



AQUAculture infrastructures
for EXCELlence in European
fish research 3.0



AEFishBIT: A Smart Device for Monitoring Fish Health and Welfare

Sustainable approaches to inland aquaculture and fisheries – advances in novel technologies

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871108 (AQUAEXCEL3.0). This output reflects only the author's view and the European Commission cannot be held responsible for any use that may be made of the information contained therein.

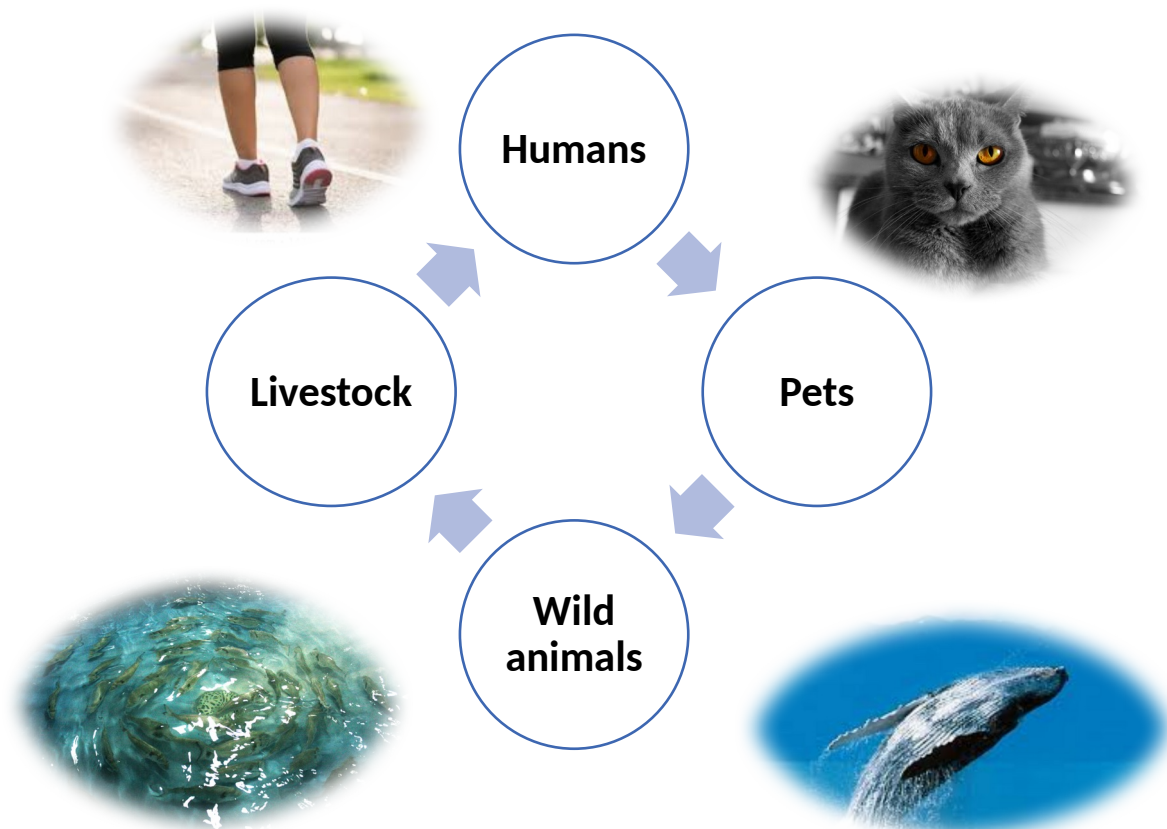


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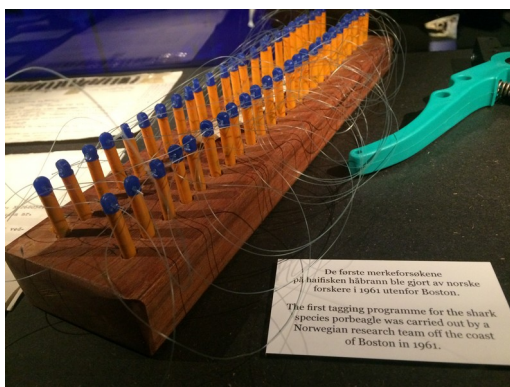
BIOSENSORS

- Activity patterns
- Feeding behaviour
- Metabolic scope
- Welfare condition
- Biological age



WILD FISH MONITORING

- First tagging programme of Shark species – Norwegian team, Boston coasts 1961
- Learning Atlantic salmon in Greenland- SATELLITE TAGS-
NOAA FISHERIES 2018
- Tracking ocean migration of salmon from rivers of Canada, Norway, Denmark, Ireland and Spain –
SeaSalar Project-
Strøm et al., 2019 Scientific Reports



FISH FARMING MONITORING

THE OBSERVATION OF FISH BEHAVIOUR AND MOVEMENTS THROUGH PRODUCTION CYCLE IS VITAL TO KNOW HOW FISH PERCEIVE AND INTERACT WITH THE ENVIRONMENT



ACOUSTIC TELEMETRY TRANSMITTERS

TYPE OF MEASURE: pressure, temperature, activity,....

ADVANTAGES: real time transmission (some delay- no control of a given process)

LIMITATIONS: size, weight



Storage & transmitter loggers



STAR:ODDI Ltd, Iceland

- Weight 3.3- 19 g
- Farm & Lab scale
- **Big fish > 500 g**
- **Internal attachment**
- Data post-processing
- Logger recovery
- Battery life 3-19 months
- Commercially available



THELMABIOTEL, NORWAY

- Weight 2.4-14 g
- Farm & Lab scale
- **Big fish > 500 g**
- **Internal attachment**
- Acoustic transmitters
- Data post-processing
- Battery life 2-10 months
- Commercially available



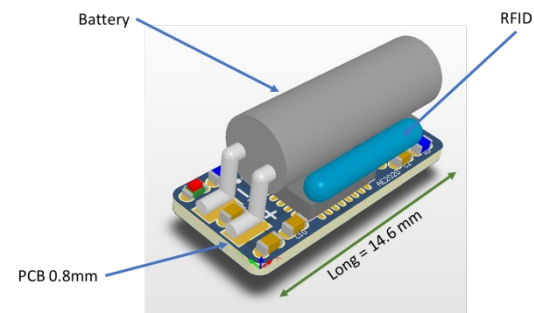
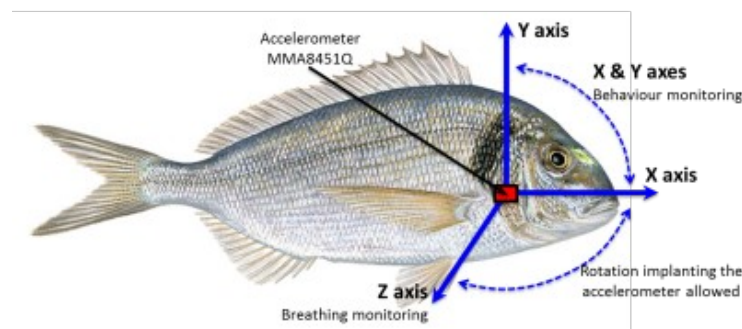
AEFishBIT

- Weight 1 g
- Laboratory scale
- **Small fish (50-500 g)**
- **External attachment-fast recovery**, 2-10 h
- On board algorithms (no data post-processing)
- Logger recovery
- Battery life 2-10 days
- Registered patent



AEFishBIT prototype

- **Triaxial accelerometer** externally attached to the operculum
- **Registers at the same time** breathing frequency and physical activity
- **Reusable device** (5 uses on average)
- **Basic operative mode:** stand-alone
- **Autonomy:** 6 h of continuous re-programmable recording (2 min window each 15 min, 2 days)



AEFISHBIT ON IMAGES

<https://vimeo.com/325943543>



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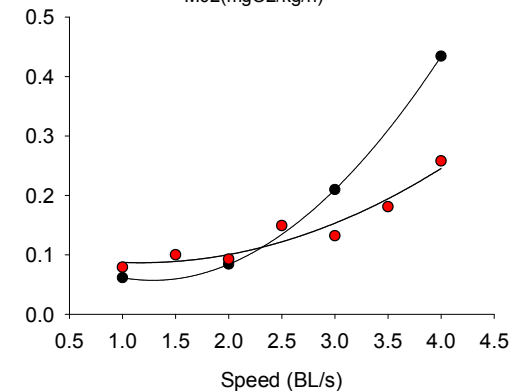
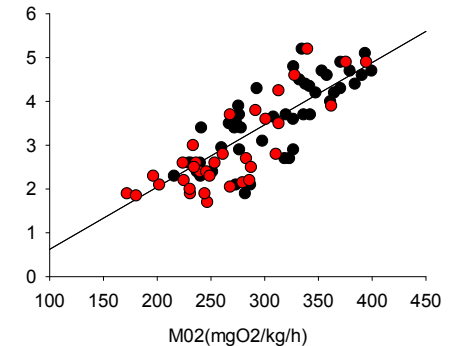
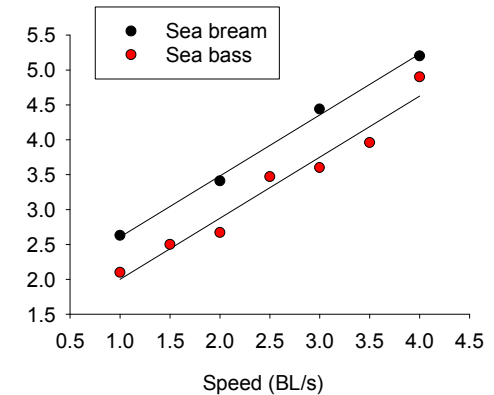
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Validation in swimming tunnel



- **GILL BREATHING** increases linearly with the increase of swimming speed in sea bream and sea bass
- **GILL BREATHING** is of the same order for a given **O₂ CONSUMPTION** in the two species
- **JERK ACCELERATIONS** follow a less pronounced exponential increase in sea bass



AEFishBIT OUTPUTS

REINFORCES Inter-species DIFFERENCES IN LOCOMOTOR CAPABILITIES



Sea bream



Figure 1. European seabass (photo: S. Kaushik).

Sea bass “ typical predator”

SPINDLE-SHAPED BODY

Larger OPERCULUM APERTURE

More regular BODY TAIL MOVEMENTS at medium/high speed

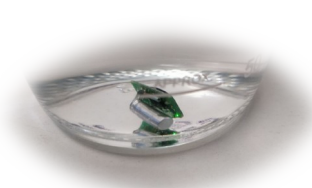
“Characteristic Features of a FAST SWIMMING PREDATOR”



AEFishBIT-FUNCTIONAL VALIDATION



- **IMPACT OF TAGGING**
 - **PHYSIOLOGICAL RESPONSE** in free-swimming SEA BREAM AND SEA BASS under different culture conditions



DEVICE TAGGING IMPACT

Observations of tissue damage, feeding behavior and growth performance reveal **NO NEGATIVE IMPACT OF TAGGING ON** 100-200 g fish 1-3 WEEKS AFTER TAGGING



Growth test (10 days) -> FCR=1.0-1.1

	with device	without device
Initial BW (g)	263 ± 6.9	259 ± 8.9
Final BW (g)	294 ± 7.4	291 ± 9.7
SGR (%)	1.14 ± 0.03	1.19 ± 0.04

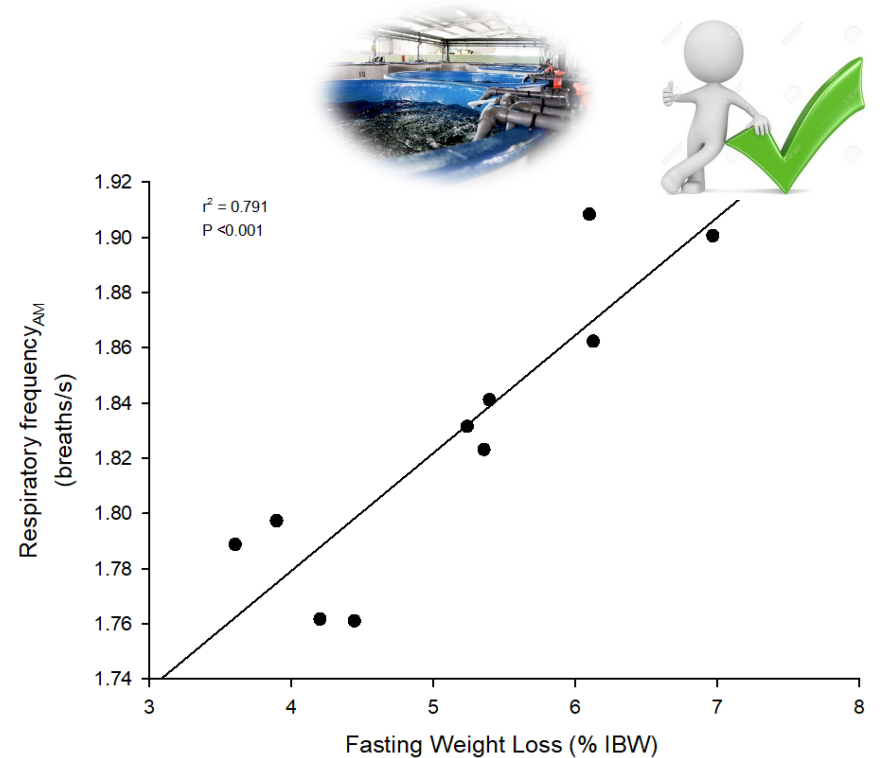


Photo: Xènia Pérez Sitjà



VALIDATION of On-board ALGORITHMS- Free swimming fish

- **Fasting Weigh Loss (7-days)** in free-swimming fish is positively correlated with Respiratory frequency- reliable measure of **ENERGY COST OF GROWTH AND MAINTENANCE**



PHYSICAL ACTIVITY AND RESPIRATION ARE SYNCHRONIZED in SEA BREAM but not in SEA BASS

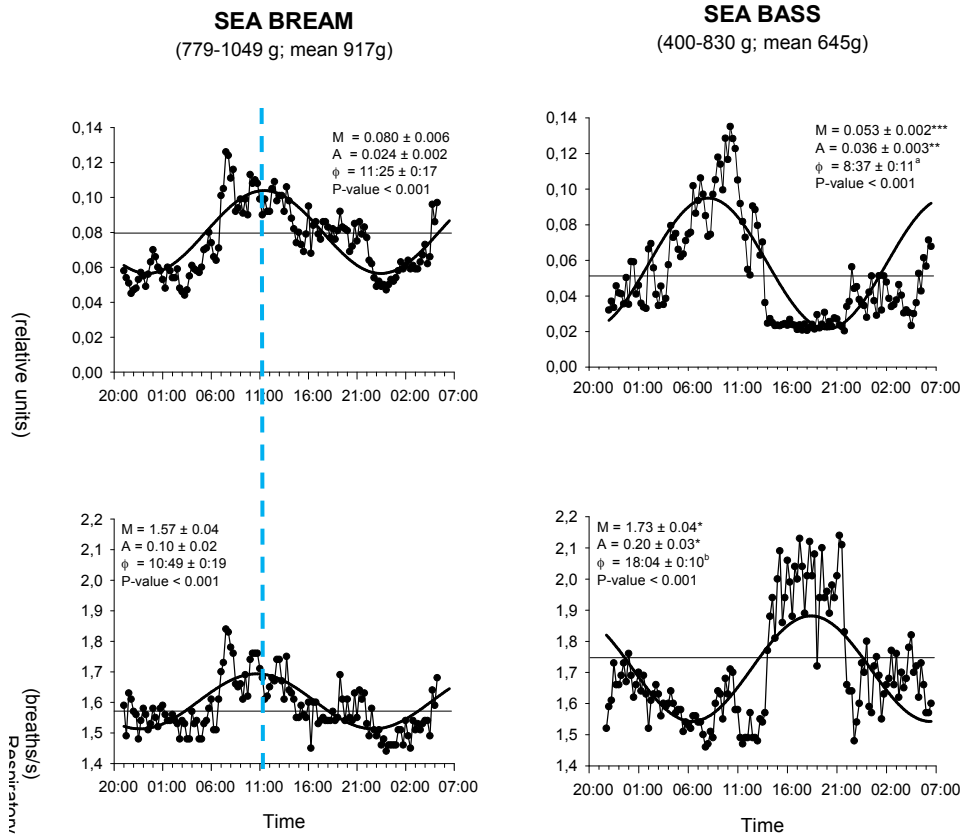
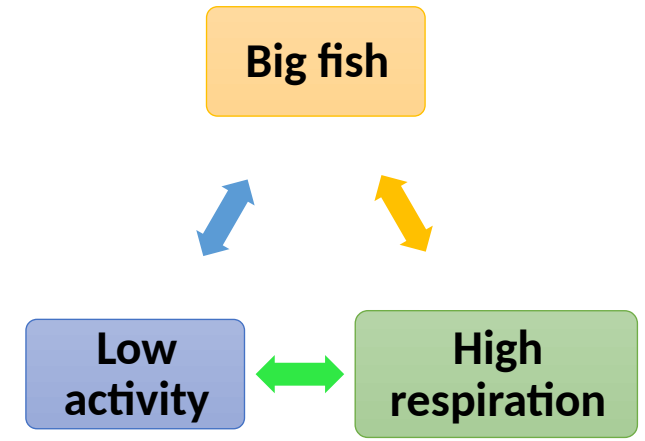


Figure 1. European seabass (photo: S. Kaushik).

Correlation Analysis



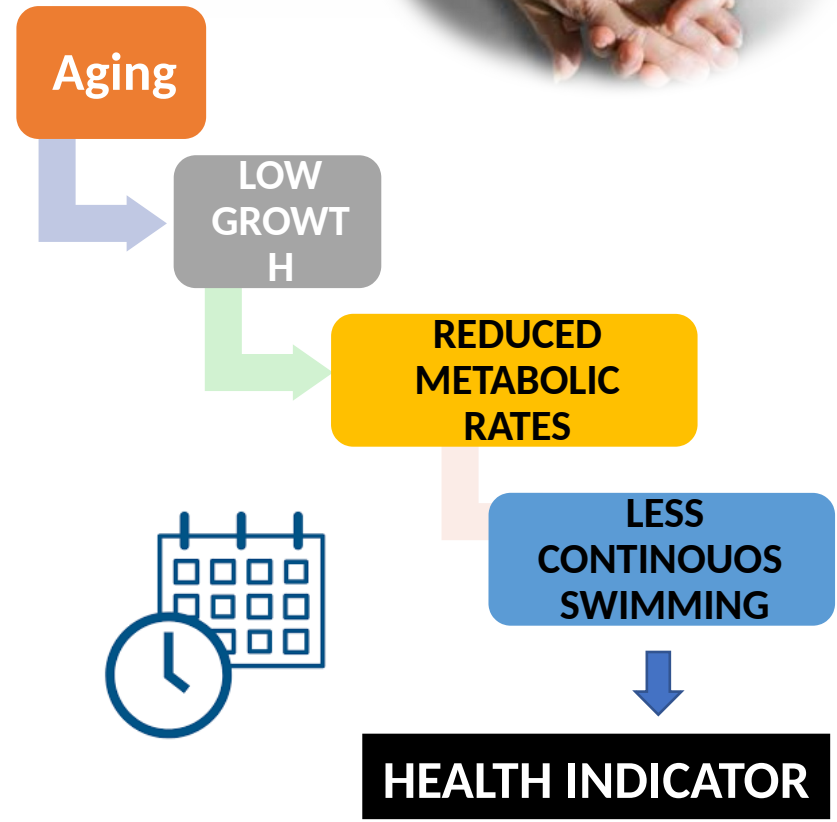
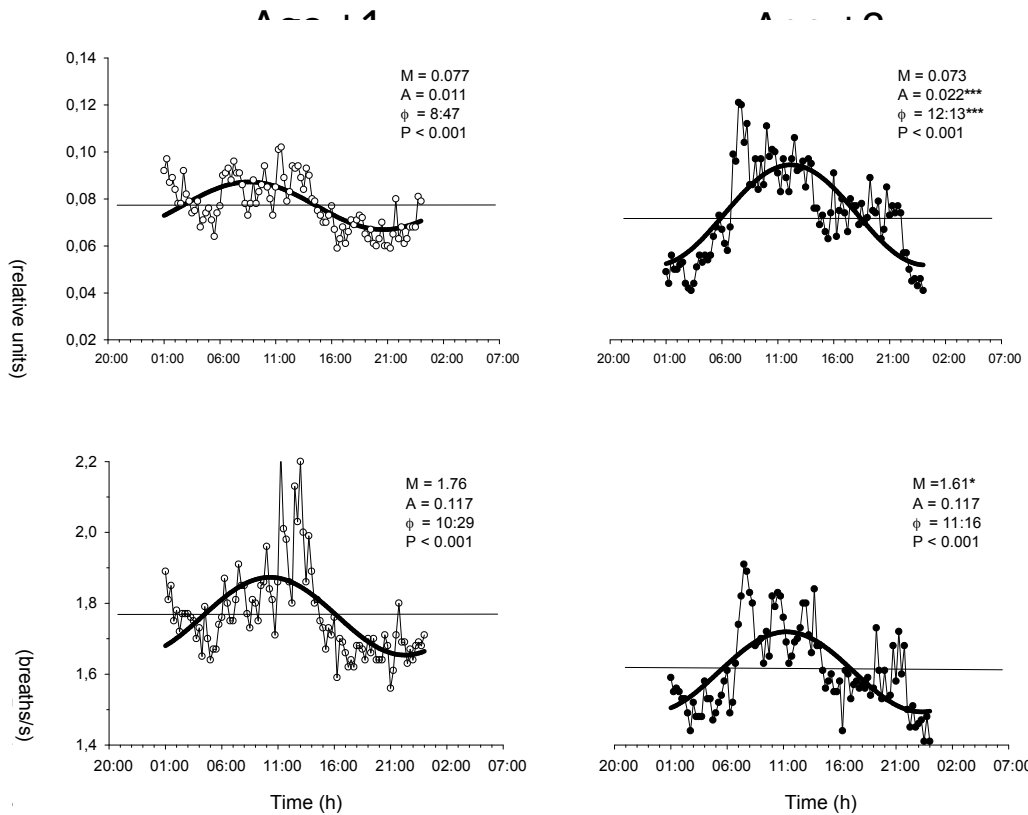
High metabolic rates for growth and maintenance are associated with **SLOW SWIMMING** and **improved FCR** -SELECTIVE BREEDING-

Different contribution of **aerobic and anaerobic metabolism** to growth and locomotor activity



TRACKING BIOLOGICAL AGE

Measurements of accelerations and respiratory frequency reveal **age-related changes** in BASAL METABOLISM AND FEEDING BEHAVIOUR



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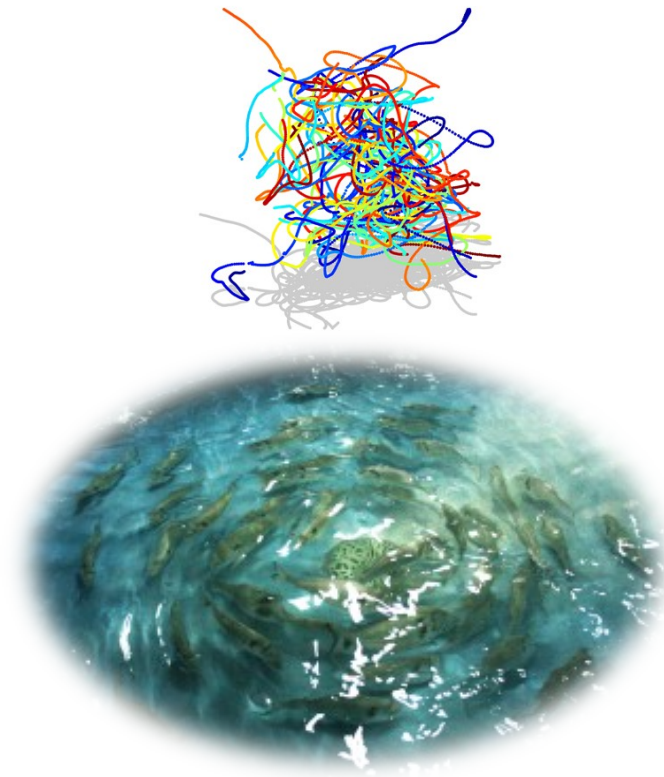
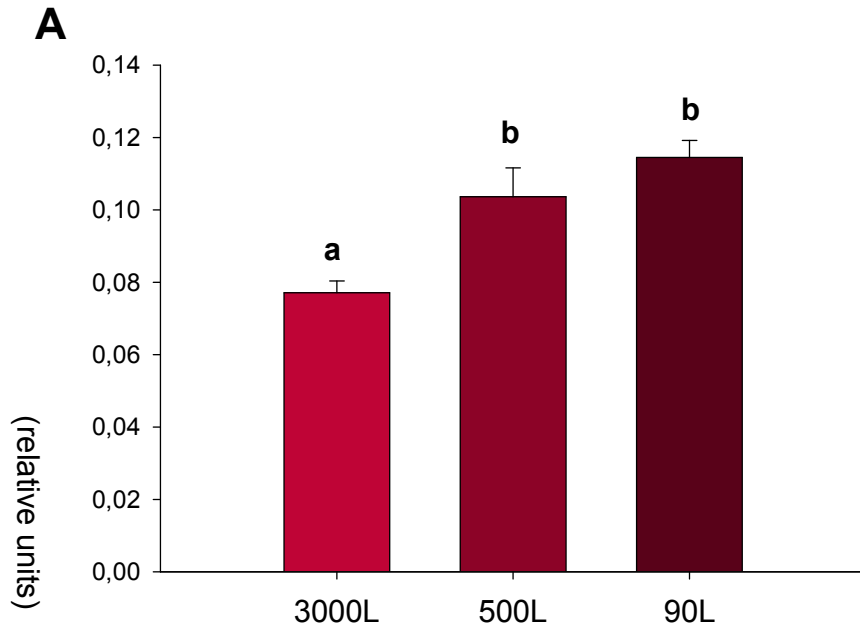


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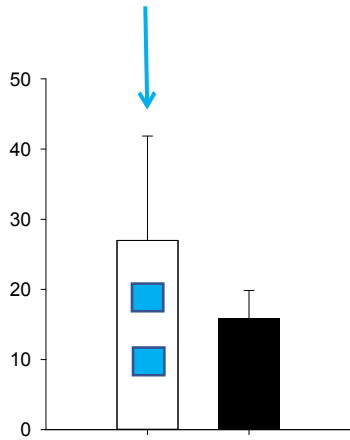
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TANK SIZE- Space Availability

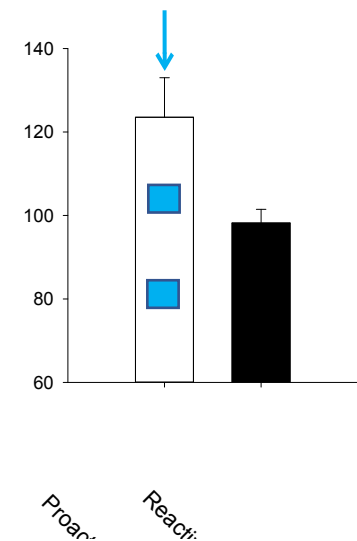
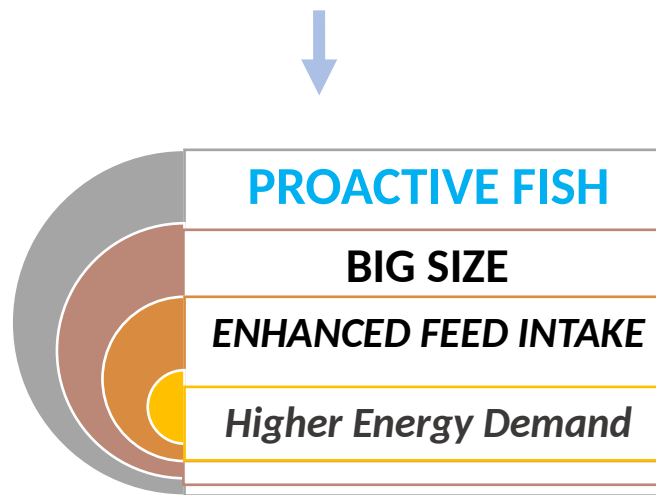
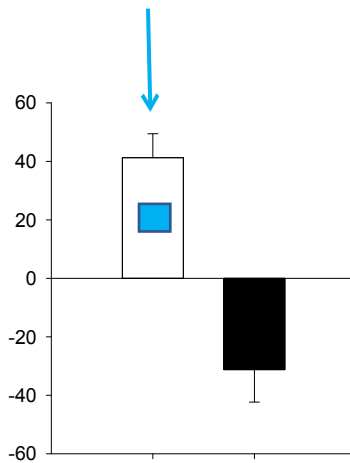
As the TANK SIZE SHRINKS, fish accelerations increase with the **CONTINUOUS CHANGES OF DIRECTION- RESULTING IN AN INCREASED ENERGY DEMAND- “MORE STRICT CRITERIA of WELFARE for a more sustainable and ethical aquaculture production”**



PROACTIVE/REACTIVE FISH-Hypoxia test

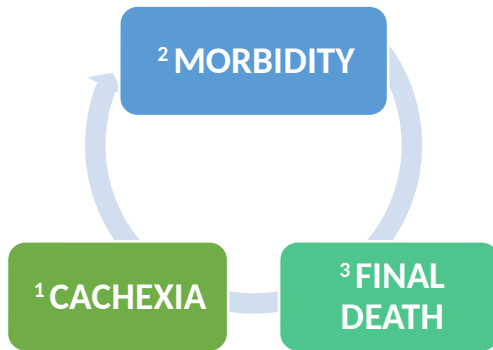


- **HYPOXIA TEST: 2-3 ppm by 2.5 hours**
- ❖ **ALL FISH INCREASE RESPIRATORY FREQUENCY**
- ❖ **TWO DIFFERENT LOCOMOTOR RESPONSES**
 - **REACTIVE FISH-Reduced activity** (reduced O₂ demand)
 - **PROACTIVE FISH-Increased activity** (escape reaction)

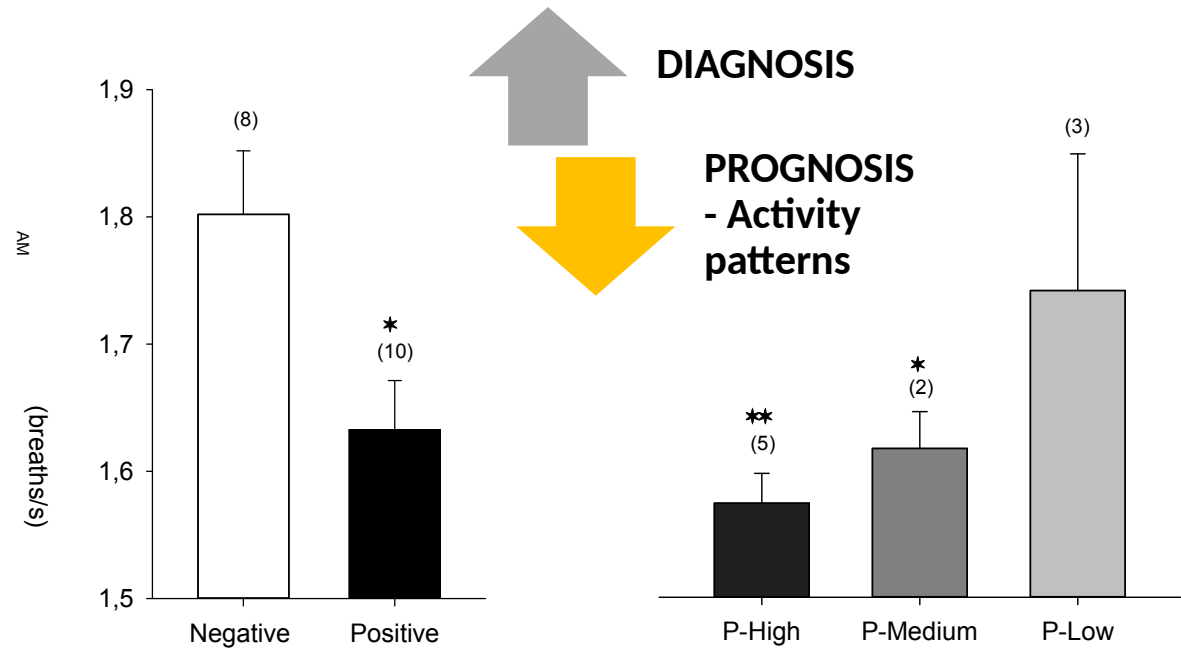


DISEASE OUTCOME-

Enteric parasite “*Enteromyxum leei*”



ParaFishControl

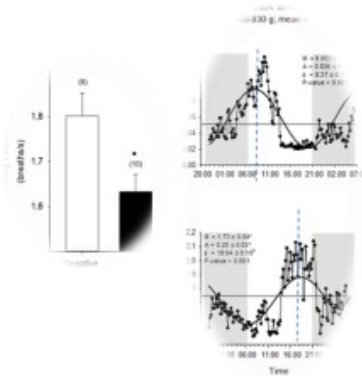


PROGRESSION OF DISEASES IS ASSOCIATED WITH
**A REDUCED RESPIRATION AND ENERGY
DEMAND FOR GROWTH**



AEFishBIT: Functional evaluation

Sea bream monitoring



**Increased fasting susceptibility
(high metabolic rate)**

Advancing age

**Proactive fish
(Severe hypoxia test)**

Reduced space availability

Advanced disease progression

AEFishBIT measurements

**Respiratory
frequency**





**Physical
activity**

Low amplitude
rhythm



AEFishBIT tagging

- **Metallic clip + polyethylene ring**
 - **Sea Bass & Sea Bream**
 - Fast tagging (< 30 s)
 - High retention (> 90%)
 - Normal behaviour
 - No damage on operculum & gill lamellae 10 days post-tagging
 - No growth impairment 10 days post-tagging

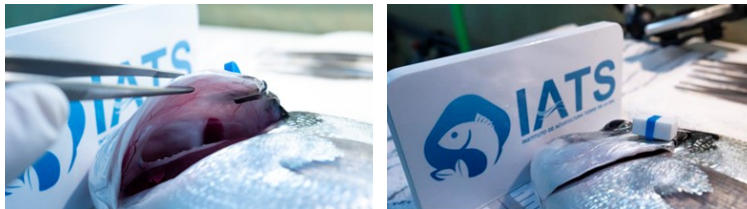


Photo: Xònia Pérez Sijà

- **Surgery intervention**
 - **Atlantic salmon, rainbow trout**
 - Laborious tagging (> 4-5 min)
 - Normal behaviour
 - No damage on operculum & gill lamellae 7 days post-tagging

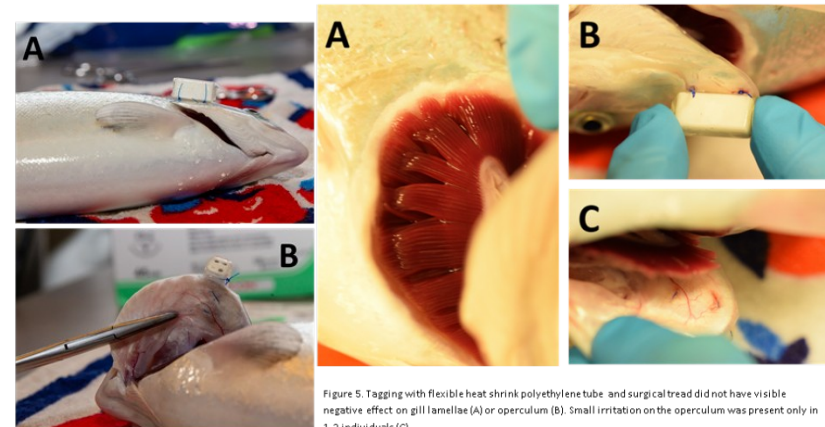


Figure 5. Tagging with flexible heat shrink polyethylene tube and surgical thread did not have visible negative effect on gill lamellae (A) or operculum (B). Small irritation on the operculum was present only in 1-2 individuals (C).

Figure 1. AEFishBIT tag placed in the polyethylene tube and is sutured to Atlantic salmon operculum

AEFishBIT tagging

Gilthead sea bream



Rainbow trout

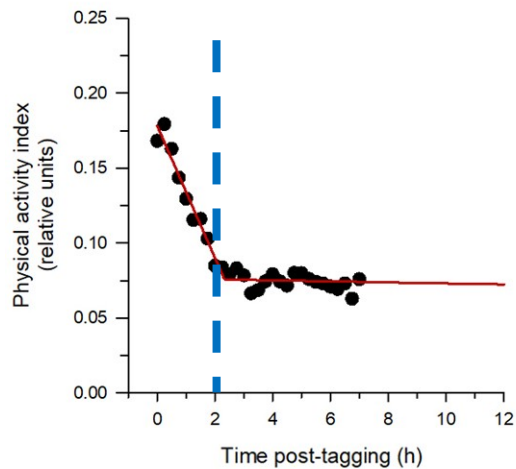


Atlantic salmon

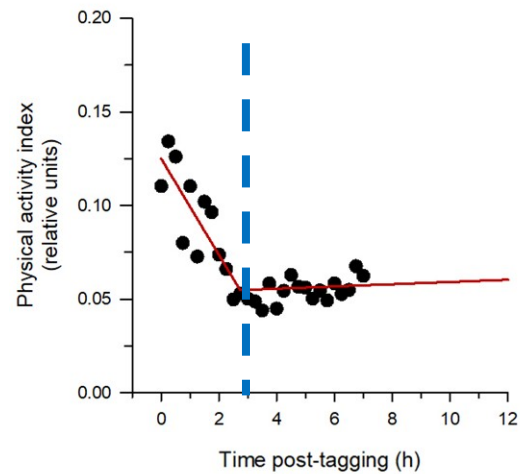


AEFishBIT tagging

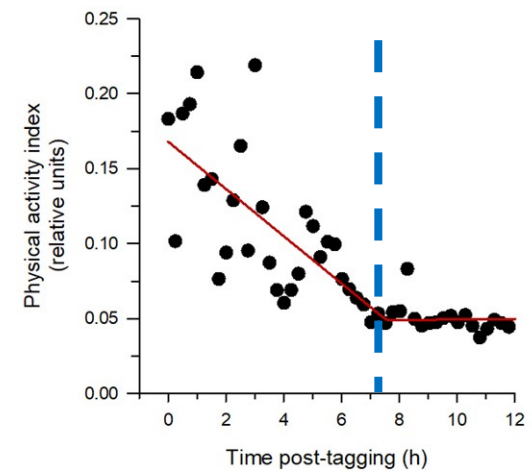
Gilthead sea bream



Rainbow trout

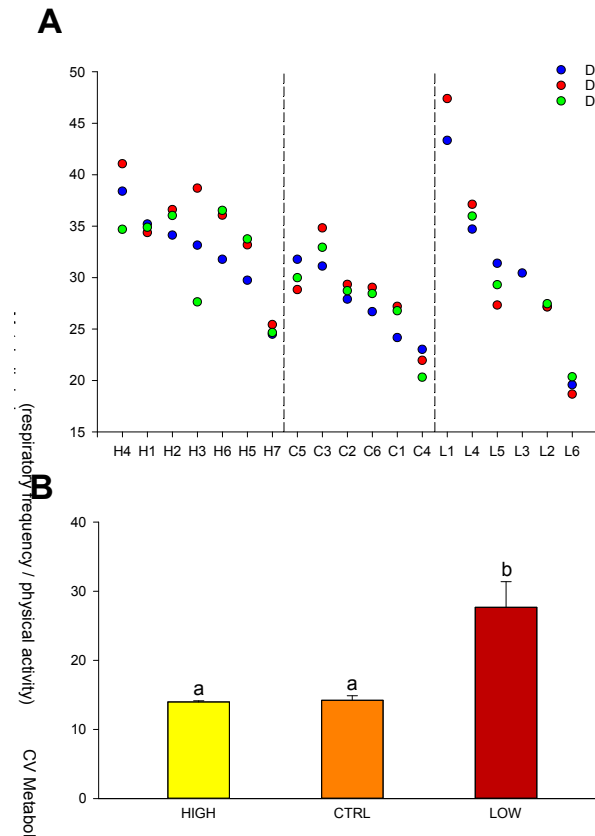


Atlantic salmon



Lighting regimes- Atlantic salmon post-smolt

Measurements of
metabolic score
(respiratory frequency
/activity) highlights
increased individual
variability after transfer to
low lighting regime -
Welfare indicator



Functional evaluation across salmonid and non-salmonid fish

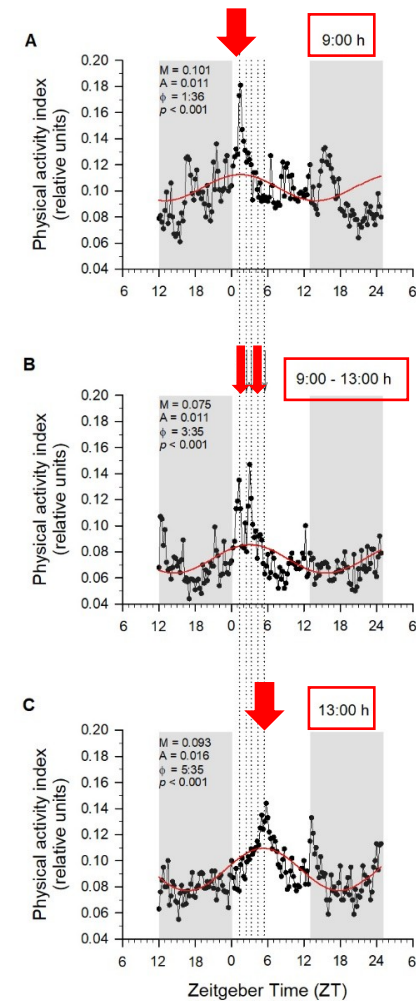


- Changes in **the amplitude and frequency** of operculum and body tail movements reflect fish species differences in swimming capabilities
- Fish species differences in **growth performance** are supported by changes in energy partitioning between growth and locomotor activity
- **Continuous light and feeding regimes** contribute to suppress daily metabolic rhythms across species

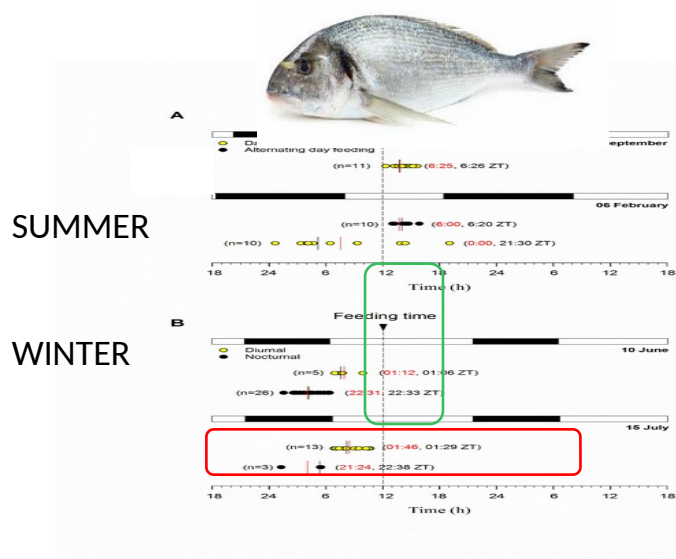


Activity synchronization

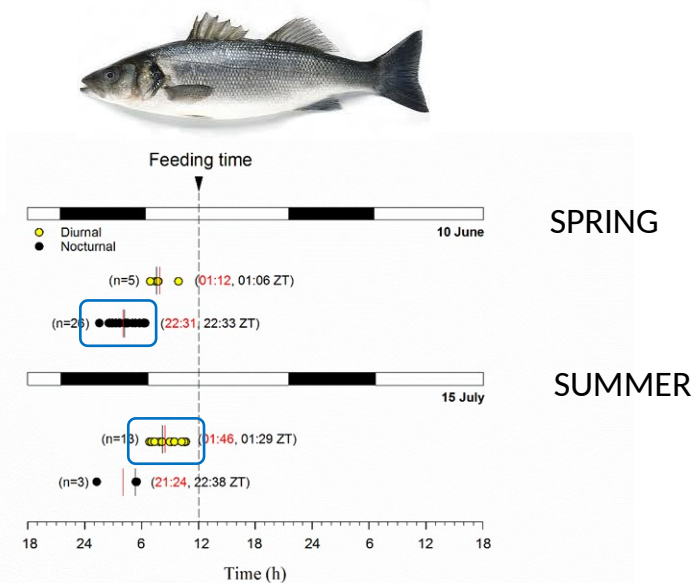
- Physical activity peak close to programmed feeding times.
- Feeding schedules as synchronizing agents of physical activity and metabolic rhythms.



Seasonal behaviour

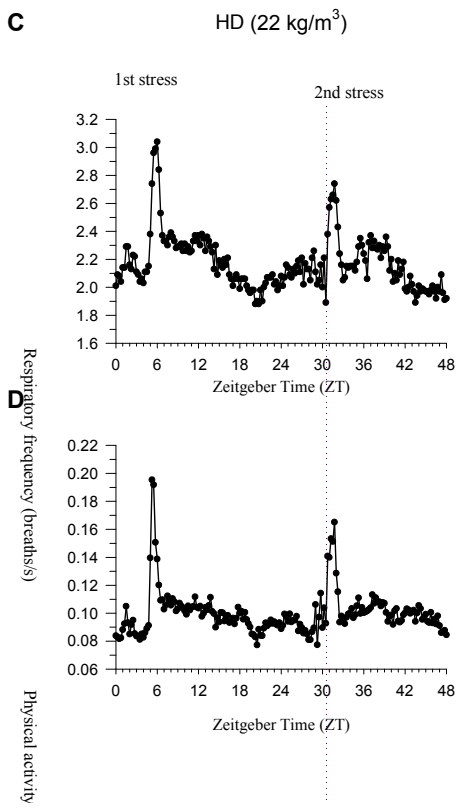
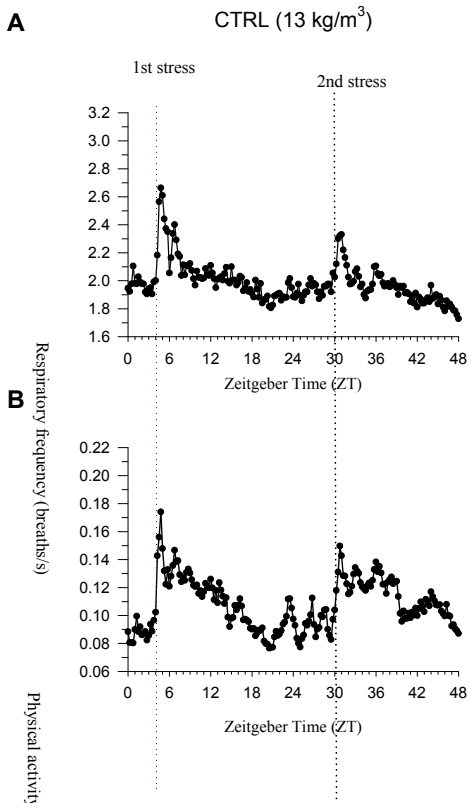


- Synchronicity is restored (summer behavior) with the change of feeding schedules.

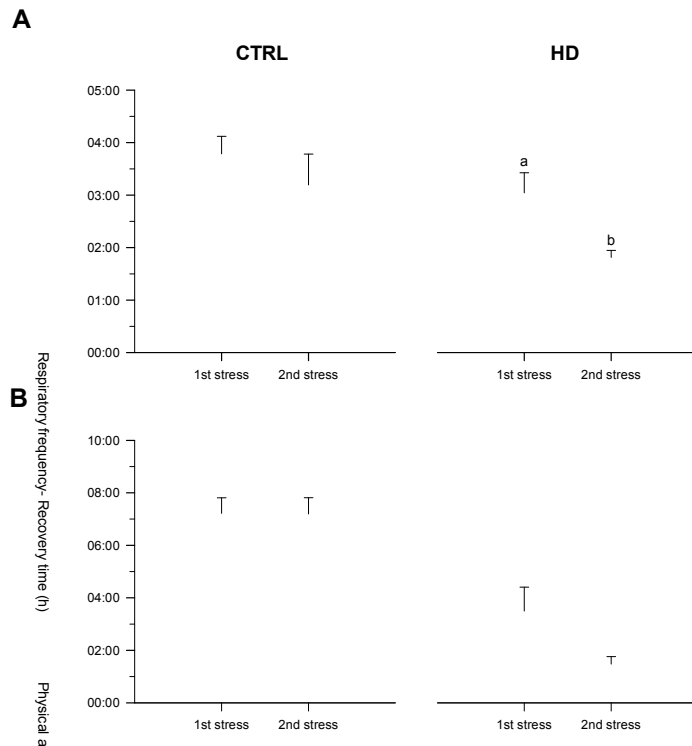


- Feeding time does not act as an activity synchronizer.

Sea bream Behaviour Monitoring after compression of fish cultured at TWO different densities



Sea bream Behaviour Monitoring after compression of fish cultured at TWO different densities



- The magnitude of changes is similar in CTRL and HD fish, **BUT HD fish** showed a **shortened recovery time** after repetitive fish compression test
- This feature is indicative of a **real adaptive condition** to high rearing density

Main outcomes



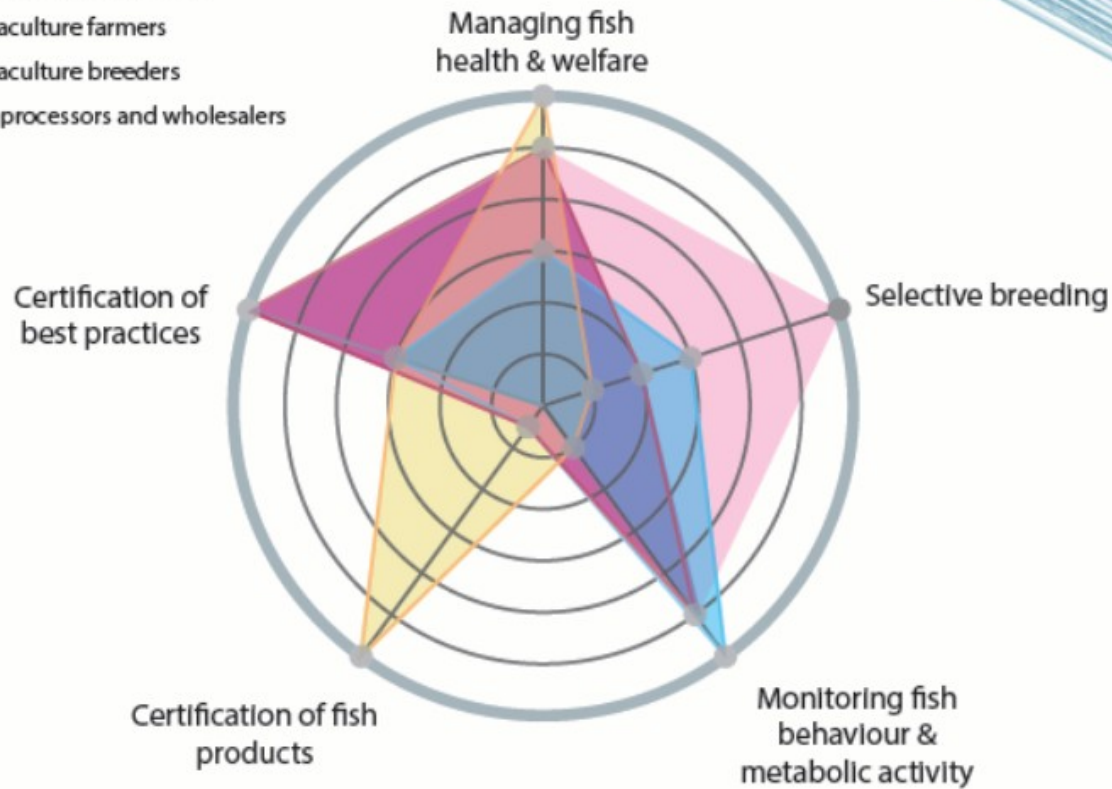
- AEFishBIT is a reliable tool for remote and individual sensing of fish behaviour and metabolic status in salmonids and non-salmonid farmed fish
- Device tagging is a fish species specific procedure
- Patterns arising from AEFishBIT measurements helps to detect changes in growth performance and stress and disease resilience
- Respiratory frequency acts as an indirect measure of basal metabolism and growth potential
- Ratio between respiratory frequency and physical activity is considered a metabolic index that informs about the adaptation to changing conditions
- Capacity to synchronize activity is informative of the adaptive potential



TAKE MESSAGE TO HOME

TO WHOM IT MATTERS

- Aquaculture researchers
- Aquaculture farmers
- Aquaculture breeders
- Fish processors and wholesalers





AQUA EXCEL 3.0



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Nutrigenomics and fish pathology groups



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