BLUEBRIDGE: CLOUD INFRASTRUCTURE SERVING AQUAFARMS AND SUPPORTING MODELS

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ICRE8 International Centre for Research on the Environment & the Economy

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Outline

- Introduction to BlueBRIDGE & VREs
- Performance evaluation, benchmarking and decision making in aquaculture VRE
- Strategic Investment analysis and Scientific Planning/Alerting VRE
- Social and environmental monetization models for Blue Economy

Why BlueBRIDGE?

Building **R**esearch environments fostering **I**nnovation, **D**ecision making, **G**overnance and **E**ducation

for Blue Growth

To **support capacity building** in **interdisciplinary research communities** actively involved in **increasing scientific knowledge about resource overexploitation**, **degraded environment** and **ecosystem** with the aim of providing a **more solid ground for informed advice** to competent authorities and to enlarge the spectrum of growth opportunities as addressed by the Blue Growth Societal Challenge

How BlueBRIDGE supports Blue Growth

- Tailor made **data management services**

Ecosystem Approach to Fisheries

Research Sector

Aquaculture

- Operated through **Virtual Research Environments (VREs)**

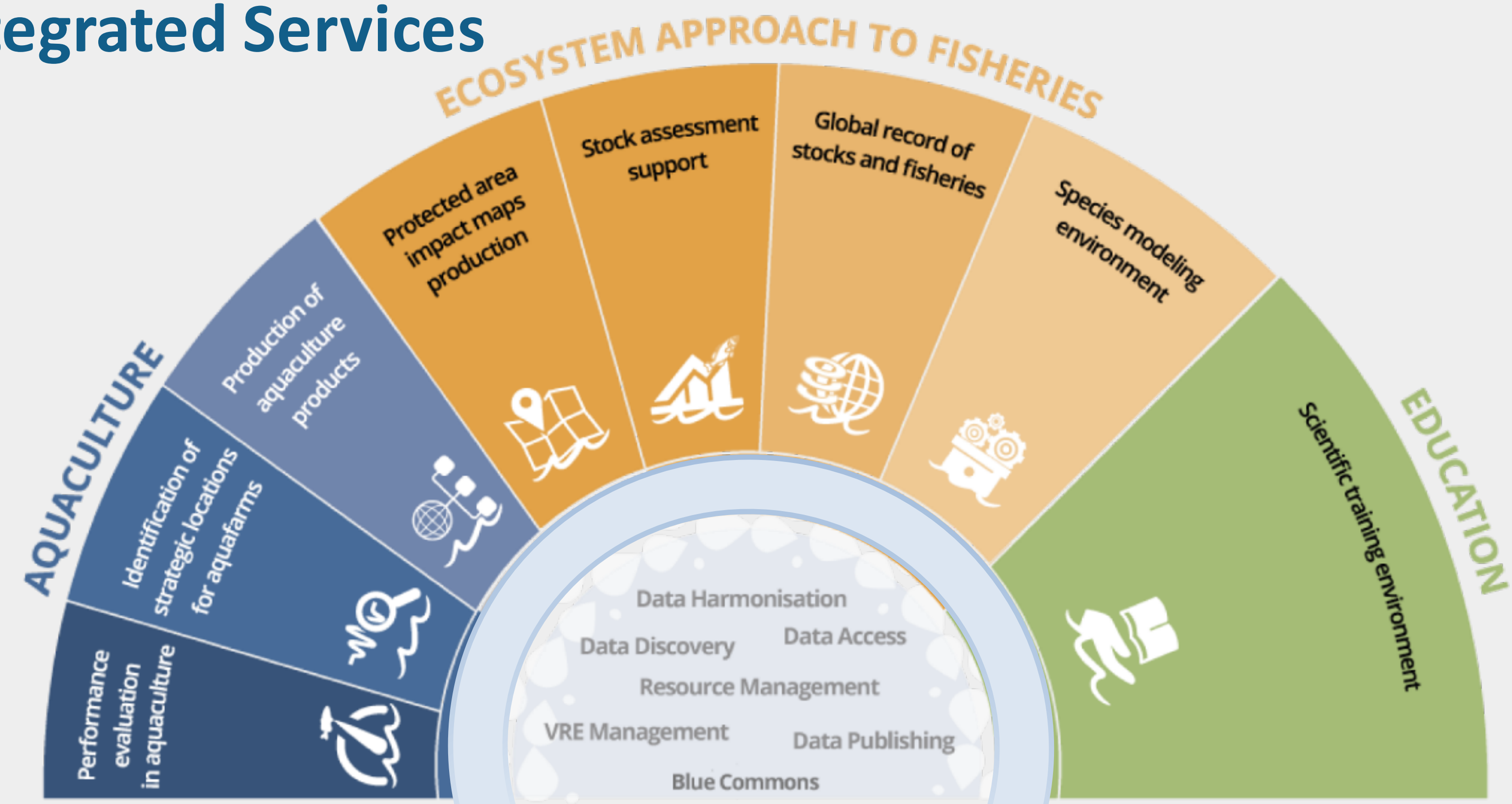
The VRE approach

- A VRE is a **web-based system** that can be **accessed on-demand** through a simple user interface**.**
- **It provides users with a secure access to** collaborative tools, services, data and computational facilities meeting their specific needs**.**
- Created on-demand, **hardware setup and software deployment** required to operate these facilities are completely **transparent to the VRE creator.**

VRE is the perfect approach to address the challenges of modern science which is increasingly **global, multi-disciplinary and networked**

The BlueBRIDGE offer

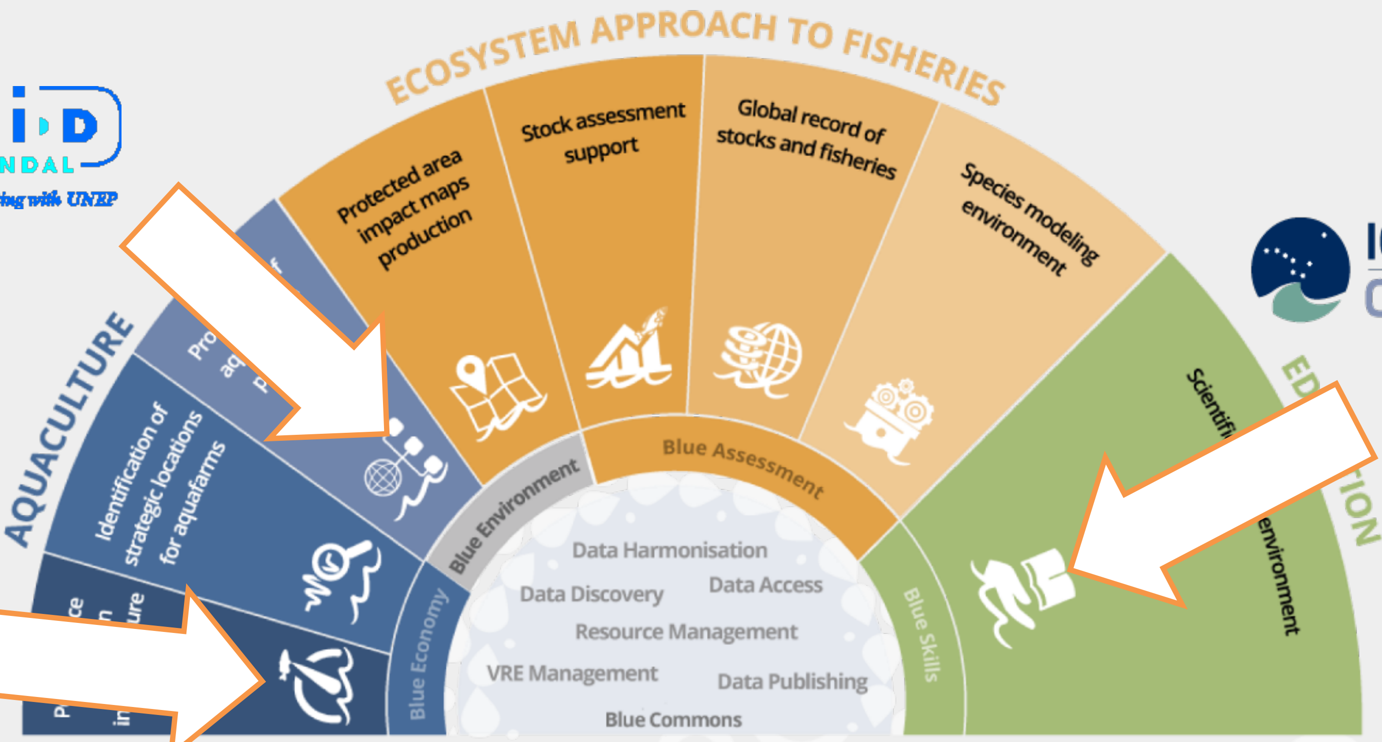
Integrated Services



- Relying on a **powerful hybrid-data infrastructure (D4Science)**

Serving different stakeholders

Supporting **capacity building**



The BlueBRIDGE added value

- **Easy to use services** to support researchers, companies (including SMEs) and international organisations.
- A **self-sustained underlying infrastructure** executing around **25,000 models & algorithms per month**.
- Access to over a **billion quality records** hosted in more than **50 worldwide repositories** and to more than **350 geo-referenced chemical and physical variables** with global geospatial coverage and with **10 years lifespan** through **standard and recognized protocols.**
- A **unique consortium** with the **right expertise** to support practitioners from multiple domains.

Performance evaluation, benchmarking and decision making in aquaculture VRE

Gerasimos Antzoulatos, i2S (gantzoulatos@i2s.gr)

Objectives…

of *"Performance evaluation, benchmarking and decision making in aquaculture VRE"* are

- provide capacities for companies to evaluate and optimize their production performance
- benchmark their production performance against best practices and the competition
- extend the capacity of scientific research communities and policy makers to quantify and comprehend aqua-farming industry operation ensuring sustainability and development

VRE Service

Goals:

a) Estimate/create KPIs cross-tab Tables based on historical data

b) Create accurate and feasible *production plans* as well as produce *financial forecasts*

Site Manager

Determine the Site by setting data regarding

- temperature
- environment

Model Manager

Estimate the KPIs Tables:

- Collect historical data
- Upload data
- Generate KPIs

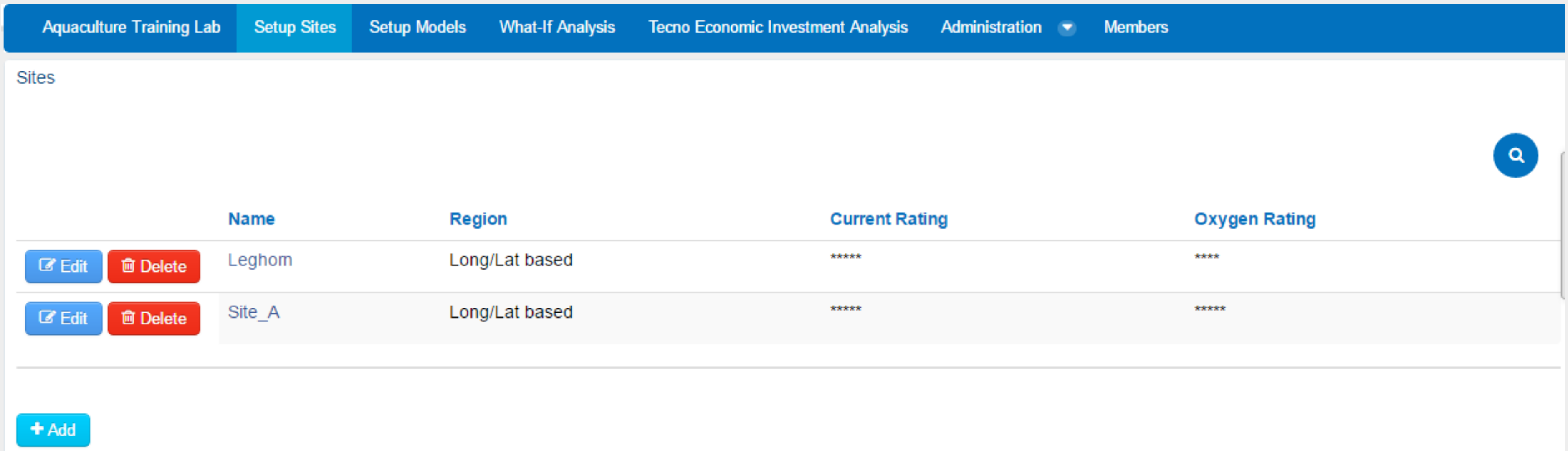
What-If Analysis

Perform production planning by:

- Create scenarios
- Assess the results

Site Manager

Site Manager - main page



BlueBRIDGE

Site Manager

Add New Site

Aquaculture Training Lab | Setup Sites | Setup Models | What-If Analysis | Tecno Economic Investment Analysis | Administration | Members

Sites

Environment

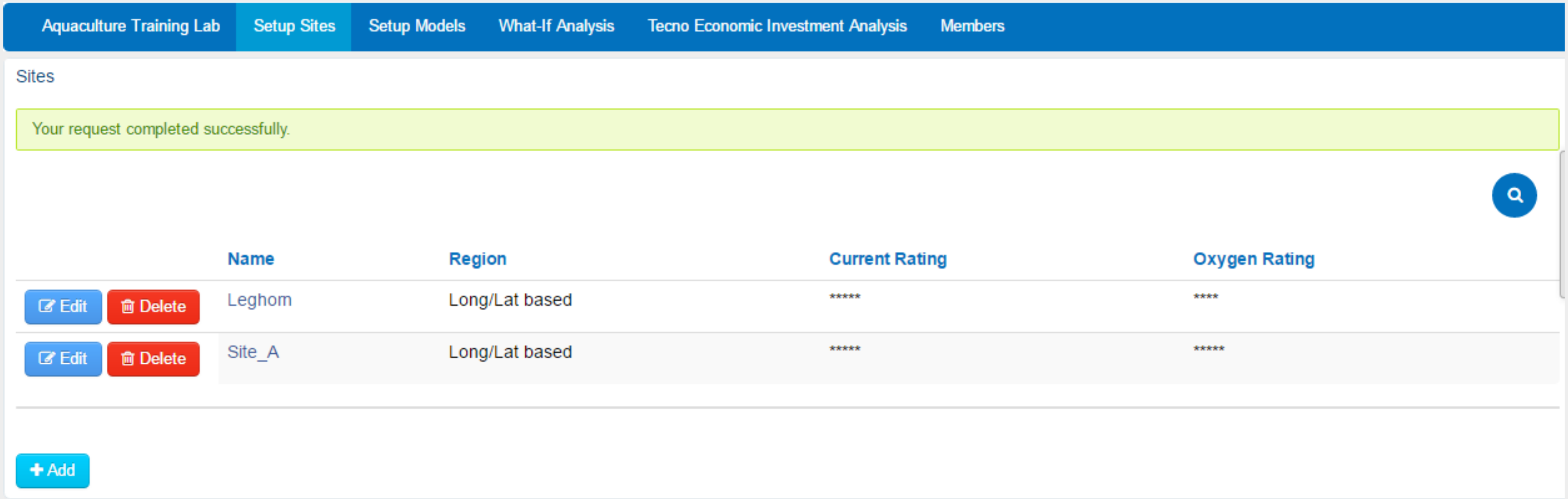
Name :	Site_A	Region :	Long/Lat based
Oxygen Rating :	*****	Current Rating :	*****
Latitude :		Longitude :	

Average temperature fortnightly

January 1-15	12	16-31	13	July 1-15	21	16-31	22
February 1-14	13	15-end	14	August 1-15	23	16-31	24
March 1-15	14	16-31	15	September 1-15	22	16-30	21
April 1-15	15	16-30	16	October 1-15	19	16-31	18
May 1-15	16	16-31	17	November 1-15	16	16-30	14
June 1-15	18	16-30	19	December 1-15	13	16-31	12

Save Cancel

Add New Site – Complete message



Site Manager

Edit Site

Aquaculture Training Lab | Setup Sites | Setup Models | What-If Analysis | Tecno Economic Investment Analysis | Administration | Members

Sites

Environment

Name : Site_A
Region : Long/Lat based
Oxygen Rating : *****
Current Rating : *****
Latitude :
Longitude :

Average temperature fortnightly

January 1-15	12	16-31	13	July 1-15	21	16-31	22
February 1-14	13	15-end	14	August 1-15	23	16-31	24
March 1-15	14	16-31	15	September 1-15	22	16-30	21
April 1-15	15	16-30	16	October 1-15	19	16-31	18
May 1-15	16	16-31	17	November 1-15	16	16-30	14
June 1-15	18	16-30	19	December 1-15	13	16-31	12

Save Cancel

Model Manager

Pre-requirements:

- Set up a new Site, or use an existing one

Steps to Create a New Model:

1. Log-in to the VRE as an authorized user
2. Create a new Site using "*Site Manager*" or use an existing one from a "Site" list
3. Define the Site and the Specie from the corresponding lists
4. Determine details regarding the Feed and Broodstock
5. Upload the appropriate dataset(s)
6. Give a name to a model
7. Save and Generate the model

Model Manager

Model Manager - main page

Aquaculture Training Lab | Setup Sites | Setup Models | What-If Analysis | Tecno Economic Investment Analysis | Administration | Members

Models

	Name	Comments	Species	Status
Edit Delete	Massimiliano's Model	This is an example model, no datasets though	Sea bream	Calculation failed
Edit Delete	Massimiliano's Model	This is an example model, no datasets though	Sea bream	Calculation failed
Edit Delete	Massimiliano's Model	This is an example model, no datasets though	Sea bream	Calculation failed
Edit Delete	Model_Bass_Site_A	Model for Sea Bass at the Site_A	Sea bass	Ready
Edit Delete	Model_Bream_Site_A	Model for Sea Bream at Site_A	Sea bream	Calculation failed

Page 1 of 2 | 5 Items per Page | Showing 1 - 5 of 6 results.

← First | Previous | Next | Last →

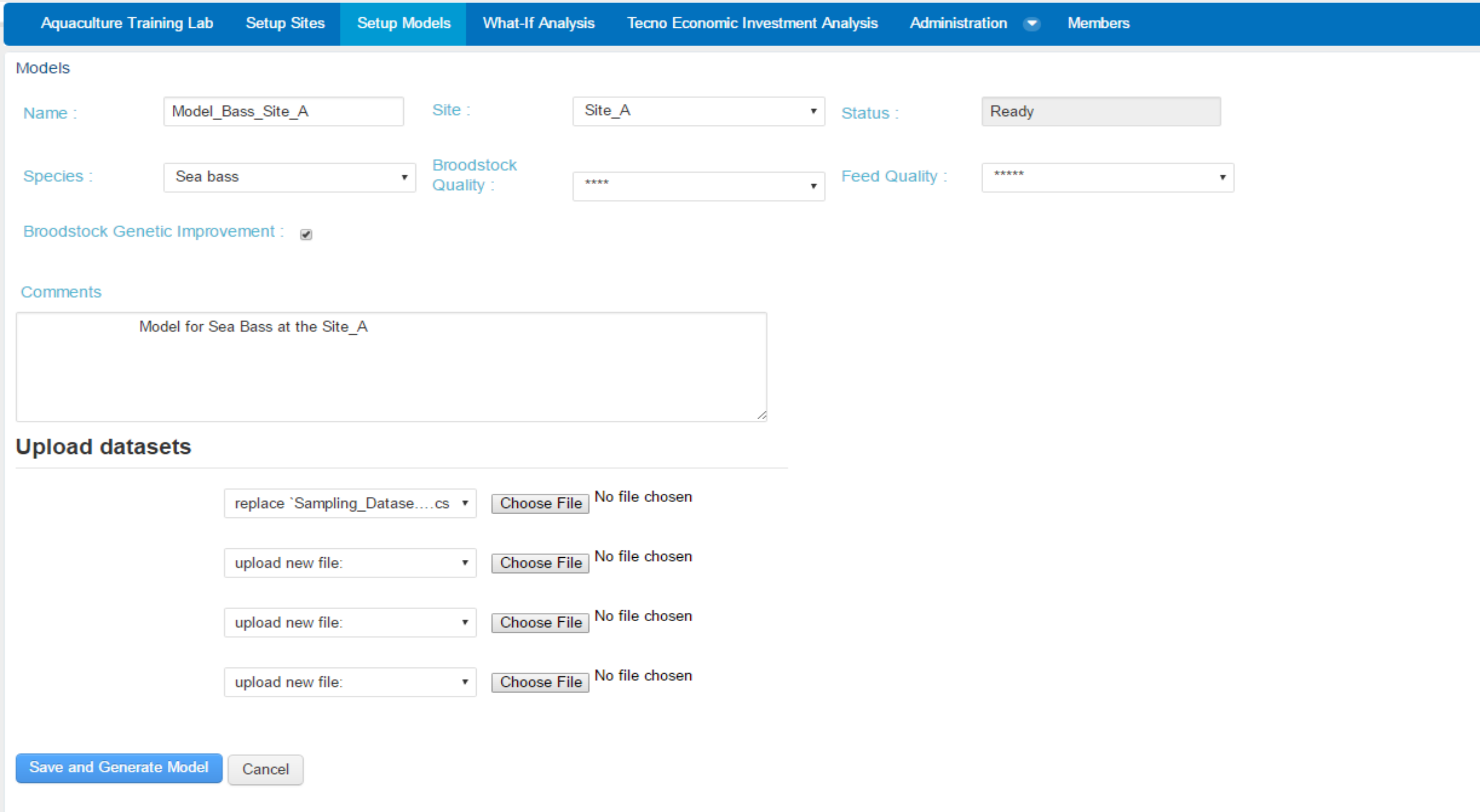
+ Add

Three (3) potential Status for each model:

- Ready
- Calculating…
- Calculation failed

Model Manager

Add (or Edit) new model



Model Manager

Add (or Edit) new model – Complete process

Aquaculture Training Lab | Setup Sites | Setup Models | What-If Analysis | Tecno Economic Investment Analysis | Members

Models

Your request completed successfully.

	Name	Comments	Species	Status
Edit Delete	Massimiliano's Model	This is an example model, no datasets though	Sea bream	Calculation failed
Edit Delete	Massimiliano's Model	This is an example model, no datasets though	Sea bream	Calculation failed
Edit Delete	Massimiliano's Model	This is an example model, no datasets though	Sea bream	Calculation failed
Edit Delete	Model_Bass_Site_A	Model for Sea Bass at the Site_A	Sea bass	Ready

+ Add

Model Manager

Back-End process

1. Preprocess the data (handling missing values, etc…) [*optional*]
2. For each KPI (FCR, SFR, Mortality %)

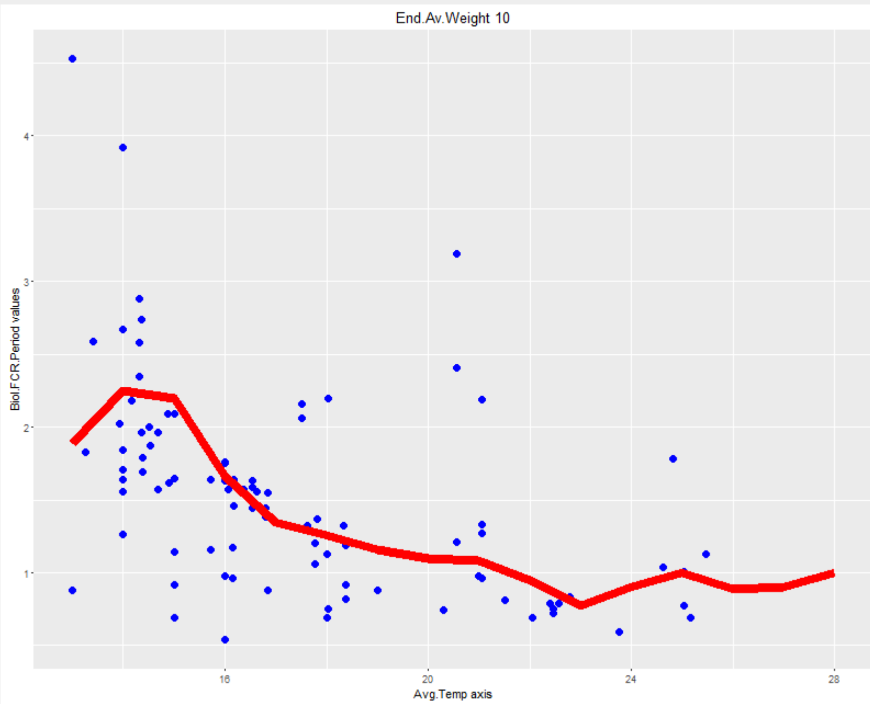
   ➢ Find the best regression model (e.g. GAM, MARS methodologies) based on R project (https://www.r-project.org/) libraries

   ➢ Create the KPI cross-tab table

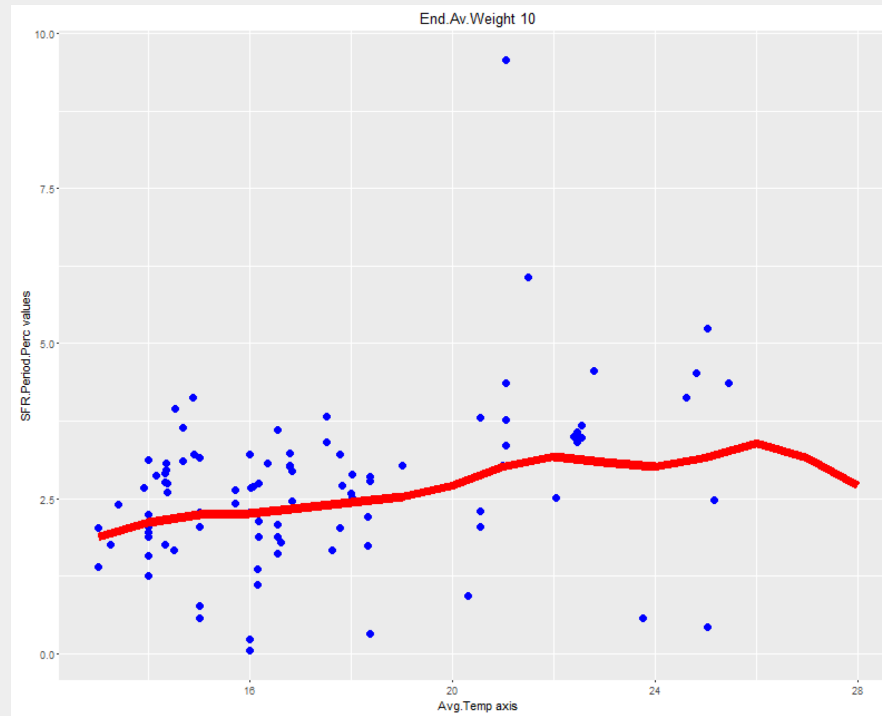
Model Manager

Back-End process

Biological FCR – Av.Wt.Cat. 0-10 gr



SFR – Av.Wt.Cat. 0-10 gr



Generalized Additive Models (GAMs)

Model Manager

Back-End process

Biological FCR Table

AvWeightCat	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
10	1,891	2,249	2,195	1,661	1,344	1,253	1,16	1,101	1,079	0,943	0,773	0,902	1,003	0,884	0,901	0,996
20	2,003	2,361	2,307	1,773	1,455	1,364	1,271	1,213	1,19	1,055	0,884	1,013	1,115	0,996	1,012	1,107
30	2,089	2,447	2,393	1,859	1,541	1,45	1,357	1,299	1,276	1,141	0,97	1,099	1,201	1,082	1,098	1,193
40	2,158	2,516	2,462	1,928	1,611	1,52	1,427	1,369	1,346	1,21	1,04	1,169	1,27	1,151	1,168	1,263
50	2,219	2,577	2,523	1,989	1,672	1,581	1,488	1,43	1,407	1,271	1,101	1,23	1,331	1,212	1,229	1,324
60	2,281	2,639	2,585	2,051	1,733	1,643	1,55	1,491	1,469	1,333	1,163	1,292	1,393	1,274	1,291	1,386
70	2,356	2,714	2,66	2,126	1,808	1,718	1,625	1,566	1,544	1,408	1,238	1,367	1,468	1,349	1,366	1,461
80	2,457	2,815	2,761	2,227	1,909	1,819	1,726	1,667	1,645	1,509	1,339	1,468	1,569	1,45	1,467	1,562
90	2,583	2,941	2,888	2,353	2,036	1,945	1,852	1,794	1,771	1,636	1,465	1,594	1,695	1,576	1,593	1,688
100	2,713	3,071	3,017	2,483	2,165	2,074	1,981	1,923	1,901	1,765	1,595	1,723	1,825	1,706	1,723	1,817
110	2,821	3,179	3,125	2,591	2,273	2,182	2,089	2,031	2,009	1,873	1,703	1,831	1,933	1,814	1,831	1,925
120	2,884	3,242	3,188	2,654	2,336	2,245	2,152	2,094	2,072	1,936	1,766	1,894	1,996	1,877	1,894	1,988
130	2,895	3,253	3,199	2,665	2,348	2,257	2,164	2,105	2,083	1,947	1,777	1,906	2,007	1,888	1,905	2
140	2,869	3,227	3,173	2,639	2,321	2,231	2,138	2,079	2,057	1,921	1,751	1,88	1,981	1,862	1,879	1,974
150	2,82	3,178	3,124	2,59	2,273	2,182	2,089	2,03	2,008	1,872	1,702	1,831	1,932	1,813	1,83	1,925
160	2,764	3,122	3,068	2,534	2,216	2,125	2,033	1,974	1,952	1,816	1,646	1,775	1,876	1,757	1,774	1,868
170	2,713	3,071	3,017	2,483	2,165	2,075	1,982	1,923	1,901	1,765	1,595	1,724	1,825	1,706	1,723	1,818
180	2,671	3,029	2,975	2,441	2,123	2,033	1,94	1,881	1,859	1,723	1,553	1,682	1,783	1,664	1,681	1,776
190	2,638	2,996	2,942	2,408	2,09	1,999	1,906	1,848	1,825	1,69	1,519	1,648	1,75	1,631	1,647	1,742
200	2,612	2,97	2,916	2,382	2,065	1,974	1,881	1,822	1,8	1,664	1,494	1,623	1,724	1,605	1,622	1,717
210	2,595	2,953	2,899	2,365	2,047	1,956	1,863	1,805	1,783	1,647	1,477	1,605	1,707	1,588	1,605	1,699
220	2,585	2,943	2,889	2,355	2,037	1,946	1,853	1,795	1,772	1,637	1,466	1,595	1,697	1,578	1,594	1,689
230	2,582	2,94	2,886	2,352	2,034	1,943	1,85	1,792	1,77	1,634	1,464	1,592	1,694	1,575	1,592	1,686
240	2,586	2,943	2,89	2,355	2,038	1,947	1,854	1,796	1,773	1,638	1,467	1,596	1,698	1,579	1,595	1,69
250	2,596	2,954	2,9	2,366	2,048	1,957	1,865	1,806	1,784	1,648	1,478	1,607	1,708	1,589	1,606	1,7
260	2,612	2,97	2,916	2,382	2,065	1,974	1,881	1,822	1,8	1,664	1,494	1,623	1,724	1,605	1,622	1,717
270	2,634	2,992	2,938	2,404	2,087	1,996	1,903	1,845	1,822	1,686	1,516	1,645	1,746	1,627	1,644	1,739
280	2,662	3,02	2,966	2,432	2,114	2,024	1,931	1,872	1,85	1,714	1,544	1,673	1,774	1,655	1,672	1,767
290	2,695	3,053	2,999	2,465	2,147	2,056	1,963	1,905	1,882	1,747	1,576	1,705	1,807	1,688	1,704	1,799
300	2,732	3,09	3,036	2,502	2,184	2,094	2,001	1,942	1,92	1,784	1,614	1,743	1,844	1,725	1,742	1,837
310	2,774	3,132	3,078	2,544	2,226	2,135	2,043	1,984	1,962	1,826	1,656	1,785	1,886	1,767	1,784	1,878
320	2,82	3,178	3,124	2,59	2,272	2,181	2,088	2,03	2,008	1,872	1,702	1,83	1,932	1,813	1,83	1,924
330	2,869	3,227	3,173	2,639	2,322	2,231	2,138	2,08	2,057	1,921	1,751	1,88	1,981	1,862	1,879	1,974
340	2,922	3,28	3,226	2,692	2,375	2,284	2,191	2,133	2,11	1,974	1,804	1,933	2,034	1,915	1,932	2,027
350	2,978	3,336	3,283	2,748	2,431	2,34	2,247	2,189	2,166	2,031	1,86	1,989	2,091	1,971	1,988	2,083
360	3,037	3,395	3,341	2,807	2,49	2,399	2,306	2,247	2,225	2,089	1,919	2,048	2,149	2,03	2,047	2,142
370	3,098	3,456	3,402	2,868	2,551	2,46	2,367	2,309	2,286	2,151	1,98	2,109	2,21	2,091	2,108	2,203
380	3,162	3,52	3,466	2,932	2,614	2,523	2,43	2,372	2,349	2,214	2,043	2,172	2,274	2,155	2,171	2,266
390	3,226	3,584	3,531	2,996	2,679	2,588	2,495	2,437	2,414	2,279	2,108	2,237	2,339	2,219	2,236	2,331
400	3,293	3,651	3,597	3,063	2,745	2,654	2,561	2,503	2,481	2,345	2,175	2,303	2,405	2,286	2,303	2,397
410	3,36	3,718	3,664	3,13	2,812	2,722	2,629	2,57	2,548	2,412	2,242	2,371	2,472	2,353	2,37	2,465
420	3,428	3,786	3,732	3,198	2,88	2,79	2,697	2,638	2,616	2,48	2,31	2,439	2,54	2,421	2,438	2,532
430	3,496	3,854	3,8	3,266	2,949	2,858	2,765	2,706	2,684	2,548	2,378	2,507	2,608	2,489	2,506	2,601

What-If Analysis Manager

Pre-requirements:

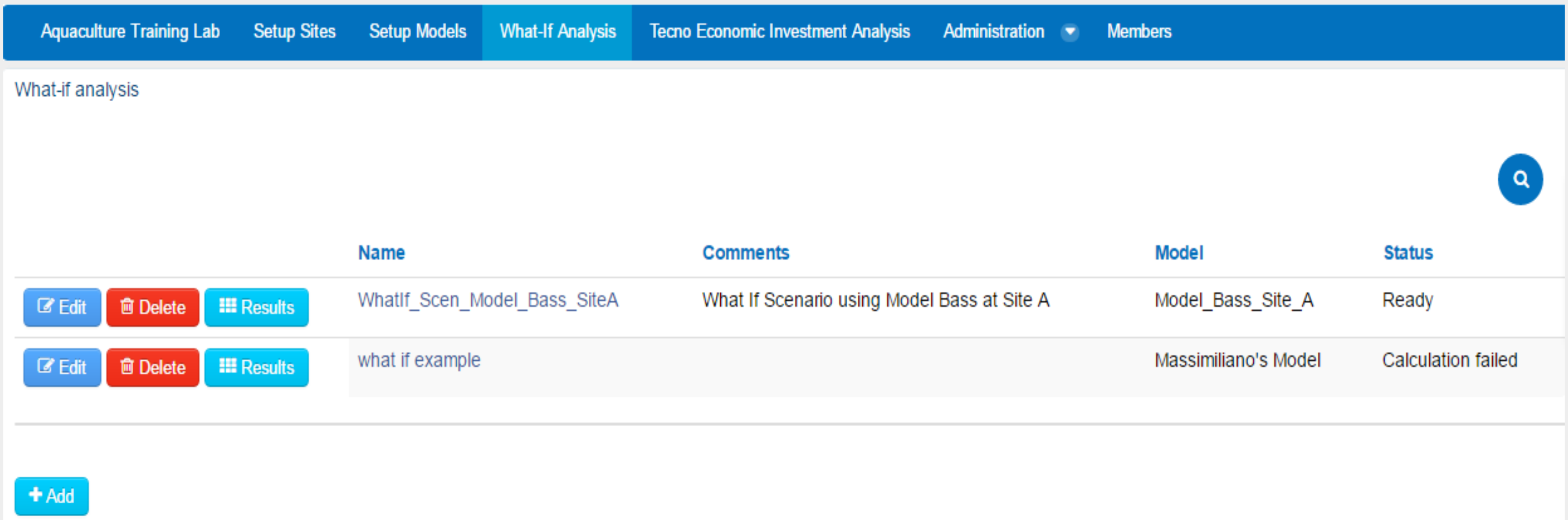
- Create a new Model, or use an existing one

Steps to Create a New What-If Analysis:

1. Log-in to the VRE as an authorized user
2. Create a new Model using “Model *Manager*” or use an existing one from a Model list
3. Give a name to the What-If Analysis
4. Determine details for the What-If Scenario
   - ✓ Initial number of fishes and their average weight
   - ✓ Initial (Stocking) Date and final (Harvest) Date
5. Save and Calculate the What-If Analysis

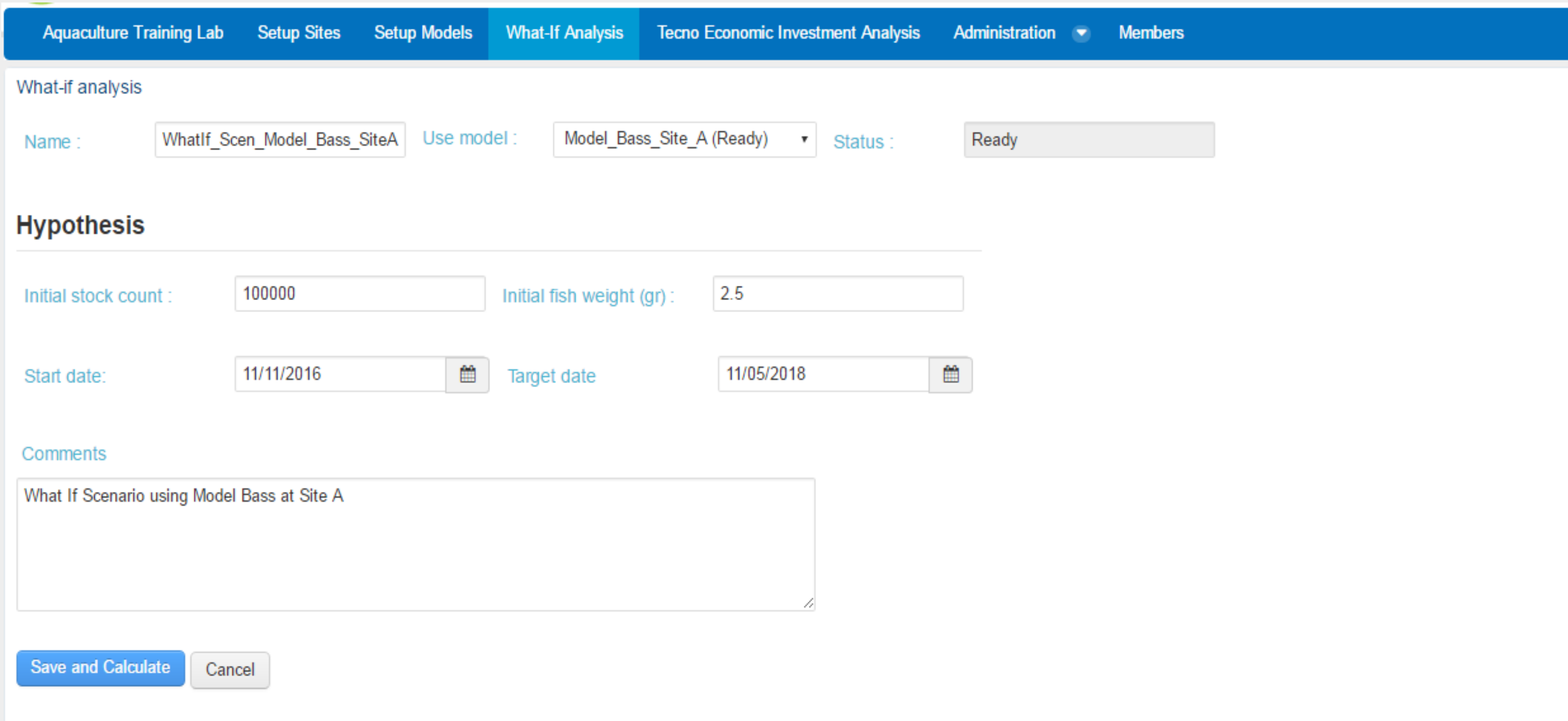
What-If Analysis Manager

What-If Analysis Manager - main page



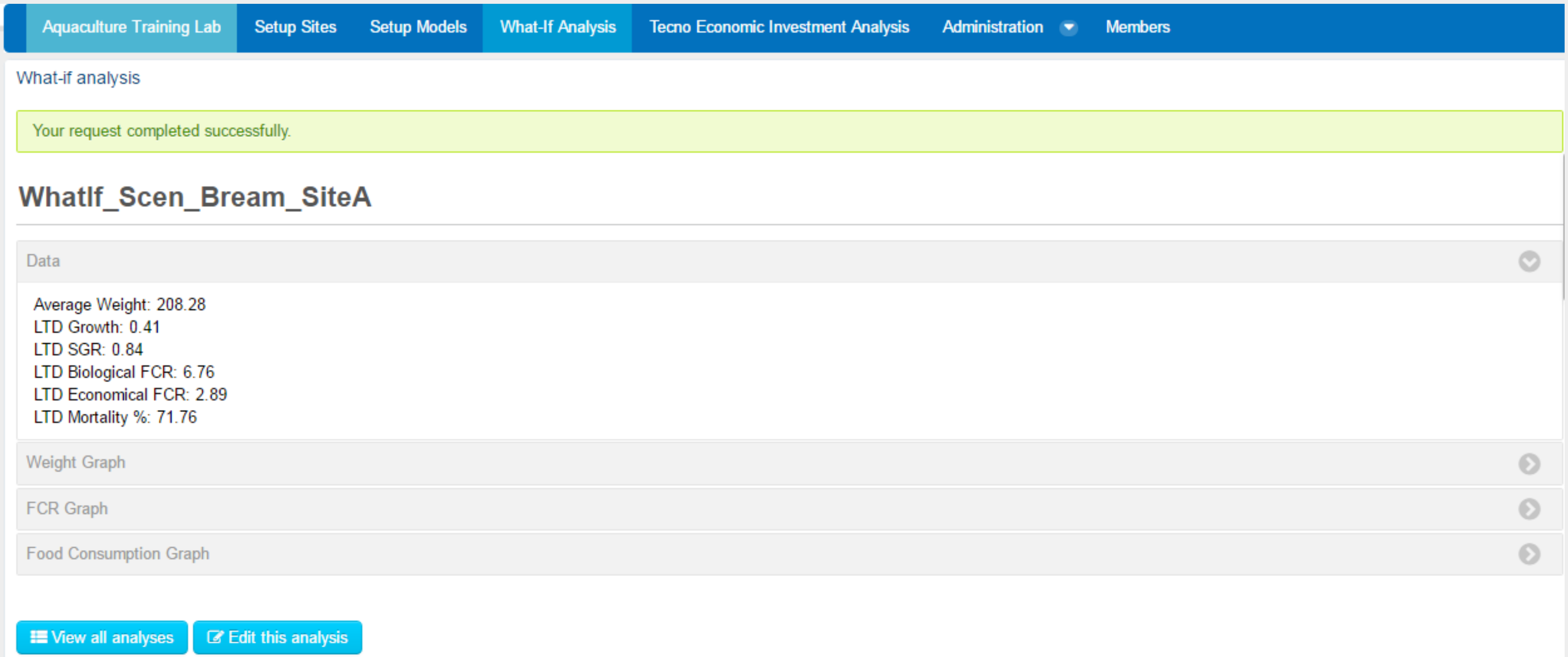
What-If Analysis Manager

Create (or Edit) new What-If Scenario



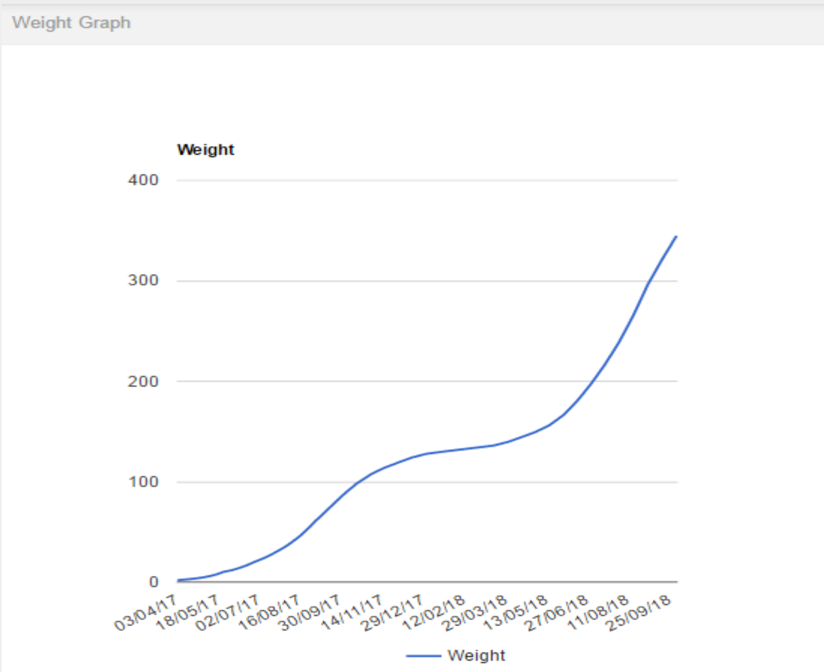
What-If Analysis Manager

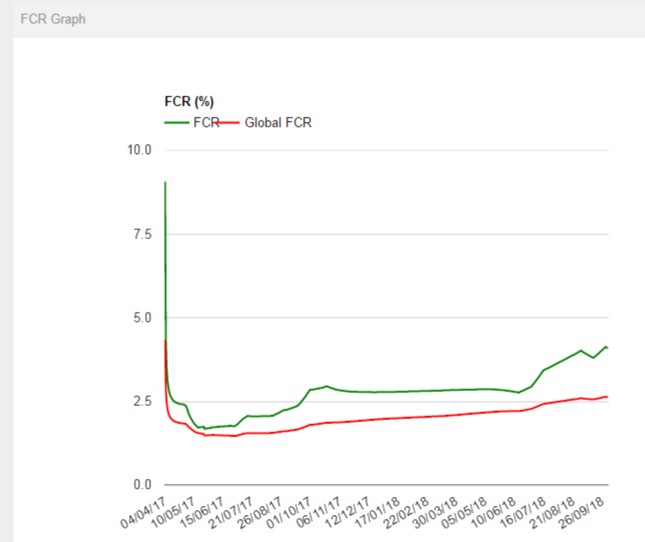
Results of What-If Scenario

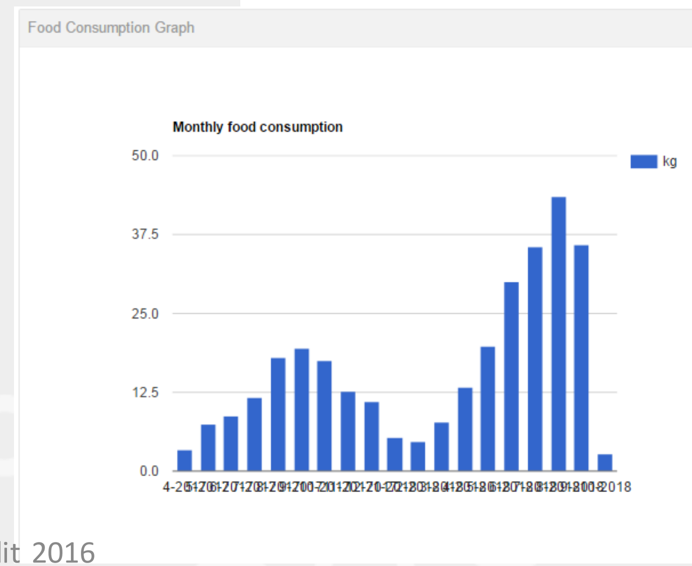


What-If Analysis Manager

Results of What-If Scenario







Future Plans

Benchmarking Analysis

Goal: is the process of comparing one’s company KPIs against other aquacultures which operate under “similar” circumstances

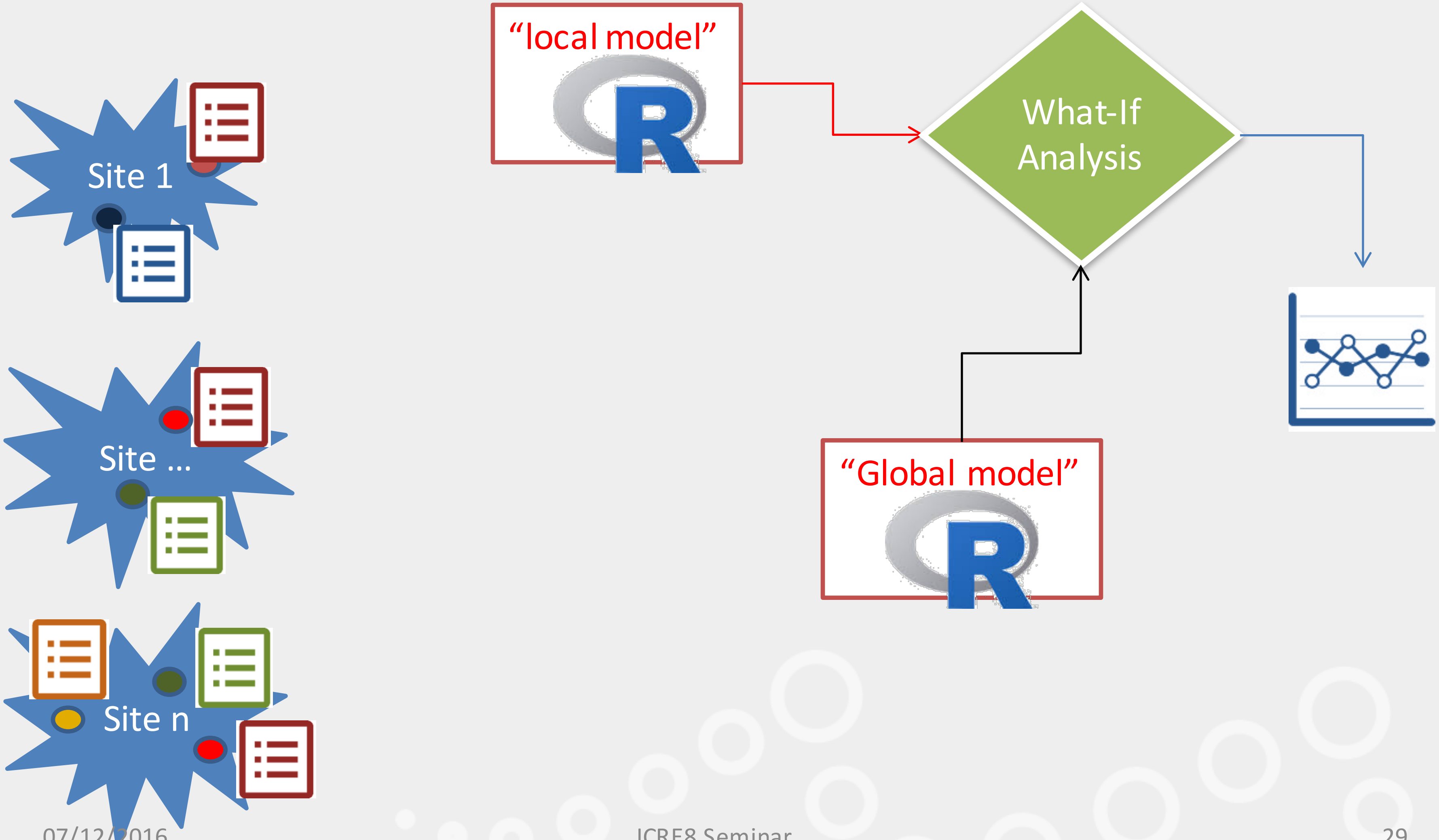
Need: Seek for “similar” sites (regions) so as to produce “global” KPIs

- Sites with the *same qualitative environmental characteristics*, such as currents and oxygen
- Differences in temperatures between the sites in the same month don't exceed ± 1°C
- Similar annual median thermal profiles (± 1°C)

Note: The benchmarking will take place if and only if more than one company operates in the similar site (region)

Future Plans

How to perform the Benchmarking Analysis?



Strategic Investment Analysis and Scientific Planning/Alerting VRE

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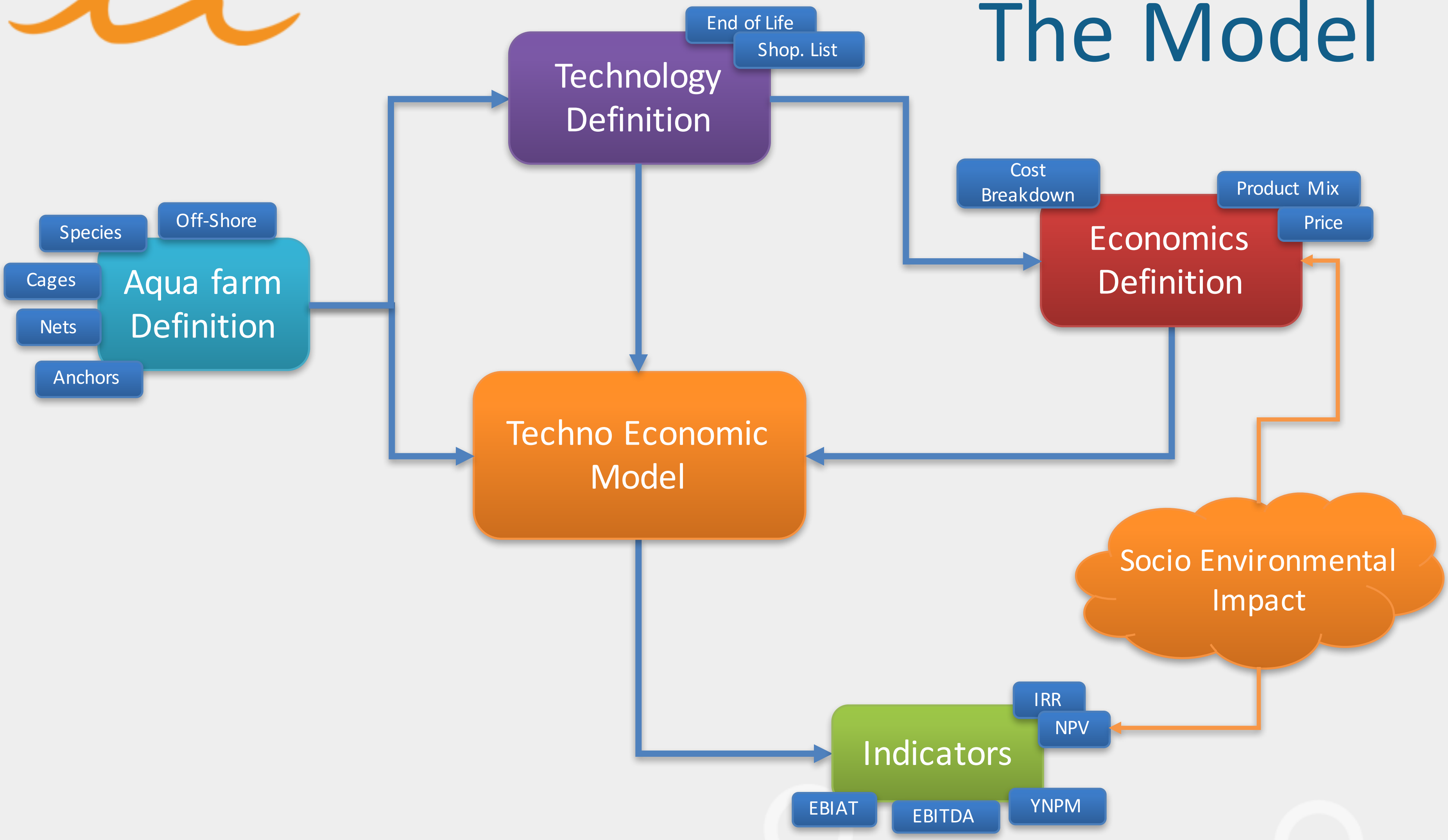
Cost-driven techno-economic evaluation: key concepts

- Aquafarm Type
- Production Schedule
- Cost Breakdown
- Sales Estimation
- Revenue Calculation
- Economics

The Model


Technology Definition
End of Life
Shop. List
Aqua farm Definition
Species
Off-Shore
Cages
Nets
Anchors
Economics Definition
Cost Breakdown
Product Mix
Price
Techno Economic Model
Socio Environmental Impact
Indicators
IRR
NPV
EBIAT
EBITDA
YNPM

Aquafarm definition

- Time to Species Maturity
  - ✓ Defines the first selling point in time for each generation
- Cages, Nets, Anchors Systems
  - ✓ Architecture of the aqua farm bulk definition
- Off-shore Location (Y/N)
  - ✓ Auto-feeding machine required on off-shore location
- Species Definition
  - ✓ Fry need, Feed requirement

Operation Administration & Misc. Expenses

- Aqua Farm License Cost
- General Industrial Expenses
  - ✓ Labour, Maintenance, Fuel, Energy, etc.
- Packaging Cost
  - ✓ Cost of packaging per fish
- **Socio-Economic Impact**
  - ✓ Translated in production cost's terms

Shopping List Estimation

- End of Life (EoL)
  - ✓ Estimated useful life of equipment
- Item Cost
  - ✓ Estimated 10-year item cost
- Shopping Cost
  - ✓ Estimated 10-year shopping cost cashflows (w/ depreciated values)

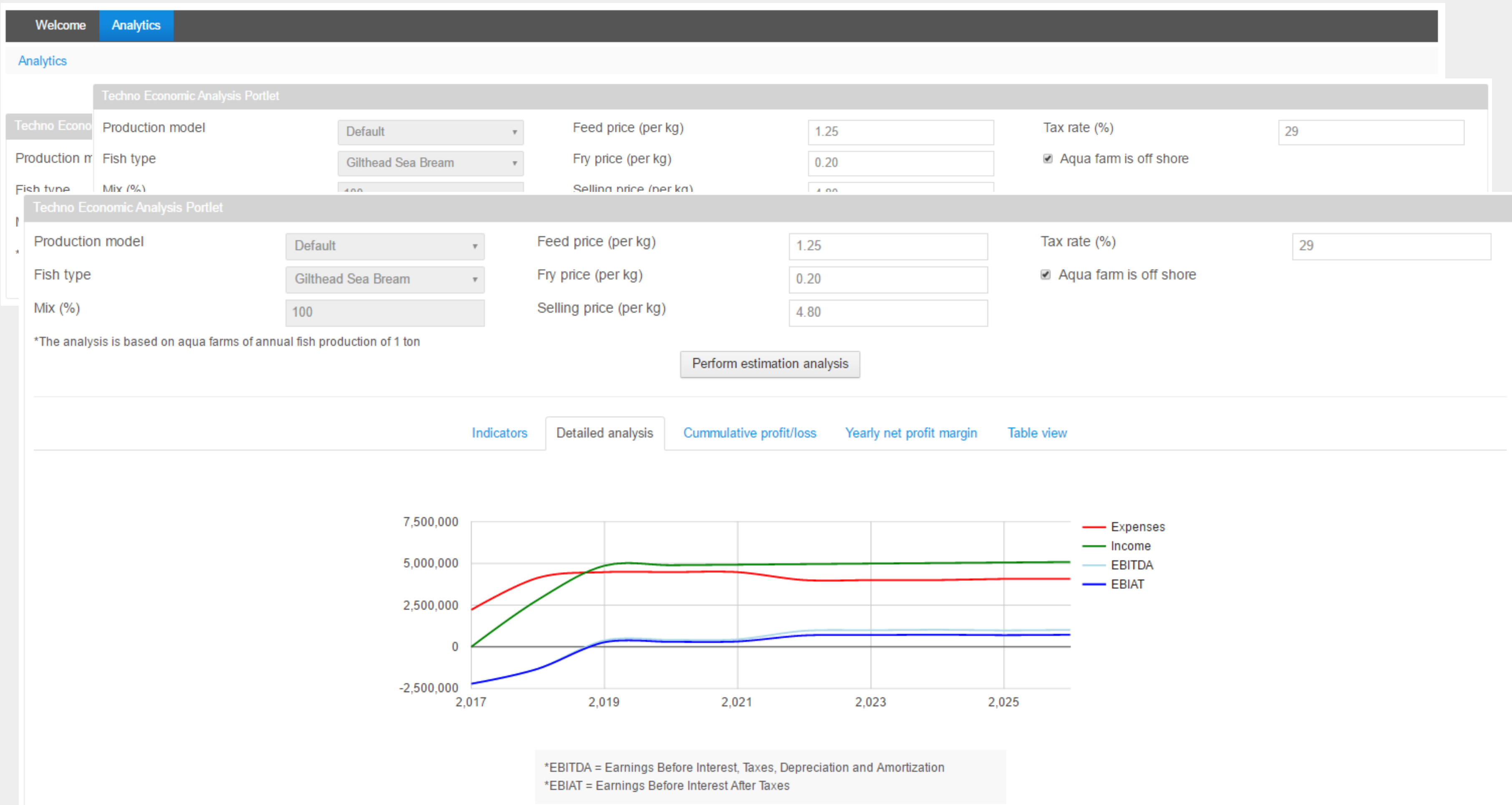
Sales & Revenues

- Product Mix Definition
  - ✓ Each species (%) over aqua farm's total capacity
- Products' Selling Prices
  - ✓ 10-year estimation of each species selling prices
- Revenue Calculation
  - ✓ 10-year revenues combining the estimated cashflows

KPIs & Financial Metrics

- Net Present Value (NPV)
  - ✓ The difference between the present value of cash inflows and the present value of cash outflows (socio-environmental enhanced formula)
- Internal Rate of Return (IRR)
  - ✓ Solving the equation NPV = 0 for r
- Yearly Net Profit Margin
  - ✓ Measures the impact to the price for every additional 1€ invested
- Earnings Before Interest, Taxes, Depreciation Amortization
  - ✓ A financial performance indicator that eliminates the effects of financing and accounting decisions
- Earnings before Interest After Taxes
  - ✓ Indicator of a company's operating performance

A preview of the VRE tools



BlueBRIDGE

Social and environmental monetization models for Blue Economy

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ICRE8

ICRE8 Seminar Meeting
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Athens, Greece

European Commission

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Outline

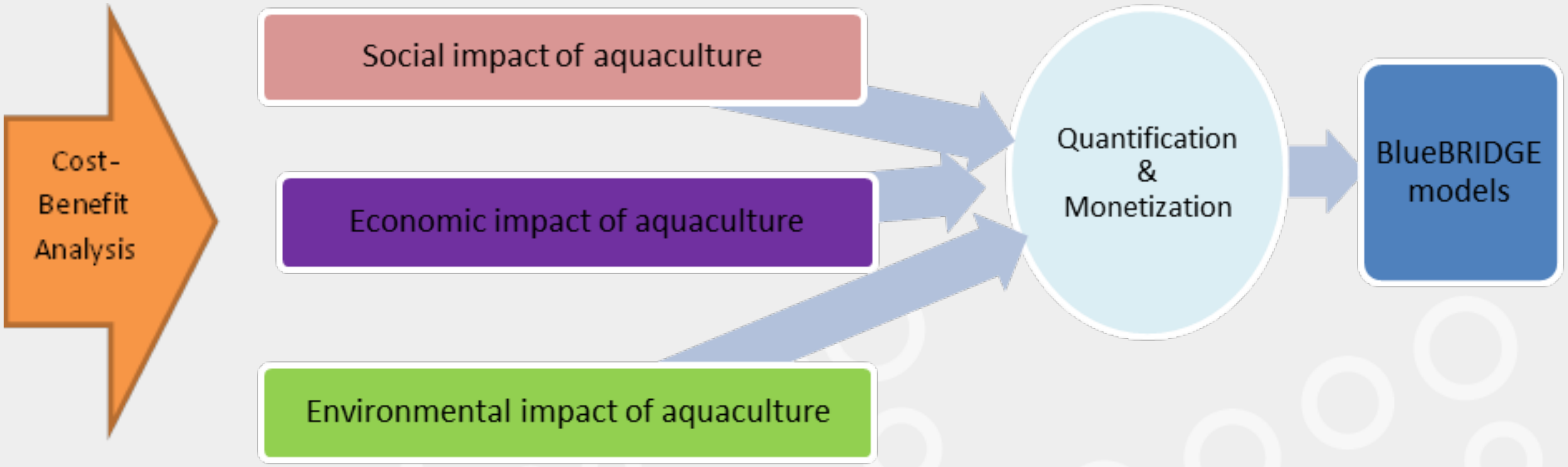
- Aim
- Methodological approach
- The economic, social and environmental effects of aquaculture
- Valuation of aquaculture costs and benefits and links to production and techno-economic models
- Data requirements and data sources

Aim

- Conceptualize and monetize the social and environmental impact of aquaculture
- Combine social and environmental impact with specific techno-economic and production models of blue economy
- Consider data and computational resources at reach
- Distinguish between private and social costs and benefits and incorporate social costs and benefits in private functions

Approach

- Drawing on the latest research, the costs and benefits associated to aquaculture have been identified and quantified in a way compatible to the techno-economic and cost-driven production models available in BlueBRIDGE
- The approach followed distinguishes between social, economic and environmental costs and benefits
- Appropriate relationships are formulated which quantify and introduce the socio-economic and environmental costs and benefits of aquaculture into the decision support system of aquaculture management



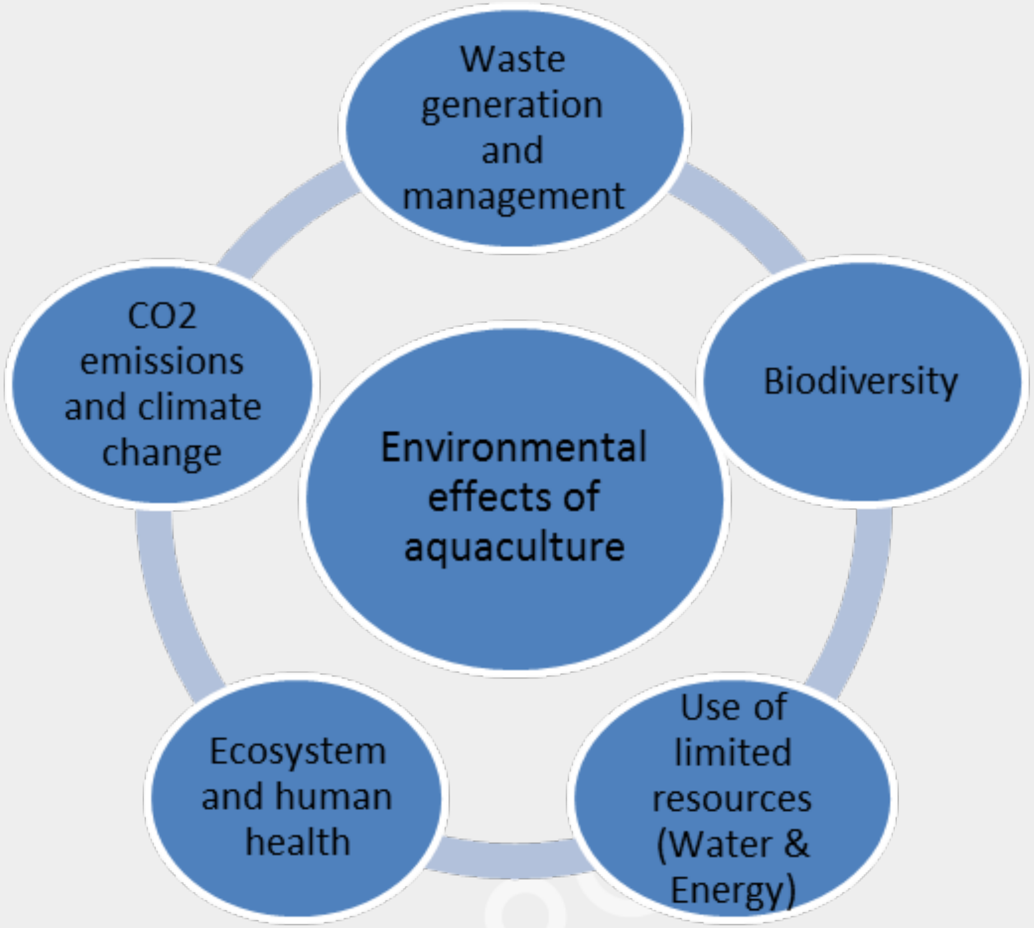
Economic effects of aquaculture

- Economic effects of aquaculture can be identified and analyzed in terms of income and employment generation
- The contribution of aquaculture to world GDP remains limited, despite rising trends recorded in the recent years. Similar evidence from EU as well
- Aquaculture has been the fastest growing food production sector in the world over the last decades
- Employment dependency of aquaculture can be significant
- Employment emerges as a primary benefit, especially in areas of deprivation and rural communities where large farms can be created
- However it has been found that over time employment numbers may not be maintained or reach high levels due to improvements in technology that replaces labour
- Additional economic costs and benefits are associated with the large initial capital investments required
- Aquaculture effects have also been identified in terms of the required investment in infrastructure

Social impacts of aquaculture

Impact	Indicative literature
Protection of traditional skills	Neiland et al. (1991), Symes et al. (2009), Plymouth Marine Laboratory (2013)
Community stability	Burbridge (2001)
Maintenance of culture and identity	White and Costelloe (1999)
Food security	James et al. (2009), Urquhart et al. (2013)
Livelihoods, sense of place and way of life	Urquhart et al. (2013), Reed et al. (2013)
Food preferences and associated utility	Govindasamy and Italia (1999), Loureiro and Hine (2002), Batte et al. (2006)

Environmental effects of aquaculture



Valuation of aquaculture costs and benefits and links to production and techno-economic models

- Prior to presenting the quantified costs and benefits of aquaculture the following methodological and data considerations should be noted
- SCBA comes with advantages such as being very inclusive. On the downside, environmental values are often hard to determine, the ecological functions are subject to changes that are hard to predict and the aggregation performed in SCBA might lead to the loss of essential information
- Given the analysis and data at reach, every effort is made so as to include as many effects as possible in the present analysis, avoiding at the same time over-identification or double-counting issues. However the list of the quantified costs and benefits is non-exhaustive and additional parameters can be added as research progresses
- Significant data limitations: non-existence of market derived prices for the environmental quality, inability to quantify the willingness of consumers to pay for differentiated aquaculture products (e.g. differentiation based on food types), quantification problems with regards to utility and opportunity costs, etc.
- Social impacts vary by societal (individuals, communities) or time (current, future) scales and type of outcome (positive, negative). Employment of evidence from similar sites is coupled with advantages of ease of application and overcoming of data limitations. However this might subject the analysis vulnerable to generalizations, or it might fail to capture accurately and site-specific effects

Introduction of socio-environmental impact in cost-driven production models

- Core idea: Introduce socio-environmental costs and benefits in the Net Present Value (NPV) function employed by cost-driven production models
- Specification of the augmented NPV function:

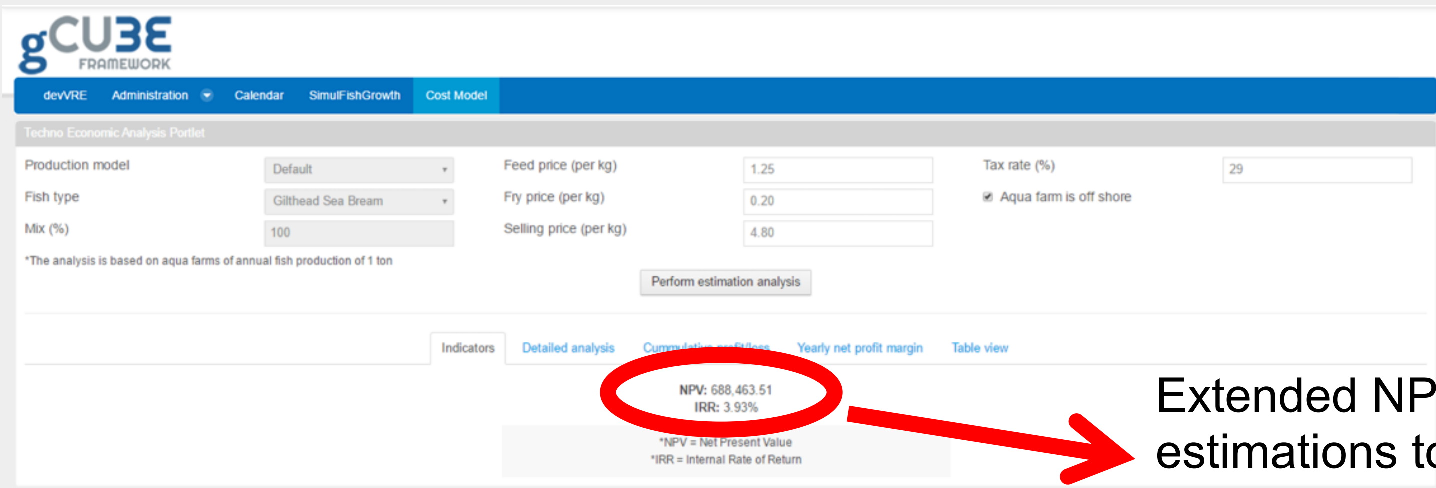
$$NPV = \sum_{i}^{n} \frac{(BF_{it} + ESBF_{it}) - (CS_{it} + ESCS_{it})}{(1+r)^t}$$

where *NPV:* Net present value, *BF:* Annual gross revenues, *ESBF:* Extended annual benefits, *CS:* Annual gross costs, *ESCS:* Extended annual costs, *r:* discount rate, *i:* Benefit/cost category, *t:* time

- Extended annual benefits and costs reflect the monetized value of socio-environmental impacts
- Given the methodological tools and data at reach, and following the literature to date and prior evidence, the following costs and benefits of aquaculture are quantified:
    - ✓ *Investment costs*
    - ✓ *Production costs (fixed/variable costs)*
    - ✓ *Employment effects and labour costs*
    - ✓ *Water pollution and waste management costs*
    - ✓ *Emissions and climate change costs*
    - ✓ *Production revenues*
    - ✓ *Income generation (Per capita income/GDP)*
    - ✓ *Consumer satisfaction-Food preferences*
    - ✓ *Community wellbeing and biodiversity*

Introduction of socio-environmental impact in cost-driven production models (cont.)

- Socio-environmental costs and benefits to be included as an additional cost/revenue (disaggregation subject to data availability) in the techno-economic analysis model (for instance as additional cost components in “Operation and Administration Cost”)



Extended NPV estimations to account for socio-environmental costs and benefits

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Investment and production costs

Investment costs : $IC_{s,t} = SCC_{s,t} + CFE_{s,t}$
$IC_{s,t}$ Investment cost
$SCC_{s,t}$: Site construction costs
$CFE_{s,t}$: Cost of farming equipment
s: aquaculture site
t: time

Production costs include fixed and variable costs : $PC_{s,t} = FC_{s,t} + VC_{s,t}$
$PC_{s,t}$: Production costs
$FC_{s,t}$: Fixed costs
$VC_{s,t}$: Variable costs

Variable costs include labour costs, maintenance costs and other variable costs (energy, feed, etc.): $VC_{s,t} = LVC_{s,t} + MVC_{s,t} + OVC_{s,t}$
$LVC_{s,t}$: Labour costs
$MVC_{s,t}$: Maintenance costs
$OVC_{s,t}$: Other variable costs

Labour costs

- Labour cost estimations can be extended so as to account for the socio-economic effects of aquaculture
- Aquaculture provides employment and income generation opportunities
- These reflect back to the costs of labour
- Producers can estimate the costs of labour and project into the future by making used of the annual growth of per capita income
- This methodology follows recent developments in the literature on the estimation of labour costs trends (see for instance Nobre et al, 2009)
- Changes in labour costs are formulated as a function of annual growth of per capita income (or GDP): $\frac{dLC}{dt} = r_y * LC$

where LC: Unit labor costs (wage rates), r_y: annual growth rates of per capita income (or GDP)

Prices and revenues

- Aquaculture revenues are formulated as follows: $R_{s,t} = Q_{s,t} + P_{s,t}$

where: $R_{s,t}$: Revenues, $Q_{s,t}$: Production quantity, $P_{s,t}$: Market price

- Aquaculture prices are formulated in international markets (local producers= price takers)
- Prices are associated with micro-and macroeconomic elements of interest (such as inflation rate, consumer preferences and trends, etc.). In order to account for these additional socio-economic interactions, prices that aquaculture producers are faced with can be formulated as a function of the inflation rate as follows: $\frac{\mathrm{dP}}{\mathrm{dt}} = \mathrm{r_p} * \mathrm{P}$

where P: price, $\mathrm{r_p}$ =price growth rate (inflation)

- In estimating the price that the aquaculture producer will be faced with, the models can consider food preferences and attitudes of consumers towards specific aquaculture (environmentally friendly, natural veggie-based feed etc.) or towards spatial characteristics of aquaculture (preference to locally farmed fish over imported, etc.)
- The costs and benefits associated with consumer preferences and wellbeing can be modelled via a price premium added or subtracted from the market price that the producer is faced with
- The premium-corrected price formulation is: $FP = P * (1 + Premium)$

where: FP: Final price that the aquaculture producer is faced with, $Premium$: Price premium reflecting consumer preferences and willingness to pay (based on the literature it ranges between 38%-44% of price)

Climate change and emission costs

- Aquaculture-related emissions entail costs for the aquaculture producer but also for the society as a whole via their impact on climate change
- This costs can be quantified and internalized with the use of information on the site-specific emissions (in CO2 equivalent) and on carbon prices
- Emission related costs of aquaculture (or benefits in case of emission reduction): $PEC_{s,t} = CO2_{s,t} * CP_t$

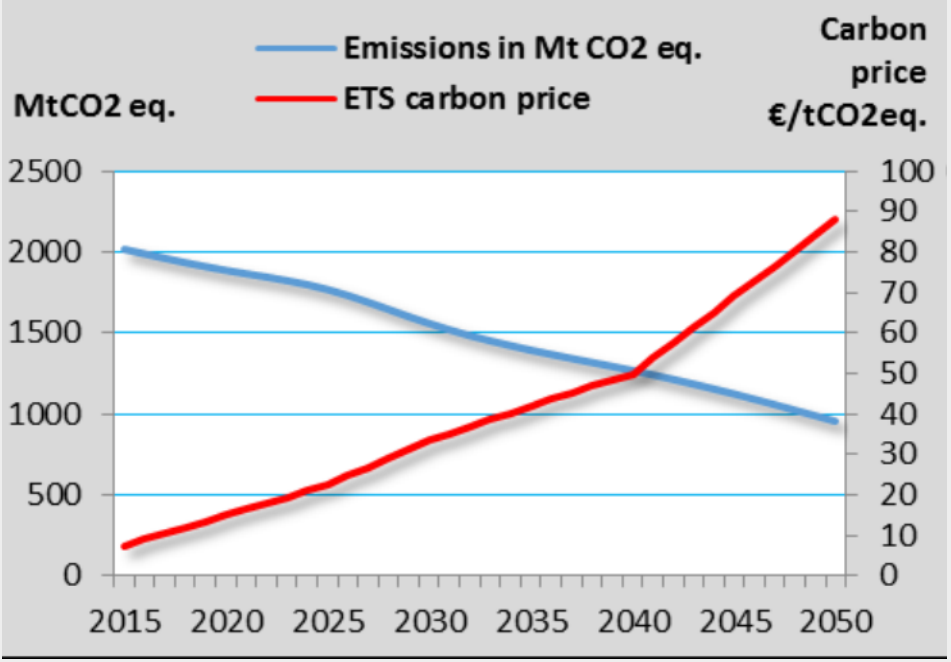
where: $PEC_{s,t}$: Emission costs, $CO2_{s,t}$: CO2 emissions, CP_t: Carbon price

- But how much: i) emissions & ii) money?

Aquaculture type	Emissions (Kg CO2 eq/kg)
Salmon (Norway)	1.8
Salmon (Chile)	2.3
Salmon (UK)	3.3
Pangasius (Pond based Vietnam)	4.7
Trout RAS France	1.6
Mussel culture raft system	2.6
Captured mussels	0.04
Asian sea bass (RAS)	1.7

Climate change and emission costs (cont.)

ETS emissions and carbon prices in the EU energy, transport and GHGs emissions- Trends to 2050



Social cost of CO2, in 2007 dollars per metric ton CO2

	Discount rate		
	5%	3%	2.5%
2020	12	42	62
2025	14	46	68
2030	16	50	73
2035	18	55	78
2040	21	60	84
2045	23	64	89
2050	23	69	95

- Carbon price projections to 2050 can be obtained from the EU Reference Scenario 2016 developed by the European Commission
- To ensure robustness of estimations but also to perform sensitivity analysis, can be used additional estimations on the social costs of CO2 provided by the USA Environmental Protection Agency

Water pollution and waste management costs

- Aquaculture waste comes in three general forms: metabolic, chemical, and pathogenic
- Research shows that by choosing the appropriate feeds during the production cycle, and paying close attention to the feeding methods and the resulting solids production, aquaculture managers can reduce aquaculture waste significantly
- Although the private costs are captured to some extent from the costs of chemicals, of the production methods and of the technologies used in the aquaculture site, incorporated in investment and production costs, the social costs are not internalized

Internalized cost of water pollution/prevention, in % of private production cost	Case study	Source
6	Trout, West Virginia	Smearman et al. (1997)
15-16	Salmon, Sweden	Folke et al. (1994)

Biodiversity, environmental attitude and community effects

Action surveyed, year and country of reference	Methodology	Willingness to pay (in 2013 US dollars)	Payment frequency	Unit	References
Improved status, Harbor seal, 2006, Canada	Hybrid Contingent Valuation / Choice Experiment	78.84–201.61	Annual	Household	Boxall et al. (2012)
Improved status, Beluga whale, 2006, Canada	Hybrid Contingent Valuation / Choice Experiment	113.58–355.73	Annual	Household	Boxall et al. (2012)
Improved status and population increase, 2007, USA	Choice Experiment	39.26–229.47	Annual	Household	Lew et al. (2010)
Protection program, 2003, Greece	Contingent Valuation	21.74–29.95	One-time	Individual	Stithou and Scarpa (2012)
Improved status, USA	Choice Experiment	47.47–73.97	Annual	Household	Wallmo and Lew (2011)
Improved status, USA	Choice Experiment	39.37–72.00	Annual	Household	Wallmo and Lew (2012)
Protection program, Norwegian lobster, 2006, Spain	Contingent Valuation	22.96	One-time	Household	Ojea and Loureiro (2010)
Protection program, Hake, 2006, Spain	Contingent Valuation	35.63	One-time	Household	Ojea and Loureiro (2010)
Protection program, Manatee, 2001, USA	Contingent Valuation	13.48–28.20	Annual	Household	Solomon et al. (2004)
Protection program, Loggerhead sea turtle, 2003, Greece	Contingent Valuation	22.46–32.12	One-time	Individual	Stithou and Scarpa (2012)
Improved status, USA	Choice Experiment	47.47	Annual	Household	Wallmo and Lew (2012)

Biodiversity, environmental attitude and community effects (cont.)

- Koundouri et al. (2014a; 2014b; 2016) provide detailed review and estimations. They also develop an appropriate Decision Support Tool
- A recent study of Halkos and Galani (2016) adds to the marine and coastal ecosystem valuation literature with particular interest in Greece (Choice Experiment, 3 areas: Volos-Pagasetic Gulf, Rethymnon, Crete and Mytilene, Lesvos)
- Willingness to pay through increased water bill for eight years until 2020
- These estimates can provide quantified inputs with regards to the costs and benefits of aquaculture that can enter the NPV estimations of aquaculture production models
- Of particular interest are the findings associated with availability of edible fish (the benefit per household can be assumed to amount to 13.07 Euro annually), the costs associated with Posidonia Oceanica State (amounting to 4.46 Euro per household annually, where aquaculture possess threat to it) and the cost of preserving the endangered species (amounting to 7.7 Euro per household annually).

Willingness to pay estimates per household and attribute for Greece regarding marine and coastal ecosystem (Halkos and Galani, 2016)

	Euro
Edible Fish	13.07
Charismatic species	7.7
Beach development	6
MPA Zoning	11.8
Posidonia Oceanica State	4.46
Non-indigenous species warnings	3.69

Data requirements and data sources

Data	Unit	Source
Site construction costs	Euro	Aquaculture producer
Cost of farming equipment	Euro	Aquaculture producer
Fixed costs	Euro	Aquaculture producer
Maintainance costs	Euro	Aquaculture producer
Other variable costs	Euro	Aquaculture producer
Wage rates	Euro/hour	Aquaculture producer
GDP growth rate	%	Eurostat/World Bank
Production quantity	Kg	Aquaculture producer
Price	Euro	Aquaculture producer/FAO/Eurostat
Inflation rate	%	Eurostat
Price premium	%	Literature
CO2 emissions	Ton CO2/kg	Literature
Carbon price	Euro/ton CO2	Reference scenario 2016, European Commission/ USA Environmental Protection Agency
Social cost of water pollution and waste management	% of private production costs	Literature
Willingness to pay (marine and coastal ecosystem)	Euro	Literature

Thank you for your attention!!!

We will be happy to hear from you!

If you have any comments, ideas or you would like to be involved in BlueBRIDGE, please send us an email or visit our web portal
http://www.bluebridge-vres.eu/