CERES
Climate change and European aquatic RESources

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CERES

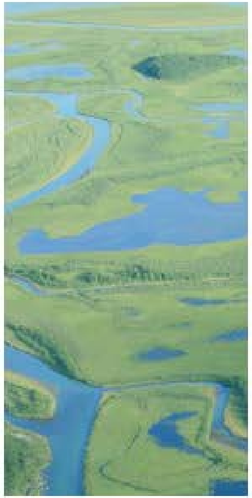
Climate change and European aquatic RESources

Combining Physical, Ecological, Economic & Social Science

5.6 million €
26 partners
15 countries
4 years

EU H2020 Project (2016-2020)















CERES for Blue growth

CERES advances a cause-and-effect understanding of **how climate change will influence Europe's most important fish and shellfish resources** and the economic activities depending on them.

CERES provides tools and adaptive strategies allowing **marine and inland fisheries and aquaculture sectors** and their governance to prepare for adverse changes or future benefits of climate change.

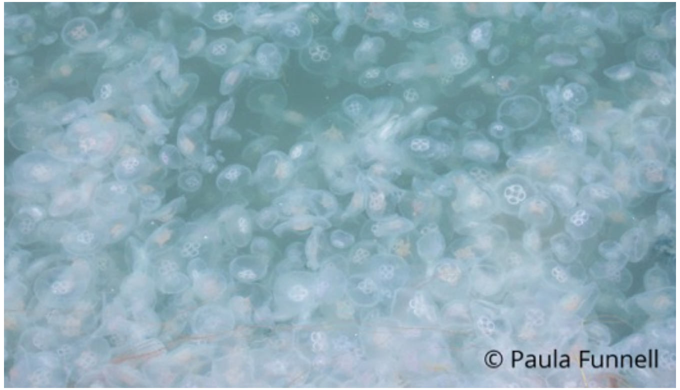
Questions for CERES

Environment

How will physical and biogeochemical features of marine and inland waters change in a future climate?

Aquaculture

Which current or emerging species will be most profitable (and sustainable) to culture in light of climate change?



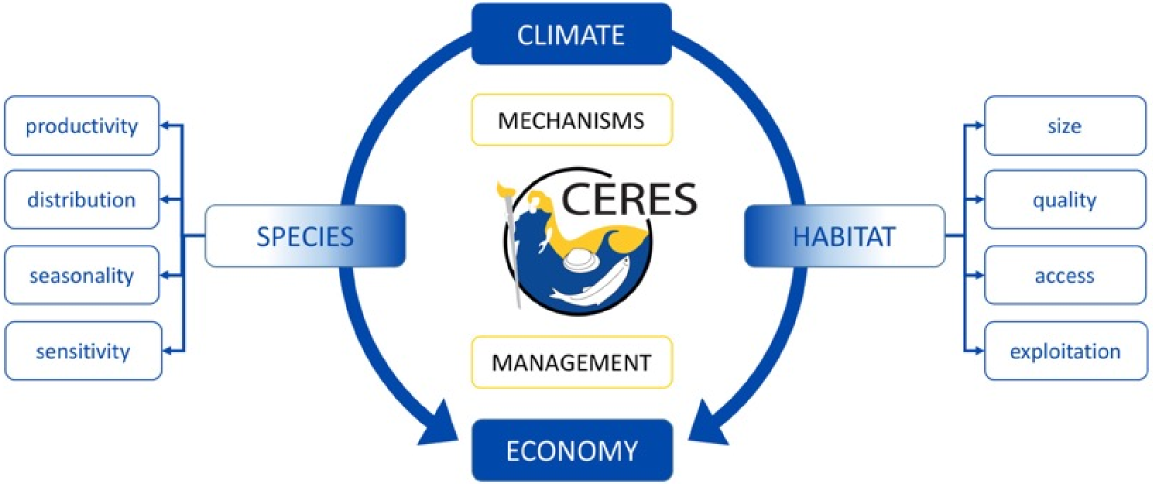
Questions for CERES

Mitigation and early warning

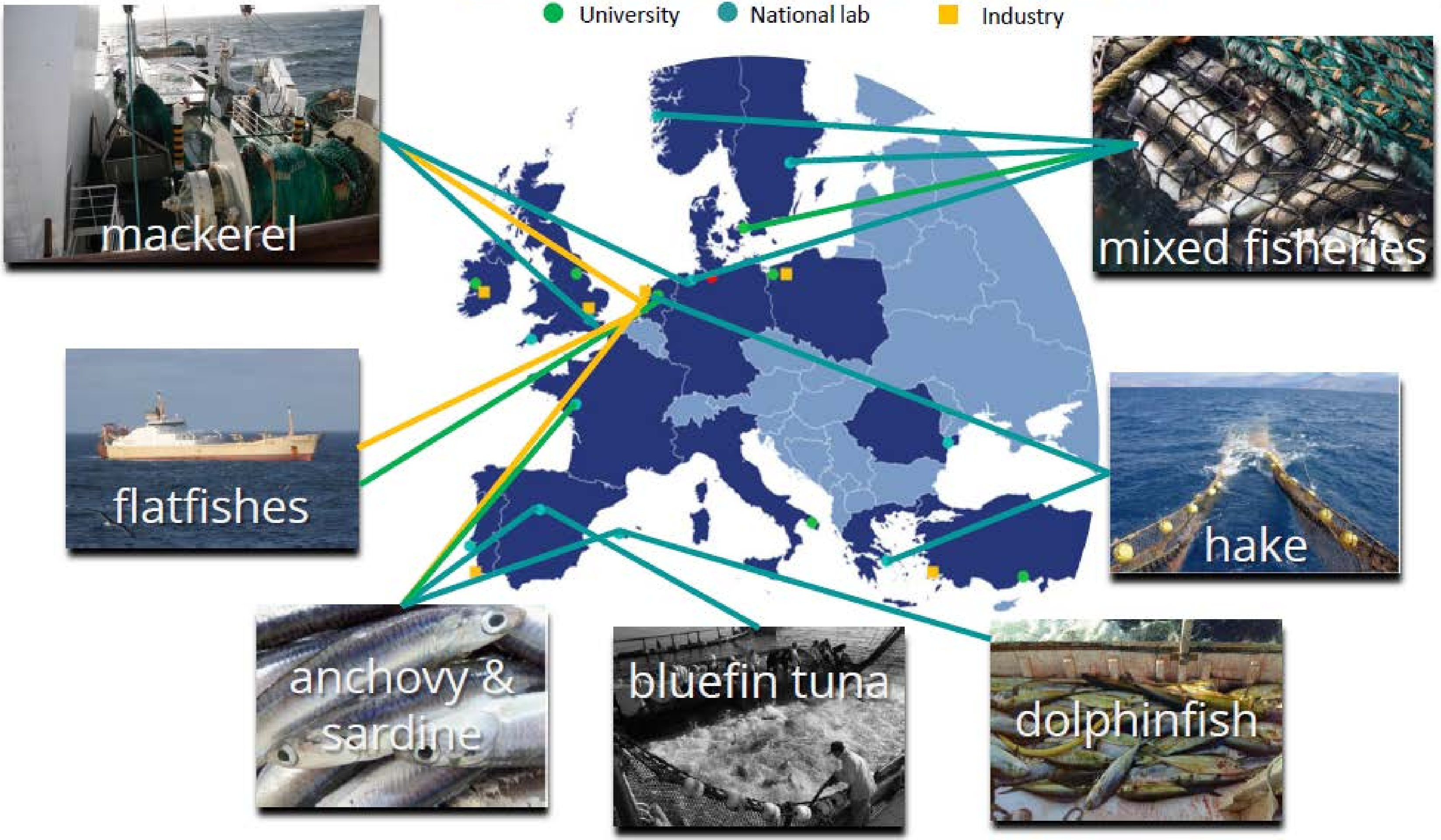
Which early warning techniques can protect against climate-driven increases in the frequency of events such as harmful algal blooms, jellyfish outbreaks, the spread of pathogens or episodes of coastal hypoxia?

Climate links to economy

Climate impacts directly and indirectly on European fisheries and aquaculture, both on target species as well as their habitat.



11 Marine Fisheries Storylines



10 Marine Aquaculture Storylines

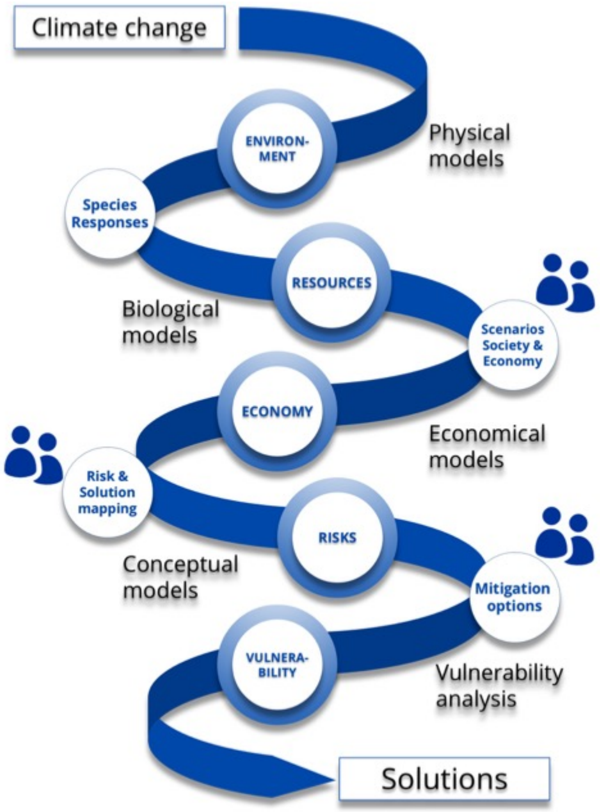
4 “Inland Waters” Storylines

CERES

University National lab Industry

CERES Storylines

Northern Europe	Rainbow trout	1
Eastern Mediterranean	Rainbow trout	2
North-east Europe	Carp	3
South-east Europe	Pike-perch	4
North Sea	Mussels	5
North Sea	Oysters	6
Atlantic coast	Mussels	7
Atlantic coast	Oysters and Clams	8
Western Mediterranean	Mussels	9
North-east Atlantic	Salmon	10
Atlantic coast	Meagre	11
Western Mediterranean & Canary Islands	Sea bass and Sea bream	12
Eastern Mediterranean	Sea bass and Sea bream	13
Barents and North-West Sea	Herring, Capelin and Cod	14
Baltic Sea	Herring, Sprat and Cod	15
North Sea	Herring	16
North Sea	Gadoids	17
North-east Atlantic	Mackerel	18
North Sea and north-east Atlantic	Flatfish	19
North-west Mediterranean	Dolphinfish	20
Bay of Biscay	Sardine and anchovy	21
North-west Mediterranean	Sardine and anchovy	22
Aegean Sea and eastern Mediterranean	Hake	23
North-west Mediterranean	Bluefin Tuna	24



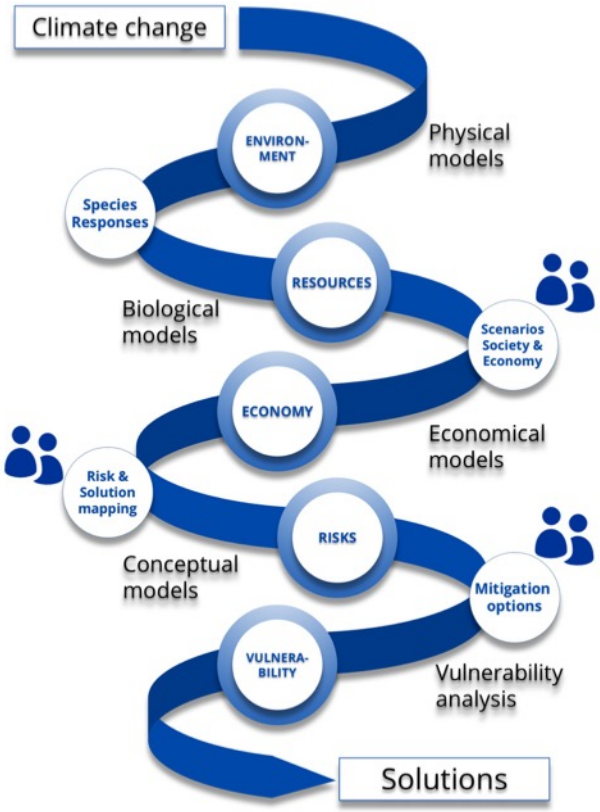
CERES in a nutshell

Environment

CERES projected future changes in physical conditions of marine and inland waters relevant for fisheries and aquaculture industries.

Resources

Biological models allowed to scale up physiological and ecological responses of target species to estimate future changes in the productivity of fish and shellfish resources.



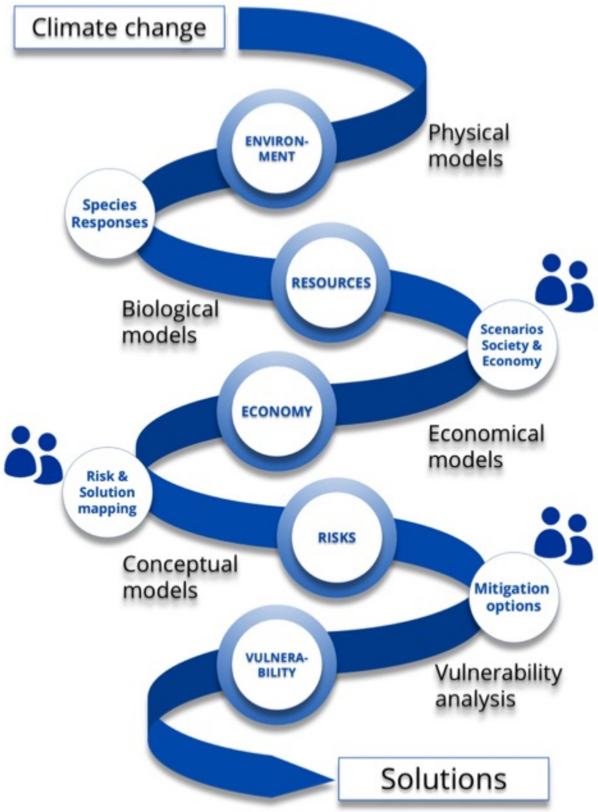
CERES in a nutshell

Economy

Based on future social and economic scenarios, CERES estimated consequences for the marine and inland fisheries and aquaculture industries.

Risks & vulnerability

CERES assessed risks, adaptive capacity and vulnerability of European fisheries and aquaculture sectors using different conceptual models.



CERES in a nutshell

Solutions

CERES will provide viable “bottom-up” (industry-driven) solutions to minimize the risks and maximize potential benefits of climate change.

CERES will also provide “top-down (policy & management) solutions and highlight challenges where current governance structures may hinder future adaptation.

Storyline 12
SEABREAM AND SEABASS IN WESTERN MEDITERRANEAN AND ATLANTIC COASTS OF SOUTHERN EUROPE

Virginia Martín (IEO), Antonio Marques (IPMA), Cornelia Kreiss (TI-SF), Alhambra Cubillo (LLE), Katie Smith (UHULL), Marta Moyano (UHAM), Susan Kay (PML), Eleni Papathanasopoulou (PML), Myron Peck (UHAM)

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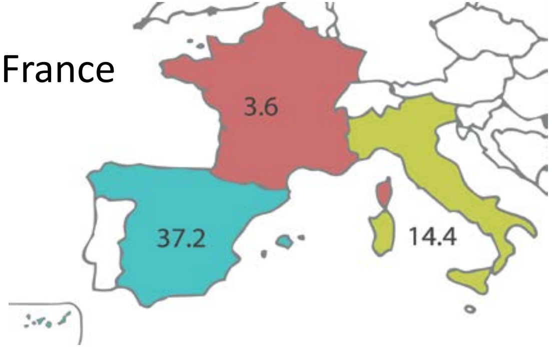
STORYLINE 12: SEABREAM AND SEABASS IN WESTERN MEDITERRANEAN AND ATLANTIC COASTS OF SOUTHERN EUROPE

- ✓ Gilthead sea bream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*) are the main species currently farmed on a large scale in South Europe.
- ✓ Commercial sizes 300g to 500g: Seabream 1.5 years, seabass 1.5 to 2 years
- ✓ Total aquaculture production of sea bream and sea bass in Europe: 443,412 tons in 2018 (FAO, 2018; FEAP, 2018)
- ✓ First-sale value of the sea bream and sea bass Mediterranean aquaculture: 2,094 million € in 2018 (FAO, 2018; FEAP, 2018)
- ✓ The main producers countries in West Europe were Spain, Italy and France

Sparus aurata **Linnaeus, 1758 Source: FAO**

Dicentrarchus labrax **Linnaeus, 1758 Source: FAO**



Total production in 2017 (x1000 tons) (data from FAO, FEAP and APROMAR)

Objective

How climate change will affect seabream and seabass culture in Western Mediterranean and Atlantic coast of Southern Europe and how should fish farms adapt to ocean warming?

Main findings & results achieved

WP1
- Socio-economic developments under different scenarios

T1.1
- Model of environmental conditions.

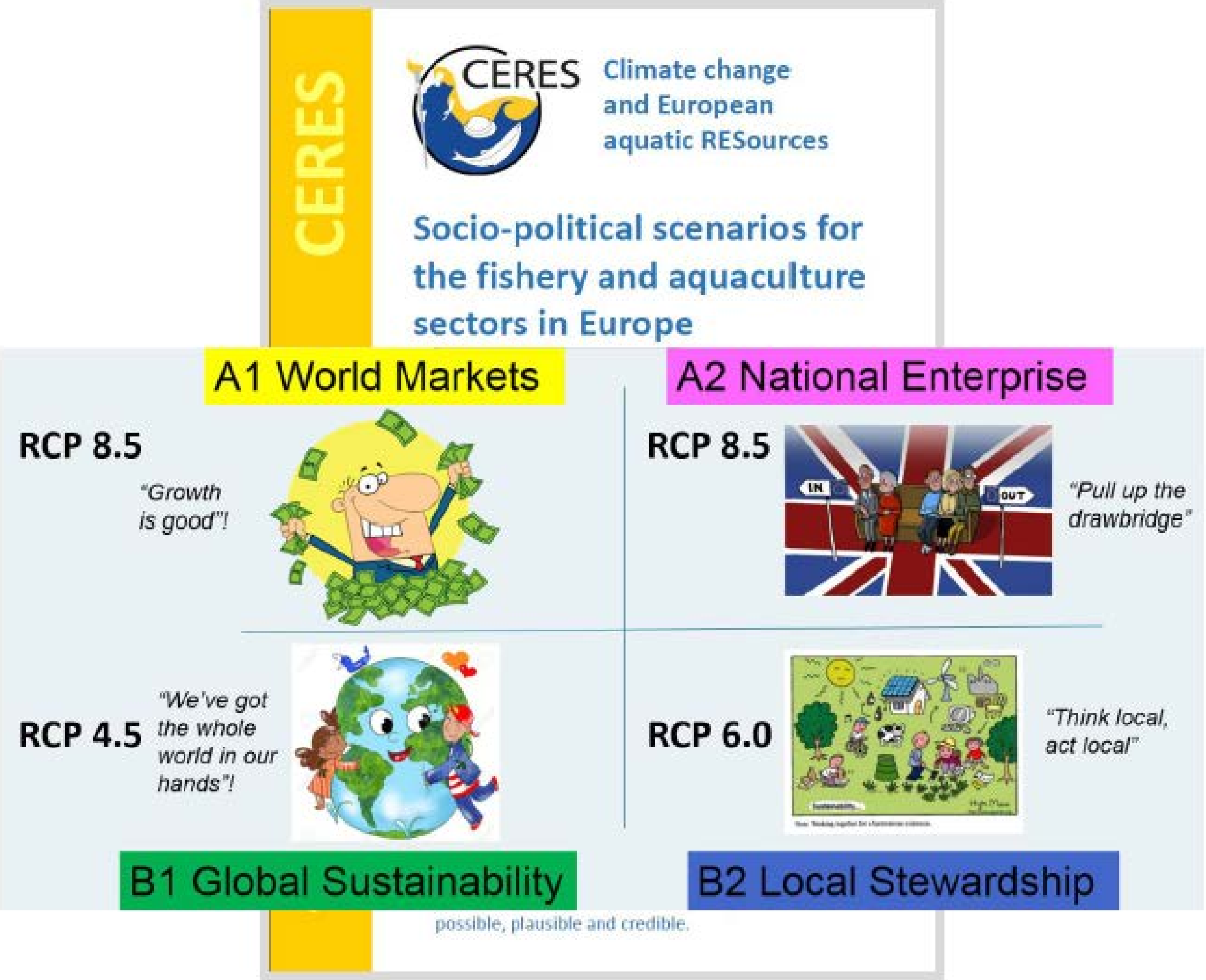
WP3
Biological consequences
- Literature Review
- Direct effects.
- Indirect effects.

T3.3
- Modelling impact in aquaculture productivity.

T4.2
Economic consequences
- Typical farm aproach.

WP5
- Bow-Tie.
- Vulnerability assays

- Socio-economic developments under different scenarios



➢ Socio-economic developments under different scenarios

What could it mean for European Aquaculture?

National Enterprise – RCP 8.5 and SSP3 (A2)

- High seafood prices, high energy prices
- Less technology, more labour
- Regional production with public subsidies
- Genetic engineering of aquaculture species
- Aquaculture to feed domestic tastes
- Some countries adopt new tech., others not
- Local certification and marketing schemes
- Food security dominates over environment

World Markets – RCP 8.5 and SSP5 (A1F1)

- Huge expansion of offshore fish farming
- Luxury product vs anonymous fish protein
- *Pangasius* dominated aquaculture markets
- Extensive use of cheap immigrant labour
- Big businesses strive for value-for-money
- Frequent fish kills due to pathogens & jellyfish
- Global trading of aquaculture products
- Technology/automation important
- Low seafood prices, low energy prices

Local Stewardship – RCP 6.0 and SSP2 (B2)

- Local/regional governance – high autonomy
- Self sufficiency viewed as important
- Small scale, low-impact fish farming
- EIA required for all new farms
- Quality and traceability important
- Sale/marketing of locally produced products
- Greater variety of organisms farmed
- Strong incentives to recycle waste materials

Global Sustainability – RCP 4.5 and SSP1 (B1)

- Tight regulation of inputs and outputs
- EIA required for new farms
- Traceability and quality standards
- Organic and fair-trade ecolabel schemes
- Technology transfer to poorer countries
- Carbon footprint considered
- Inland, closed systems more common
- Renewable energy powering most farms
- Expansion of offshore production

Main findings & results achieved

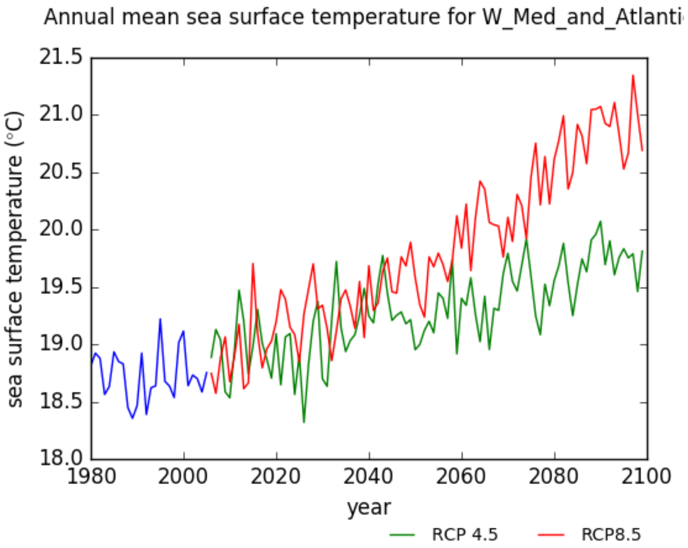
WP1

- Socio-economic developments under different scenarios

T1.1

- Model of environmental conditions.

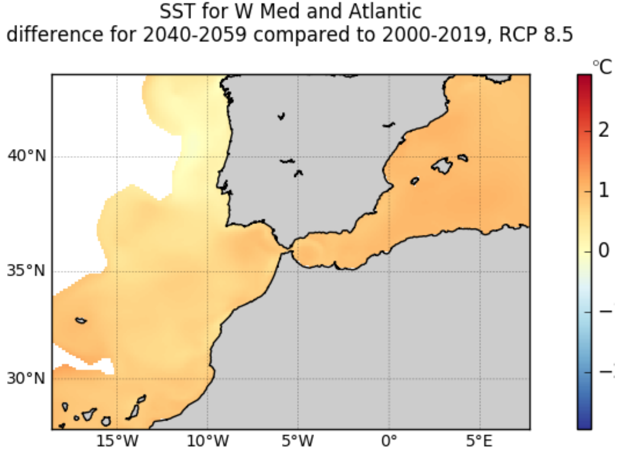
- Modelled of environmental conditions and projected change under different scenarios in West Mediterranean and South Atlantic (PML)



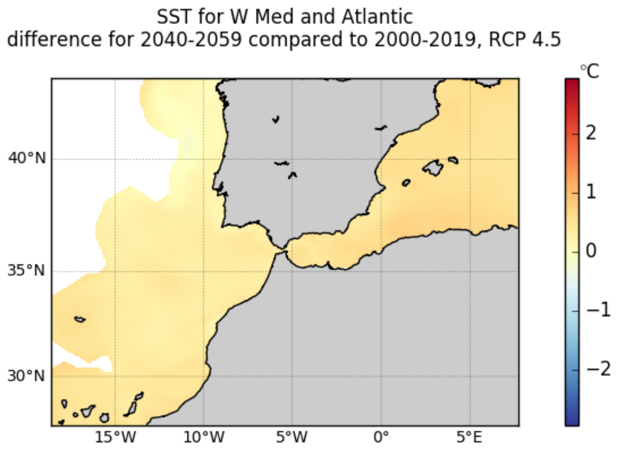
Projected changes of sea surface temperature for West Mediterranean/South Atlantic for mid and end-century under RCP 8.5 (left) and RCP 4.5 (right).

- Modelled of environmental conditions and projected change under different scenarios in West Mediterranean and South Atlantic (PML)

“World market scenario”



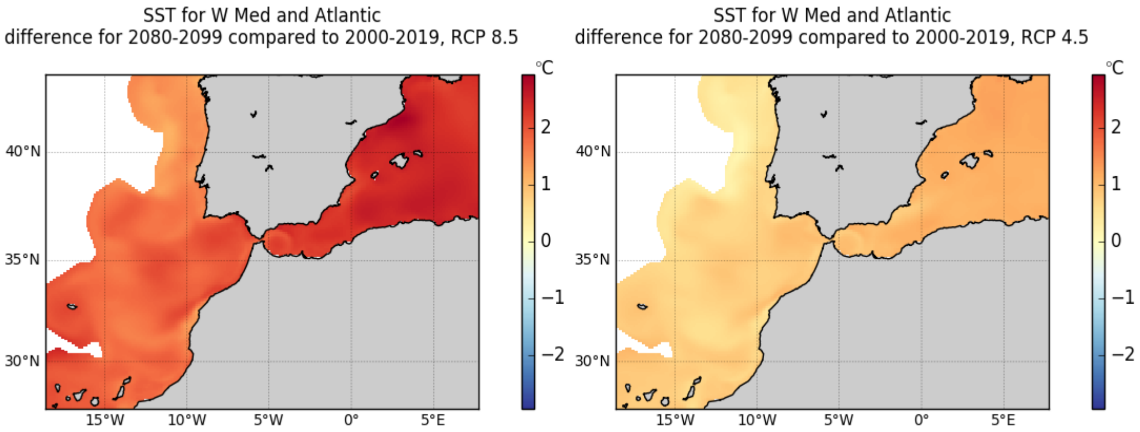
“Global sustainability scenario”



Projected changes of sea surface temperature for West Mediterranean/South Atlantic for mid and end-century under RCP 8.5 (left) and RCP 4.5 (right).

- Modelled of environmental conditions and projected change under different scenarios in West Mediterranean and South Atlantic (PML)

“World market scenario” “Global sustainability scenario”



Projected changes of sea surface temperature for West Mediterranean/South Atlantic for mid and end-century under RCP 8.5 (left) and RCP 4.5 (right).

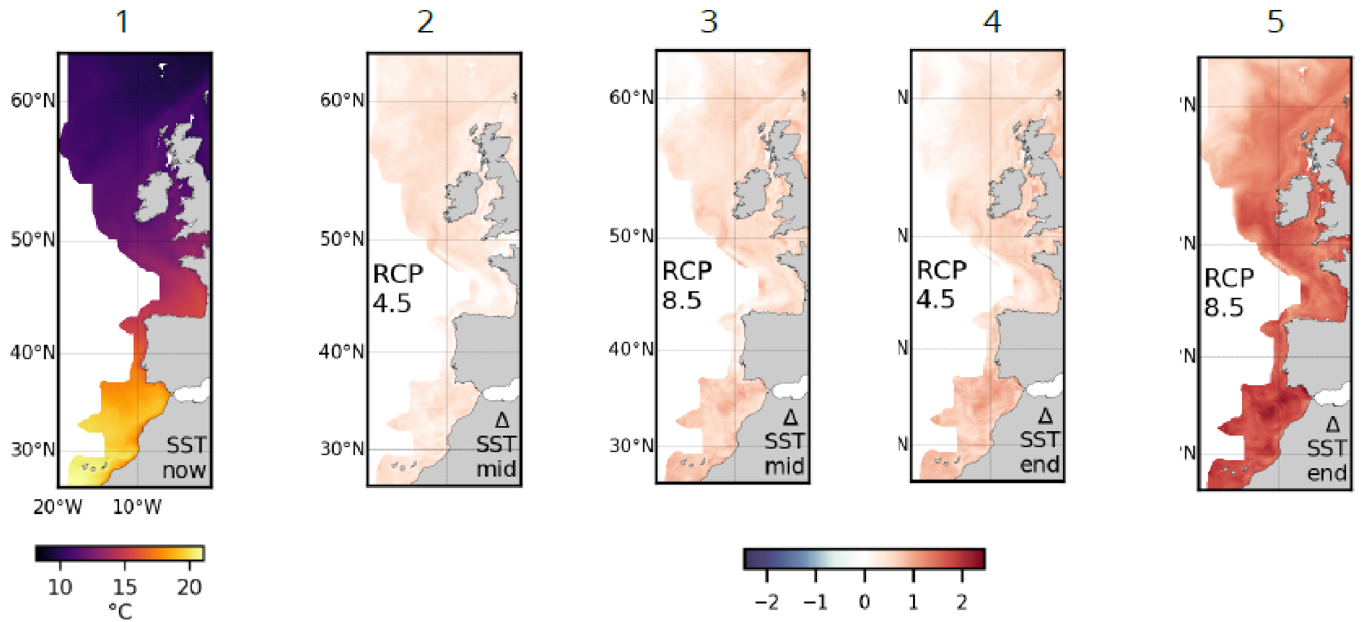


Figure 2.3 Present day sea surface temperature for the Atlantic coastal region (1) and projected change at mid-century (2,3) and end century (4,5) for RCP4.5 and RCP8.5. Present day values are the median for 2000-2019, mid-century 2040-2059 and end century 2080-2099.

Main findings & results achieved

WP1
- Socio-economic developments under different scenarios

→

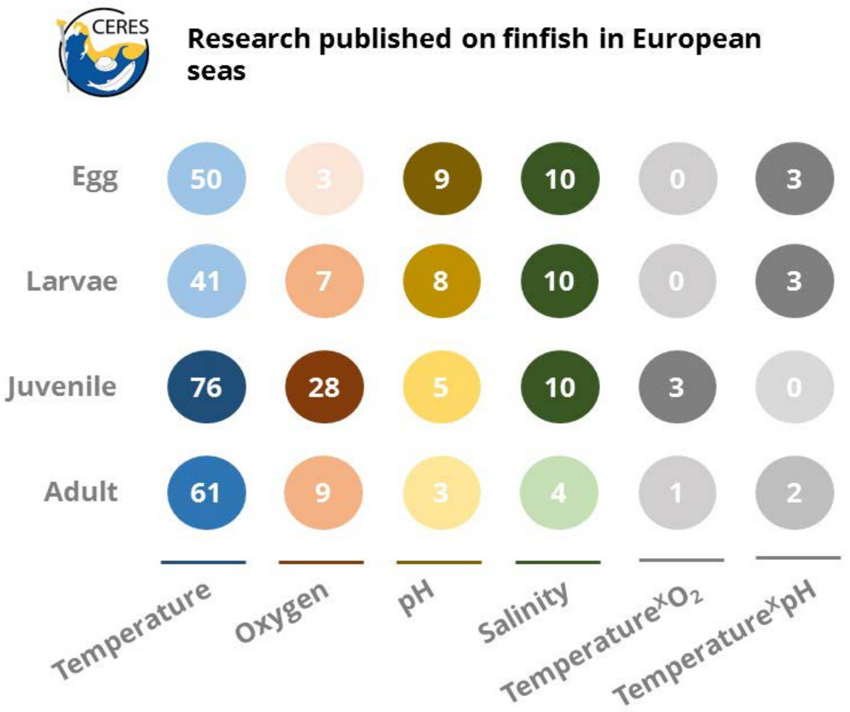
T1.1
- Model of environmental conditions.

→

WP3
Biological consequences
- Literature Review
- Direct effects.
- Indirect effects.

Collected existing data on CC

- Data-reviews on direct and indirect effects on seabream and seabass production.
- A meta-analytical approach to analyze quantitatively the collected data.



- Seabass ranked 8 out of 28 European fish and shellfish genera reviewed here (12 studies). Sea bream ranked 17 out of 28 (3 studies).
- 11 studies were done in the Western Mediterranean, 6 of them in Spain.
- Most studies focused on juveniles (6) and embryos (3)
- The most common response studied was growth (10) followed by mortality (5).
- The most common stressor studied was temperature (8).

Main Findings & Results

WP3
Biological consequences

- T3.1. Direct effects. *UHAM, IEO*

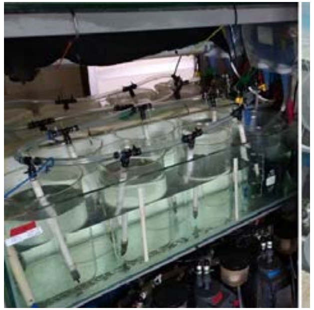
WP3
Biological consequences

- T3.2 Indirect effects. *IPMA*

Combined effect of temperature and feed restriction on growth, survival and stress biomarkers of farmed seabream juveniles (IEO)

Estimation of critical thermal limits (CT) in seabream and seabass larvae and early juveniles (UHAM)

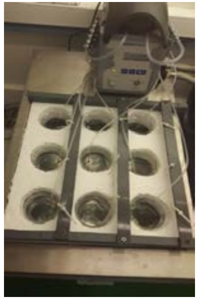
Impact of toxic algal exposure on farmed seabream under warming and acidification (IPMA)



Effect of acidification on Fish-jellyfish interactions (IPMA)

➢ Estimation of critical thermal limits (CT) in seabream and seabass larvae and early juveniles (UHAM)

- Thermal Windows versus Life Stage
- Critical Thermal Maximum & Minimum
- Fish cultured in Med & Atlantic tested



✓ **No significant effect of heating rate on CTmax** in seabass larvae.

✓ 15 mm SL larvae reared at 18-20°C, average CTmin and CTmax was:

  ✓ 7.4 and 32.9 °C for seabass larvae

  ✓ 6.0 and 33.0°C for seabream larvae

Moyano et al., 2017

➢ Combined effect of temperature and feed restriction on growth, survival and stress biomarkers of farmed sea bream juveniles (IEO)

- Temperatures: 23 ºC, 25 ºC, 27 ºC
- Ration sizes: 100% feeding rate/60% feeding rate

❖ growth performance

❖ biomarkers of oxidative stress and antioxidant enzymes in nervous, branquial, intestinal and hepatic tissues and blood of gilthead seabream juveniles.

Experimental tanks at IEO facilities.

Combined effect of increasing temperature and feed restriction in seabream juveniles

Methodology

- 288 gilthead seabream juveniles (*Sparus aurata*) born in captivity: weight 6.2±1.15g size 7.1±0.3cm
- 18 groups of 16 fish
- **Three different temperatures** : 23ºC, 25ºC, 27ºC
- **Two different ration sizes**: 100% feeding rate (control group) and 60% (feeding restriction group) Feed supplied daily (6 meals day^{-1}).

	T 27º			T 25º			T 23º		
FEED 100%	24	23	22	21	20	19	18	17	16
FEED 60%	1	2	3	4	5	6	7	8	9

Biological consequences: Direct effects of CC

➢ Combined effect of increasing temperature and feed restriction in seabream juveniles

Methodology

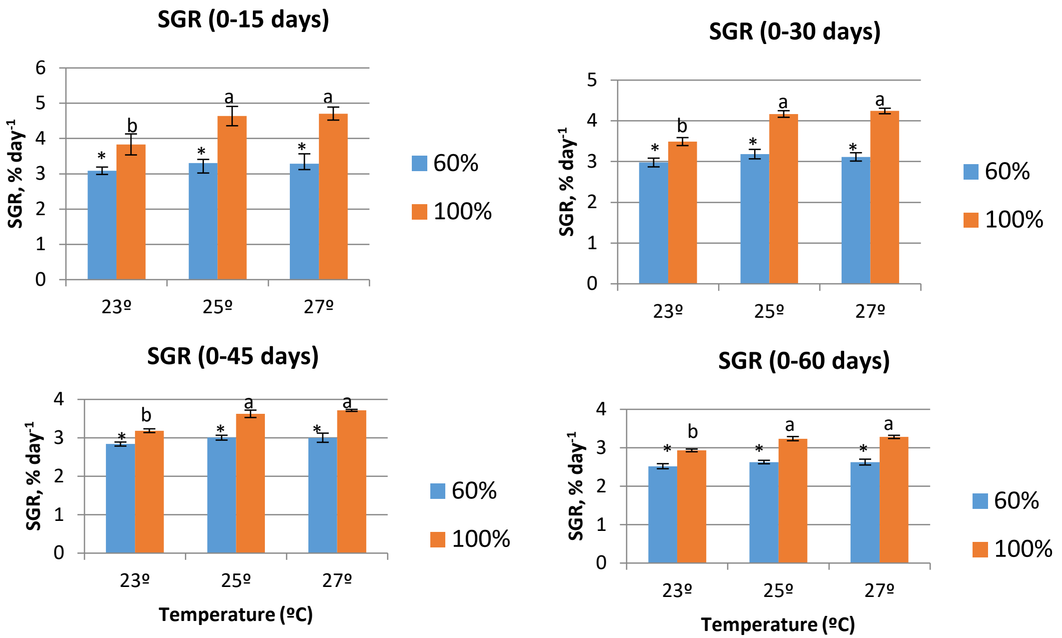
- Samplings: 0, 15, 30, 45, 60 days
- **Growth performance***:* specific growth rate (SGR, % day^{-1}), coefficient of variation for weight (CV, %), condition factor (CF, g cm^{-3}), Hepatosomatic index (HSI, % body weight), survival (S, %) and feed intake (FI, % body weight)
- **Stress biomarkers** : reactive oxygen species (ROS): catalase, superoxide dismutase, glutathione peroxidase, GSH/GSSH
- **Blood indicators** *:* hematocrit, cortisol, glucose, lactate, Na+, K+, Cl- . cholinesterase.

Biological consequences: Direct effects of CC

➤ Combined effect of increasing temperature and feed restriction in seabream juveniles

Results

Growth performance: Specific Growth Rate (SGR)



Specific Growth Rate, SGR (ln final Body weight (g) - ln initial Body weight (g)) x days-1 of fish fed at two rations under different temperatures. Different letter indicates significant differences among groups (*P*<0.05).

Two-way analysis of variance of SGR in different periods of feed restriction and acute temperature exposure.

Periods	Factors	P-value
0-15	Temperature	0.002
	Feed restriction	0.000
	Interaction	0.051
0-30	Temperature	0.000
	Feed restriction	0.000
	Interaction	0.000
0-45	Temperature	0.000
	Feed restriction	0.000
	Interaction	0.003
0-60	Temperature	0.000
	Feed restriction	0.000
	Interaction	0.005

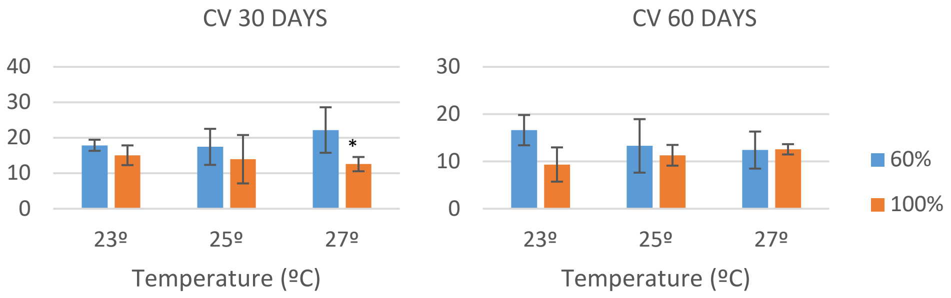
- Significant main effects of feed restriction and temperature on SGR
- Exposure to 27 °C significantly increased SGR and feed-restriction significantly decreased SGR.

Biological consequences: Direct effects of CC

➢ Combined effect of increasing temperature and feed restriction in seabream juveniles

Growth performance

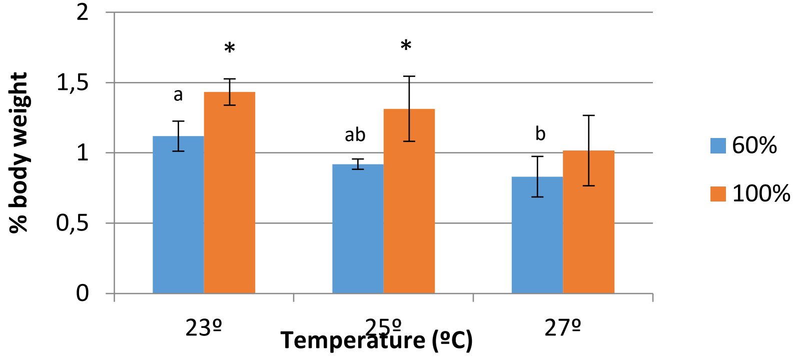
Coefficient of variation for weight (CV, %)



Coefficient of variation for weight (CV, tank standard deviation weight x tank mean weight-1) of fish fed at two rations under different temperatures. Different symbol indicates significant differences among groups (*P*<0.05).

Temperature increase did not affect body size variations of fish (*P*>0.05)

Hepatosomatic Index (HSI)



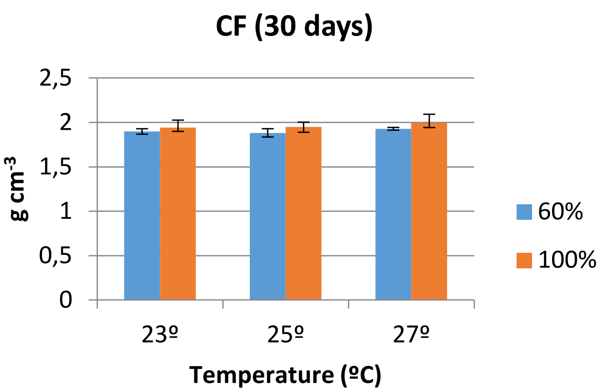
Hepatosomatic Index (HSI=100 x Liver weight (g) x Body weight-1 (g)) of fish fed at two rations under different temperatures. Different symbol indicates significant differences among groups (*P*<0.05).

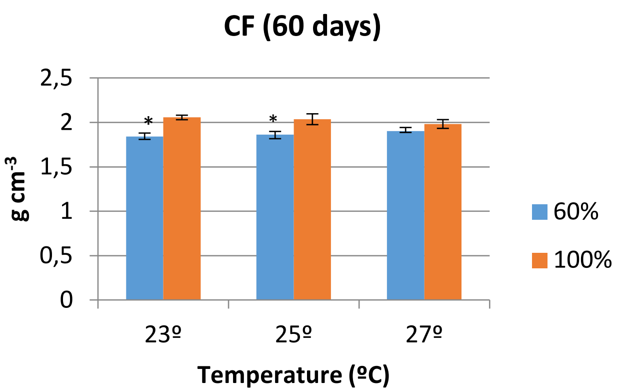
HSI was lower in the feed restricted group and with temperature decreased (*P*<0.05)

Biological consequences: Direct effects of CC

➤ Combined effect of increasing temperature and feed restriction in seabream juveniles

Growth performance: Condition Factor (CF)





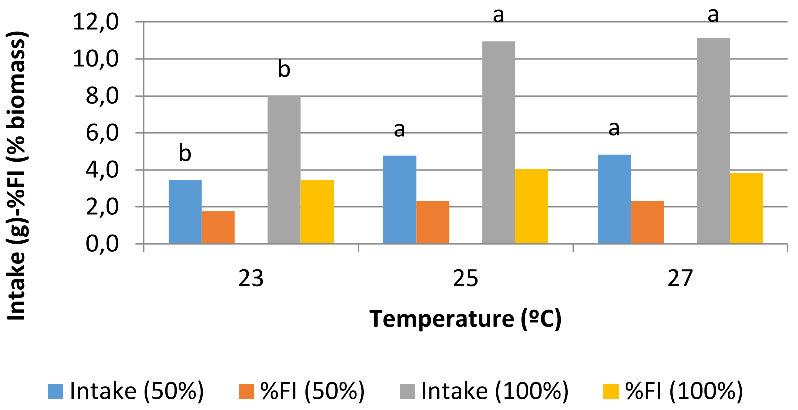
Condition factor (CF=100 x (Body weight (g) x Total length-3 (cm)) of fish fed at two rations under different temperatures. Different symbol indicates significant differences among groups (*P*<0.05).

- There was no effect of temperature.
- Feed-restriction significantly decreased (*P*<0.05) CF at 23º and 25º at the end of the assay

Biological consequences: Direct effects of CC

➢ Combined effect of increasing temperature and feed restriction in seabream juveniles

Growth performance: Feed Intake

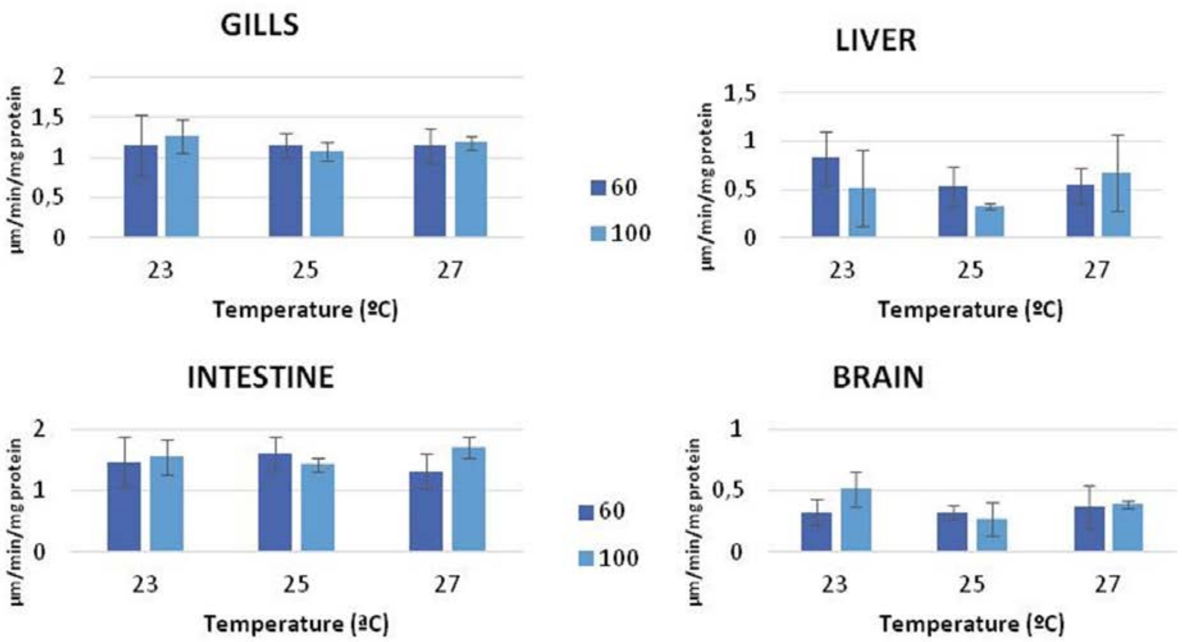


Intake (g) and % Feed Intake (FI, % biomass day^{-1}) of fish fed at two rations under different temperatures. Different letter indicates significant differences among groups (*P*<0.05).

- Increase of total intake (g) with temperature increase
- No effect of temperature or feed restriction on FI (% biomass per day)

➢ Combined effect of increasing temperature and feed restriction in seabream juveniles

Stress biomarkers reactive oxygen species (ROS): **CATALASE**



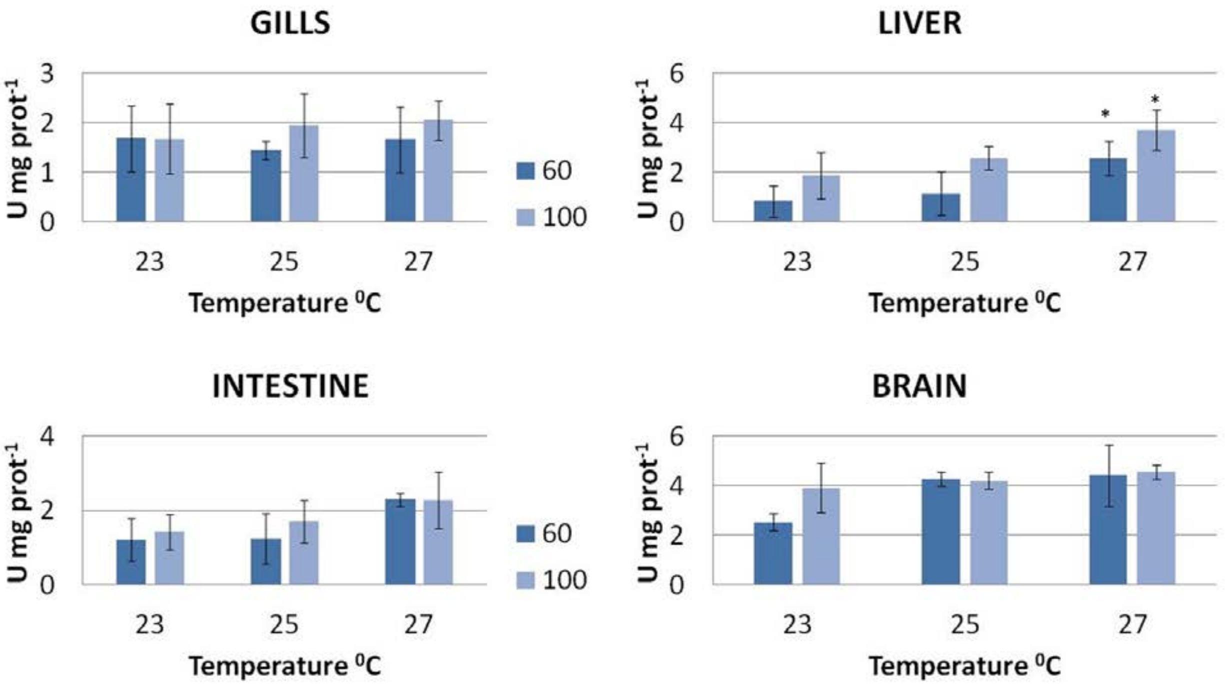
- No significant main effect of feed restriction or temperature on catalase levels after 60 days of treatments
- No significant interaction between temperature and feed restriction.

Catalase (µm min^{-1} mg protein $^{-1}$) activities in liver, gills, intestine and brain of seabream following a two months of feed restriction trial and acute temperature exposure

Biological consequences: Direct effects of CC

1. Combined effect of increasing temperature and feed restriction in seabream juveniles

Stress biomarkers reactive oxygen species (ROS): **SUPEROXIDE DISMUTASE (SOD)**

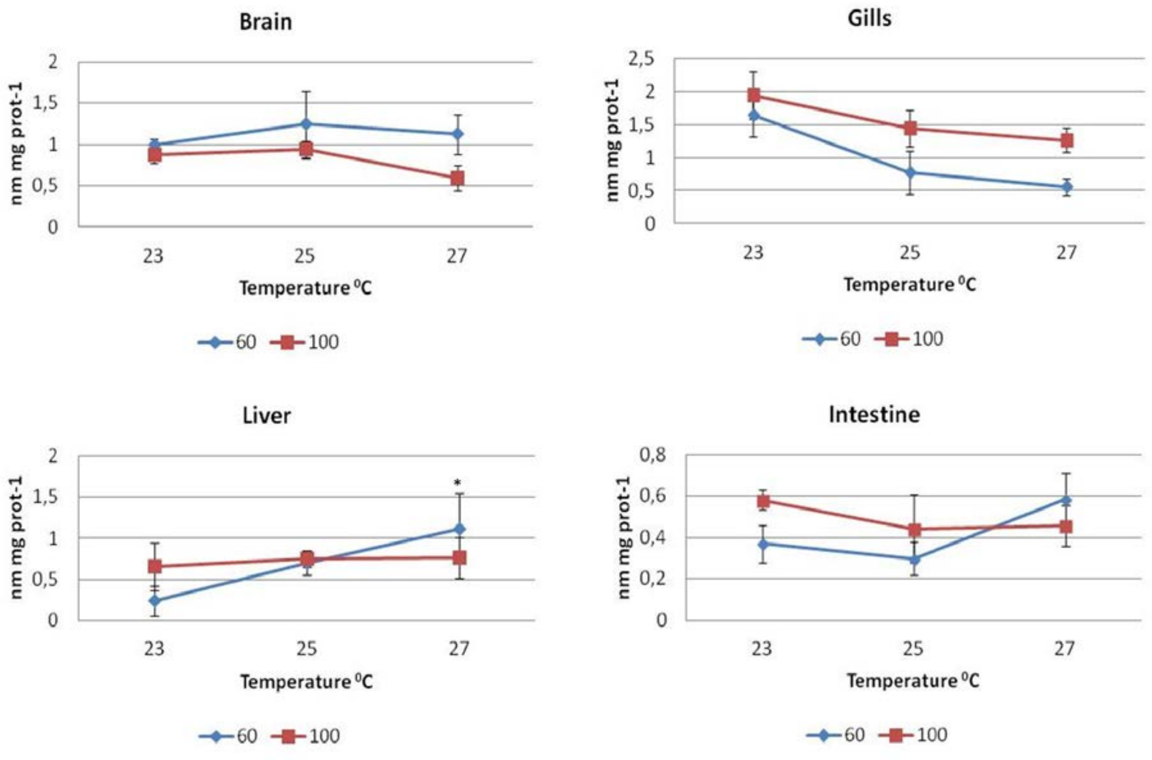


- In liver and intestine, SOD activity was significantly higher at 270C when compared to 230C.
- No significant main effect of feed restriction or temperature on SOD levels of gills and brain

Superoxide dismutase (μm min^{-1} mg protein $^{-1}$) activities in brain and liver of seabream following a 60 days of feed restriction trial and acute temperature exposure

1. Combined effect of increasing temperature and feed restriction in seabream juveniles

Lipid peroxidation. Thiobarbituric acid reactive substances (TBARS)



- In liver, lipid peroxidation was significantly higher at 270C when compared to 230C (P < 0.05).
- No significant main effect of feed restriction or temperature on lipid peroxidation levels of gills, intestine and brain

TBARS (nmol mg prot $^{-1}$) levels in liver, gills, intestine and brain of seabream following a two months of feed restriction trial and acute temperature exposure. *significantly different from controls (*P* < 0.05).

Combined effect of increasing temperature and feed restriction in seabream juveniles

Haematological and biochemical parameters

Hematocrit (%), glucose (mg/dl), lactate (mg/dl), sodium (mg/dl), clorure (mg/dl) in blood from gilthead seabream following a two months of feed restriction trial and acute temperature exposure

	60%			100%		
	23º	25º	27º	23º	25º	27º
HEMATOCRIT	29.55±2.88	32.75±6.88	36.10±0.01	27.57±3.94	34.95±2.47	35.60±7.83
GLUCOSE	35.95 ± 9.88	23.99 ± 7.41	27.03 ± 9.87	27.24 ± 4.01	30.24 ± 12.93	25.13 ± 11.41
LACTATE	16.27 ± 5.90	29.06 ± 4.61	24.67 ± 5.38	22.35 ± 1.39	19.99 ± 4.18	24.29 ± 8.21
SODIUM	328.11 ± 17.91	332.71 ± 8.14	280.14 ± 87.26	317.75 ± 9.77	343.08 ± 90.97	292.42 ± 106.19
CHLORIDE	171.75 ± 14.25	166.69 ± 39.39	151.26 ± 14.88	185.24 ± 9.66a	159.14 ± 11.84ab	132.42 ± 7.78b

Data were presented as mean ± S.D. (n=5). Different letter indicates significant differences (P<0.05).

No significant differences were observed with temperature increased or feed restriction

➢ Combined effect of increasing temperature and feed restriction in seabream juveniles

- Higher temperatures promoted increased SGR regardless of the food restriction
- No mortality was observed during the experiment
- No significant effect of temperature increased on the coefficient of variation for weight and condition factor was observed
- Higher temperature promoted increased intake (g) but not FI (% biomass day^{-1})
- Stress biomarkers and blood indicators were not affected by temperature increased
- This suggests that the degree of thermal stress endured by these fish is not severe.

➢Impact of toxic algal exposure on farmed sea bream under warming (IPMA)

Fish species: Seabream *(Sparus aurata)* juvenile with 0.1-0.5g

3 temperatures:
- 18ºC (control)
- 21ºC (warming, Δ 3ºC)
- 24ºC (warming, Δ 6ºC)

8 replicates for each treatment (TºC)
18 fish/replicate (Total = 432)

Sampling:
- T0, T1, T2, T3, T4, T5, T6, T7, T8, T10
- 2 hours after feeding

➢Impact of toxic algal exposure on farmed sea bream under warming and acidification

Acclimation: 20 days

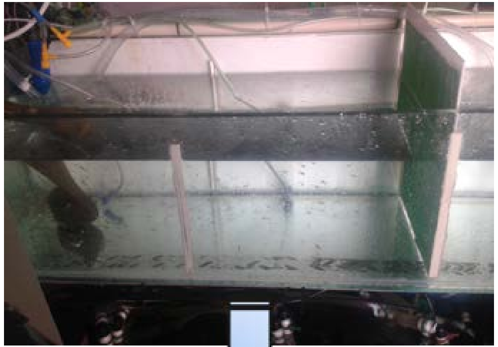
- 15 days (fed with 7.6% b.w. commercial feed)
- 5 days (fed with 7.6% b.w. non toxic mussels)

Accumulation:

- 5 days (**fed with fed** 7.6% b.w. **toxic mussels: paralytic shellfish poisoning toxins, PSTs**)

Depuration:

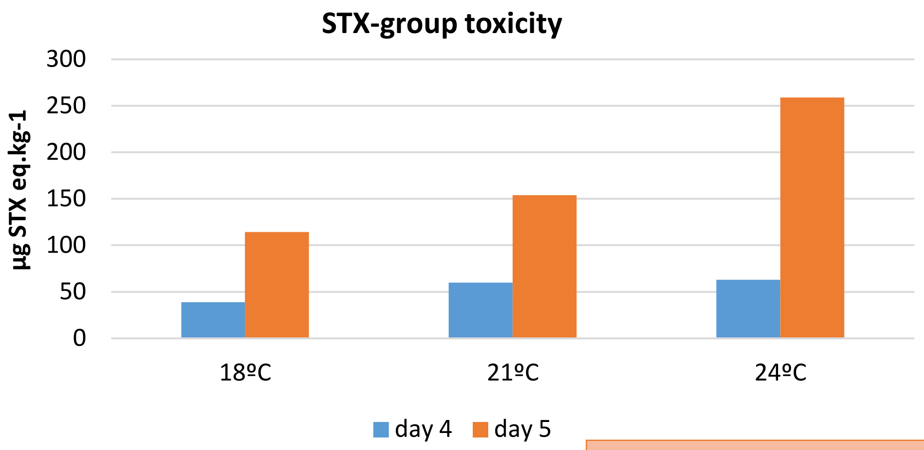
- 5 days (fed with 7.6% b.w. non toxic mussels)



Biological consequences: Indirect effects of CC

➢Impact of toxic algal exposure on farmed sea bream under warming and acidification

- Accumulation: → T0, T1, T2, T3 = PSP's NOT DETECTED
  → **T4, T5, = PSP's DETECTED**
- Depuration: → T6, T7, T8, T9, T10 = PSP's NOT DETECTED in all treatments



< 800 µg STX eq/kg

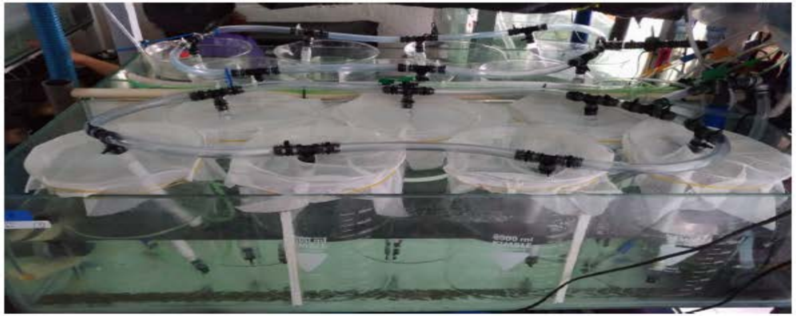
STX-group toxins current limits:

Commission Regulation (EC) No 853/2004: 800 µg PST's/kg

✓ Significant higher accumulation of toxins in fish under 24ºC

Biological consequences: Indirect effects of CC

➢ Effect of acidification on Fish-jellyfish interactions (IPMA)



Jellyfish species: *Aurelia* sp.
Fish species (2 levels)

Argyrosomus regius (2.0-2.5 cm)
Diplodus sargus (1.5 cm)

pH treatment (3 levels)

8.1 (current)
7.7 (2100)
7.3 (extreme)

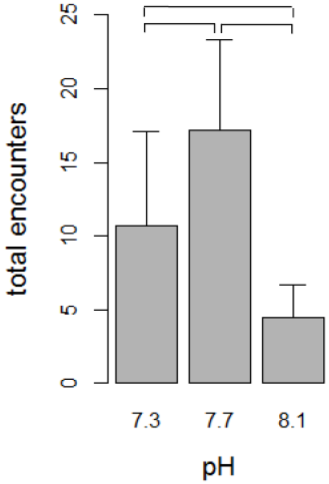
Acclimation: 8 days
Exposure 30 minutes

10 replicates per pH treatment and species
Total= 60 (30/species)

Biological consequences: Indirect effects of CC

➢ Effect of acidification on Fish-jellyfish interactions (IPMA)

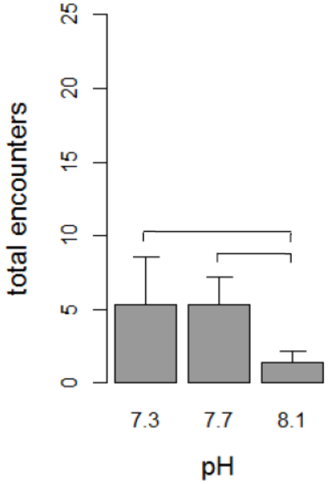
meagre



p-value= 0.000609*

8.1 vs 7.7 : 5.08e-07*
8.1 vs 7.3 : 0.00021*
7.7 vs 7.3 : 0.0018*

seabream



p-value= 1.34e-07*

8.1 vs 7.7 : 0.000534*
8.1 vs 7.3 : 0.000535*
7.7 vs 7.3 : 1.0

- Acidification conditions the increased number of encounters with jellyfish
- Acidification treatments led to significantly increased levels of:
  - acethylcholiesterease (AChE)
  - heat shock proteins (HSP)
  - catalase (CAT)
  - glutathione S transferase (GST)

Summary of direct (temperature, pH, food) and indirect (HABs, jellyfish) effects of CC on seabream and seabass

- ✓ Mortalities rates are not significantly affected by temperature, pH or feed restriction
- ✓ Seawater warming promote increased growth (SGR) regardless of the food restriction
- ✓ Seawater warming may promote toxin accumulation in fish during HABs
- ✓ Acidification conditions result in a higher vulnerability of bream to jellyfish predation.

Main findings & results achieved

WP1
- Socio-economic developments under different scenarios

T1.1
- Model of environmental conditions.

WP3
- Biological consequences
  - Literature Review
  - Direct effects.
  - Indirect effects.

T3.3
- Modelling impact in aquaculture productivity.

➢ Modelling impacts on aquaculture productivity

Descriptor	Detail
Species	Sparus aurata
Location	39° 47' N, 0° 4' W
Size and layout	Leased area: 857,600 m^2; length: 640 m; width: 1,340 m
	Cultivated area: 13-m cage depth; 8,345 m^2
Culture structure	Marine net pens
Culture practice	Starting day: 195; Culture cycle: 510 days
	Stocking density: 519.5 ind. m^{-2}
	Juvenile weight: 38 g LW
Harvest	Harvestable weight: 400-500 g LW
Mortality	8% over cycle
Environmental drivers	Semi-diurnal tide; current inverts with tide
	Current speeds generated by peak spring and neap tides: 0.2 and 0.1 m s^{-1}, respectively
	Temperature, salinity, dissolved oxygen, and DIN for 2015
Finance	Juvenile cost: 275 € per thousand fish
	Feed cost: 1.00 € kg^{-1}
	Farmgate sale price: 5.44 € kg^{-1}

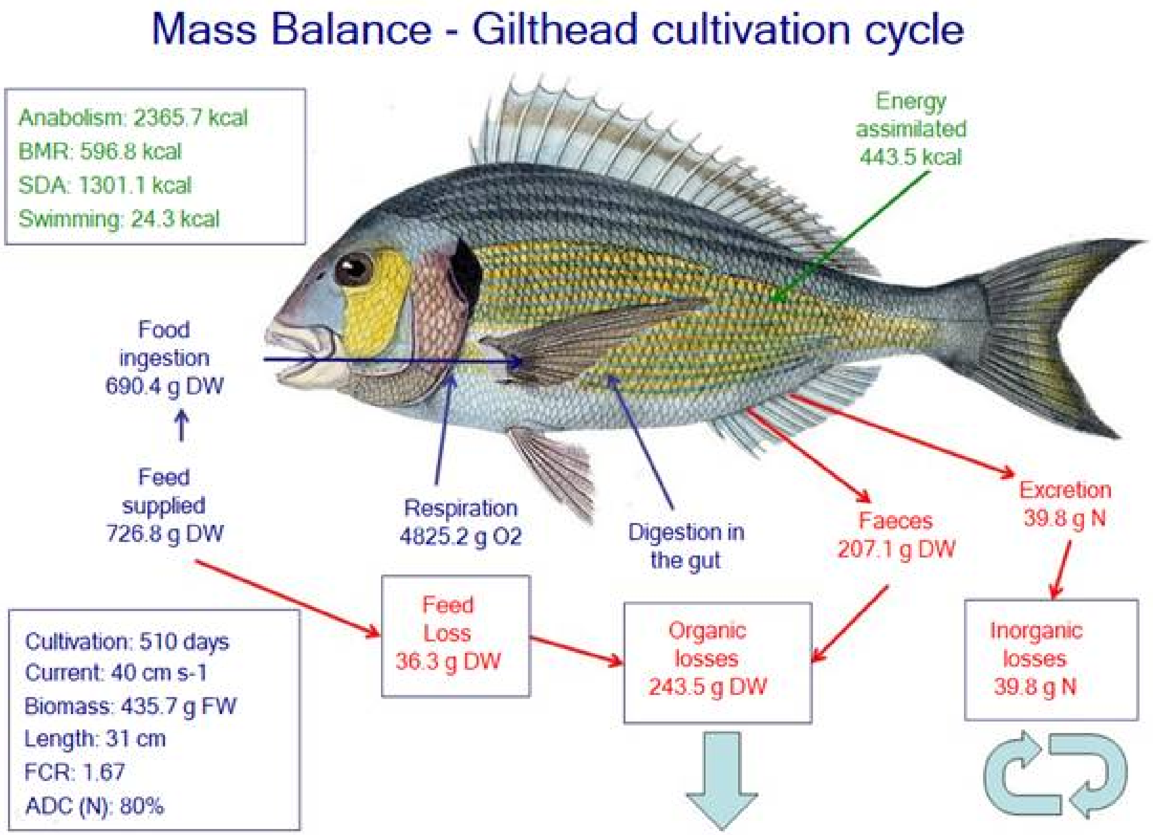
✓Individual growth model (WinFish) and Population model (FARM model) were developed for seabream

✓FARM modelling results for the typical sea bream farm in Western Mediterranean (Spain) under climate change scenarios

Table 1. Culture practice data for a typical European gilthead sea bream farm in the Western Mediterranean (Spain). This data was used to run the FARM model under current conditions and different climate change scenarios. LW: live weight.

Modelling impacts on aquaculture productivity

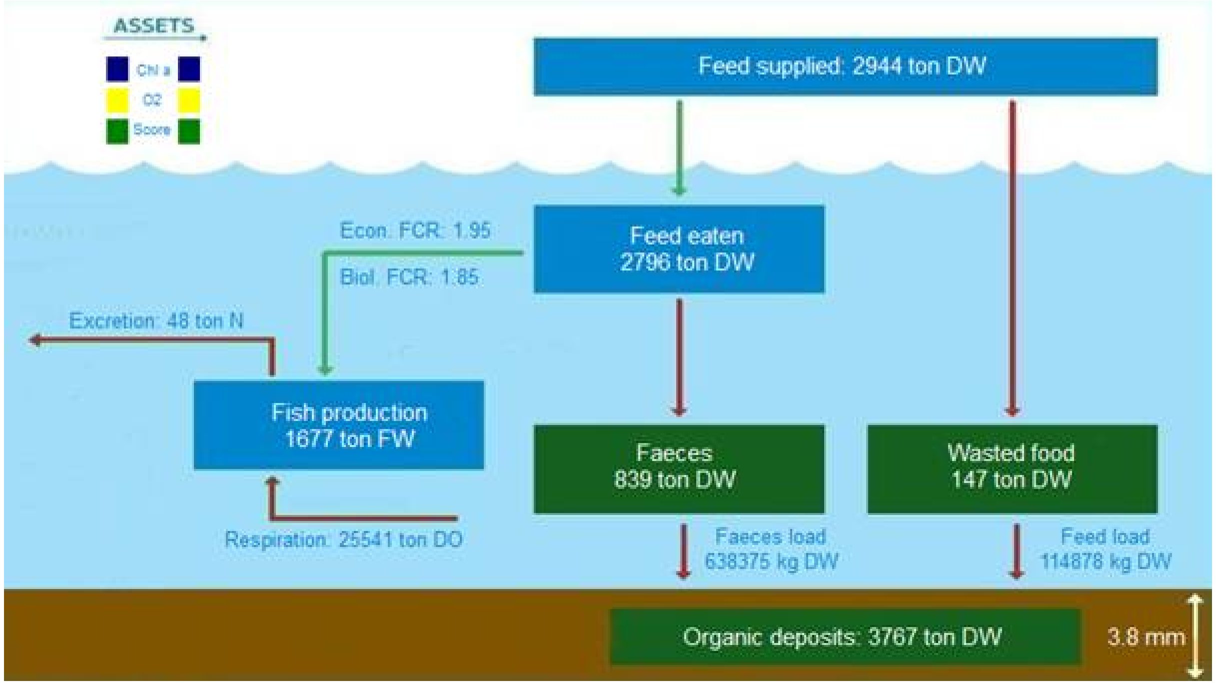
- Individual growth model (WinFish) developed for seabream



WinFish mass balance results for an individual sea bream over a full growth cycle at the typical open water farm in Spain. DW (FW): dry (fresh) weight; BMR: basal metabolic rate; SDA: specific dynamic action; FCR: feed conversion rate

Modelling impacts on aquaculture productivity

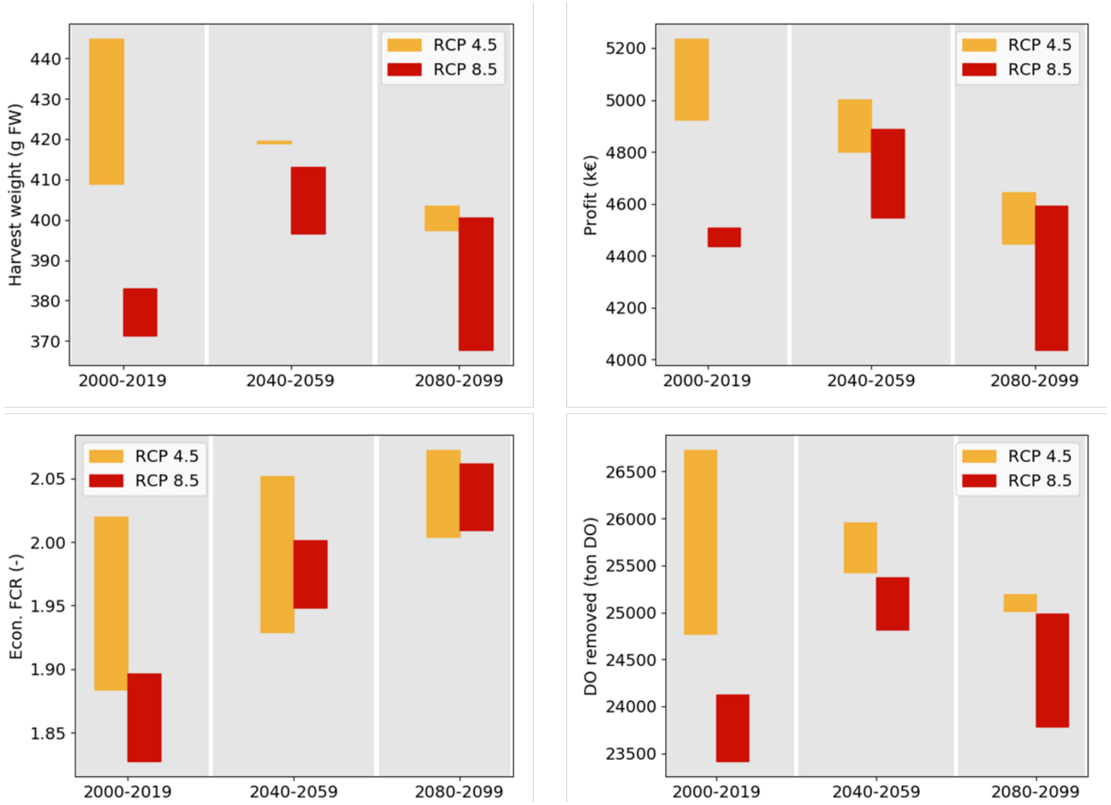
- Population model (FARM model) developed for seabream



FARM model annualized mass balance for sea bream culture in open water cages at the typical Spanish farm (Table 1). Sea bass weight at harvest: 420 gLW.

Modelling impacts on aquaculture productivity

- FARM modelling results for the typical sea bream farm in Western Mediterranean (Spain) under climate change scenarios



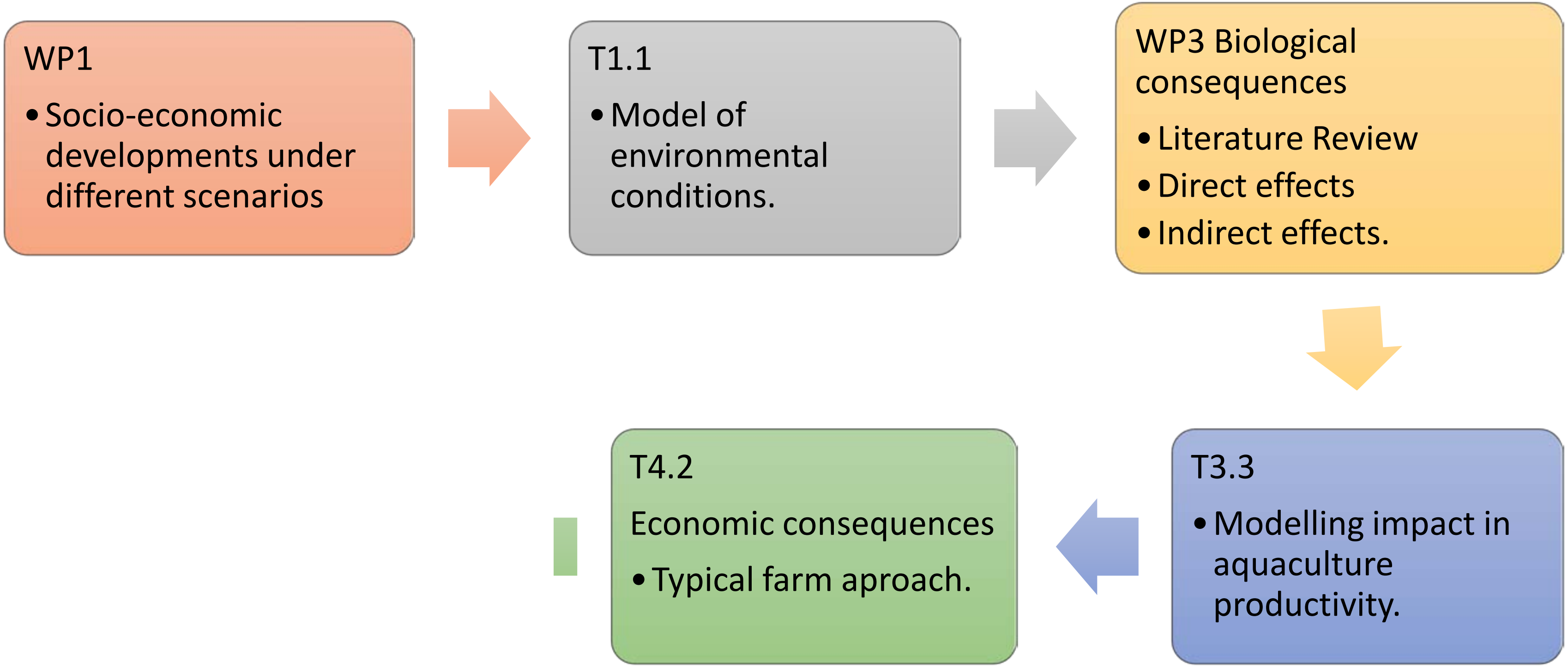
- **Growth and profit** are always greater under the low emission scenario, although they tend to converge with time
- Under both emission scenarios the **feeding efficiency** of sea bream diminishes as climate change progresses (**Feed Conversion Rate** increases).

FARM outputs for the typical seabream farm in the Western Med under different climate change scenarios. Orange and red bars represent the range (spread) of simulation values for low- and the high-emission scenario, respectively. The drivers for the different climate change scenarios were obtained from the POLCOMS model as detailed in the text. LW: live weight; DO: dissolved oxygen.

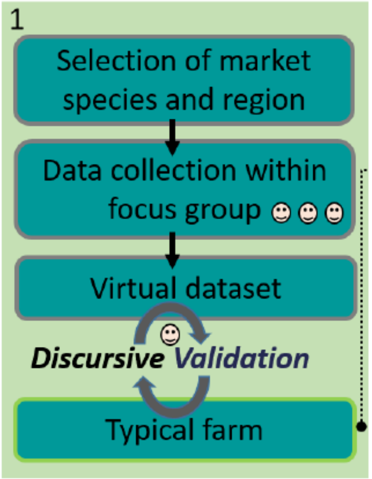
CERES

Climate change and European aquatic RESources

Main findings & results achieved



Typical farm approach background

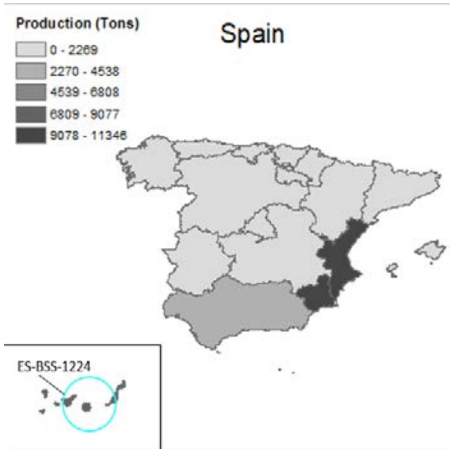


1. **Opportunity costs** (labour, capital, property)
2. **Depreciation** (Buildings, Equipment, Farming systems)
3. **Cash costs**

Note: in CERES we refer everything to the operating costs, which are the returns minus the cash costs without interests.

Economic consequences

- Analysis on farm-level productivity for Spain and seabass production using the "typical farm approach". (TI-SF)



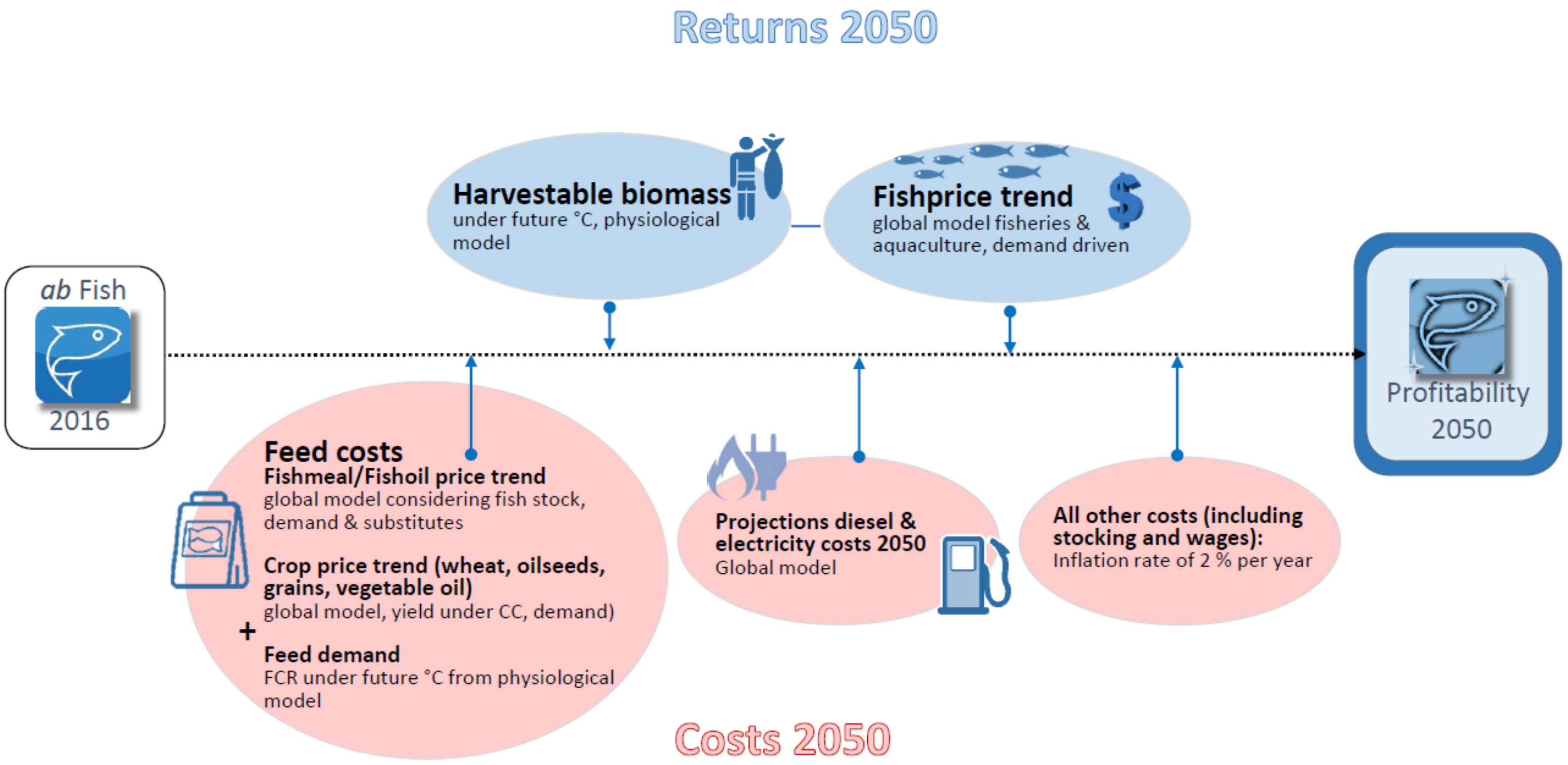
Typical sea bass farm from Canary Islands (ES-BSS-1224):

- Annual production 1224 tons
- Main cost factors
  - feed costs 61.67%
  - stocking costs 18.13%
  - labour costs 9.16%.

Typical seabass farm for Canary Islands

- Total annual catching weight is around 1.224 tons per year.
- Feed costs (61.67% of overall cash costs), stocking costs (18.13%) and labour costs (9.16%)
- Market returns are between 5 and 6 Euros per kg fish

Trends in costs/returns considered for future Seabass production

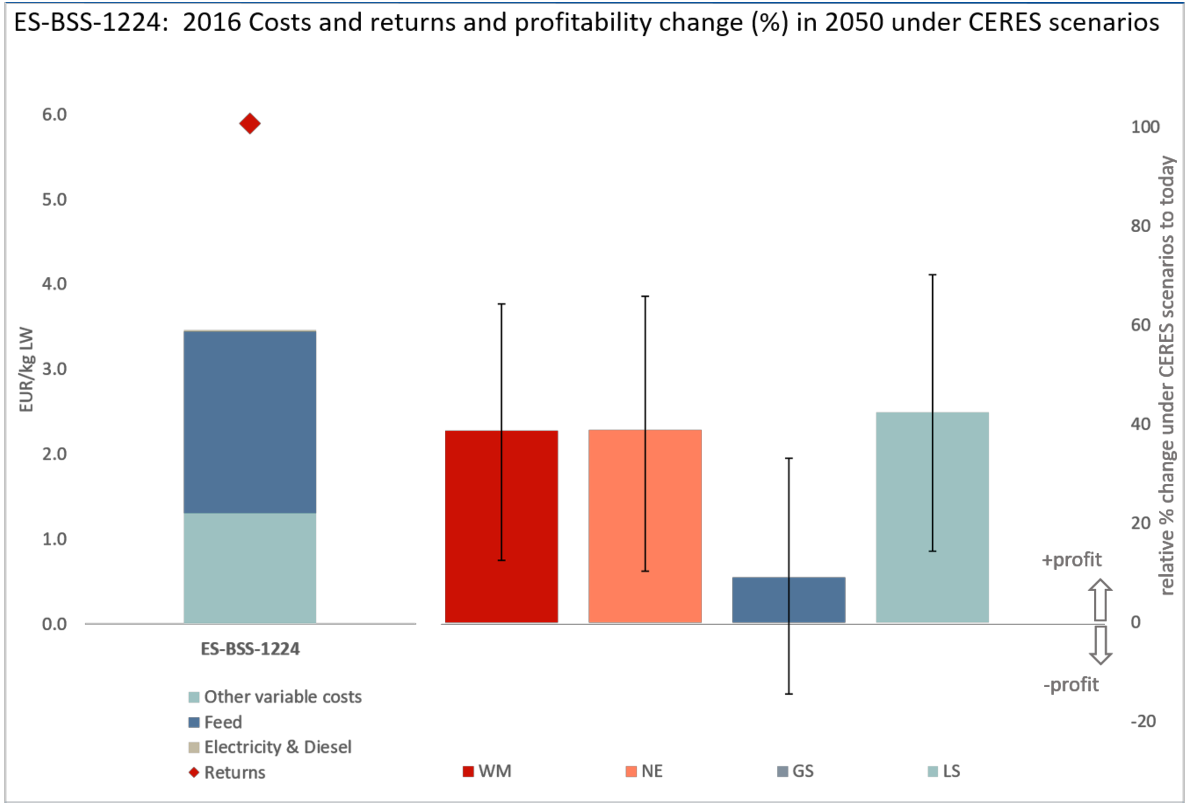


Feed component price development under CERES scenarios+/-historic variation

Estimated changes of production and prices for fish meal and fish oil by 2032

		"Global Sustainability"	"National Enterprise"	"World Markets"
Production	**Fish meal**	+19%	-34%	-94%
	Fish oil	+31%	-26%	-92%
Price	**Fish meal**	+56%	+68%	+477%
	Fish oil	+39%	+83%	+522%

Economic consequences: Analysis on farm-level productivity for Spain and seabass production using the "typical farm approach (TI-SF)



Stacked plot of cost and returns of typical Spanish seabass farm (ES-BSS-1224) in 2016 (left) and relative changes in profitability (returns against costs) in the year 2050 under the CERES scenarios World Markets = WM, National Enterprise = NE, Global Sustainability = GS, Local Stewardship = LS compared to today (right). Error bars indicate 95% upper and lower probability ranges from Monte Carlo simulation results on potential price variation.

Main findings & results achieved

WP1
- Socio-economic developments under different scenarios

T1.1
- Model of environmental conditions.

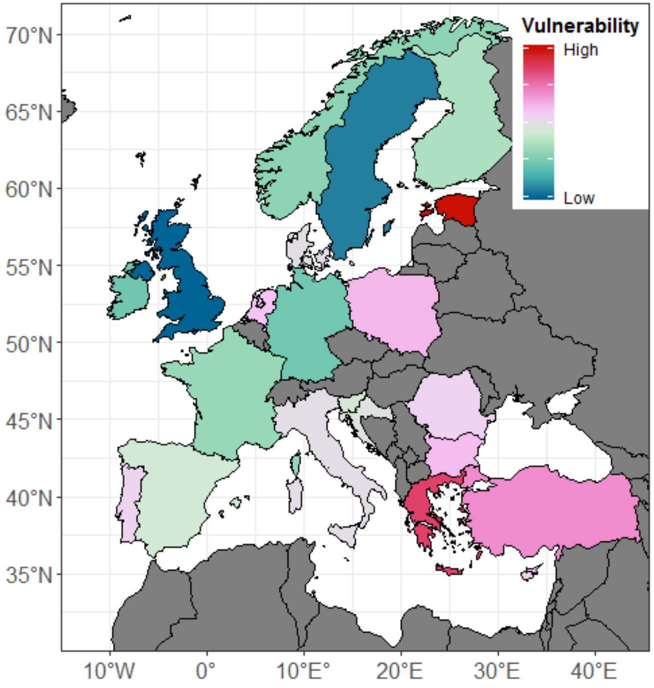
WP3 Biological consequences
- Literature Review
- Direct effects.
- Indirect effects.

T3.3
- Modelling impact in aquaculture productivity.

T4.2
Economic consequences
- Typical farm aproach.

WP5
- Bow-Tie.
- Vulnerability assays

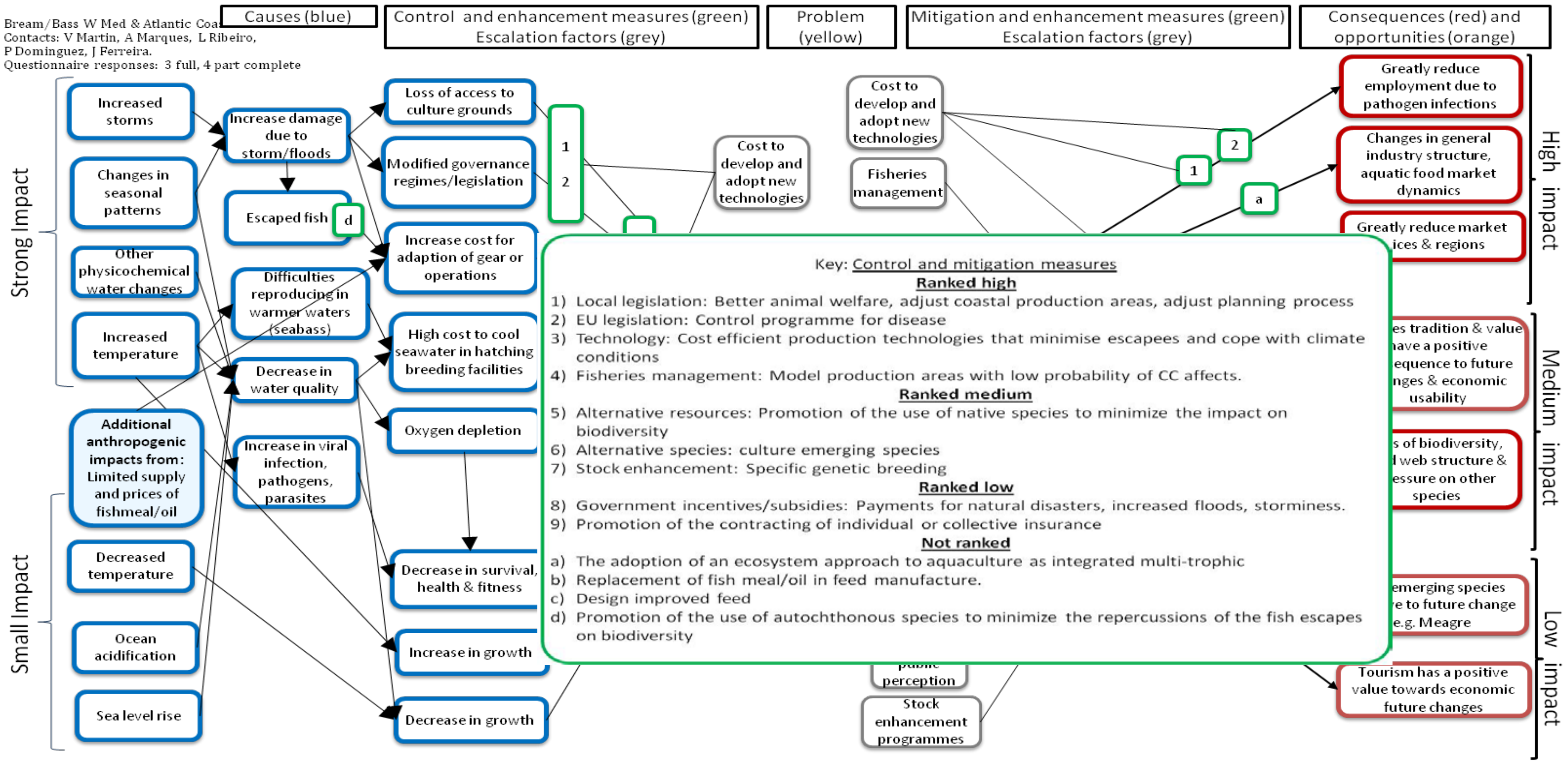
Vulnerability assays (UHam

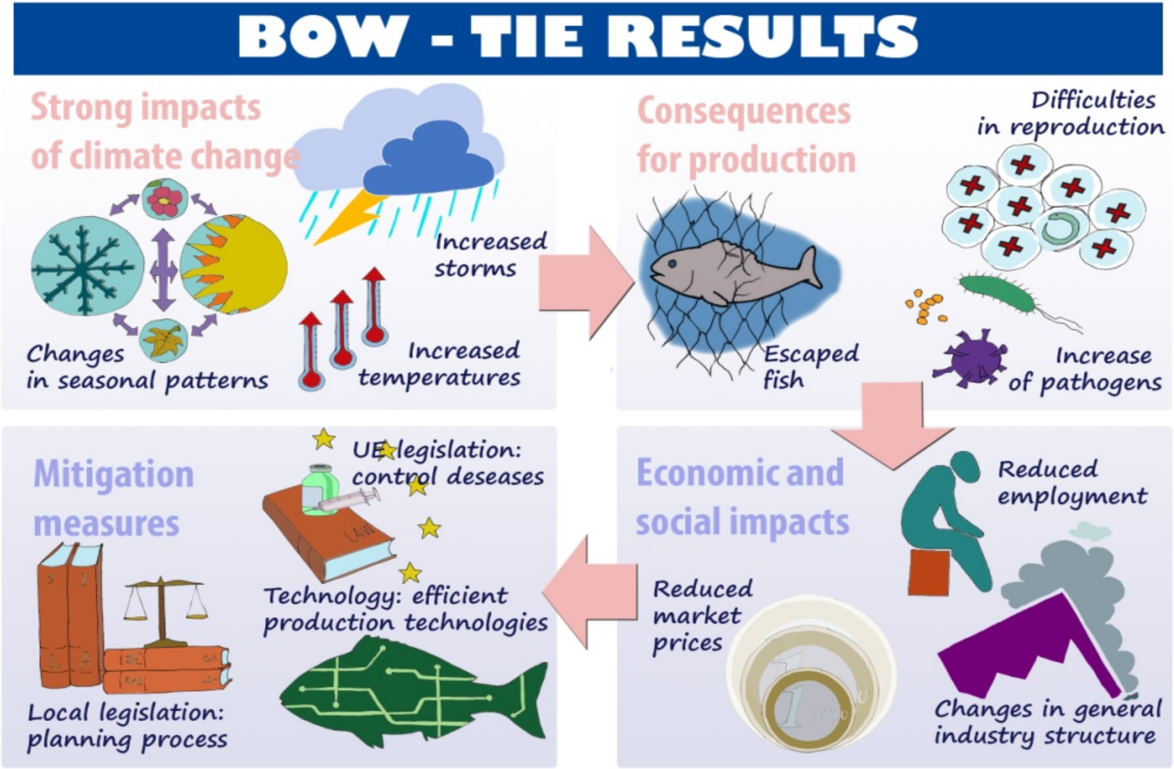


Climate vulnerability assessment for Europe. Colour scale is linear in the value of the corresponding score, but is presented without values, as they have little direct meaning. *Picture credit: Myron Peck*

- The CVA included the physiological and farming methods of **seven species** (Atlantic salmon, seabass, seabream, trout, carp, mussels, oysters and clams) representing > 95% of the value for the region.
- Based on available economic data, the vulnerability of **22 countries** – the top producers in the Europe28 as well as Norway and Turkey – was ranked and relative values are shown (right)
- By 2050 in RCP8.5, projected warming reduced the suitability of culture conditions for seabass and seabream in the Western Mediterranean Sea. Indirect threats of climate change (e.g. increases in disease or jellyfish blooms) were not included in this analysis.
- Many of the firms growing seabass and seabream in the Mediterranean region are relatively large and, therefore, have better adaptive capacity in terms of potential technological innovation in the future.
- National-level vulnerability was variable in the Western Mediterranean because countries had a different: i) level of economic reliance on aquaculture, ii) portfolio of species grown and iii) progress towards implementing climate adaptation plans.

➢ Bow-Tie analyses to conceptualize CC impacting fish farm for seabream and seabass in this area (UHULL).




BOW - TIE RESULTS
Strong impacts of climate change
Increased storms
Changes in seasonal patterns
Increased temperatures
Consequences for production
Difficulties in reproduction
Escaped fish
Increase of pathogens
Mitigation measures
UE legislation: control deseases
Technology: efficient production technologies
Local legislation: planning process
Economic and social impacts
Reduced employment
Reduced market prices
Changes in general industry structure

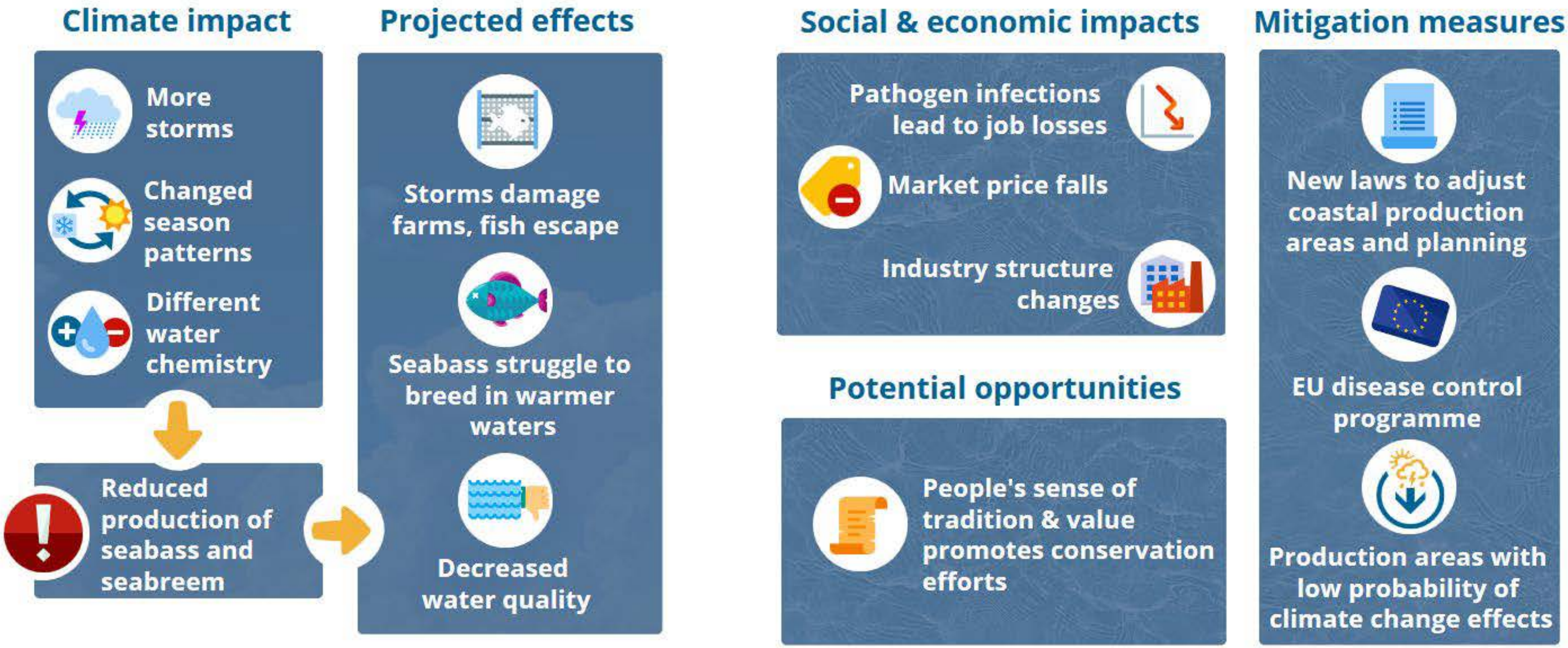


Figure 7 BowTie analysis based on stakeholder feedback. All full BowTies available http://bit.ly/CERESbowties2020

Main recommendations

- Simplify certain administrative procedures. Regulations and administrative procedures appropriate to the possible adaptation measures of the facilities.
- Diversification of species. Development of techniques for rearing and production of the new species for aquaculture including promotion of the use of native species.
- Proper planning and management of aquaculture sites. Facility designs to minimize massive leaks.
- Control diseases. Implementing severe biosecurity programs.
- Implementation of an ecosystem approach in aquaculture
  - Integrated multi-trophic aquaculture.
  - Economic and/or fiscal incentives at the national, regional and local levels

CERES

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