Sound production and reception in teleost fish

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ISPA- Instituto Universitário

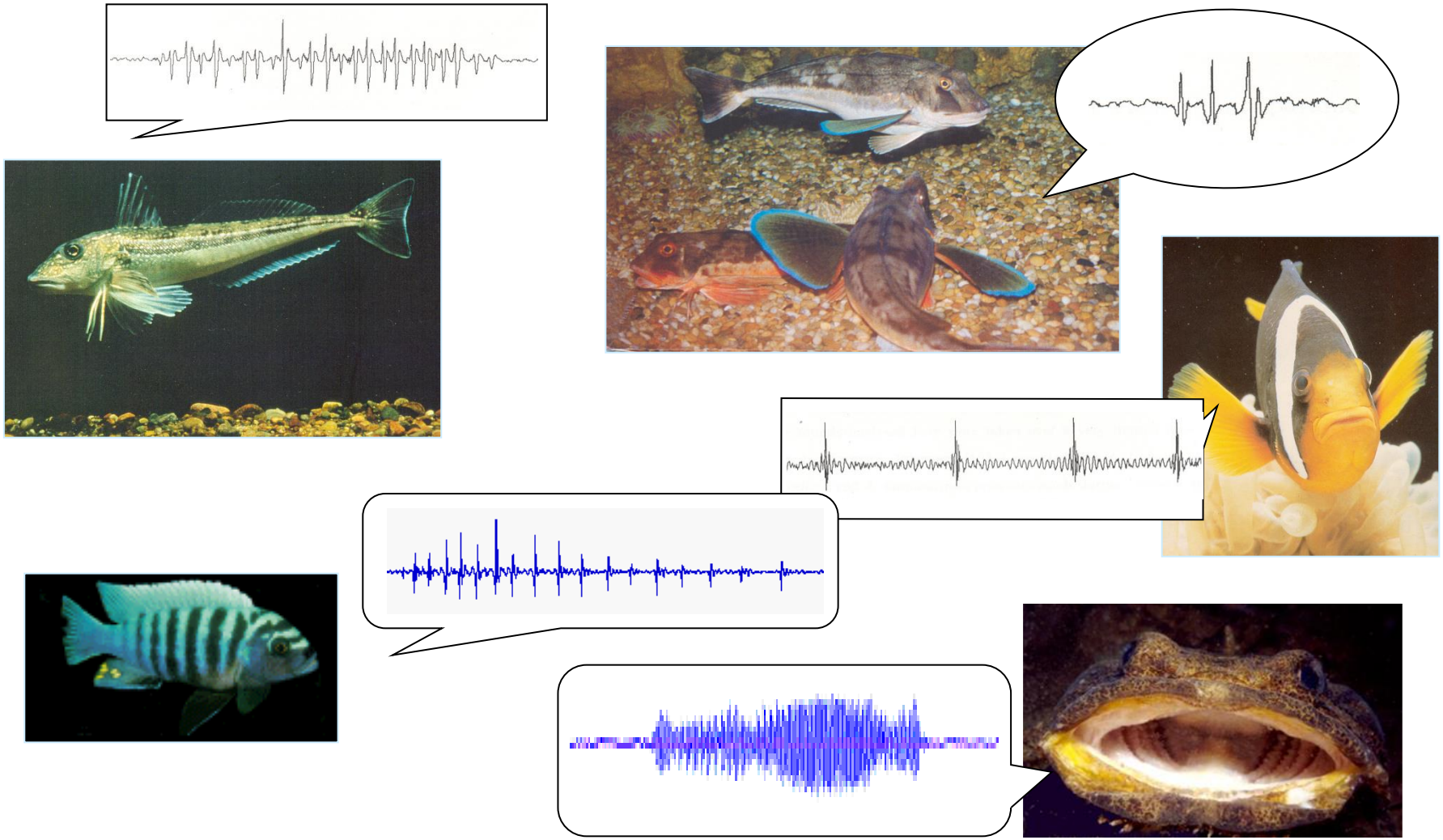
DOSITS Webinar

Outline

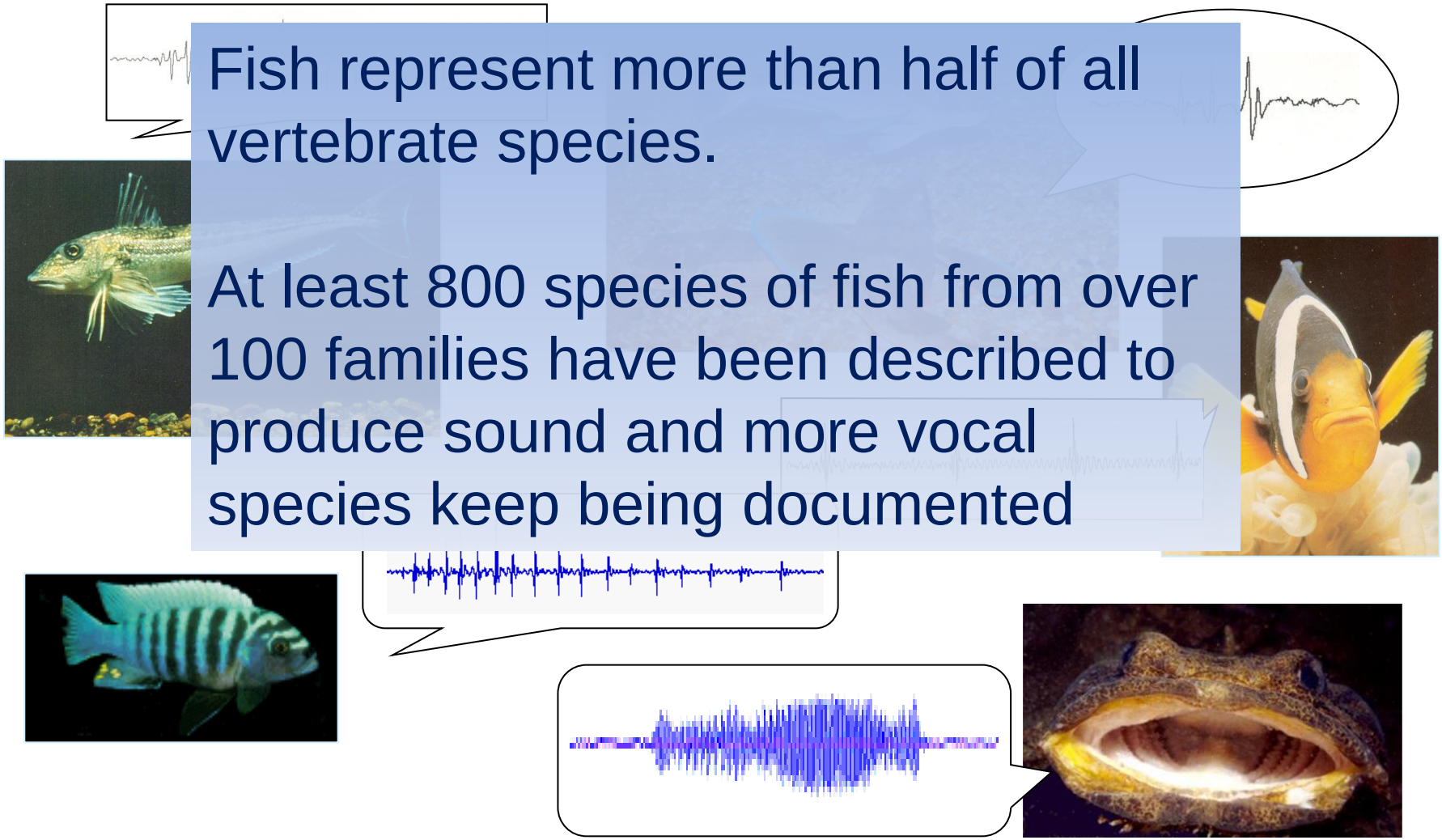
1. Vocal fish
2. Sound-generating mechanisms
3. Sound characteristics
4. Sound reception
5. Context of sound production

1. Vocal fish

Fish are likely the largest vocal vertebrate group



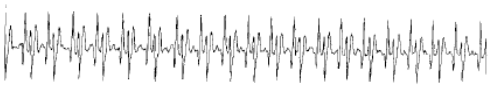
1. Vocal fish

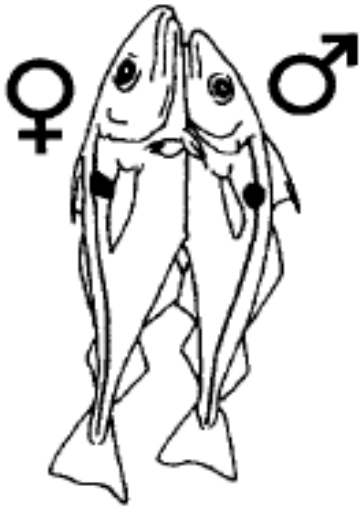


Fish represent more than half of all vertebrate species.

At least 800 species of fish from over 100 families have been described to produce sound and more vocal species keep being documented

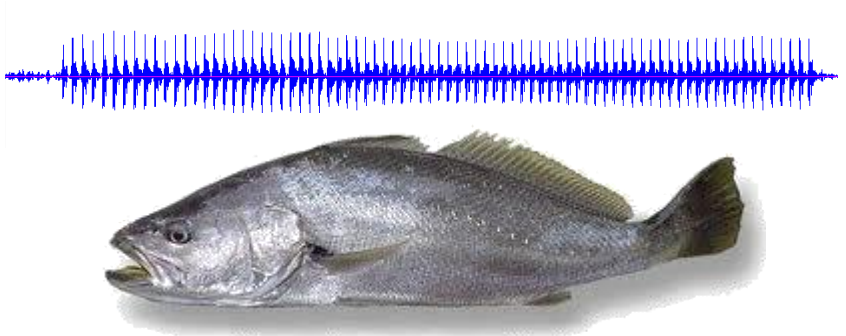
This include many commercial marine species





Cod family (Gadidae)

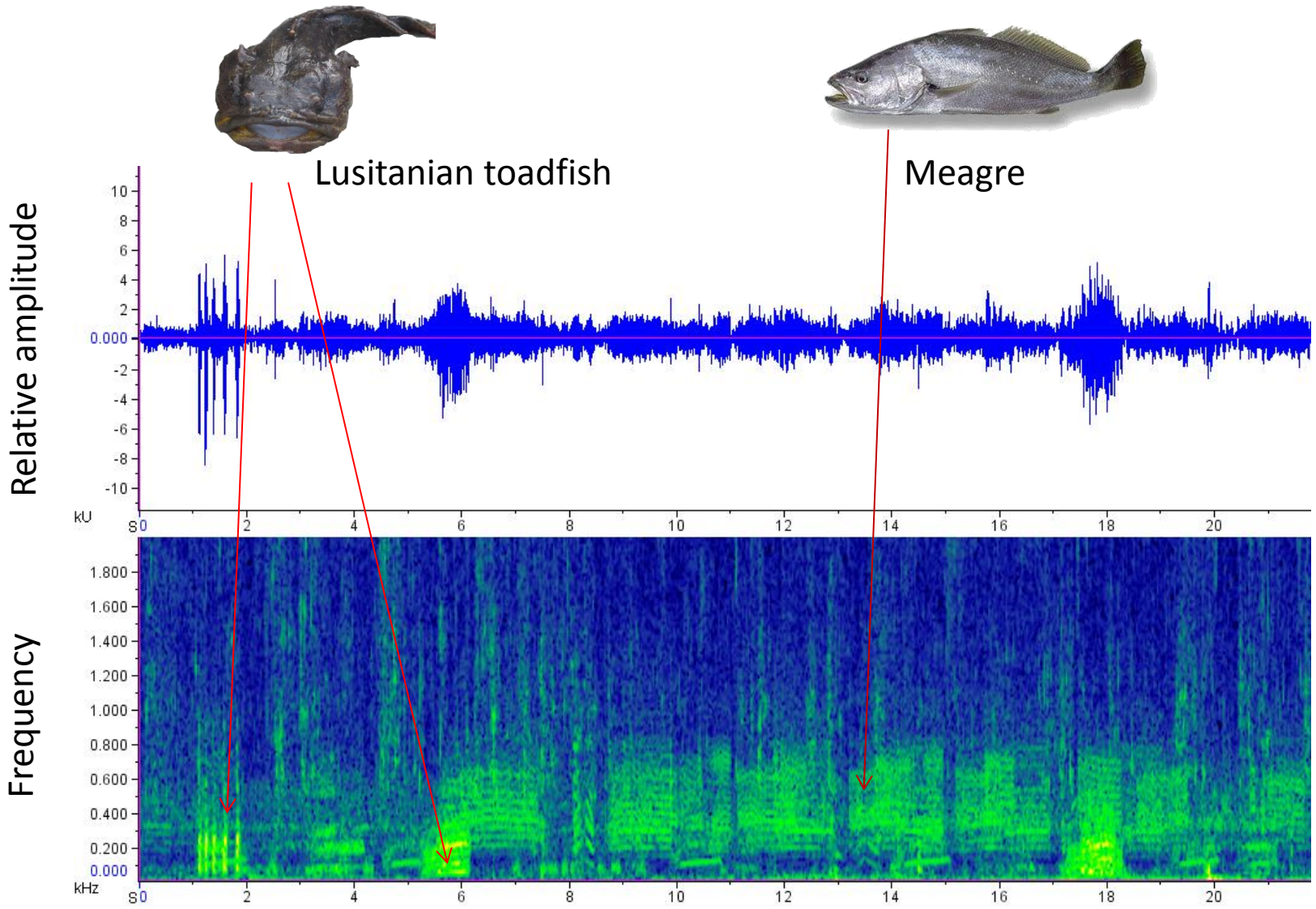
Drawing by Tony Hawkins



Drum/croaker family (Sciaenidae)

Sea bass / grouper family

Fish sounds can be an important part of marine soundscapes



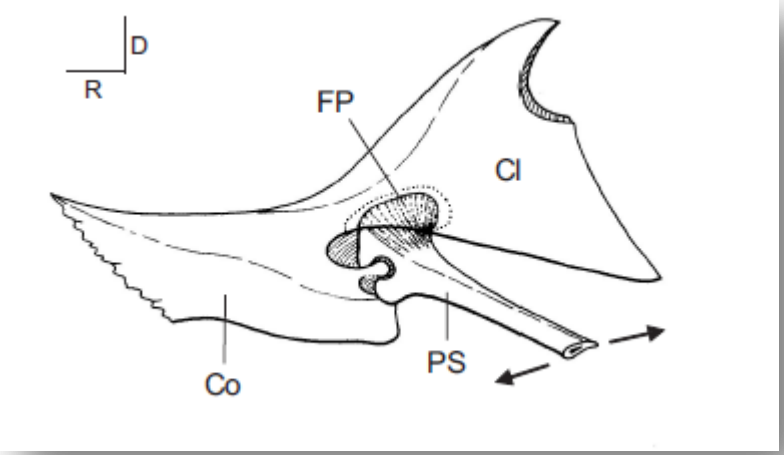
April-May, Tagus estuary, Portugal

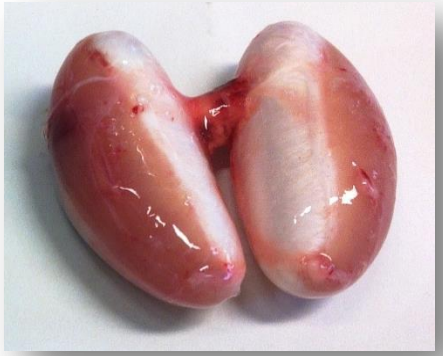
2. Sound-generating mechanisms

Fish possess the most diversified sonic mechanisms among vertebrates

In many species mechanisms are unknown

- Sonic muscles that vibrate the swimbladder
- Rubbing of bony elements

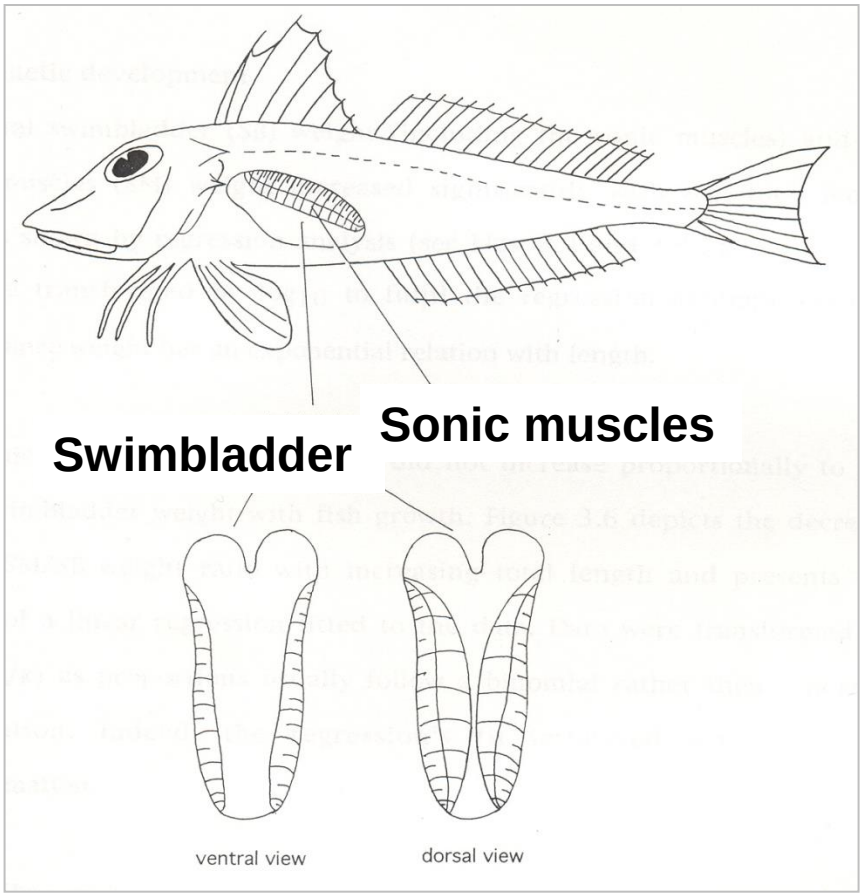




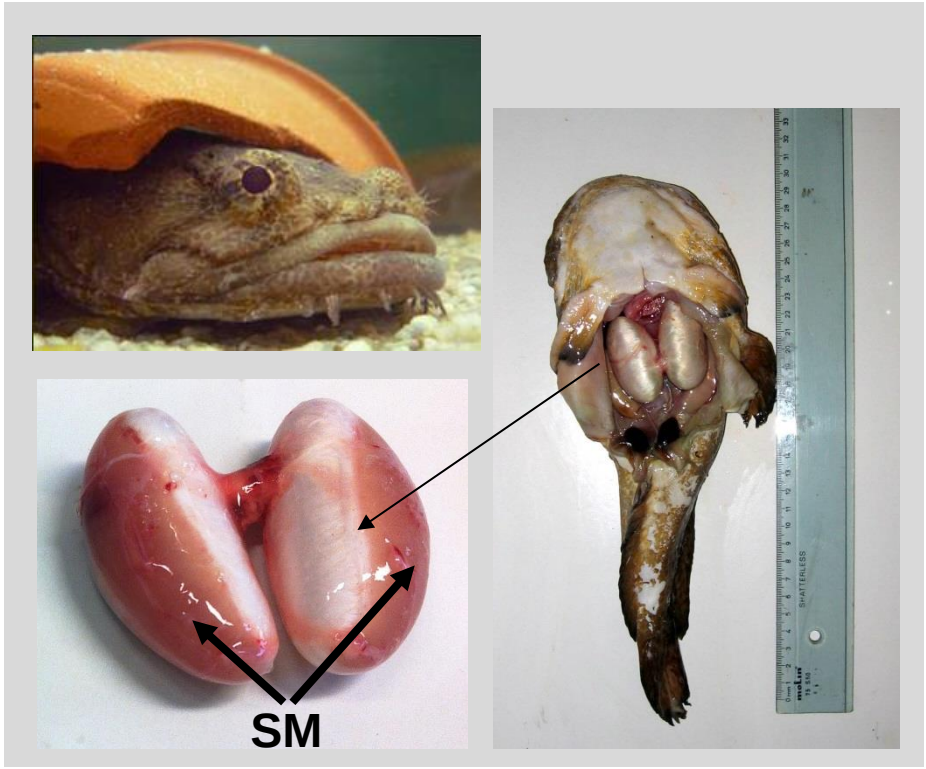
Reviewed in Ladich & Fine (2008)

- Sonic muscles that vibrate the swimbladder

Instrinsic sonic muscles



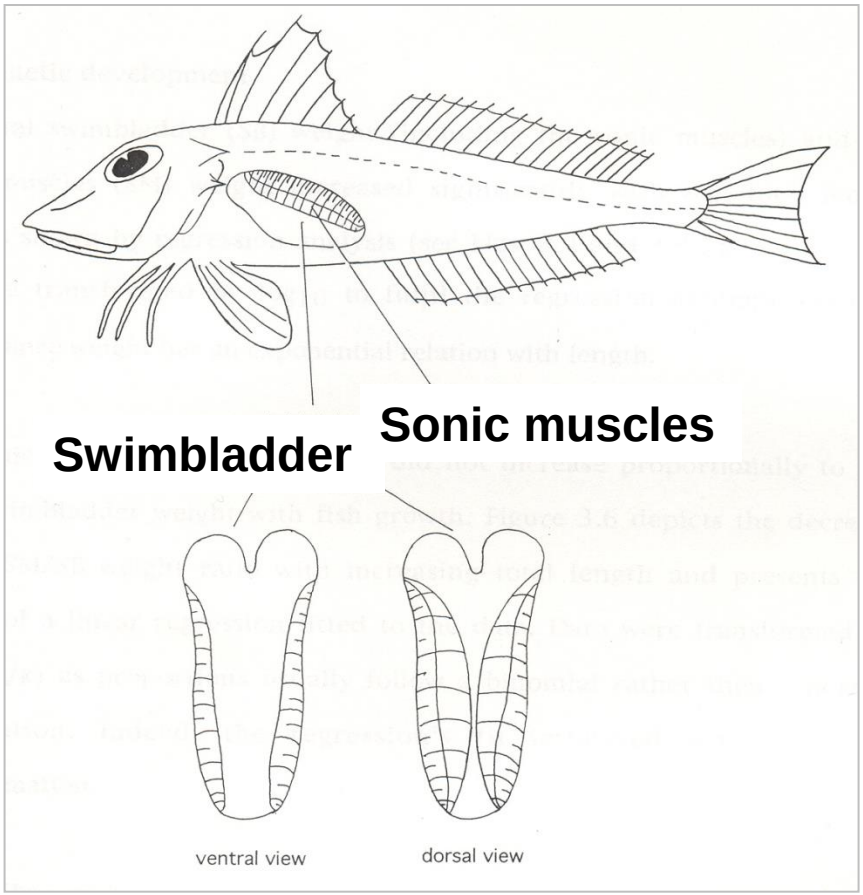
***Eutrigla gurnardus* (Triglidae)**



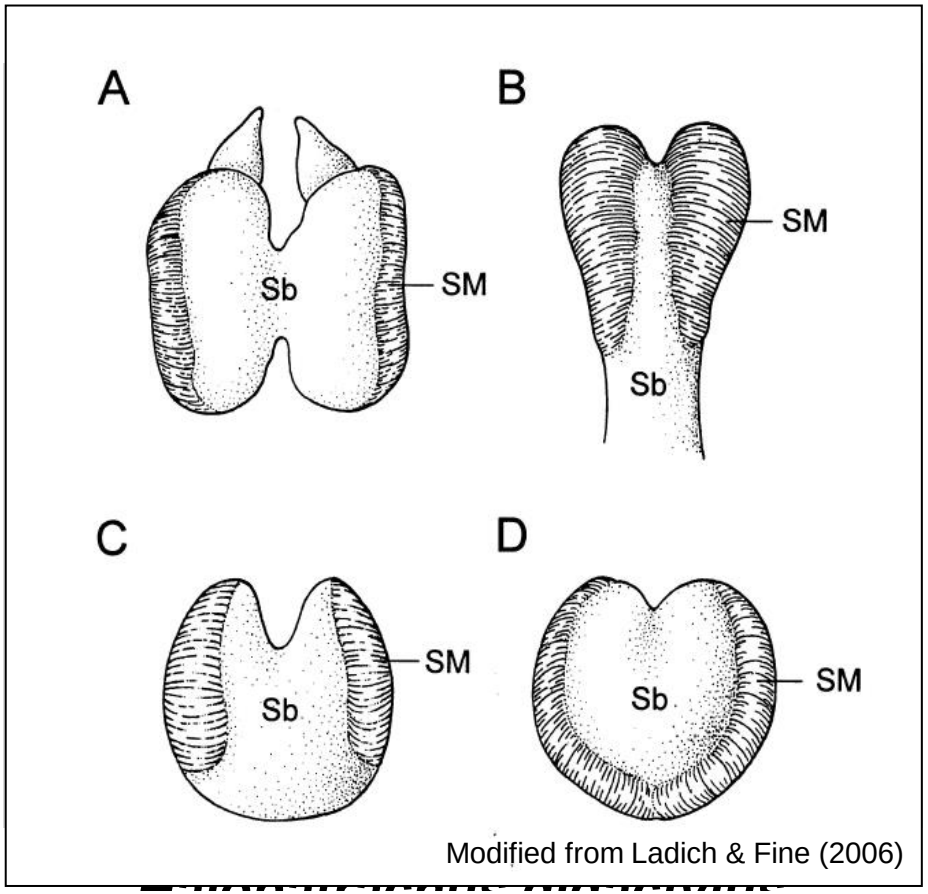
***Halobatrachus didactylus* (Batrachoididae)**

- Sonic muscles that vibrate the swimbladder

Instrinsic sonic muscles



***Eutrigla gurnardus* (Triglidae)**

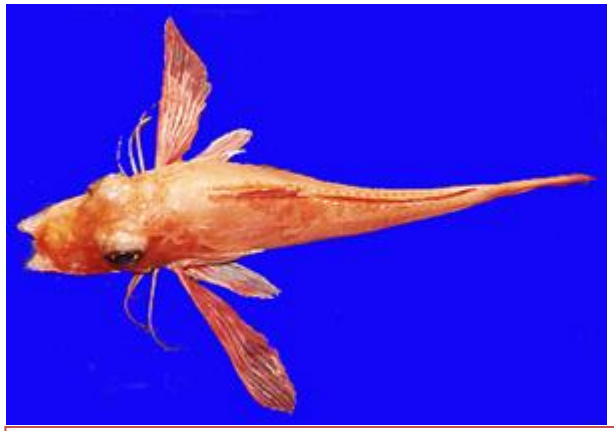


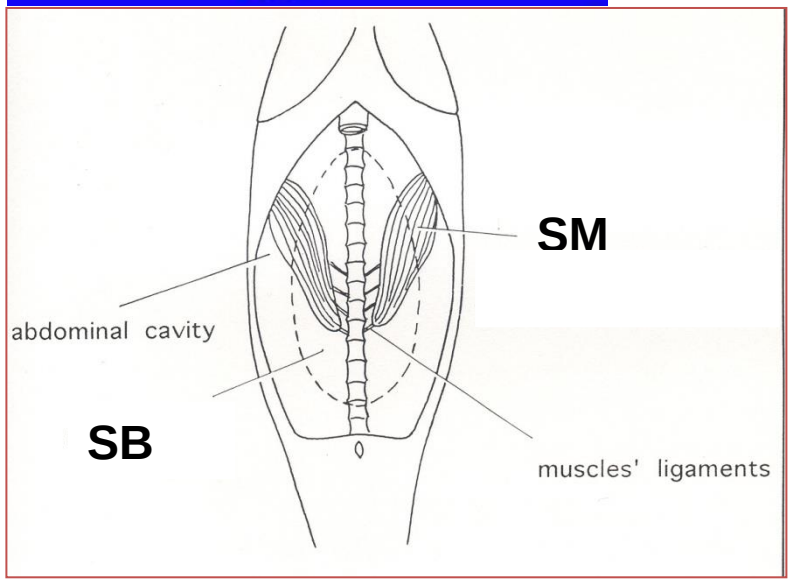
Modified from Ladich & Fine (2006)

A: Dactylopterus sp. (Dactylopteridae)
B: burbot, Lota lota (Gadidae)
C, D: Batrachoididae

- Sonic muscles that vibrate the swimbladder

Extrinsic sonic muscles





***Trigla lyra* (Triglidae)**

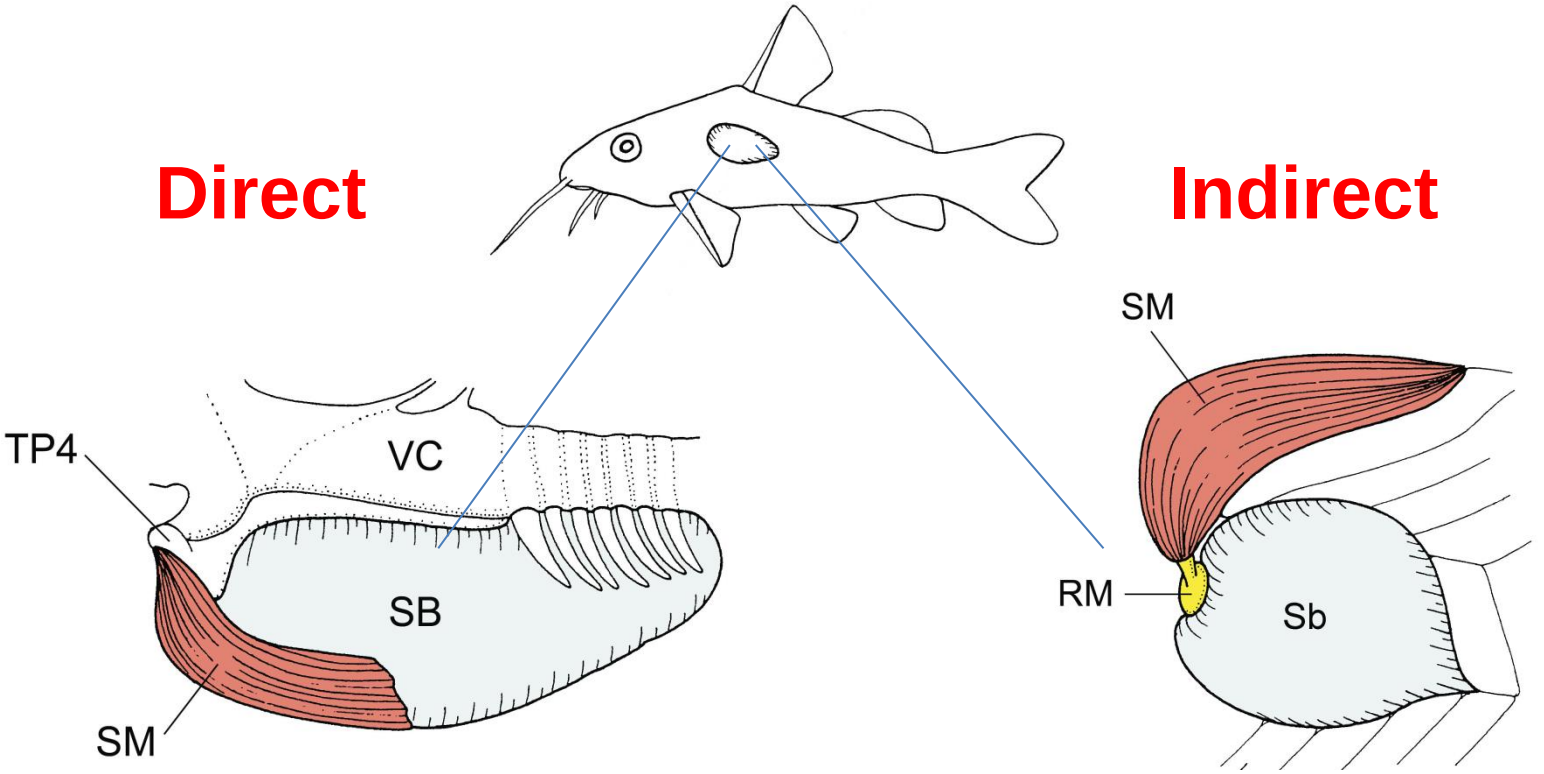
Amorim (1996)

There is a great variety within extrinsic mechanisms because muscles originate in a variety of places such as the skull, ribs, vertebrae, etc.

Extrinsic SM can have a direct or indirect action

- Sonic muscles that vibrate the swimbladder

Examples of extrinsic sonic muscles in catfishes (Siluriformes)



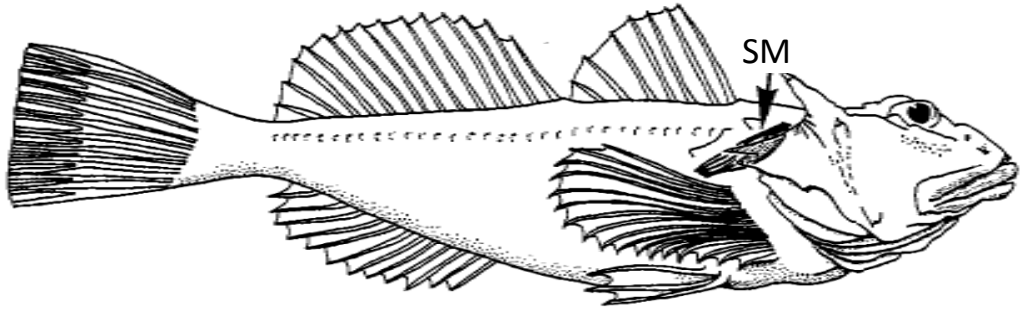
***Pimelodus* sp. (family Pimelodidae)** **Synodontis sp. (family Mochokidae)**

TP4—transverse process of the 4th vertebra; RM—ramus Mülleri (=elastic spring)

Modified from Ladich & Fine (2006)

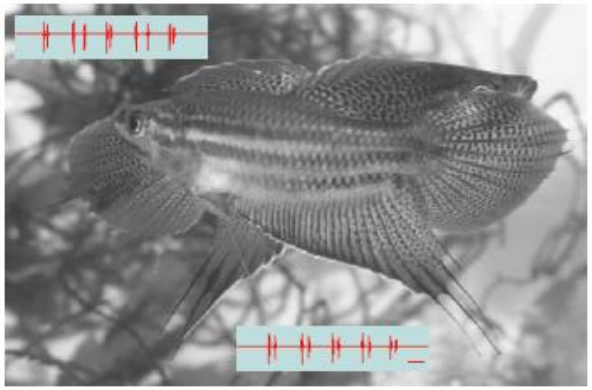
- Rubbing of bony elements

Pectoral mechanisms: pectoral girdle, pectoral fin rays, and fin tendons

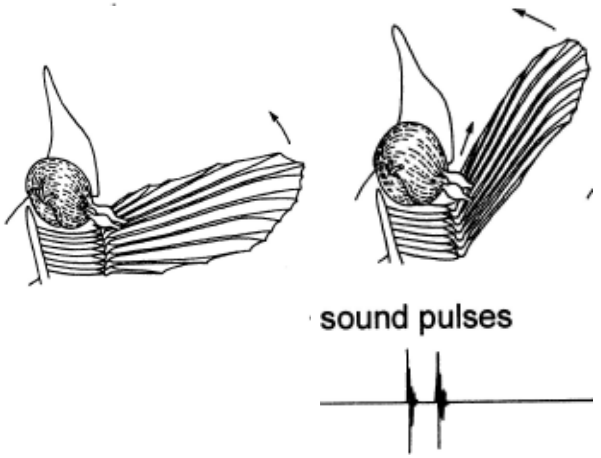


longhorn sculpin *Myoxocephalus scorpius*

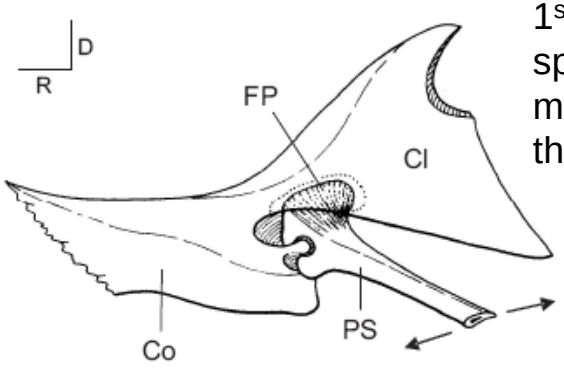
Cottidae



Pectoral tendon plucking mechanism



croaking gourami *Trichopsis vittata* (family Osphronemidae).



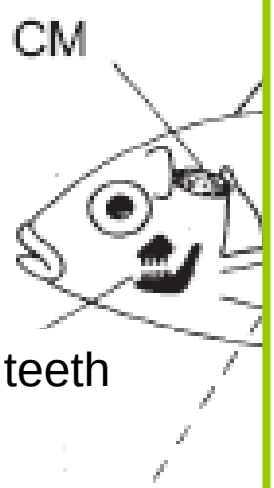
1st **pectoral ray** (pectoral spine, PS) has ridges that move against a groove in the pectoral girdle

Pectoral stridulatory mechanism in catfishes.

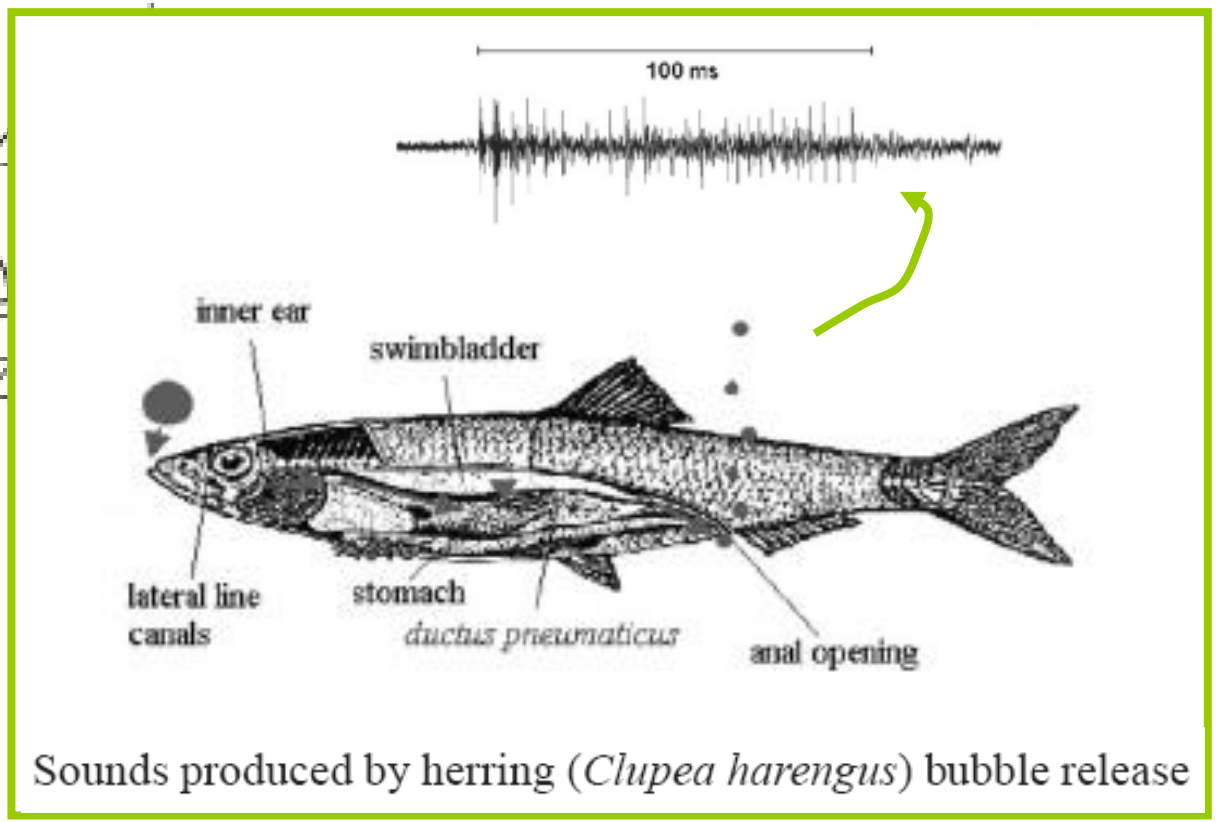
catfish *Rhamdia quelen* (family Pimelodidae)

Ladich & Fine (2006)

- Rubbing of bony elements and other mechanisms



Pharyngeal teeth



Sounds produced by herring (*Clupea harengus*) bubble release

Wahlberg & Westerberg (2003)

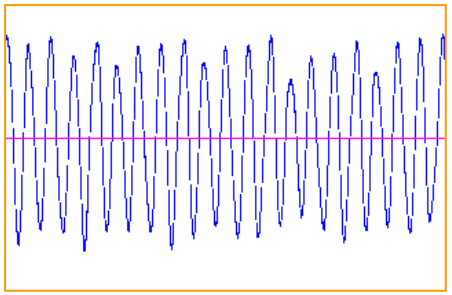
3. Sound characteristics

- Sonic muscles that vibrate the swimbladder

1 contraction – 1 sound pulse

Frequency < 1kHz

Duration typically < 1s

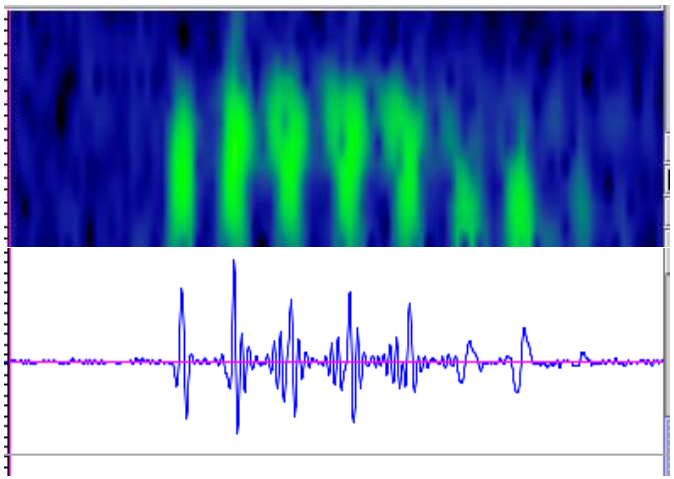


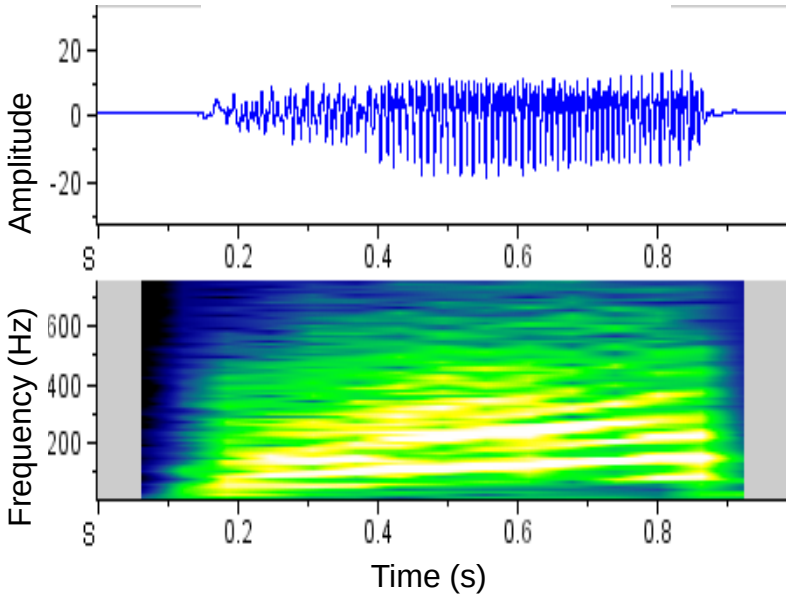
Fast SM contraction

Tonal sounds

Slow SM contraction

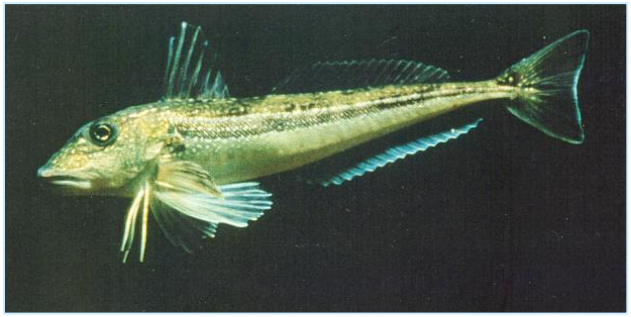
Pulsed sounds





3. Sound characteristics

- Sonic muscles that vibrate the swimbladder

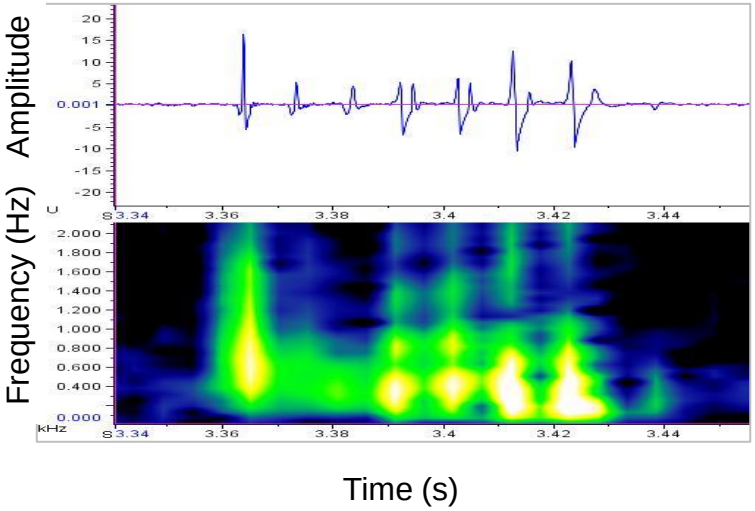


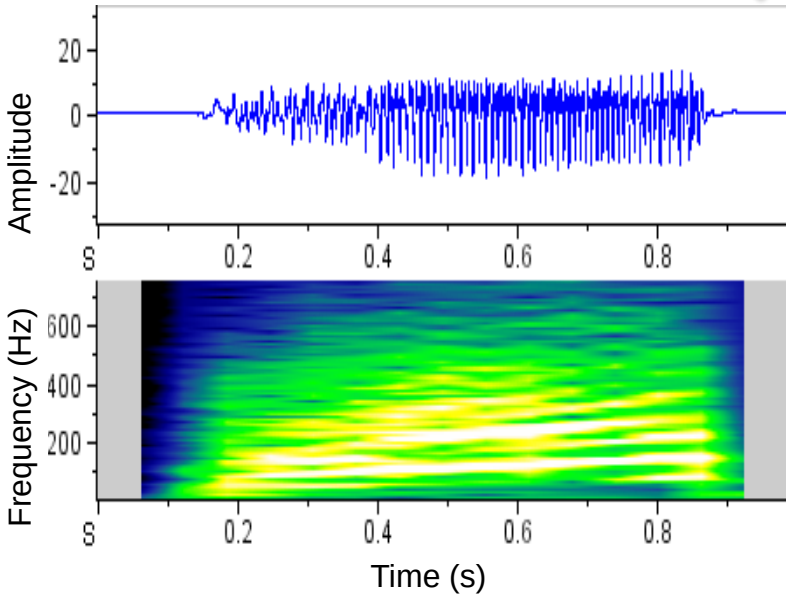
Slow SM contraction

Pulsed sounds 1

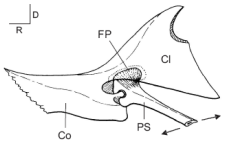
Fast SM contraction

Tonal sounds 2



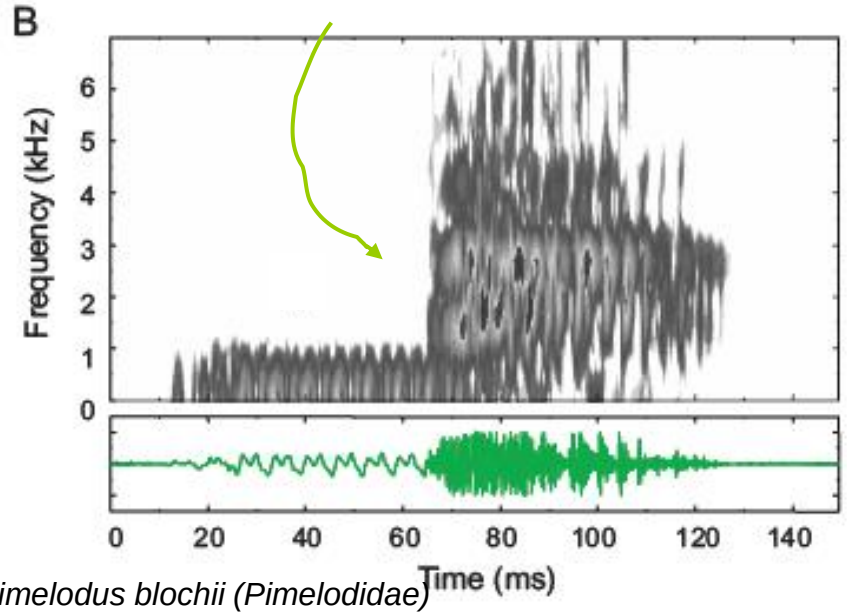


- Rubbing of bony elements - pectoral mechanisms



3

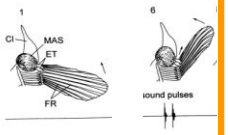
Frequencies 2-4 kHz

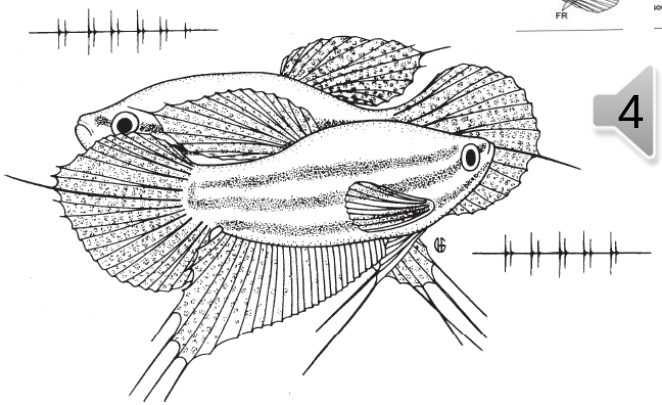


Pimelodus blochii (Pimelodidae)

Courtesy of Fritz Ladich

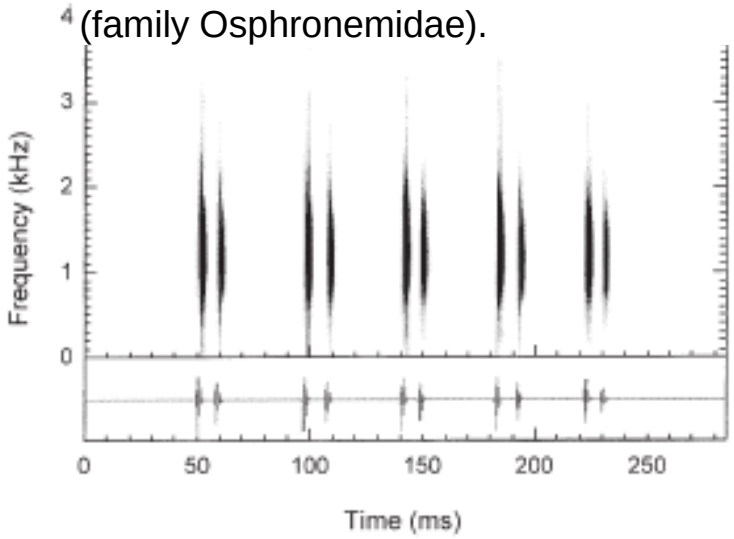
Frequencies 1-2 kHz





4

croaking gourami *Trichopsis vittata* (family Osphronemidae).

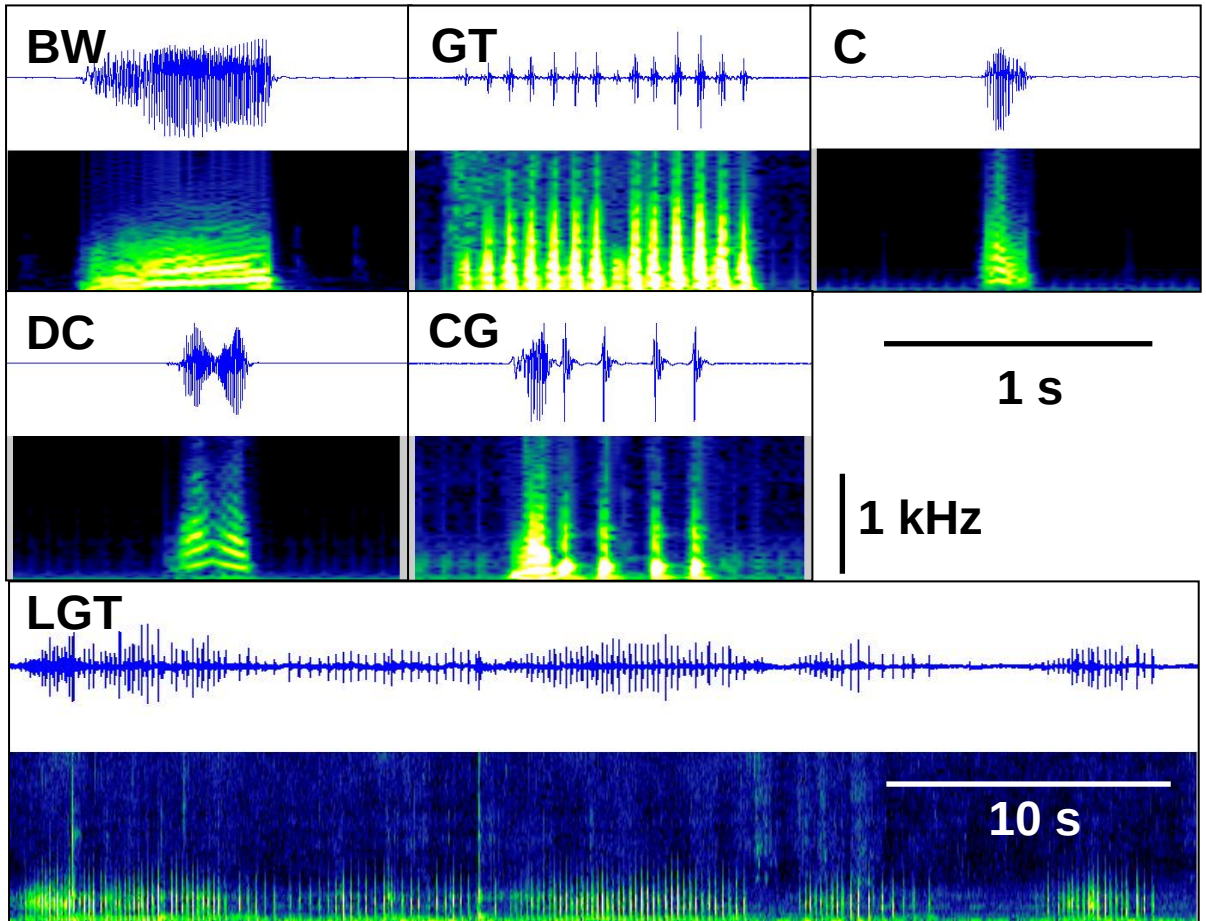


Sound variability

✓Sound rate

✓Temporal pattern of pulses

✓ Few sound types



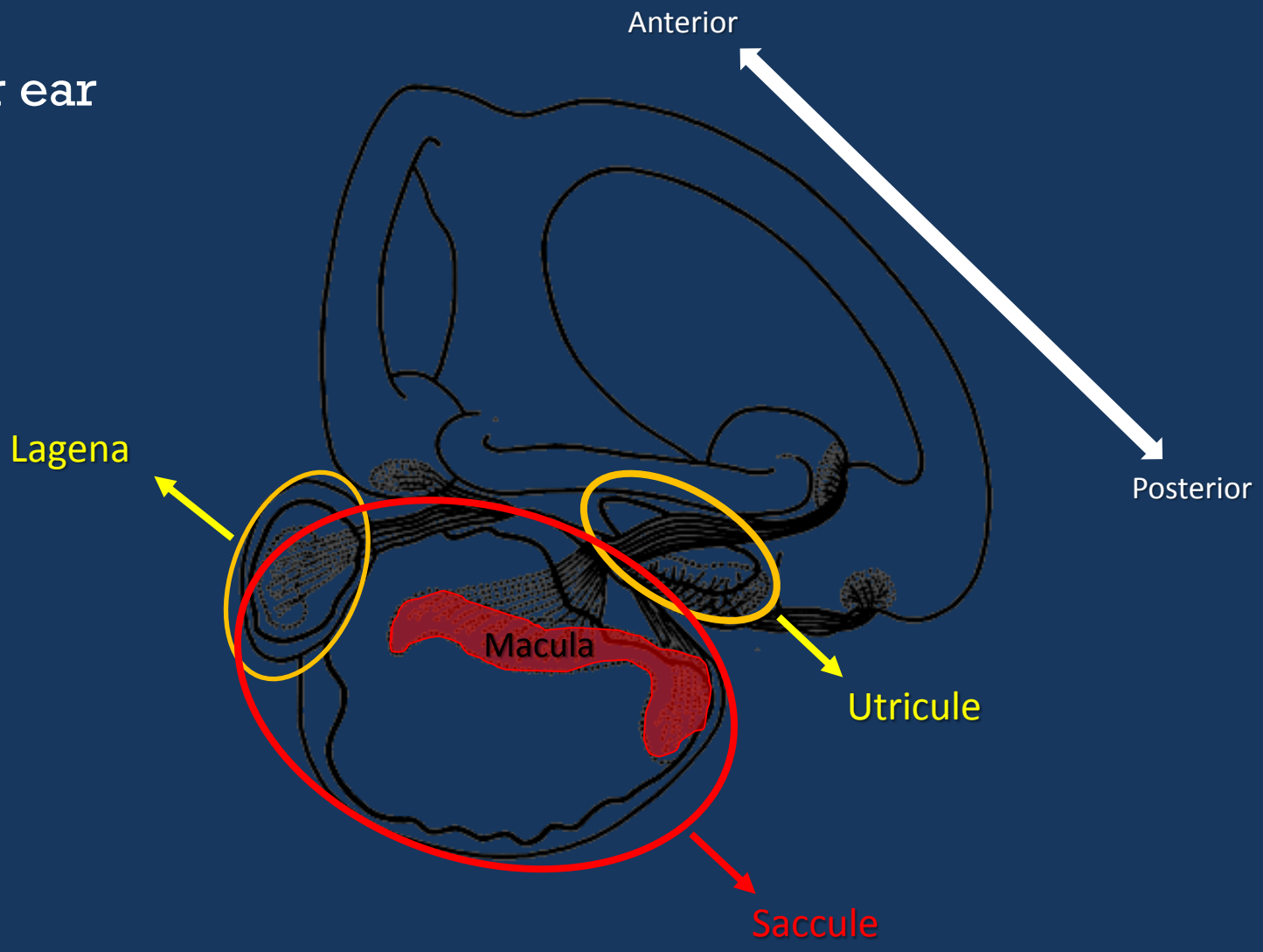
> 5 sound types

Lusitanian toadfish
Halobatrachus didactylus
(Batrachoididae)

Amorim et al. (2008)

4. Sound reception

Inner ear

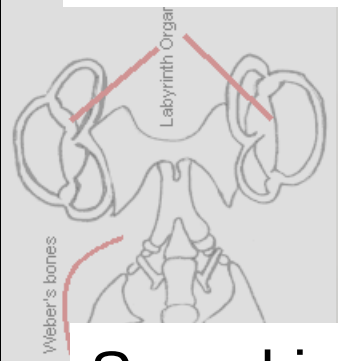


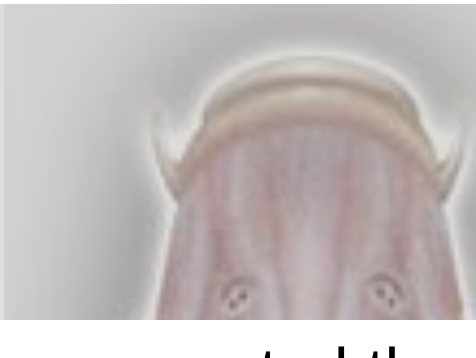
4. Sound reception

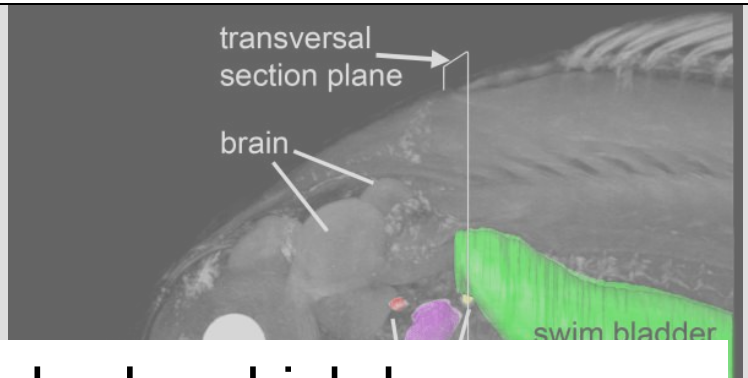
Sensory hair-cells - macula

Popper & Schilt (2008)

4. Sound reception



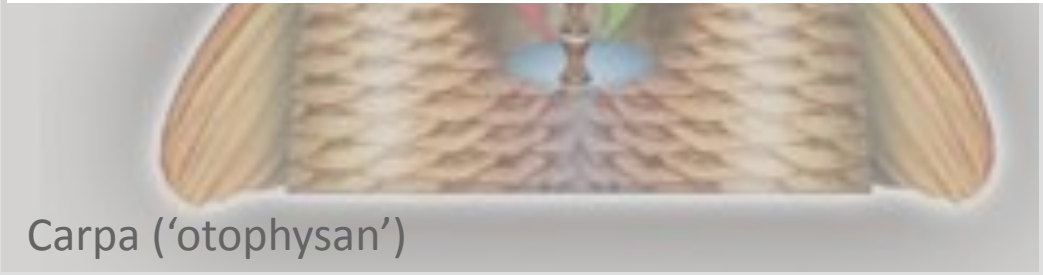




Sound is propagated through the fish body, which has a similar density to water and thus conduct a sound's vibratory motion through the body to the macula.

The otolith, has a 3-fold greater density than the surrounding tissue, and responds to sound vibration with a smaller amplitude and a phase lag.

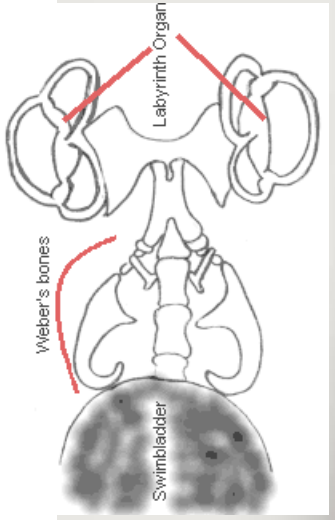
Schulz-Mirbach et al. 2013



Carpa ('otophysan')

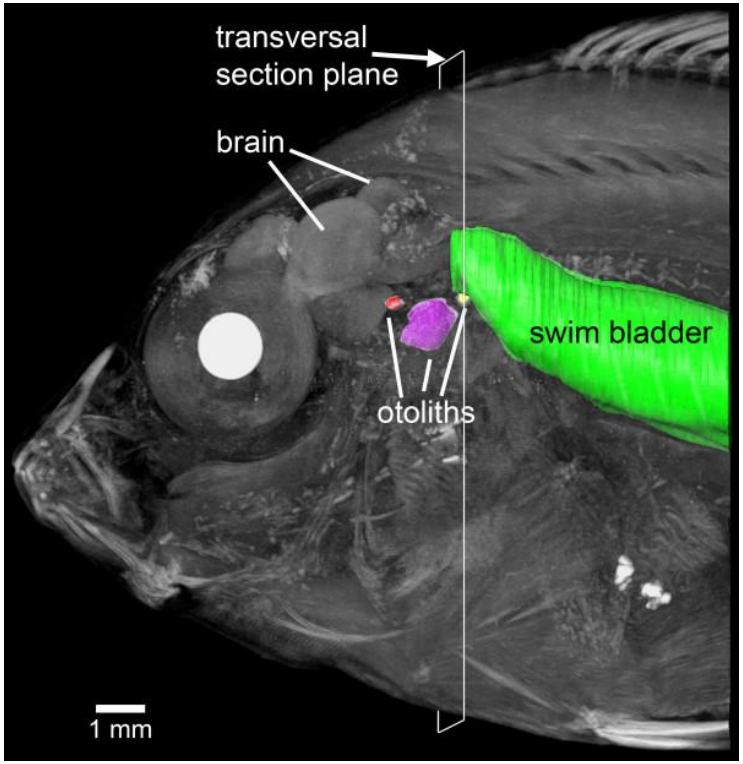
http://www.gofishing.co.uk/Angling-Times/Section/how-to/Coarse-fishing-advice/Fishing-Tips2/Fishing-Charts--Guides/Fish-ears/

4. Sound reception



Weberian ossicles

Carp ('otophysan')

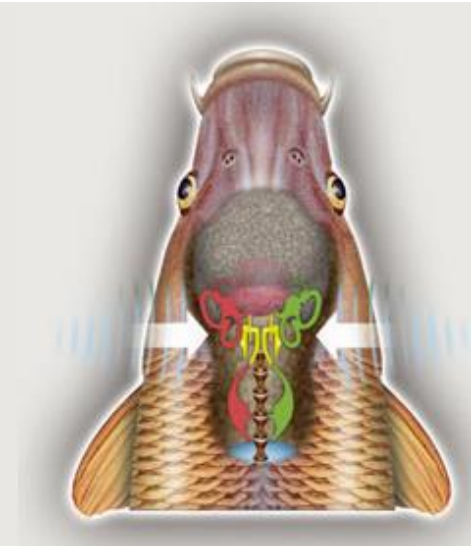


Asian cichlid *Etroplus maculatus*
SB close to the lagena
Schulz-Mirbach et al. (2013)

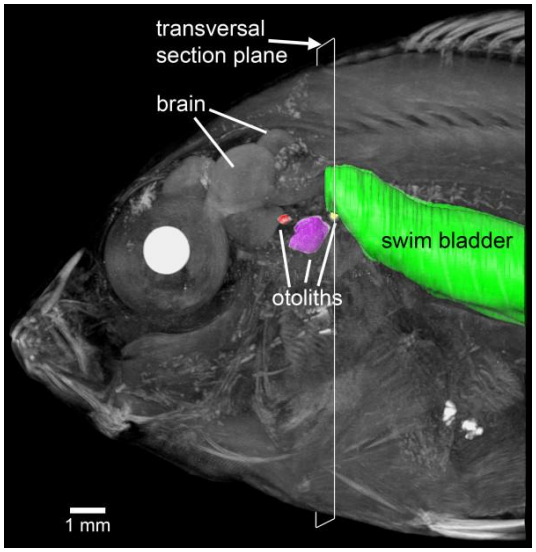
The swimbladder (or other air-filled structures) acts as pressure-to-displacement transducer when coupled with the inner ear.

4. Sound reception

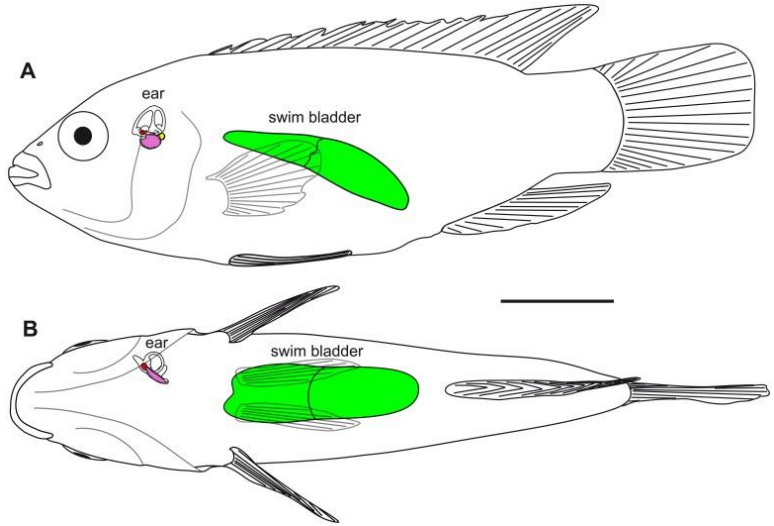
Specialists……. generalists



Carp



Asian cichlid *E. maculatus*



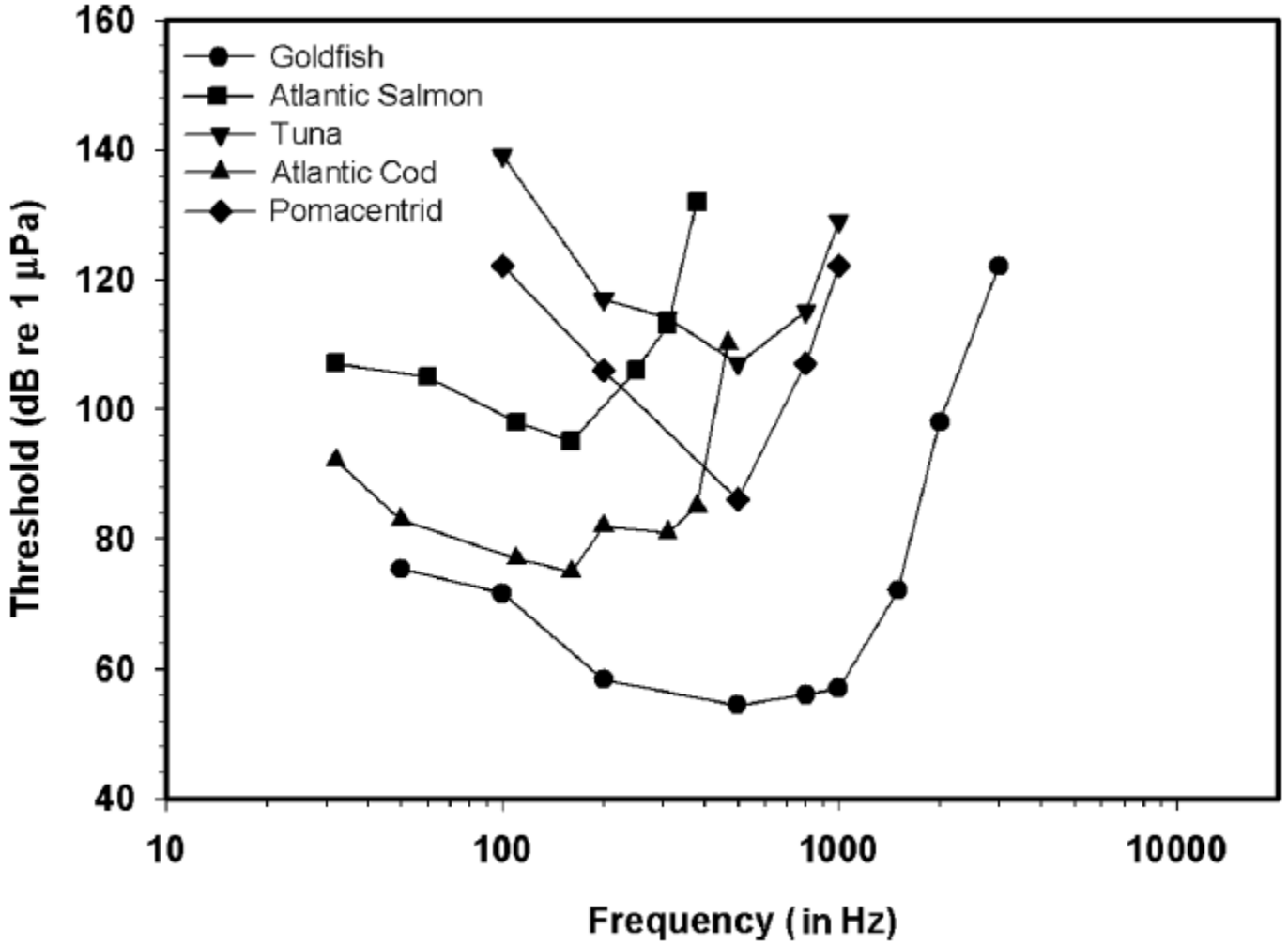
African cichlid *Hemichromis guttatus*

Schulz-Mirbach et al. (2012)

Fish with hearing specializations (pressure transductors) such as the **Weberian ossicles** or with the **SB in close proximity to the inner ear** can detect the **pressure** component of sound. Fish that lack such specialisations can only detect **particle motion**.

4. Sound reception

Audiograms



Popper et al. (2005)

5. Context of sound production

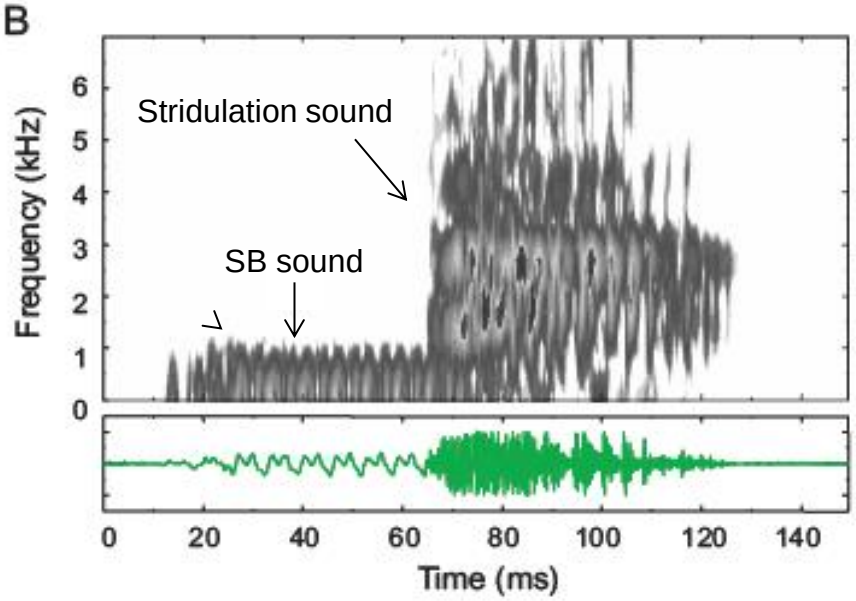
- **Alarm sounds** – presence of predators, distress
- **Aggressio**n – Fights, territorial defence, feeding competition
- **Reproduction –** mate attraction, courtship and spawning

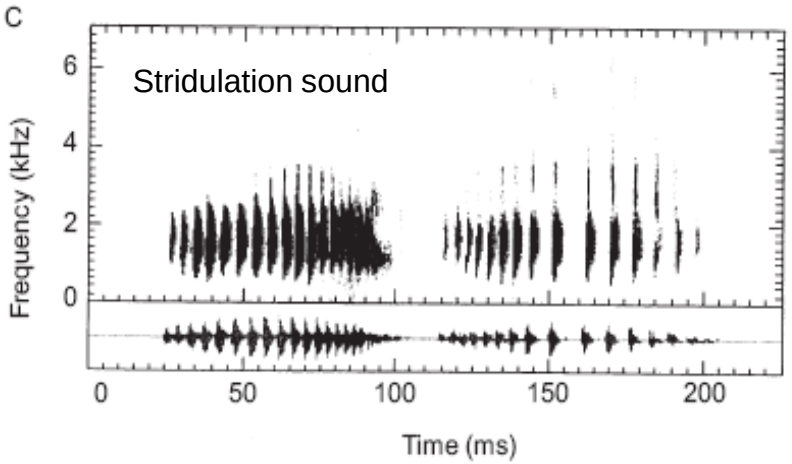
- **Alarm sounds** – presence of predators, distress

Catfishes make more stridulatory sounds in distress situations – when held in air

Pimelodus blochii (Pimelodidae)

Platydoras costatus (Doradidae)

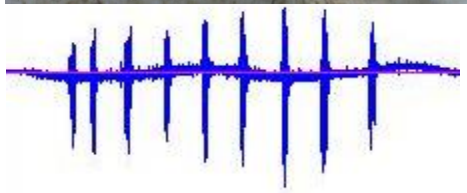


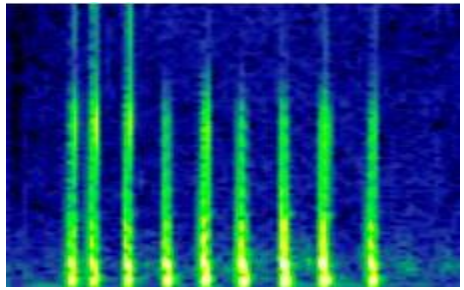


Ladich (1997)

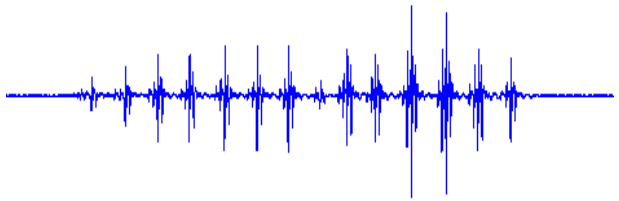
- **Alarm sounds** – presence of predators, distress

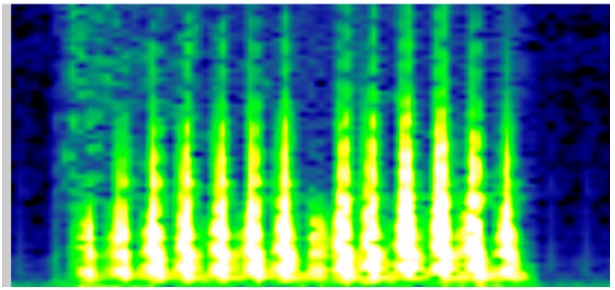
Lusitanian toadfish make distress SB sounds similar to agonistic sounds





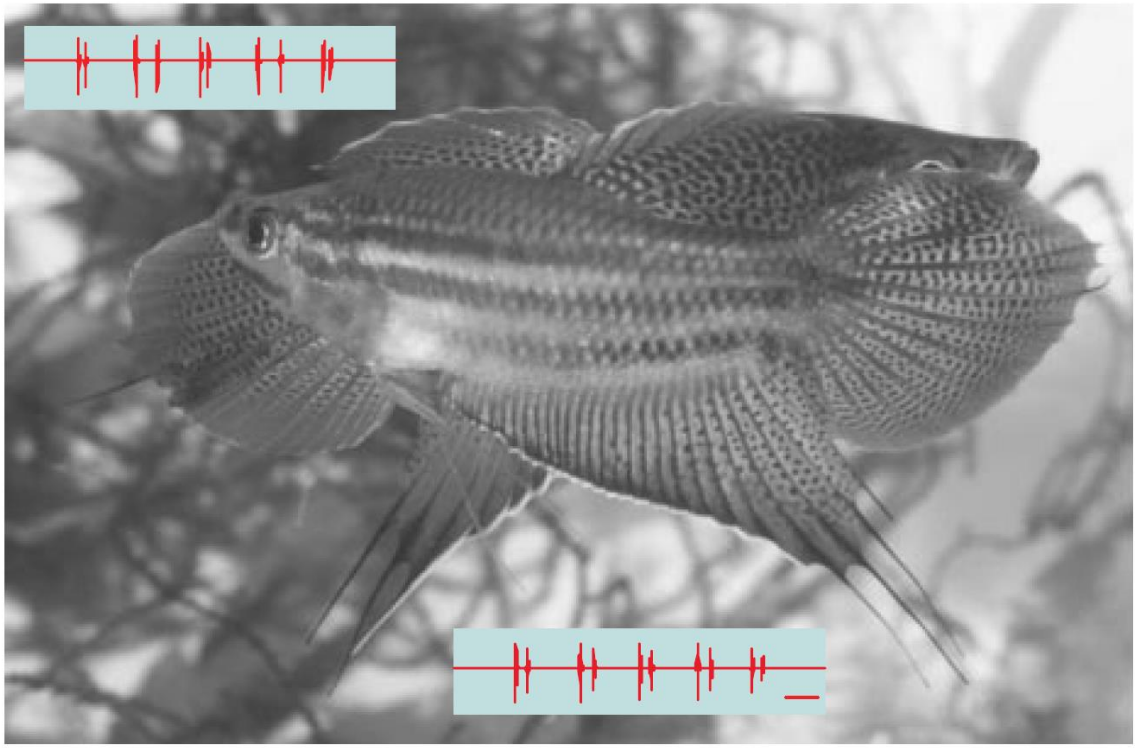
Grunt train - alarm





Grunt train - agonistic

- **Aggressio**n – Fights, territorial defence, feeding competition



When sizes are similar vocal males win more fights than silent (muted) males.

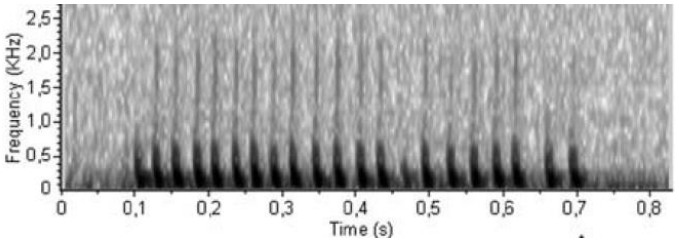
Larger males – make higher amplitude and lower frequency sounds

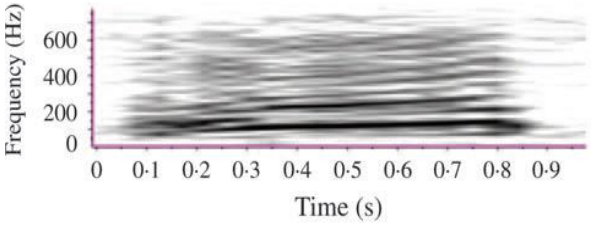
Croaking gourami *Trichopsis vittata* (family Osphronemidae).

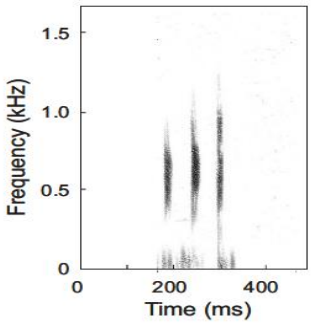
Ladich et al. (1992)

- **Aggressio**n – Fights, territorial defence, feeding competition

Agonistic sounds function as territorial deterrents







Painted goby
Pomastoschistus pictus
(Gobiidae)

Pereira et al.(2014)

Lusitanian toadfish
Halobatrachus didactylus
(Batrachoididae)

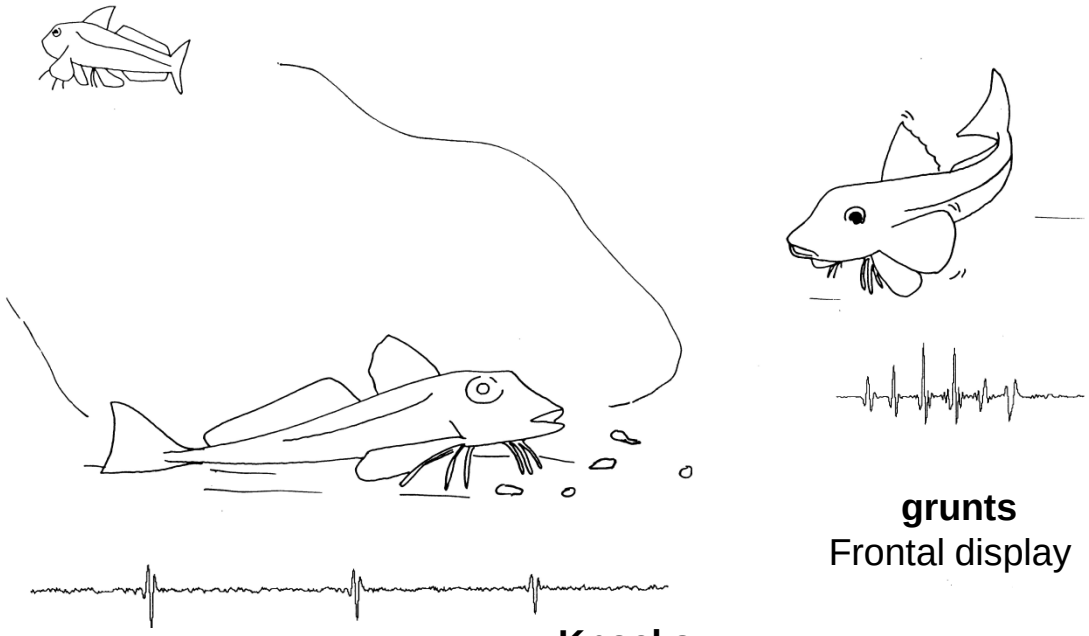
Conti et al. (2015)

Bicolor damselfish
Stegastes partitus
(Pomacentridae)

Myrberg (1997)

- **Aggressio**n – territorial defence, feeding competition

Eutrigla gurnardus (Triglidae)

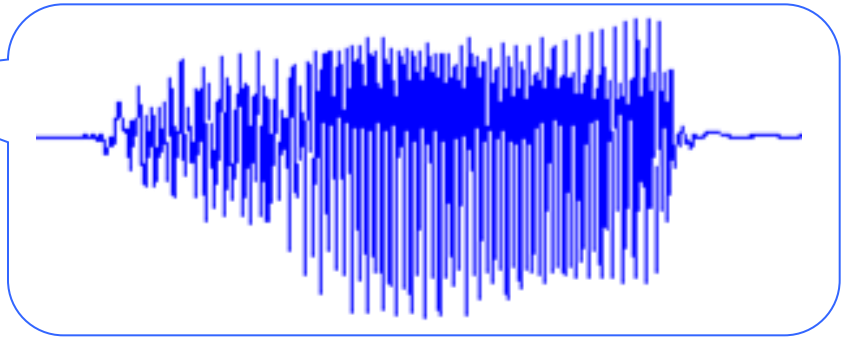


grunts
Frontal display

Knocks
Grasping food and fleeing

Amorim et al. (2004). J. Fish Biol. 65: 182-194**.**

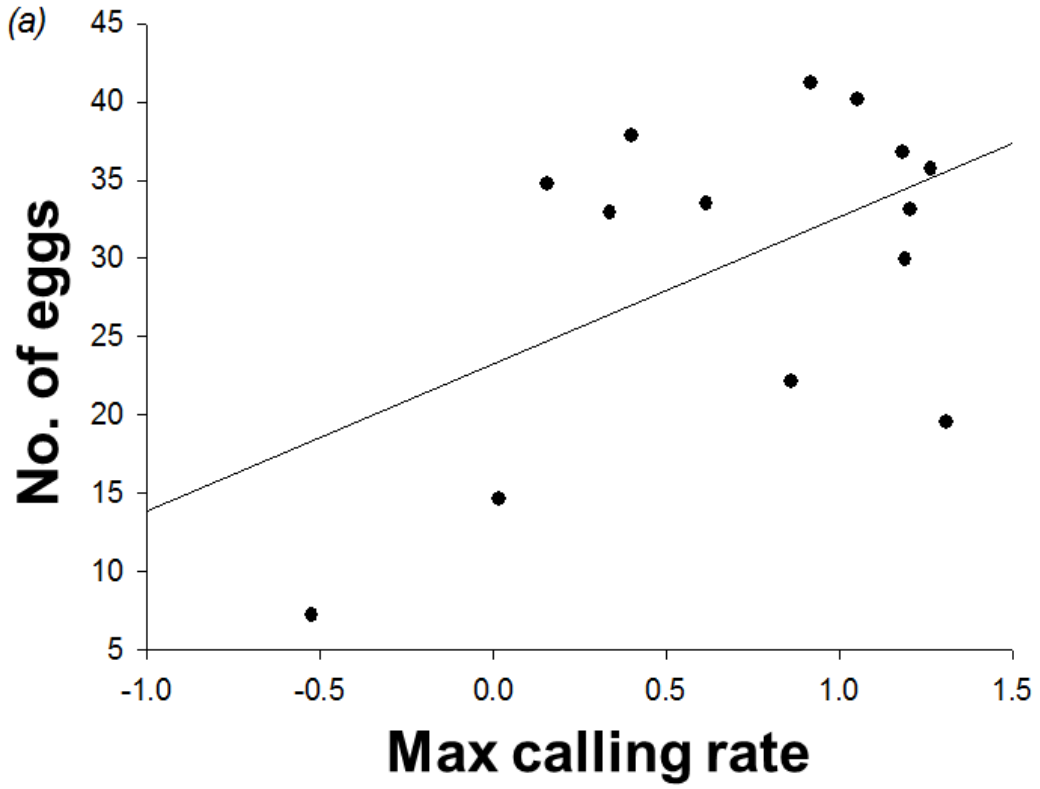
- **Reproduction** – mate attraction, courtship and spawning



Lusitanian toadfish males *Halobatrachus didactylus, produce* boatwhistle in chorusses to attract females to mate with

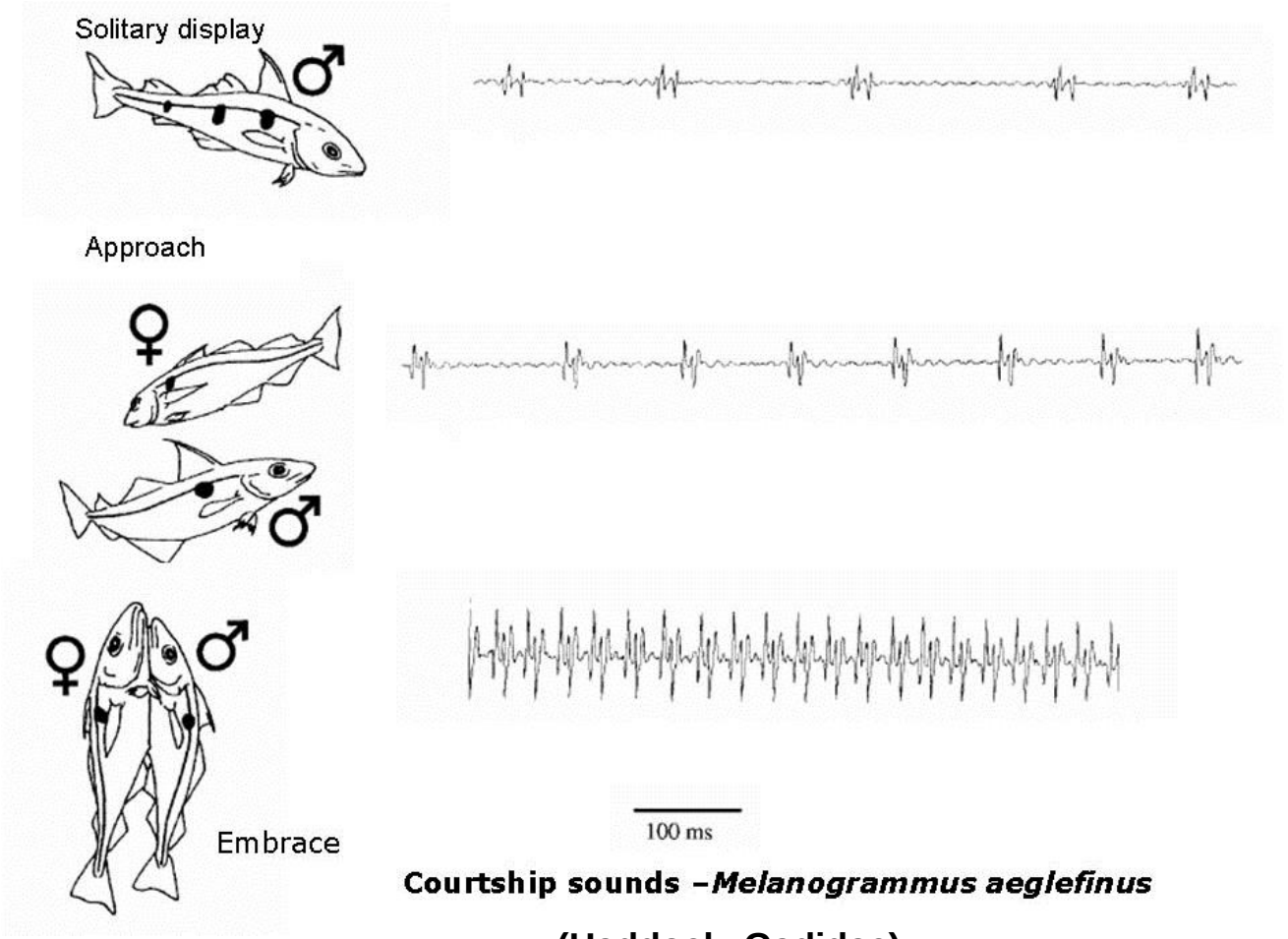
- **Reproduction** – mate attraction, courtship and spawning

In the lusitanian toadfish calling activity influences male reproductive success



Vasconcelos et al. (2012)
Amorim et al. (in press)

- **Reproduction** – mate attraction, courtship and spawning



Courtship sounds –*Melanogrammus aeglefinus*

(Haddock, Gadidae)

Hawkins & Amorim (2000)

Take home message

- Many teleost fish are vocal.
- Sonic mechanisms are extremely diversified and include swimbladder and stridulatory mechanisms.
- Sounds are usually pulsed, short and broadband (<1 kHz), but some fish produce tonal sounds.
- Fish detect particle motion with the inner ear and hear up to 1 kHz but many species detect pressure and hear up to several kHz.
- Acoustic signals are produced during distress situations and social interactions and are important to gain access to limited resources such as food, territories or mates.