Efeitos de alterações climáticas na produtividade de sistemas costeiros: o estuário do Rio Minho como caso de estudo

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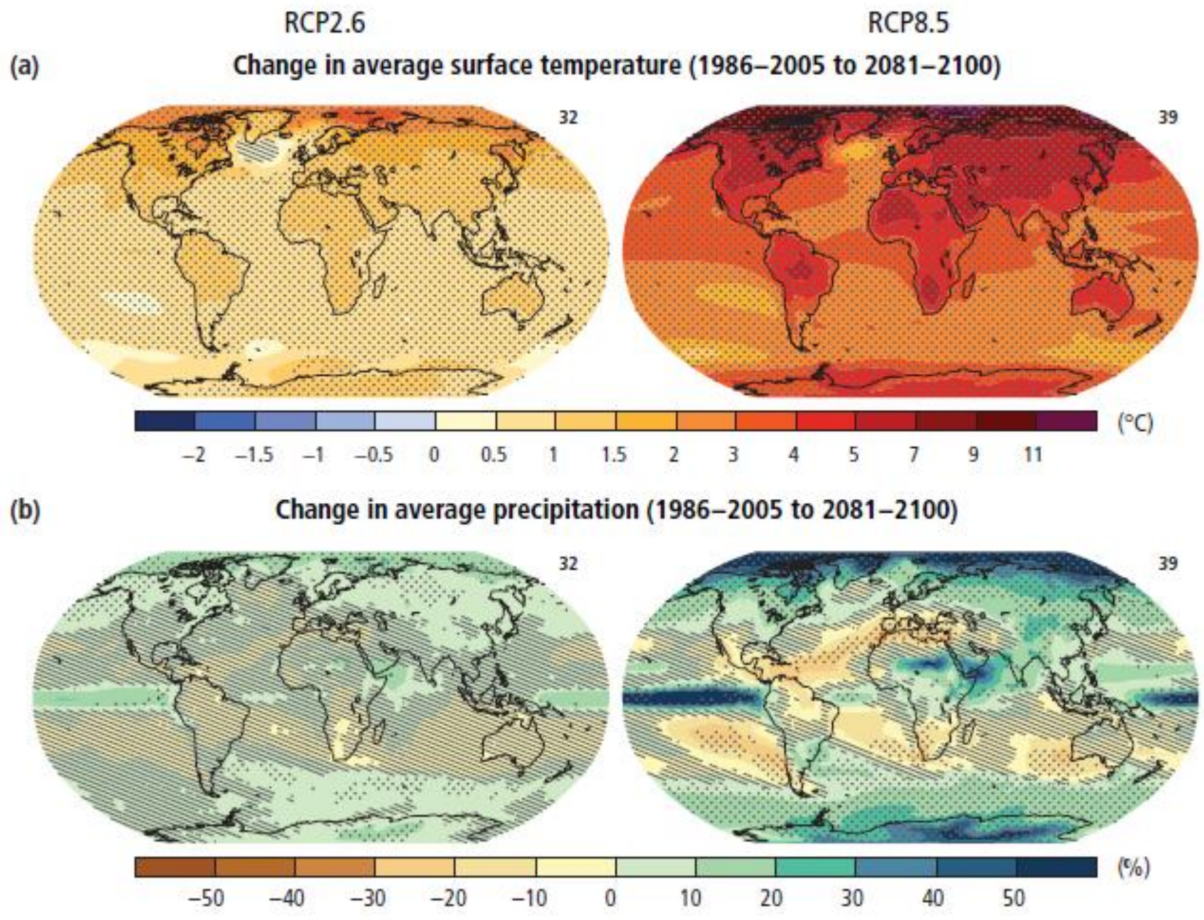
Climate change | temperature & precipitation



Projections for Portugal:

- Temperature will increase
- Precipitation will decrease

Source: IPCC 2014, Climate Change 2014- Synthesis Report for Policy Makers

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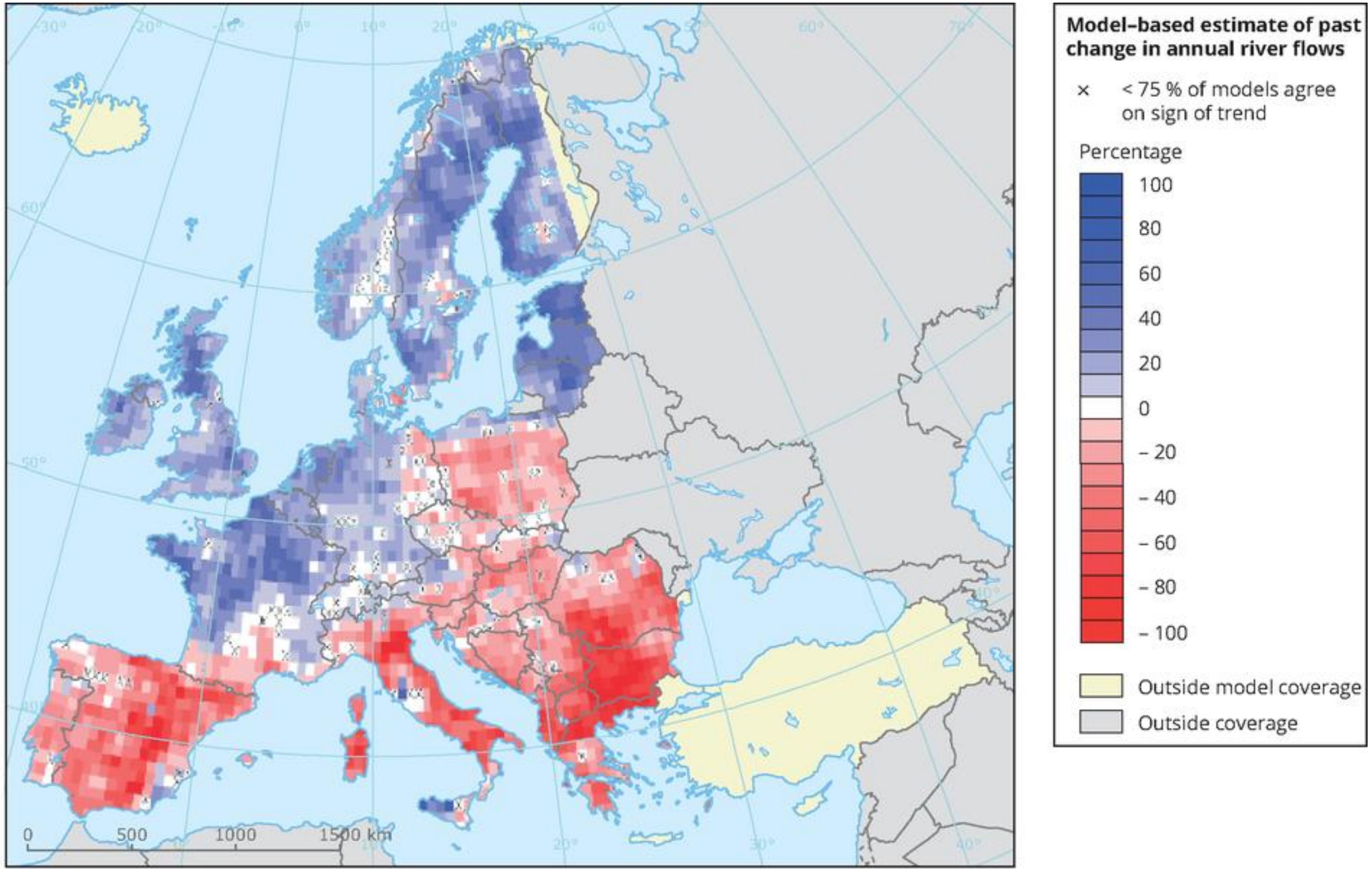
Climate change | River flow



Source: European Environment Agency (eea.europa.eu)

- Temporal coverage: 1963-2000
- Significant decreases in river flow in Southern and Eastern Europe

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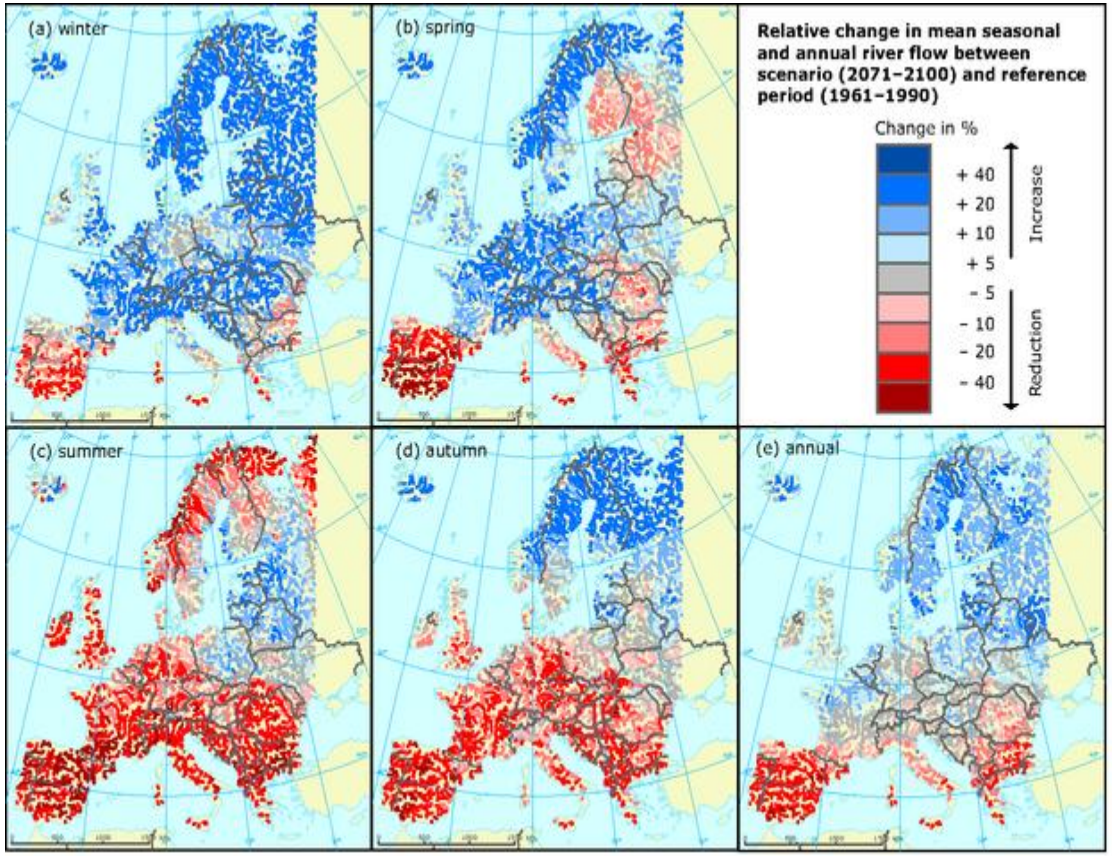
Climate change | River flow



Source: European Environment Agency (eea.europa.eu)

- Relative change between scenario (2071-2100) and reference period (1961-1990)
- Significant decreases for Southern Europe
- Predominant in the Iberian Peninsula
- Reductions of more than 20%

Climate change | temperature & river flow

- Climate change is projected to cause **significant changes** in the seasonality of **river flows** across Europe.

- North- and northwest regions will tend to present increased wetting trends in the winter; south- and south-eastern Europe will show a widespread **drying tendency from late winter until late summer**

- River flow variations will be adding to **temperature rise**.

Why are estuaries important?

- They provide important ecosystem services (relevant for human populations)

Coastal protection

Productivity

Highly productive | Nurseries for species of commercial interest

Economical Importance

Fisheries | Tourism | Harbors | Ports

Using ecosystem models | Prediction tools

- Implementing an **ecosystem model** to check for temporal variations on the biological communities of the Minho estuary under the effect of climatic stressors

- comparing **single-stressor** and **multiple-stressor** scenarios to check for potential stressor interactions

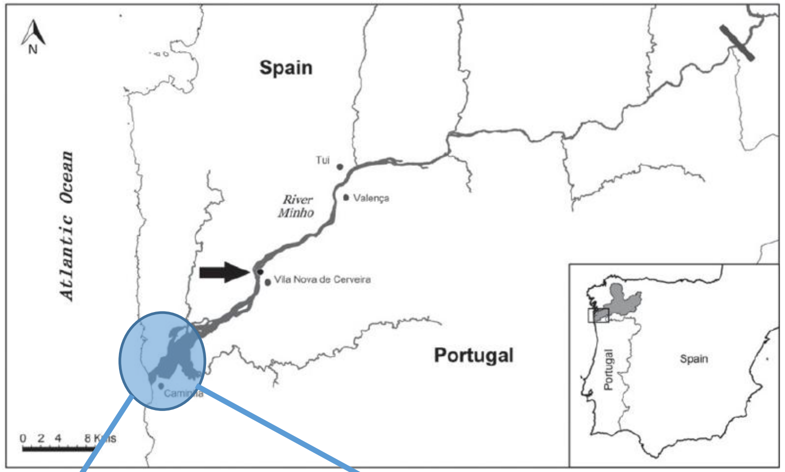


Figure extracted from Mota et al. 2014

Estuário do Rio Minho

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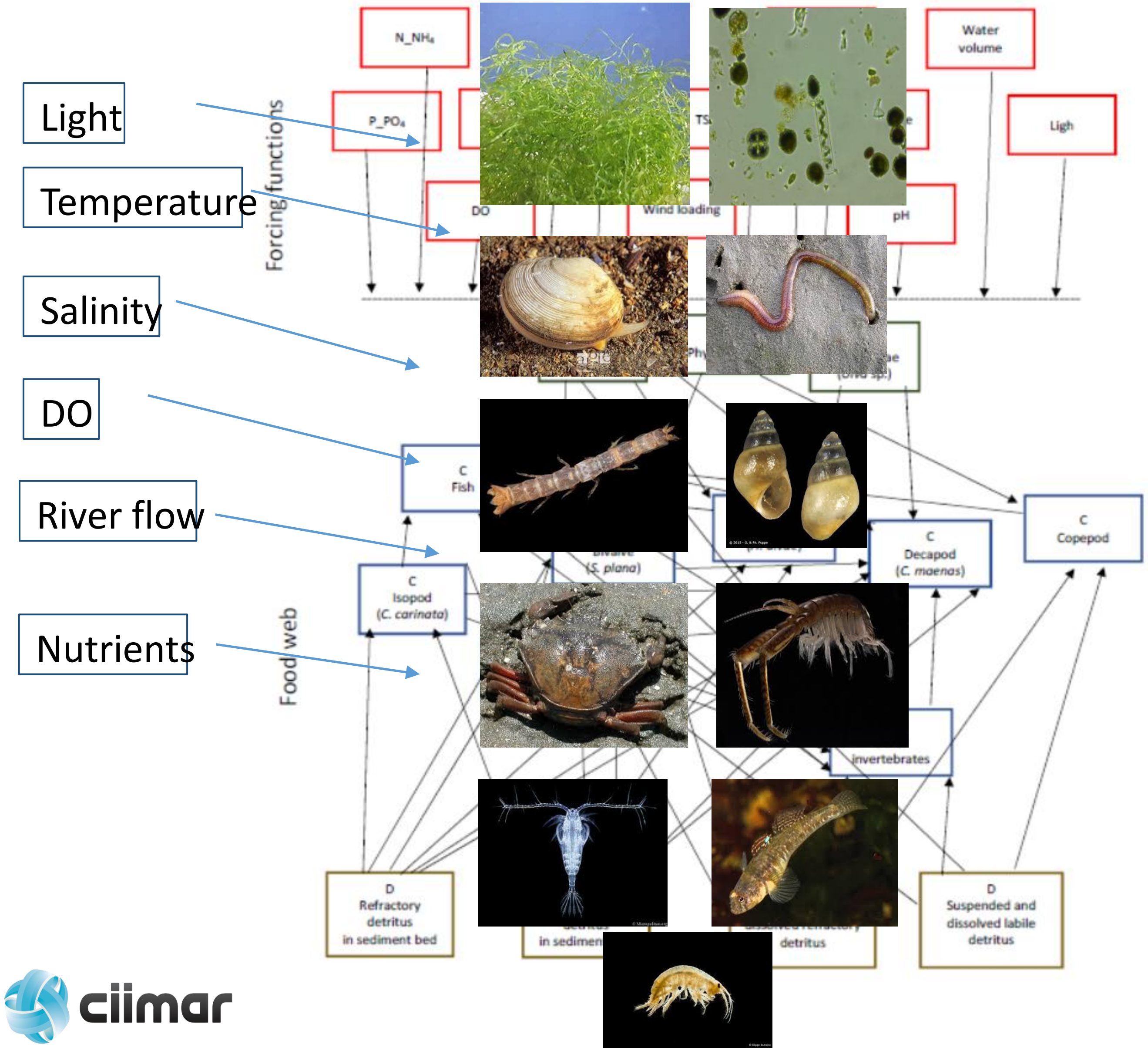
4. Conceptual diagram



- **12 external (forcing) functions**

NH4, PO4, NO3, DO, CO2, TSS, Wind loading, Salinity Temperature, pH, Water volume, light

- **Food web**
- **3 primary producers groups**

Periphyton, Phytoplankton, Macroalgae

- **9 consumers groups**

Isopod, Amphipod, Polychaete, Bivalve, Gastropod, Decapod Copepod, Other invertebrates, Fish

- **4 detritus groups**

Refract. detritus in sediment, Labile detritus in sediment, Suspended and dissolved refract. detritus, Suspended and Dissolved labile detritus

4. Conceptual diagram

Light

Temperature

Salinity

DO

River flow

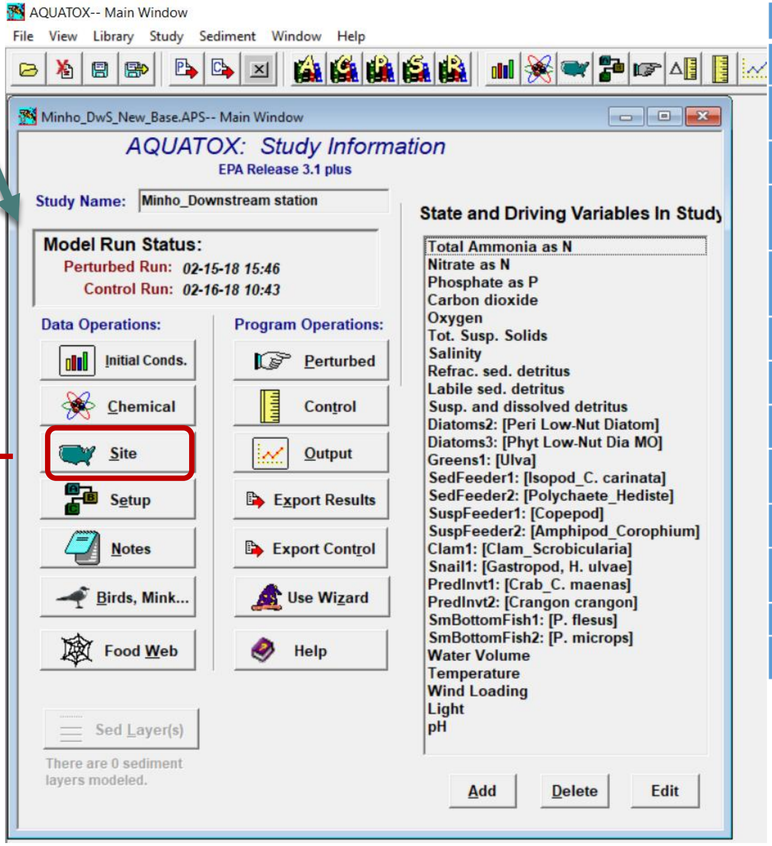
Nutrients

Minho Ecosystem Model- implemented in AQUATOX 3.1 (US- EPA)

- Incorporates physical, hydrodynamics, biogeochemical and physiological processes performing on ecosystems
- Accounts and integrates oscillations of different factors and, thus, project the expected variations on the ecosystem

MOHID
Water Modelling System

Parameter	Value	Units	Reference
Maximum length	40	km	Sousa et al. 2007
Volume	7.0E+07	m^3	Ferreira et al. 2003
Surface area	2.3E+07	m^2	Sousa et al. 2007; Freitas et al. 2009
Site width	2000	m	Sousa et al. 2005
Mean depth	2	m	Ferreira et al. 2003
Maximum depth	4	m	Ferreira et al. 2003
Av. temperature	16	°C	Sousa et al. 2008 and in situ measurements (unpublished)
Temperature range	15	°C	Sousa et al. 2008 and in situ measurements (unpublished)
Latitude	41.53	degrees	Google Earth
Altitude	0	m	Google Earth
Av. light	324.46	Ly day^{-1}	Estimated from http://pvshop.eu/Solar-Irradiation-in-Europe
Annual light range	404	Ly day^{-1}	Estimated from http://pvshop.eu/Solar-Irradiation-in-Europe
Mean evaporation	43.39	$year^{-1}$	Estimated based on Sumner and Belaineh, 2005
Extinc. Coeffi. water	2.76	m^{-1}	Martins et al. 2001
Extinc. Coeffi. sediment	0.17	$(m\ g/m3)^{-1}$	Default used in AQUATOX
Extinc. Coeffi. DOM	0.03	$(m\ g/m3)^{-1}$	Default used in AQUATOX
Extinc. Coeffi. POM	0.12	$(m\ g/m3)^{-1}$	Default used in AQUATOX



Parameters	Hediste diversicolor	Cyathura carinata	Corophium sp.	Scrobicularia plana	Hydrobia ulvae	Carcinus maenas	Other invert.	Fish
Half-saturation feeding (mg L^{-1})	0.07 (prof. assump)	0.05 (default)	0.05 (default)	0.05 (default; calibration)	0.01 (prof. assump.)	0.5 (prof. assump.)	0.05 (default)	0.25 (AQUATOX)
Max. consump. (g (g day)$^{-1}$)	0.55 (prof. assump)	0.23 (in AQUATOX)	1.3 (prof. assump)	0.7 (in AQUATOX)	0.05 (in AQUATOX)	0.097969585 (Brylawski and Miller, 2006)	0.17 (Adamack et al., 2012)	1.36 (in AQUATOX)
Temp. response slope	2.4 (default)	2.4 (default)	2 (default)	2 (default)	1.4 (in AQUATOX)	2 (Brylawski and Miller, 2006)	1.72 (Adamack et al. 2012)	2.8 (in AQUATOX)
Optimum temp. (°C)	18 (prof. assump.)	20 (prof. assump.)	18 (Poggiale & Dauvin, 2001)	19 (Verdelhos et al. 2015; calibration)	20 (prof. assump.)	20 (McGaw& Whiteley 2012; calibration)	20 (prof. assump.)	18 (from fishbase.org for P. microps)
Max. temp (°C)	40 (prof. assump)	45 (Burbank & Burbank, 1987)	35 (Poggiale & Dauvin, 2001)	32 (Verdelhos et al. 2015; calibration)	35 (in AQUATOX)	38 (McGaw& Whiteley 2012; calibration)	35 (prof. assump.)	24 (from fishbase.org for P. microps)
Min. temp (°C)	3 (prof. assump)	0 (in AQUATOX)	5 (default)	10 (in AQUATOX; calibration)	5 (prof. assump.)	5 (prof. assump.)	10 (prof. assump.)	8 (from fishbase.org for P. microps)
Mean weight (g wet wt)	6 (based on Barragão, 2013)	0.01219 (Sprung, 1993)	$3.7E^{-5}$ (default)	2.8231 (Verdelhos et al., 2005)	0.001007 (Cardoso et al. 2002)	26.18 (Brylawski and Miller, 2006)	5.74 (Adamack et al. 2012)	0.002575 (Souza et al. 2014)
Endogenous resp. (day^{-1})	0.01985 (in AQUATOX)	0.04 (in AQUATOX)	0.005 (in AQUATOX)	0.0058 (in AQUATOX)	0.002 (in AQUATOX)	0.008281 (Brylawski and Miller, 2006)	0.01928 (Adamack et al. 2012)	0.01541 (in AQUATOX)
Mortality coeff. (day^{-1})	0.0007 (prof. assump)	0.02 (prof. assump.)	0.02 (default)	0.005 (calibration)	0.005 (calibration)	0.001 (in AQUATOX)	0.002 (Minello and Zimmerman, 1985)	0.0004 (in AQUATOX)
Carrying capacity (g m^{-2})	11.1 (prof. assump)	100 (prof. assump.)	10 (default)	10 (default)	174 (observ-unpublished)	10 (Observ-unpublished)	20 (prof. assump)	0.7 (in AQUATOX)
Mean life span (day)	730 (based on García-Arberas & Rallo, 2012)	720 (Ferreira et al. 2004)	300 (noaa.gov)	1860 (Verdelhos et al., 2015)	1200 (Cardoso et al., 2002)	1095 (in AQUATOX)	365 (in AQUATOX)	1080 (from fishbase.org for P. microps)
Min. salinity_mortality	0 (prof. assump)	0 (prof. assump.)	0.5 (Cunha et al., 2000)	5 (Verdelhos et al. 2015; calibration)	6 (prof. assump.)	0 (in AQUATOX)	0.2 (in AQUATOX)	0 (prof. assump)
Max. salinity_mortality	50 (prof. assump)	45 (prof. assump.)	40 (Cunha et al., 2000)	40 (Verdelhos et al. 2015; calibration)	40 (prof. assump.)	50 (in AQUATOX)	40 (in AQUATOX)	35 (prof. assump)

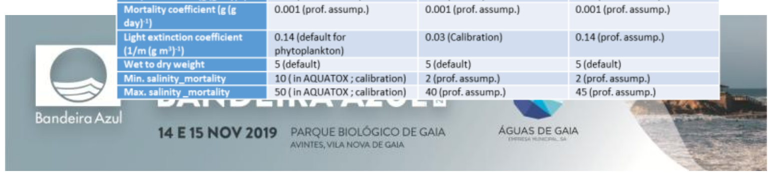
AQUATOX-- Trophic Interaction Matrix

Preference percentages are initially normalized to 100% based on species in the simulation. Renormalize PREDATORS

Show Preferences Show Egestion Coefficients Show Comments

PREY	Isopod_C. c	Polychaete_	Copepod	Amphipod_(	Clam_Scrot	Gastropod,	Crab_C. ma	Other benth	P. flesus	P. microps
R detr sed	37.5	0.0		0.2	0.1	4.3	10.4			
L detr sed	62.5	0.0		0.2	0.1	21.7	52.1			
R detr part		4.2	33.3		39.6			10.9		
L detr part		4.2	33.3		39.6			10.9		
Peri Low-Nut Diatom				99.6	0.8	65.2	0.2			
Phyt Low-Nut Dia MO			33.3		19.8					
Ulva						8.7	0.2			
Isopod_C. carinata		35.0					6.5	1.1		12.1
Polychaete_Hediste								1.1		12.1
Copepod										24.2
Amphipod_Corophium		7.0					9.8	54.3	53.2	
Clam_Scrobicularia		49.6					10.4		17.7	0.0
Gastropod, H. ulvae										12.1
Crab_C. maenas									13.8	39.6
Other benth.invet							10.4			
P. flesus								10.9		
P. microps								10.9	15.2	

Parameter	Phytoplankton	Periphyton	Ulva species
Max. saturation light (Ly day^{-1})	300 (default)	300 (in AQUATOX)	1000 (default)
P-half-saturation (mg L^{-1})	0.0456 (Santos et al., 2013; calibration)	0.006 (in AQUATOX)	0.030973 (Martins et al., 2007)
N-half-saturation (mg L^{-1})	0.13 (Santos et al., 2013; calibration)	0.07 (in AQUATOX)	0.28 (Martins et al., 2007)
Optimum temperature (°C)	22 (in AQUATOX; calibration)	18 (in AQUATOX ; calibration)	22 (prof. assump.)
Maximum temperature (°C)	35 (in AQUATOX ; calibration)	39 (in AQUATOX ; calibration)	35 (prof. assump.)
Minimum temperature (°C)	2 (in AQUATOX ; calibration)	2 (in AQUATOX ; calibration)	2 (prof. assump.)
Max. photosynthetic rate (day^{-1})	1.4 (Santos et al., 2013; calibration)	2.65 (default; calibration)	1.08 (in AQUATOX)
Photorespiration coeff. (day^{-1})	0.069 (Santos et al,. 2013; calibration)	0.01 (default)	0.03 (in AQUATOX)
Respiration rate (g (g day)$^{-1}$)	0.08 (in AQUATOX)	0.01 (default)	0.05 (in AQUATOX)
Mortality coefficient (g (g day)$^{-1}$)	0.001 (prof. assump.)	0.001 (prof. assump.)	0.001 (prof. assump.)
Light extinction coefficient (1/m (g m^3)$^{-1}$)	0.14 (default for phytoplankton)	0.03 (Calibration)	0.14 (prof. assump.)
Wet to dry weight	5 (default)	5 (default)	5 (default)
Min. salinity_mortality	10 (in AQUATOX ; calibration)	2 (prof. assump.)	2 (prof. assump.)
Max. salinity _mortality	50 (in AQUATOX ; calibration)	40 (prof. assump.)	45 (prof. assump.)



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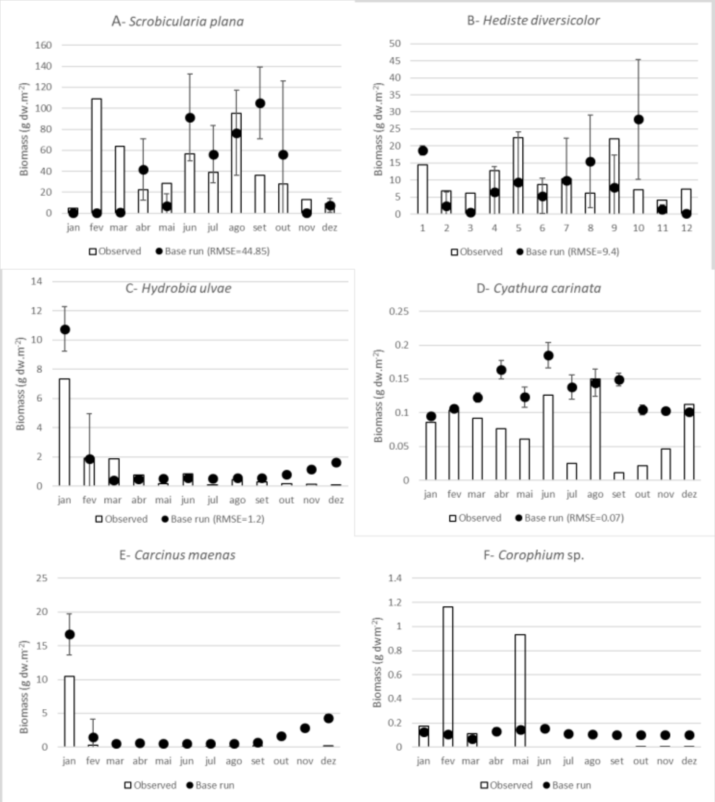
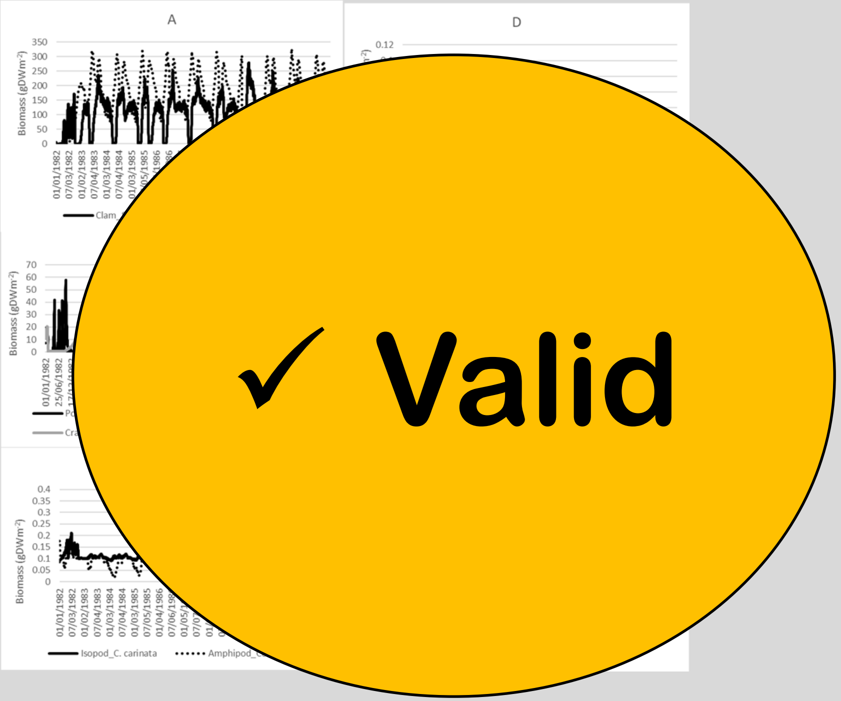
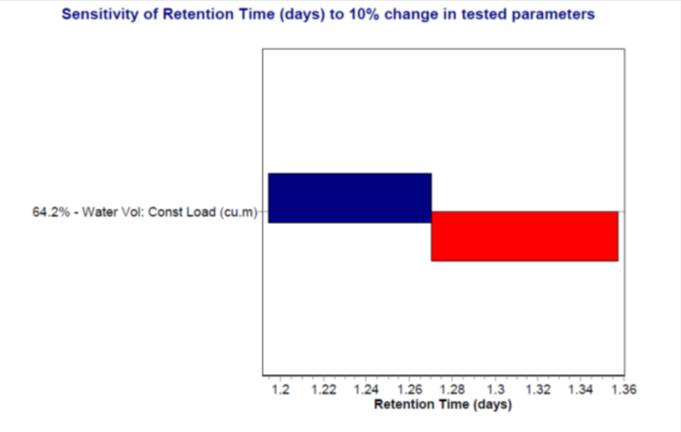
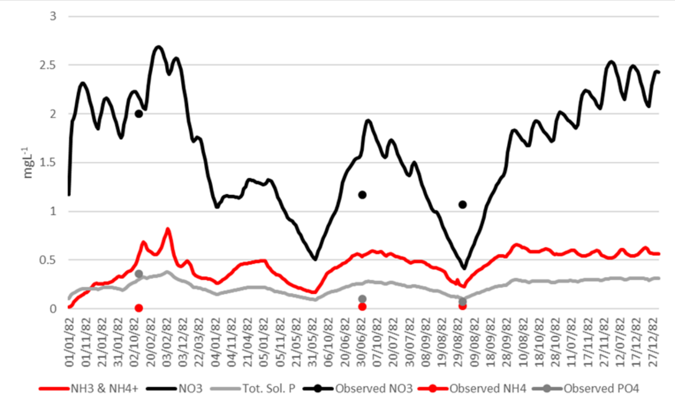
Assessing the model performance

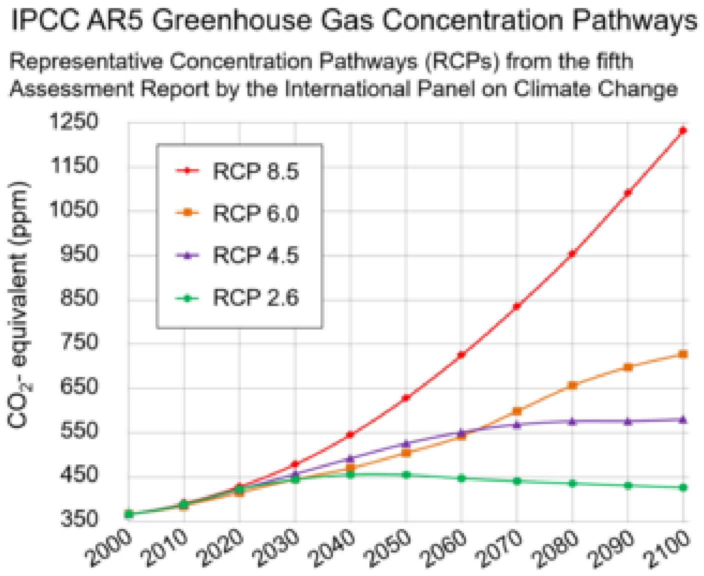








IPCC scenarios



- RCP stands for *Representative Concentration Pathways* trajectories for future greenhouse concentrations (IPCC, 2014)

- RCP 2.6: max. 450 ppm CO_2 equivalents|av. increas. temp=1°C (0.3-1.7)

- RCP 8.5: continuous increase of CO_2 equiv.|av. increas. temp= 3.7°C (2.6-4.8)

Scenario simulations

➢ Single-stressor

SS1. “**Dry years**” forced with conditions of the driest year (2012) within the period 2007-2016.

SS2. “**Rainy years**” forced with conditions of the wettest year (2010) within the period 2007-2016.

SS3. “**RCP2.6**” forced with temperature increase according to the lowest emission scenario RCP2.6 (1°C + Base run).

SS4. “**RCP8.5**” forced with temperature increase according to the highest emission scenario RCP8.5 (3.7°C + Base run).

SS5. “**30% less river flow (RF)**” forced with a 30% decrease on the average river flow observed within 2007-2016.

➢ Multiple-stressor

MS1. “**Dry years_RCP2.6**”- dry year coupled to RCP2.6.

MS2. “**Dry years _ RCP8.5**”- dry year coupled to RCP8.5.

MS3. “**Rainy years _ RCP2.6**”- rainy year coupled to RCP2.6.

MS4. “**Rainy years _ RCP8.5**”- rainy year coupled to RCP8.5.

MS5. “**30% less RF_RCP2.6**”- 30% less river flow coupled to RCP2.6.

MS6. “**30% less RF_RCP8.5**”- 30% less river flow coupled to RCP8.5.

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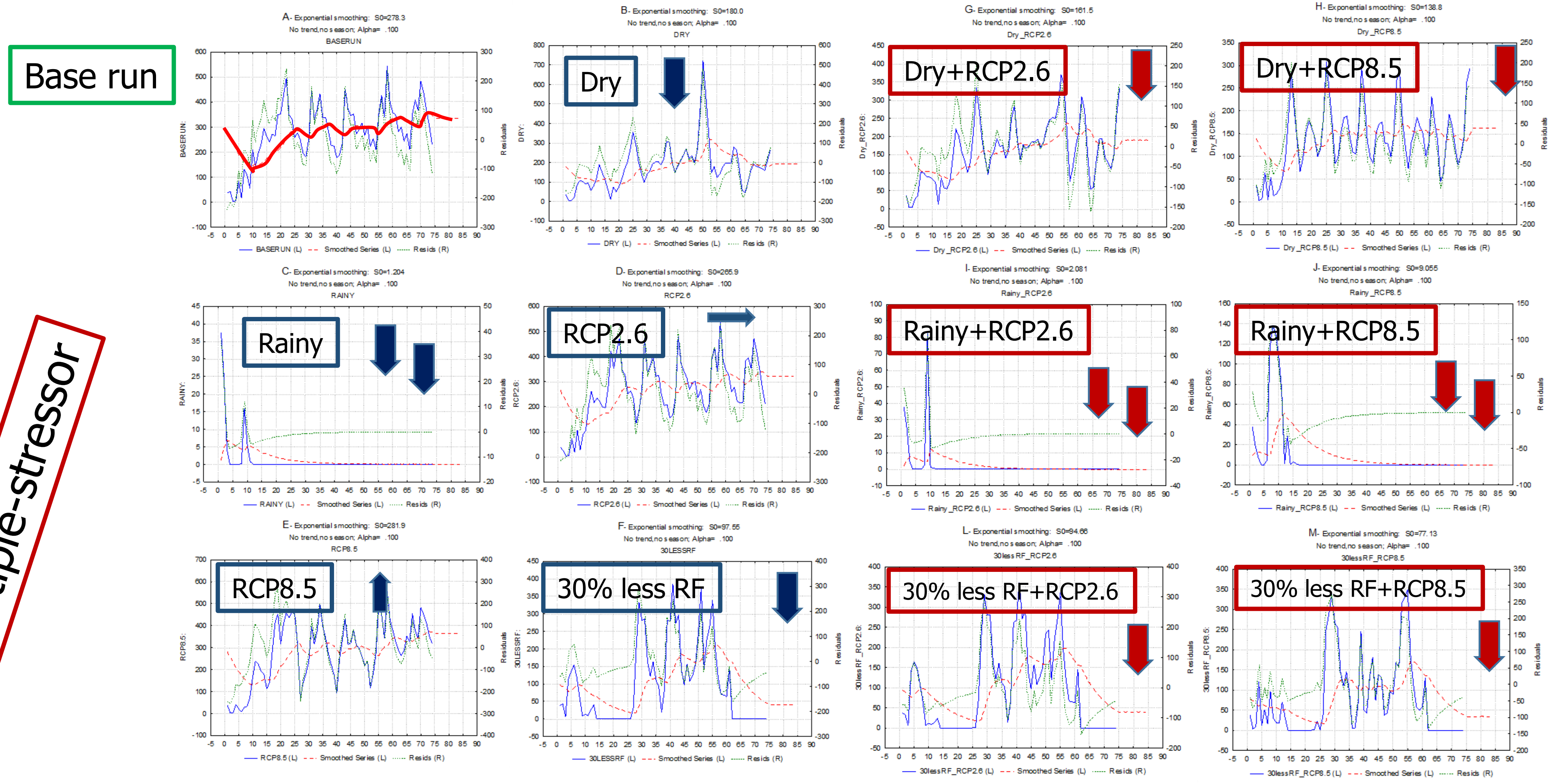
Results | Macroinvertebrate estuarine communities biomass

Single-stressor

Multiple-stressor



Conclusions

- Macroinvertebrate communities **do not** respond the same way to stressors acting isolated or in combination *(**stressors interactions**).*
- Temperature rise **alone enhances** benthic production but **not when combined** with rainy conditions or river flow decrease. This is known as an **antagonistic interaction.**
- Estuarine productivity will tend to decrease under drier conditions.
- The Minho estuary is **highly** sensitive to rainy conditions (continuous).
- We recommend a carefull management of the water flow in the Minho River Basin.



Take-home message

- **Climate change is on** and it will affect the productivity of estuaries and other marine ecosystems.
- Prediction tools (e.g. **Ecosystem models**) are **paramount** to decide upon effective **mitigation** measures, which will help to **protect** marine ecosystems and ecosystems services.

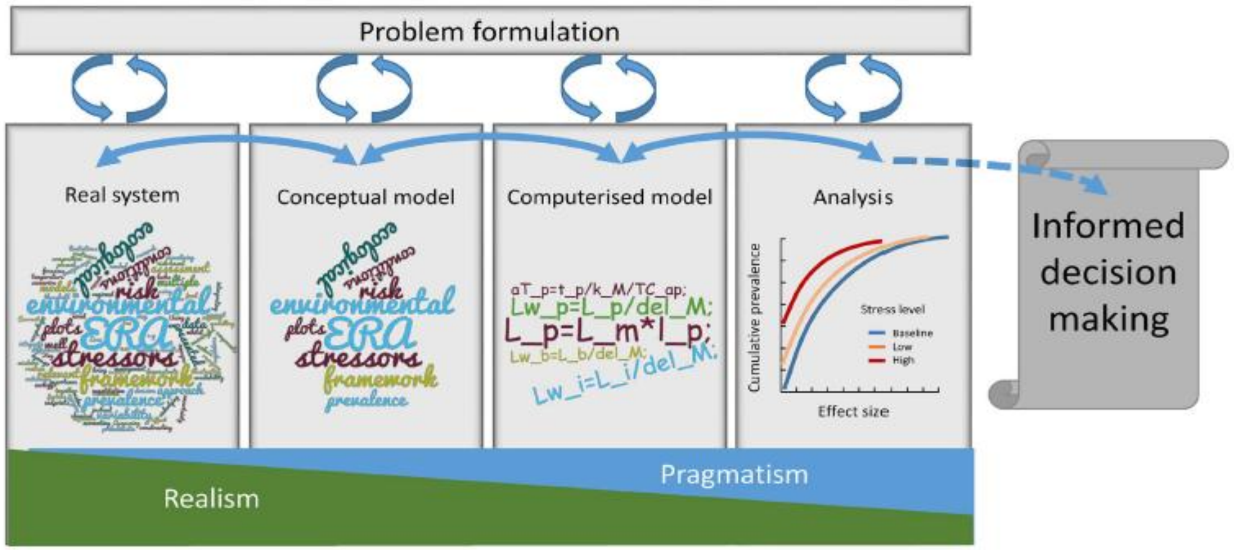


Figure 5. Schematic view of the framework and the underlying scientific improvements needed.

Extracted from Goussen et al. 2016

Photo by Irene Martins