SD4

Improved understanding of the potential population, community and ecosystem impacts for all life stages for commercially important species and their capacity to resist and adapt

Kevin J Flynn et al.

Swansea University
Prifysgol Abertawe

University of Exeter

University of Strathclyde
Glasgow

PML
Plymouth Marine Laboratory

The Team

Swansea University
Prifysgol Abertawe

SWANSEA

- **Kevin J Flynn** (PI) – plankton physiology & modelling
- **Robin Shields** (Director of CSAR) - aquaculture
- **Purazen Chingombe** – water chemistry
- Ingrid Lupatsch – nutritional bioenergetics & modelling
- **Alex Keay** – CSAR manager
- ***1 Technician*** ***appointment in progress***
- ***1 PDRA*** ***adverts being placed***
- ***1 tied student (standard NERC quota, CASE with PML working on crustacea & zooplankton)*** **start Jan'11**

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- **Rod Wilson** – fish physiology
- **Ceri Lewis** (NERC Fellow) – invertebrate physiology
- ***1 PDRA***
- ***1 student (standard NERC quota – bivalves & fish)*** ***started***

STRATHCLYDE

- **Dougie Speirs** – modelling
- ***1 PDRA***

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- **Claudia Halsband-Lenk** – zooplankton physiology
- **Gorka Merino** – commercial fisheries bioeconomic modeller
- **Caroline Hattam** – non-commercial marine socio-economics
- Nicola Beaumont – non-commercial marine environmental economics
- Melanie Austen – integration of natural and social sciences
- ***Plus input from ecosystem modellers and other expertise from PML as necessary***

(short-form) aims of SD4 are -

- Aim 4.1 Examine physiological and behavioural responses to OA
- Aim 4.2 Scale up laboratory studies to population/stock responses to OA including an analysis of possible socio-economic consequences.
- Aim 4.3 Examine how changes in planktonic and benthic food-webs, as a result of ocean acidification impact upon the production and yields of commercial fish and shellfish stocks.
- Aim 4.4 Investigate possible socio-economic consequences of OA at an ecosystem level.

The essence of the subject area for SD4 is the impact of OA upon higher trophic levels

esp. commercial species

Project activities –

i) Experimental work (Swansea, Exeter, PML) covering Aim 4.1, to provide data in support of modelling for Aims 4.2 and 4.3. £400k over first 2 years.

ii) Modelling work (Strathclyde, Swansea) covering Aims 4.2 and 4.3. £200k for 2 years from year 2.

iii) Socio-economic studies of commercial species (primarily PML) aimed at primarily Aim 4.2 (overlapping into 4.3 and 4.4). £100k for 2 years from year 2.

iv) Socio-economic studies of generic (non-commercial) ecosystem impacts (primarily PML) aimed at satisfying Aim 4.4. £200k over whole project.

Experimental

Swansea, Exeter, PML

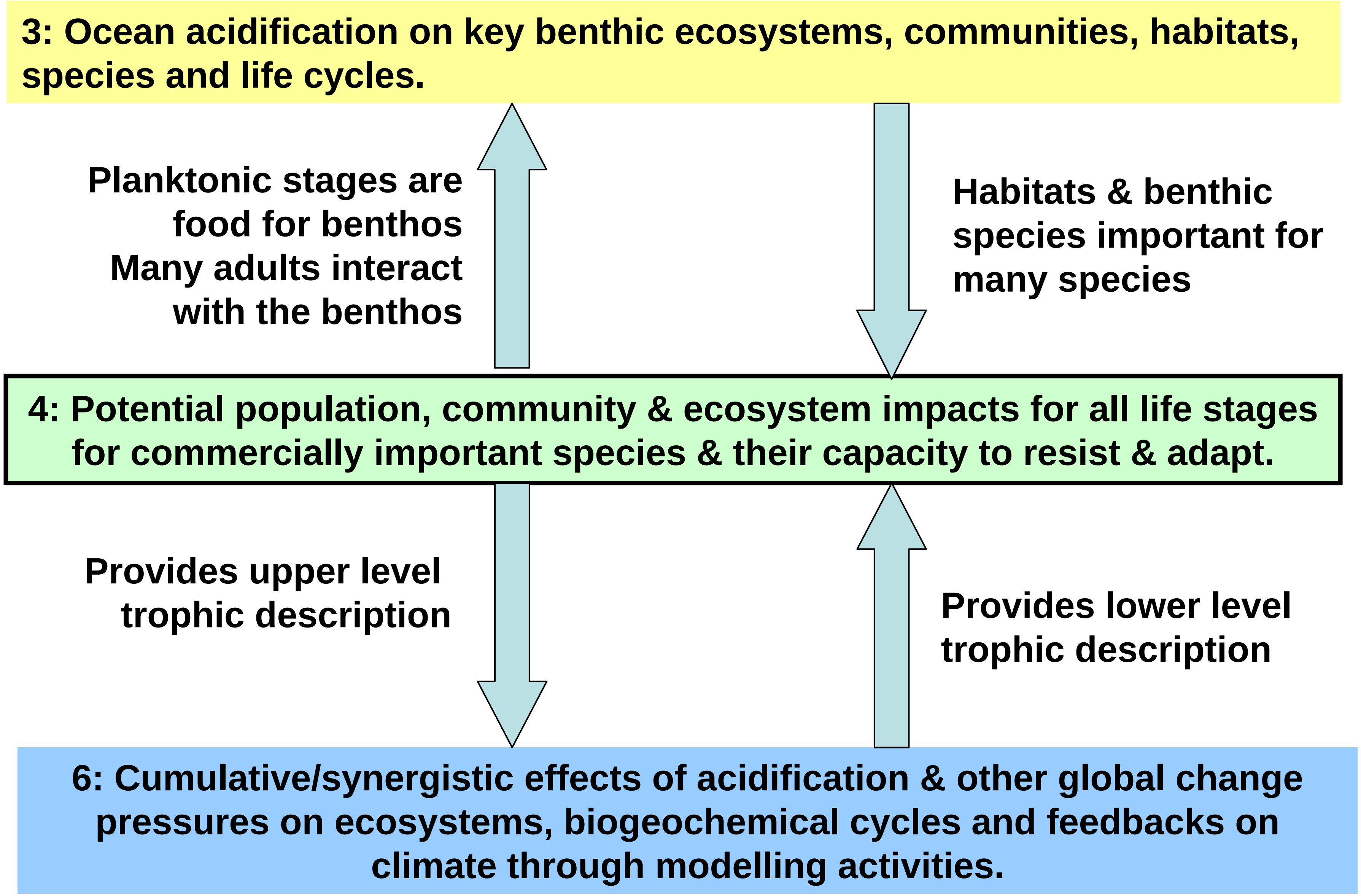
Modelling

Strathclyde & Swansea (+PML)

Socio-economics

PML (+Strathclyde)

Linkages to UKOARP #3 and #6



3: Ocean acidification on key benthic ecosystems, communities, habitats, species and life cycles.

Planktonic stages are food for benthos
Many adults interact with the benthos

Habitats & benthic species important for many species

4: Potential population, community & ecosystem impacts for all life stages for commercially important species & their capacity to resist & adapt.

Provides upper level trophic description

Provides lower level trophic description

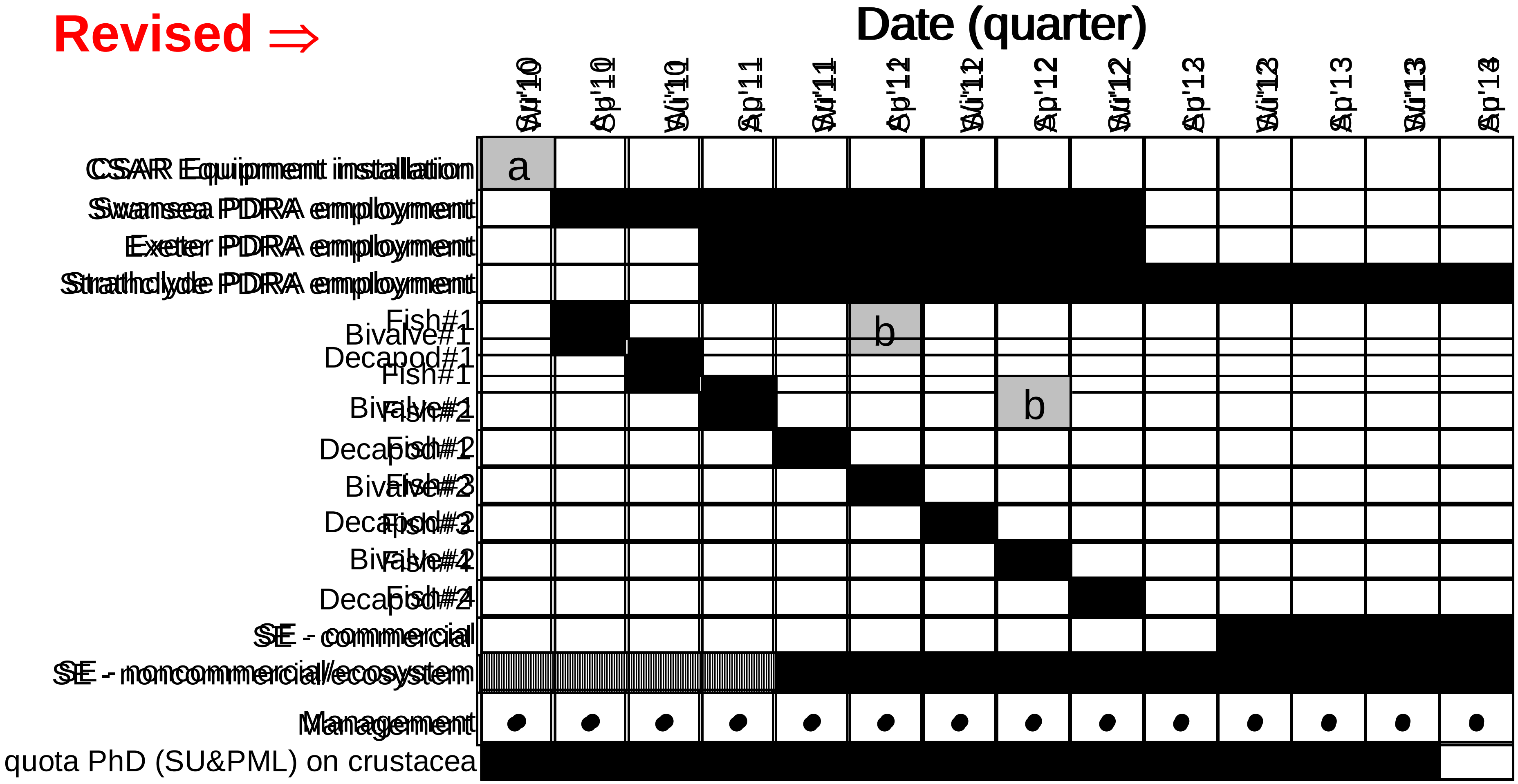
6: Cumulative/synergistic effects of acidification & other global change pressures on ecosystems, biogeochemical cycles and feedbacks on climate through modelling activities.

Additional Linkages

- **BIOACID** **(http://bioacid.ifm-geomar.de/ via AWI [Niehoff, Boersma])** physiological tolerance of zooplankton, food web effects and competitive interactions incl. bacterial communities
- **EPOCA** **(http://www.epoca-project.eu/ via PML)** ecosystem function, experimental links, outreach
- **MEECE** **(www.meece.eu via PML)** ecosystem models to outreach, knowledge transfer, and socio-economics
- **BASIN** **(FP7, inc. PML, Swansea)** N.Atlantic ecosystem model inc ocean acidification
- **MetOffice UK** **(Exeter)** role of fish carbonate release in global C-cycling
- **PhD studentship** **(PML, Swansea)** **Ocean acidification: impacts upon copepod growth and reproduction**

Timetable

Revised ⇒



1. EXPERIMENTAL COMPONENT

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Prifysgol Abertawe

CSAR
Centre for Sustainable Aquaculture Research

State of the art aquaculture facilities and plankton growth rooms for fin and shell fish



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Expertise in developmental processes and their underlying molecular mechanisms; aquatic ecophysiology; systems biology.


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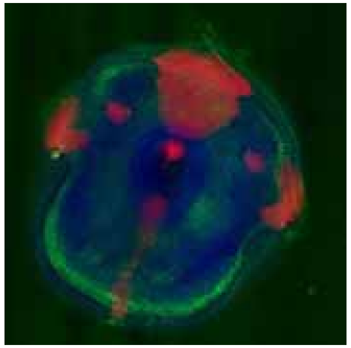
Expertise in planktonic interactions and benthic interactions



Previous and ongoing experimental work

- Impacts of acidification on phytoplankton growth & DOC release **(Flynn, Clark, Blackford)**

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- Impacts of OA on carbonate deposition in teleosts **(Wilson, MetOffice, et al.)**

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Experimental - organisms

- *Pecten maximus* (scallop)
- *Mytilus edulis* (mussel)
- *Nephrops norvegicus* (langoustine, scampi)
- *Clupea harengus* (herring)
- *Melanogrammus aeglefinus* (haddock)
- *Dicentrarchus labrax* (European sea bass)
- **diatom, prymnesiophyte, cryptophyte**
- **copepods**

Fundamental Q is whether changes in DIC chemistry etc. affects physiology / behaviour

- BUT do we know what aspects of physiology/behaviour we should be looking for?
- Best to follow whole life cycle to capture integrated impacts **(against the high natural variability in growth and survival, which has major logistic impacts)** …
- … or at least parts of the life cycle considered to be most sensitive – juvenile stages
- … adults naturally encounter high variable environments ….
- … overlap is at reproduction **(e.g., fertilization)**

Study period

- Data collected for organisms growing over the first 2-4 months of their life, from fertilization, will inform model construction.
- These stages are planktivorous - plankton composition and production are likely to be impacted upon by OA as well as the known impacts of temperature.
- Accordingly, **live feed will be supplied to the juvenile stages, grown under the same OA-conditions of the animals being studied….**
- … and such studies will go on for months, many generations of the feed phyto- and zoo- plankton

Experimental - conditions

- Matrix of 2 OA + 2 temperatures
- OA – equivalent to extant **&** 750ppm CO_2
- Logistics of large-scale culture facilities requires a combination of CO_2 injection with close monitoring of pH and ALK
- Temperature – upper range of extant (90-95% limit for species under study) **&** that value + 4°C

  i.e. not a single fixed temp, but varies with season

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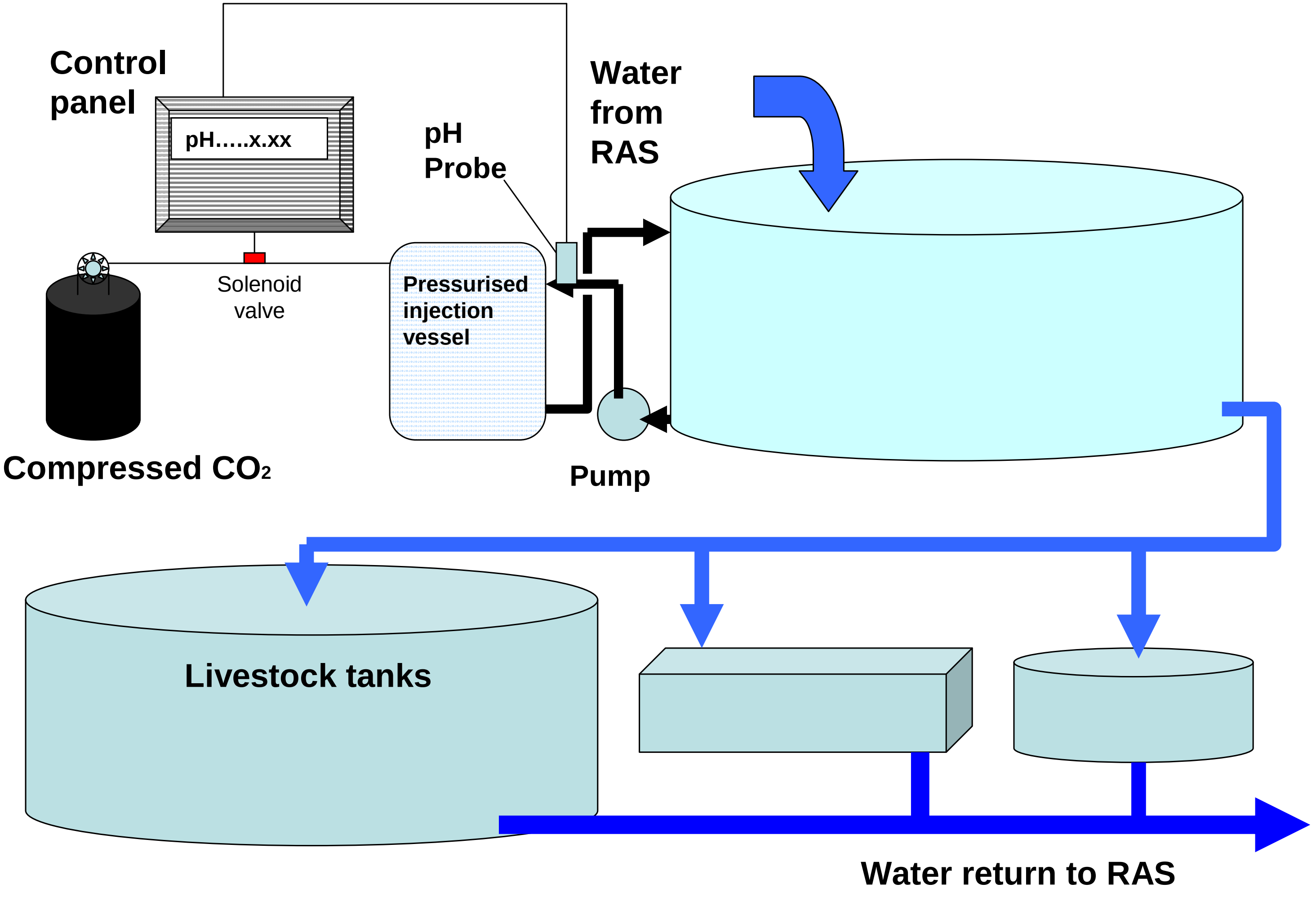
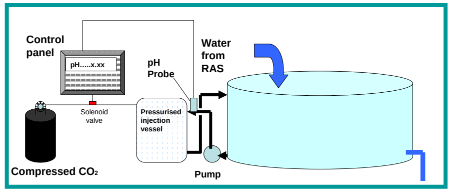
http://www.aquaculturewales.com/



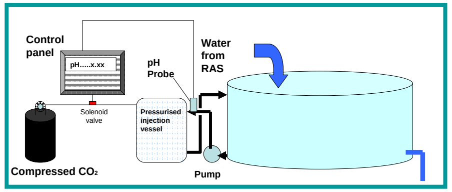
pH / CO_2 control system

X 4 with temperature control

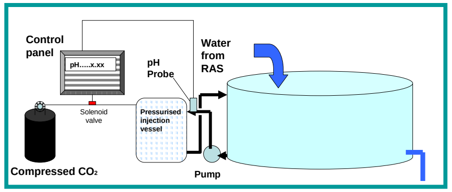
Extant pH / CO_2
Extant T



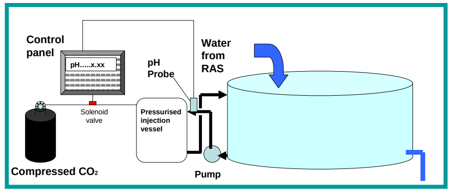
Extant pH / CO_2
Elevated T

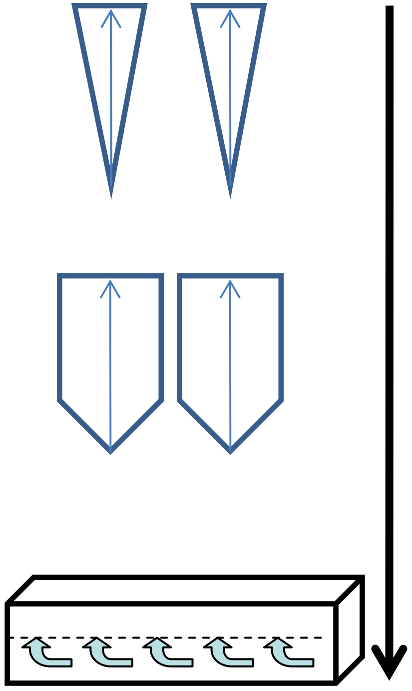


Future pH / CO_2
Extant T



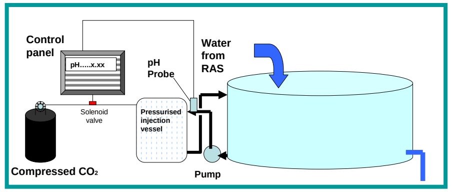
Future pH / CO_2
Elevated T



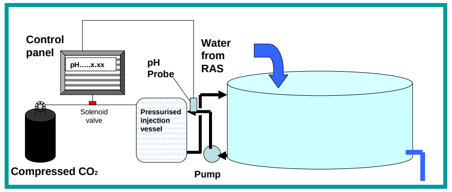


Mussels / Scallops

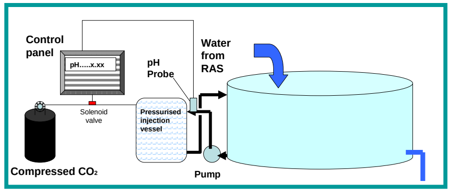
Extant pH / CO_2
Extant T



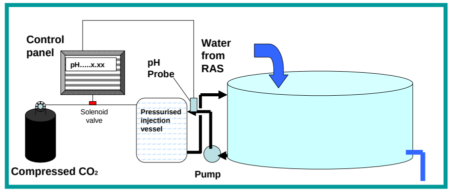
Extant pH / CO_2
Elevated T

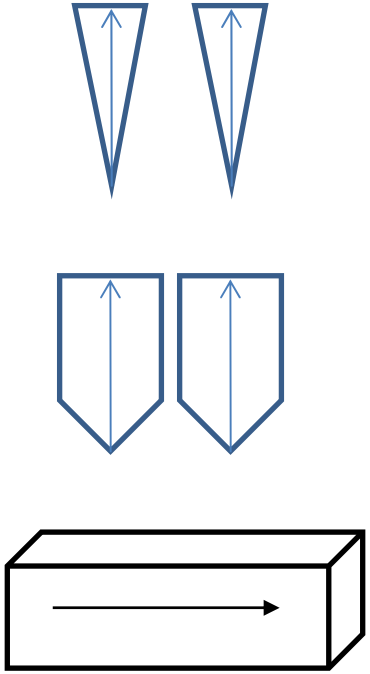


Future pH / CO_2
Extant T



Future pH / CO_2
Elevated T





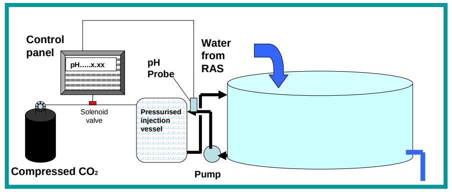
Nephrops or Lobster

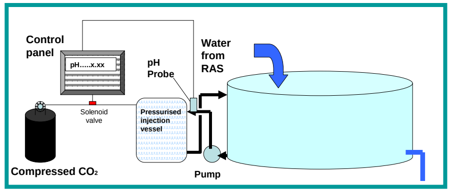
Extant pH / CO_2
Extant T

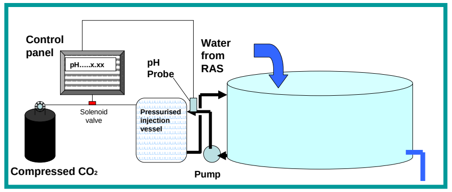
Extant pH / CO_2
Elevated T

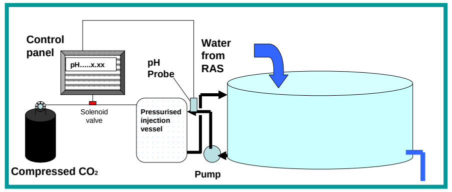
Future pH / CO_2
Extant T

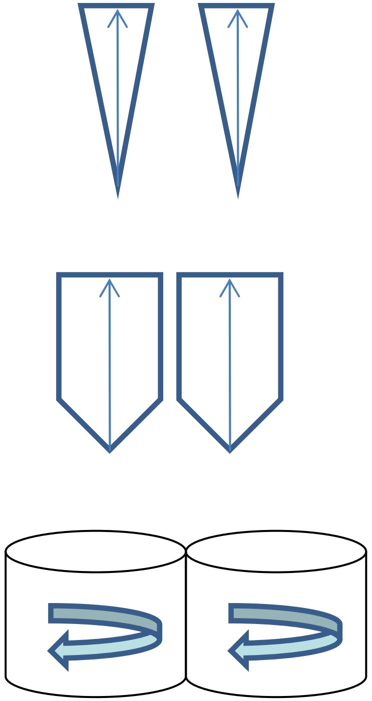
Future pH / CO_2
Elevated T

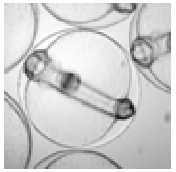












Herring / Haddock / Sea Bass

Primary data for modelling

Swansea University
Prifysgol Abertawe

- Size at age (in terms of carbon and other estimators of biomass, wet & dry weight, length etc.; additional information on energy and fatty acid content)
- Ingestion, net growth and mortality rates at age/weight; (gC/gC/d)
- Assimilation efficiency (AE) with different feeding rates at age/weight, and with different food stoichiometry (C:N:P) if feeding on phytoplankton at age/weight; (%)
- Larval and juvenile metabolic rates at age/weight (gC/gC/d)
- Crustacea cuticle thickness and loss (moult) rate at age/weight (gC/gC) - (impacts on energy/resource allocation, but also disease resistance)
- net and gross growth efficiencies (NGE and GGE) at age/weight (%)

- Gonad size at age/weight (gC/gC) and subsequent egg / sperm production in adults
- Fertilization success (%) and, as possible, the sex ratio

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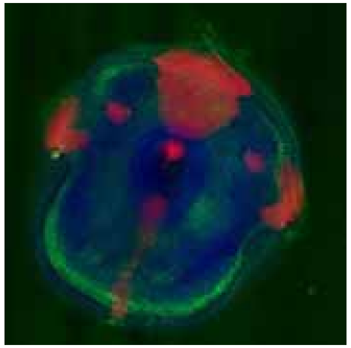
Detailed physiological status

In Fish

- Aerobic scope
- Aerobic to anaerobic muscle metabolism
- Energetics of Acid-Base and Osmotic Regulation
- Reproductive processes
- Carbonate production

In bivalves also …

- OA impacts on fertilization dynamics
- Comparative studies of larval nutrition
- Molecular mechanisms of molluscan larval shell formation
- Comparative proteomics

Zooplankton

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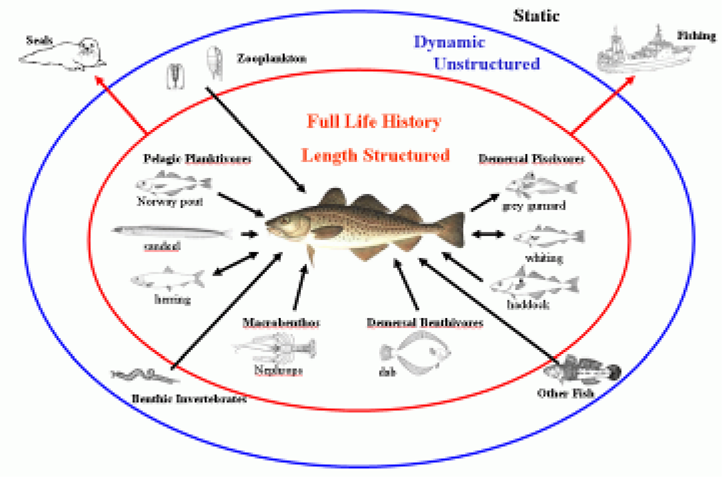
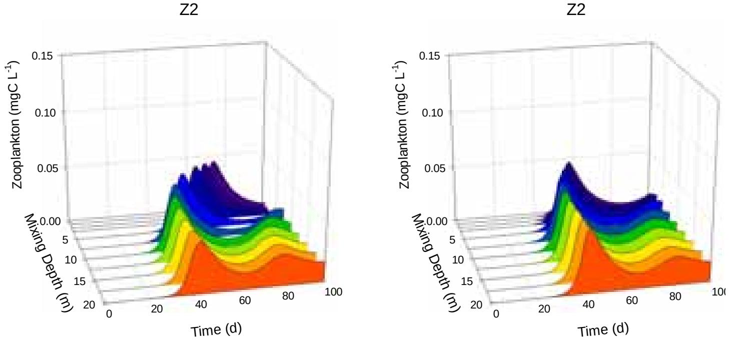
- Copepod survival, growth and development at present day and elevated pCO_2
  - coastal calanoids (e.g. *Acartia* sp., *Temora* sp. or *Centropages* sp.)
  - Seasonal temperature cycle vs. T + 5° degrees C
  - Feeding studies
  - Long-term exposures
- *Acartia* is used as a feed organism in CSAR
- Supported via NERC CASE studentship between Swansea and PML

Swansea University
Prifysgol Abertawe

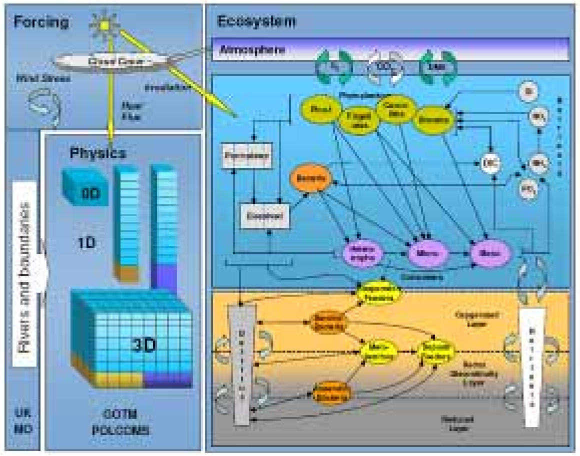
2. MODELLING APPROACHES



Expertise in fisheries population growth dynamics & ecosystems modelling.



Expertise in plankton, & food stoichiometric/quantity modelling.



Expertise in complex ecosystem modelling, OA Research, socio-economics

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Modelling phase 1

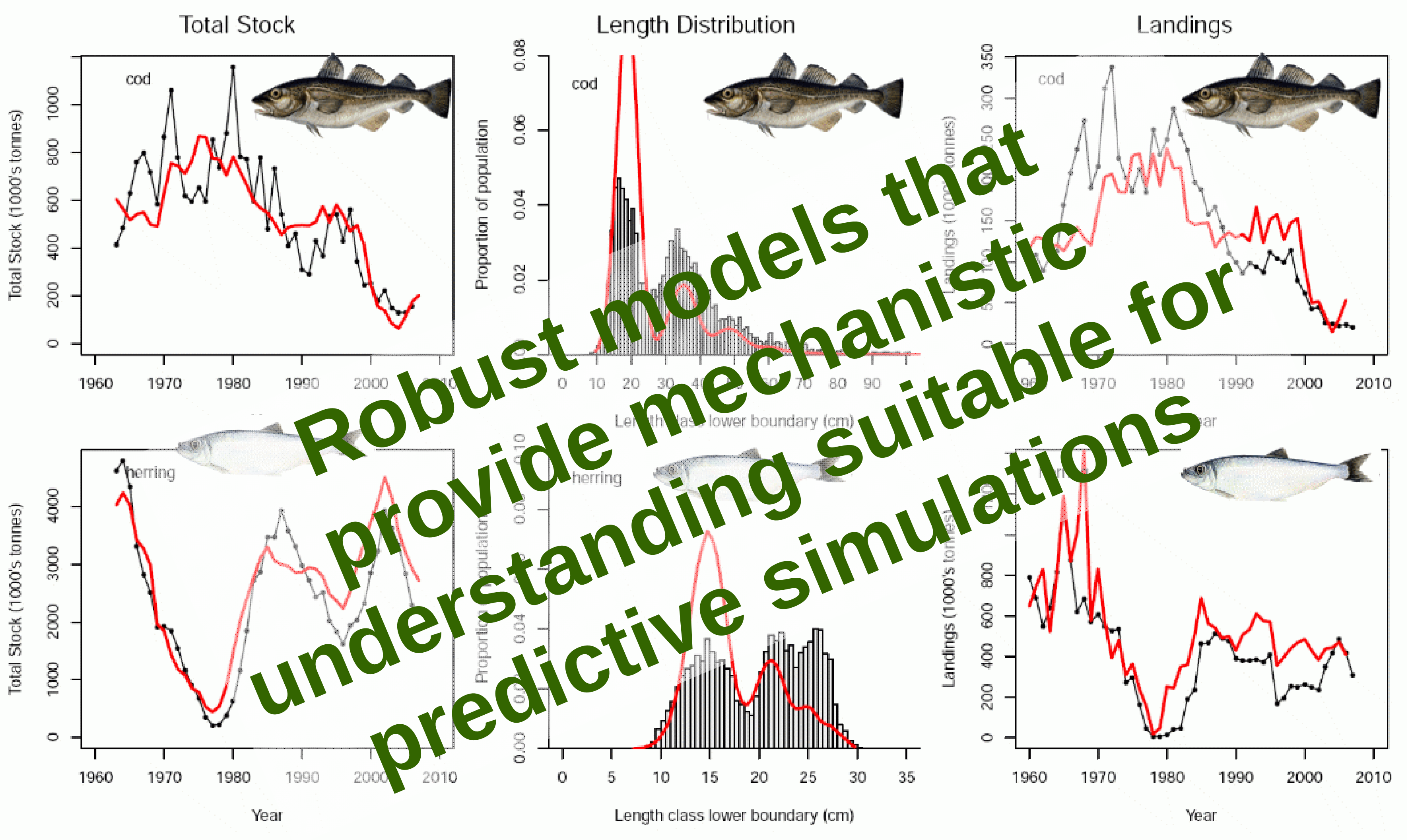
University of Strathclyde Glasgow

- Develop & model mechanistic understanding of OA effects to describe growth and physiology
- Physiological modelling **(Swansea)** coupled with population level models **(Strathclyde)**
- Risk assessments on mechanistic models will inform the population model to the most sensitive areas.
- Mechanistic models enable synergistic links to food quality and quantity to be explored; there are suggestions that stoichiometric interactions could be changed in OA, for example.

Modelling phase 2

- Population modelling - focus on moving from individual-level responses to OA to multispecies-level responses (**Aim 4.3**)
- Focus on small sets of species that are trophically linked strongly
  phytoplankton – zooplankton - planktivorous fish - piscivorous fish
- Outputs include stock biomass, recruitment, and full length distributions - model can be driven by actual time series of fishing mortality (F) or it can generate equilibrium yields under assumed F’s and OA changes
- **Work will inform fisheries part of SE study**

What we are aiming for …..



Robust models that provide mechanistic understanding suitable for predictive simulations

Socio-economics

Socio-economics

- Part model-driven **(via linkage between models from deliverable 4 and others)**
  - **Development of bioeconomic model to explore impacts of OA on supply for commercial species**
  - **Explore implications for fishing industry (e.g. value, employment) at regional, national and global level**
- Part non- or indirectly model driven **(goods & services related, and valuation of benefits)**

Socio-economics: model driven

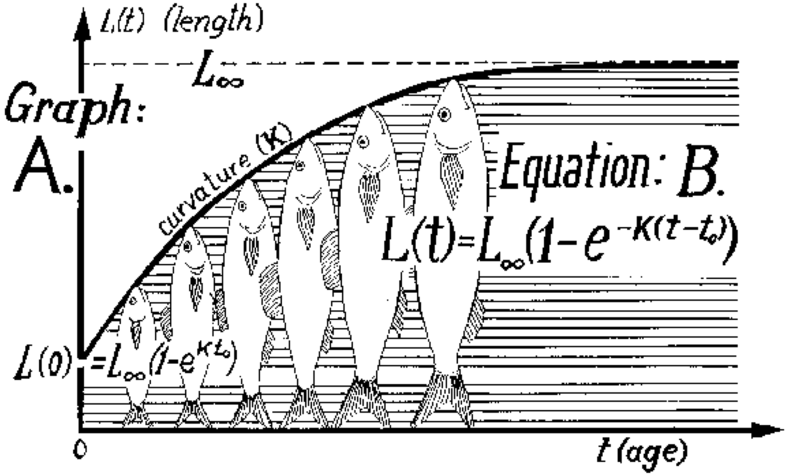
A bioeconomic model can be understood as a set of tools designed to make projections of a set of biological and economic variables into the future

(Maynou, 2005)

1) Project scenarios of potential OA impacts on key commercial species.
2) Use experimental evidence to assess the impact on fisheries production and profits of a set of OA scenarios.
3) Run the model:
   - locally (single species level and a single fleet);
   - regionally (considering the effect on main commercial species and fleets); and
   - globally (to provide a global assessment of the potential effects of OA on global fisheries)
4) Assess alternative management measures to elucidate the optimal regulation to mitigate the effects of OA. The potential contribution of OA and management on economic loss will be investigated.

Socio-economics: model driven

- Consider fish population dynamics as a result of recruitment, individual growth, natural mortality and fishing.
- The impact of OA on fisheries productivity will be introduced through growth.



Socio-economics: ecosystem service valuation

The Challenge:

Identify the social and economic impacts of OA as a consequence of ecosystem change

Socio-economics: ecosystem service valuation

Use an ecosystem services approach to:

1) Identify the wider benefits society obtains from the marine environment **(Yr 1)**
(e.g. regulation of atmospheric gases; space for leisure and recreation, etc)

2) Assess potential change resulting from OA

(Yr 1&2)

3) Value the changes predicted in ecosystem service **(Yr3)**

4) Discuss findings with stakeholder groups

(Yr3)

Socio-economics: ecosystem service valuation

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Socio-economics: ecosystem service valuation

The problem:

Very little scientific evidence goes beyond single species and the impact on individual species is variable

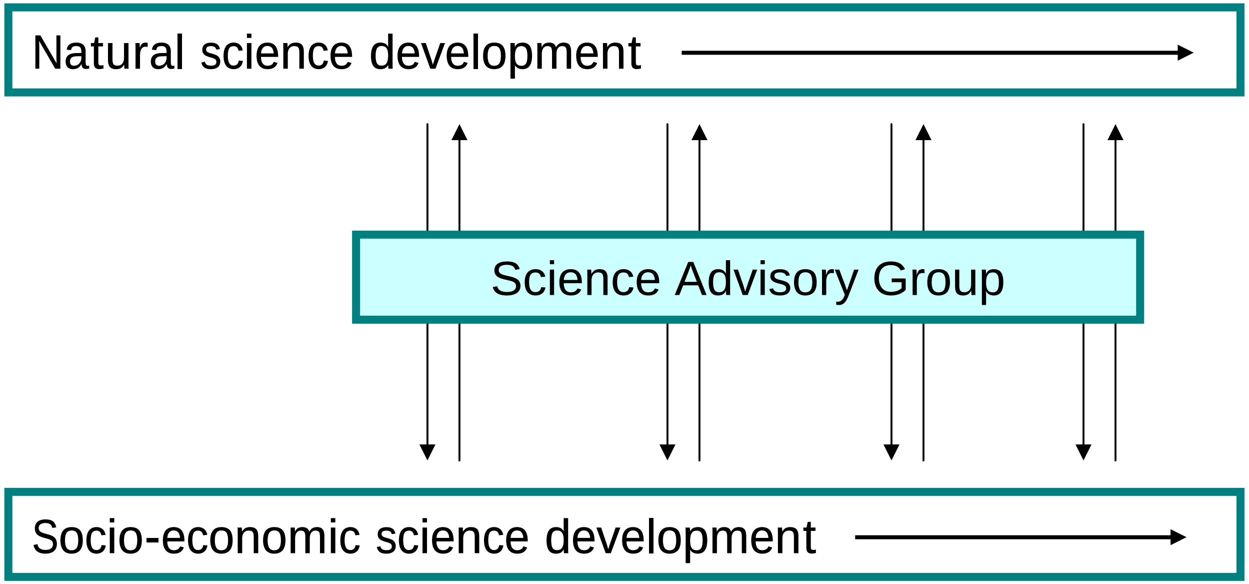
We need your help!

Plymouth Marine Laboratory

Socio-economics: ecosystem service valuation

- Gather evidence from the literature
- Keep in contact with all other OA projects to identify emerging findings
- Work closely with ecosystem modelling project
- Form a “Science Advisory Group” to aid the integration of methods and data

Socio-economics: ecosystem service valuation



Natural science development

Science Advisory Group

Socio-economic science development

Characteristics

Regular contact & ownership
Natural/social science partnership

Less time lag
Good dissemination
Improved influencing