Passive Acoustic Monitoring of Fishes in the Mediterranean Sea: past, present and future perspectives.

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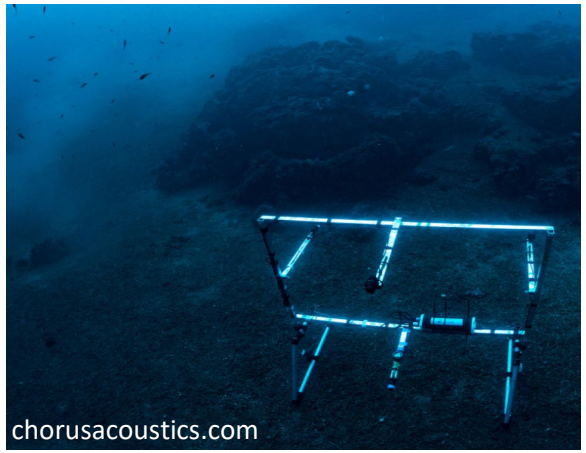
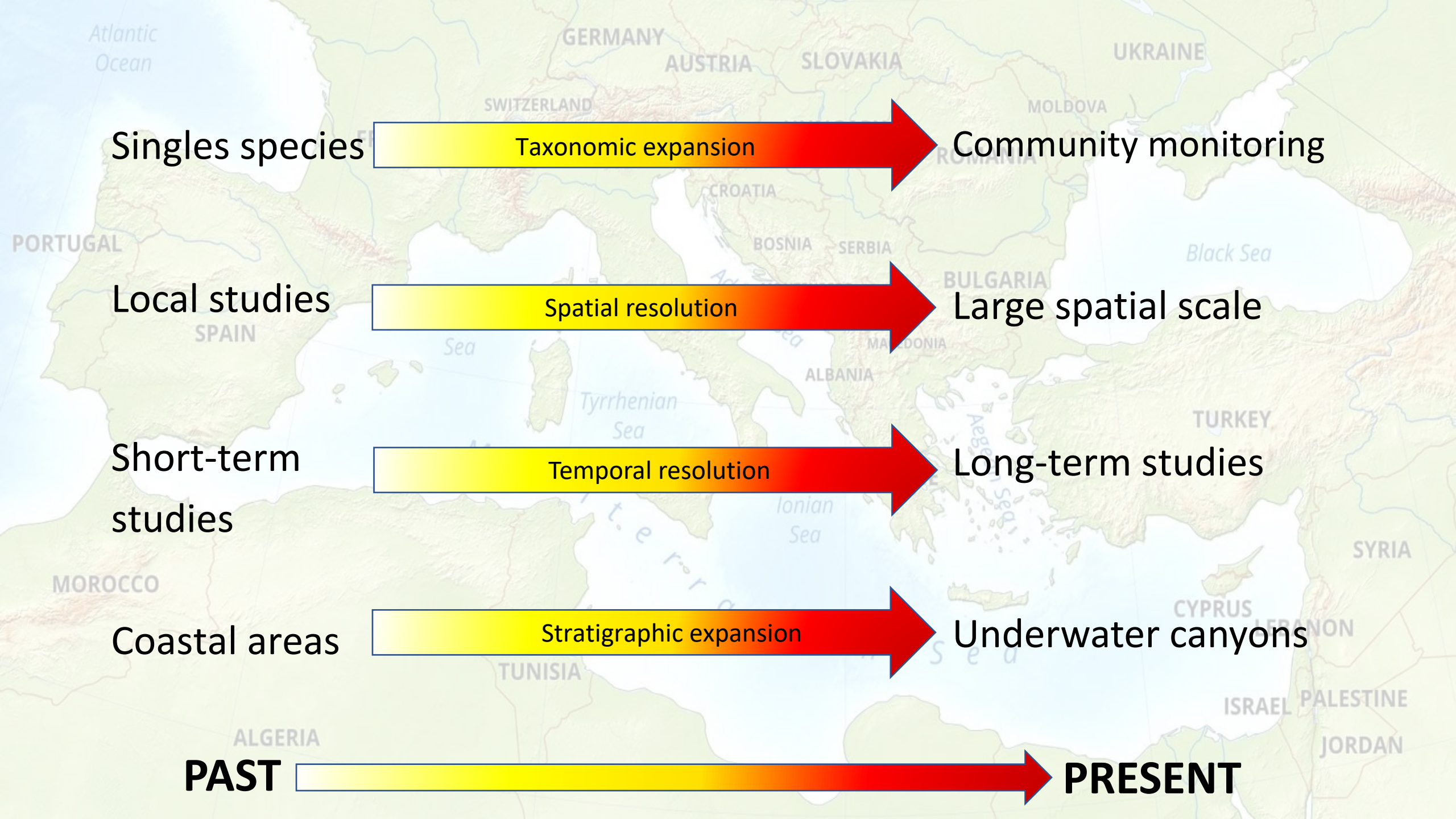
Passive Acoustic Monitoring (PAM)

In aquatic environments, **use of hydrophones** to record all components of **underwater soundscapes**

Primarily applied in relation to marine mammals, now used to investigate several aspects of **vocal fish** populations

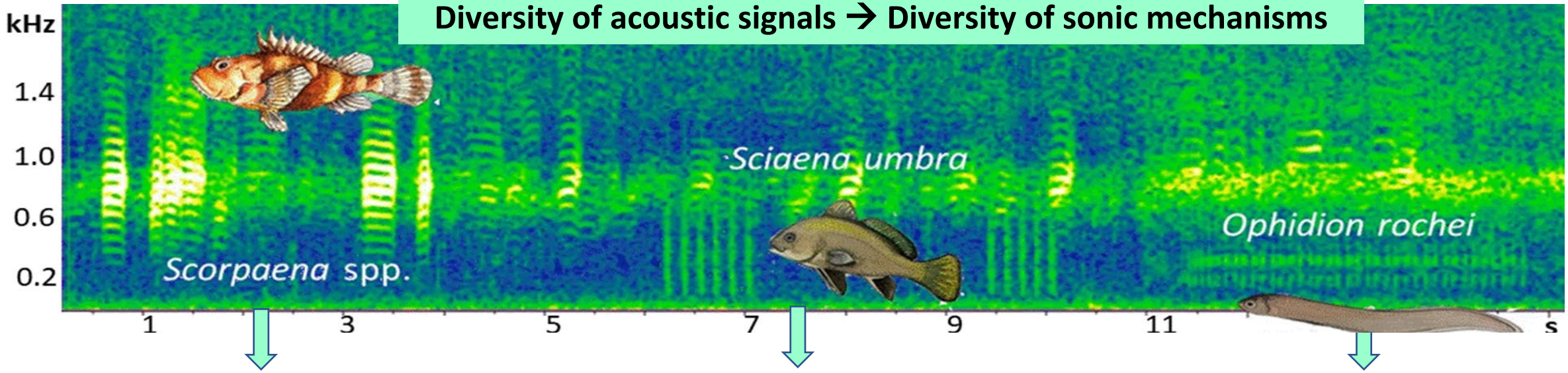
- Non-invasive census
- Continuous monitoring
- Independent of weather, time of day and human effort



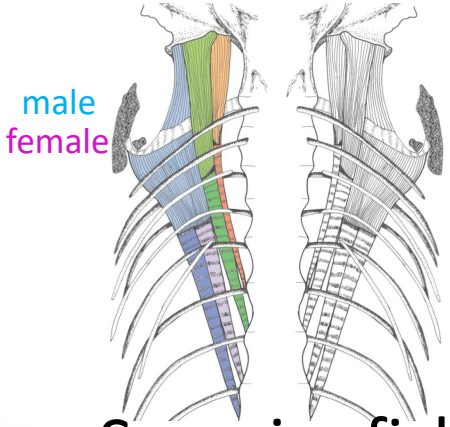

Singles species
Taxonomic expansion
Community monitoring
Local studies
Spatial resolution
Large spatial scale
Short-term studies
Temporal resolution
Long-term studies
Coastal areas
Stratigraphic expansion
Underwater canyons
PAST
PRESENT

Single taxa studies

Diversity of acoustic signals → Diversity of sonic mechanisms



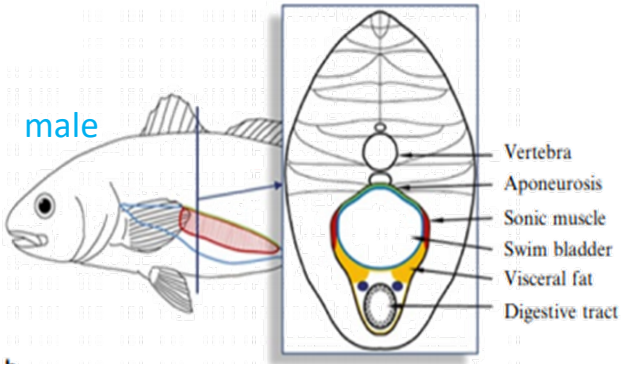
Chordophones



Scorpionfish

(Scorpaena spp.)

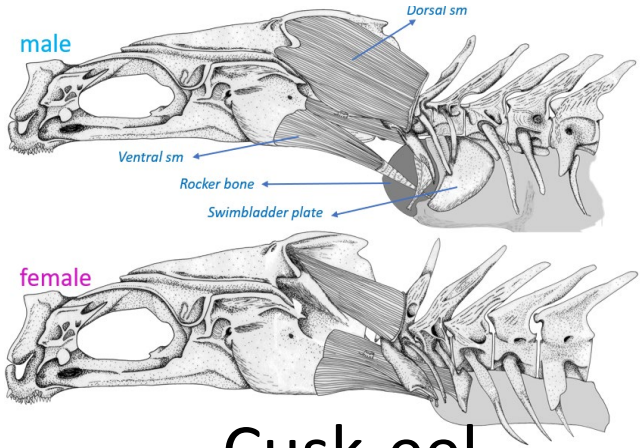
Swimbladder forced response



Brown meagre

(Sciaena umbra)

Swimbladder rebound



Cusk-eel

(Ophidion rochei)

Brown meagre (Sciaena umbra)

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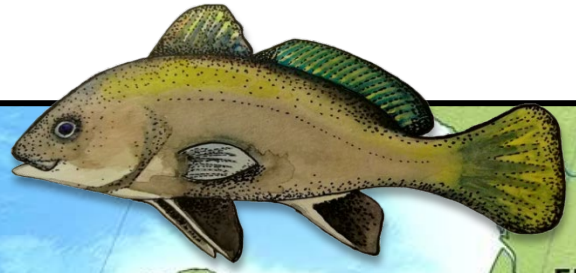

Cusk-eel
(Ophidion rochei)

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- Kéver et al. (2015). JFB, 87(2), 502–509.
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- Picciulin et al. (2019). Aquatic Conserv, 2, 1-9
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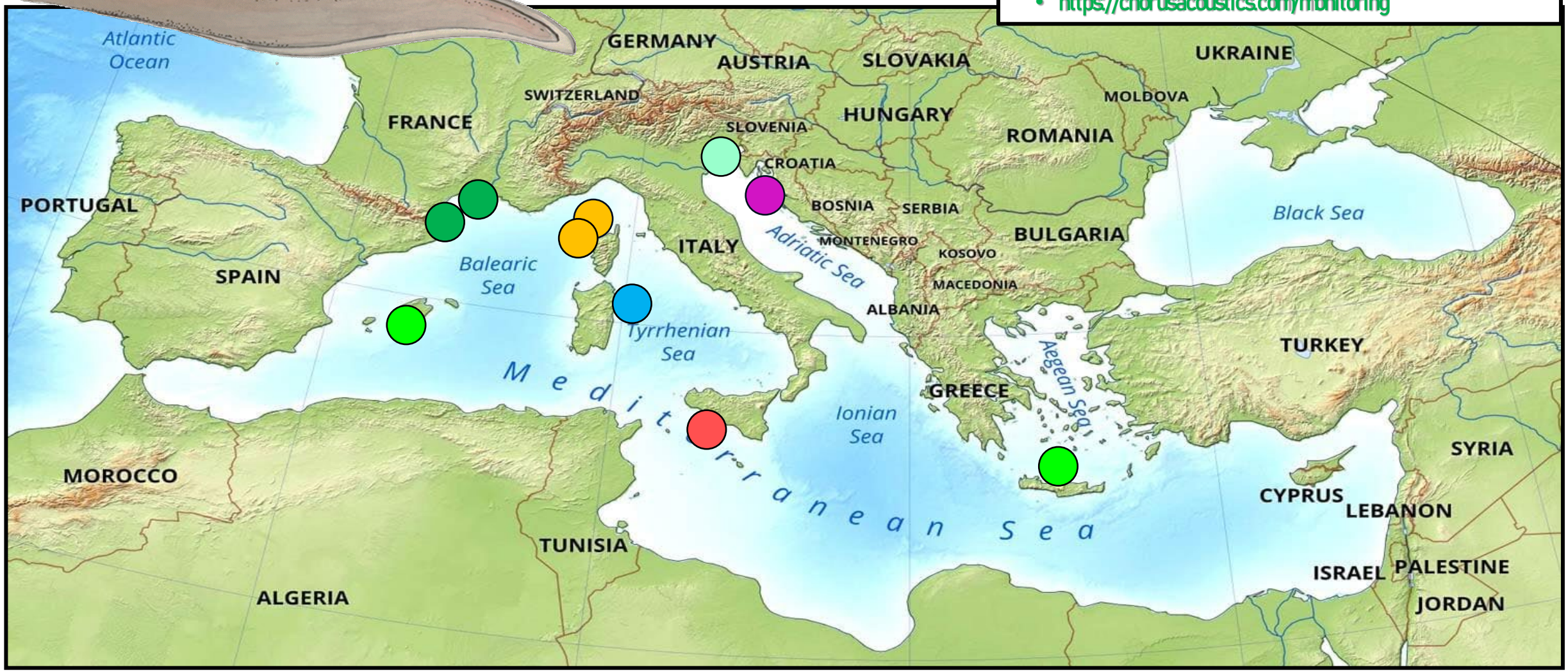
- Bolgan et al. (2019) IBAC 2019
- https://chorusacoustics.com/monitoring



Scorpionfish
(Scorpaena spp.)

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- https://chorusacoustics.com/monitoring

What we have learnt from single-species studies

Sound and sonic apparatus characterisation, location of vocal species in the wild, characterisation of specific behaviours

- *Sciaena umbra* (Picciulin et al. 2012a,b; 2020)
- *Ophidion rochei* (Kéver et al. 2016)
- *Epinephleus marginatus* (Bertucci et al. 2015)


Serranidae>*Epinephleus marginatus*

Consistency of fish call features along a Mediterranean gradient

- *Sciaena umbra* (Parmentier et al. 2017)

Year-round characterisation of fish vocal activity

- *Ophidion rochei* (Kéver et al. 2016)


Ophidiidae>*Ophidion rochei*

Influence of environmental conditions on fish vocal behaviour

- *Ophidion rochei* (Kéver et al. 2015)


Sciaenidae> *Sciaena umbra*

- Bertucci et al. (2015). Journal of Fish Biology, 87(2), 400–421.
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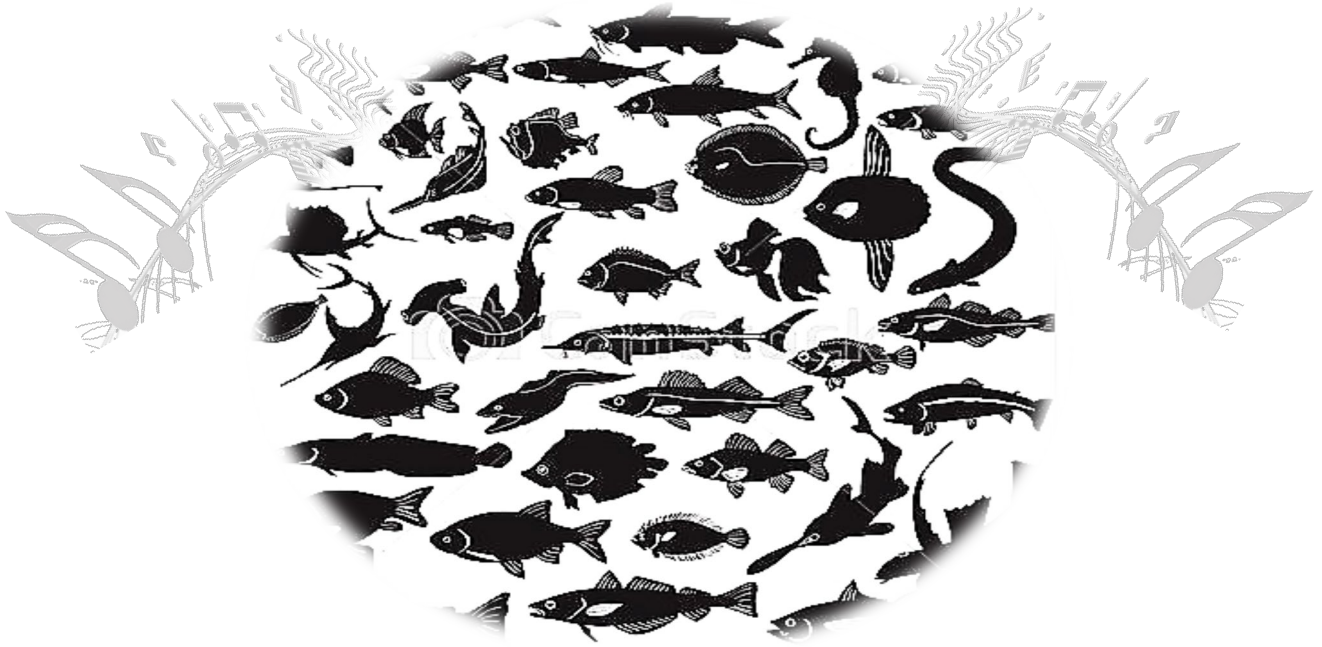
Vocal community

Aggregation of species that produce sounds by using internal or external sound-producing tools and which interact acoustically in a specific habitat (Farina & James, 2016).

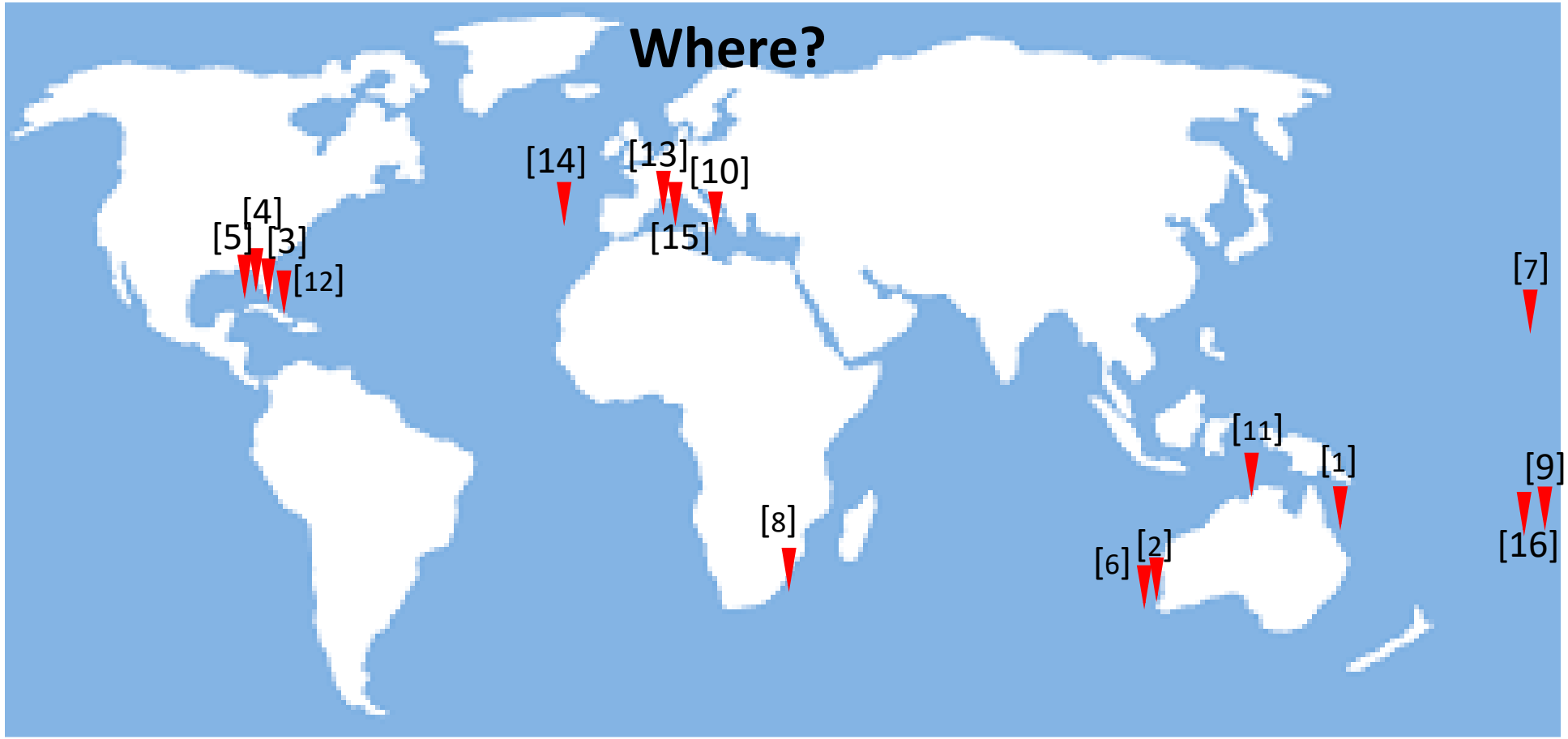


Vocal communities have been recently suggested as indicators of habitat conditions in space and time (Mullet et al. 2017).

Global view on studies on vocal fish communities

= 1 study

- paucity of studies, new emerging field;
- different approaches, extent and levels of the investigation



	Reference	Where	Rec. method	ANALYSIS FRAME
1	McCauley & Cato (2000)	Australia	SAM	Sound type
2	McCauley (2012)	Australia	SAM	LTS + PSD
3	Staaterman et al (2012)	Florida	SAM	LTS + Index
4	Wall et al (2012)	Florida	MAM	Sound type
5	Wall et al (2013)	Florida	SAM + MAM	Sound type
6	Parson et al (2013)	Australia	SAM	LTS
7	Tricas & Boyle (2014)	Hawai	Scuba, video-PAM	Catalog fish sound type
8	Ruppe et al (2015)	South Africa	SAM	Sound type
9	Bertucci et al (2016)	French Polynesia	SAM	Indexes
10	Buscaino et al (2016)	Med. shallow waters	SAM	Indexes
11	Parson et al (2016)	Australia	SAM	PSD + Sound type*
12	Rice et al (2017)	Florida	SAM	LTS+ Indexes
13	Desidera' et al (2019)	Med. rocky reefs	SAM	Sound type
14	Carriço et al (2019)	Azores seamounts	SAM	Sound sequences + Indexes
15	Bolgan et al (2020)	Med. canyon	SAM +MAM	Sound type
16	Bertucci et al (2020)	French Polynesia	SAM	Sound type

Vocal fish communities

2 major analysis trends

Automated analysis

LTS- Long term spectrogram

PSD- Power Spectral Densities

Acoustic Indexes

Temporal and frequency entropies,
Acoustic diversity index (ADI)
Acoustic complexity index (ACI).

≠

Sound types

Manually recognised
(in most cases)
Traditional community ecology indexes applied to sound types

Shannon
Simpson

Quickly to compute, do not require prior knowledge

Can be setting dependent, difficult to interpret, poor resolution

Can provide high resolution information on the community composition

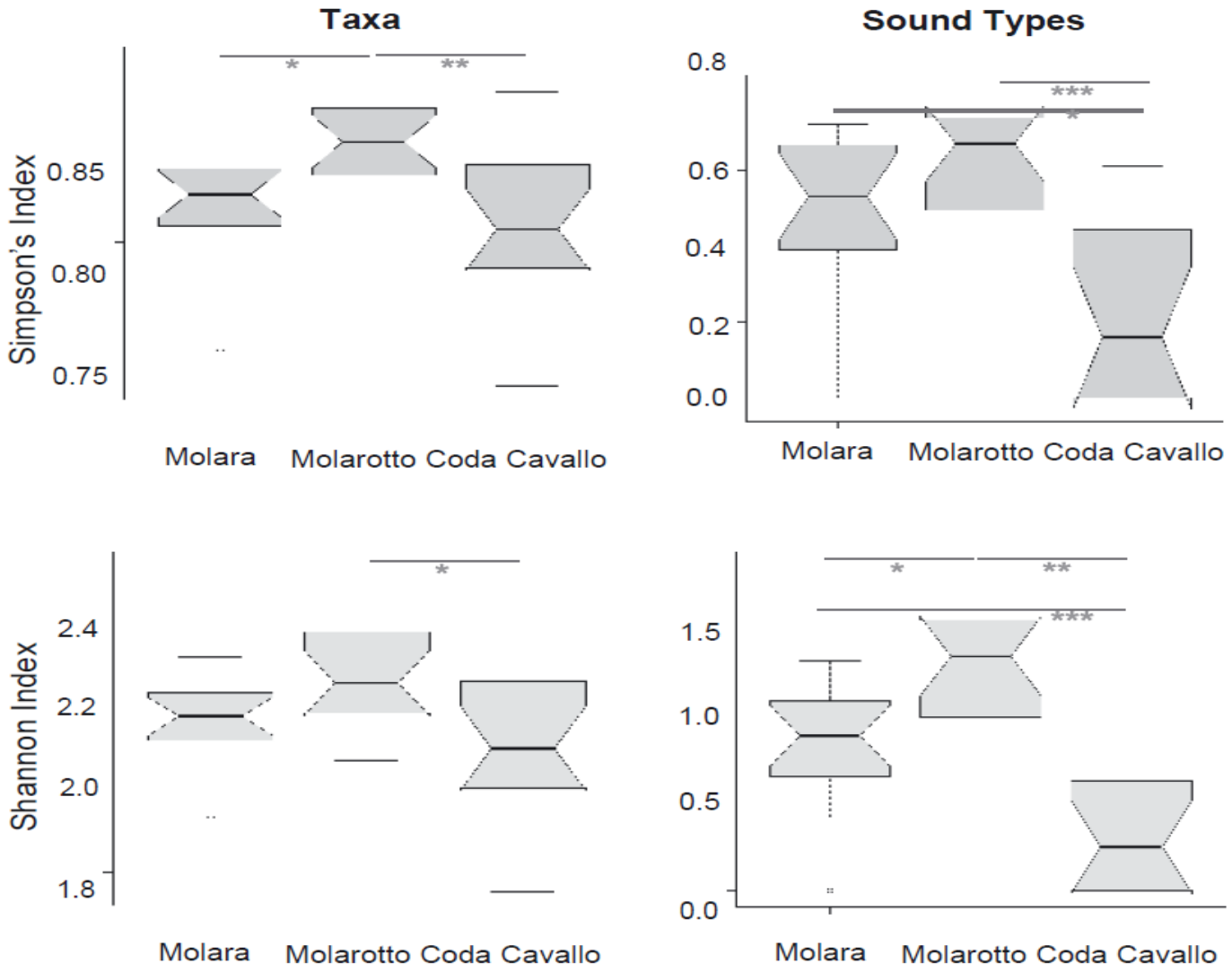
Extremely time consuming analysis (if manual analysis)

Vocal fish communities

Desideràet al. (2019). MEPS 608, 183-197

Bolgan et al (2020). JASA, 147(4) 2466-2477

Sound type: unit of measure for fish biodiversity



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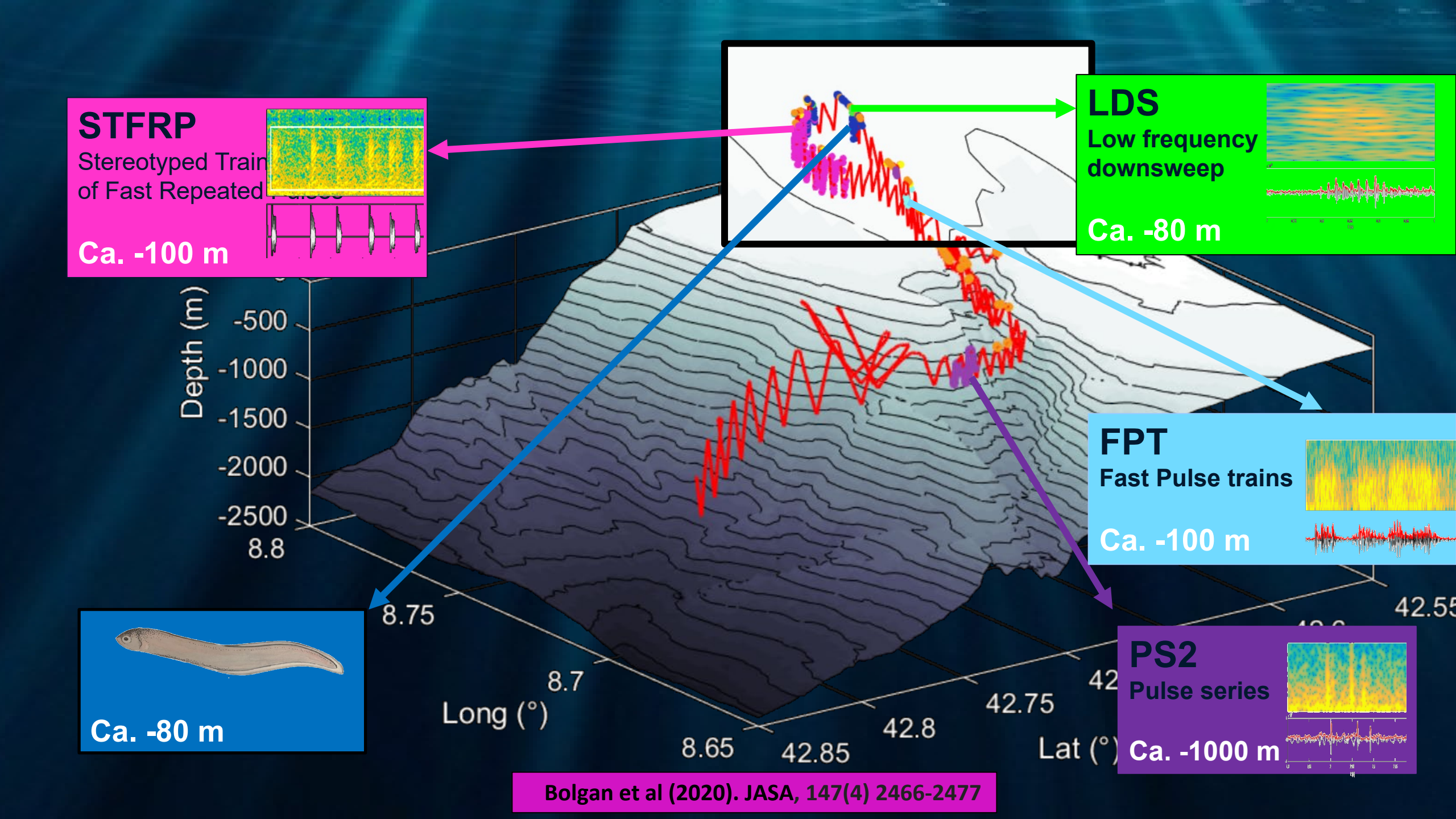


Bolgan et al (2020). JASA, 147(4) 2466-2477

And what about anthropogenic noise?

BIOPHONY

Animal sounds

GEOPHONY

Natural sounds from abiotic sources

SOUNDSCAPE

ANTHROPHONY

Man-made noise

And what about anthropogenic noise?

The ocean has been reported to be **2–10 times** louder compared to the pre-industrial periods

Man made noise: form of pollution which we are required to monitor under diverse international legislations (e.g United Nations Convention on the Law of the Sea and the European Marine Strategy Framework Directive)

Type of sources

Acute → high intensity and short duration (e.g. explosions, air guns, pile driving, sonar)

Chronic → more widespread, main contributor to the increase in ocean background noise levels (e.g. boat noise)

Unit of measurements

1. Sound pressure levels
2. Spectral levels
3. Particle motion

Type of effect on fish

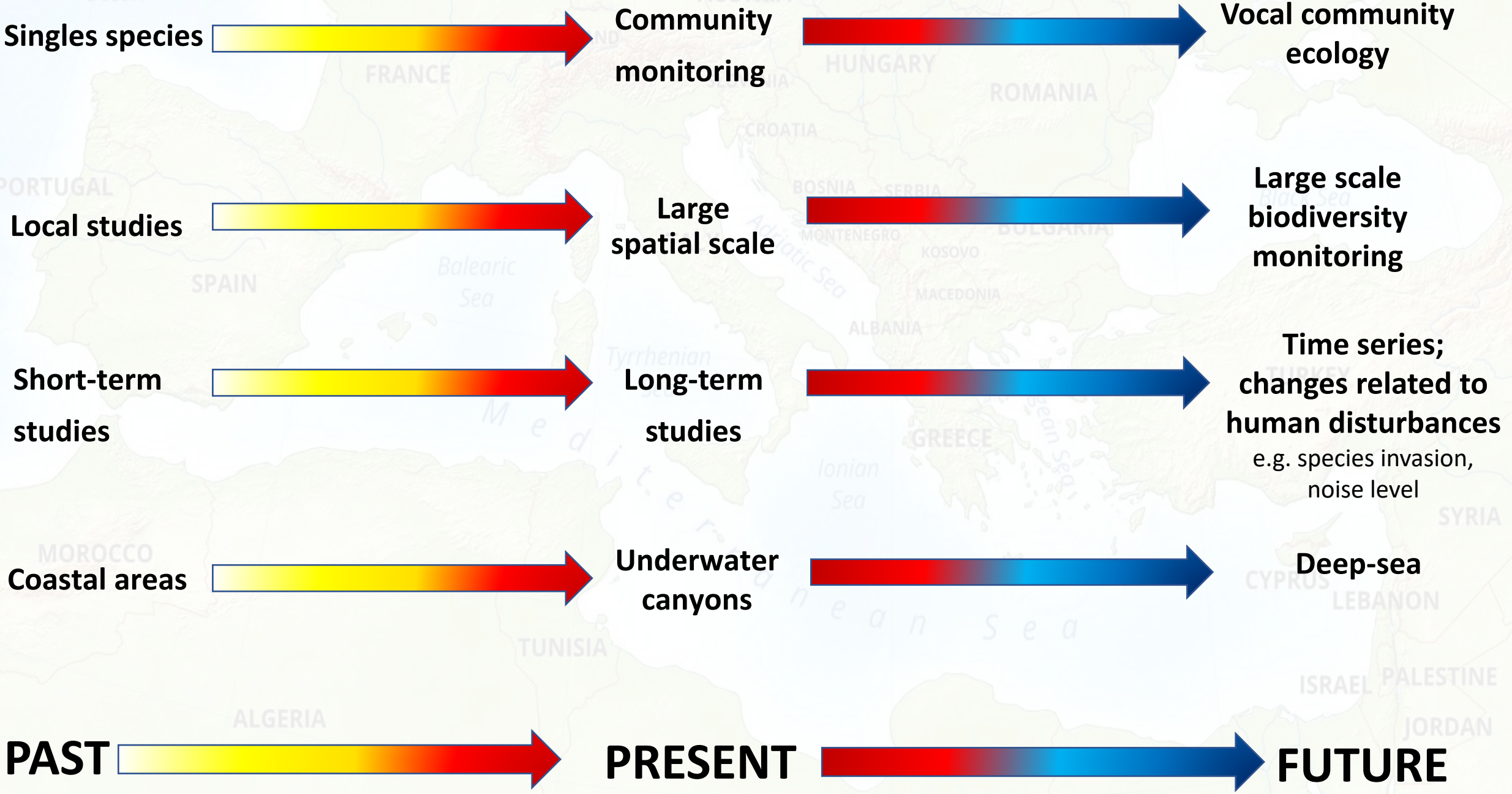
1. Behavioural
2. Physiological

PAM allows **to measure the extent of man-made noise pollution.** It can also be used to **monitor potential effects on fish populations in their natural environments**, thus complementing studies carried out under controlled conditions, e.g. laboratories

Field-based studies: noise effects on Mediterranean fishes

Species	Noise type	Response variable		Reference
		Behavioural	Physiological	
ACUTE				
Dicentrarchus labrax	Airguns	Startle response, swimming behaviour	Cortisol, glucose, lactate, AMP, ADP, ATP and cAMP	Santulli et al. 1999
	Pile driving		Primary and secondary stress response	Debusschere et al. 2016
Spondyliosoma cantharus	Pile driving		Oxygen uptake	Bruintjes et al. 2016
Pleuronectes platessa	Pile driving		Oxygen uptake	Bruintjes et al. 2016
Scomber scomber	Pile driving	Group behaviour and swimming depth		Hawkins et al. 2014
CHRONIC				
Dicentrarchus labrax	Boat noise	Swimming behaviour	Lactate, hematocrit levels and glucose	Buscaino et al. 2010
Chromis chromis	Boat noise	Foraging behaviour	Body Condition Index	Bracciali et al. 2012
			Glucose, lactate and total proteins in plasma	Vazzana et al. 2017
	Boat noise	Nest caring behaviour		Picciulin et al. 2010
Gobius cruentatus	Boat noise	Territorial behaviour		Picciulin et al. 2010
Hippocampus guttulatus	Boat noise	Displacement	Respiration rate	Palma et al. 2019
Sparus aurata	Boat noise	Swimming behaviour	Lactate, hematocrit levels and glucose	Buscaino et al. 2010
Sciaena umbra	Boat noise	Flight reaction and hiding behaviour		La Manna et al. 2016
		Vocal activity (call rate)		Picciulin et al. 2012
Thunnus thynnus	Boat noise	Schooling behaviour		Sara' et al. 2007

Di Franco et al (2020). *Marine Pollution Bulletin*, *159*, 111450.


Singles species
Community monitoring
Vocal community ecology
Local studies
Large spatial scale
Large scale biodiversity monitoring
Short-term studies
Long-term studies
Time series; changes related to human disturbances
e.g. species invasion, noise level
Coastal areas
Underwater canyons
Deep-sea
PAST
PRESENT
FUTURE

Passive Acoustic Monitoring

STATUS & **CHANGES**

from **SPECIES** to **COMMUNITY**

in **SPACE** and **TIME**

TAKE HOME

Funding sources

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Thanks for your attention!

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