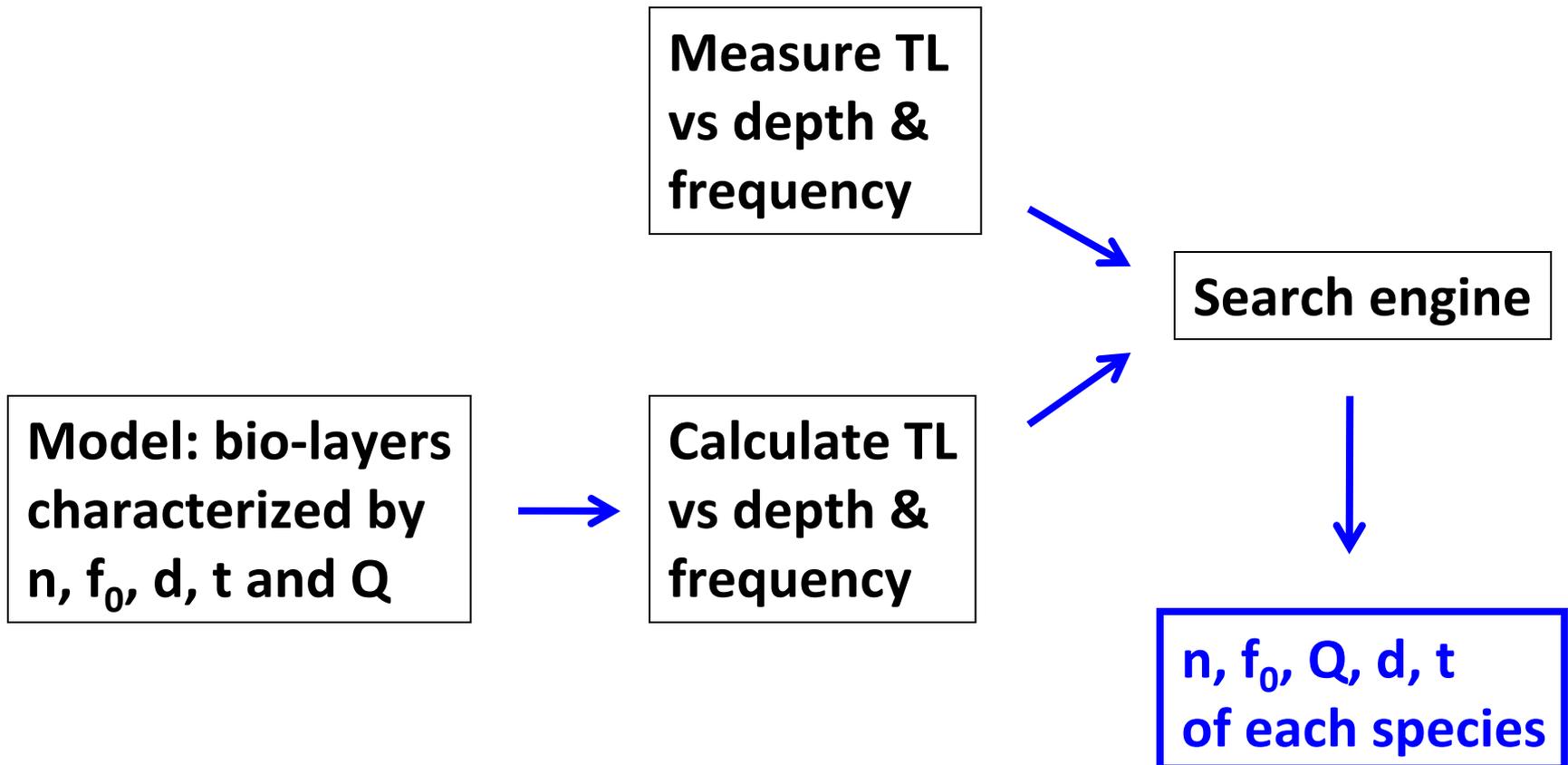
**Right: Transmission Loss. Absorption lines due to 25 hake (h),  
15 cm sardines, and 6 and 11 cm anchovies (a)**



# Inversion of bio and geo-acoustic parameters from TL data. Geo-acoustic parameters may be inverted with high confidence when fish are absent



# Estimation of resonance frequencies, $f_0$ , number densities, $n$ , average depth, $d$ , and thickness, $t$ , of layers, and $Q$ ( $\Delta f/f_0$ ) of absorption lines

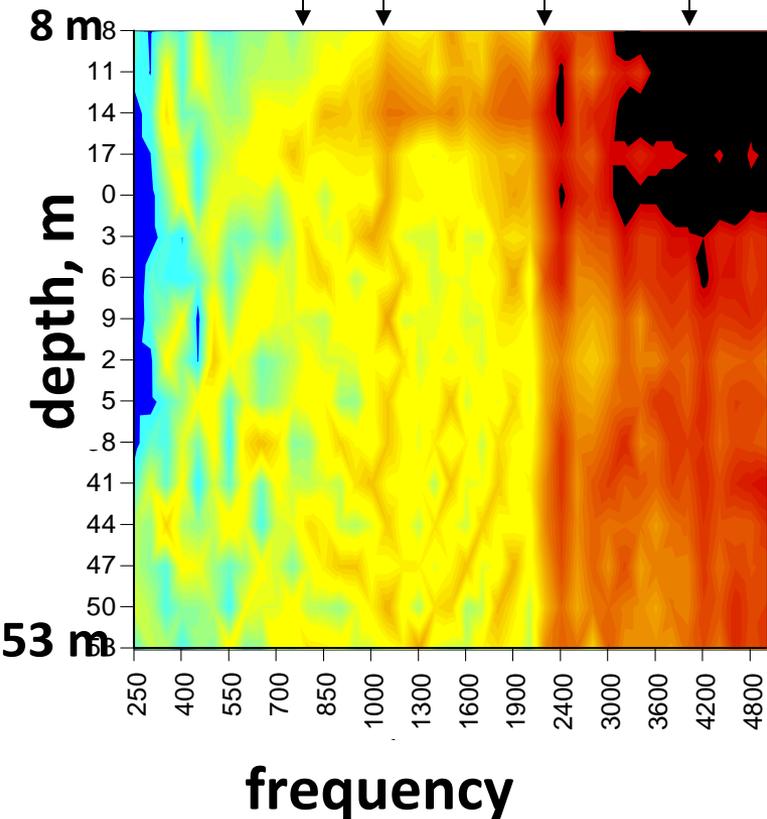


## **Scintillation Index, SI ( $SD/I_0$ ) of biological absorption lines**

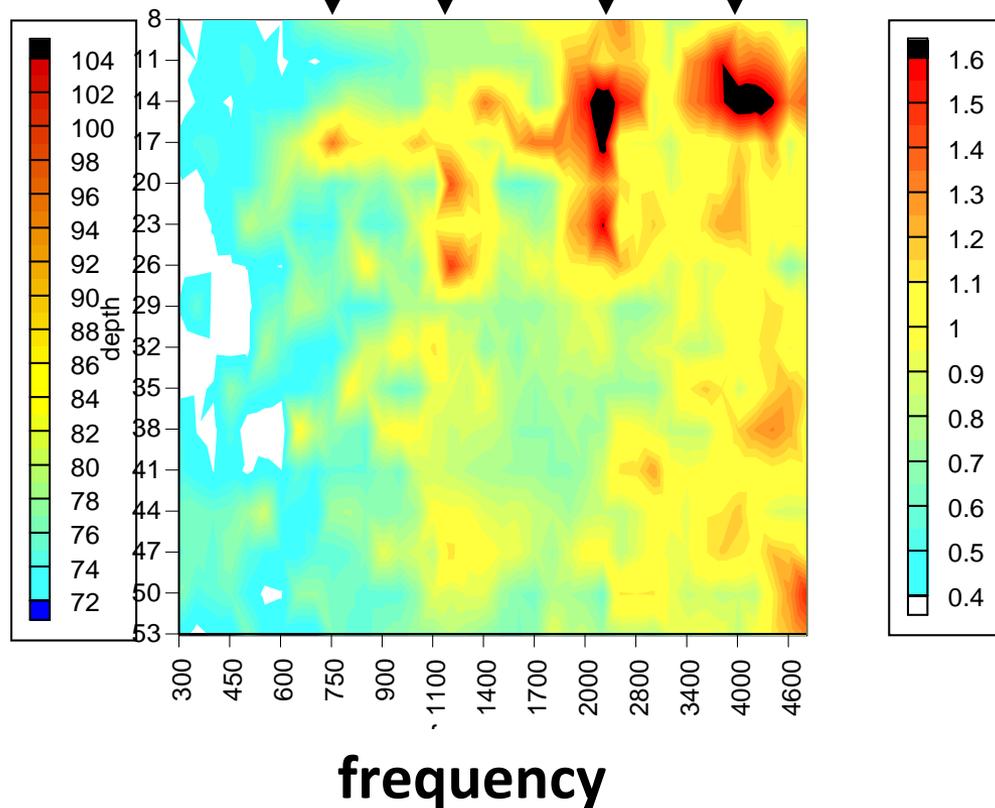
- **Fish in “layers” are highly dynamic, frequently changing depth and forming schools, on a scale of 10’s of minutes...which causes received signals to scintillate**
- **Measurement of SI facilitates classification of absorption lines**

# Range: 3.8 km, night, TL (left) and SI (right) 25 cm hake (h), 15 cm sardines (s), 6 & 11 cm anchovies (a)

25 h 15 s 10 a 6 a

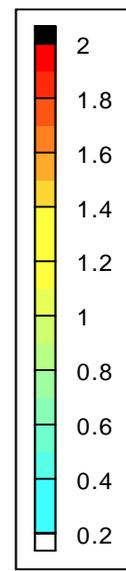
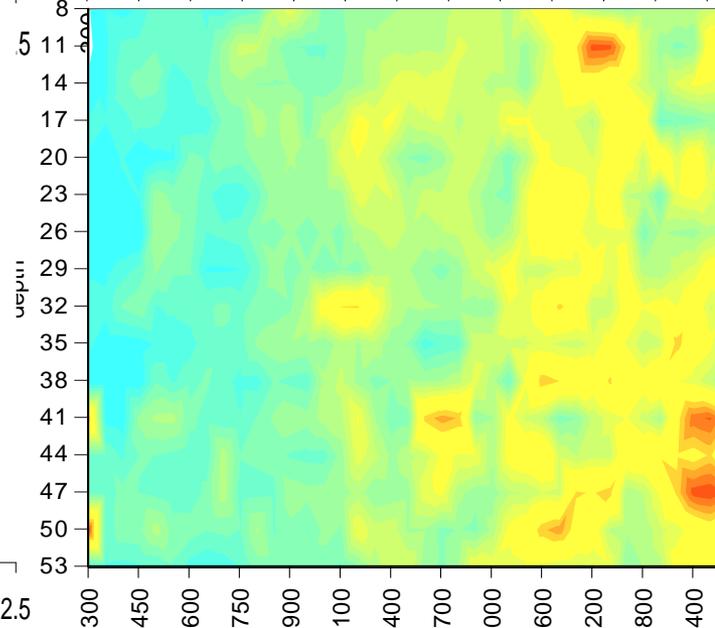
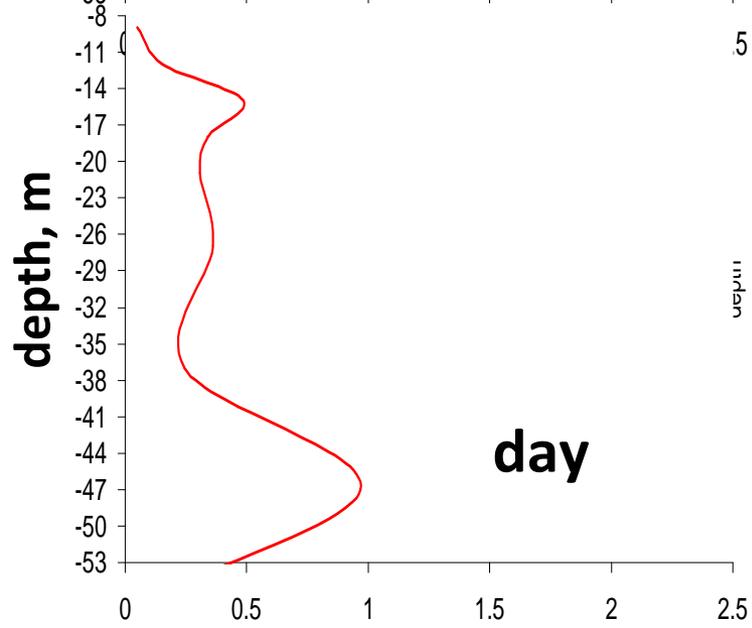
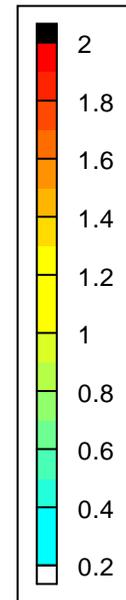
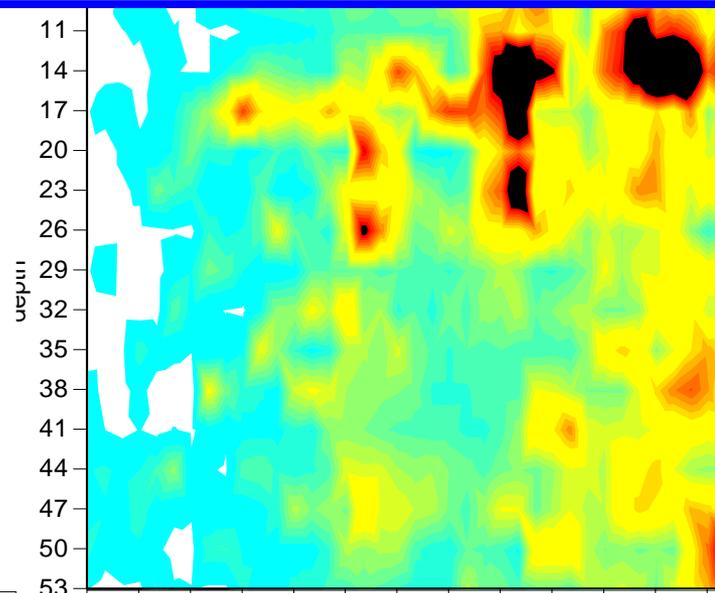
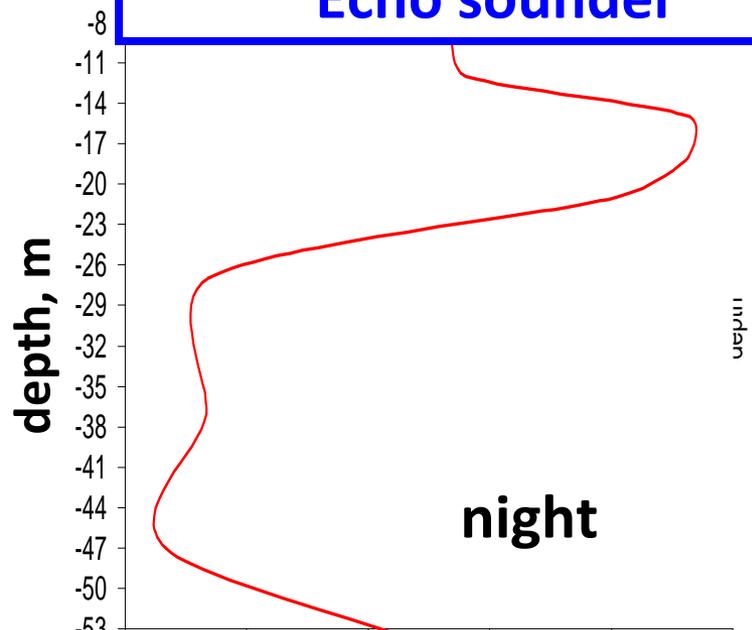


25 h 15 s 10 a 6 a



# Echo sounder

# bio-alpha



# The plan

- **Select site**
- **Conduct 14 day experiment; demonstrate effectiveness**
- **Develop next generation broadband source**
- **Purchase/adapt vertical arrays**
- **Install broadband source & vertical arrays; transmit data to shore; display & analyze for 1 year “proof of concept” demonstration**
- **Install multiple BAS systems; transmit data to shore for multiple years**

## Select site

- **Suggested site: off west coast USA**
- **Target species: hake, sardines, anchovies, others**

## Conduct 14 day experiment

- **Deploy broadband source & vertical arrays**
- **Autonomous recording of data**
- **Co-ordinate with ONR *Fish Acoustics Experiment***

# **Develop next generation broadband source**

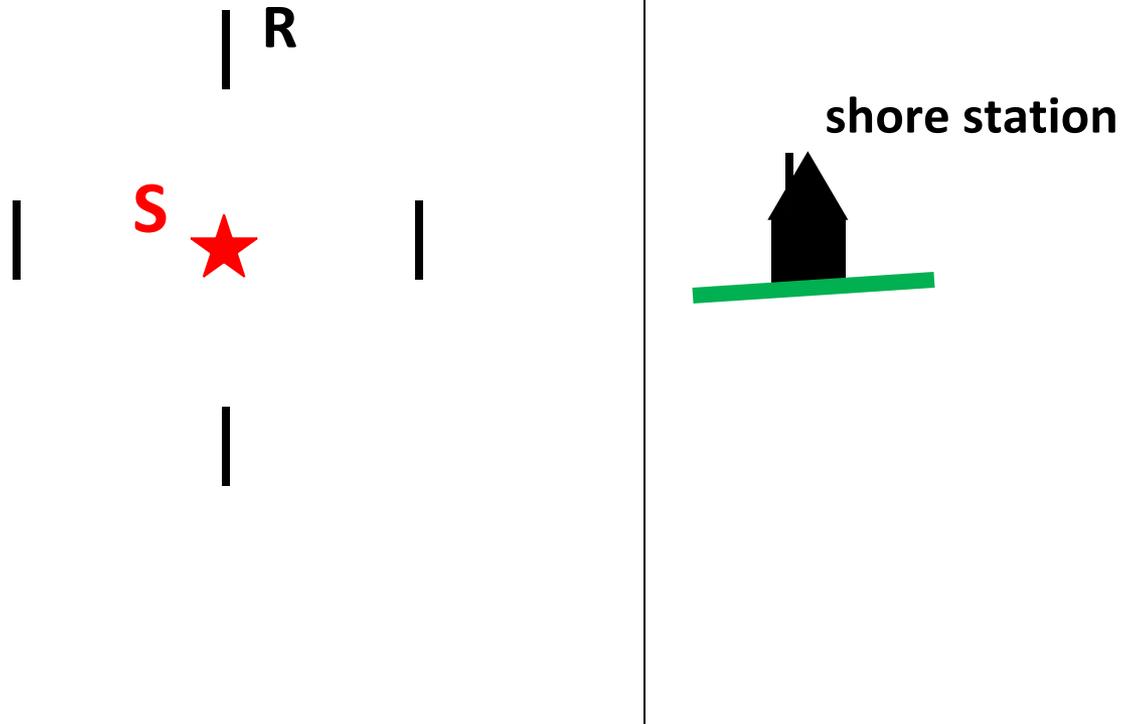
- **Suitable for multi-year deployment**
- **Solar powered**
- **Transmit engineering data (SL, tilt...) to shore**

## **Purchase/adapt vertical arrays**

- **Nominally 16 elements**
- **Suitable for multi-year deployment** (adapt as appropriate)
- **Solar powered**
- **Transmit acoustic and engineering (hydrophone depth,etc) data, and temperature vs depth data to shore**

# Install broadband source & multiple vertical arrays

- **Recommendation: deploy within RF range of shore station (longer range requires cables)**
- **Separation between source (S) and receiving arrays (R): about 5 km**



# **“Proof of concept” demonstration: transmit data to shore; display & analyze data for 1 year**

- **Demonstrate effectiveness of BAS for monitoring number density, diurnal vertical migrations, *association with fronts and eddies*, and effects of migrations**

# Install multiple BAS systems; transmit data to shore for long term monitoring

Monitor changes in number densities, *associations with fronts and eddies* and migration patterns of dominant species: hake, sardines, anchovies, others

