"Using ultrasound for the monitoring and control of larval development of gilthead seabream (Sparus aurata) in tanks"

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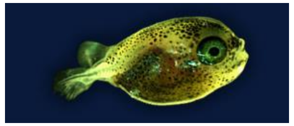

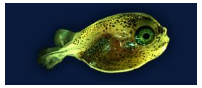

Ultrasonic monitoring of larval development of fish in tanks. Case study: Sparus aurata.

OUTLINE

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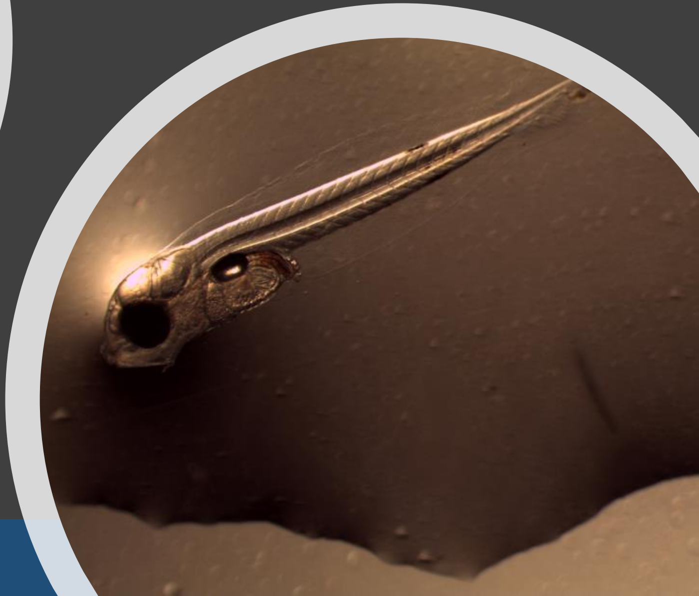
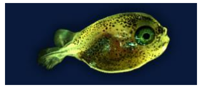
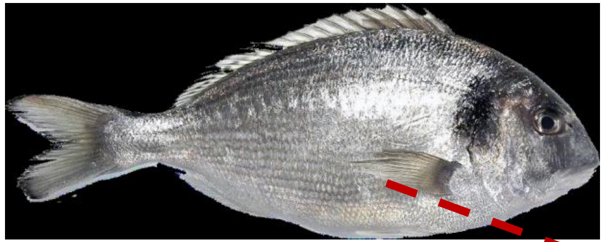
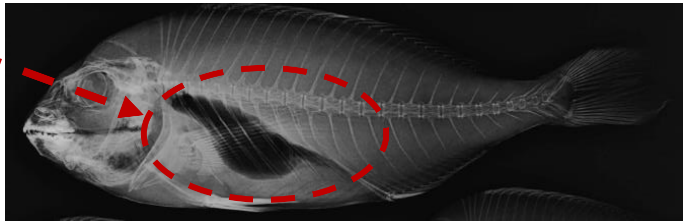


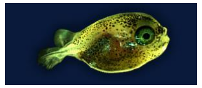


1. Introduction

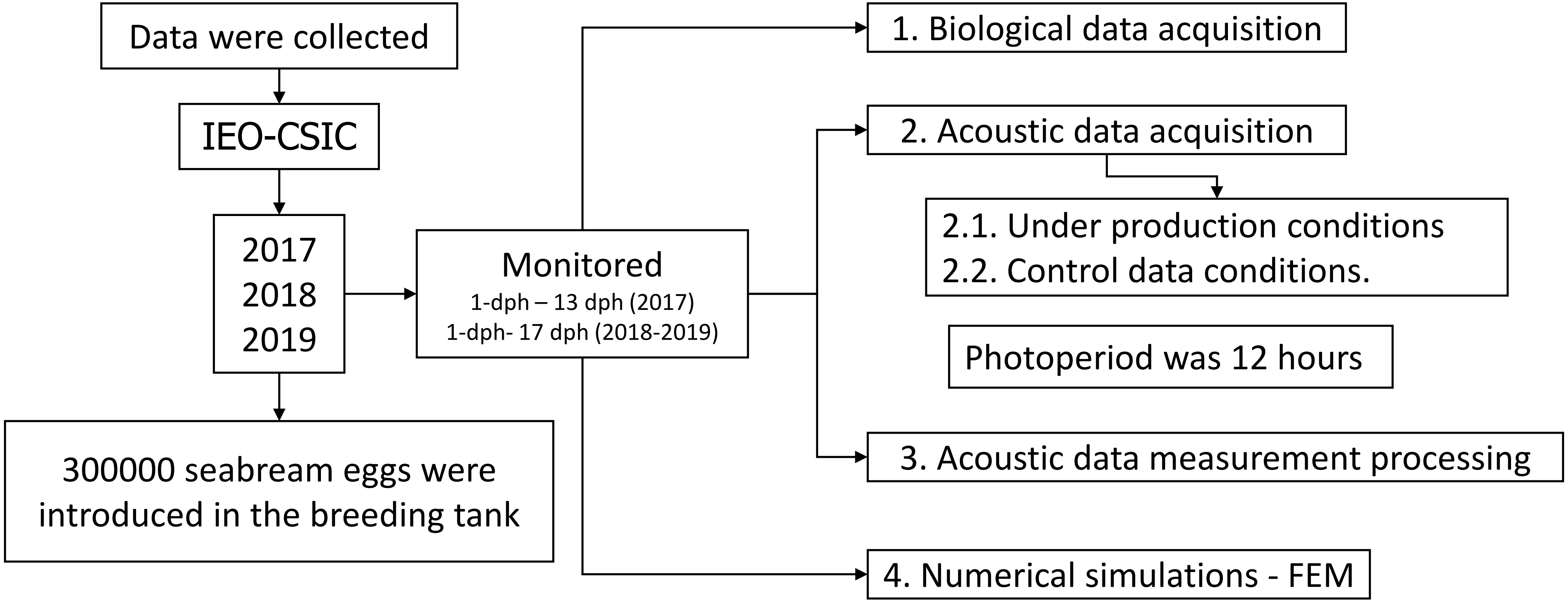




- The gilthead seabream (Sparus aurata).
- Optimal rearing conditions of larvae: swimbladder inflation.
- Swimbladder allows the buoyancy control.
- The non-inflated swimbladder is a principal problem for larval: increase mortality.
- The swimbladder absence: physiological problems (spinal deformities and lordosis).
- This problem: generates losses in the aquaculture industry.
- Ultrasonic techniques have proven to be effective method to control abundance of fish and to estimate biomass in a non intrusive way. To do it, target strength (TS) is used.
- The swimbladder is responsible for the greatest amount of acoustic energy reflected by the fish.
- We will present an ultrasonic acoustic method to monitor larval development and detect swimbladder inflation.

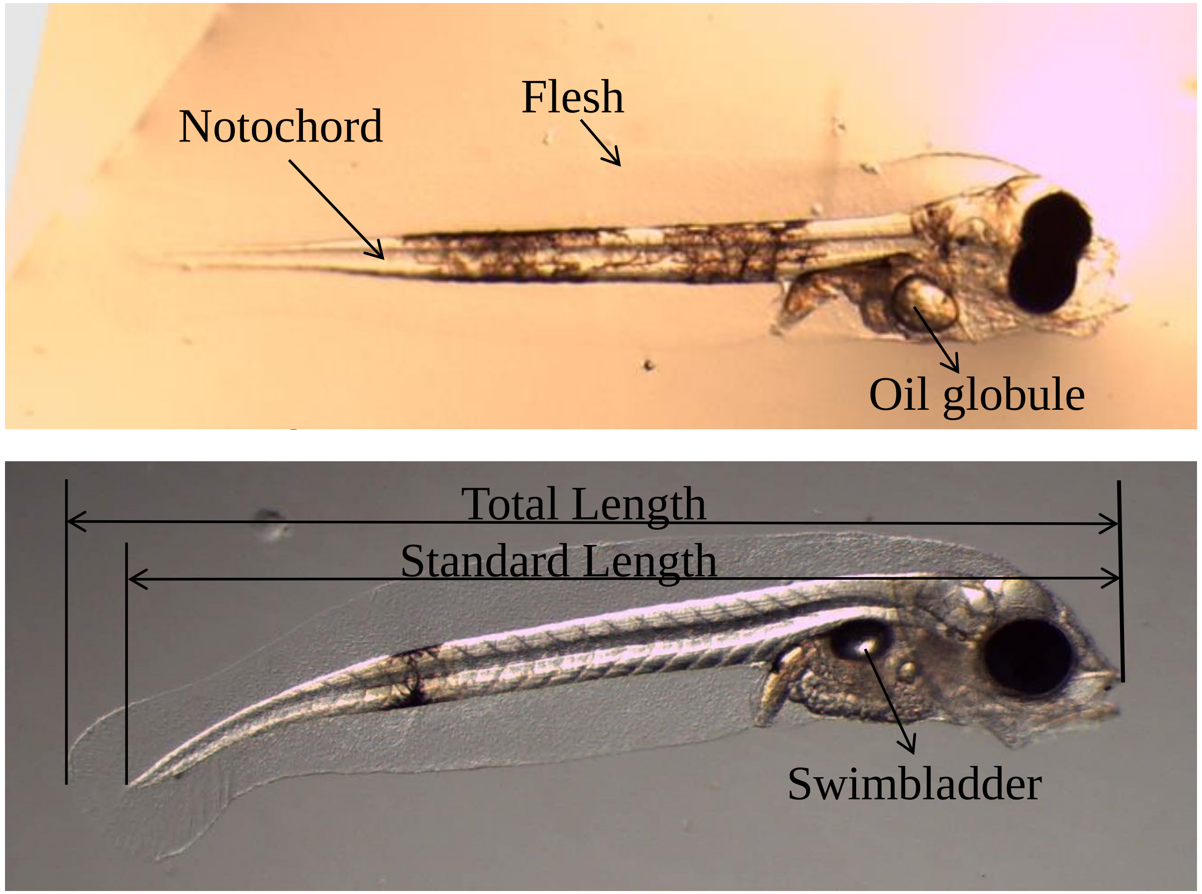


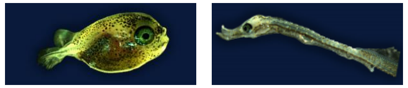
2. Materials and methods



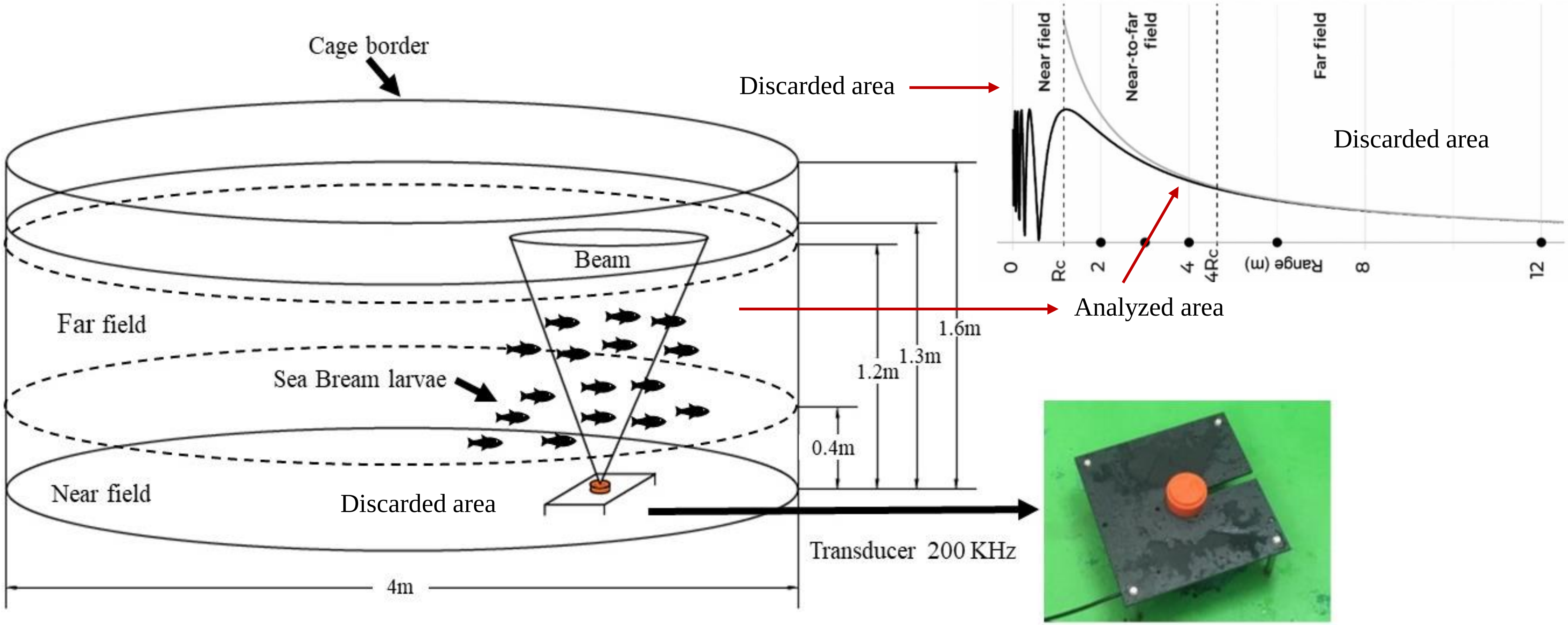
2.1. Biological data acquisition

- Information about the larvae growing.
- Representative sample were taken from 1-dph to the end of the experiments.
- Samples were taking at night.
- At least 25 larvae were collected every day and sized using a Leica MS5 optical microscope with a Leica S3 high-definition camera.
- To process recorded images a Leica Aplication Suit (LAS 123).
- Standard length and swimbladder surface are were measured.
- Abiotic parameters were monitored daily.





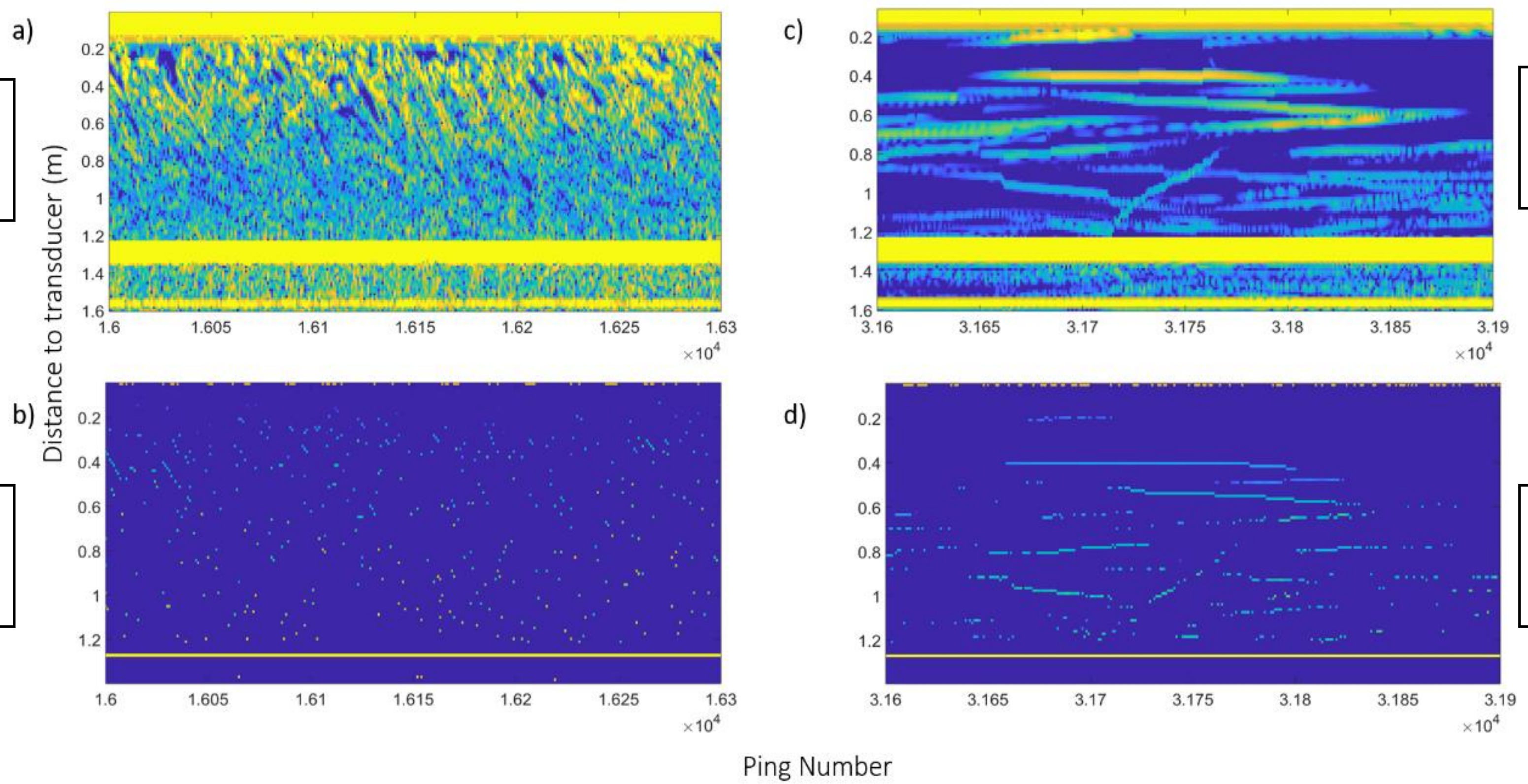
2.2. Acoustic data acquisition



2.3. Acoustic data measurements processing

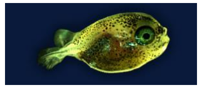
Echogram under production condition

Echogram under control conditions

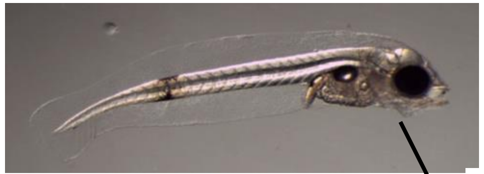


SED echogram under production conditions

SED echogram under control conditions

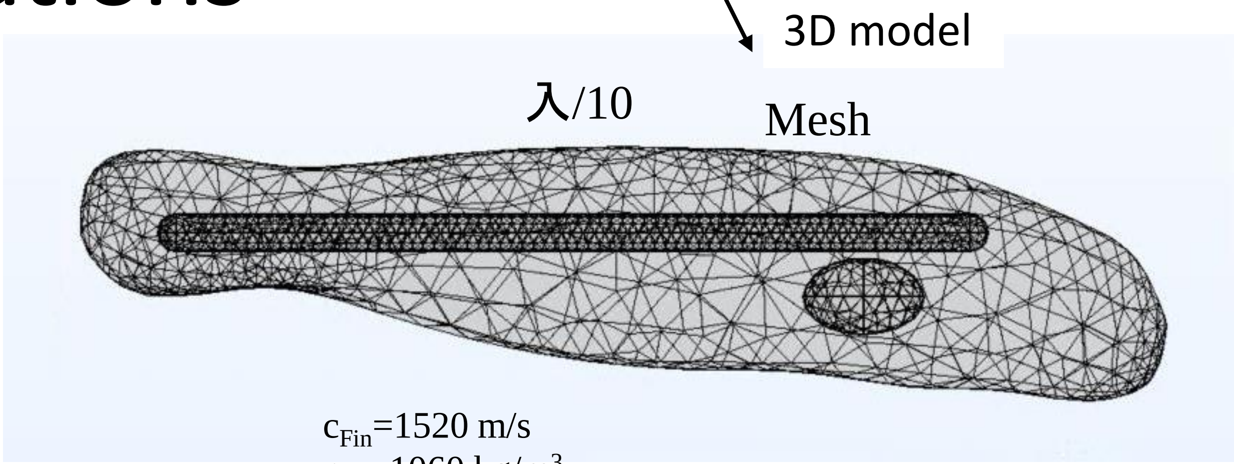


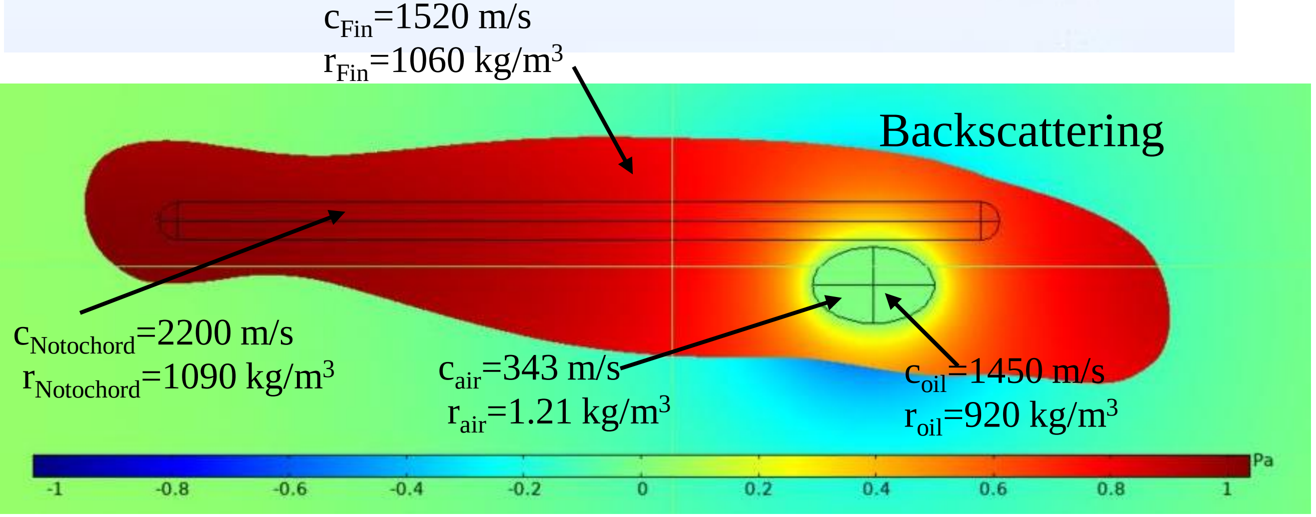
2.4. Numerical simulations

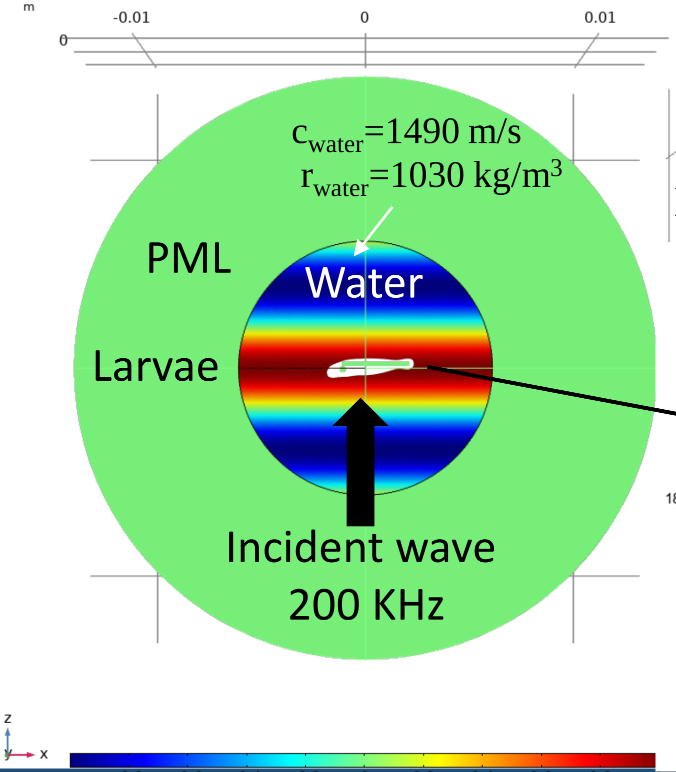


Finite element method (FEM)

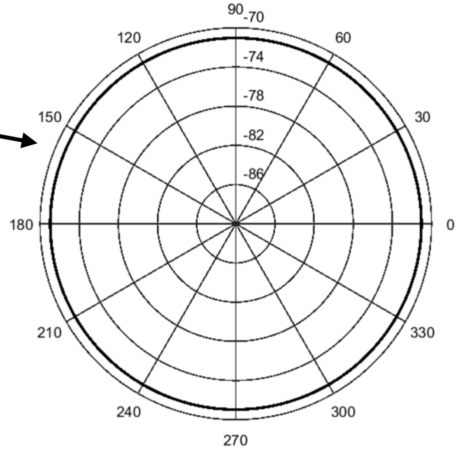
FEM solver the inhoogeneous Helmholtz equation in 3D $\nabla \cdot \left(\frac{-\nabla p}{\rho} \right) - \frac{w^2}{\rho c^2} p = 0$







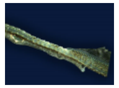
Directivity of the larvae is omnidirectional

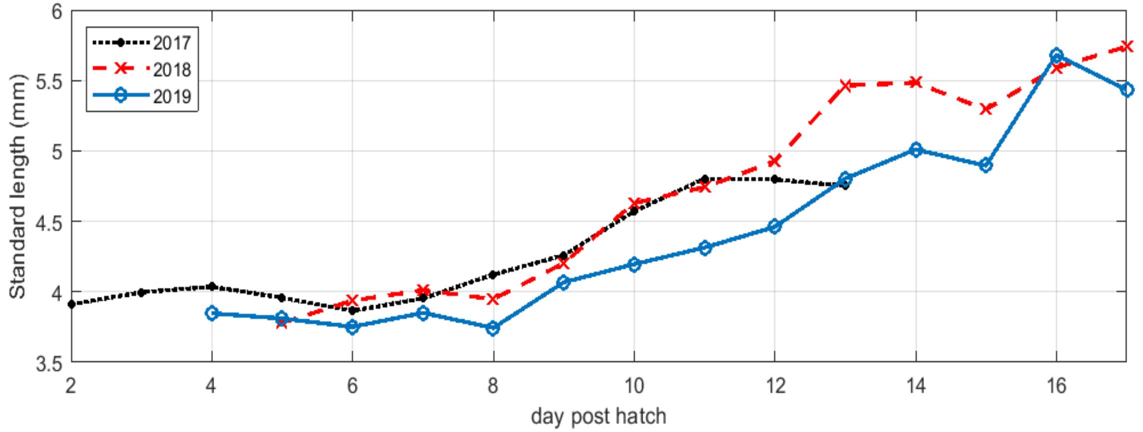


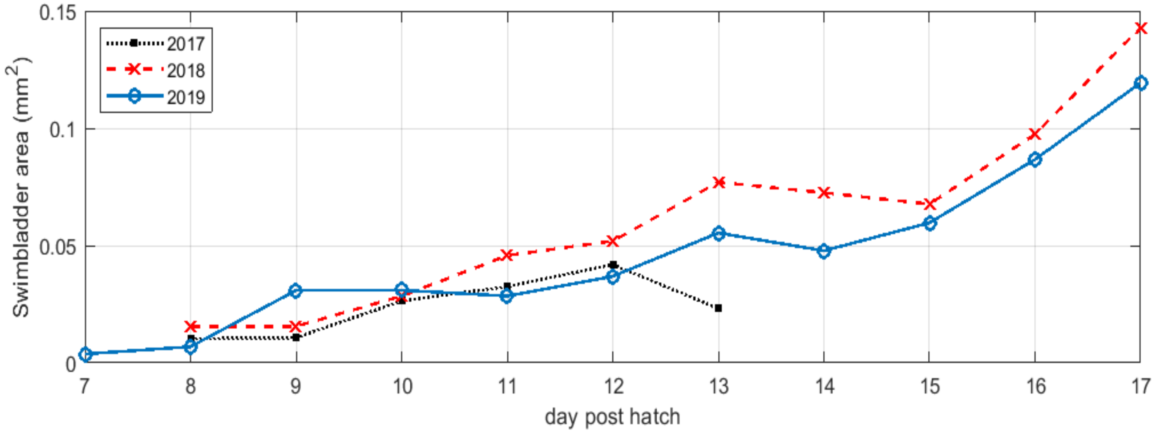
3. Results

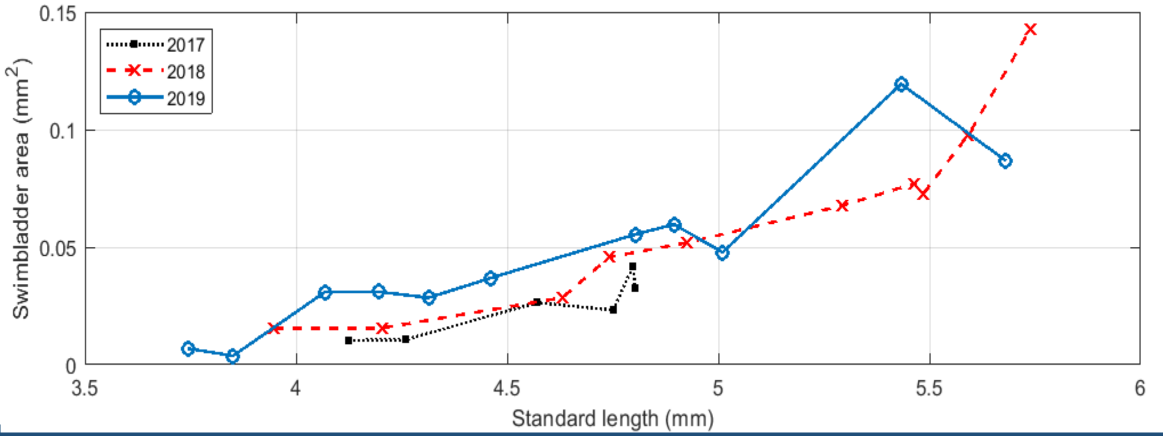
Biological: Standard length and Swimbladder

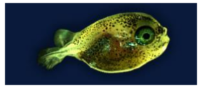
$Ls(mm) = a \cdot dph + b$				
Experiment	a	b	r^2	p
2017	0.09	3.56	0.88	<0.01
2018	0.18	2.78	0.97	<0.01
2019	0.15	2.89	0.94	<0.01
$\emptyset(mm^2) = a \cdot dph + b$				
2017	0.01	-0.04	0.87	0.02
2018	0.01	-0.09	0.95	<0.01
2019	0.01	-0.07	0.93	<0.01
$\emptyset(mm^2) = a \cdot Ls\,(mm) + b$				
2017	0.04	-0.15	0.89	0.01
2018	0.06	-0.23	0.91	<0.01
2019	0.05	-0.18	0.92	<0.01









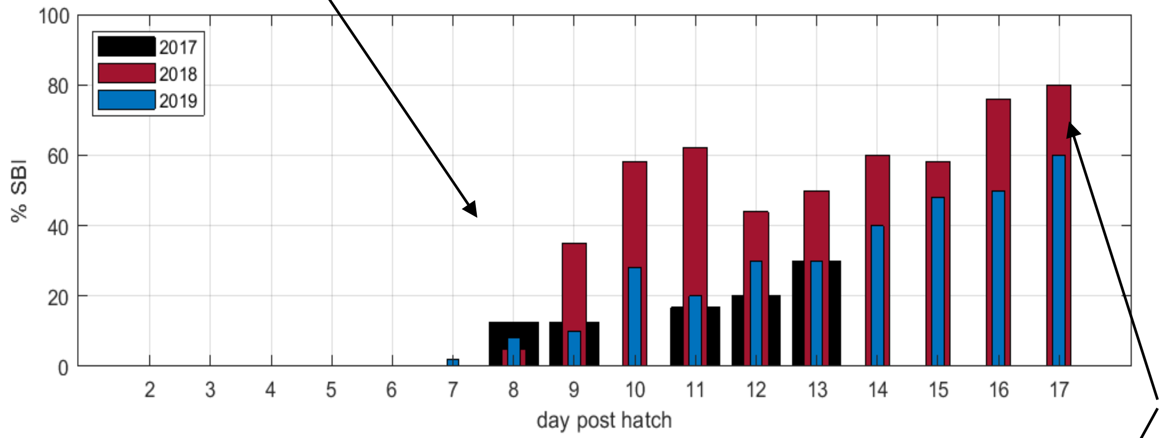


3. Results

Biological: Swimbladder Inflation (%SBI)

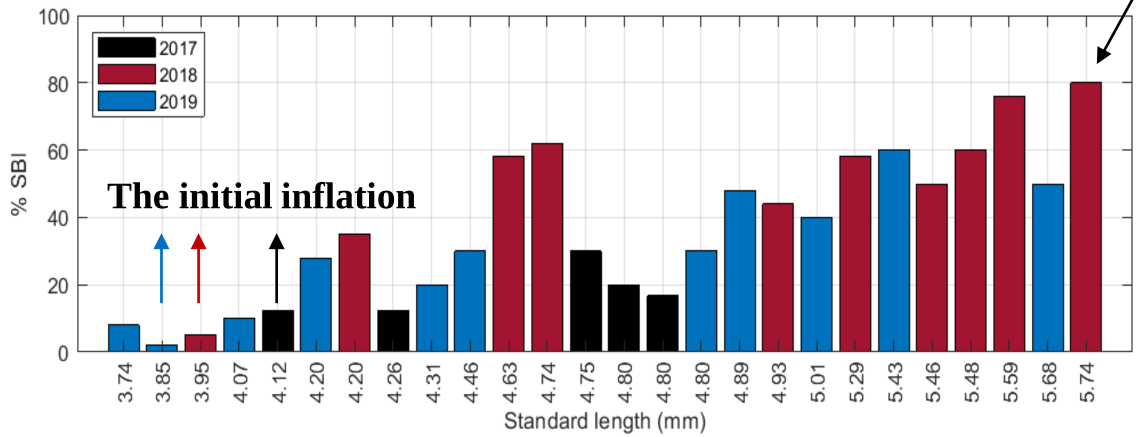
The initial inflation 7-dph / 8-dph
2017 (12.5%, Ls=4.12mm)
2018 (5%, Ls=3.95mm)
2019 (2%, Ls=3.85mm)

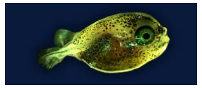
2017 (r^2=0.91; $p<0.01$)
2018 (r^2=0.92; $p<0.01$)
2019 (r^2=0.97; $p<0.01$)



The max day of %SBI
2017 (13-dph 30%, Ls=4.75mm)
2018 (17-dph 80%, Ls=5.74mm)
2019 (17-dph 60%, Ls=5.43mm)

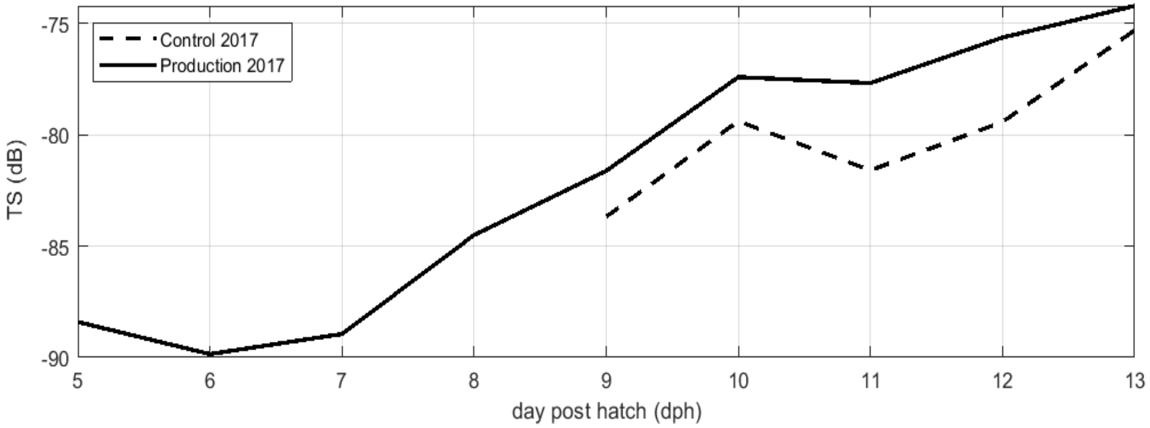
2017 and 2018 (r^2=0.91; $p<0.01$)
2019 (r^2=0.95; $p<0.01$)

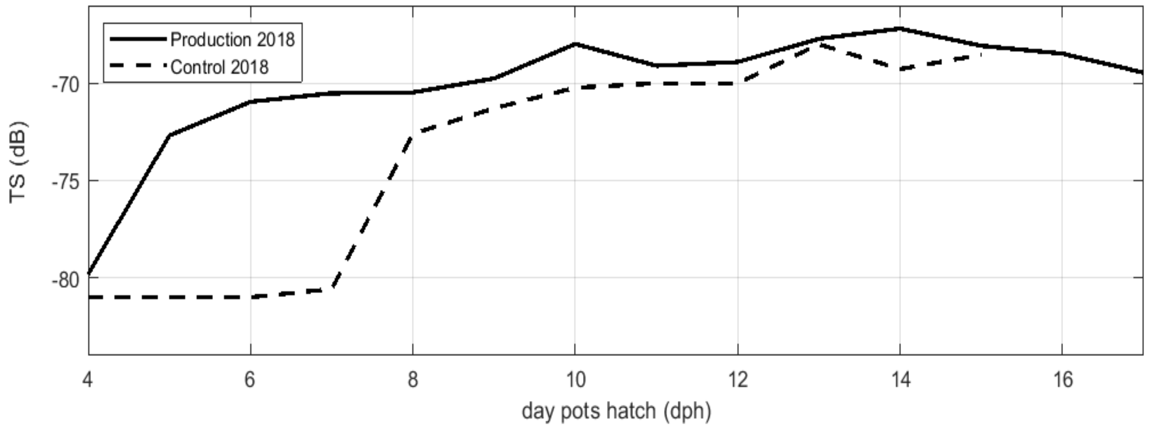


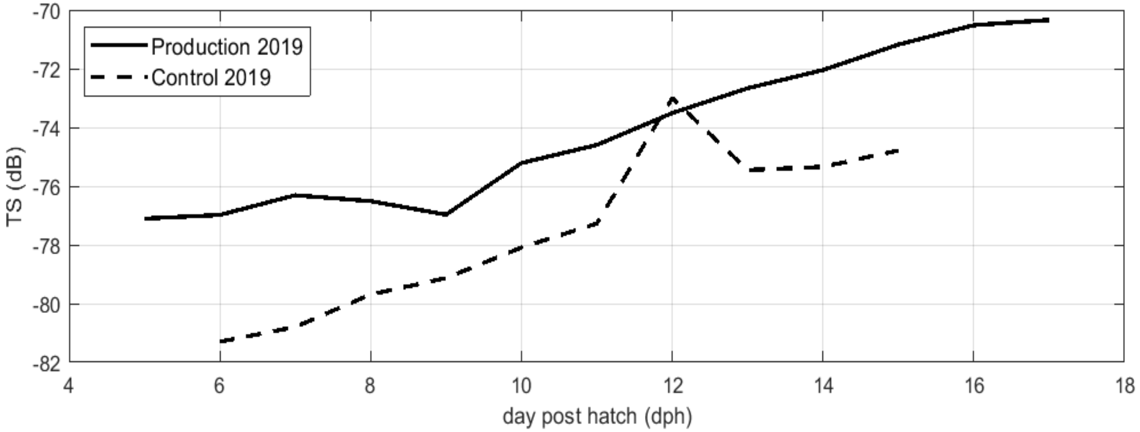


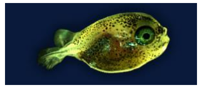
3. Results

Measured target strength under production and control conditions







3. Results

Measured target strength individual traces

Day (dph)	2018				2019			
	mean TS	n	% SBI	Ls (mm)	mean TS	n	% SBI	Ls(mm)
6	-80,7	392	0	3.938	-85,6	8	0	3.752
7	-82,2	134	0	4.012	-83,5	9	2	3.851
8	-80,6	63	5	3.948	-82,3	111	8	3.851
9	-79,6	53	35	4.203	-81,5	157	10	4.068
10	-74,8	154	58	4.630	-80,8	160	28	4.196
11	-75	63	62	4.742	-80,3	103	20	4.314
12	-	-	-	-	-77,8	392	30	4.461
13	-	-	-	-	-76,8	517	30	4.803

$$TS(dB) = a \cdot log_{10}Ls(mm) + b$$

	TS mean			
Experiment	a	b	r^2	p
2018	84.20	-131.58	0.96	<0.01
2019	75.24	-127.57	0.96	<0.01

$$TS(dB) = a \cdot (\%SBI) + b$$

	TS mean			
Experiment	a	b	r^2	p
2018	0.10	-81.57	0.95	<0.01
2019	0.21	-84.42	0.91	<0.01

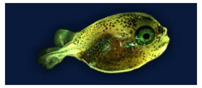
3. Results

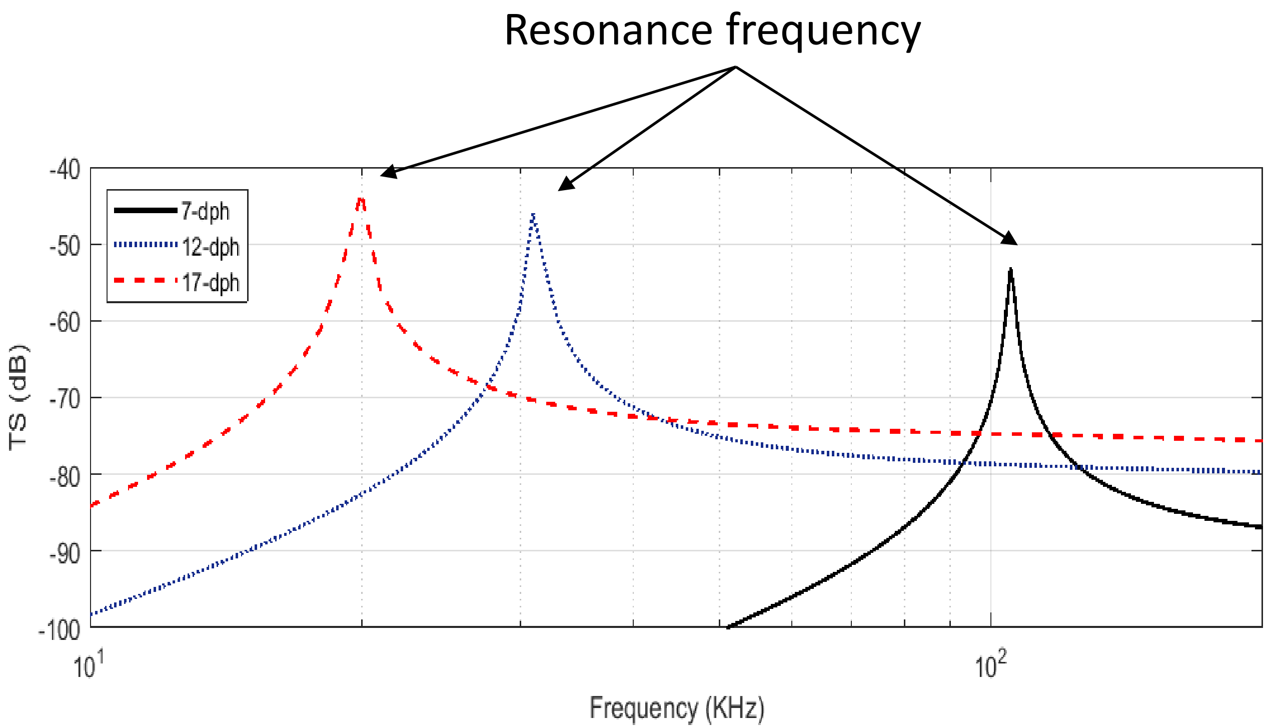
Numerical simulations

$$f_r = \frac{1}{2\pi a}\sqrt{\frac{3\gamma P_0}{\rho}}$$

$$\sigma_{bs} = \frac{a^2}{\left(\left(\frac{f_r}{f}\right)^2 - 1\right)^2 + \delta^2}$$

$$TS = 10log_{10}(\sigma_{bs})$$

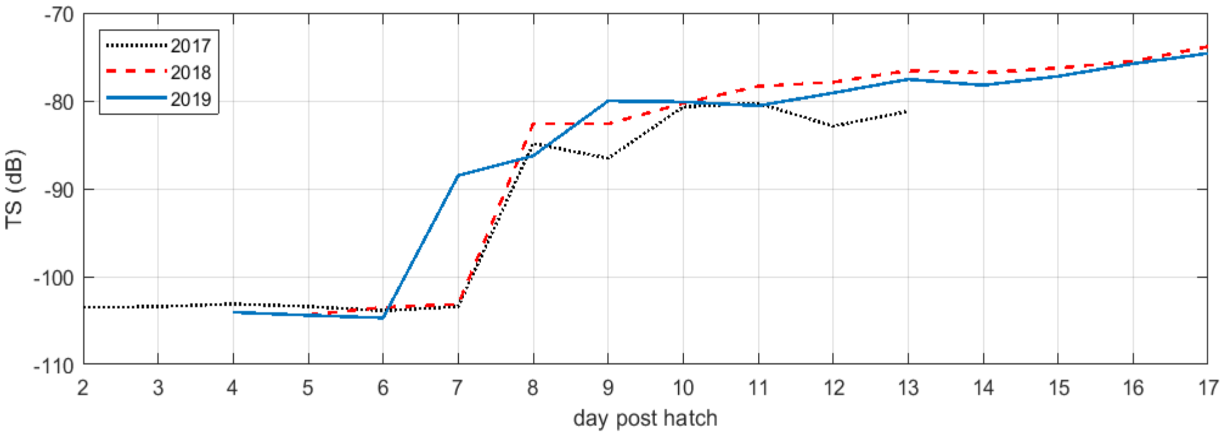


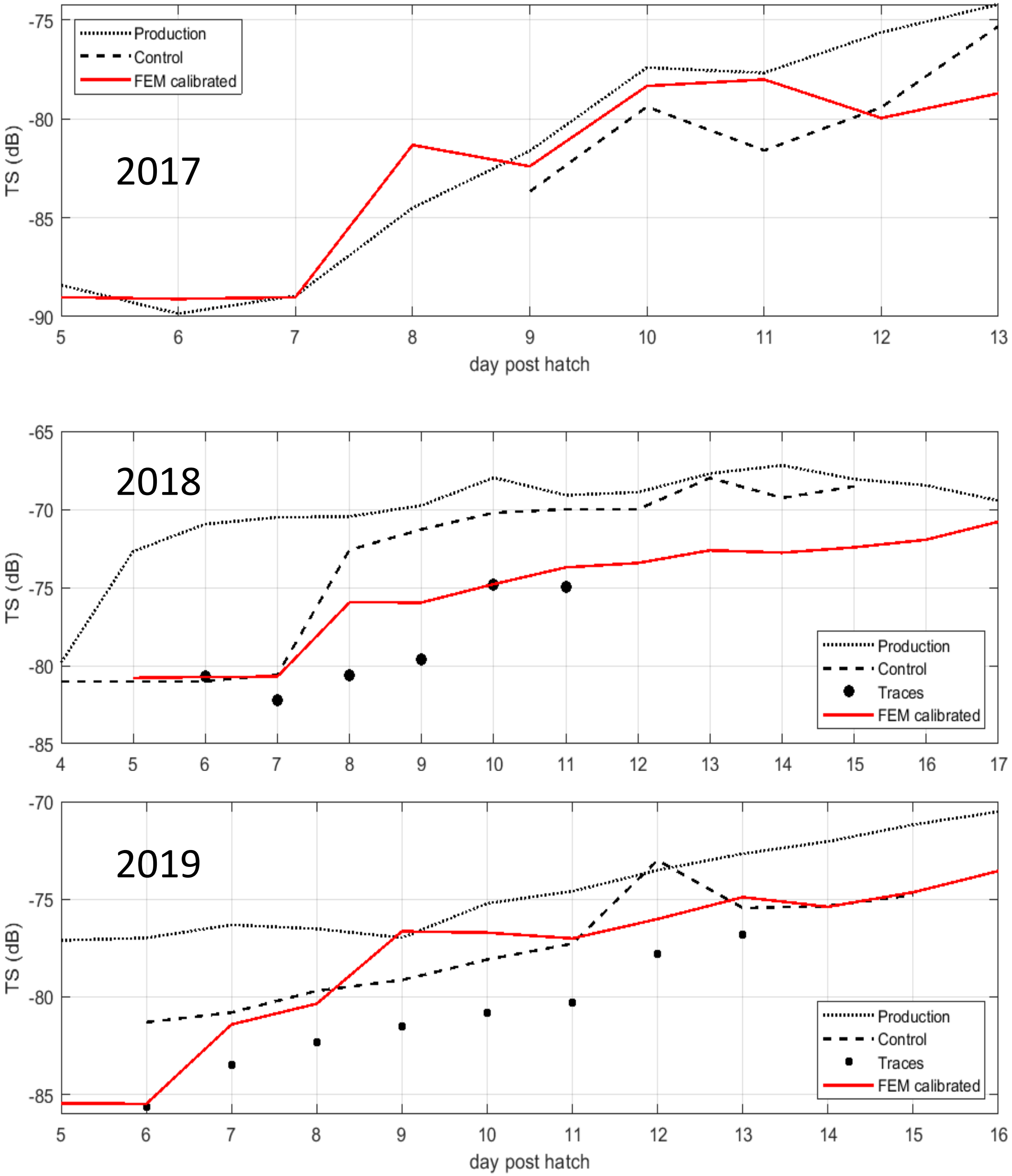


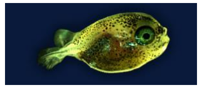
3. Results

Numerical simulations

Normalized and calibrated whit the background noise level of the exprerimental control measures

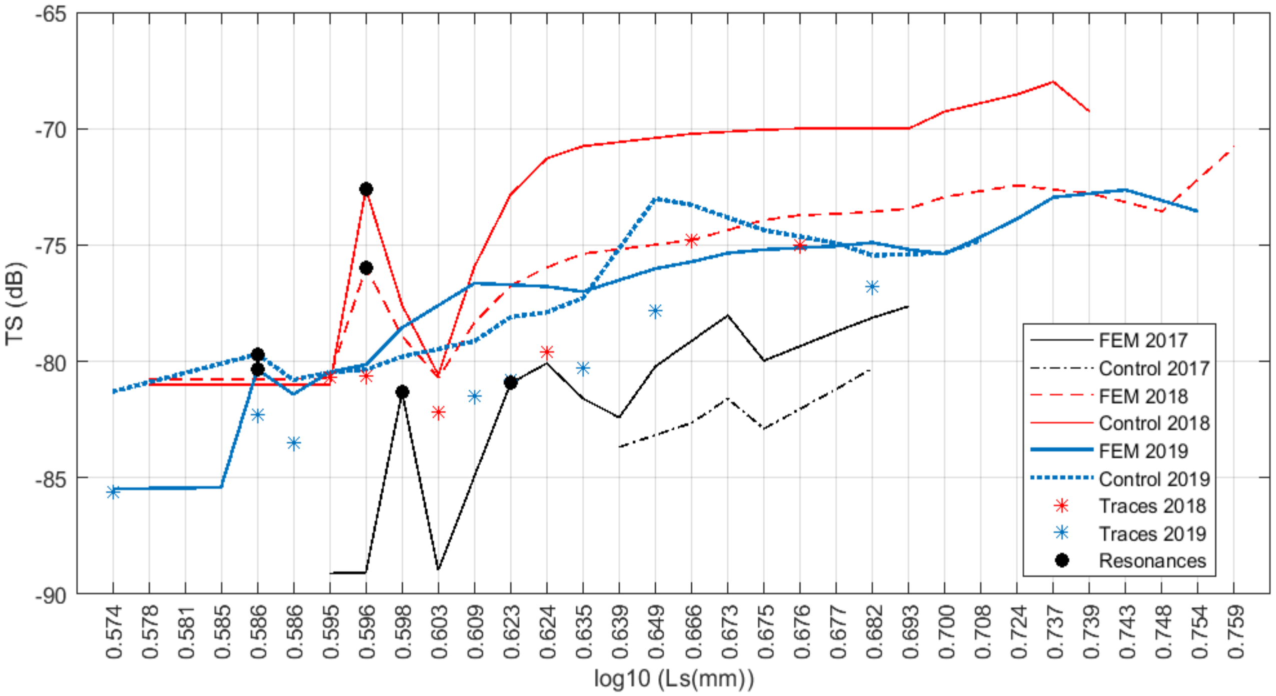




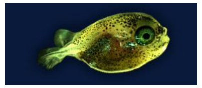


3. Results

Relation between TS and the standard length



Experiment		$TS(dB) = a \cdot log_{10}Ls(mm) + b$				$TS(dB) = a \cdot (\%SBI) + b$			
		a	b	r^2	p	a	b	r^2	p
2017	Control	60.34	-122.44	0.82	<0.01	0.11	-84.61	0.74	0.26
	FEM	95.23	-142.87	0.83	<0.01	0.16	-83.03	0.64	0.24
2018	Control	83.47	-127.35	0.87	<0.01	0.17	-78.79	0.89	<0.01
	FEM	49.50	-108.36	0.91	<0.01	0.10	-79.48	0.90	<0.01
2019	Control	57.79	-113.98	0.90	<0.01	0.14	-80.56	0.90	<0.01
	FEM	58.02	-115.18	0.87	<0.01	0.21	-83.00	0.90	<0.01



3. Conclusions

- Experimental analyses and numerical simulations of backscattered acoustic intensity of seabream larvae up to 13-15 days post hatch during three consecutive years have been made.
- Larval growth and swimbladder inflation were controlled from 2-dph to end of experiment.
- Uneven growth, swimbladder inflation percentage and swimbladder area of larvae was observed depending on the year.
- Due to it, different TS increases were recorded every year. However, from initial swimmblader inflation day (8-dph) the same trend was detected in all experiments.
- Raises of at least 3 dB were measured. Those increases were larger under control conditions in absence of bubbles from aeration system.
- By fitting the larvae standard length and TS good relationships were calculated. The swimbladder inflation percentage presented good correlation with TS values. Based on these relations, larvae growth could be controlled in offshore tanks using ultrasonic monitoring techniques.

Ultrasonic monitoring of larval development of fish in tanks. Case study: (Sparus aurata)

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