Tools for Assessment and Planning of Aquaculture Sustainability

SHORT TITLE:	**TAPAS**
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ORGANISATION:	**University of STIRLING, UK**
TOPIC:	**H2020- SFS-11b-2015**
PROJECT NUMBER:	**678396**

DELIVERABLE: 3.2

Workshop to evaluate existing models for the environmental risk assessment of chemicals used in aquaculture in the EU (D.3.2)

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History of changes:

Ver	Date	Changes	Author
0.1	27.10.2016	First version	Mechteld ter Horst (ALT)
0.2	28.10.2016	Review/edits	Paul van den Brink (ALT) Andreu Rico (IMDEA) Mechteld ter Horst (ALT)
0.3	01.11.2016	Review/edits	Andreas Focks (ALT) Arpad Ferinczs (SZIU) Dorte Rasmussen (DHI) Manolis Tsapakis (HCMR) Ian Payne (ASC) Lynne Falconer (UOS) Tania Teixeira (ABT) Mechteld ter Horst (ALT)
0.4	01.11.2016	Review/edits	Paul van den Brink (ALT) Mechteld ter Horst (ALT)

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Refer to this document as:

Ter Horst M.M.S., Van den Brink P.J, Rico A., Falconer L., Ferincz, A., Focks, A., Gazsi, G., Macken, A., Marin, A., Payne, I., Rasmussen, D., Teixeira T.T., Telfer T.C., Tsapakis M., 2016. Workshop to evaluate existing models for the environmental risk assessment of chemicals used in aquaculture in the EU. EU H2020 TAPAS Deliverable 3.2. Report. 91 pp.

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SUMMARY

This document provides an overview of a workshop, held in Wageningen, The Netherlands, between 24th and 26th October, 2016, for work package 3 (WP3 – Environmental Risk Assessment (ERA) of potentially toxic substances) of the TAPAS project. The first aim of the workshop was to evaluate existing models for the environmental risk assessment of chemicals used in aquaculture in the EU (review; Task 3.1) and to design a strategy for their development and improvement. During the workshop the pros and cons of the modelling approaches described in the review were discussed and a set of modelling tools that better allow the evaluation of environmental impacts of chemical used with the current EU regulatory framework was selected. It was agreed that a key outcome of the WP3 modelling task is focussing the modelling on the sediment compartment and the development of effect modelling. A second aim of the workshop was to get an overview of the systems and facilities that the various TAPAS partners can provide for the (experimental) case studies to be used by the various work packages in the TAPAS project and to select specifically for WP 3 the four experimental sites that will be used to carry out experimental studies for the calibration and evaluation of the different components of the selected and improved modelling tools. It was concluded that it is vital to take in to account multiple stressors (e.g. chemical and nutrients combined). Therefore, modelling of exposure to chemicals together with nutrients is required. Close collaboration between WP3 (chemicals), WP5 (nutrients) and WP 7 (case studies) is needed and it was agreed to organise in conjunction with WP5 and WP 7 a meeting in early spring 2017 to discuss and make detailed protocols in order to align the case study designs and experiments.

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1. Introduction and agenda of the workshop

1.1 Introduction

Deliverable 3.2 (Workshop to evaluate existing models for the environmental risk assessment of chemicals used in aquaculture in the EU) is part of Task 3.2 of WP 3: The development of an improved modelling approach for the ERA of potentially toxic substances.
The workshop was delayed by 1 month to allow participation from as many partners as possible. Also, this would provide the participants of the workshop more time to evaluate the review of environmental risk assessment models (Task and Deliverable 3.1).

Task 3.2 is the development of an improved modelling approach for the ERA of potentially toxic substances. Partners involved are: ALT, IMDEA, PML (not present in workshop but will be contacted), HCMR and UOS. In addition, NIVA, UM, ABT will not be main partners but will contribute to the modelling strategy by participating in the workshop as well. DHI indicated that they can make and are willingly to make the following contribution to WP3 within their budget: DHI collects data from fish-farming ponds with different degree of re-circulation and biological treatments from various sites in Denmark. This includes also measurements of disinfectants and medicine (consumption, concentration in various compartments) enabling a mass balance of these toxicants. DHI can contribute with an exposure modelling study of these toxicants and the results can be included in the results of WP3. University of Stirling would provide input partly via PhD student funded by TAPAS.

Prior to the workshop detailed information on each case study and the partner capabilities has been collected using a questionnaire (see Appendix 1). This will be used to inform discussion and help in deciding the particular case studies and ERA models to be used for work package 3.

Alterra provided an introduction to the aims and goals of the workshop and the presentation can be found in Annex 1.

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1.2 Agenda of the workshop

The workshop has been organized by ALT in Wageningen from Monday 24 October to Wednesday 26 October. The agenda of the workshop is given below:

Monday 24 October

12.00 – 13.00 Arrival and lunch

13.00 – 13.30 Introduction to partners and work package and linkage between model development and case studies (Paul Van den Brink)

13.30 – 14.00 Presentation ERA model review - task 3.1 (Andreu Rico)

14.00 – 16.30 Discussion on model gaps and linkage of models

16.30 – 17.00 ASC data and model output needs (Ian Payne)

19.00 Workshop dinner

Tuesday 25 October

9.00 – 10.00 Agreement on model development, coupling and design

10.00 – 12.30 Division of work between partners and time planning

12.30 – 13.30 Lunch

13.30 – 15.00 Presentation of possible case study locations

15.00 – 17.30 Discussion on case studies suitable for the work package

Wednesday 26 October

9.00 – 10.00 Selection of case study locations

10.00 – 12.30 Discussion on planning of case studies (subgroups)

12.30 – 13.30 Reporting back of case study locations and lunch

13.30 Leave

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2. Participants of the workshop

The list of participants of the workshop is given in Table 1 and a scan of the attendance list is given in Annex 2.

Table 1. List of participants of the TAPAS workshop to evaluate existing models for the environmental risk assessment of chemicals used in aquaculture in the EU (D3.2).

Affiliation	Name	Email address	Relevant for:
Alterra, WUR (ALT)	Paul van den Brink	Paul.vandenbrink@wur.nl	Modelling & case studies
Alterra, WUR (ALT)	Andreas Focks	Andreas.Focks@wur.nl	Modelling & case studies
Alterra, WUR (ALT)	Mechteld ter Horst	Mechteld.terhorst@wur.nl	Modelling & case studies
IMDEA	Andreu Rico	andreu.rico@imdea.org	Modelling & case studies
University of Murcia (UM)	Arnaldo Marin	arnaldo@um.es	Case studies
NIVA	Ailbhe Macken	ailbhe.lisette.macken@niva.no	Case studies
Hellenic Centre for Marine Research (HCMR)	Manolis Tsapakis	tsapakis@hcmr.gr	Modelling & case studies
Szent Istvan University (SZIU)	Arpad Ferincz Gyöngyi Gazsi	Ferincz.Arpad@mkk.szie.hu Gazsi.Gyongyi@mkk.szie.hu	Case studies
AquaBioTech (Malta)	Tania Teixeira	tpt@aquabt.com	Case studies
DHI	Dorte Rasmussen	dor@dhigroup.com	Modelling
University of Stirling (UOS)	Trevor Telfer	t.c.telfer@stir.ac.uk	Modelling & case studies
University of Stirling (UOS)	Lynne Falconer	lynne.falconer1@stir.ac.uk	Modelling & case studies
ASC	Ian Payne	ai.payne88@gmail.com	Data provision

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Figure 1. Pictures of the participants taken during workshop

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3. Selection of a (set of) modelling tool(s) for the Environmental Risk Assessment (ERA) of chemicals used in aquaculture in the EU

3.1 Model review

Starting point for the discussion on the selection of modelling tools for the ERA of chemicals used in aquaculture in the EU was the literature review of existing model for the ERA of potentially toxic compounds (Task 3.1). A summary of the review and possible discussion points for the workshop were presented by Dr. Andreu Rico using a power point presentation (Annex 3).

3.2 Production systems selected for modelling

First it was discussed and decided which production system to model. For the marine environment net pens and cages are the most relevant systems. For the fresh water environment fish ponds are considered most relevant and preferably include different degrees of recirculation. Hatcheries were discussed as well, but it was concluded that they are too diverse for making a proper scenario and therefore less fit for modelling.

Next for each system an inventory of existing models was made (Table 2) and pros and cons of existing models were discussed.

The discussion resulted in two important outcomes:

- It is relevant consider multiple stressors – modelling of exposure to chemicals together with nutrients is required. Close collaboration between WP3 (chemicals) and WP5 (nutrients) is therefore needed.
- There is no need to create scenarios for the different systems, because of the homogenous nature of aquaculture production practices used in the EU. Focus instead on testing whether the models work well in the different case-study locations and corresponding systems.

After this discussion, it was decided to proceed with the discussion on the case studies, because the selection of a suitable model is directly related to data for validation and parameterization of the models measured in the systems used for the case studies.

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Table 2. Aquaculture systems selected for modelling of ERA

Aquaculture systems	**Marine/fresh water**	**Exposure**	**Promising (existing) models**
Net pens and cages	Marine	1. Application to water 2. Feed application 3. Antifouling	1. Bath-auto 2. DEPOMOD – version 1: single site model; DEPOMOD – version 2 (called NewDEPOMOD - http://www.sams.ac.uk/kenny-black/newdepomod. The link also includes a link to the NewDEPOMOD report which has information on the updated model.): large scale; 3. MOM; MAMPEC (?);For non-local modelling, i.e. outside net pens and cages: MIKE (licence needed); PML – matlab model(s): • FVCOM (Finite Volume Coastal Ocean Model), a hydrodynamic model that can be used to model residence times of pollutants from aquaculture activities, dispersion patterns etc. • For WP5, Ricardo from PML is using a shellfish model (shellsim) coupled to FVCOM-ERSEM. ERSEM (Earth and Regional Seas Ecosystem Model) is a lower trophic level ecosystem model. Ricardo will be able to provide any information on what is possible/not possible for WP3.
Fish ponds	Fresh water	Water Mixed with feed (in Hungary antibiotics or anti parasites are not used profilactic, only to treat disease outbreaks according SZIU)	ERA-AQUA for the fish pond (chemical mass/concentration in discharge) TOXSWA or MIKE for concentration in river AQUATOX - both exposure and effects – large number of input parameters needed.

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4. Experimental case studies

To get a quick overview of the systems and facilities that the various TAPAS partners can provide for the (experimental) case studies to be used by the various work packages of TAPAS a questionnaire was developed. The questionnaire is a joint product of work packages 3, 4, 5, 6 and 7
The work packages supporting this questionnaire will mainly use the results of the case studies for the parameterisation and validation of models and scenarios.

For WPs 6 and 7, questions were included regarding site suitability for continuous optical registration of biogeochemical parameters, and questions regarding the uptake of products from Earth Observation.

Annex 3 provides the questionnaire sent to the various TAPAS partners. During the workshop, UM, HCMR, ABT, NIVA and SZIU presented information about their case study sites using the questionnaire as a guideline. The presentations on the case study sites of the different TAPAS partners are given in Annex 4. After the presentations and corresponding discussions, an overview of the capacity (experience, facilities etc.) of the different partners was made (Table 3).

Highlights of the discussion:

- Fresh water fish ponds Hungary (SZIU):
    - Chemicals are seldomly applied, however antibiotics (and other toxicants as e.g. disinfectants) might enter the system via the manure that is brought into the pond for feeding the fish and improving microbiology.
    - Focus shifts to genetic resistance problem (check with EU if shift in focus is ok)
- Marine net pens/cages in North sea – Norway (NIVA)
    - Use of copper based antifoulings and antiparasitics
    - Limited budget – what to do depends on the budget (consult options with Alterra)
    - Farmers are quite happy to cooperate and share information
    - MOM model is used (MAMPEC for the antifoulings) https://www.deltares.nl/en/software/mampec/#7)
- Marine net pens/cages in Mediterranean sea – Spain (UM)
    - Antibiotics are only used in case of an outbreak – it might be a problem to know exactly the dose and timing of an application
    - Copper based antifoulings
    - Farms are far away from the coast compared to Malta and Greece
- Marine net pens/cages in Mediterranean sea – Malta (ABT)
    - Active ingredient of antifouling product used is not clear. It is not copper base, but a kind of paint; producer will not give the recipe. What to analyse?
    - Antibiotics are only used in case of an outbreak (fish are vaccinated)

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- Marine net pens/cages in Mediterranean sea – Greece (HCMR)
    - Own model: MERAMOD and AIM model (Manolis will bring Andreas in contact with the person responsible for the AIM Model)
    - Good facilities for measuring, but help with the protocols is needed – idea launched: develop protocols: partners use the same protocols for the same jobs
    - Antibiotics are only used in case of an outbreak – farmers are happy to cooperate and thus willing to make a phone call to notify when they will apply the chemical. However acting quickly on such a notification (gathering a team and sending it off) is difficult for HCMR.
    - Copper based antifoulings

- General
    - Key outcome of WP 3: effect modelling and focus on sediment
    - Budget/time for case studies in different work packages (3, 5, 6 and 7). It is difficult to determine how much is exactly available. Try to streamline this in the Brussels meeting in November (proposal of UOS).

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Table 3. Capacity of the different TAPAS partners considering the case studies that are relevant for the modelling task in WP3

features	**SZIU**	**NIVA**	**UM**	**ABT**	**HCMR**
System	Fresh water Fish pond Hungary (carps)	Marine Net pen/cages North sea Norway (salmon)	Marine Net pen/cages Mediterranean sea Spain (seabass, seabream)	Marine Net pen/cages Mediterranean sea Malta (seabass, seabream)	Marine Net pen/cages Mediterranean sea Greece (seabass, seabream)
Can you determine the dose and timing of the application during the study?	Possibly (antibiotics enter the system via manure, would be wise to monitor antibiotic use in agricultural farms and residues in manure)	Yes	Possibly (very difficult at the moment). Perhaps base mass balances on annual loads.	Possibly	Yes
Which chemicals are used?	Antibiotics might enter the system via manure applications to increase the primary productivity of ponds	- Sea lice treatments - Cu based antifouling	- Cu based antifouling - Antibiotics	- Antifouling - Formaldehide	- Cu based antifouling - Antibiotics
Do you apply models?	No	Yes (MOM)	No	No	Yes (MERAMOD, AIM)
Analytical capacity?	+/-	+	- (ask for support from IMDEA)	- (ask for support to other partners)	+
Water quality + sediment?	+	+	+	+/-	+
Time in project (months)	WP3: 39 WP5: - WP7: 36	WP3: 4 WP5: 4 WP7: 6.5 UOS PhD student attached to case study north sea.	WP3: 16 WP5: 27 WP7: -	WP3: 12 WP5: 7 WP7: 10	WP3: 18 WP5: 18 WP7: 22
Toxicity testing?	+	+/-	+	+	-

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5. Proposals for exposure and effect models and case study design

During the workshop the most important features of the case studies including proposal for exposure and effect models to use were listed (Table 4). This was followed by a discussion on what would be needed considering additional mesocosm/laboratory tests and capacity (experience, facilities etc.) of partners (SZIU, UM, ABT, NIVA) for performing such tests (Table 5).

Agreement:

> ALT will organise a meeting in early spring 2017 (probably aligned with the Malta consortium meeting in March) to discuss and make detailed protocols in conjunction with WP5 and WP 7 to align everything.

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Table 4. Relevant features of the case studies used for the modelling task in WP3

features	**SZIU**	**NIVA**	**UM**	**HCMR**
System	*Fresh water* *Fish pond* *Hungary* *(carp pond)*	*Marine,* *Net pen/cages* *North sea* *Norway* *(salmon)*	*Marine,* *Net pen/cages* *Mediterranean sea* *Spain* *(seabream and seabass)*	*Marine* *Net pen/cages* *Mediterranean sea* *Greece* *(seabream and seabass)*
What to assess?	Antibiotic resistance enrichment of bacterial communities.	Non target populations of invertebrates	Non target populations of invertebrates/ biofilms - antibiotics, cu? antifouling	Non target populations of invertebrates/ biofilms - antibiotics, cu? antifouling
Exposure model	ERA-AQUA and additional equations from Heuer et al. (2008)	BathAuto (sus.solids – dispersion modelling by e.g. MIKE?) DEPOMOD v2 MOM? MAMPEC for antifouling?	MERAMOD local	MERAMOD multi sites (incorporated in AIM)
Target exposure concentration	Water/sediment	Sediment	Water/sediment	Water/sediment
Effect endpoint	Enrichment of the frequency of resistant genes	Long-term population effects (2-3 years) Abundance Nutrient effects IBM	Invertebrate community	Invertebrate community
Effect models	Dose-response (thresholds) Response community	IBM	Multi species model	Multi species model
Spatial/temporal components	Pond Years (time step days)	1 km2 (grids 10x10 m^2), 1 year	Fate and effects: 1x1 km^2 (resolution 50x50 m^2) 1 year	Fate: 5x5 m2, but MERAMOD+AIM: 1x1 km^2 (resolution 50x50 m^2) Effects: 1x1 km^2 (resolution 50x50 m^2) 1 year

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features	SZIU	NIVA	UM	HCMR
system	*Fresh water fish pond Hungary*	*Marine, Net pen/cages North sea-Norway*	*Marine, Net pen/cages Mediterranean sea-Spain*	*Marine, Net pen/cages Mediterranean sea-Greece*
What needs to be measured in the field?	Exposure in sediment (antibiotics concentration) qPCR with selection of genes marker for bacterial biomass like 16S rRNA	Exposure in sediment (time and space) Abundance selected species Community?	Effects: Invertebrate community gradient both inside and outside farm Fate: sediment traps, Water/sediment, biofilm	Effects: Invertebrate community gradient both inside and outside farm Fate: sediment traps, Water/sediment, mussels
comment		Antifouling modelling approach needed (MAMPEC?)	Antifouling modelling approach needed	Antifouling modelling approach needed

ABT is not in the table because their focus is on the effect assessment in the lab.

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Table 5. Relevant features of and partners' capacity for performing additional (mesocosm/laboratory) studies needed to support the case studies that are used for the modelling task in WP3. ALTERRA and IMDEA will provide expertise and technical support the different studies when needed.

features	**SZIU**	**NIVA** (**?** depends on budget available)	**UM**	**ABT**
Chemicals	antibiotics	sea-lice treatments and copper (antifouling)	antibiotics copper (antifouling)	antibiotics copper (antifouling)
Additional stressors	nutrients	nutrients	nutrients (feed)	nutrients
Species/endpoint	Cyanobacteria (growth rate) Daphnia (immobilization, reproduction)	Copepods (development endpoints) Lobster *(development endpoints) Oysters (biomarkers) Bivalves (development studies) * Lobsters (and other decapods) may require ethical approval, need to check this with the EU and national guidelines.	***Copper:*** Polichaeta (bioaccumulation, mortality) Amphipods (bioaccumulation, mortality) Bivalves (bioaccumulation, mortality) --- ***Copper and antibiotics:*** Amphipods (indirect effect) Biofilm (indirect effect, community composition – functional groups) Micro/mesocosm (multispecies test)	Sea orchids (settlement) Mussels (bioaccumulation, mortality – biomarkers) Amphipods (feeding, inhibition) Micro/mesocosm(multispecies test)
Chemical analyses	Yes (via service provision)	Yes	Copper – Yes Antibiotics – supported by ALT or IMDEA, when needed	No, to be arranged (ALT)
Exposure	water	Sediment as much as possible	Sediment (except biofilm)	Water (single species) Sediment (mesocosms)

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6. Other possible data sources to use for the WP3 modelling task

Ian Payne of ASC was present to explain the work of ASC on aquaculture accreditation (Annex 5). ASC requires a number of data to be reported regularly during the productions cycles under certification. As a result, ASC owns a substantive dataset from the many aquaculture sectors throughout the world. WP3 and other WPs, will use the data relevant to EU aquaculture to underpin the data gathering and help assess the outcomes in terms of wider aquaculture accreditation. The data however will need processing into a usable form. Relevant data for the EU many relate to salmon and trout production. Main streams of data are show below and more details are given in Annex 6.

Environmental data

- Water quality – measures of N, P and O2
- Sediment (Chemical)– redox, sulphide
- Sediment (biotic) – Shannon Weiner or indicator species

Health

- Mortalities
- Therapeutant and antibiotic use

Feed

- Feed efficiencies

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Annex 1. Introduction by Prof. Paul van den Brink

WP3: Environmental Risk Assessment (ERA) of potentially toxic substances

D3.2 Workshop with relevant project partners to evaluate the ERA models and to design a strategy for their development and improvement.

D3.3 - Workshop with all relevant project partners on the model development and to design the case studies for validation and evaluation

Goals of this workshop

1. Agreement on model development, coupling and design (and division of work
2. Selection of case study locations

- Only make commitments when time is available (no relocation of time)!

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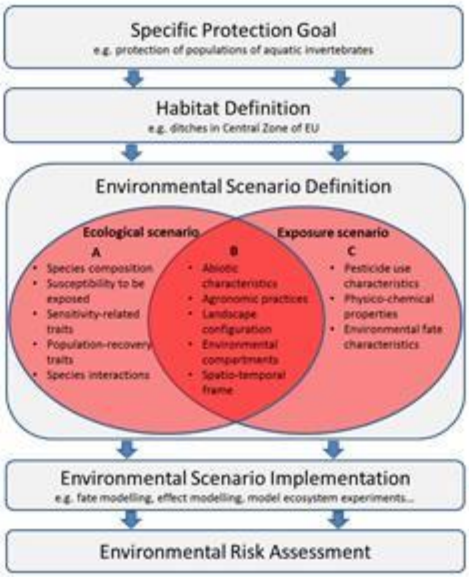
Goals of this workshop



- Scenario development for pesticides
- Similar approach for TAPAS
- Connection between exposure and effects models , trigger values and scenarios

WP3: ERA of potentially toxic substances

Objectives

1. *To evaluate and improve existing farm-scale modelling tools for the evaluation of the ecotoxicological risks generated by antifouling agents, veterinary medicines and potentially toxic compounds.*
2. To compile, develop, and test environmental thresholds for potentially toxic substances used in EU aquaculture.
3. To develop rapid assessment tools for the prospective ERA of potentially toxic substances that can be used by farm applicants and regulators (WP8).

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WP3: ERA of potentially toxic substances

Tasks

Task 3.1: Literature review of existing models for the ERA of potentially toxic compounds (IMDEA)

Task 3.2: Development of an improved modelling approach for the ERA of potentially toxic substances (ALT)

Task 3.3: Development and evaluation of EU aquaculture scenarios for the ERA of potentially toxic substances (ALT, NIVA, UOS, PML, ASC, SZIU, ABT)

Task 3.4: Development of environmental quality thresholds for ERA (SZIU)

Task 3.5: Model and scenario validation through case studies (ALT, SZIU, UM, ABT, NIVA, UOS, HCMR, PML)

TAPAS

Task 1: Model development

- Discuss the pros and cons of the modelling approaches described in Task 3.1 (Talk Andreu)
- Proposed modelling approach will be evaluated and improved:
  1. mechanistic link between organic matter contamination, toxicant exposure and effects will be improved by, for example, including water quality indirect effects and mechanistic toxicant-effect modelling approaches
  2. the influence of aquaculture contamination by veterinary medicinal and other potentially toxic substances on ecosystem services provided by aquatic organisms in the surrounding aquaculture farms will be explored and incorporated as evaluation endpoints (WP4).
  3. multiple-stress conditions will be incorporated including climate change and aquaculture-related stressors using stressor-response relationships and biological trait information collected from the literature

TAPAS

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Goal 1: Model development

- To assess the impacts of potentially toxic substances (e.g. antifouling agents, veterinary medicines and other biocidal compounds) to aquatic ecosystems surrounding aquaculture farms
- Provide an ecologically relevant link between aquaculture management practices and their associated biological impacts,
- Integrated into appropriate spatio-temporal scales to assess the assimilative capacity of ecosystems and the carrying capacity of different production systems
- University of Stirling would provide input partly via PhD student not funded by TAPAS. Plymouth Marine Lab can contribute and many other would like to be discussion partners.

Goal 2: Case studies

- Four experimental studies (a freshwater case study, and three marine in the Mediterranean sea, east and west, and in the North sea) will be carried out
- Aims:
  - to calibrate and evaluate the different components of the modelling tools derived in Task 3.2,
  - to evaluate the efficiency on the implementation of the modelling scenarios generated in Task 3.3,
  - and to test the environmental threshold concentrations and evaluation endpoints derived within Task 3.4.
- Enough parties are interested: NIVA, UM, HCMR, ABT as marine systems and SZIU in Hungary for fresh water systems.

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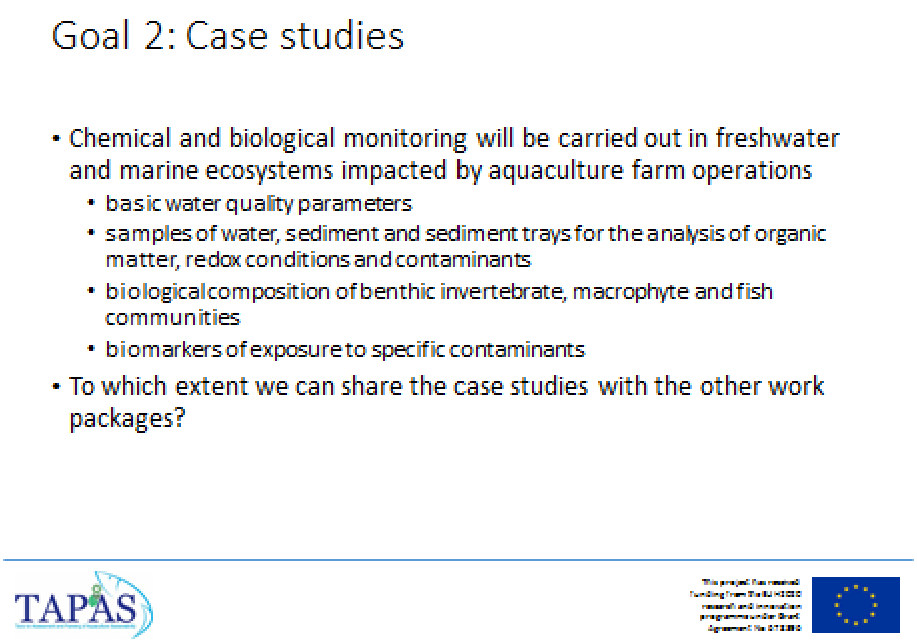

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Annex 2. List of attendance

TAPAS WP3 Workshop (D3.2) 24-26 okt. Wageningen – List of participants

Affiliation	Name	Email address	Signature
ALT	Paul van den Brink	Paul.vandenbrink@wur.nl	
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ASC	Ian Payne	ai.payne88@gmail.com	

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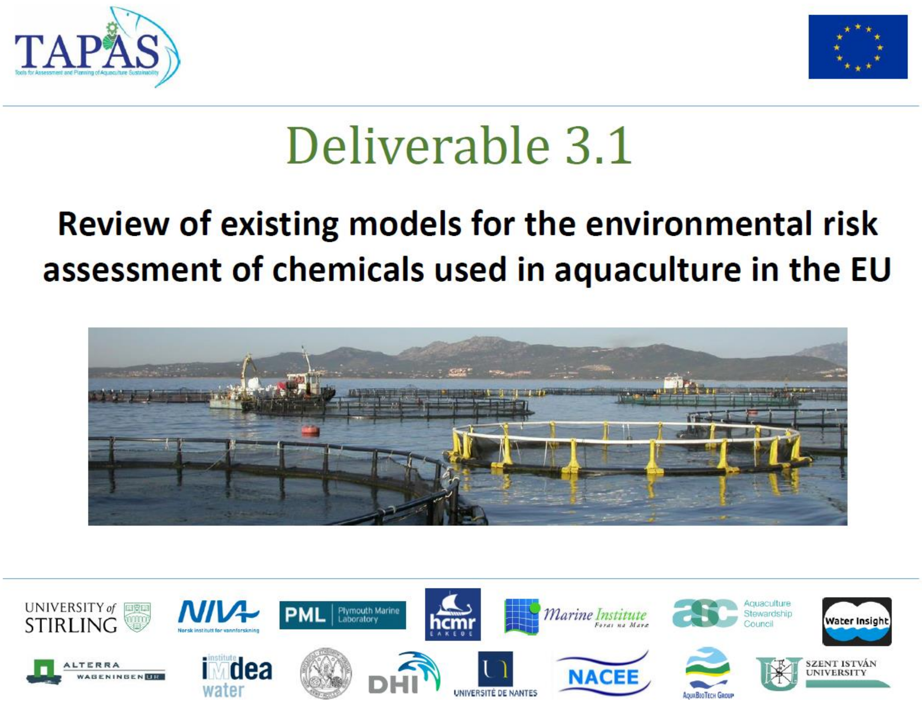
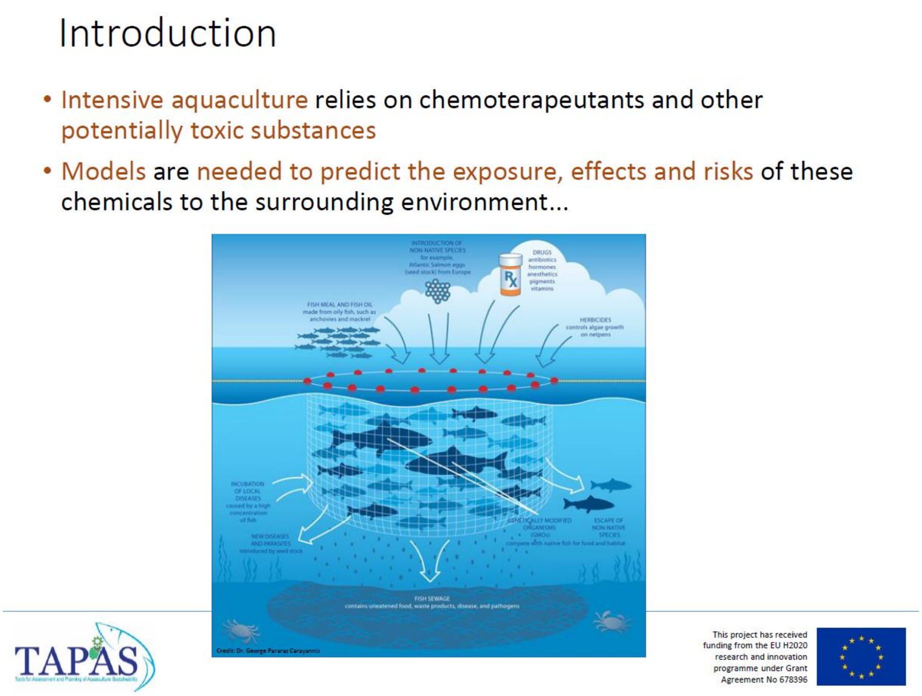
Annex 3. Summary of the review of existing models for the environmental risk assessment of chemicals used in aquaculture in the EU





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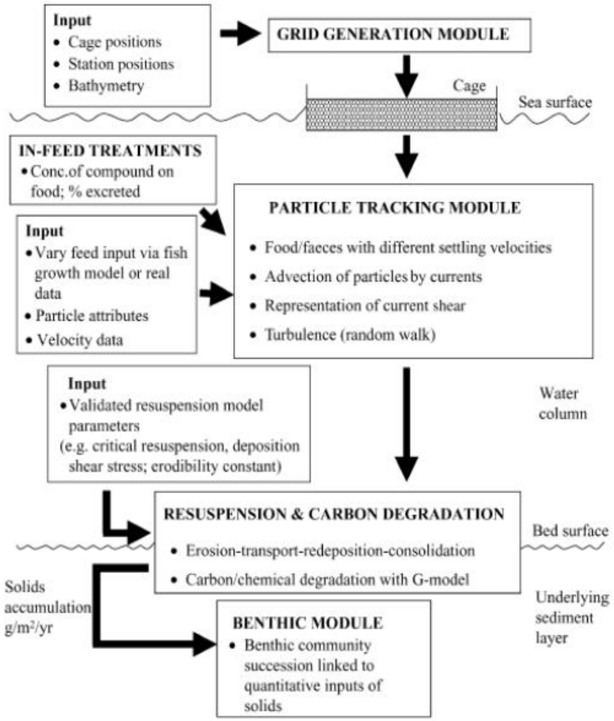
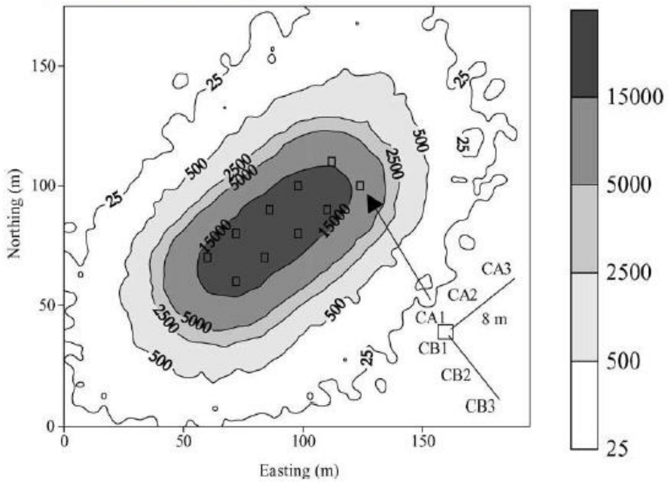
Introduction

- Example 1: DEPOMOD (Cromey et al. 2002)



g solids / m^2 / year



TAPAS

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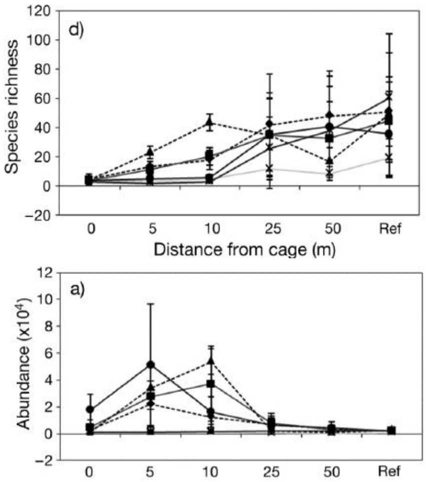
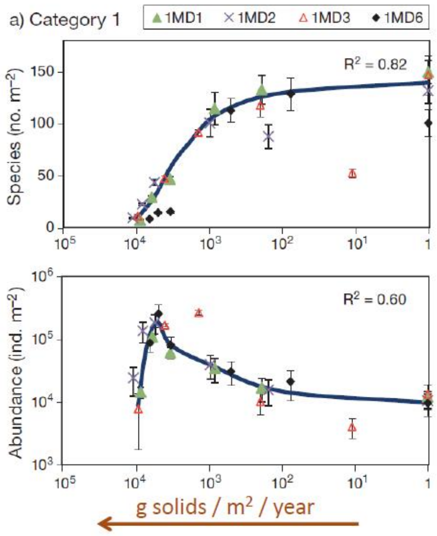
Introduction

- Example 1: DEPOMOD (Cromey et al. 2002)





Introduction

- Example 2: ERA-AQUA (Rico et al. 2013)

Pond Water

$$\frac{\partial M_{pond\,water}}{\partial t} = M_{adsorption/desorption} + M_{excretion} + M_{irrigation} - M_{drainage} - M_{percolation} - M_{volatilization} - M_{degradation} - M_{absorption}$$

Pond Sediment

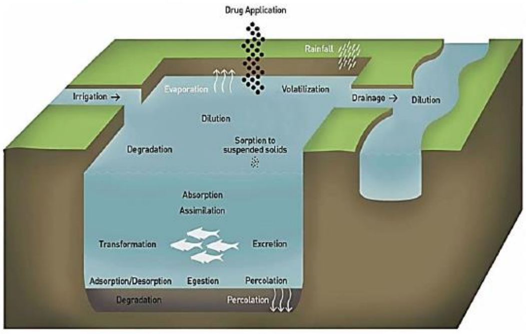
$$\frac{\partial M_{pond\,sediment}}{\partial t} = M_{percolation} + M_{egestion} + M_{adorption/desorption} - M_{degradation}$$

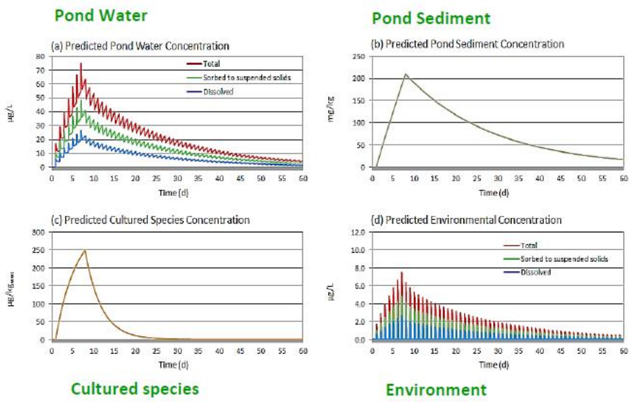
Cultured Species

$$\frac{\partial M_{cultured\,species}}{\partial t} = M_{absorption} + M_{assimilation} - M_{excretion} - M_{egestion} - M_{transformation}$$

Environment

$$PEC = \frac{PWC \cdot Q_{effluent}}{Q_{watercourse} + Q_{effluent}}$$





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Introduction

- Example 2: ERA-AQUA (Rico et al. 2013)

Endpoint	Exposure Assessment			Effect Assessment			Risk Characterization	
Cultured Species	PeakPWC	74.8	µg/L	$PNEC_{cs}$	11,600	µg/L	RQ_{cs}	**0.01**
Aquatic ecosystems (acute)	PeakPEC	7.44	µg/L	$PNEC_{algae}$	3.42	µg/L	RQ_{algae}	**2.18**
	PeakPEC	7.44	µg/L	$PNEC_{inv.}$	102	µg/L	$RQ_{inv.}$	**0.07**
	PeakPEC	7.44	µg/L	$PNEC_{fish}$	116	µg/L	RQ_{fish}	**0.06**
Aquatic ecosystems (chronic)	TWA3	1.27	µg/L	$PNEC_{algae}$	18.3	µg/L	RQ_{algae}	**0.07**
	TWA21	0.84	µg/L	$PNEC_{inv.}$	4,620	µg/L	$RQ_{inv.}$	**$1.82 \cdot 10^{-4}$**
	TWA28	0.74	µg/L	$PNEC_{fish}$	NA	µg/L	RQ_{fish}	**NA**
Consumers	EDI	$2.33 \cdot 10^{-6}$	mg/(kg · d)	ADI	30.0	mg/(kg · d)	$RQ_{cons.}$	**$7.8 \cdot 10^{-8}$**
Trade	$PCC_{harvest}$	1.47	$µg/kg_{wwt}$	MRL	100	µg/kg	RQ_{trade}	**0.01**

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Objectives

- To compile the existing modelling tools and evaluate them regarding:
  - Capacity to be used for aquaculture scenarios in the EU
  - Coverage of the main chemicals applied in EU aquaculture
  - Capacity to address the protection goals and standards set by the EU regulation
- To use existing information to discuss how TAPAS can contribute to improve the available modelling approaches

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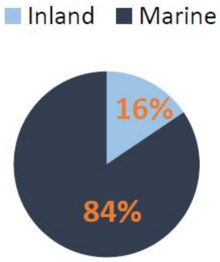
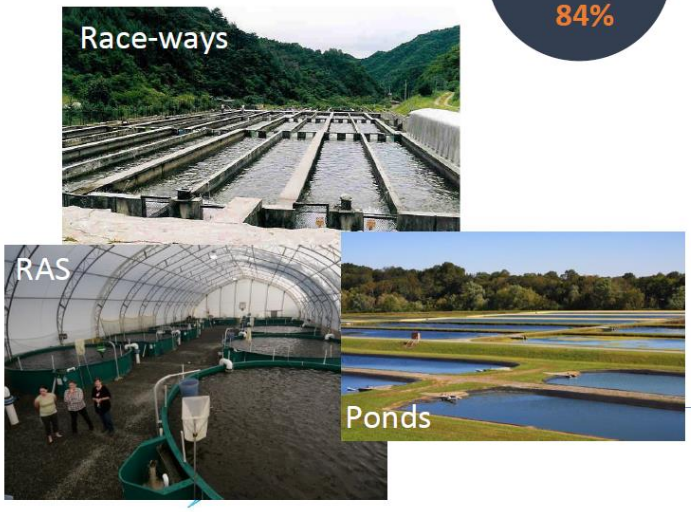
Aquaculture production in the EU

- In 2014 the EU produced nearly 2Mt of fish

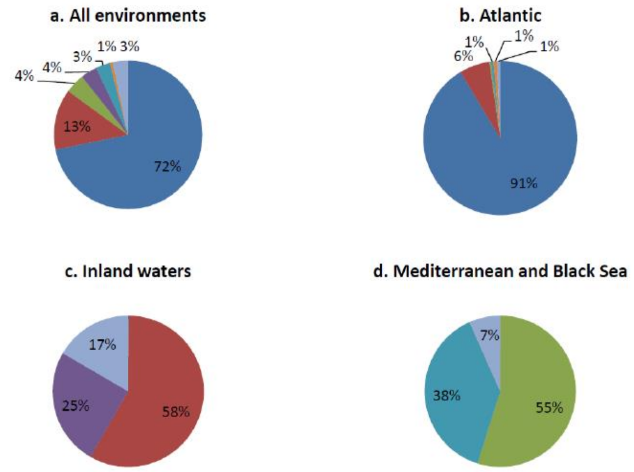


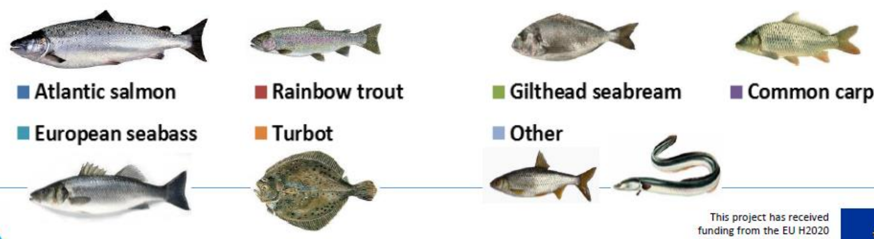
Inland aquaculture



Off-shore aquaculture

Aquaculture production in the EU





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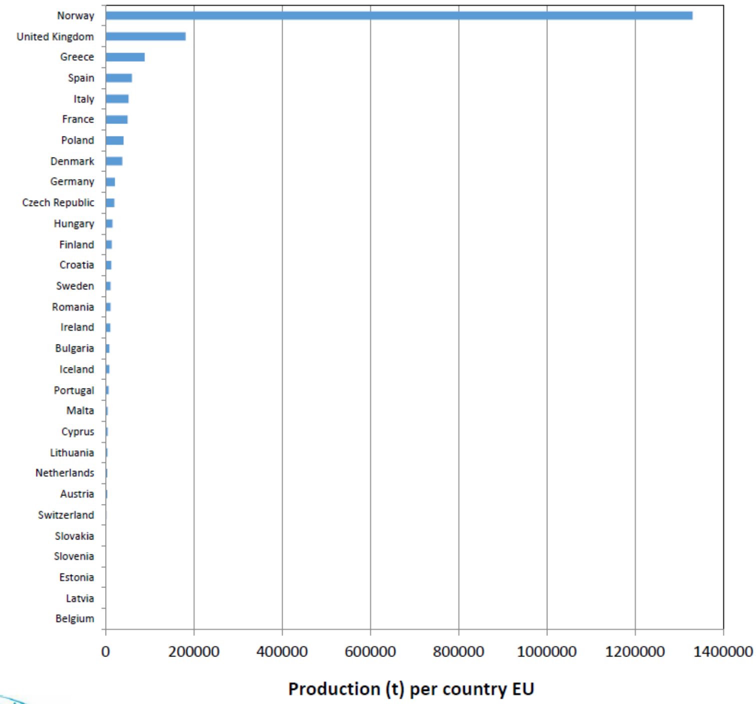
Aquaculture production in the EU



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Potentially toxic chemicals

- Veterinary medicines: list of authorized compounds

	Norway[1]	United Kingdom[2]	Greece[3]	Spain[4]	Italy[5]
Antibiotics					
Florfenicol	x	AS	GS, ES	RT	x*
Oxyetracycline		AS, RT	GS, ES	AS, RT, TB, GS, EE, ES, CC	x
Chlortetracycline			GS, ES		x
Amoxicillin		AS	GS, ES		x
Flumequine			GS, ES	RT	x
Sulfadiazine-trimethoprim	x		GS, ES		x
Oxolinic acid	x		GS, ES		
Antiparasitics					
Azamethiphos	x	AS			x*
Teflubenzuron	x	AS			
Diflubenzuron	x				
Emamectin benzoate	x	AS	GS, ES	AS, RT	
Deltamethrin	x	AS, RT			
Cypermethrin	x				
Hydrogen Peroxide	x	AS	GS, ES		
Formaldehyde			GS, ES	GS, TB	
Antifungals					x
Bronopol		AS, RT		AS, RT	

AS: Atlantic salmon, RT: rainbow trout, GS: gilthead seabream, ES: European seabass, TB: turbot, EE: European eel, CC: common carp

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Potentially toxic chemicals

- Antifouling agents:
  - To prevent net collapse: copper based compounds, herbicides
- Disinfectants:
  - To disinfect farm infrastructure and materials and for fish disinfection: formaldehyde, iodophors
- Food additives:
  - Residues of chemicals in food constituents: PCBs, PAHs, metals

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ERA regulations

- ERA guidance veterinary medicines: set by the International Cooperation on Harmonization of Technical Requirements for Registration of Veterinary Products (VICH) and the European Medicines Agency (EMA)
- Protection goal: the main protection goal is '*the protection of ecosystems*' in a broad sense, while it specifies that the '*impacts of greatest potential concern are usually those at community and ecosystem function levels, with the aim being to protect most species*'.
- Phase I (trigger exposure value 1 µg/L)
- Phase II (tiered exposure and effect assessment)

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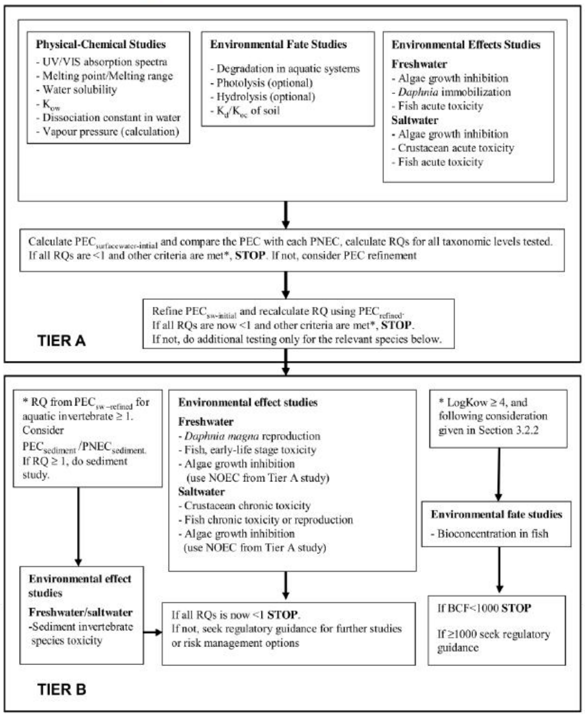
ERA regulations

- Phase II (tiered exposure and effect assessment)



If $PEC_{sw,initial}$>PNEC, **PEC refinement**: taking into account water/sediment systems

Little specific guidance and **no specific tools recommended** for refinement

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ERA regulations

- Criticism raised on current ERA guidance for veterinary medicines
  - Effects of antimicrobials on non-target microorganisms (bacteria, archae, fungi) and side-effects on microbial mediated ecological functions (e.g. organic matter breakdown, nitrification) not taken into account (Brandt et al. 2016)
  - Antimicrobial effects on bacterial resistance not addressed (Bengtsson-Palme and Larsson 2016)
  - Concerns of benzoylurea sea-lice treatment (diflubenzuron, teflubenzuron) effects on moulting of non-target crustaceans (e.g. copepods, shrimps, lobsters) (Langford et al. 2014; Macken et al. 2015; Olsvik et al. 2015)

- Room for improvement in current regulatory framework (Lillicrap et al. 2015)

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ERA regulations

- The ERA framework implemented to a varied degree into the different EU members
- Scotland is a special case: assumes that different waters have different capacity to absorb veterinary medicine residues and the ERA and chemical authorization is made at a farm level
- SEPA has issued their own standards for sea-lice treatments
  - Temporal component for chemicals applied directly to water:
    - Azamethiphos

      MAC3h: 250ng/L   MAC24h: 150ng/L   MAC72h: 40ng/L
  - Spatial component for chemicals applied mixed with feed:
    - Emamectin benzoate

      MAC:7.63 µg/kg within 25 m from cages   MAC:0.763 µg/kg beyond 100 m from cages

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Review of models

- Inland aquaculture systems

Model acronym and reference	Relation to aquaculture ERA?[1]	Production system (and species)	Chemical type and mode of application	Chemicals evaluated	Regulatory use?	Model type	Validation status for veterinary medicines
Algorithms (Metcalfe et al. 2009)	Full	Ponds, net pens, cages, or flow-through systems (no species-specific)	No specific	None	Yes	Exposure	None
VDC (Phong et al., 2009)	Full	Ponds (no species-specific)	Antibiotics applied mixed with fed	Oxytetracycline and oxolinic acid	No	Fate and exposure	Unknown
ERA-AQUA (Rico et al., 2012 and 2013a)	Full	Ponds or tanks (tilapia, Pangasius catfish, shrimp, prawn). Can be parameterized for a wide range of finfish and crustacean species	All kind of veterinary medicines applied mixed with feed or directly to water	A wide range of antibiotics and antiparasitic substances used in Asian aquaculture	No	Fate, exposure, effects (PNEC) and risks (RQ)	Partly validated (exposure/fate antibiotic)
Chloramine-T dilution models (Gaikowski et al. 2004)	Full	Flow-through hatchery (no species-specific)	Disinfectant applied directly to water	Chloramine-T	Unknown	Exposure	Unknown
WASP (Ambrose et al. 1993) used by Rose and Pedersen (2005)	Moderate	Hatcheries (no species-specific)	Antibiotic applied mixed with feed	Oxytetracycline	Unknown	Fate and exposure	None
TOXSWA (Adriaanse, 1997, Adriaanse et al., 2013)	Low	No specific. Diffuse and point source discharges into ponds, streams, ditches.	All kind of veterinary medicines released in farm effluents or veterinary medicines applied directly to water in ponds	None	No	Fate and exposure	Partly (exposure pesticides)
GREAT-ER (Koormann et al. 2005)	Low	No specific. Point source discharges into rivers.	All kind of veterinary medicines released in farm effluents.	None	No	Exposure	Yes (but with down-the-drain chemicals)
GEMCO (Baart et al. 2003)	Low	No specific. Point source discharges into estuaries and marine open waters.	All kind of veterinary medicines released in farm effluents.	None	No	Fate and exposure, and bioaccumulation	Partly (exposure pesticides, bioaccumulation PCBs)
AQUATOX (Park et al. 2008)	Low	No specific. Diffuse and point source discharges into rivers.	All kind of veterinary medicines released in farm effluents.	None	No	Fate, exposure and effects	Partly validated (other chemicals)
MASTEP (Van den Brink et al., 2008)	Low	No specific. Diffuse and point source discharges into rivers.	All kind of veterinary medicines released in farm effluents.	None	Few times	Effects (population-level)	Partly (population effects pesticides)

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Review of models

- Offshore aquaculture systems

Model acronym and reference	Relation to aquaculture ERA?[1]	Production system (and species)	Chemical type and mode of application	Chemicals evaluated	Regulatory use?	Model type	Validation status for veterinary medicines
Algorithms (Metcalfe et al. 2009)	Full	Net pens / cages (no species-specific)	No specific	None	Yes	Exposure	None
No name (dichlorvos model) Gillibrand and Turrell (1997)	Full	Net pens / cages (no species-specific) in lochs	Antiparasitic treatment applied directly to water	Dichlorvos	Unknown	Exposure, risks (exceedance EQS)	Yes (dichlorvos)
Bath-Auto (SEPA 2008)	Full	Marine net pens / cages (salmonids)	Antiparasitic treatments applied directly to water	Cypermethrin Deltamethrin Azamethiphos	Yes (SEPA, UK)	Exposure, risks (exceedance EQS and maximum dose)	Yes (dichlorvos)
Pyceze model, Novartis and University of Stirling (no reference)	Full	Freshwater net pens / cages (salmonids)	Antifungal/antiprotozoo treatment applied directly to water	Bronopol	Yes (SEPA, UK)	Exposure	Yes (bronopol)
DIVAST (Falconer and Hartnnett 1991)	Full	Marine net pens / cages (salmonids)	Antiparasitic treatments applied directly to water	Dichlorvos	Unknown	Exposure	Yes (dichlorvos)
DEPOMOD (Cromey et al. 2002)	Full	Marine net pens / cages (salmonids)	Antiparasitic treatments applied mixed with feed	Teflubenzuron Emamectin benzoate	Yes (SEPA, UK)	Exposure, fate, risks (exceedance sediment EQS)	Partly (only for solid waste dispersal)
MERAMOD (Cromey et al. 2012)	Full	Marine net pens / cages (gilthead sea bream and sea bass)	Chemical treatments applied mixed with feed	None	Unknown	Exposure, fate, risks (exceedance sediment EQS)	Partly (only for solid waste dispersal)
MOM (Stigebrandt et al. 2004)	Full	Marine net pens / cages (salmonids)	Chemical treatments applied mixed with feed	None	Yes (Norway)	Organic matter fate, effects (sediment anoxia)	No
CAPOT (Telfer et al. Under development)	Full	Marine net pens / cages (salmonids)	Chemical treatments applied mixed with feed	None	No	Exposure, fate	Partly (only for solid waste dispersal)

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Preliminary findings

- Are exposure models applicable to the main chemicals and production systems?
  - High-tier exposure assessment models exist for the main production systems, but…
  - For inland systems, the link of in-farm exposure and downstream environmental exposure and fate is poorly implemented
  - For off-shore systems, exposure modelling has mainly focused on sea-lice treatments applied directly to water
  - Overall there is a need for calibration and validation of exposure models in different environments…
  - …particularly for particle tracking models

TAPAS Tools for Assessment and Planning of Aquaculture Sustainability
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Preliminary findings

- Are available models properly addressing the protection goals and standards set in the EU regulation?
  - The effect modelling part is less developed than the exposure part
  - Risk assessments based on a PEC/PNEC or PEC/EQS ratio
  - Evaluation of exceedance of EQS is easily performed with a proper exposure model, but…
  - are PNECs and EQS sufficiently protective for effects on aquatic populations and communities?
  - Not much information on PNEC or EQS validation under field conditions (organic matter contamination, indirect effects, recovery)
  - Link of toxicological impacts of aquaculture on ecosystem services rather unexplored

TAPAS Tools for Assessment and Planning of Aquaculture Sustainability
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Discussion

- Towards a suitable modelling approach within TAPAS:
  - What systems are we going to model?
  - What model outcomes are most relevant to the TAPAS objectives and to other WPs?
  - Can we select a set of models to be used within the project?
  - How can we improve their environmental realism?
  - What parts of models need validation/calibration under field conditions?
  - Can we generate a series of standard environmental scenarios for rapid assessment of chemical impacts?
  - Can we think on a set of common validated standards for use in the ERA of aquaculture chemicals in the EU?

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Annex 4. Questionnaire on the experimental case study sites

Tools for Assessment and Planning of Aquaculture Sustainability

SHORT TITLE:	**TAPAS**
COORDINATOR:	**Prof. Trevor Telfer**
ORGANISATION:	**University of STIRLING, UK**
TOPIC:	**H2020- SFS-11b-2015**
PROJECT NUMBER:	**678396**

QUESTIONNAIRE ON SITES FOR CASE STUDIES

Contributing Authors:

Mechteld ter Horst (ALT), Paul van den Brink (ALT), Andreu Rico (IMDEA), Annelies Hommersom (WI), Lynne Falconer (UOS), Trever Telfer (UOS), Stefano Ciavatta (PML), Stefan Simis (PML), Trine Dale (NIVA), Tamas Bardocz (ABT).

Table 1: History of changes

Ver	Date	Changes	Author
0.1	12-05-2016	First draft	Mechteld ter Horst (ALT) Paul van den Brink (ALT) Andreu Rico (IMDEA)
0.2	20-05-2016	Add questions relevant to EO and *in situ* optical data gathering (WP6/7)	Annelies Hommersom (WI)
0.3	24-05-2015	review / edits	Lynne Falconer (UOS), Trevor Telfer (UOS)
0.4	27-05-2015 01-06-2016	review / edits	Stefano Ciavatta (PML), Stefan Simis (PML)
0.5	14-06-2016	Second draft – taking into account review / edits of TAPAS partners incl. comments send by email	Mechteld ter Horst (ALT)
0.6	14-06-2016	review / edits	Annelies Hommersom (WI)
0.7	15-06-2016	review / edits	Stefan Simis (PML)
0.8	15-06-2016	review / edits	Lynne Falconer (UOS)
0.9	16-06-2016	Third draft – taking into account review / edits of TAPAS partners incl. comments send by email – using TAPAS template	Mechteld ter Horst (ALT)
1.0	20-06-2016	review / edits	Lynne Falconer (UOS) Mechteld ter Horst (ALT)
1.1	21-06-2016	Release	Mechteld ter Horst (ALT)

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This questionnaire is a joint product of work packages 3, 4, 5, 6 and 7. The aim of this questionnaire is to quickly get an overview of the systems and facilities that the various TAPAS partners can provide for the (experimental) case studies to be used by the various TAPAS WPs. The work packages supporting this questionnaire will mainly use the results of the case studies for the parameterisation and validation of models and scenarios.

For WPs 6 and 7, this inventory includes questions regarding site suitability for continuous optical registration of biogeochemical parameters, and questions regarding the uptake of products from Earth Observation.

Note that there is one questionnaire for marine systems and one questionnaire for fresh water systems.

This questionnaire is sent to the TAPAS partners who will run (or indicated they would like to run) a case study. The contact persons addressed are specified in Table 2.

Please complete the following tables with contact information, and the tables below regarding your study site. Please return your completed questionnaire by email to mechteld.terhorst@wur.nl by **1 September 2016**.

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Table 2 List of (possible) case study sites and corresponding contact persons of the various TAPAS partners who will run (or indicated they would like to run) a case study

Location	Type of system	Partner	Contact person	Email address
Western Channel, UK (Earth Observation reference site)	coastal marine	PML	Stefan Simis	stsi@pml.ac.uk
Lyme Bay, UK	coastal marine	PML	Ricardo Torres	rito@pml.ac.uk
Eastern Mediterranean Aegean Sea	marine	HCMR	Manolis Tsapakis	tsapakis@hcmr.gr
Central Mediterranean	marine (possibly IMTA system)	ABT	Tamas Bardocz	thb@aquabt.com
Western Mediterranean	marine	UM	Arnaldo Marin	arnaldo@um.es
Western Norway, Hardangerfjorden	marine	NIVA	Trine Dale	trine.dale@niva.no
Loire estuary	marine	UN	Laurent Barille	Laurent.Barille@univ-nantes.fr
Clews Bay	marine (IMTA system)	MI/UOS	Dave Jackson	Dave.Jackson@marine.ie
FREA ponds Denmark	freshwater ponds	DHI	Anne Lise Middelboe	AMI@dhigroup.com
Carp ponds in Hungary	freshwater ponds	SZIU	Arpad Ferincz	Ferincz.Arpad@mkk.szie.hu
Salmonid farms in Scotland	freshwater lochs	UOS	Trevor Telfer	t.c.telfer@stir.ac.uk

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Case study questionnaire

Contact details:

Name of Institute	
Name and function of Contact Person	
Contact Details (email, phone number)	
Name of study area	
Location of the study area	d.ddd latitude, d.ddd longitude
Marine or Freshwater?	☐ Marine ☐ Freshwater

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Study Site Questionnaire (Marine):

Site characteristics	
Name of the site	
Location of the site (if possible include a small map).	d.ddd latitude, d.ddd longitude
Commercial farm or research site?	☐ Commercial farm ☐ Research site
Min / Max / Average distance to coast.	
Min / Max / Average water depth.	
Name / variety of aquaculture species	
Brief description of production system and scale.	
How long has the site been in use for aquaculture?	
Are there any agreements with the farmers that we can take samples from the study area? Please indicate how many farmers and if possible the name of the farm/owner of the farm.	
Are there any other kinds of permissions required to take samples in the study area?	
Are there any protected areas in the surrounding of the study area (Natura 2000 or similar)?	
Auxiliary information sources	
Which hydrological information of the area (waves, tides...) is available? Please provide source and/or contact email.	
Which biological information of the area	

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(type of sea bed, benthic fauna...) is available? Please provide source and/or contact email.	
Which meteorological information of the area (wind speed, air temperature...) is available? Please provide source and/or contact email.	
Do you regularly collect and analyse water and sediment samples? Please list the parameters (and how often):	YES / NO If YES, check tick box if parameter is regularly collected and analysed. ☐ chlorophyll-a ☐ phytoplankton Cell counts ☐ daily water temperature ☐ suspended matter ☐ turbidity ☐ pH ☐ transparency (Secchi depth) ☐ nutrients – specify : ☐ toxic chemicals – specify : ☐ More? Please specify: ….. Frequency: ☐ Daily ☐ Weekly ☐ Monthly ☐ Other: ….
Do you have datasets for previous years? Please provide information: -which parameters? -please provide a link to the data source and/or contact email	YES/NO If YES, specify parameters, observation period, frequency:
Do you have information available on the bathymetry of the study area?	

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Please provide sources and/or contact email.	
Which water quality data is available from dedicated cruises/projects? Please specify sources and contact details (e.g. samples from a scientific investigation	
Sampling capability – toxic chemicals	
What potentially toxic chemicals are applied and what is their mode of application?	
Do you, as a TAPAS partner, have the facilities, capacity and resources to analyse these chemicals in water and sediment samples and in biota?	☐ toxic chemicals applied (water) ☐ toxic chemicals applied (sediment) ☐ toxic chemicals applied (biota)
Sampling capability - biogeochemical parameters	
Do you, as a TAPAS partner, have an analytical lab capable of measuring, biogeochemical parameters (e.g. chlorophyll-a, suspended matter...) from water and sediment samples?	☐ chlorophyll-a ☐ phytoplankton Cell counts ☐ suspended matter ☐ organic carbon content sediment ☐ turbidity ☐ transparency ☐ pH ☐ More? Please specify: ….
Do you, as a TAPAS partner, have the capacity (time, manpower, funding) to take and analyse these samples?	☐ chlorophyll-a ☐ phytoplankton Cell counts ☐ suspended matter ☐ organic carbon content sediment ☐ turbidity ☐ transparency ☐ pH ☐ More? Please specify: ….
Sampling capability - nutrients	
Do you, as a TAPAS partner, have the facilities, capacity and resources to analyse nutrients in feed (if it is a fed aquaculture system), water and sediment samples?	☐ Feed: Carbon content ☐ Feed: Nitrogen content ☐ Feed: Phosphorus content

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Please note this data will have to be collected at multiple locations (e.g. an environmental gradient)	☐ Water: Carbon (e.g. CO_2, DOC) ☐ Water: Nitrogen (e.g. TN, NO_3, NO_2, NH_3) ☐ Water: Phosphorus (e.g. TP, PO_4) ☐ Sediment: Carbon content ☐ Sediment: Nitrogen content ☐ Sediment: Phosphorus content ☐ Collection of benthic macrofauna ☐ Identification of benthic macrofauna (abundance and biomass of each species per m^2) ☐ More? Please specify: ….
Sampling capability - General	
Do you, as a TAPAS partner, have the equipment required and capacity to collect current (hydrography) data for waste dispersion models?	☐ Currents (hydrography)
Do you have access to infrastructure and consumables required for sampling? Please describe what is available.	
Is there a preferred season for sampling? Please provide the reason for this, and the relevant period.	
When will data collection be able to start at the site?	
Is there any priority on the chemical(s) and nutrients (carbon, nitrogen, phosphorus) to be evaluated and the biological endpoints that are to be monitored?	
WP 6/7 specific	
Are there any clear data gaps that we could try to fill by monitoring or sampling? Please specify on which parameters data gaps exist.	
Are you interested to install an EcoWatch with a meteo-station at the site? (see note at the end of this questionnaire *)	

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<table>
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<tr><td>Turbidity</td><td>10 m / 300 m / 1 km</td><td>☐</td></tr>
<tr><td>Suspended matter</td><td>10 m/ 300 m / 1km</td><td>☐</td></tr>
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The EcoWatch requires a stable pole or platform above the water (and waves) for construction. Because the measurements are optical, the site should have not bottom visibility. The observed area (one to a few square

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meters water surface, depending on mounting height) should be free of other substances, such as macrophytes, cages etc. There should not be anything blocking the light from above (trees, buildings). A solar panel is used for power. Where a mobile network is present, measurements are sent to a central database. Maintenance should include regular cleaning of optical surfaces.

There are three instruments available during the project (from spring 2017 onwards). Some partners already indicated their interest. Yearly shifts are possible.

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Study Site Questionnaire (Freshwater):

Site characteristics	
Name of the site.	
Location of the site (if possible include a small map).	d.ddd latitude, d.ddd longitude
Commercial farm or research site?	☐ Commercial farms ☐ Research site ☐
Name / variety of aquaculture species.	
Brief description of production system and scale.	
How long has the site been in use for aquaculture?	
Are there any agreements with the farmers that we can take samples from the study area? Please indicate how many farmers and if possible the name of the farm/owner of the farm.	
Are there any other kinds of permissions required to take samples in the study area?	
Are there any protected areas in the surrounding of the farms (Natura 2000 or similar)?	
Auxiliary information sources	
Is information on the water discharge rates of the farms in the study area available? What is the water discharge mode (e.g. pumping...)? Please provide source and/or contact email.	
In case relevant - please describe the aquatic ecosystems receiving effluent	

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discharges from the farms (e.g. lake or a river, size of the system, min/max water depth, min/max flow rates).	
Which biological information of the aquatic ecosystems surrounding the farms (water quality parameters, benthic fauna...) is available? Please provide source and/or contact email.	
Which meteorological information of the area (wind speed, air temperature...) is available? Please provide source and/or contact email.	
Do you regularly collect and analyse water and sediment samples? Please list the parameters (and how often):	If YES, check tick box if parameter is regularly collected and analysed. ☐ chlorophyll-a ☐ phytoplankton cell counts ☐ daily water temperature ☐ suspended matter ☐ organic carbon content sediment ☐ turbidity ☐ transparency ☐ pH ☐ electric conductivity ☐ alkalinity ☐ bulk density sediment ☐ nutrients – specify which ones: Total Phosphorus ☐ any toxic chemicals – specify which ones: ☐ More? Please specify: …. Frequency: ☐ Daily ☐ Weekly ☐ Monthly

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	☐ Other:
Do you have datasets for previous years? Please provide information: -which parameters? -please provide a link to the data source or contact email	If YES, Please provide information
Which water quality data is available from dedicated cruises/projects? Please specify sources and contact details (e.g. samples from a scientific investigation)	
Sampling capability – toxic chemicals (WP3)	
What potentially toxic chemicals are applied and what is the mode of application?	
Do you, as a TAPAS partner, have the facilities, capacity and resources to analyse these chemicals in water and sediment samples and in biota?	☐ toxic chemicals applied (water) ☐ toxic chemicals applied (sediment) ☐ toxic chemicals applied (biota)
Sampling capability - biogeochemical parameters	
Do you, as a TAPAS partner, have an analytical lab capable of measuring, biogeochemical parameters (chlorophyll-a, suspended matter) from water and sediment samples?	☐ chlorophyll-a ☐ phytoplankton cell counts ☐ suspended matter ☐ turbidity ☐ organic carbon sediment ☐ pH ☐ electric conductivity ☐ alkalinity ☐ bulk density sediment ☐ More? Please specify: ….
Do you, as a TAPAS partner, have the capacity (time, manpower, funding) to take and analyse these samples?	☐ chlorophyll-a ☐ phytoplankton Cell counts ☐ suspended matter ☐ turbidity

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	☐ organic carbon sediment ☐ pH ☐ electric conductivity ☐ alkalinity ☐ bulk density & porosity sediment** ☐ More? Please specify: …. ** not measured directly: see for instance http://edepot.wur.nl/340781 for a possible method
Sampling capability – nutrients (WP5)	
Do you, as a TAPAS partner, have the facilities, capacity and resources to analyse nutrients in feed (if it is a fed aquaculture system), water and sediment samples?	☐ Feed: Carbon content ☐ Feed: Nitrogen content ☐ Feed: Phosphorus content ☐ Water: Carbon (e.g. CO_2, DOC) ☐ Water: Nitrogen (e.g. TN, NO_3, NO_2, NH_3) ☐ Water: Phosphorus (e.g. TP, PO_4) ☐ Sediment: Carbon content ☐ Sediment: Nitrogen content ☐ Sediment: Phosphorus content ☐ Collection of benthic macrofauna ☐ Identification of benthic macrofauna ☐ More? Please specify: ….
Sampling capability - General	
Do you have access to infrastructure and consumables required for sampling? Please describe what is available.	
Is there a preferred season for sampling? Please provide the reason for this, and the relevant period.	
When will data collection be able to start at the site?	
Is there any priority on the chemical(s) and nutrients (carbon, nitrogen, phosphorus) to be evaluated and the biological endpoints that are to be monitored?	
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Annex 5. Power point presentations of the various partners on the experimental case study sites

SZIU (fresh water fish ponds Hungary)

TAPAS

Ecological impact assessment of Hungarian fish ponds: study plan

Árpád Ferincz, Ádám Staszny, Gyöngyi Gazsi, Béla Urbányi
Szent István University (Hungary)

Background and importance

- Common carp (Cyprinus carpio) production:
  - Accounted for 25% of total frshwater fish production in Europe
  - Most commonly semi-extensive earthen ponds in Central and Eastern Europe
- Polyculture:
  - 90-95% common carp
  - „Others": asian carps, european catffish, pikeperch
- Earthen ponds:
  - Connected to natural waters directly or via channels and sluices
- Production based on:
  - Manure: characteristically dispensed before filling-up or liquid manure (dispensed daily, max 30-60kg/ha)
  - Feed: cereals (wheat, corn etc.), 60-70kg/ha daily
- The usage of chemicals (antibiotics, antiparasitics): not characteristic

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Environmental/Ecological Impacts

- Limited knowledge on the effect of effluents (compared to e. g. similar channel catfish systems of North America)
  - **Nutrients – euthrophication problems**
  - Alterations of flow regime
  - **Fish fauna**
- Preliminary results suggests:
  - Strong modifiying effect
  - Correlation with the abundance of non-native species
  - Fish pond systems: potential source of invasives
    - Source-sink dynamics

Aims

- 1. Discover the patterns of the fish fauna- environmental factor- fishpond relations
- 2. Assess the environmental impacts of different fish ponds
- 3. Identify the most important environmental and management variables
- 4. Based on the results: Determine the „best practice" of carp pond management in order to minimize the impacts

Case study on Hungarian carp ponds

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Sampling 1.: Fish and environmental variables

- Time schedule: from spring 2017
  - Seasonal sampling (spring, summer, autumn)
- Sampling methods:
  - Electrofishing:
    - On the inflow
    - On the outflow(within 50m; 300m; 500m)
    - On the pond (if possible)
- „Water chemistry"
  - Paralelly with fish sampling
  - Parameters: temperature, dissolved O_2, conductivity, pH, TSS, NO3-N, NO2-N, NH4-N, PO4-P, chlorophyll-A

Sampling 2.: Management variables

- Chemical usage: desinfectant (0/1); antibiotics (0/1); other;
- Manure/fertilizer usage(0/1); volumen (kg/ha)
- stocking (abundance%; density(kg/ha) spring and autmun)
- stocking: predatory fish (0/1), asian carp (biomass, abundance%)
- Frequency of harvesting; date of last harvesting
- area (ha); depth (m); shoreline length; shoreline vegetation
- Feed (quantity/quality)
- Water supply: gravity/pumping

(any other idea?)

Analysis and Results

- Redundancy analysis (RDA)
- Foward selection of significantly effecting variables
- Variance partitionong

- The least „impacting" management scenario could be identified...
- „Best practice" could be described

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Questions...

- Eco-Watch... we want to deploy (at least) one
  - When?
  - For how long period?

- Contribution to the ecotox studies
  - Freshwater recirculation system effluents (Clarias farms)
  - Ecotoxicological characterization of selected chemicals

NIVA (Marine net pens/cages North sea - Norway)

This project has received funding from the EU
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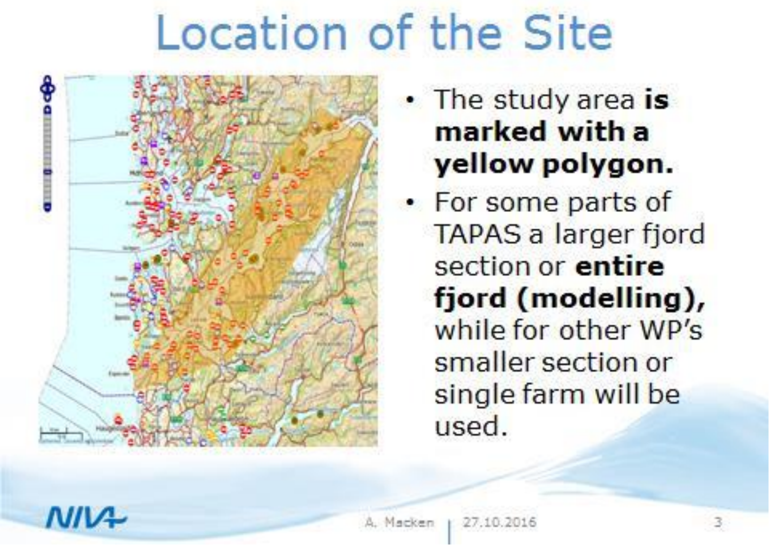

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Fjord and Production system

- 2nd largest fjord in Norway, (180 x 2-10 km)
- Max depth of 830 m in the basin
- Open sea cages
- The entire area has an annual production of salmonids of ca. 70 000 metric tonnes.
- Depending on the site the length of time the site has been used in aquaculture varies

NIVA A. Macken | 27.10.2016 5

Access to the sites in Hardangerfjord

- Access: not granted yet but can be applied for through the fish farmers association.
- Further than 100 m from farm is open to everyone. Within 100 m permission from the individual farm is required.
- Bouys or moorings: Notify Norwegian Coastal Administration

NIVA A. Macken | 27.10.2016 6

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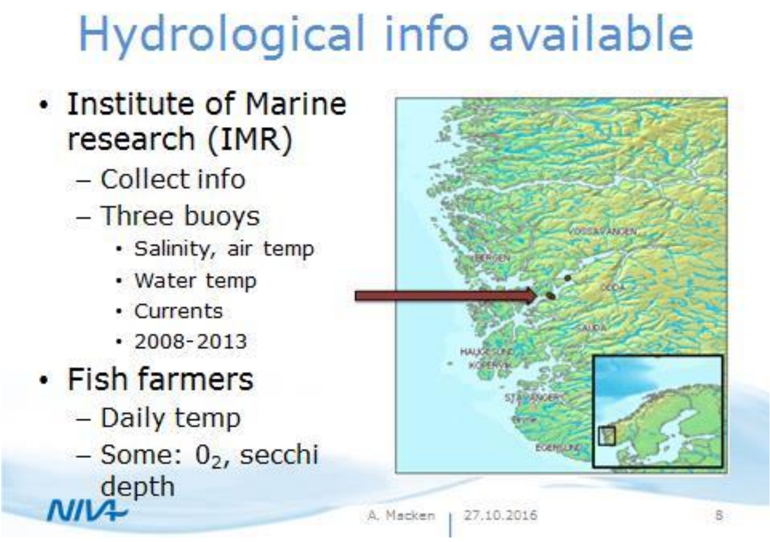

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Benthic surveys

- NIVA has been given access to all compulsory benthic surveys that have been conducted in the last 5-10 years

Datasets available

- Datasets from previous years
  - NIVA have dataset of cell counts from a number of stations in fjord for the period 2006-2010
  - Weekly samples from Feb to October
- Bathymetry data available
  - Norwegian Mapping Authority (Trine Dale, NIVA)

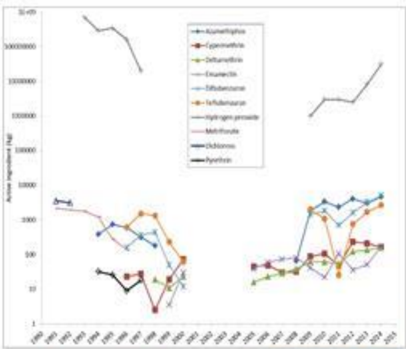
Water Quality data available

- Some investigations by IMR (published data)

NIVA A. Macken | 27.10.2016 9

Potentially toxic chemicals

- Antiparasitic substances over the years (see Fig below)
  - Hydrogenperoxide (H_2O_2) topical treatment against salmon lice
  - Azamethiphos-topical treatment against salmon lice
  - Deltamethrin- topical treatment against salmon lice
  - Cypermethrin- topical treatment against salmon lice
  - Diflubenzuron-feed administered treatment for salmon lice
  - Teflubenzuron- feed administered treatment for salmon lice
  - Emamectin- feed administered treatment for salmon lice
- Others
  - Cu containing antifoulants on nets in many areas



Antiparasitic medication usage in Norway (Denholmet al.,2002; Norwegian Institute of Public Health, 2015).

NIVA A. Macken | 27.10.2016 10

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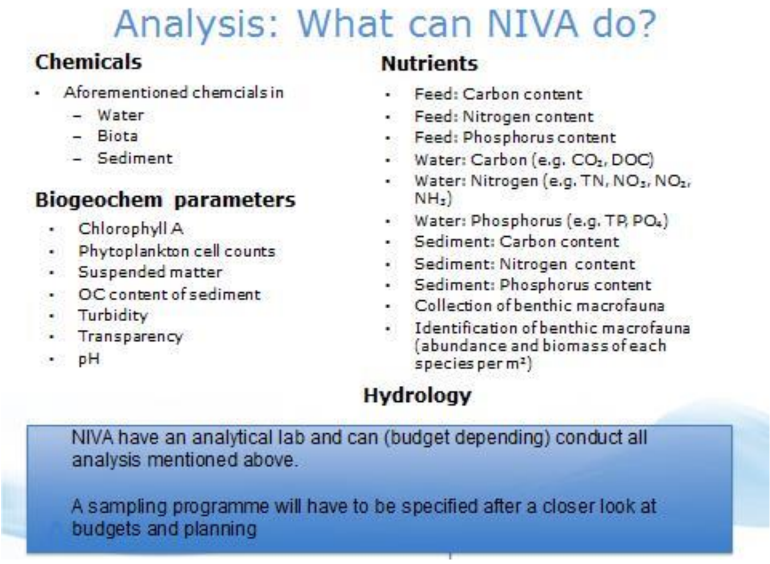

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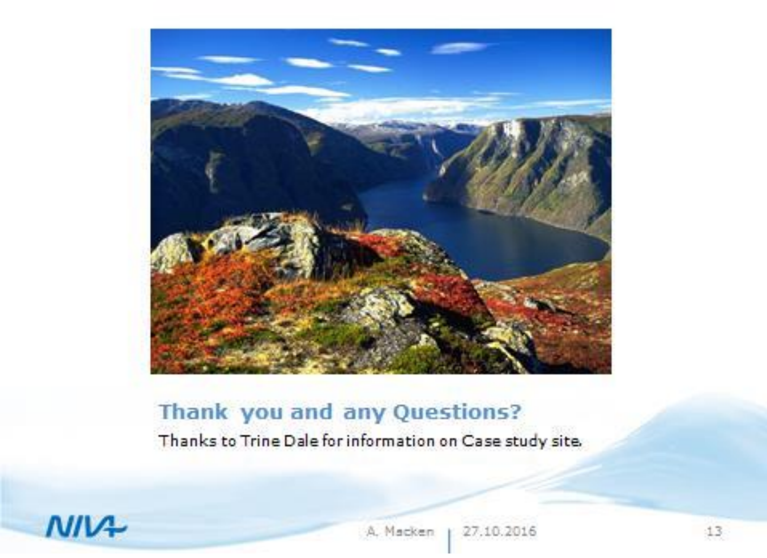
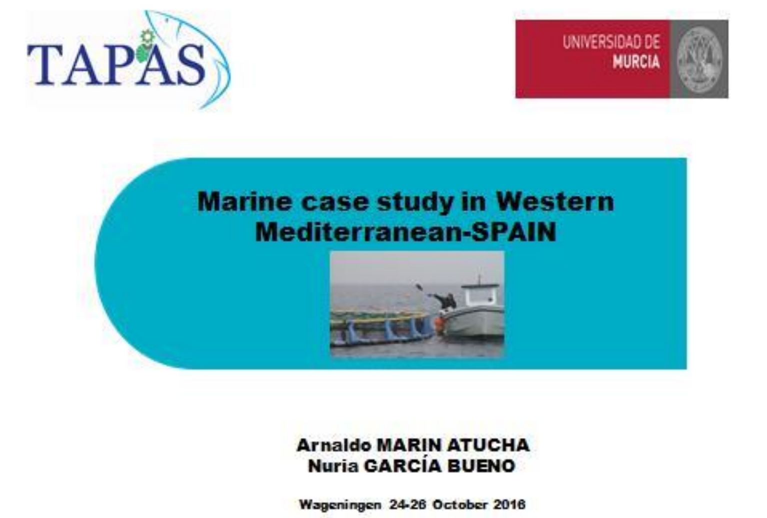


UM (Marine net pens/cages Mediterranean sea - Spain)



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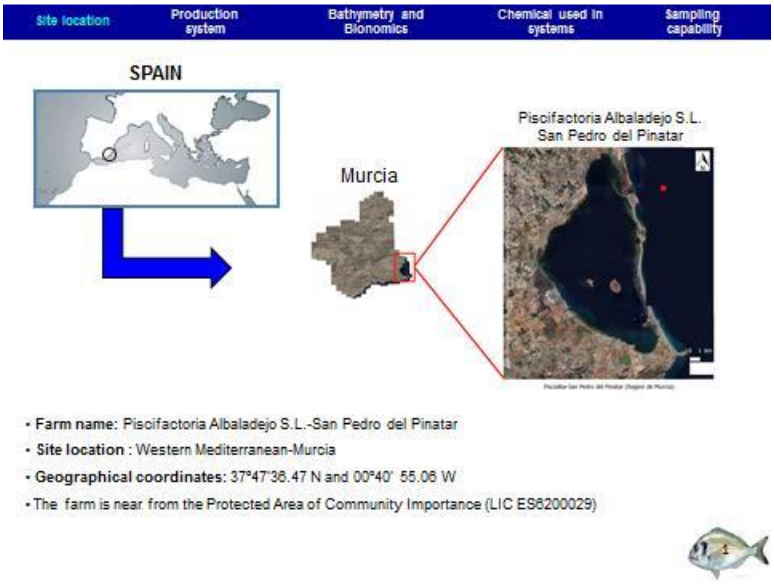

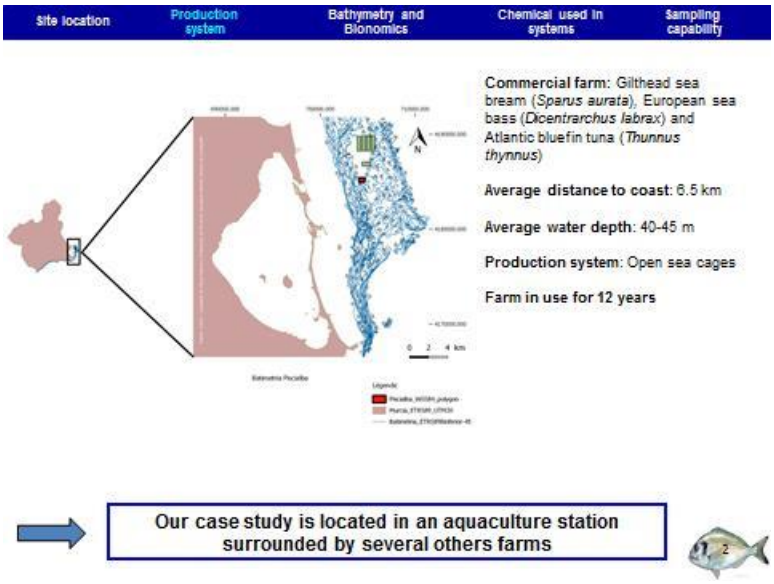

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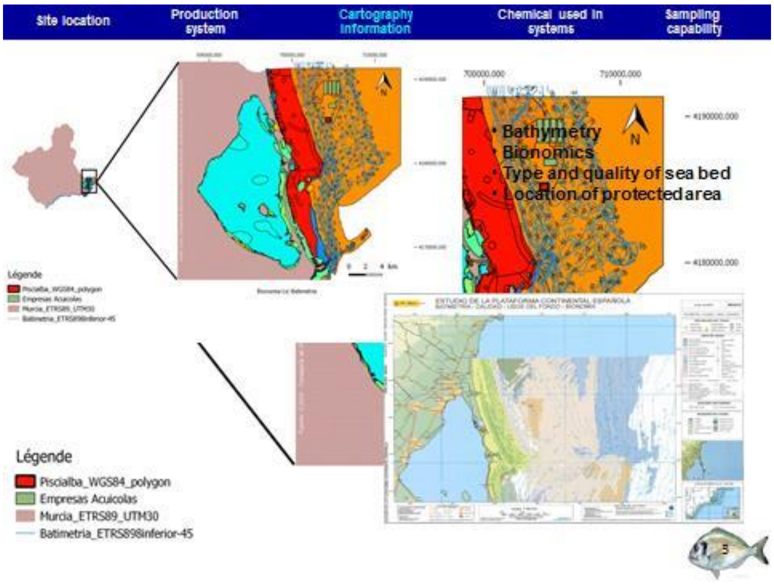

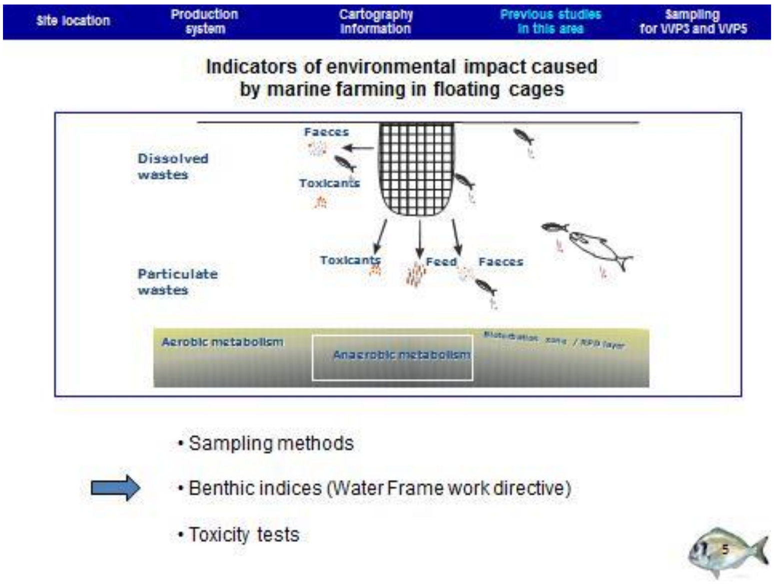

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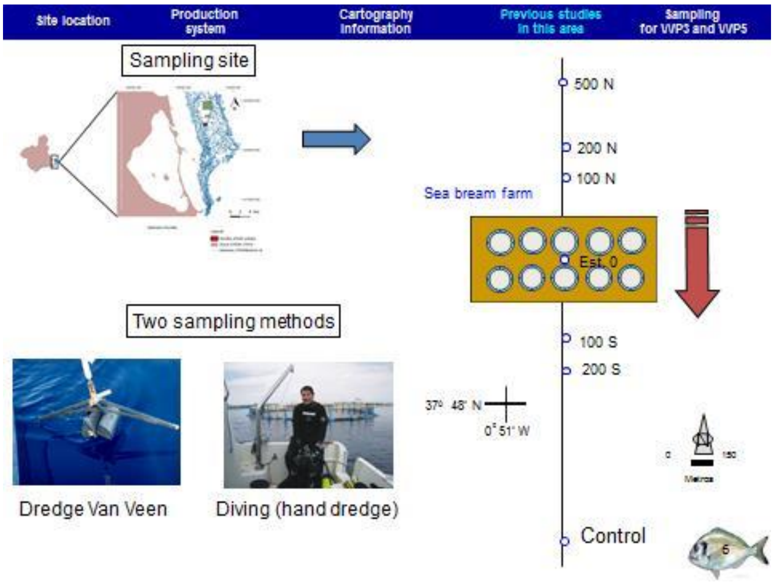

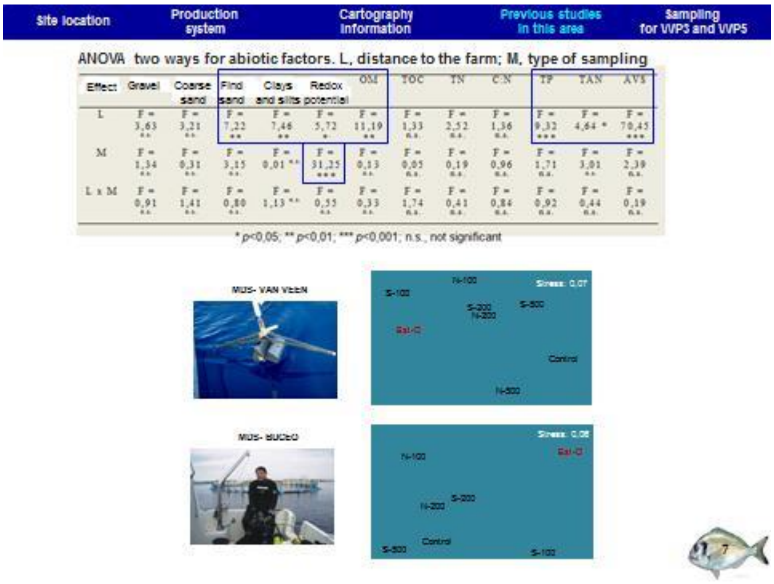

Effect	Gravel	Coarse sand	Find sand	Clays and silts	Redox potential	OM	TOC	TN	C:N	TP	TAN	AVS
L	F = 3,63 n.s.	F = 3,21 n.s.	F = 7,22 **	F = 7,46 **	F = 5,72 *	F = 11,19 **	F = 1,33 n.s.	F = 2,52 n.s.	F = 1,36 n.s.	F = 9,32 ***	F = 4,64 *	F = 70,45 ***
M	F = 1,34 n.s.	F = 0,31 n.s.	F = 3,15 n.s.	F = 0,01 **	F = 31,25 ***	F = 0,13 n.s.	F = 0,05 n.s.	F = 0,19 n.s.	F = 0,96 n.s.	F = 1,71 n.s.	F = 3,01 n.s.	F = 2,39 n.s.
L x M	F = 0,91 n.s.	F = 1,41 n.s.	F = 0,80 n.s.	F = 1,13 **	F = 0,55 n.s.	F = 0,33 n.s.	F = 1,74 n.s.	F = 0,41 n.s.	F = 0,84 n.s.	F = 0,92 n.s.	F = 0,44 n.s.	F = 0,19 n.s.

* p<0,05; ** p<0,01; *** p<0,001; n.s., not significant

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Site location | Production system | Cartography information | Previous studies in this area | Sampling for WP3 and WP5

ANOVA two ways for benthonic index. L, distance to the farm; M, type of sampling

	Species richness	Abundance	Shannon-Wiener H'	ITI	AMBI	BENTIX
L	F = 2,0021 n.s.	F = 1,9641 n.s.	F = 1,1199 n.s.	F = 350,58	F = 3,9485 *	F = 8,5396 **
M	F = 0,8502 n.s.	F = 1,1584 n.s.	F = 0,9606 n.s.	F = 0,1825 n.s.	F = 0,1826 n.s.	F = 0,0641 n.s.
L x M	F = 1,0128 n.s.	F = 0,8247 n.s.	F = 1,4239 n.s.	F = 0,1269 n.s.	F = 1,1934 n.s.	F = 1,0823 n.s.

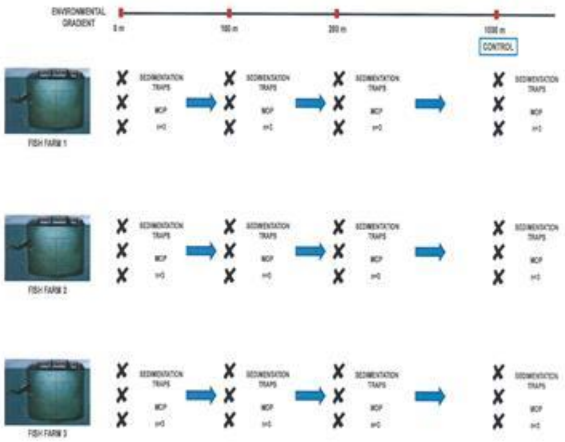
* $p<0,05$; ** $p<0,01$; *** $p<0,001$; n.s., not significant

Analysis of Cost-Effectiveness: flexible costs in Euros

	Employee/day	Time (days)	Equipment	
DIVING (SD)	8 Professional Diving	1	3 complet equipment SD	
Costs	2400		5115	TOTAL 7515
VAN VEEN DREDGE	2 Marine Biologist	1	VV dredge, winch, 50 m rope	
Costs	400		4250	TOTAL 4650

Site location | Production system | Cartography information | Previous studies in this area | Sampling for WP3 and WP5

SAMPLING PROTOCOL IN MEDITERRANEAN SEA FOR WP3 AND WP5



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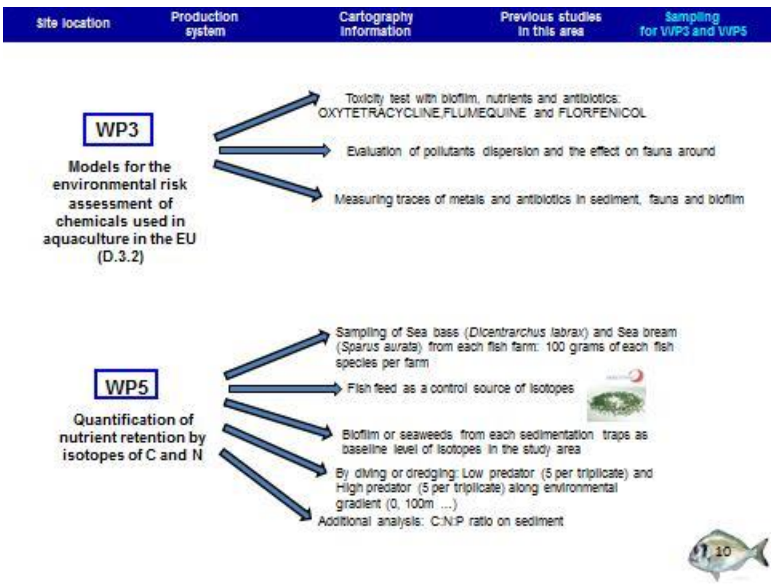

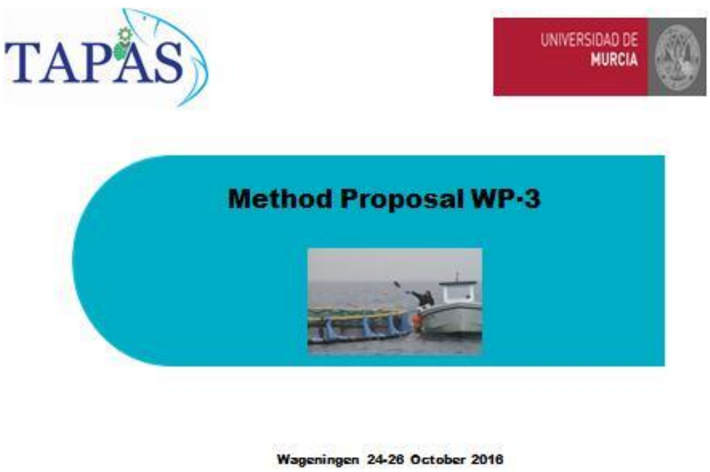

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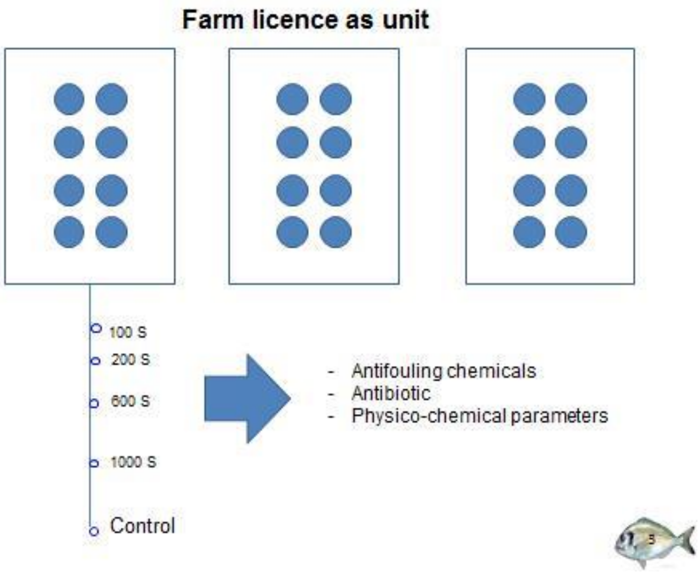

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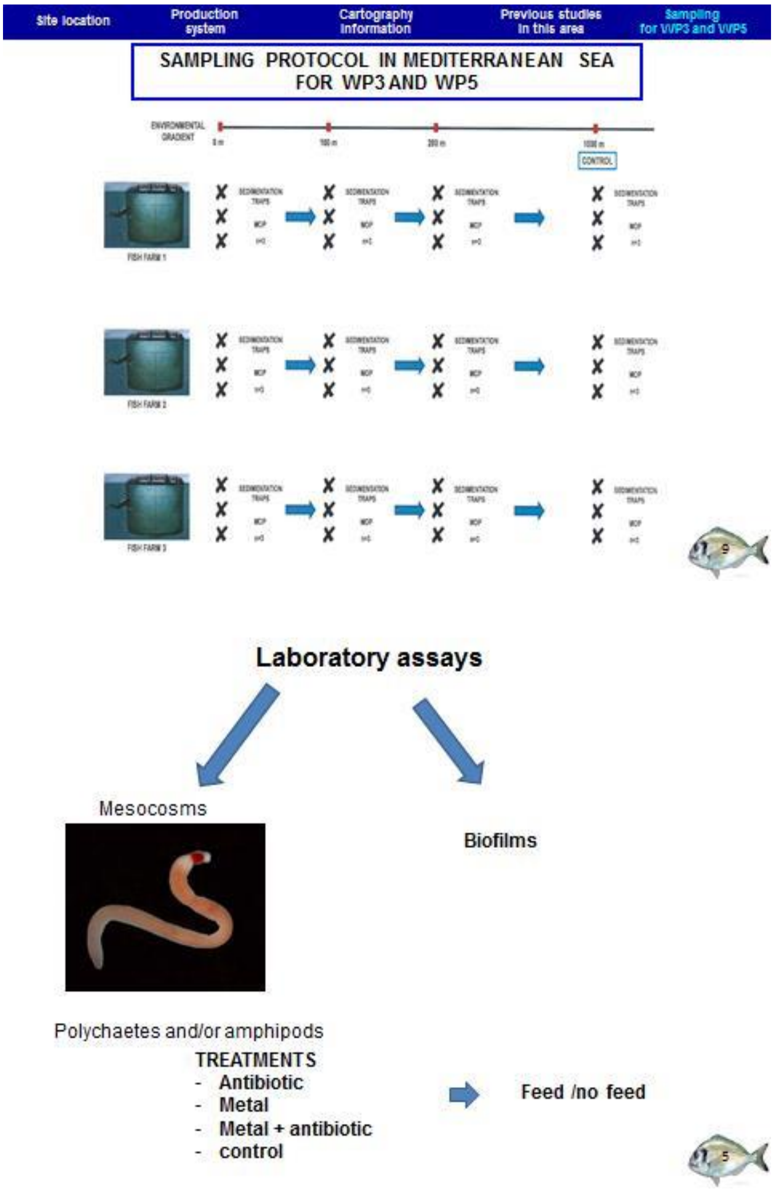

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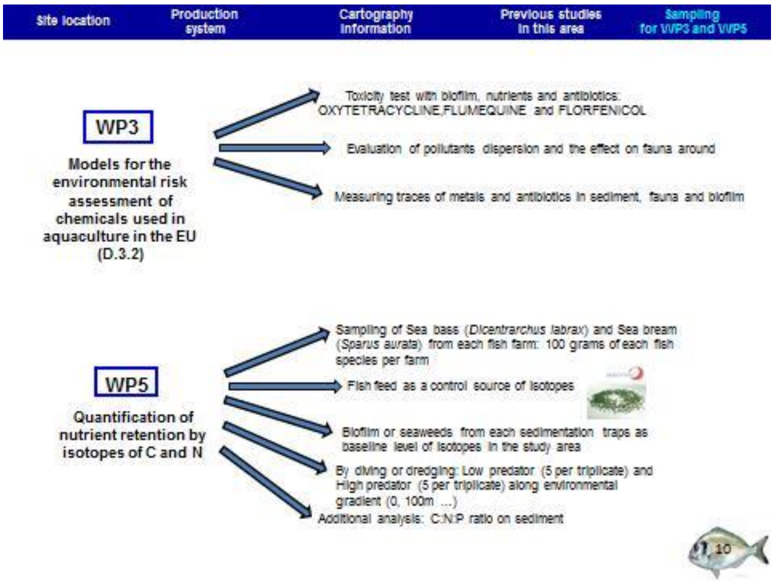

ABT (Marine net pens/cages Mediterranean sea - Malta)

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Malta

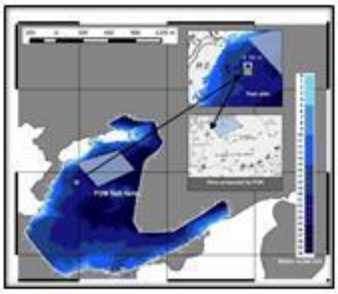
Malta is located in the central-south Mediterranean. Due to its location, it is considered an important site for monitoring the fauna and flora between the western and eastern Mediterranean Sea (Knittweis *et al.*, 2015).

The main currents surrounding the Maltese islands are the surface Modified Atlantic Water (MAW) flowing towards the East, passing on the east side of the archipelago and the deeper more saline Levantine Intermediate Water (LIW) flowing towards West by the southwest side (Dargo *et al.*, 2010).

TAPAS

ABT - Research Site

- The test site is located in the north eastern part of Malta, at Saint Paul's bay, close to St. Paul's island.
- This location provides shelter from predominant wind coming from northwest – Mistral (Dimech et al., 2002)
- **This test site is located in a protected area. (Natura 2000).** --> *Posidonia oceanica*



TAPAS

ABT - Research Site

According to Axiak (2004) the characteristics of the water body near the test site, at the surface, varies from summer to winter:

- In the summer (June 2003): temperature ranges from 25.8 - 25.9 °C, salinity around 38.1 ‰, chl a 0 - 0.261 µg/l, dissolved O2 90.9 - 93.2%, nitrates & phosphates were not detected.
- In the winter (March 2003): temperature 15.1°C, salinity 36.3 ‰, chl a 0.479 - 0.787 µg/l, dissolved O2 94.9 - 96.7%, nitrates ranging 0.25-1.20 µg/l & phosphates from 0 – 0.013 µg/l.

TAPAS

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AquaBioTech TAPAS possible case study

- The main case study in Malta will be carried out on the AquaBioTech field research site in Saint Paul's bay next to a commercial fish farm (WP7 → IMTA system)

- Other minor research activities according to the needs of WP3, WP5 and WP4 or WP7 can be planned by using the existing, available resources like:
  - Main case study sites in Saint Paul's bay;
  - Other commercial and research sites in Malta listed in D3.2;
  - AquaBioTech research recirculation aquaculture systems (RAS);
  - AquaBioTech existing laboratory capacities (Evaluation of the field efficacy tests of antifouling paints and net treatments, Eco-toxicological tests of new antifouling compounds, Monitor the water quality parameters of the RAS units)

TAPAS

HCMR (Marine net pens/cages Mediterranean sea - Greece)

TAPAS

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Task 3.2: Workshop on the development of an improved modelling approach for the ERA of potentially toxic substances

Overview of Case Study in Eastern Mediterranean (Greece)

Dr. Manolis Tsapakis
Hellenic Centre for Marine Research

24-26, October 2016, Wageningen Campus

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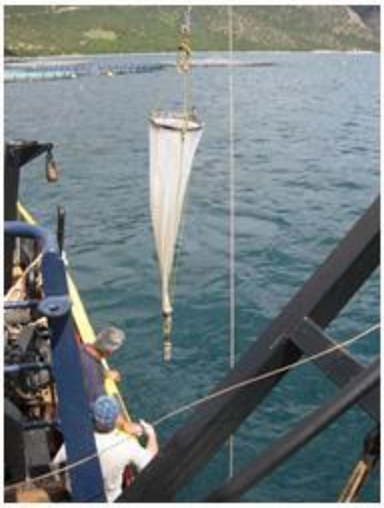

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Water quality data

Water quality data for assessment and monitoring of environmental status of the area are existing from 2012. Data are collected during the seasonal cruises for the Greek national project "Implementation of the water framework directive 2000/60/EU

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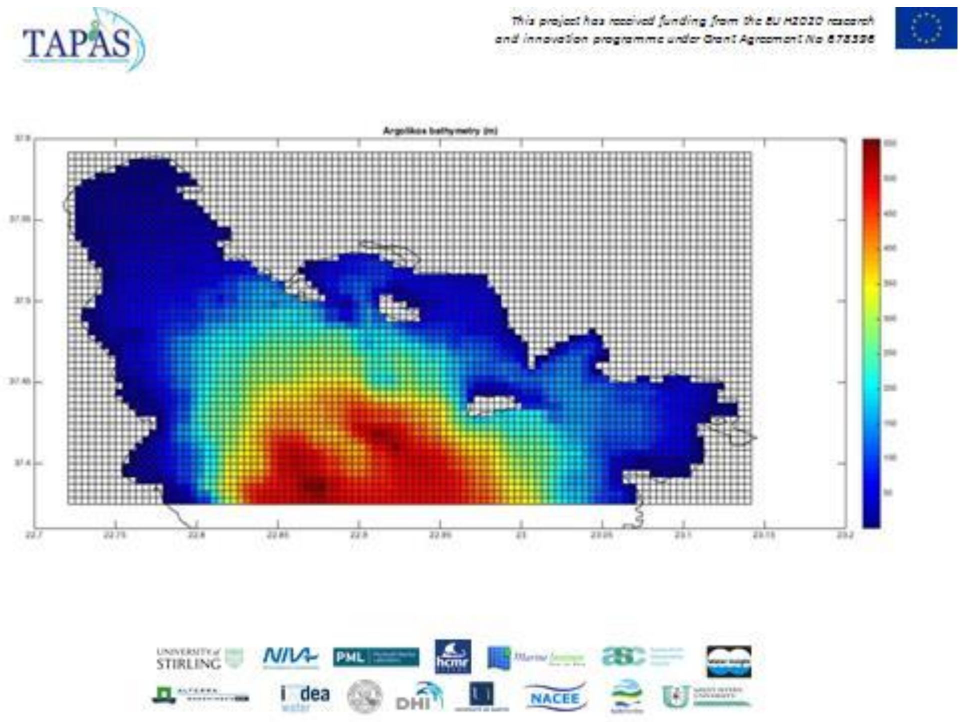

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HCMR Facilities

HCMR is the national research center of Greece for all aspects of marine research, physical oceanography, marine geology, wave prediction, coastal geomorphology, fisheries, aquaculture, marine biology, marine genetics and inland waters. HCMR operates the system Poseidon that provides real time forecasts for winds and waves in the Greek seas, through a network of deep ocean buoys. HCMR operates three oceanographic ships, one manned submarine and three remote operated vehicles.

Institute of Oceanography are comprised by the departments of Physical Oceanography, Chemical Oceanography, Biological Oceanography & Marine Geology and Geophysics complemented by three inter-sectoral and interdisciplinary sections Open Seas, Coastal Environment & Operational Oceanography Laboratories The Biogeochemical Laboratory covers all scientific sectors by means of nine Laboratory Analytical Units: Sedimentology, Inorganic and Organic Chemistry, Plankton, Benthos, Toxicology, Sediment Traps, Geotechnology, Electron Microscopy Databank Dept.: (GIS and databases) and the Department of Technological Support and Development Equipment State-of-the-art laboratory equipment includes automated nutrient analytical apparatus, dissolved carbon dioxide and total organic carbon, atomic absorption spectrophotometers equipped with graphite oven and generator of hydrides, spectrophotometers, «clean room», gaseous and humid chromatographs, mass spectrograph, CHN analyzer, fluorescence, X-ray diffraction analysis and fluorescence analysis, Pb 210 analysis, Sedigraph, coulter counter, Microtox, multi-channel system analysis and radiograph of cores, Scanning Electronic Microscope and many other laboratory apparatuses. Field equipment: side-scan sonar, boomer, multi plankton net etc., samplers for water, sediments and marine organisms

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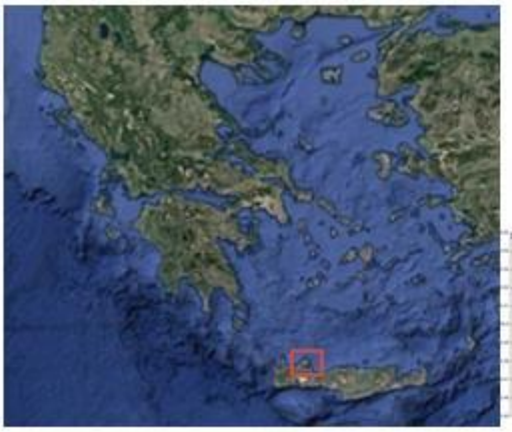
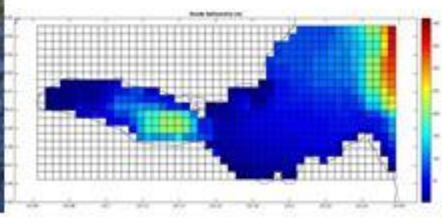
HCMR Research fish farm





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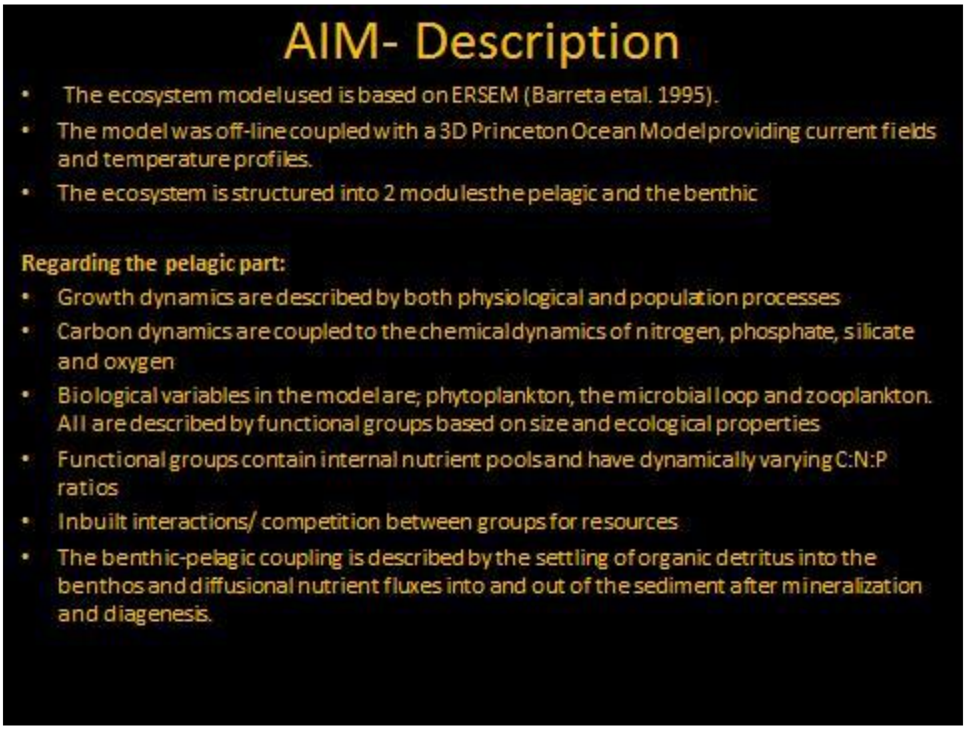

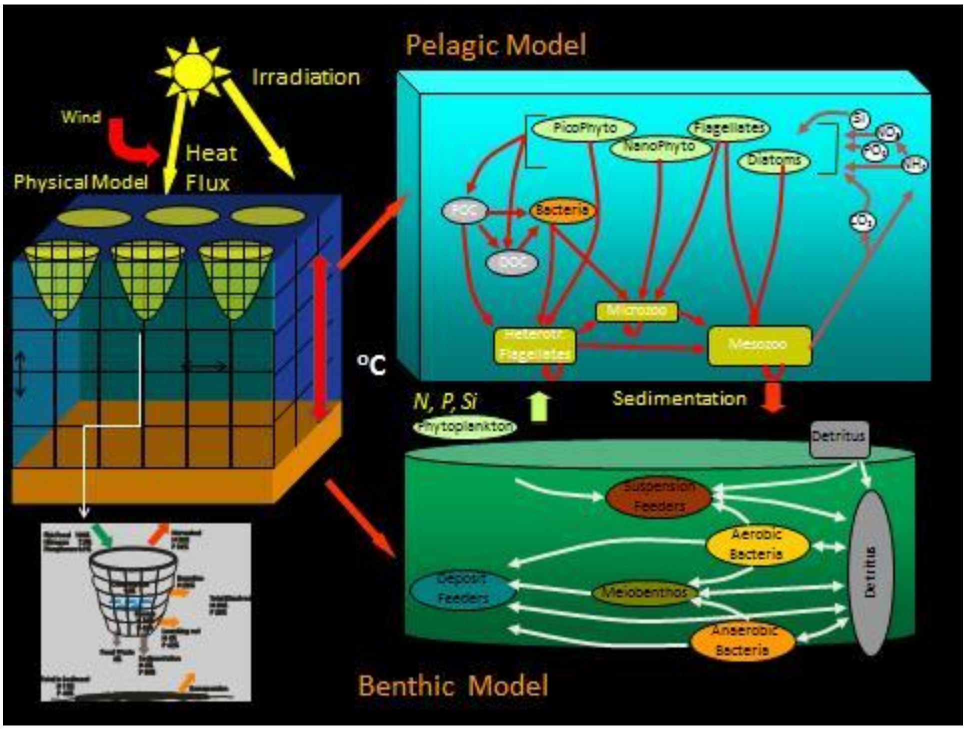

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Annex 6. Power point presentation of ASC

ASC and data sources

TAPAS WP3

24th October 2016

Wageningen

What is the mission of the ASC?

The mission of ASC is to transform global aquaculture in such a manner that it is able to increasingly meet the need for **responsibly produced** fish.

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ASC Strategy

To use ***market forces* to *transform* aquaculture** through reducing the key negative **social and environmental** impacts of aquaculture through compliance with standards

There are three key processes involved in this strategy:

1. **Create a Standards** holding entity (the ASC) and consumer label.
2. Develop and implement an **outreach and marketing** programme that creates demand for ASC products in the marketplace.
3. Institute a certification process that uses **independent third-party** entities to certify farms.

It is in achieving this final element that forms the main objective of this training course which, in turn, underpins the strategy.

ASC Aims

The ASC aims to transform aquaculture practices globally through:

Credibility: Standards developed according to ISEAL guidelines, multi-stakeholder, **open and transparent, science-based** performance metrics.

Effectiveness: Minimising the **environmental and social footprint** of commercial aquaculture by addressing key impacts.

Added value: Connecting the farm to the marketplace by **promoting responsible practices** through a consumer label.

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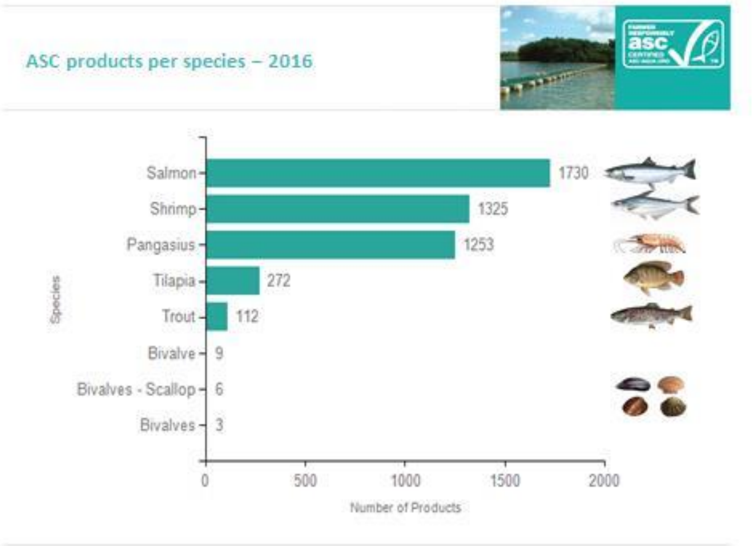

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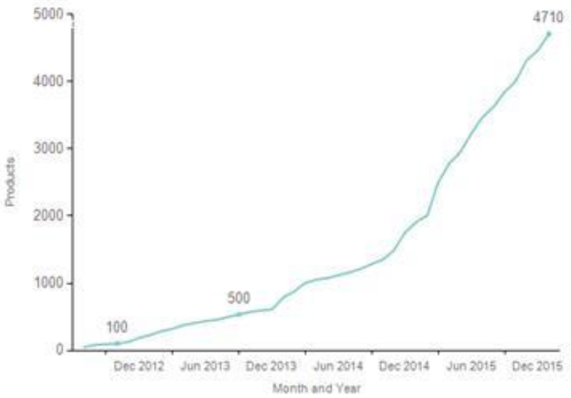
Farms in programme – 5 February 2016

ASC Farm standard	Farms certified	Certified volume (t)	Farms in assessment	# of auditing companies*
Abalone	2	500	0	1 (-)
Bivalves	8	6.675	7	2 (2)
Pangasius	33	144.555	4	1 (2,*)
Salmon	97	341.161	57	4 (*)
Farmed shrimp	42	41.092	17	1 (1,*)
Tilapia	28	147.919	12	3 (1)
Freshwater trout	16	6.735	6	- (1,*)
Total	226	688.637	103	

* Number of certifiers accredited (in process for accreditation, * = 1 suspended).

ASC products over time – 5 February 2016



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Main streams of metric data

Transparency – reporting to ASC

Environmental data

- Water quality – measures of N, P and O2
- Sediment (Chemical)– redox, sulphide
- Sediment (biotic) – Shannon Weiner or indicator spp

Health

- Mortalities
- Therapeutant and antibiotic use

Feed

- Feed efficiencies

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ASC Salmon Standard reporting table

37 metrics in total

Item	Option	Relevant Requirement	Measurement	Units	Measurement Frequency	Calculations and Sampling Methodologies, Additional Notes
1			Species in production	species		
2	a	2.1.1	Redox potential	mV	production cycle	Appendix I-1
	b		Sulfide levels	microMoles/l	production cycle	Appendix I-1
3	a	2.1.2	AZTI Marine Biotic Index (AMBI)	AMBI score	production cycle	Appendix I-1
	b		Shannon-Wiener Index	S-WI score	production cycle	Appendix I-1
	c		Benthic Quality Index (BQI)	BQI score	production cycle	Appendix I-1
	d		Infaunal Trophic Index (ITI)	ITI score	production cycle	Appendix I-1
4		2.1.3	# of microfaunal taxa	#	production cycle	Appendix I-1
5		2.2.1	Average % DO saturation	%	weekly	Appendix I-4
6		2.2.2	Max % samples under 1.85 mg/l DO	%	weekly	Appendix I-4
7		2.2.4	Nitrogen monitoring		weekly	Appendix I-5
8		2.2.4	Phosphorous monitoring		weekly	Appendix I-5
9		2.2.5	Calculated BOD		production cycle	Footnote in 2.2.5

Chemical and faunal indictors of sediment and water

Parameter		Units	Frequency
Sediment indicators			
	Redox potential	mV	Per Production cycle
	Sulphide	µMoles/l	Per Production cycle
	Shannon Wiener Index	score	Per Production cycle
	Total macrofaunal taxa	#pollution indicators	Per Production cycle
	Cu if used in net treatment	µg/g	Per Production cycle
Water quality indicators			
	Average DO sat^n	%	weekly
	Temp and salinity	°C/ppt	weekly
	*** Monitoring TN, NH_4, NO_3**	µg/ltr	weekly
	*** Monitoring TP, Ortho P**	µg/ltr	weekly
	Mass balance BOD	Kg O_2	Production cycle

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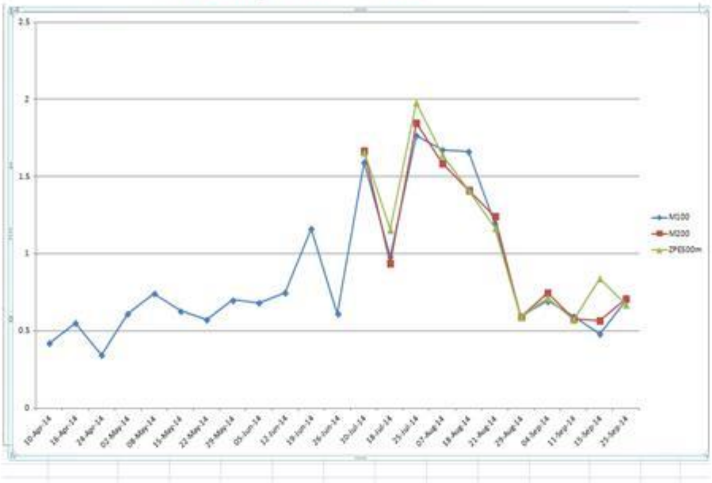
Concentrations of NO3 – N mg/ltr
in Chile production unit.



Sea lice and parasiticide treatment

Parameter	Units	Frequency
Sea lice		
Max lice load for ABM*	number	annual
On farm lice levels	number	weekly
Parasiticide use		
Treatment frequency	Number	Production cycle
Agents/treatment	Names	Production cycle

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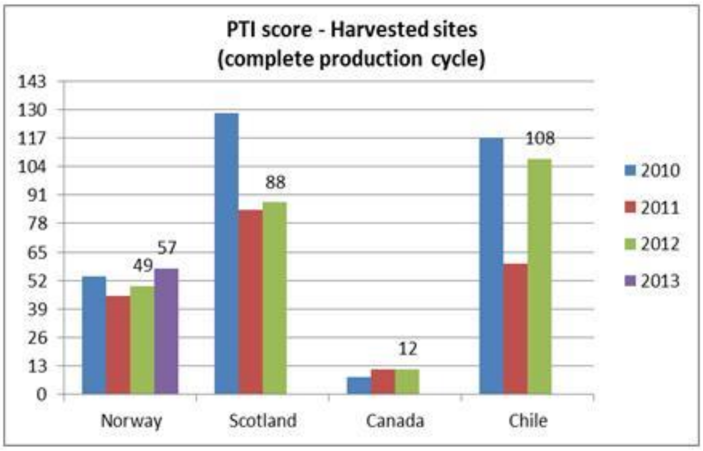
Annual and regional variation in PTI



Fish feeding efficiencies

	Parameter	*Units*	*Frequency*
Indicators			
	Total feed	mt	Production cycle
	FCR	ratio	Production cycle
	FFDR*/FIFO fishmeal	ratio	Production cycle
	FFDR/FIFO fish oil	ratio	Production cycle
	Fishmeal sources	names	Production cycle

* Forage Fish Dependency Ratio – excludes trimmings

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Annex 7. ASC Reported Data Series (provided by ASC)

Scope of ASC reported data

As part of its commitment to transparency ASC requires a number of data to be reported regularly during the productions cycles under certification. There are now at least 200 salmon farms under the process in all the salmon producing regions, principally:

- Norway
- Faeroes
- Scotland
- Ireland
- Western Canada
- Chile

All are required to submit data which therefore provides a comparative global data set.
The data lines collected are summarised below segregated into related groups:

- Chemical and faunal indicators of sediment
- Chemical indicators of water quality
- Sea lice and parasiticide treatment
- Fish health
- Fish feeding efficiencies

There is also the production information, eg. duration of cycle, harvest value (mt)
The protocols for sampling are also provided. In addition, there have been ad hoc data collections particularly in the areas of parasiticide treatments and N/P water monitoring.
These data series need compiling, checking and articulating.

1. Chemical and faunal indictors of sediment and water

Parameter	Units	Frequency
Sediment indicators		
Redox potential	mV	Per Production cycle
Sulphide	µMoles/l	Per Production cycle
Shannon Wiener Index	score	Per Production cycle
Total macrofaunal taxa	#pollution indicators	Per Production cycle
Cu if used in treatment	µg/g	Per Production cycle
Water quality indicators		
Average DO sat^n	%	weekly
Temp and salinity	^{0}C/ppt	weekly
* Monitoring TN, NH_4, NO_3	µg/ltr	weekly
* Monitoring TP, Ortho P	µg/ltr	weekly
Mass balance BOD	Kg O_2	Production cycle

* *Largely only available for farms in Chile*

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Protocols

Sampling Framework – the AZE

To create the sampling framework for all the above the farm must calculate or model the Allowable Zone of Effect (AZE) around the pen array within which some chemical impact may be detectable. This is approximately 25m around the edge of the array but my be modelled more realistically with AUTODEPOMOD or similar.

Duplicates of 9 samples (=18) are taken at specified position in and around the AZE with one being a reference sample from similar sediments beyond the influence of the farm. There should be no significant difference between the samples at the edge of the AZE and the reference site.

The measurements are taken from core or grab samples below and around the AZE.

This framework applies to all sediment monitoring

Protocol for sampling dissolved oxygen

DO, salinity and temperature shall be measured twice daily (proposed at 6 am and 3 pm, but with recognition that this will vary depending on region and operational practices). Percent saturation shall be calculated for each sample from the data and a weekly average percent saturation shall result. A minimal amount of missed samples due to extreme weather conditions will be considered acceptable.

DO shall be measured at a depth of five meters at a location where the conditions of the water will be similar to those the fish experience. Measurements shall be taken at the same location, recorded with GPS, at the same time to allow for comparison between days. Weekly averages shall be calculated and remain at or above 70 percent saturation. Should a farm not meet the minimum 70 percent weekly average saturation requirement, the farm must demonstrate the consistency of percent saturation with a reference site. The reference site shall be at least 500 meters from the edge of the net pen array, in a location that is understood to follow similar patterns in upwelling to the farm site and is not influenced by nutrient inputs from anthropogenic causes including aquaculture, agricultural runoff or nutrient releases from coastal communities.

Protocol for sampling water nitrogen and phosphorous

Farms are required to monitor nitrogen and phosphorous levels on the farm and at reference sites. Farms shall monitor total N, NH4, NO3, total P and Ortho-P in the water column. Monitoring of nitrogen and phosphorous shall follow the following methodology or an equivalent:

- The N and P (dissolved) sampling shall be conducted at a depth equivalent to mid-cage depth within and near the centre of the net pen array, at the same depth (5 meters) from the outside edge of the net pen array along the predominant current direction, at the same depth (50 meters) from the outside edge of the net pen array along the predominant current direction and at a similar depth at a nearby reference site shown to be beyond the influence of the farm (minimum separation distance of 500 meters from the net pen array).
- Samples should be taken using a VanDorn or Kemmerer type water sampler. 500 ml samples should be placed in clear plastic bottles, placed on ice and in a cooler, and analyzed within 48 hours. Ideally, analyses shall be done by a private (third-party) laboratory following standard methods.

Method for mass balance calculation of BOD

BOD calculated as: ((total N in feed – total N in fish)*4.57) + ((total C in feed – total C in fish)*2.67). Multipliers are empirical values of the oxygen equivalents for the preak down of N and C containing products. A farm may deduct N or C that is captured, filtered or absorbed through approaches such

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as IMTA or through direct collection of nutrient wasted. In this equation, “fish” refers to harvested fish. Reference for calculation methodology: Boyd C. 2009. Estimating mechanical aeration requirement in shrimp ponds from the oxygen demand of feed. In: Proceedings of the World Aquaculture Society Meeting; Sept 25-29, 2009; VeraCruz, Mexico. And: Global Aquaculture Performance Index BOD calculation methodology available at http://web.uvic.ca/~gapi/explore-gapi/bod.html

2. Sea lice and parasiticide treatment

Parameter	*Units*	*Frequency*
Sea lice		
Max lice load for ABM*	number	annual
On farm lice levels	number	weekly
Parasiticide use		
Treatment frequency	Number	Production cycle
Agents/treatment	Names	Production cycle

* ABM – Area Based Management scheme

Protocol for Setting and revising ABM lice loads and on-farm lice levels

The ABM scheme must set a maximum lice load. A core purpose of this requirement is to be able to see the potential cumulative infection pressure from on-farm lice, expressed as the number of mature female lice on all farms in the scheme. This “total load” figure is a better reflection of the potential risks to wild populations than on-farm lice levels, measured as lice per farmed fish.
An ABM scheme shall initially set this total load figure based on the regulatory obligations of the jurisdiction in which it operates and the results of any wild monitoring done to date. In practice, this would mean that farms in most ABM schemes would take the on-farm lice levels they are required to achieve by regulators, and multiply them times the number of farmed fish in the area. This would be a starting place.
Any adjustments to the area’s lice load would lead to corresponding limits on lice levels on individual farms. This feedback loop must be transparent and document how the ABM scheme is being protective of wild fish through the interpretation of wild monitoring data.
There is also a requirement for farms seeking certification to maintain on-farm lice levels at 0.1 mature female lice (leps) during and immediately prior to sensitive periods, particularly outmigration of wild juvenile salmon. If data from wild monitoring or national regulations consistently demonstrates healthy wild populations would allow a farm to make the case for a level higher than 0.1this can be taken into account.

3. Fish health

Parameter	*Units*	*Frequency*
Mortalities		
Total mortalities	%	Ongoing
Cause of mortalities	diagnoses	Ongoing
Max unexplained	%	Production cycle
Therapeutants		

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	Total amount of each used	Kg	Production cycle
	Antibiotic load*	Kg/mt fish	Production cycle
	Antibiotic agents	names	Production cycle

* Antibiotic load = the sum of the total amount of active ingredient of antibiotics used (kg) per mt harvested salmon.

4 Fish feeding efficiencies

	Parameter	*Units*	*Frequency*
Indicators			
	Total feed	mt	Production cycle
	FCR	ratio	Production cycle
	FFDR*/FIFO fishmeal	ratio	Production cycle
	FFDR/FIFO fish oil	ratio	Production cycle
	Fishmeal sources	names	Production cycle

* Forage Fish Dependency Ratio – excludes trimmings

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