FROST Webinar on WATER BODY POLLUTION
(Forum for River and Ocean Scientists and Technologists)
Odisha
(www.frostodisha.com)
October 8-9, 2021; 17:00-20:30 IST

Session I

Ocean Pollution-Application of Sound Signal

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General Outline:

- **Introduction**
- **Understanding the Sound in the Ocean**
- **Ongoing monitoring methods using <u>living</u> and <u>non-living</u> resources.**
- **Active Acoustic Applications.**
- **Passive Acoustic Applications.**
- **Applications carried out in this region……..**
- **Future directions………………..**

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- ***<u>Biophony:</u> Fish Sound, Whale, Dolphin***
- ***<u>Geophony</u>*: natural like Wind, waves, underwater current etc.**
- **<u>Anthrophony:</u> *M*an made sound; shipping**

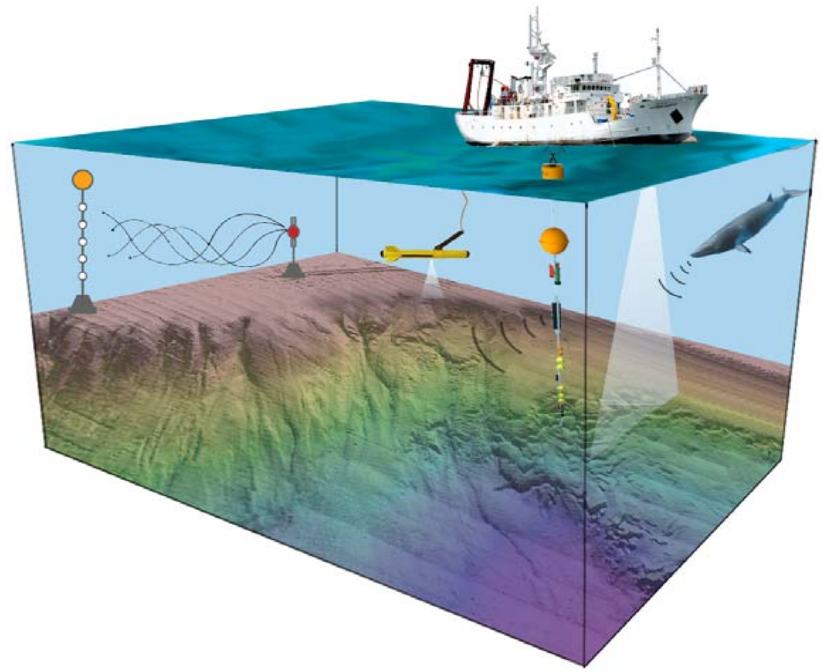
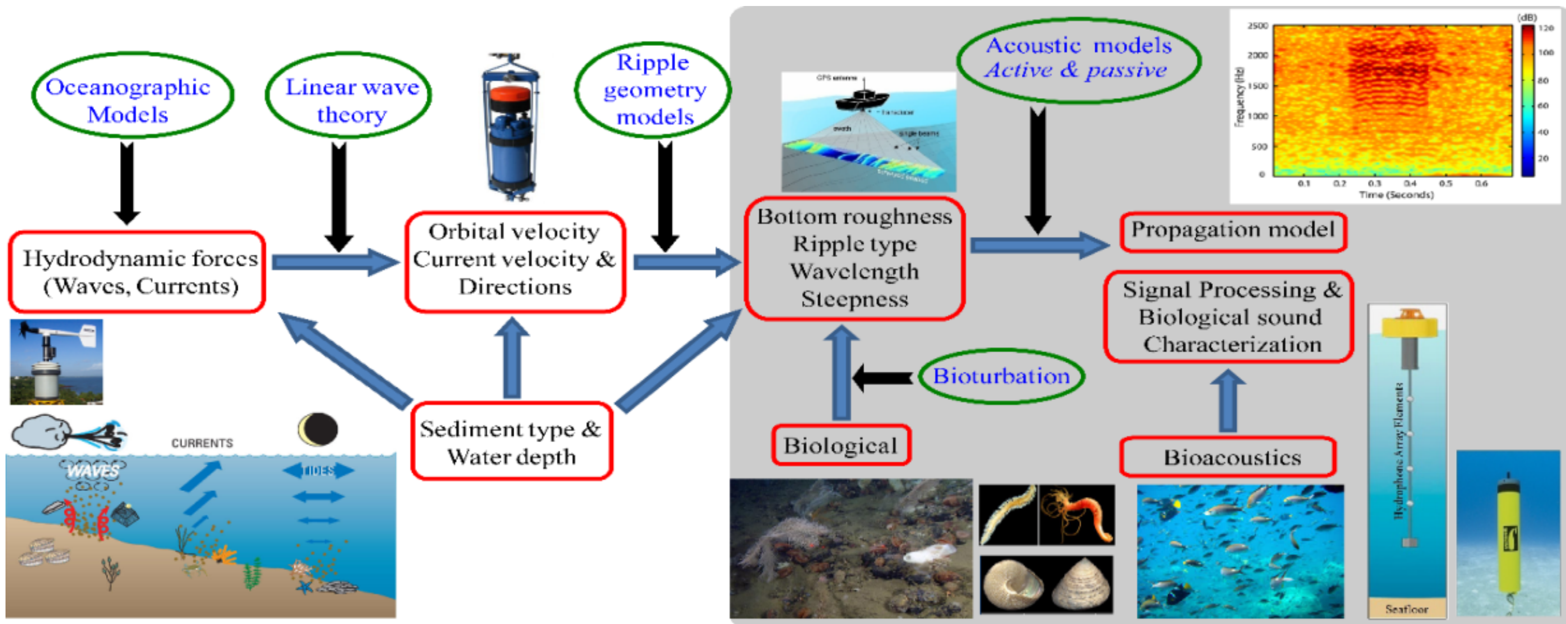


Figure shows Ocean Acoustics Field Equipment's

- **Underwater Processes & Acoustics:**

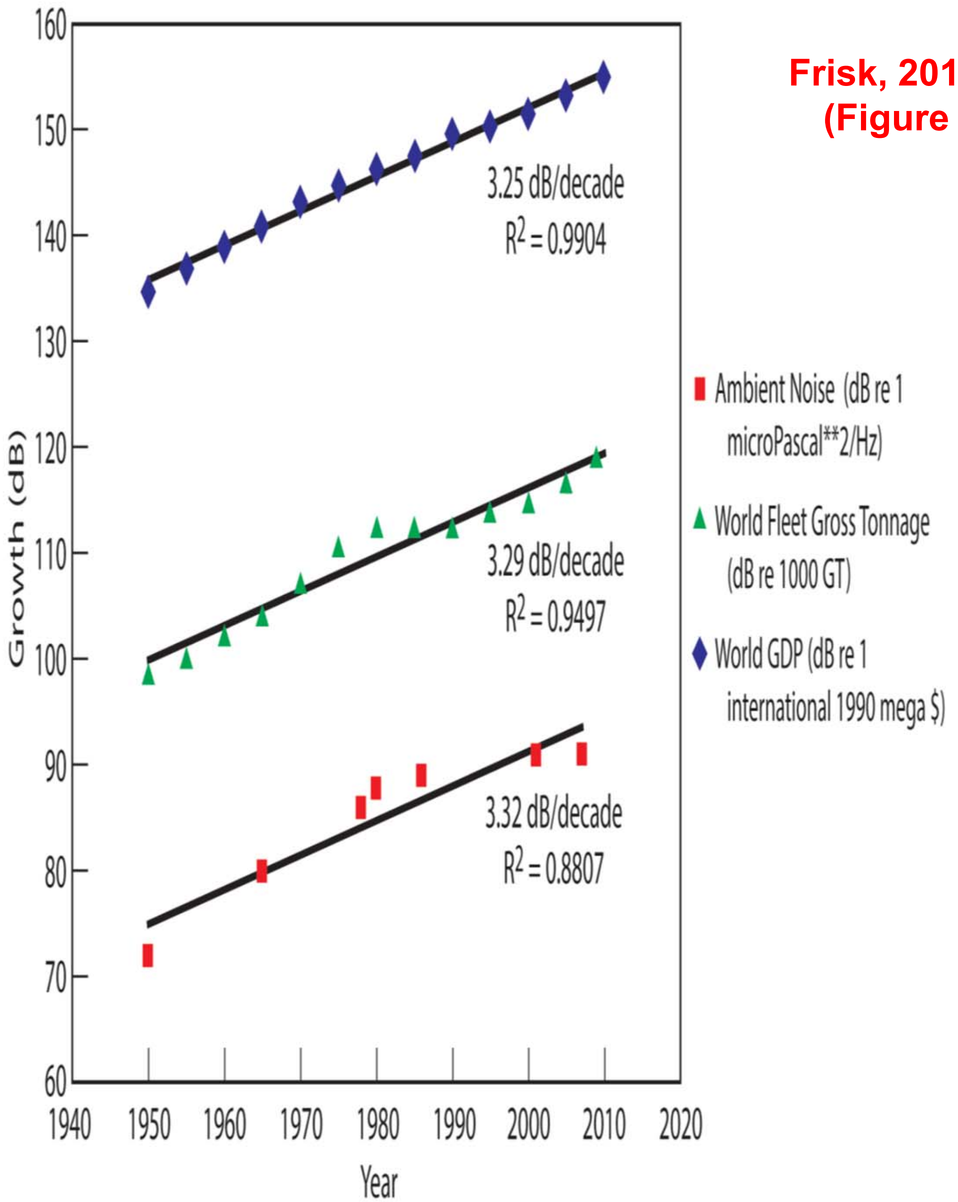
A scheme of coupling hydrodynamic, biological and acoustic models



Objectives:

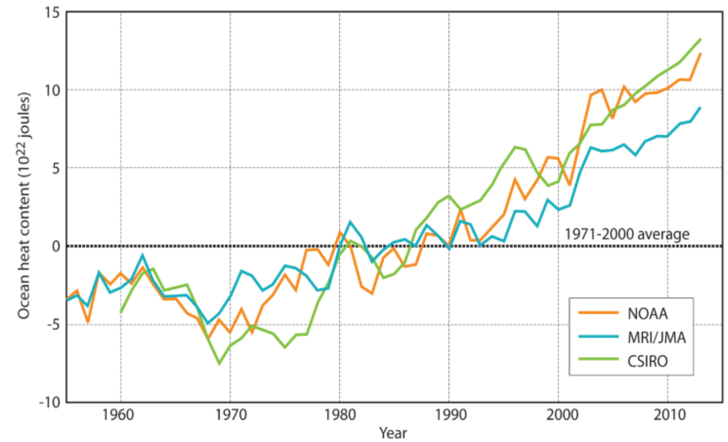
•Identify marine biodiversity hotspots through soundscape and ground & sea truth.
•To quantify anthropogenic sound their impacts on the biodiversity.
•Ecologically sensitive & fishing exclusion zones for biological conservation.

Soundscape data acquisition and investigate effects of ambient noise on the marine environment

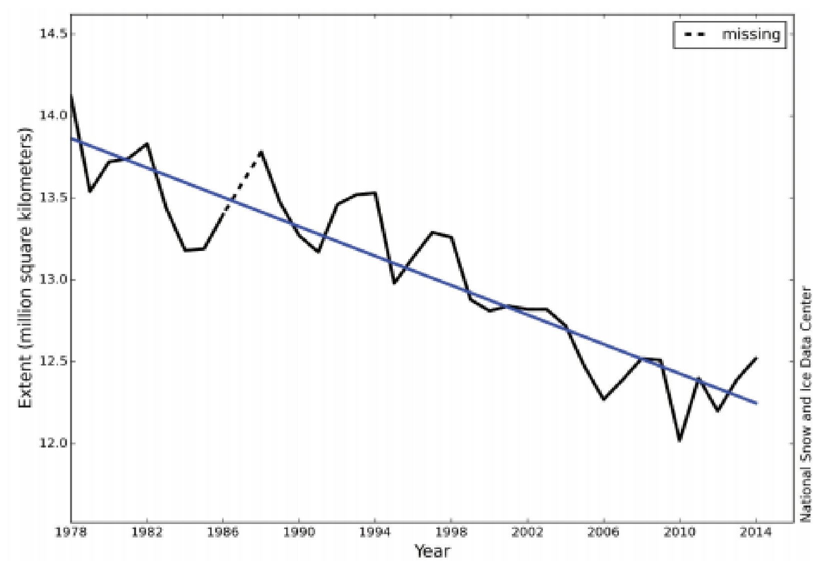


Measurements of ambient noise levels, world fleet gross tonnage, and world gross domestic product

Frisk, 2012 Nature Scientific Reports 2, Article No. 437 (Figure shows how GDP, Fleet Gross Tonnage and Ambient noise are related)

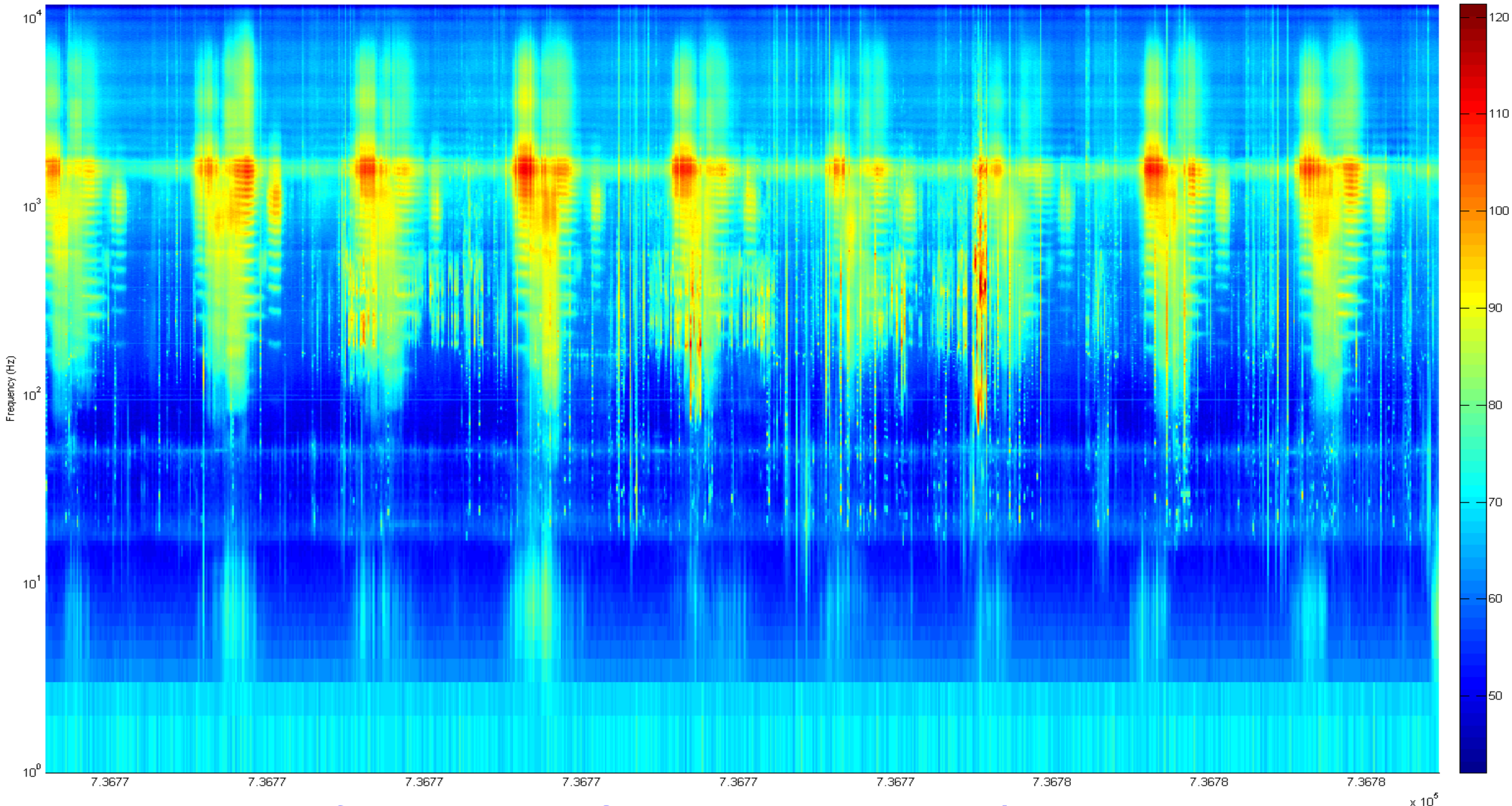


Ocean heat content, 1955-2013



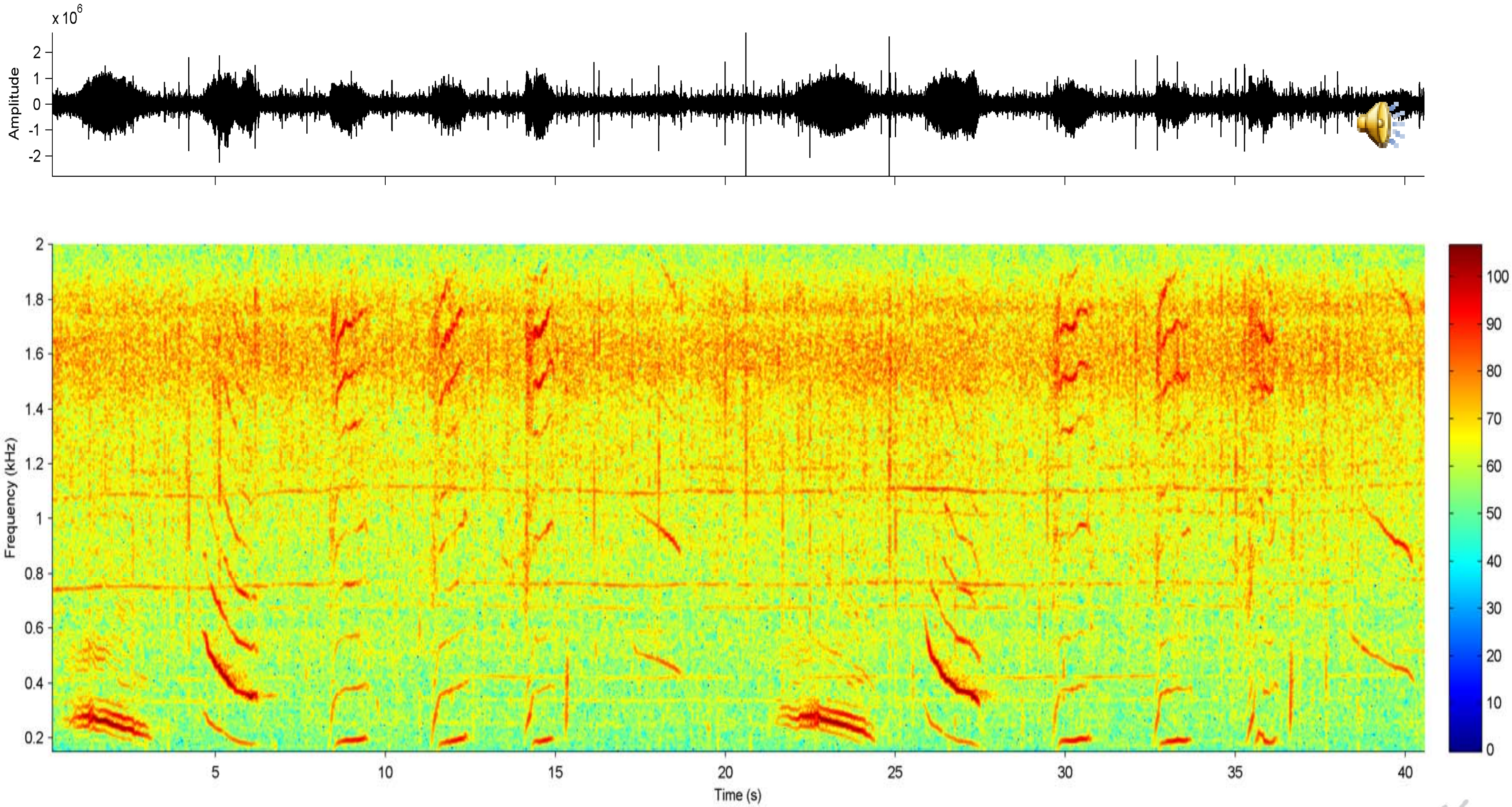
Monthly Arctic Sea Ice

Nine days passive acoustics Soundscape (Frequency vs.Time axis) off Grande Island, Goa



- Analyses of data reveal Sciaenid, *Terapon Theraps,* Humpback whale and unidentified Sound (most probably Anthrophony??)

Characterizing Humpback whale sound recorded data off Goa



Shyam Kumar et al Bioacoustics (2019)

Ocean pollution- some view points

Increase in toxicity or pollutant results in:

- **Bio-accumulation of toxicants in the benthic organisms.**
- **Ultimately, this leads to bio-magnification of pollutants in higher trophic levels**
- **Results in local extinction of sensitive benthic community (e.g.: bivalves)**

Example: Eutrophication or organic matter enrichment generally results in altered benthic community:

- **Reduction in diversity and increase in dominance of few species**
- **Increase in detritivores and reduction in filter feeders (in cases) since bivalves and many crustaceans are considered sensitive**

Why to locate and study Fish?:

- **Fish possess > 10,000 species and 800-2000 million tonne biomass of Global live biomass of 550-560 billion tonnes (2009 data).**
- **India 9.6 billion kg total annual Fisheries Harvest volume**
- **Locating and counting fish is difficult,** but defining and **mapping a fish's habitat** is more difficult.
- A **fish's habitat is the physical, chemical, geological and biological environment** in which it resides or migrates through and includes the pelagic (open water), benthic (on or in the sea floor), and demersal (on or near the sea floor) realms.
- Fisheries trawl or net surveys can provide an overall picture of fish distribution, but are **destructive** of the species being surveyed.
- One of the greatest challenges to the study of fish populations is the ability to collect data over large spatial scales and to study behaviour such as **spawning, nursery and feeding areas for fishes**

<u>Sources for pollution in fish's aquatic home:</u>

Chemicals from production plants; plastic from waste facilities; Fertilizers from agriculture.

Not only does pollution affect fish and their ecosystem, but the effect of pollution make their way back to polluters (us) in the form of contaminated seafood.

THE TIMES OF INDIA

THIS STORY IS FROM JULY 8, 2017

NIO: High decibel pile drilling on river beds hits marine life

Nida Sayed / TNN / Jul 8, 2017, 03:33 IST

Panaji: Unwelcome sonic disturbances caused by pile drilling in the Mandovi ar Zuari river beds for building bridges has produced sound exposure level anywh between 130 to 140 decibels, even going up to 180 decibels, disturbing the behaviour of marine animals, said experts from National Institute of Oceanography (NIO), Dona Paula. This was revealed by a passive acoustic study done in these areas.

The deafening sounds caused by drilling would have affected the auditory sens of the fish along the coastline, said Dr Bishwajit Chakraborty, a senior scientist with geological oceanography division at NIO. It also affects dolphins and other marine mammals who use sound to find food, communicate and travel.

Since sound travels more easily under water than through the air, these higher noise levels impact marine life and unsettle even their eating habits essential tc survival. He further explained that the fishes have only inner ears unlike humar other land animals and are therefore, more vulnerable to hearing problems.

The passive acoustic study of Mandovi and Zuari river areas was done with the help of a device called data logger, developed at the NIO.

THE TIMES OF INDIA

THIS STORY IS FROM JULY 3, 2017

NIO to use sounds to check marine health

Nida Sayed / TNN / Jul 3, 2017, 09:00 IST

Panaji: Effluents from River Sal could be affecting the wellbeing of the Terapon theraps fish species in Betul. Scientists at the National Institute of Oceanography (NIO), who have been using a unique device called a data logger to determine the health of marine life, said shoals of 'korkoro' — as the Terapon theraps are locally known - could be less healthy at Betul than at Grande Island.

Fish create sounds through swim bladders, stridulation (bone friction) and tail movements, which the data logger picks up, thereby helping scientists determine various parameters including the overall health of marine species.

A direct indication of the aquatic conditions of a particular area lies in the health of its marine life. Scientists have therefore attributed the reasons of the korkoro's declining health in Betul to the water conditions there.

"Effluents at Betul could be coming from River Sal, thus affecting the health of marine life. However, long-term data collection and a routine study must be done to back this hypothesis," NIO senior scientist Bishwajit Chakraborty, said.

THE TIMES OF INDIA

THIS STORY IS FROM MARCI

115 fish species at Grande Island

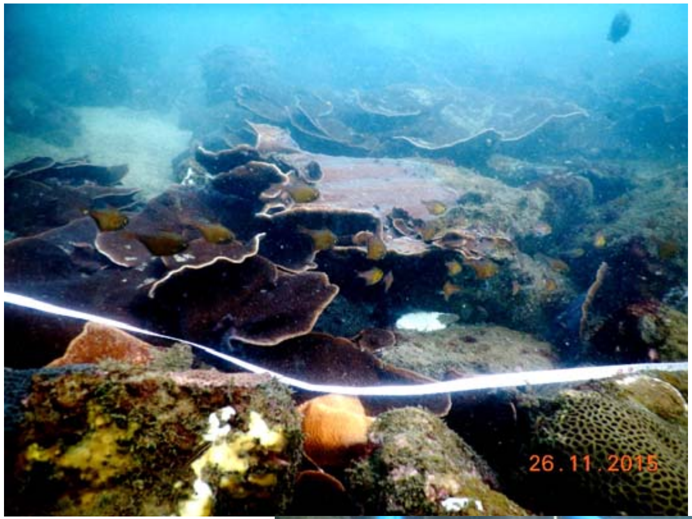
TNN / Mar 20, 2016, 10:46 IST

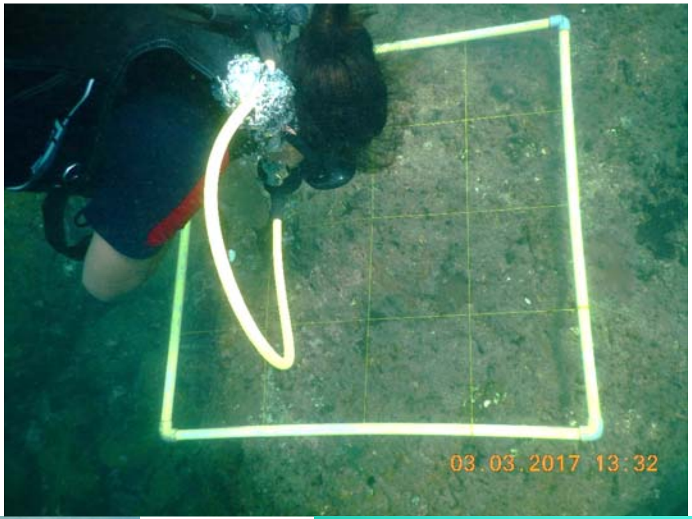
Panaji: Goa's Grande Island is all set to grab national attention for its fish diversity with about 115 fish species recorded in its depths, taking it on par with Lakshadweep and Andaman and Nicobar islands, which are among the few island ecosystems in India, popular for their rich aquatic resources.

An underwater census conducted jointly by ICAR-Central Coastal Agricultural Research Institute (CCARI), Old Goa and DIVEGOA, a private recreational diving training centre, has thrown up interesting findings. "The fish count is noteworthy compared to the 280 fish species documented in Andaman and Nicobar islands, 200 each in Gulf of Kutch and Minicoy atoll and 120 species in Lakshadweep," says N P Singh, director of Indian ICAR-CCARI. The first concerted effort to document the fishes of Grande island also saved considerable amount of public money with the public private partnership with DIVEGOA, which did the census along with their dive operations, ICAR sources said.

Divers, scientists and researchers are excited as the natural reef patches, shipwrecks, coral-laden rocky zones and sandy bottom habitats around the twin island ecosystems of St George and Grande islands are turning out to be a natural aquarium. Barely three kms from the Vasco coast, the island ecosystem is home to assemblages of fishes with beautiful colours, intricate patterns and unusual contours. "As a fisheries scientist, I am surprised that this habitat has a good diversity of fishes on par with other islands in India, but the underwater marvels had remained unexplored for a long time," says fisheries scientist with ICAR-CCARI, G B Sreekanth.

Diver data analyses:





Dr. Mandar N

Diver monitoring or spot sampling

Acoustics Methods:

Two uses of acoustics have been developed for studying fish populations and behaviour.

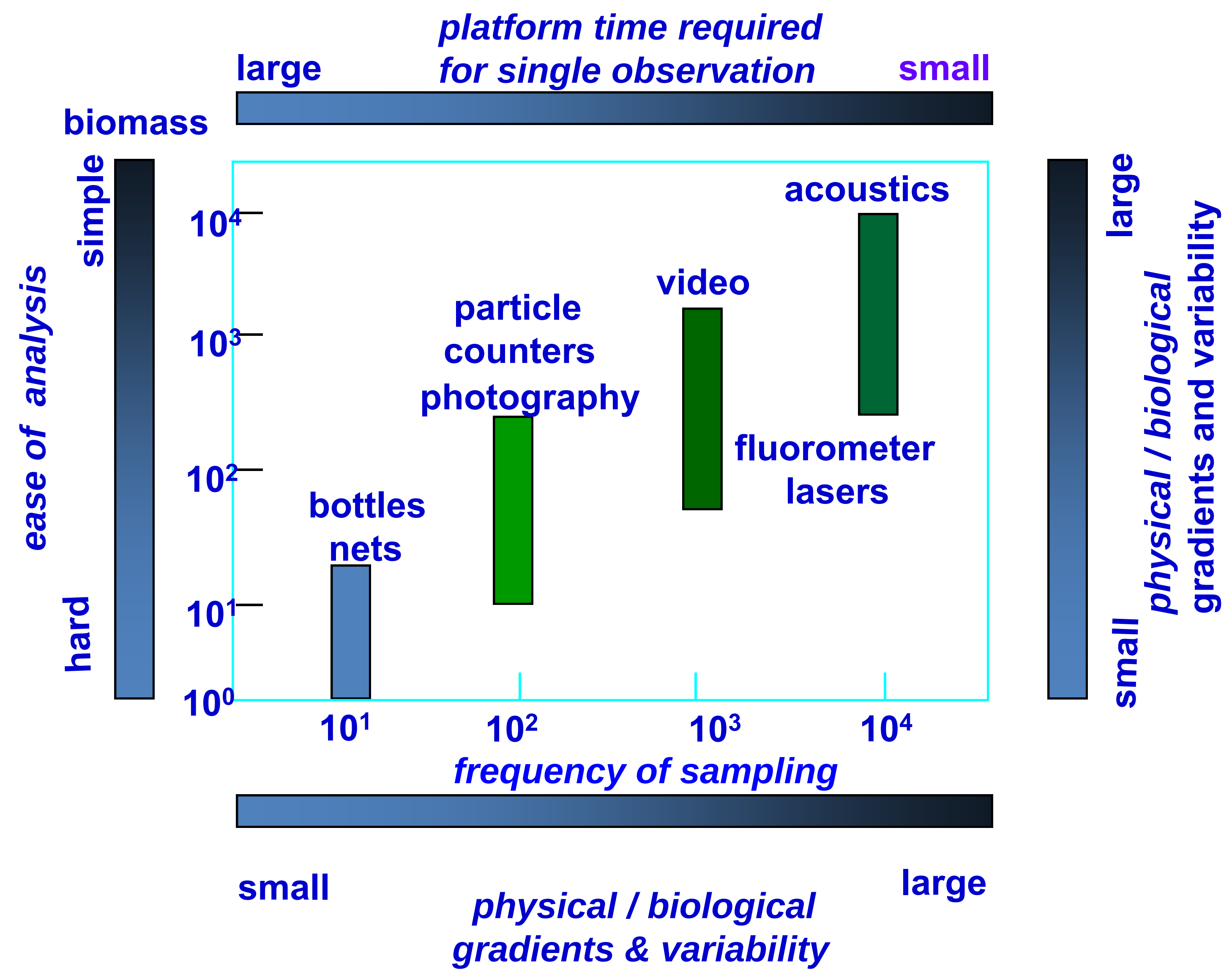
Active acoustics uses sound generated actively by transducers and the acoustic scattering properties of fish to image individual fishes and populations of fishes.

Passive acoustics relies on listening to the sounds produced by fishes with a hydrophone to infer their distribution and behaviour.

For passive acoustics to be useful a fish must make a sound, thus this technique is limited to species that produce sounds and to the times and places where they produce them.

These techniques have typically been used independently, depending on the situation and goals of the study.

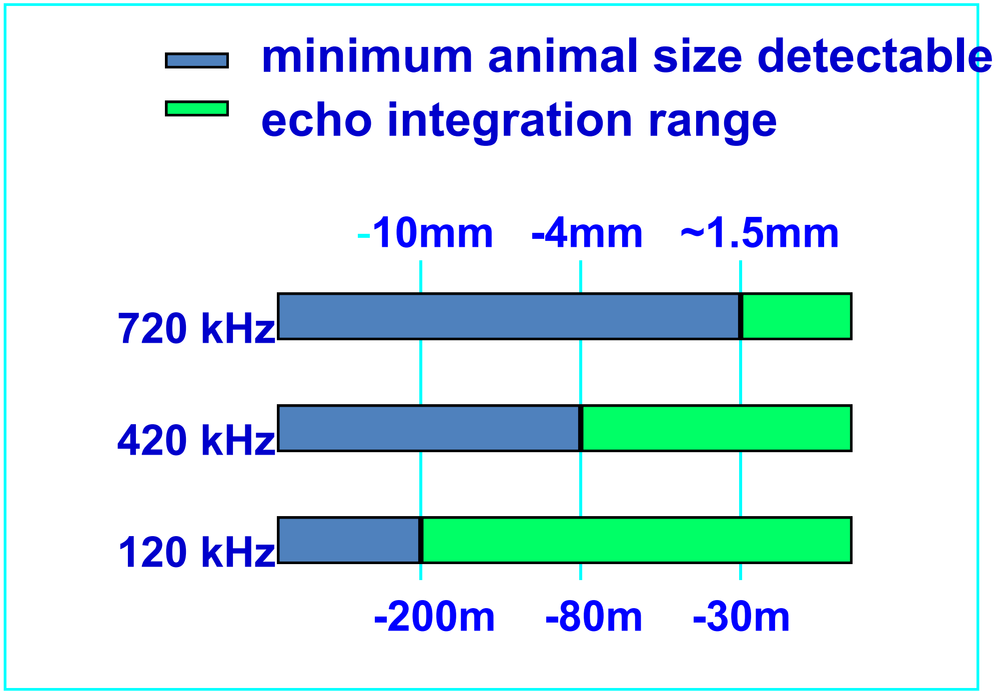
Figure: Acoustics sampling methods--- Most efficient mehod

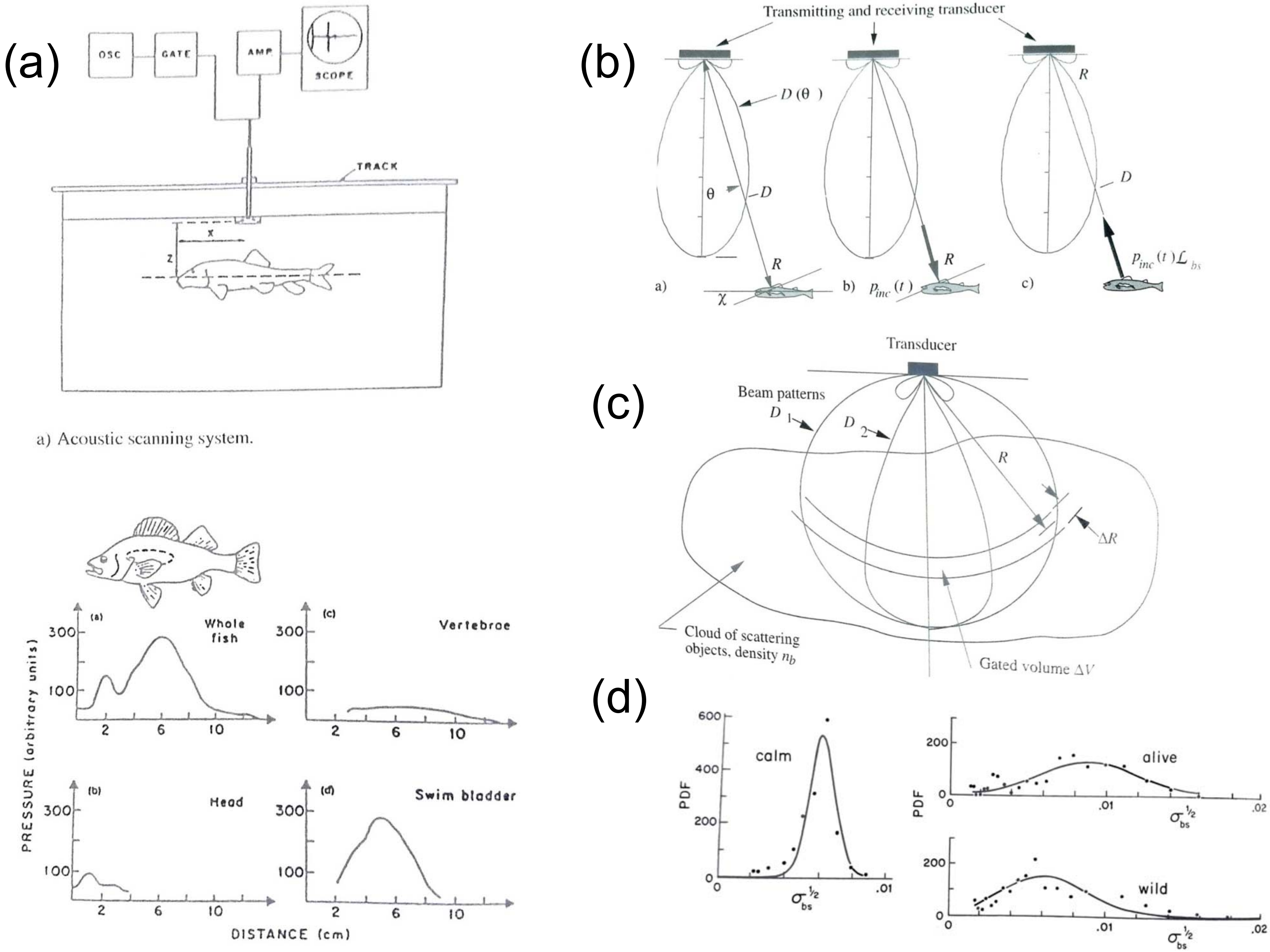


acoustic techniques-constraints

- resolution vs range
- acoustic modelling
- environmental parameters effect

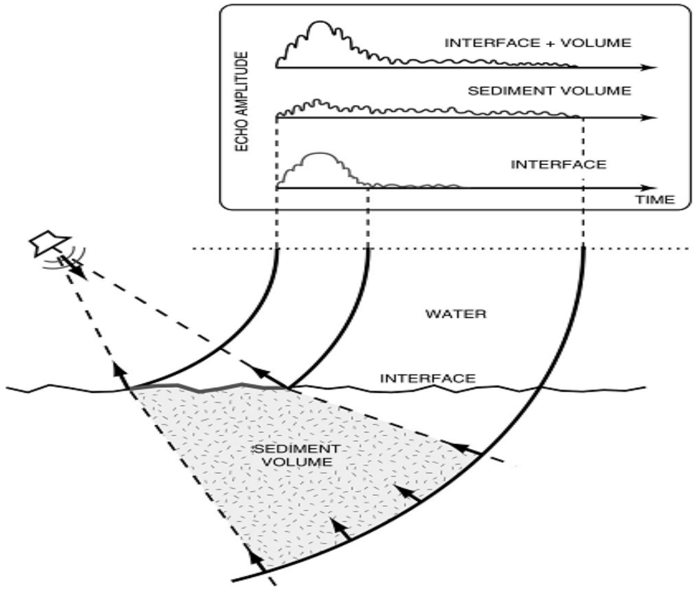
resolution vs. range

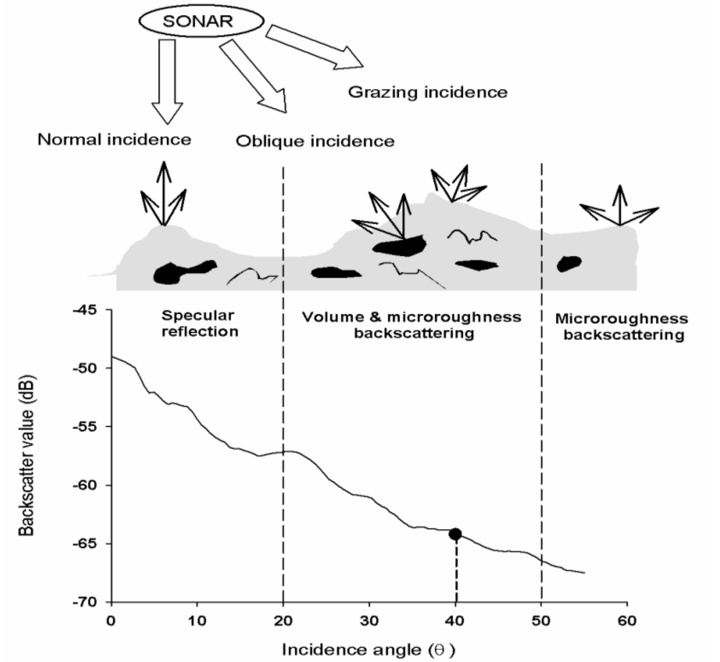


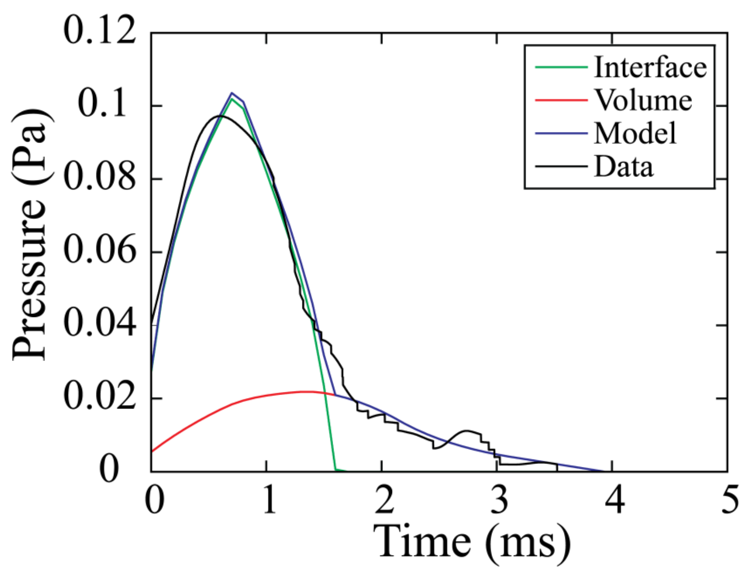


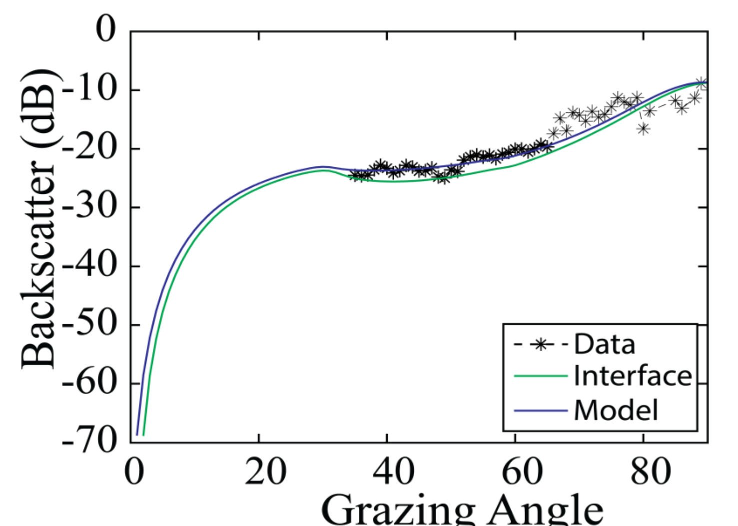
(a) Target strength (Laboratory arrangement); (b)Scattering from single fish and (c) fish cloud; (d) PDF of scattering data

Temporal / angular backscatter model of high frequency SBES and MBES









$$I(t) = I_i(t) + I_v(t)$$

$$P_a(t) = \sqrt{\rho_w v_w I(t)}$$

Haris et al JASA 2011; De & Chakraborty IEEE TGRS 2011

$$BS_{model}(\theta_g) = 10\log_{10}\left[S_S(\theta_g) + S_v(\theta_g)\right]\text{dB}$$

Benthic habitat mapping is a multi-disciplinary task that combines physical (geological), biological, oceanographic, and chemical components of the seafloor

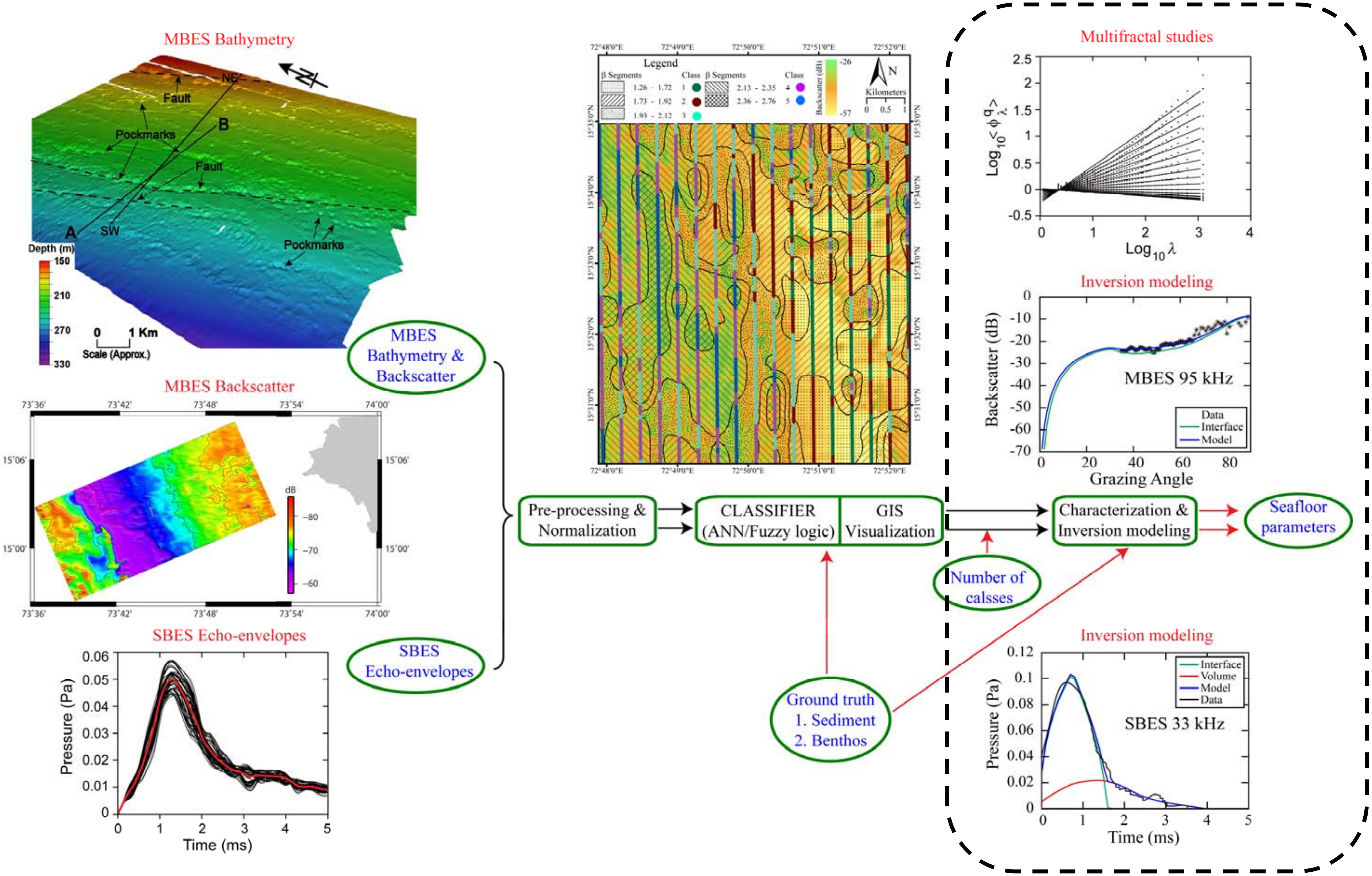
Sand ripple

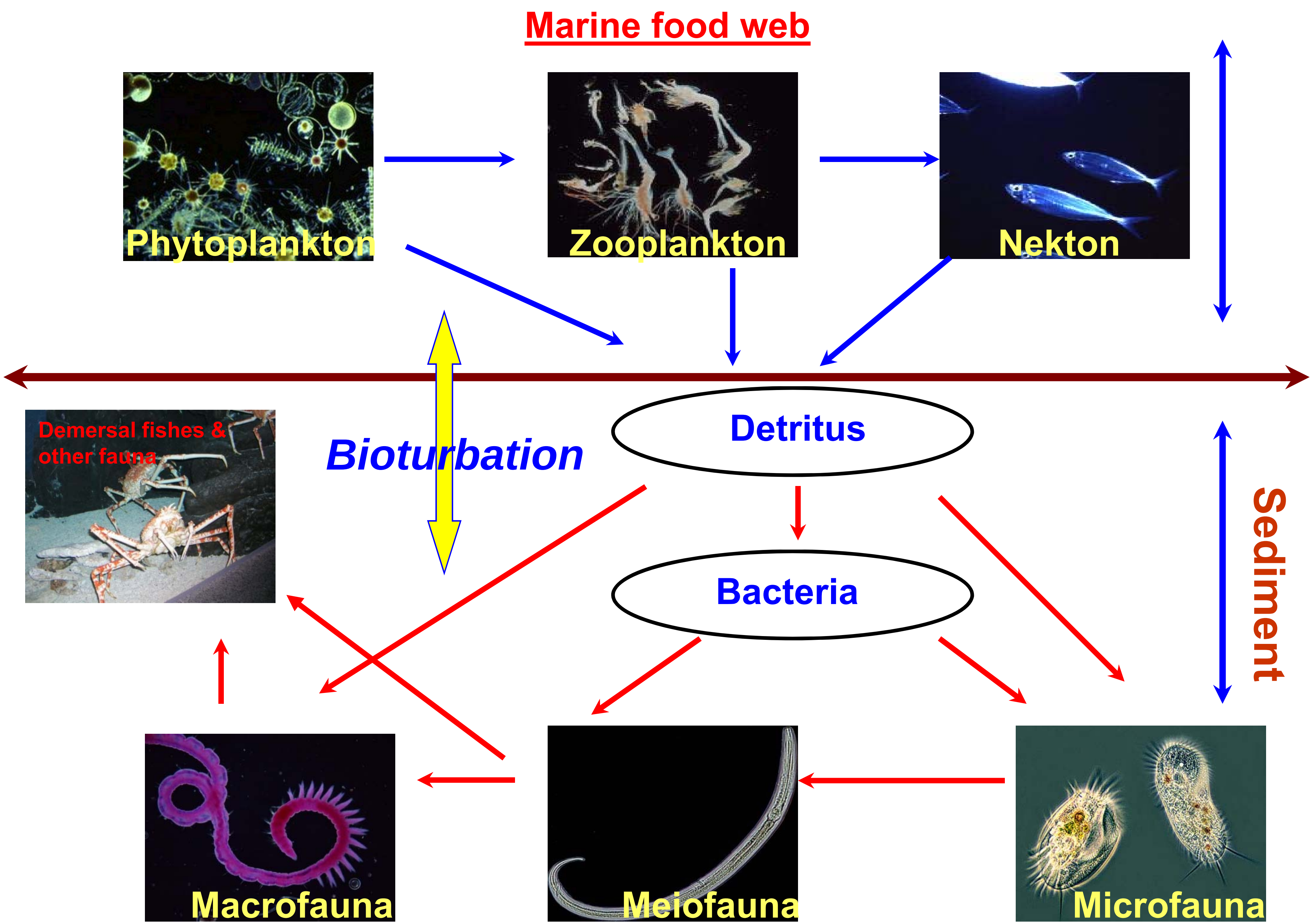
Soft body organisms

Polychaete and foram tubes, fewer ophiuroids.

Hard body organisms

General procedure for seafloor studies




Marine food web
Phytoplankton
Zooplankton
Nekton
Demersal fishes &
other fauna
Bioturbation
Detritus
Bacteria
Sediment
Macrofauna
Meiofauna
Microfauna

❑ Seabed habitat mapping employing SBES and MBES backscatter

- Multi-frequency backscatter changes along benthic dominant seafloor
- Relationship between backscatter, sediment texture, and benthos
- The effect of bioturbation on acoustic backscatter (using inversion results)

Benthic burrowing organisms collected from Goa coast

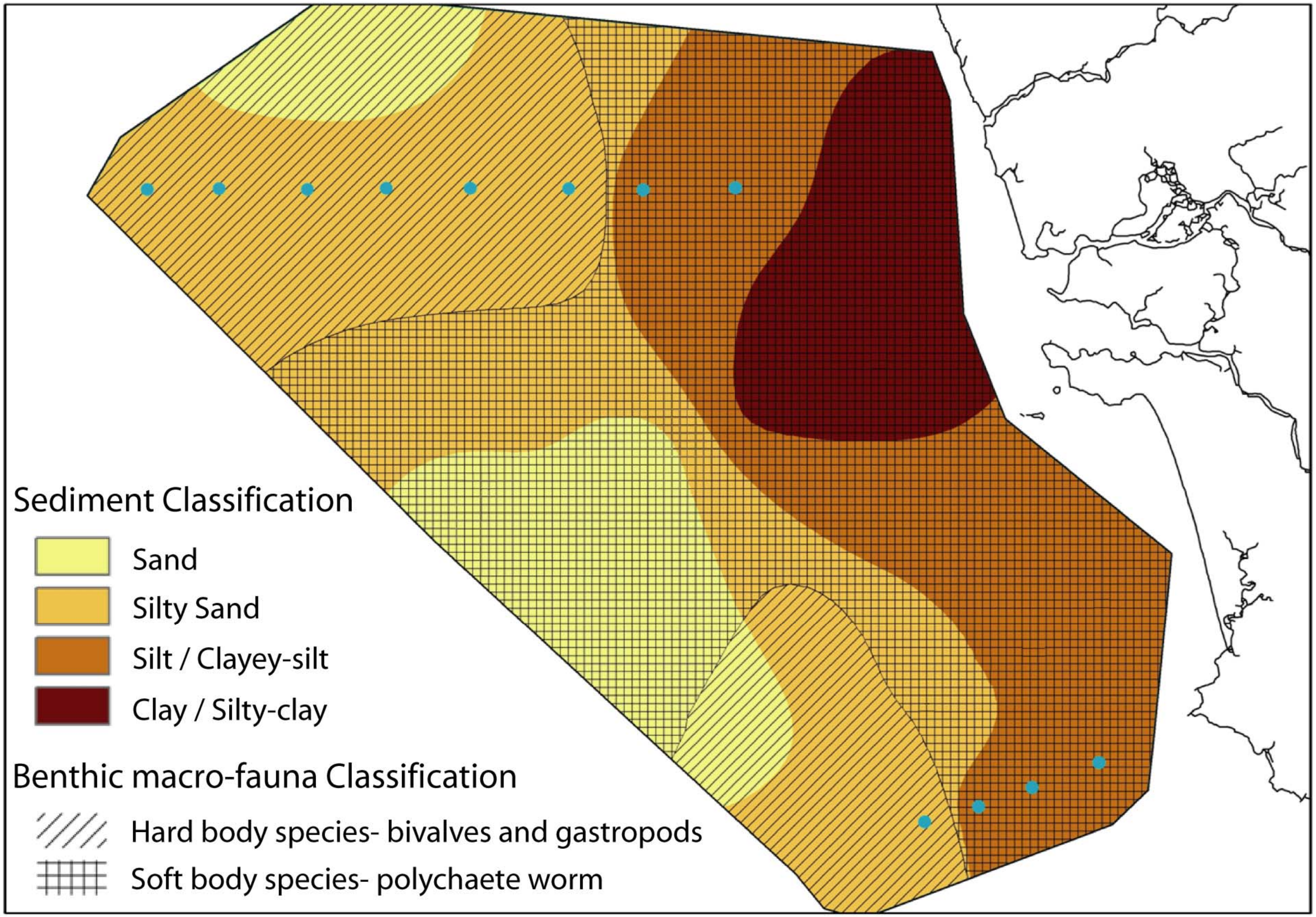
Filter- feeding (hard body)

Bivalves and gastropods

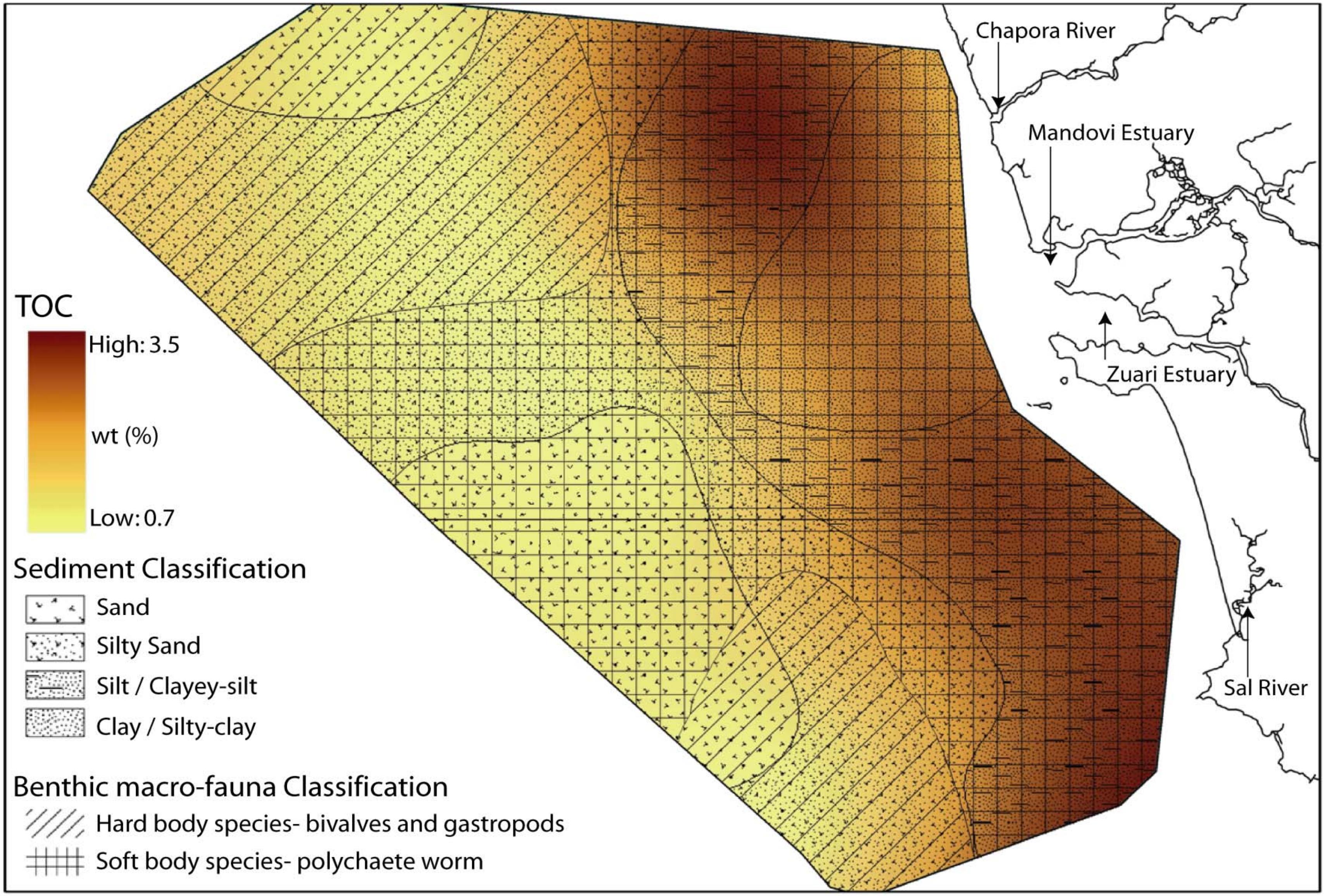
Deposit-feeding (soft body)

Polychaete worms and related species
(nematode, oligochaetes, nemertinea, and echurids)

Benthic macro-fauna in relation to the sediment type

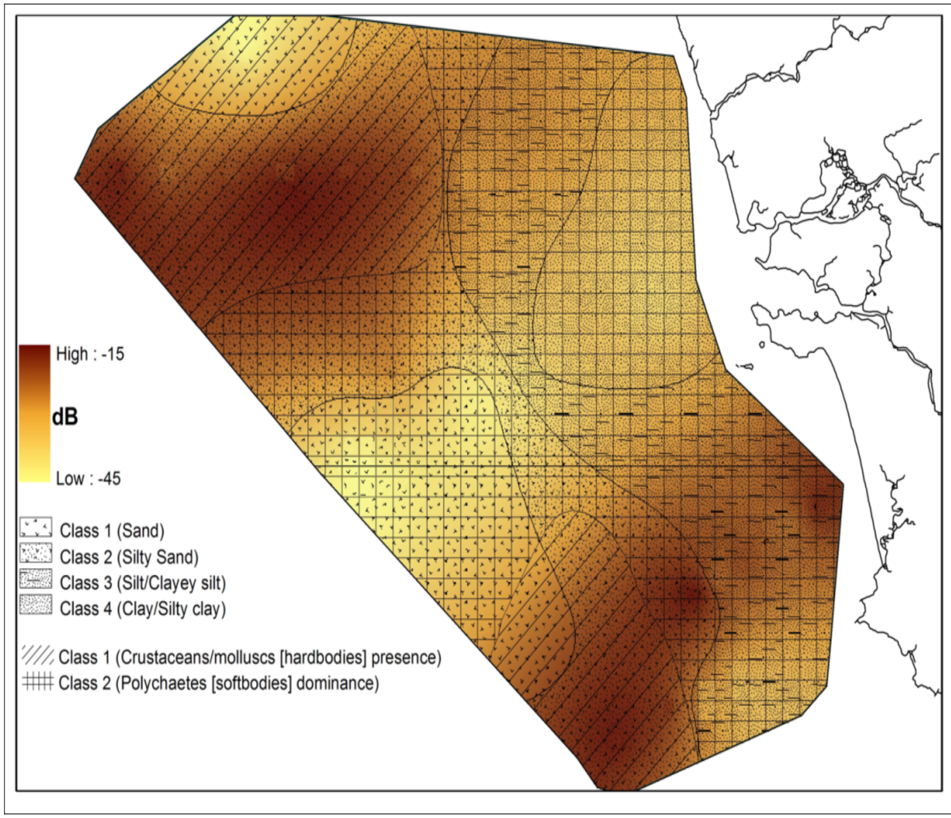


Sediment, habitat, and TOC based classification:

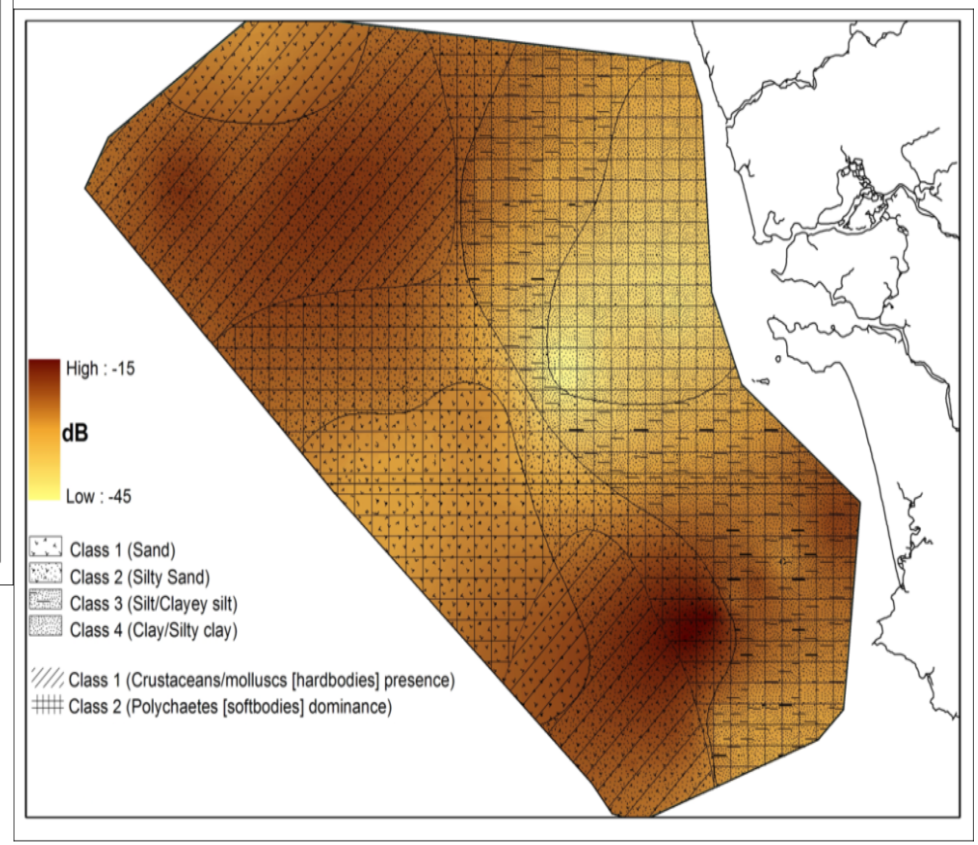


Sediment, habitat, and backscatter strength based classification – 33 & 210kHz:

33 kHz

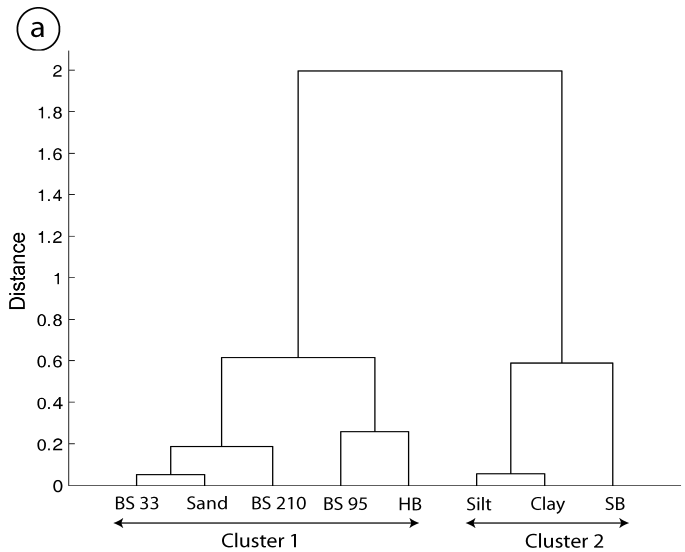


210kHz

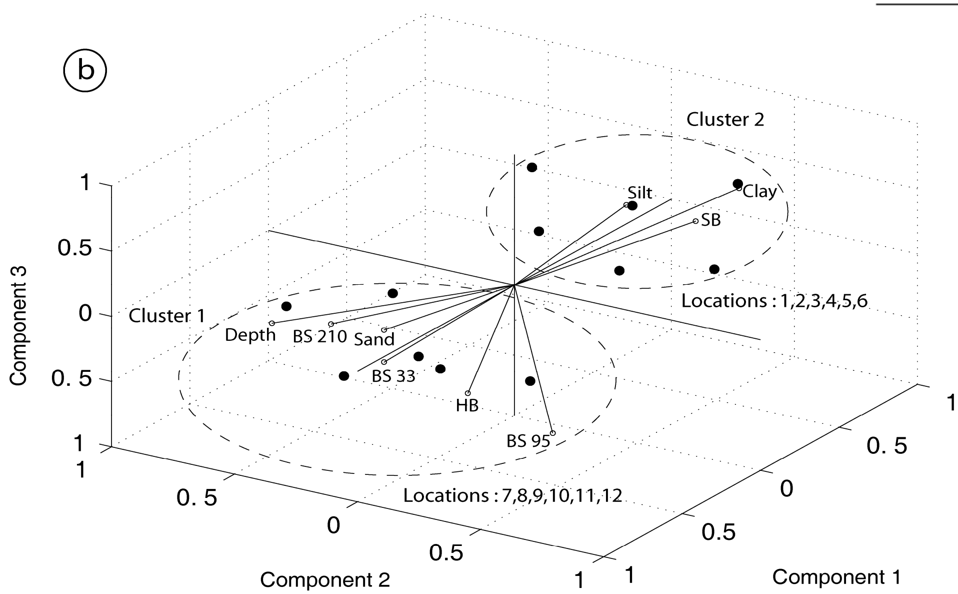


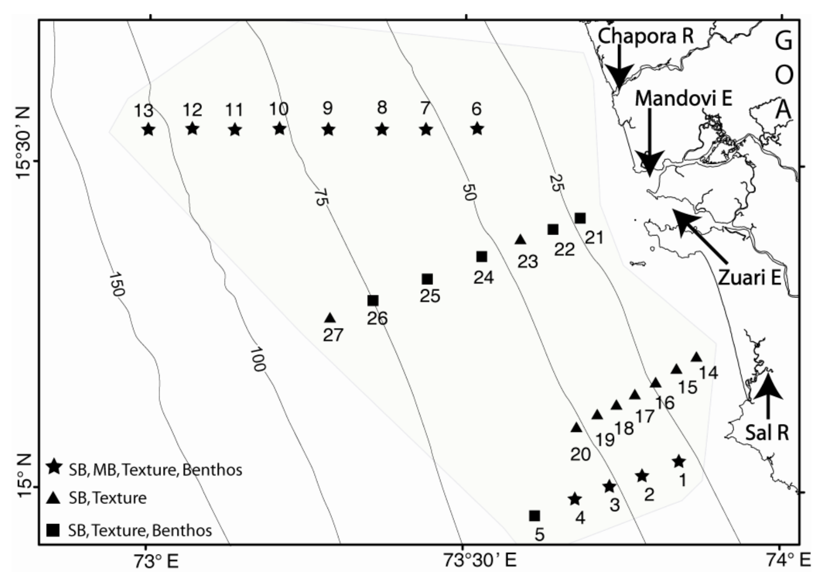
Haris et al, 2012 Cont. Shelf Res.

Clustering of the Benthic density and estimated acoustic parameters



Variables	BS 33	BS 210	BS 95	Sand (%)	Silt (%)	Clay (%)	SB[a]	HB[b]
BS 33	1							
BS 210	0.81306	1						
BS 95	0.50243	0.38501	1					
Sand (%)	0.94710	0.82313	0.63332	1				
Silt (%)	-0.94072	-0.79311	-0.67337	-0.99627	1			
Clay (%)	-0.92545	-0.88723	-0.49381	-0.96839	0.94361	1		
SB	-0.31544	-0.50915	-0.33078	-0.45414	0.41096	0.56640	1	
HB	0.78653	0.57044	0.74050	0.84496	-0.84411	-0.80015	-0.36307	1



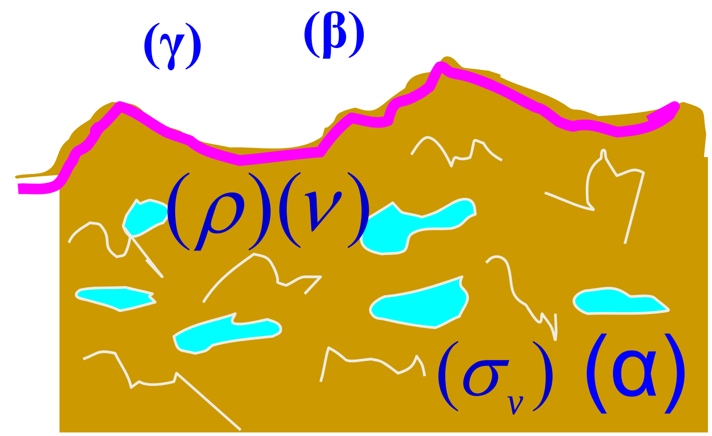


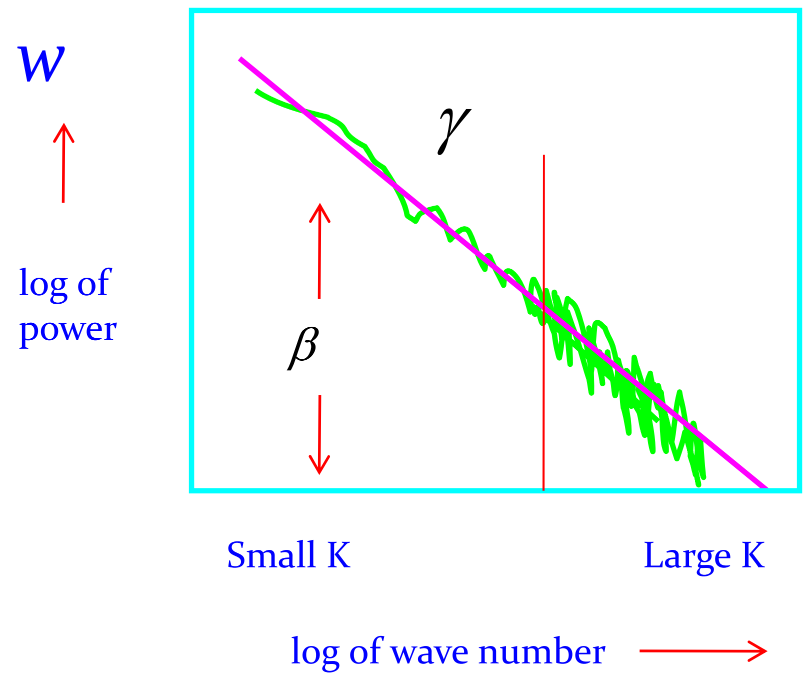
Backscatter: seafloor parameters

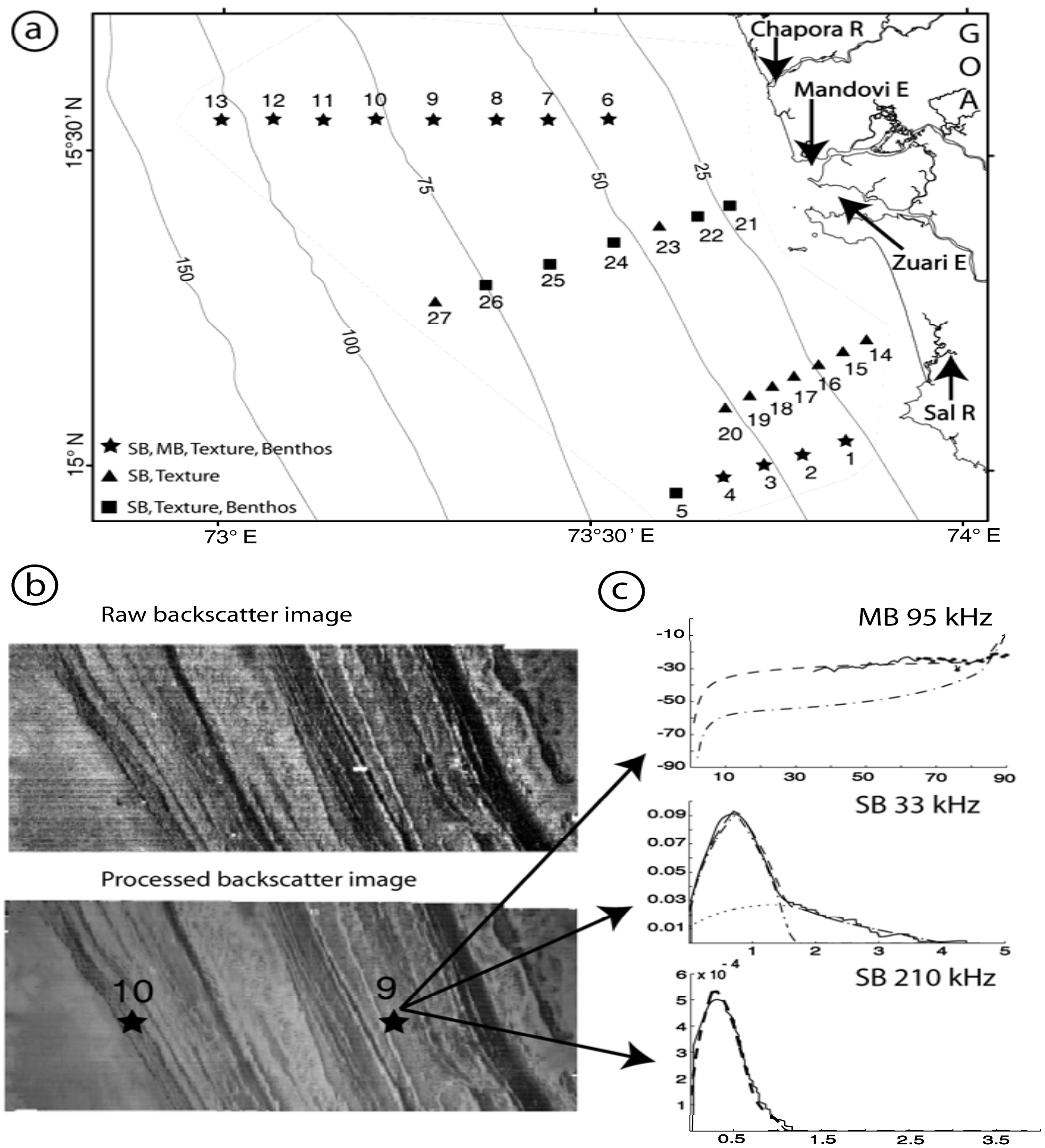
- ❑ **Impedance terms**
  - – **Water-Sediment density ratio (ρ)**
  - – **Water-Sediment sound speed ratio (v)**

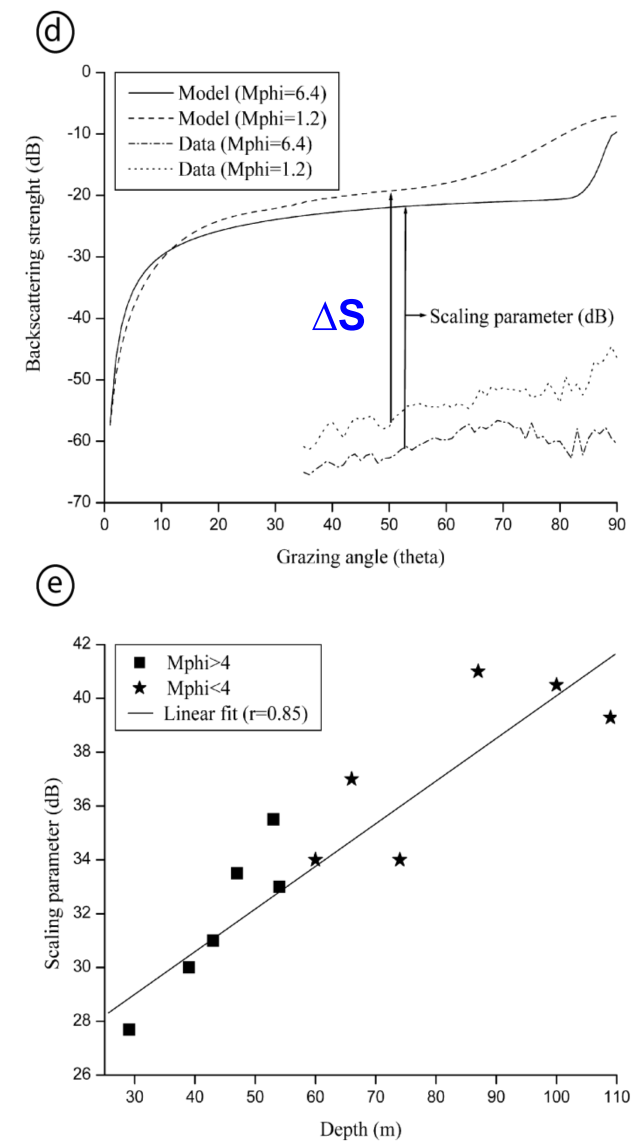
- ❑ **Roughness terms**
  - – **spectral strength (γ)**
  - – **spectral slope (β)**

- ❑ **Sub bottom terms**
  - – **Volume heterogeneity (σ_v)**
  - – **Sediment attenuation coefficient (α)**









$$E/_S = \frac{\sum_{\theta g=35}^{\theta g=65}\{(BS_{data} + \Delta S[\theta g]) - BS_{model}[\theta g])\}^2}{\sum_{\theta g=35}^{\theta g=65}(BS_{data}^2 + \Delta S[\theta g])}$$

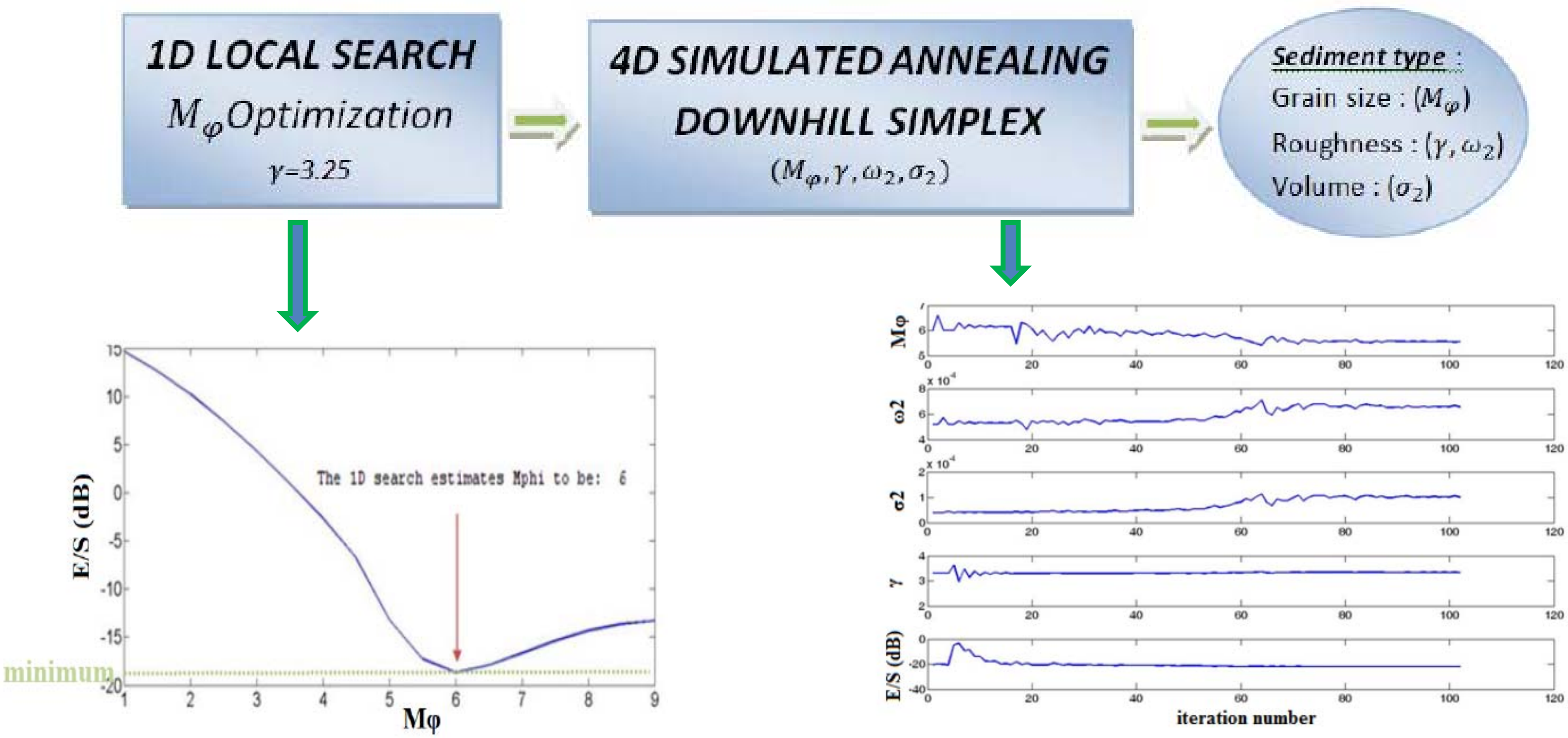
(a) Experimental area, (b) EM 1002 raw and processed backscatter image, (c) processed single and multi-beam data for inversion modeling, (d) and (e) procedure to calibrat the multi-beam data for inverse modeling.

Haris et al., 2012 JASA

Model parameters:

- The mean grain size
- The spectral strength
- The spectral exponent
- The volume parameter

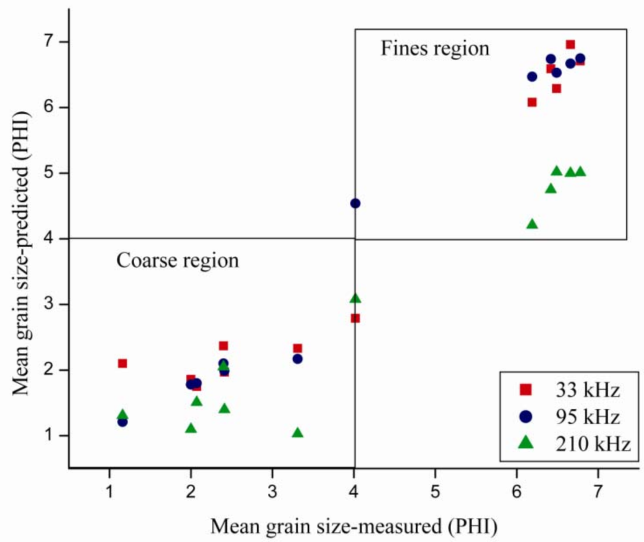
Two-stage parametric optimization



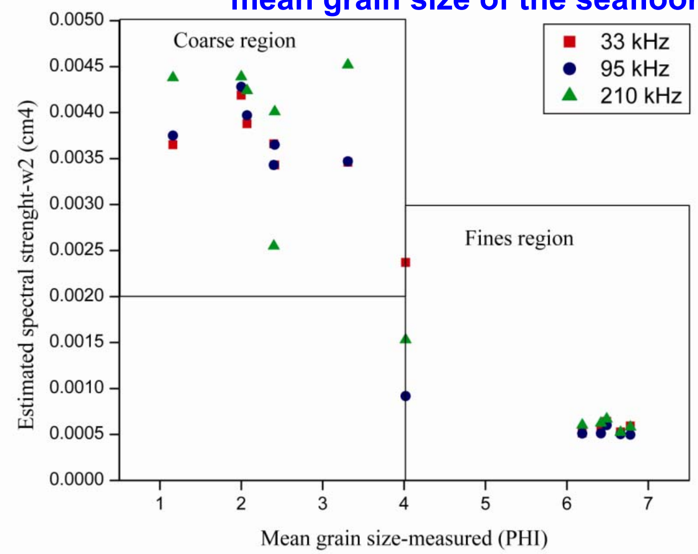
Minimizing error to signal ratio E/S: $E/S = \dfrac{\sum_{n=1}^{N}(P_{data}[n] - P_{model}[n])^2}{\sum_{n=1}^{N} P_{data}[n]^2}$

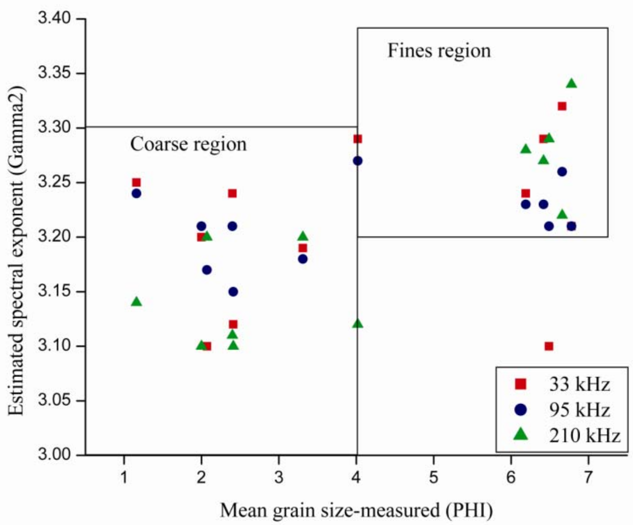
Model inversion results for single and multi beam data:

Estimated vs. measured mean grain size of the sediment

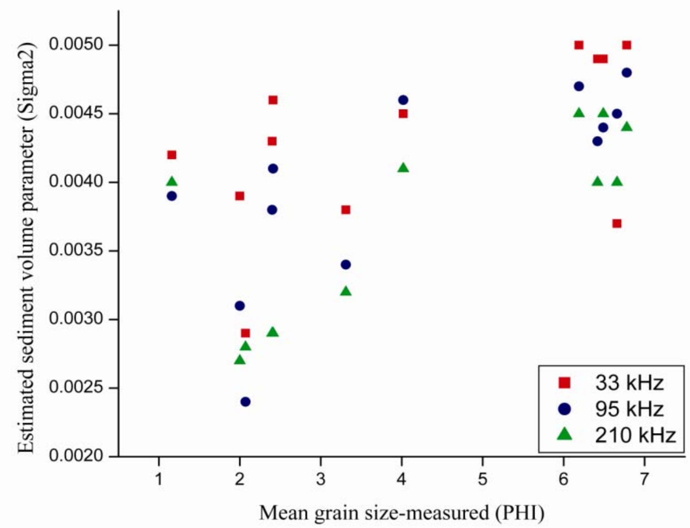


Estimated spectral strength vs. measured mean grain size of the seafloor



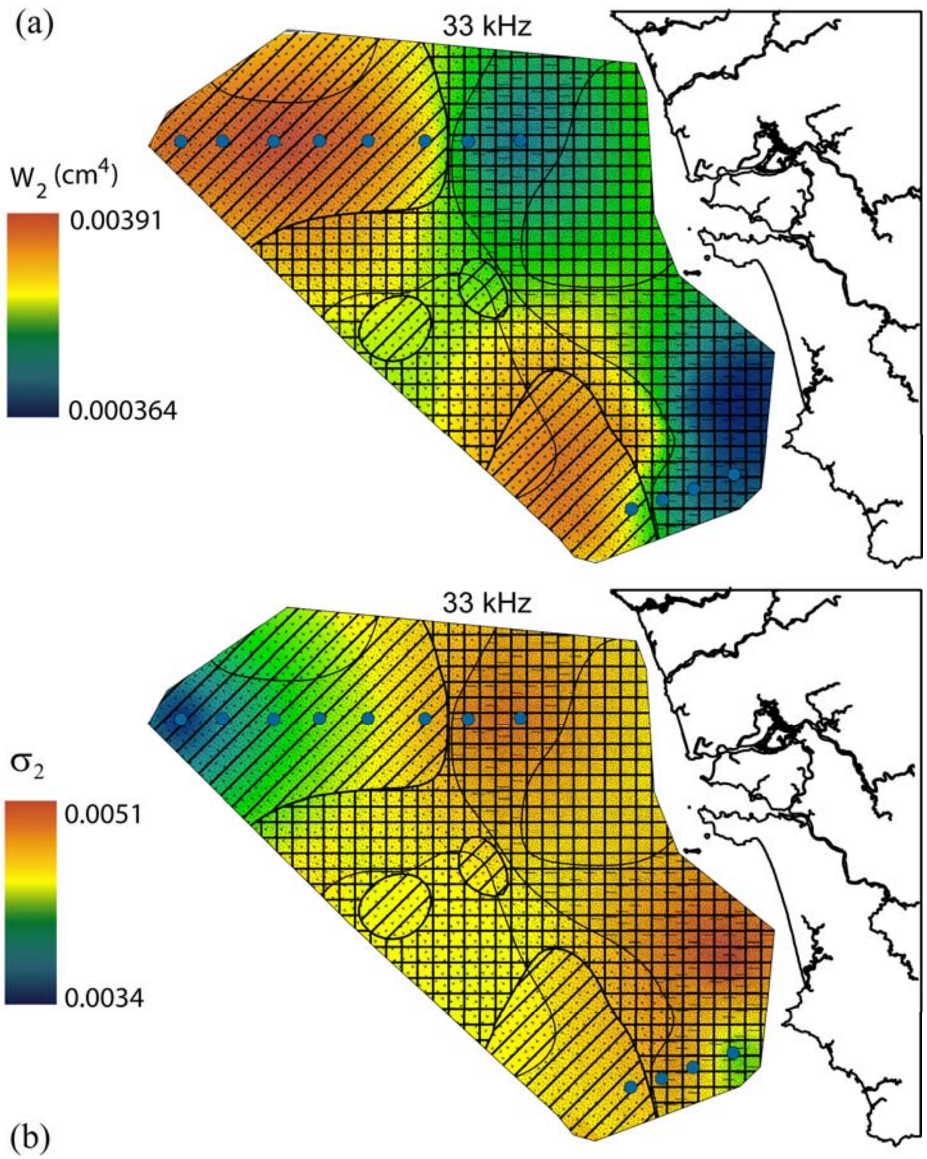


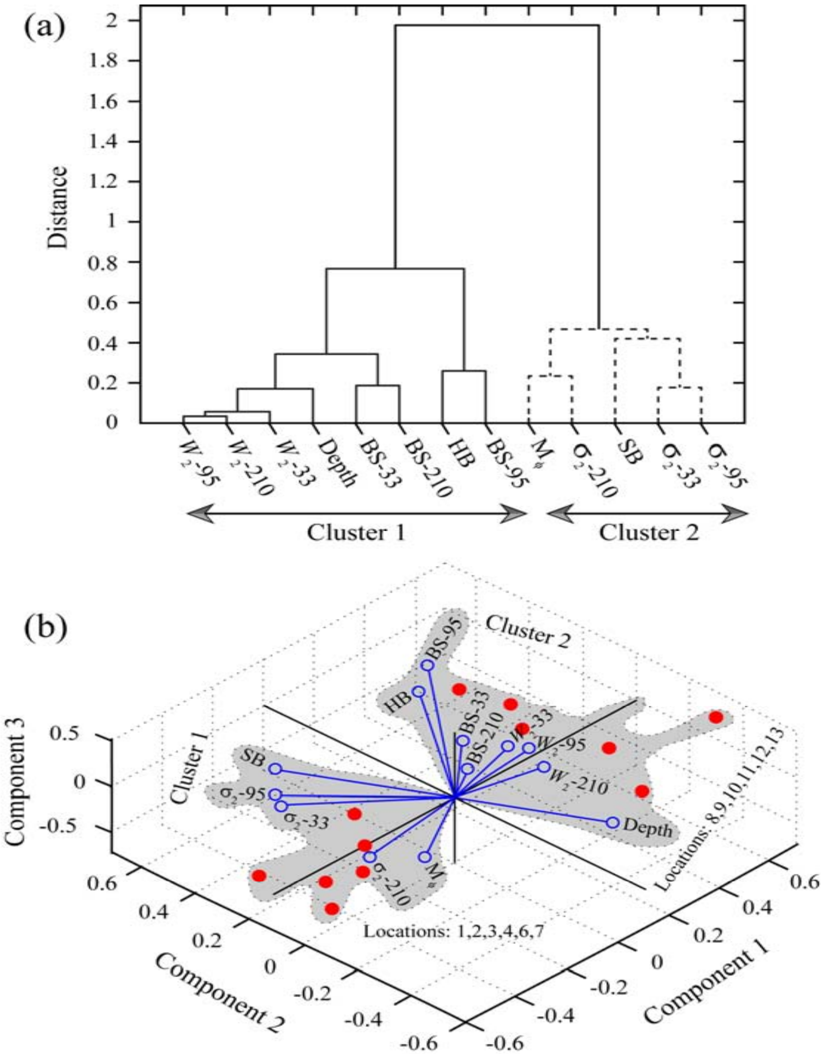
Estimated spectral exponent vs. measured mean grain size of the seafloor:



Estimated sediment volume parameter vs. measured mean grain size of the seafloor:

Inversion results and habitat characterization





Haris et al, IJMS (2015) Spl. issue

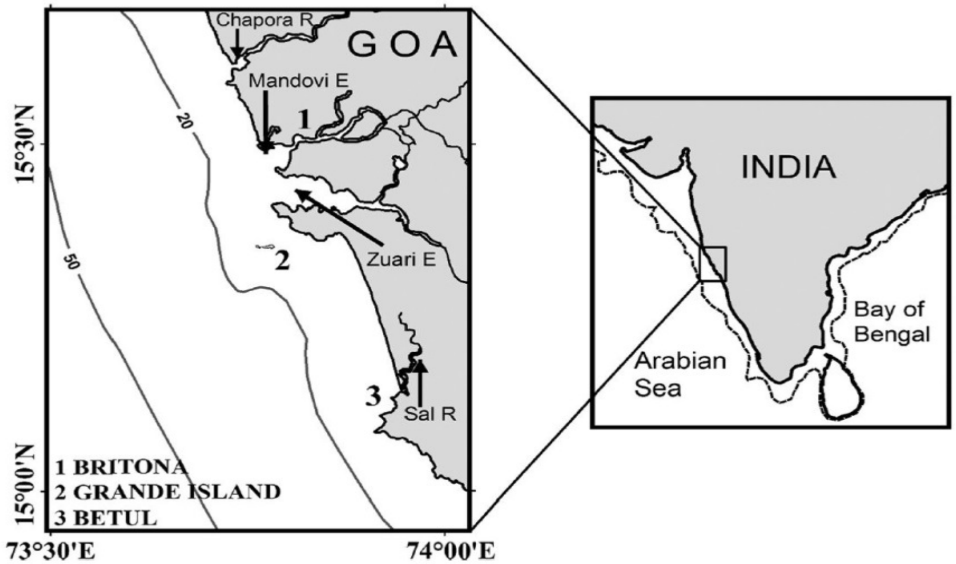
- The role of bioturbation on acoustic backscatter and resulting inversion parameters

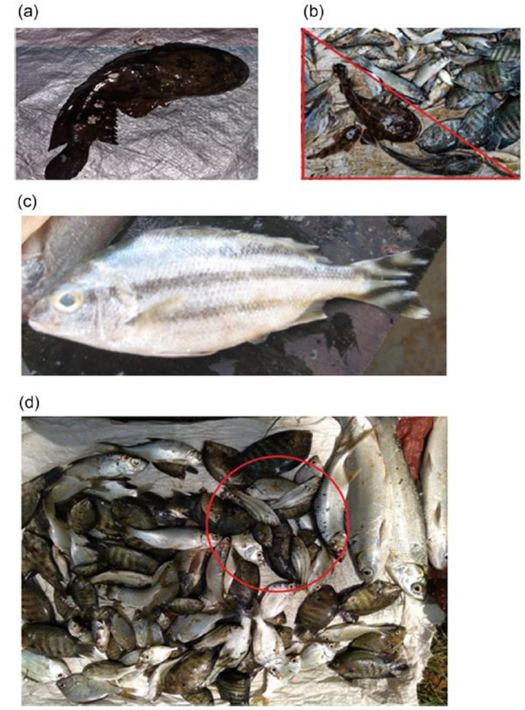
System Deployment

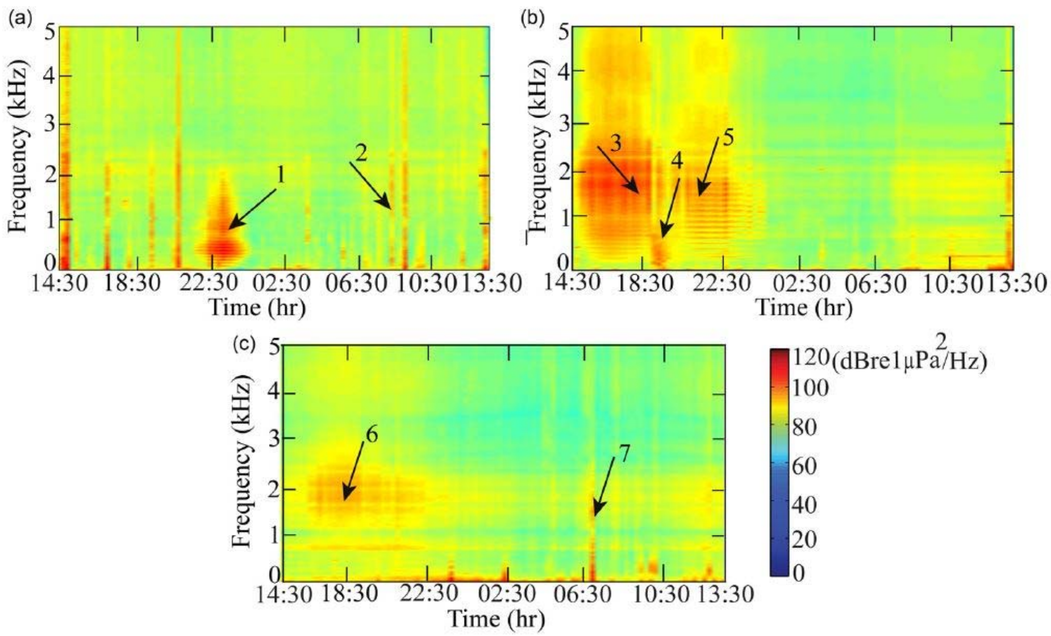
Hydrophone array with fixture

SM3M Sound Recorder

Buoyancy Float



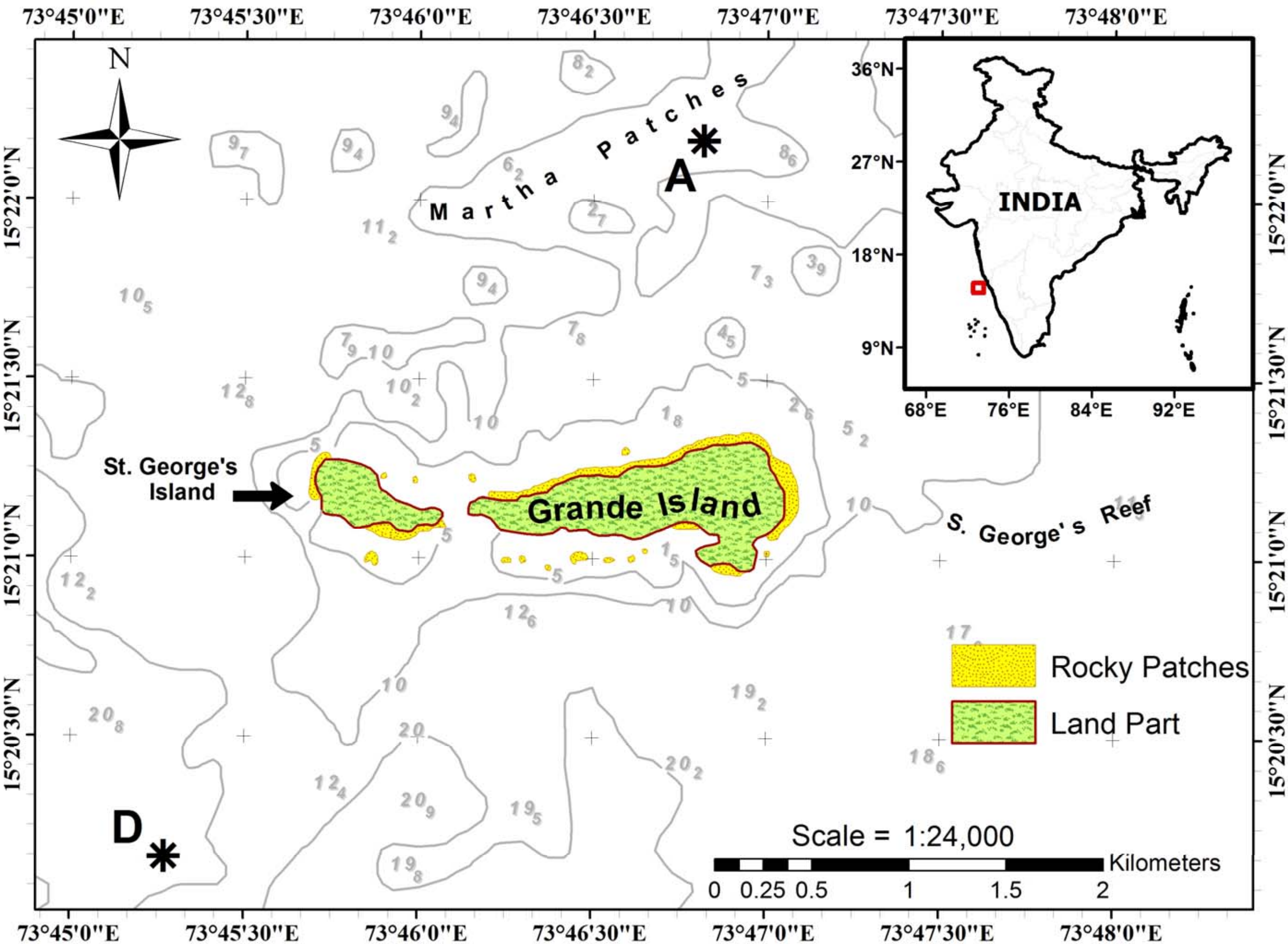




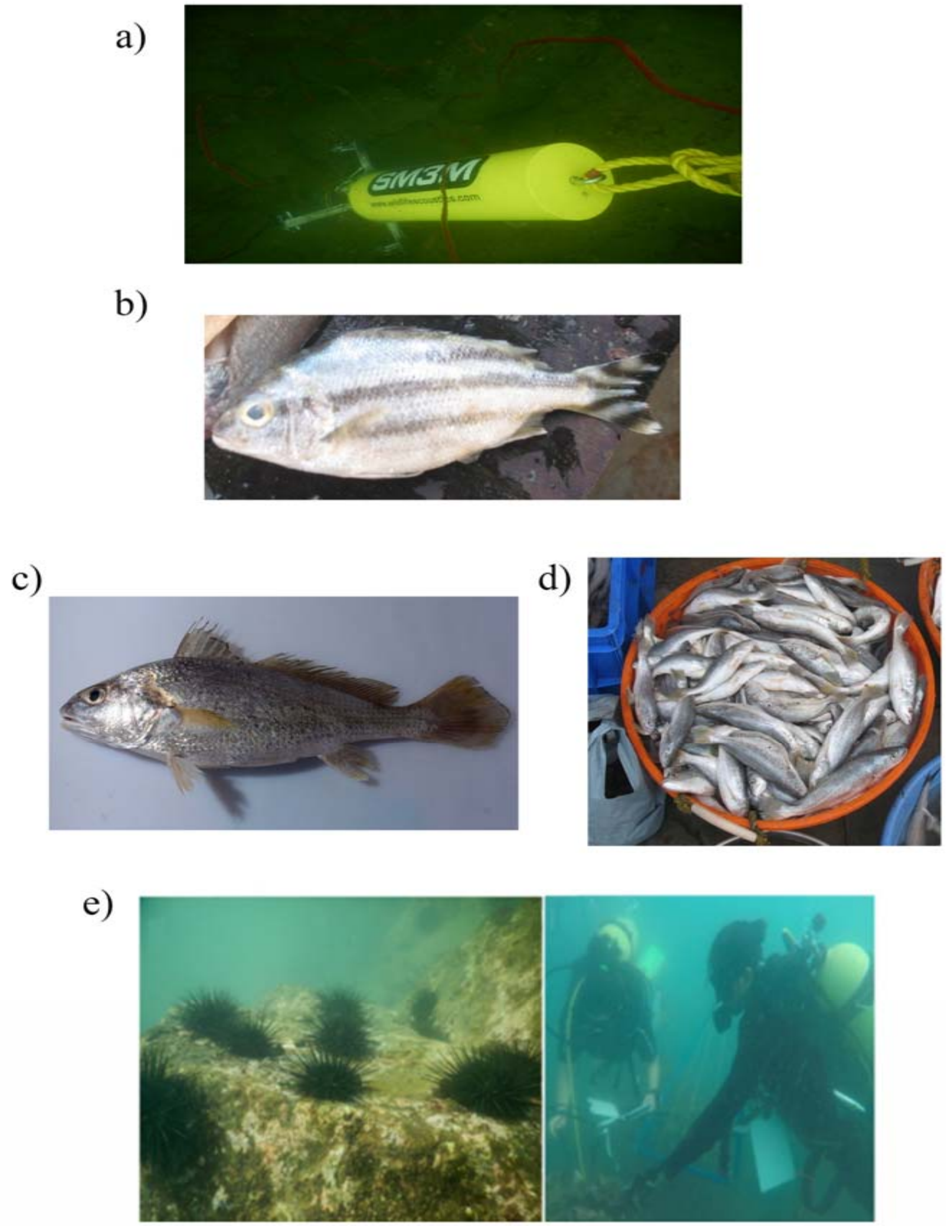
Three study locations, Soundscape from 1. Mandovi, 2. Zuari and 3. Sal. Estuaries.

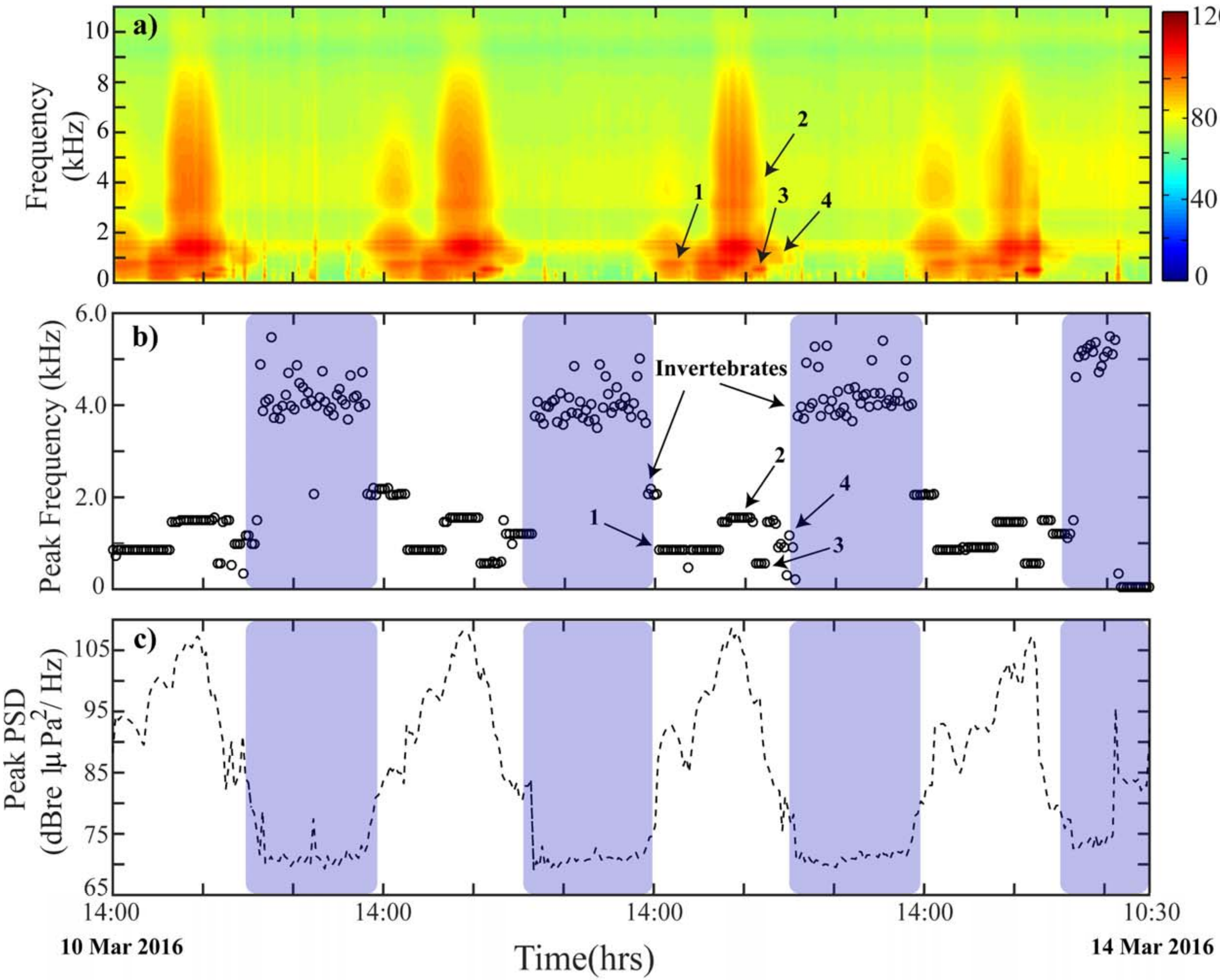
Components of soundscape reveal *Terapon Theraps* and Toadfish (*C. dussimieri)* sound.

We characterized fish sound recorded from three locations off Goa

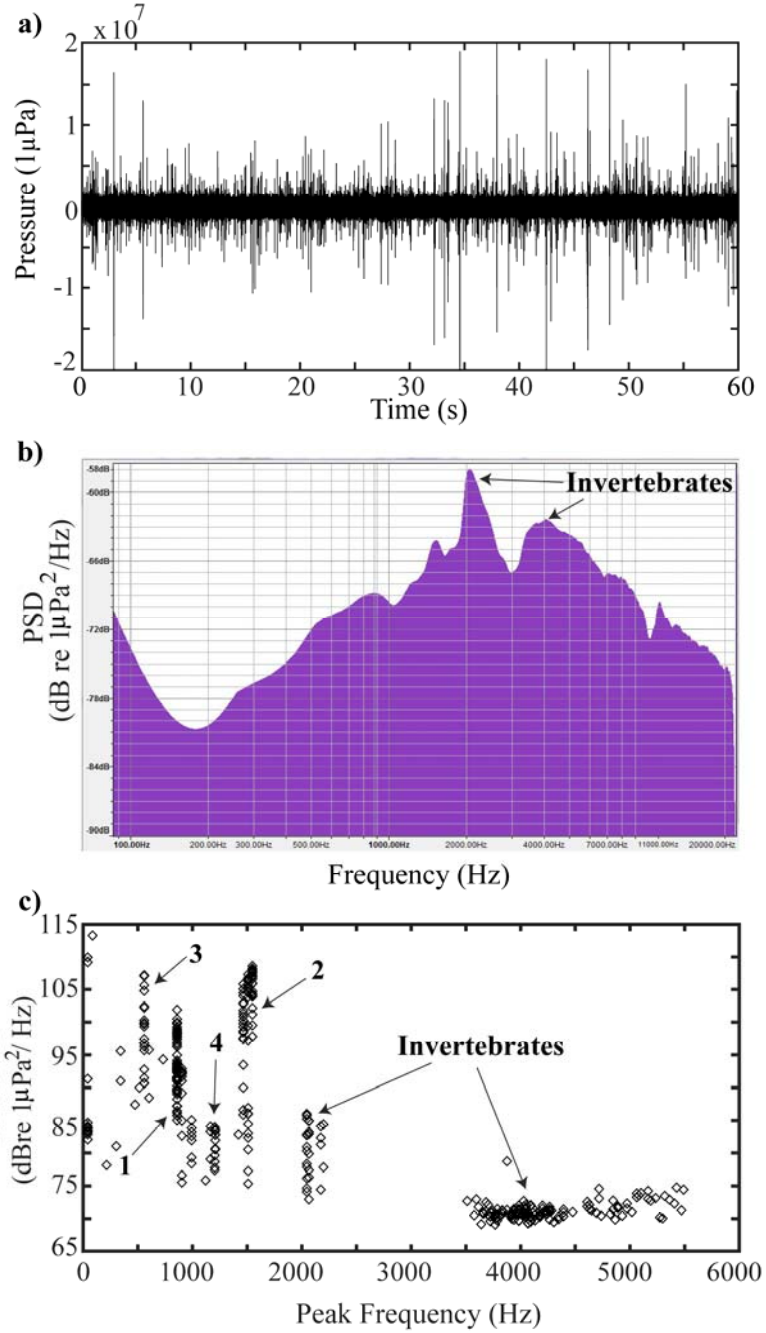


Martha Patches
A
Grande Island
St. George's Island
S. George's Reef
D
INDIA
Rocky Patches
Land Part
Scale = 1:24,000
Kilometers
0 0.25 0.5 1 1.5 2
73°45'0"E
73°45'30"E
73°46'0"E
73°46'30"E
73°47'0"E
73°47'30"E
73°48'0"E
15°22'0"N
15°21'30"N
15°21'0"N
15°20'30"N
36°N
27°N
18°N
9°N
68°E
76°E
84°E
92°E
N


a)
SM3M
b)
c)
d)
e)



a)
b)
c)
Frequency (kHz)
(dBre 1μPa²/Hz)
Peak Frequency (kHz)
Invertebrates
Peak PSD (dBre 1μPa²/ Hz)
14:00
10:30
10 Mar 2016
14 Mar 2016
Time(hrs)


a)
x 10^7
Pressure (1µPa)
2
1
0
-1
-2
0
10
20
30
40
50
60
Time (s)
b)
Invertebrates
PSD
(dB re 1µPa^2/Hz)
-58dB
-60dB
-66dB
-72dB
-78dB
-84dB
-90dB
100.00Hz
200.00Hz
300.00Hz
500.00Hz
1000.00Hz
2000.00Hz
4000.00Hz
7000.00Hz
11000.00Hz
20000.00Hz
Frequency (Hz)
c)
Peak PSD
(dBre 1µPa^2/ Hz)
115
105
95
85
75
65
3
2
4
1
Invertebrates
0
1000
2000
3000
4000
5000
6000
Peak Frequency (Hz)

Oscillogram segmentation technique: Chanda et al (2020) JASA

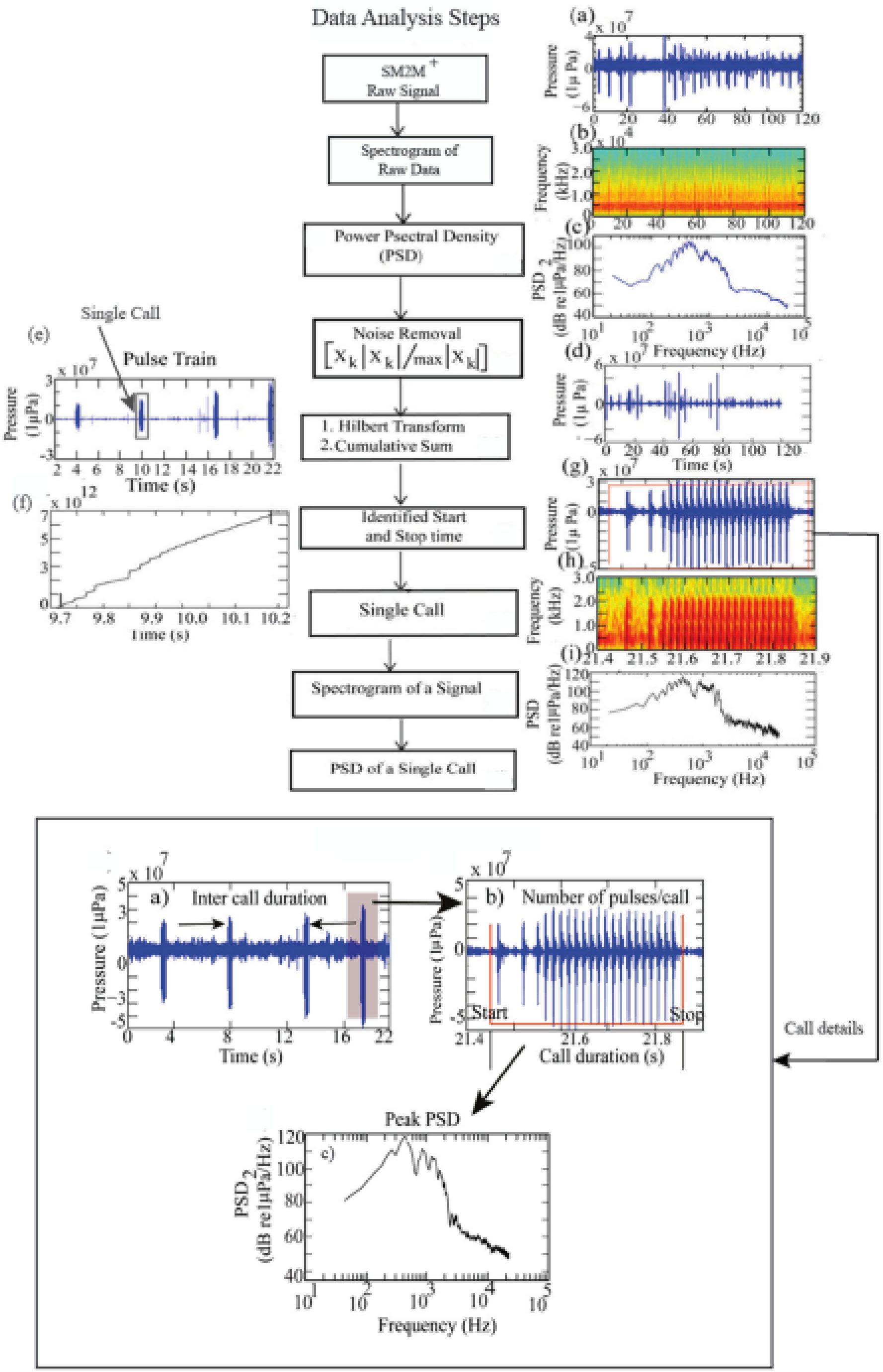
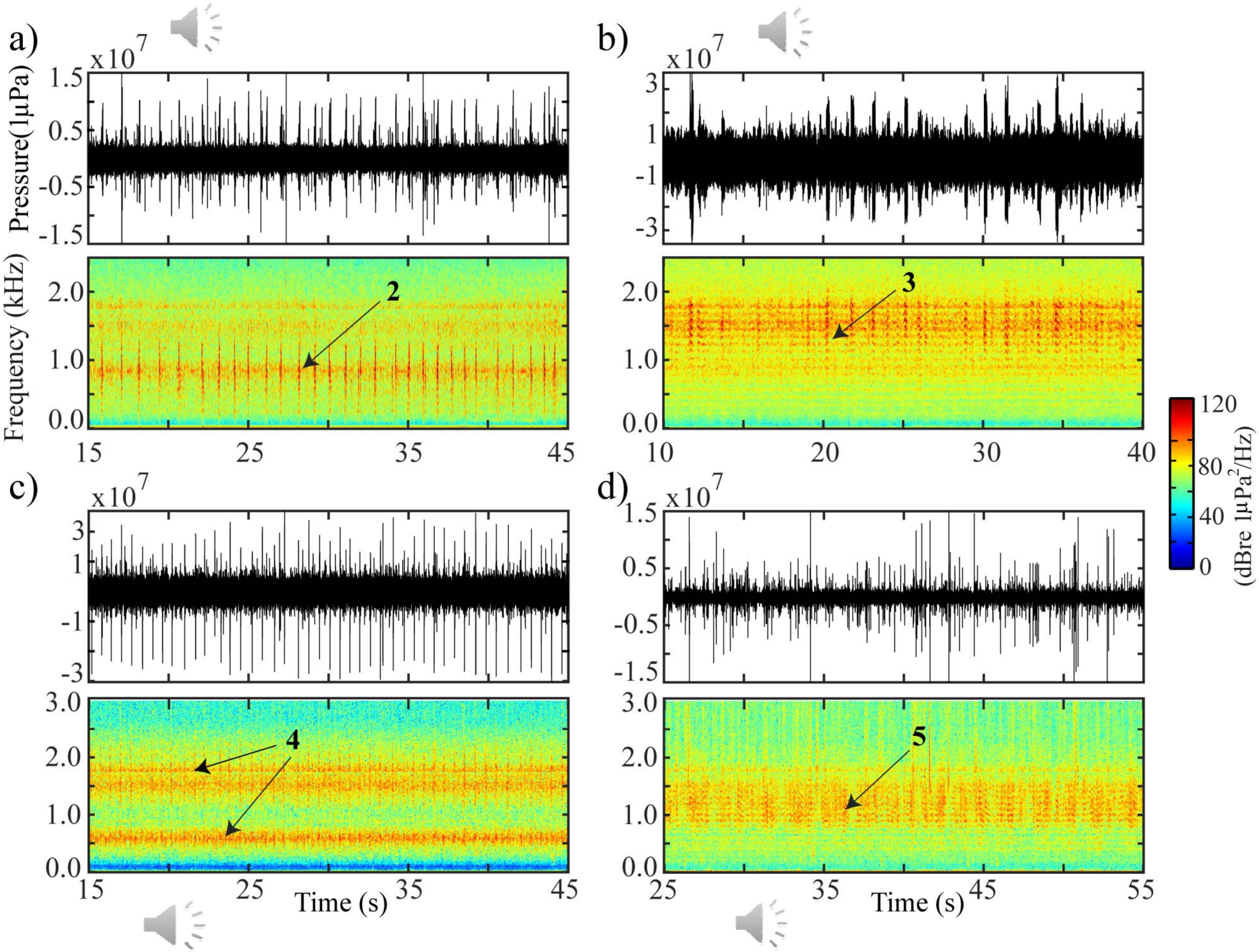
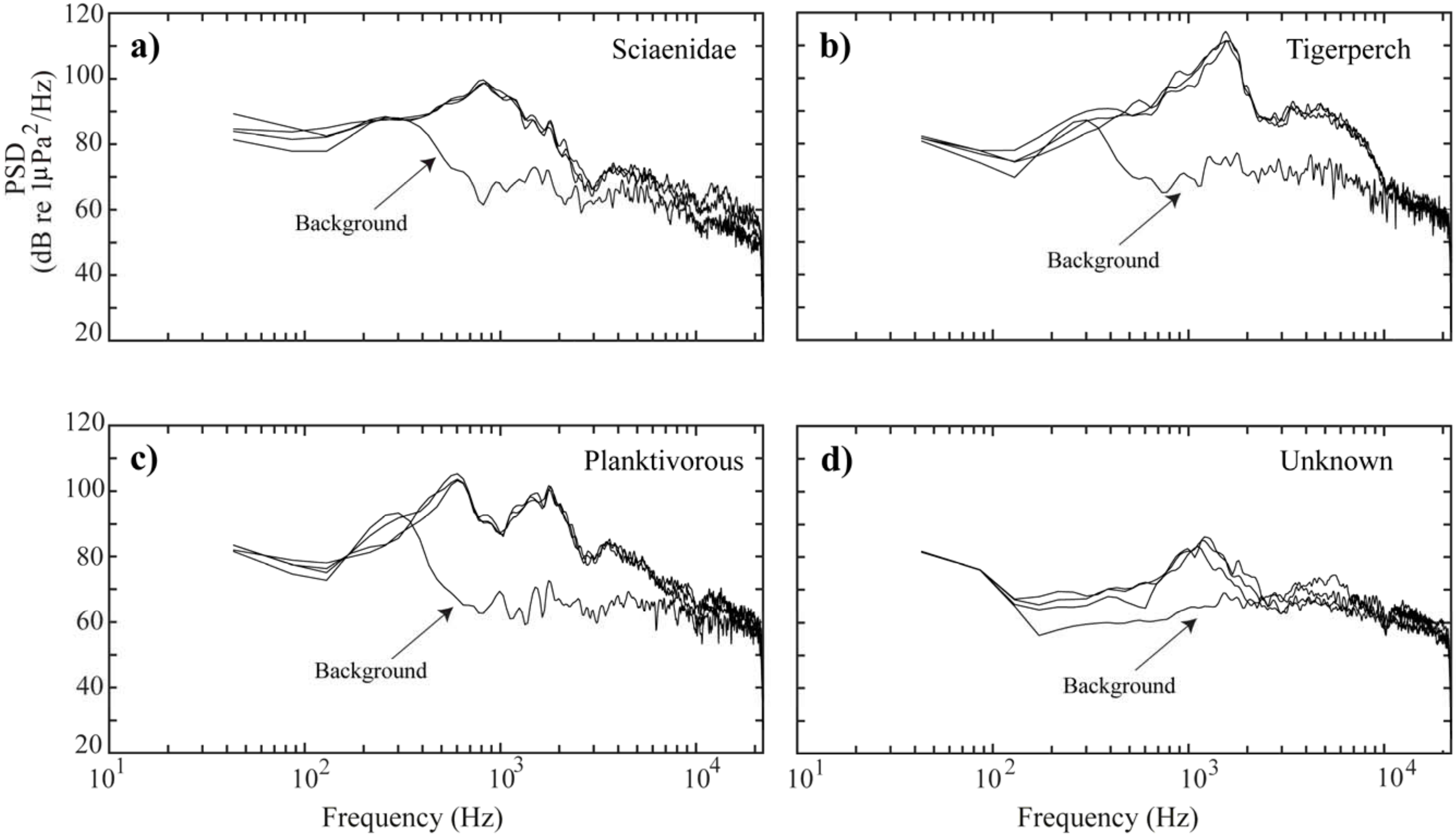


FIG. 3. (Color online) Fish sound segmentation flow chart employed in this work.



a)
b)
c)
d)
x10^7
Pressure(1μPa)
Frequency (kHz)
Time (s)
2
3
4
5
(dBre 1μPa²/Hz)
120
80
40
0



PSD (dB re 1µPa²/Hz)
a)
Sciaenidae
Background
b)
Tigerperch
Background
c)
Planktivorous
Background
d)
Unknown
Background
Frequency (Hz)
Frequency (Hz)

Sound Pressure Level:

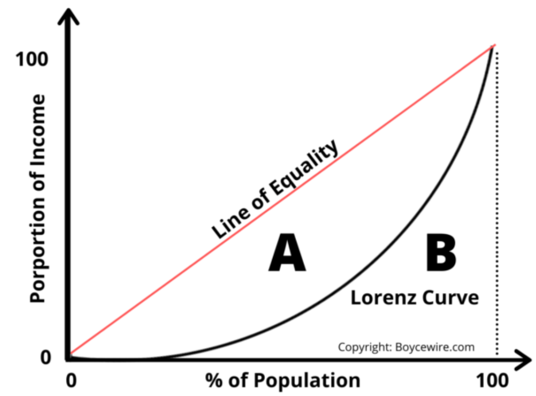
$$SPL_{rms} = 20\log_{10}\left(\sqrt{\frac{1}{T}\int_t P(t)^2 dt}\right)$$

where P(t) is a root-mean-square (RMS) pressure level.

Acoustic Evenness Index (AEI):

$$\text{Gini Coefficient} = \frac{A}{(A + B)}$$

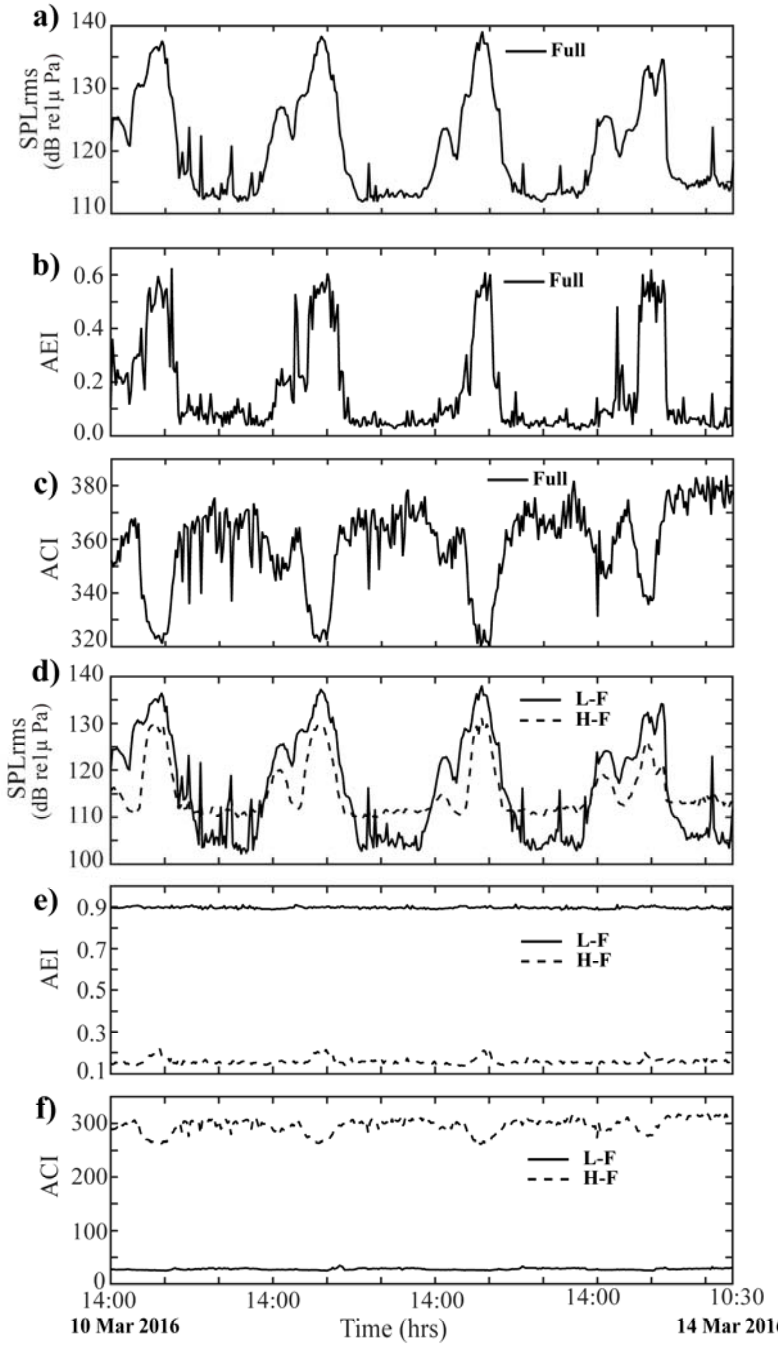
Where A = area above Lorenz Curve and B = area below Lorenz Curve



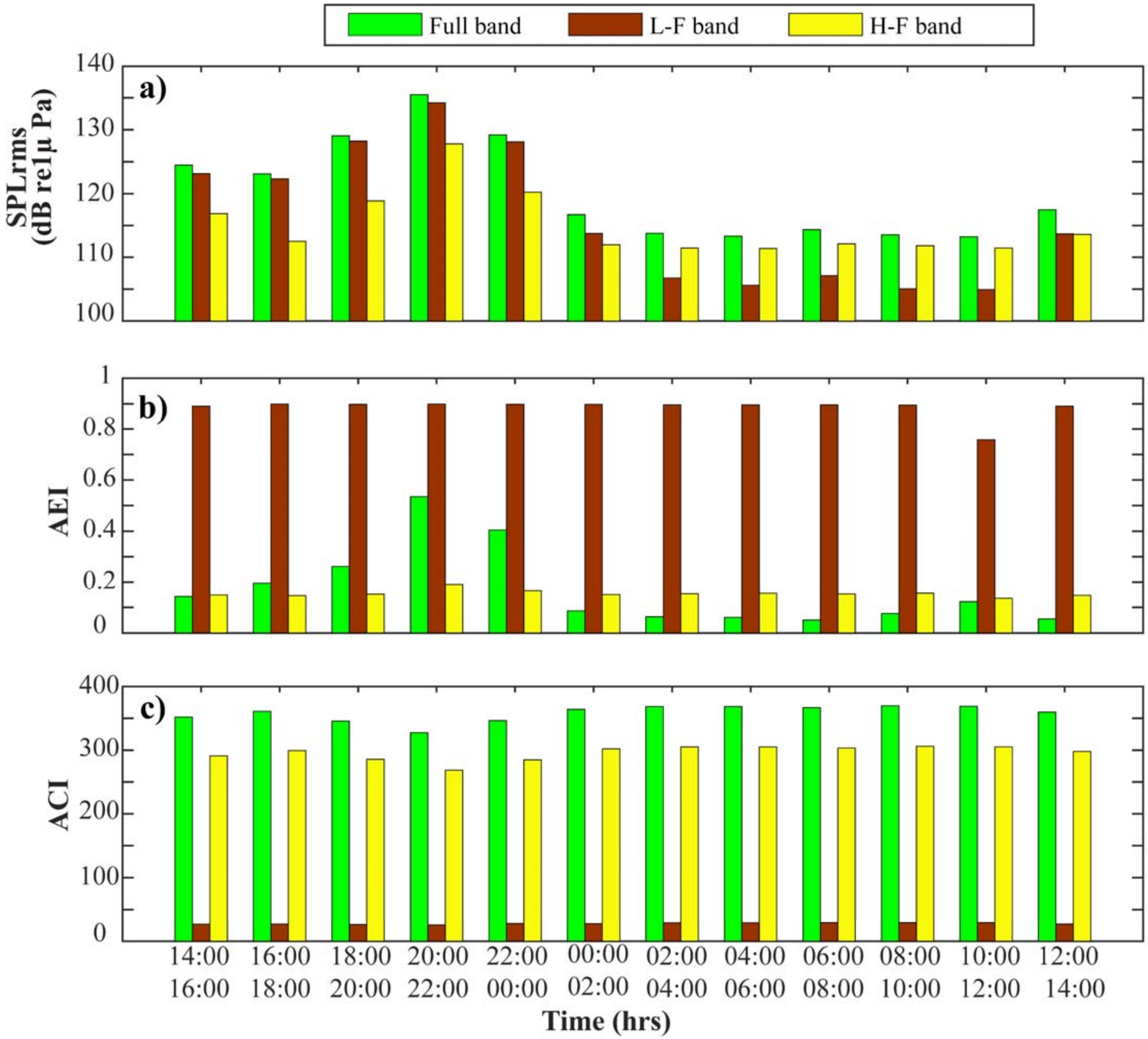
Acoustic Complexity Index:

$$\mathrm{ACI}_{ij} = \frac{\sum_{k=1}^{n} |I_k - I_{k+1}|}{\sum_{k=1}^{n} I_k}$$

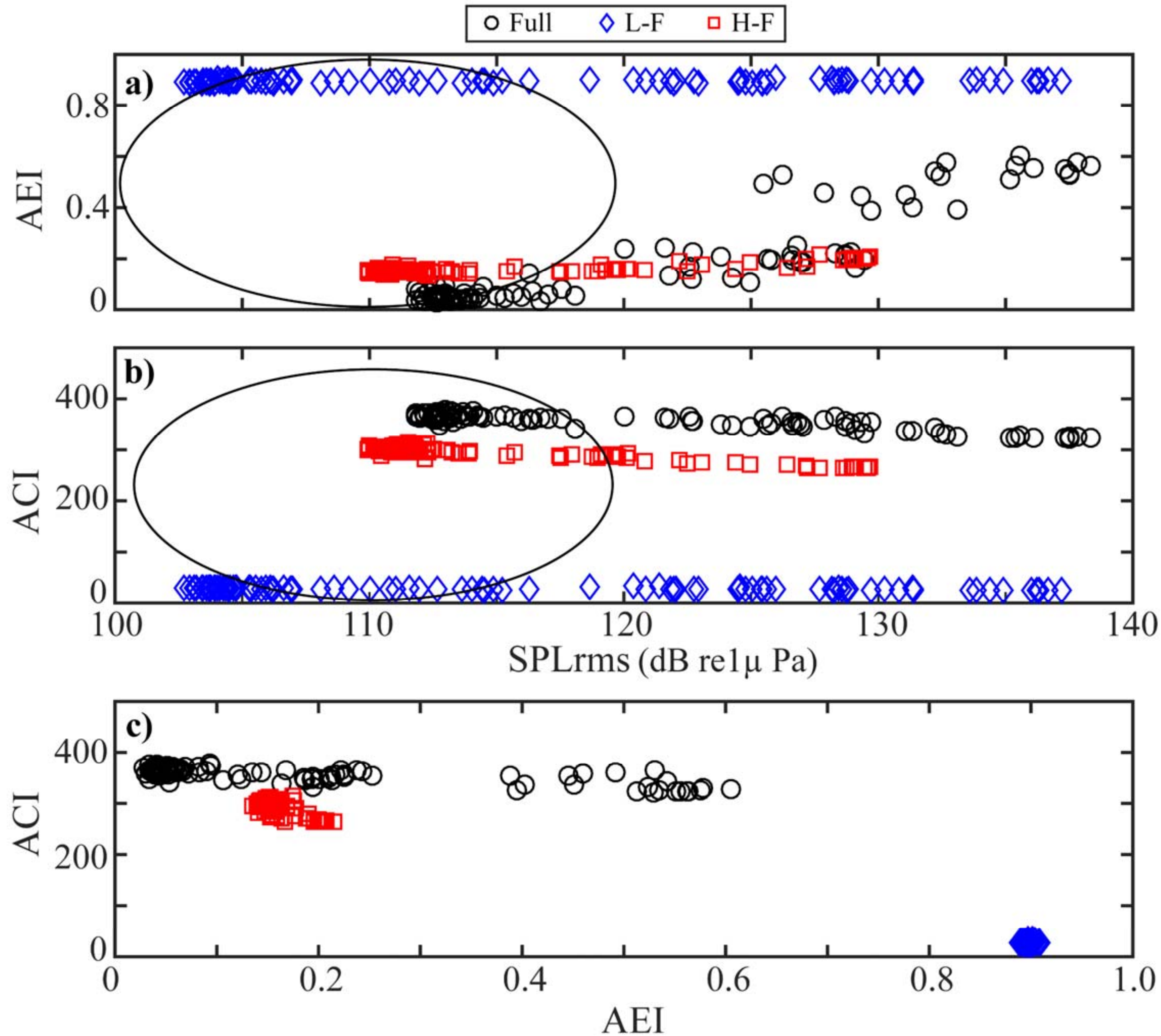
where Ik represents a value of intensity in resulting from a selected frequency bin (i) and a selected temporal step (k), and Ikþ1 represents the adjacent value of intensity the next temporal step in the same frequency bin.



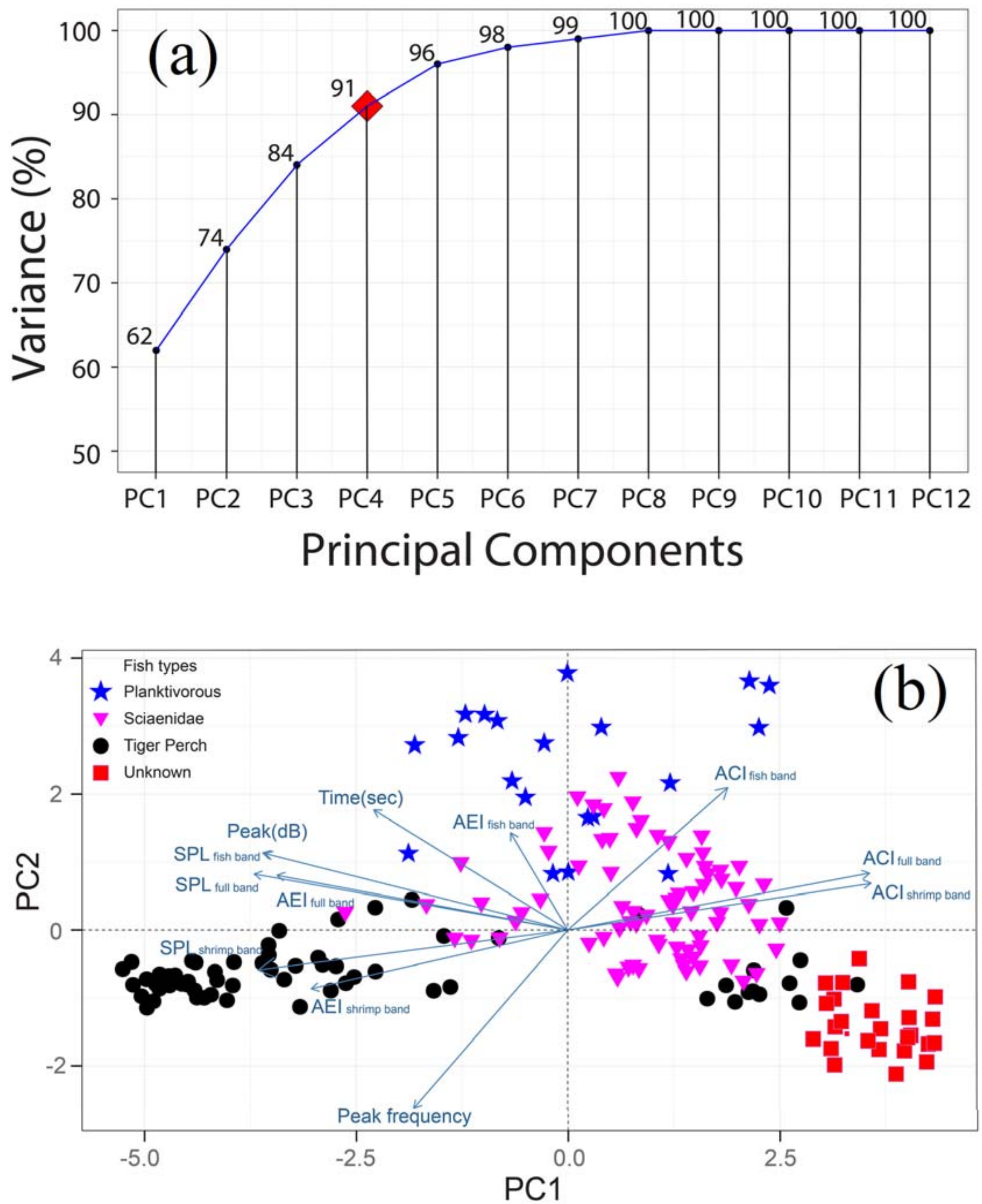
a)
SPLrms
(dB re1μ Pa)
Full
b)
AEI
Full
c)
ACI
Full
d)
SPLrms
(dB re1μ Pa)
L-F
H-F
e)
AEI
L-F
H-F
f)
ACI
L-F
H-F
14:00
14:00
14:00
14:00
10:30
10 Mar 2016
Time (hrs)
14 Mar 2016



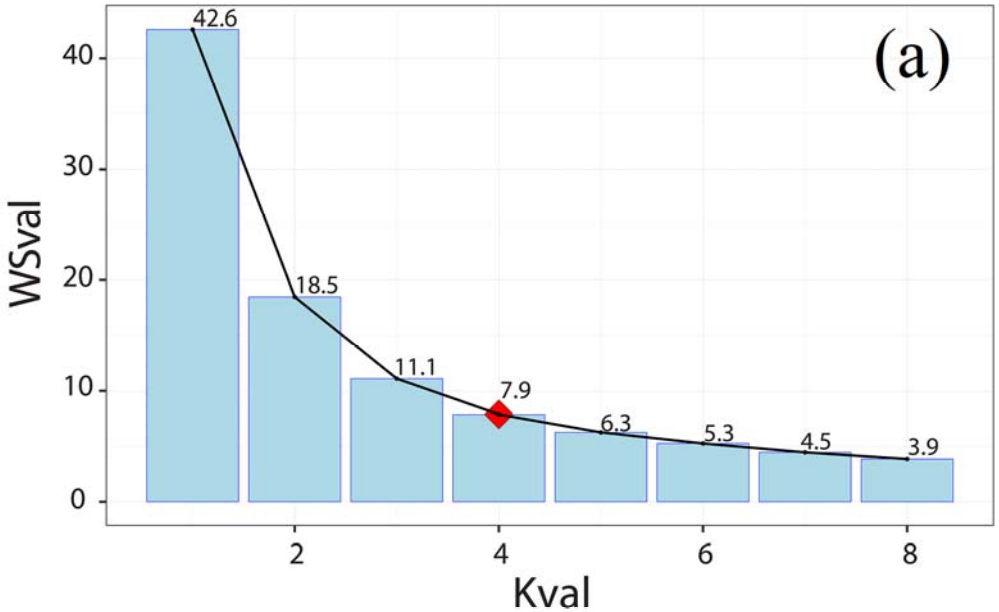
Full band
L-F band
H-F band
a)
SPLrms (dB re1μ Pa)
140
130
120
110
100
b)
AEI
1
0.8
0.6
0.4
0.2
0
c)
ACI
400
300
200
100
0
14:00 16:00
16:00 18:00
18:00 20:00
20:00 22:00
22:00 00:00
00:00 02:00
02:00 04:00
04:00 06:00
06:00 08:00
08:00 10:00
10:00 12:00
12:00 14:00
Time (hrs)



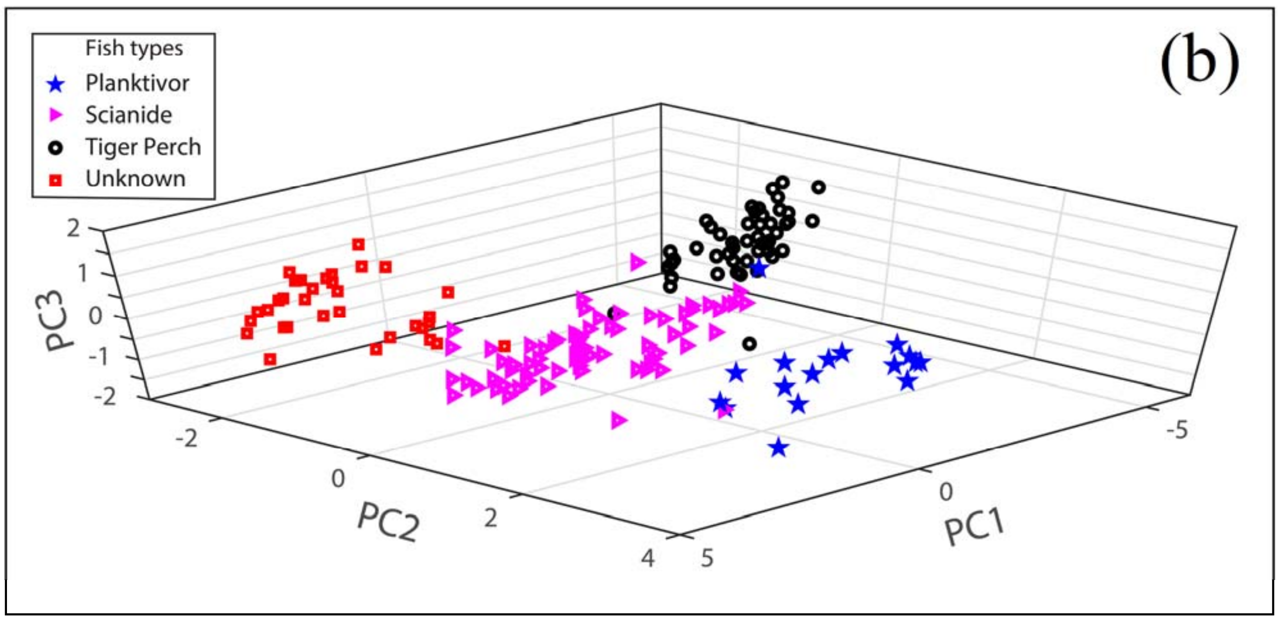
Full
L-F
H-F
a)
b)
c)
AEI
ACI
0
0.4
0.8
200
400
100
110
120
130
140
SPLrms (dB re1μ Pa)
0.2
0.6
1.0



(a)
Variance (%)
Principal Components
62
74
84
91
96
98
99
100
PC1
PC2
PC3
PC4
PC5
PC6
PC7
PC8
PC9
PC10
PC11
PC12
(b)
Fish types
Planktivorous
Sciaenidae
Tiger Perch
Unknown
PC1
PC2
Time(sec)
Peak(dB)
SPL fish band
SPL full band
AEI full band
SPL shrimp band
AEI shrimp band
AEI fish band
ACI fish band
ACI full band
ACI shrimp band
Peak frequency



(a)
WSval
Kval
42.6
18.5
11.1
7.9
6.3
5.3
4.5
3.9



(b)
Fish types
Planktivor
Scianide
Tiger Perch
Unknown
PC1
PC2
PC3

Table 3: Unsupervised classification results (in percentage) for four identified fish vocalizations.

Fish type	Fishes classified as			
	Unknown	Sciaenidae	Terapon theraps	Planktivorous
Unknown	100	0	0	0
Sciaenidae	0	96.0	1.3	2.6
Terapoon theraps	15.6	7.8	76.5	0
Planktivorous	0	20	0	80

Underlying the IQOE (https://www.iqoe.org/science/ themes) are five fundamental questions:

1. How have human activities affected the global ocean soundscape compared with natural changes over geologic time?

2. What are the current levels and distribution of sound in the ocean?

3. What are the trends in sound levels across the global ocean?

4. What are the current effects of anthropogenic sound on important marine animal populations?

5. What are the potential future effects of sound on marine life?

The IQOE will address its five fundamental questions within four themes:

- **The Ocean Soundscapes (Theme 1)**
- **Theme 1= Q1-3 (Acoustician)**
- will describe ocean soundscapes from regional to global scales. This theme will include the identification of the primary sound sources and how they contribute to the components of the soundscape, empirical modeling of components of each soundscape, the modeling of acoustic propagation, and the validation of these models using ocean observation systems. This theme will be the main focus of efforts to measure trends in ocean sound levels and to define sound budgets within regions. It will also investigate soundscape diversity and examine the concept that the conservation of soundscapes may be an appropriate objective for the integrated management of the marine environment.

- **The Effects of Sound on Marine Organisms (Theme 2)**
- **Theme 2= Q4 and 5 (Marine Biologist)**

theme will plan and carry out experiments. This may include experiments to make regions quieter and to observe the responses of marine organisms to quieting. This theme will include the use of planned experiments as well as opportunistic studies using post-hoc statistical modeling to test for effects. This theme is the main vehicle through which the biological significance of sound will be assessed and, where possible, this will be focused on estimating dose-response relationships so that assessments of the effects of sound can be predictive, with special emphasis on the Population Consequences of Acoustic Disturbance (PCAD) approach. Much of this theme will rely upon the use of a small set of representative species.

- **The Observing Sound in the Ocean (Theme 3)**
- **Theme 3= Theme 1 and Theme 2**
- will be the primary focus for adding sound measurements to existing and future observing systems and will encourage technical innovation in the measurement of sound. This theme will develop data standards—where these do not already exist—and will promote observation of the key biological and physical variables. Much of the data management needed by the IQOE will be managed from within this theme.

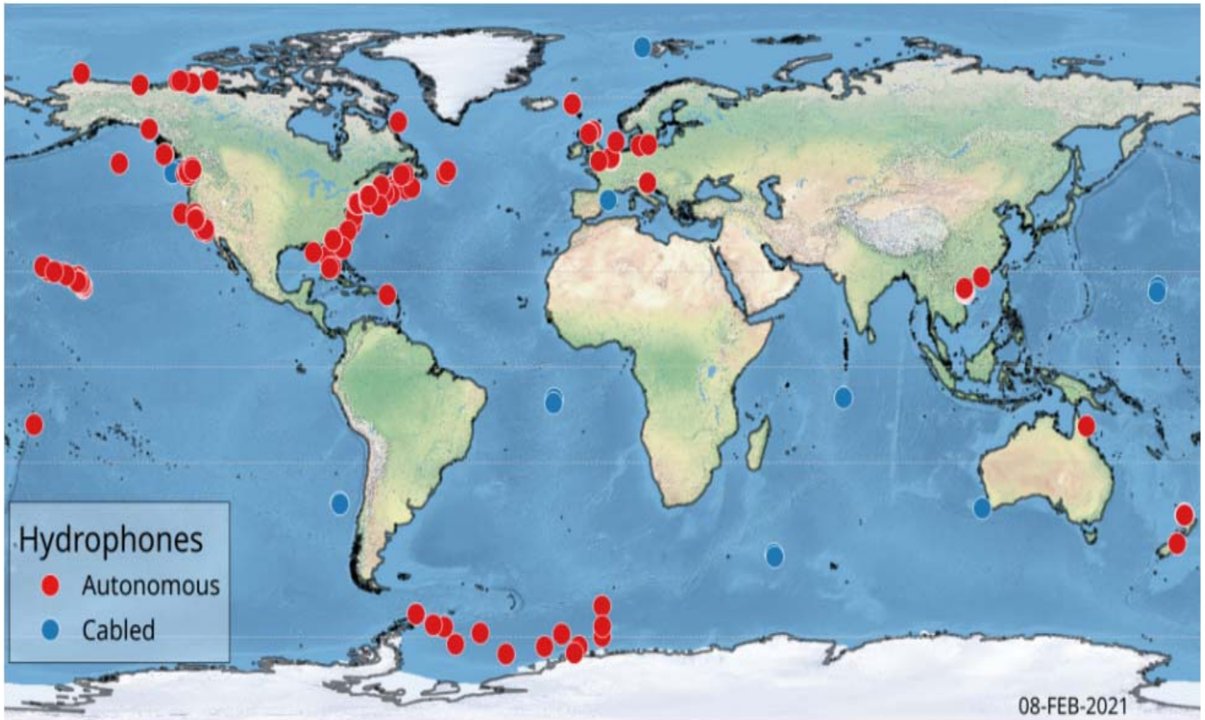


Fig. 1. Locations of civilian hydrophones potentially useful to study effects of the COVID-19 pandemic on ocean sound and other acoustic characteristics of the ocean are shown here, as of 8 February 2021.

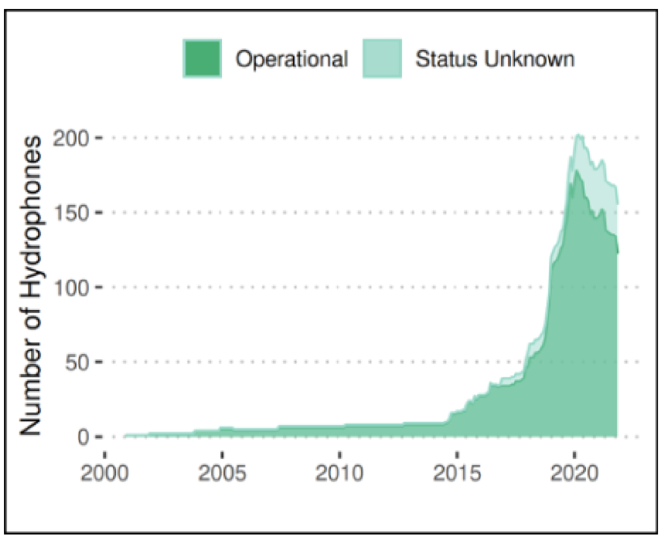


Fig. 2. Trends in the number of nonmilitary hydrophones deployed over the

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