Global Conference on Aquaculture 2010

Farming the waters for People and Food

22-25 September 2010, Phuket, Thailand

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Expert Panel Presentation V.3
Progressing aquaculture through virtual technology and decision-support tools for novel management
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22–25 September 2010, Phuket, Thailand
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NACA


VITAL – Outline of talk
Review topics, objectives, and definitions 4
Data acquisition and the virtual world 4
Types and objectives of virtual technologies 1
From technologies to decision-making tools 6
Novel management and case studies 5
Emerging issues and the way forward 4
24
Gulf of Trieste, Italy
VITAL: Virtual Tools for Aquaculture

Objectives

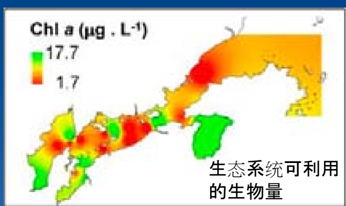
- **The Bangkok declaration (NACA/FAO 2000) aims to ensure the sustainable development of aquaculture over a ten-year horizon. Virtual technologies and decision-support tools for novel management are directly related to strategic elements in the declaration, such as:**
  - Applying innovations in aquaculture;
  - Investing in research and development;
  - Improving information flow;
  - Improving communication.

- **Our report provides:**
  - An overview of current and emerging issues and trends related to this topic over the past decade;
  - An assessment of progress with regard to the expectations and commitments expressed in the Bangkok Declaration;
  - Some thoughts for the future.

Virtual technology – definitions

Virtual Technology is defined as **any artificial representation of ecosystems that support aquaculture, whether directly or indirectly**.

Such representations are designed to help measure, understand, and predict the underlying variables and processes, in order to inform an *Ecosystem Approach to Aquaculture*.



Simulation of food availability for shellfish aquaculture, Xianshan Gang, China

We distinguish between:

- Tools which allow measurements to be made and translate data into information (Information and Communication Technology);
- Modelling tools (the way by which information is used for a given purpose) and the link to data collection technology.

Data and information

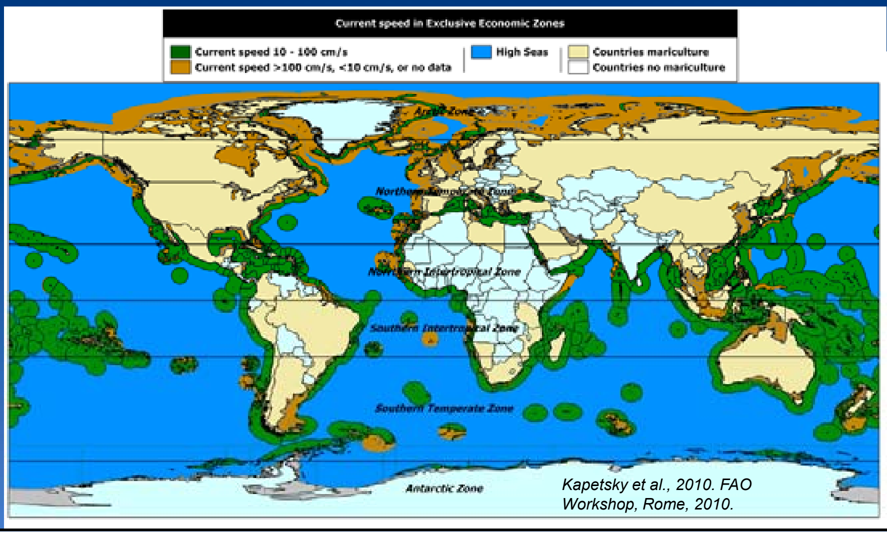
Issue	Key variables
Morphology and climate	Geometry, bathymetry, rainfall distribution, air temperature, wind speed, relative humidity
Water availability, inputs, and exchange	Volume, seasonal and annual hydrographs, tidal range and prism, current velocities, residence time
Water quality	Temperature, salinity, suspended matter, nutrients, organic detritus, oxygen, chlorophyll, submerged aquatic vegetation, xenobiotics, microbiology
Environmental interactions	Fouling, pathogens, extent of submerged aquatic vegetation, benthos
Culture practice	Timing of seeding and harvesting, mortality, cultivation density, size range, feeding (finfish and shrimp)
Socio-economics	Business fundamentals, infrastructure, direct employment, economic multipliers, vessels, etc

Thematic data collection for use of virtual tools, applied on scales ranging from individual farm to watershed

Example – Geographic Information Systems

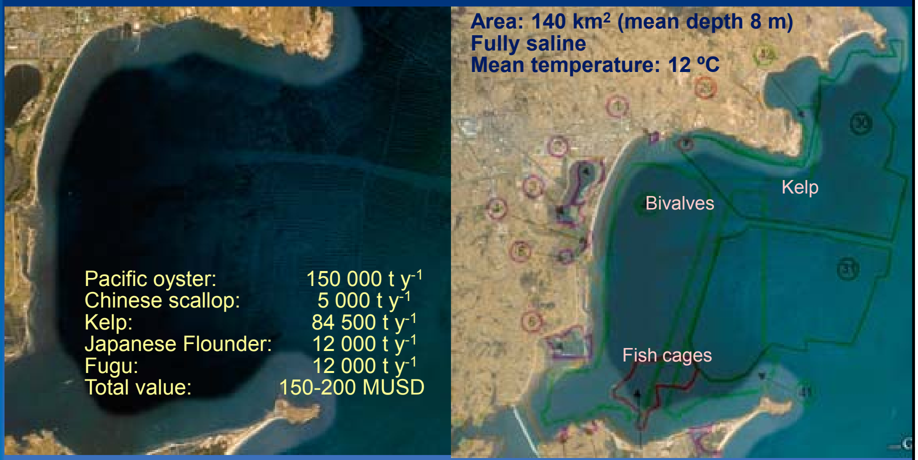
Current speeds: 0.1-1 m s^{-1}, suitable depth range for cages and longlines

123 countries with at least 100 km^2 that meet these criteria: 10^6 - 10^7 ton y^{-1}



Kapetsky et al., 2010. FAO Workshop, Rome, 2010.

Example – remote sensing tools

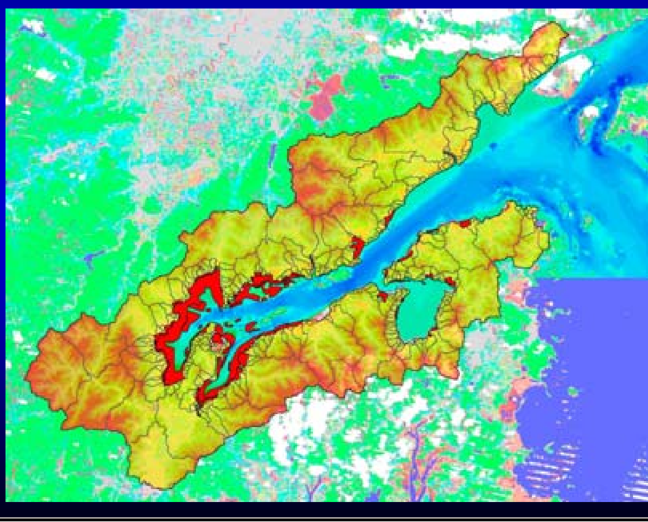


Sanggou Wan, northeast China (http://biaoqiang.org)

SPEAR Data description数据背景描述

GIS representation of data

- Water quality bay and boundaries
- Currents
- Bathymetry
- Hydrology
- Aquaculture practice
- Aquaculture mapping
- Land cover
- Meteorology
- 湾内和边界的水质
- 水流
- 高程图
- 水文
- 养殖活动
- 养殖图
- 地表植被
- 气候



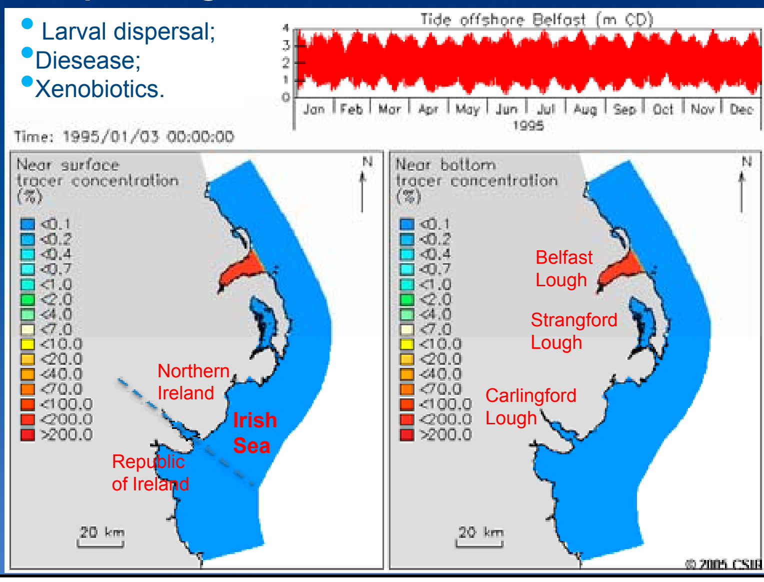
Types of virtual technology

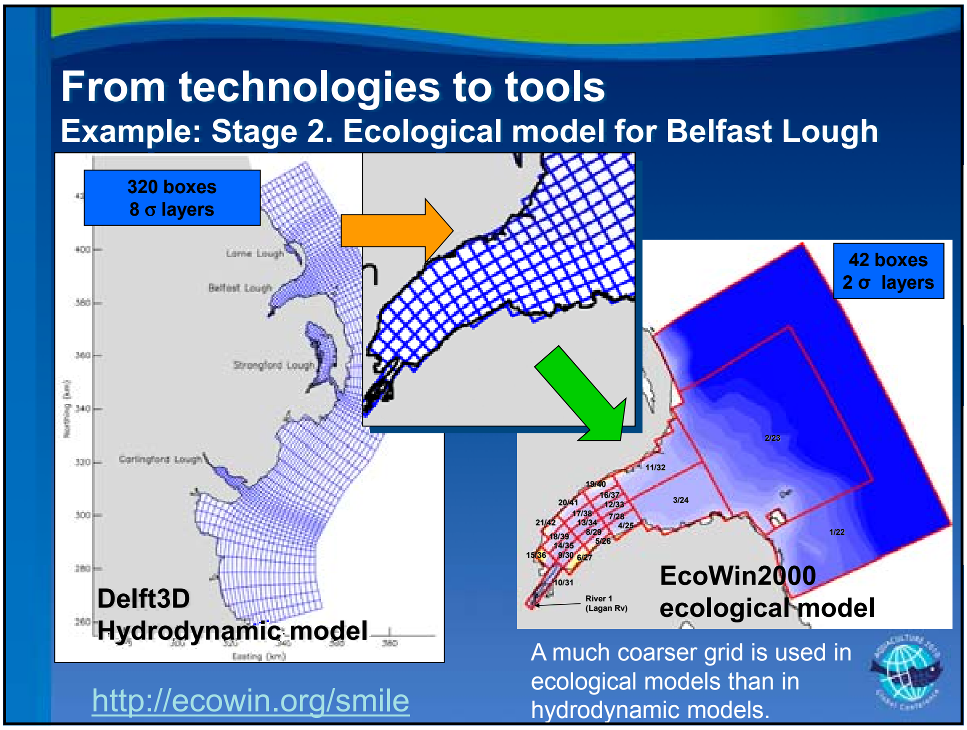
Objective and issues	Technology	Scale
Control production	Information technology, sensors	Microscale (farm)
Optimise production	Mathematical models	Microscale to mesoscale
Map resources and environment	GIS, remote sensing	Mesoscale (coastal to national boundaries)
Risk assessment	Handbooks, models, expert knowledge, literature, monitoring	Micro to macroscale (transboundary)
Build indicators of sustainability	Stakeholder forums, enquiries, indicator databases, LCA	Mesoscale (economic sector)
Assess system changes	System approach, mathematical models	Meso- (regional) to macroscale
Communication and learning	Web technologies, e-learning, forums, technical networks, demonstration tools	Meso- (regional) to macroscale (national, transboundary)

From technologies to tools

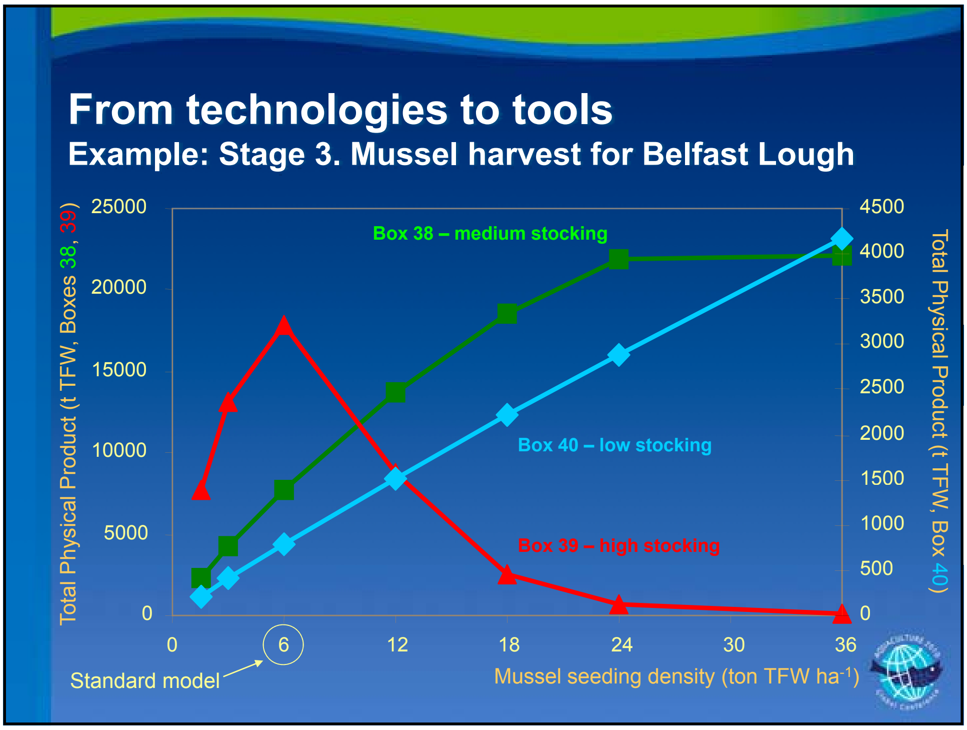
Example: Stage 1. Circulation model – connected systems

- Larval dispersal;
- Diesease;
- Xenobiotics.

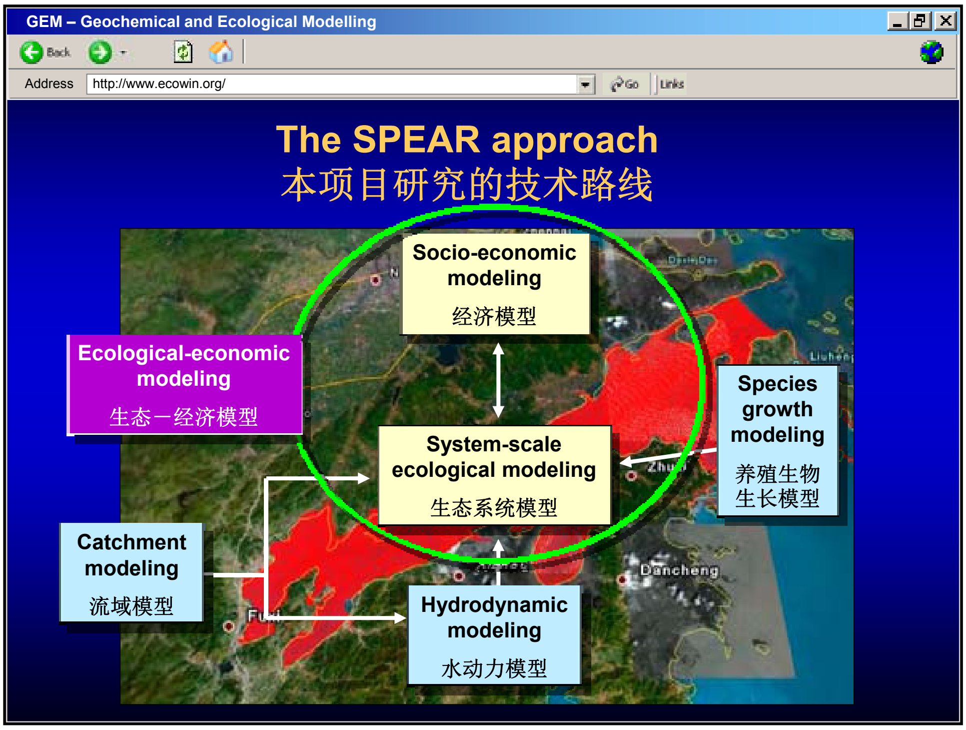


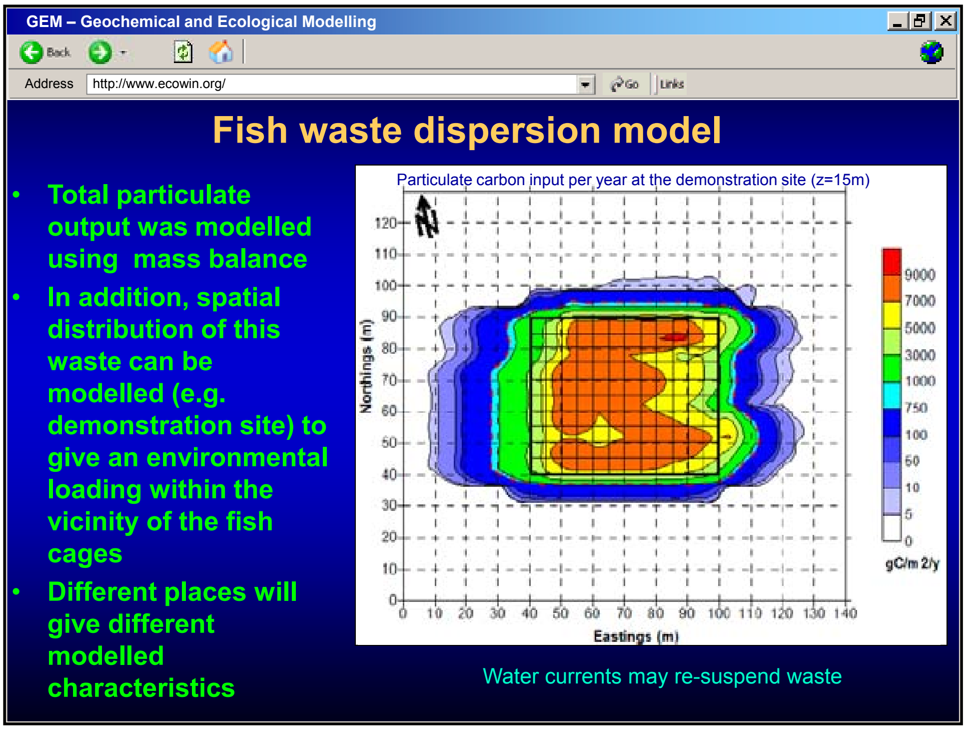


From technologies to tools
Example: Stage 2. Ecological model for Belfast Lough
320 boxes
8 σ layers
Larne Lough
Belfast Lough
Strangford Lough
Carlingford Lough
Delft3D
Hydrodynamic model
42 boxes
2 σ layers
EcoWin2000
ecological model
River 1
(Lagan Rv)
http://ecowin.org/smile
A much coarser grid is used in ecological models than in hydrodynamic models.



From technologies to tools
Example: Stage 3. Mussel harvest for Belfast Lough
Box 38 – medium stocking
Box 40 – low stocking
Box 39 – high stocking
Total Physical Product (t TFW, Boxes 38, 39)
Total Physical Product (t TFW, Box 40)
Mussel seeding density (ton TFW ha-1)
Standard model
0
5000
10000
15000
20000
25000
500
1000
1500
2000
2500
3000
3500
4000
4500
6
12
18
24
30
36


GEM – Geochemical and Ecological Modelling
Address http://www.ecowin.org/
The SPEAR approach
本项目研究的技术路线
Socio-economic modeling
经济模型
Ecological-economic modeling
生态－经济模型
Species growth modeling
养殖生物生长模型
System-scale ecological modeling
生态系统模型
Catchment modeling
流域模型
Hydrodynamic modeling
水动力模型
Dancheng


GEM – Geochemical and Ecological Modelling
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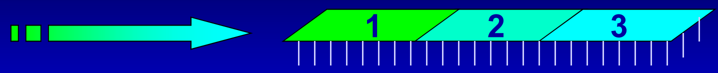
Fish waste dispersion model
• Total particulate output was modelled using mass balance
• In addition, spatial distribution of this waste can be modelled (e.g. demonstration site) to give an environmental loading within the vicinity of the fish cages
• Different places will give different modelled characteristics
Particulate carbon input per year at the demonstration site (z=15m)
Northings (m)
Eastings (m)
gC/m 2/y
9000
7000
5000
3000
1000
750
100
50
10
5
0
Water currents may re-suspend waste

GEM – Geochemical and Ecological Modelling

Address http://www.ecowin.org/

FARM: Sanggou Bay – Integrated Multi-Trophic Aquaculture



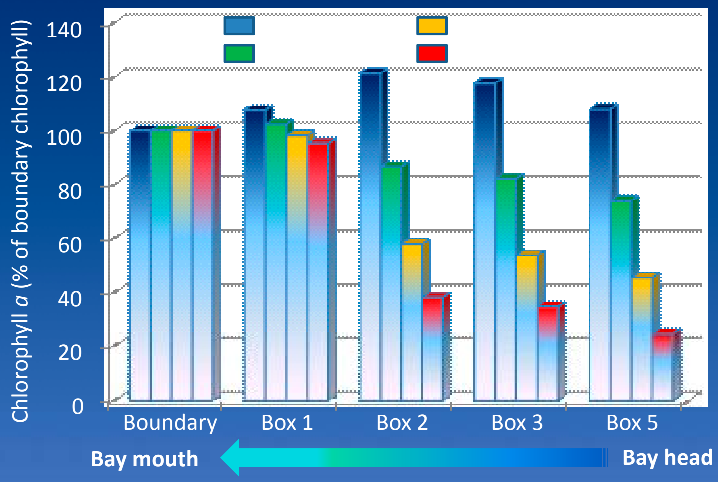
Scenario	A	B
Description	Oysters in monoculture all sections	Oyster and fish IMTA all sections
People		
Total Physical Product (ton TFW)	7.5	219.7
Average Physical Product	0.32	9.34
Planet		
Chlorophyll *a* (P_{90})	9.4 → 6.2	9.4 → 5.9
N removal (kg y^{-1})	356	2468
Population Equivalents (PEQ)	108	748
Organic detritus removal (kgC y^{-1})	7816	39973
ASSETS	4	4
Profit		
Income (shellfish k€ y^{-1})	22.9	668.4
Income (N credits k€ y^{-1})	3.2	22.4
Net profit (aquaculture k€)	14.01	1075 + 15 = 1090 (Fish)

Novel management approaches

How can virtual tools address specificities of aquaculture?

Topic	Now	Tomorrow
Feed-based (cage, pond)	Site selection based on holding capacity (cages), wastewater minimisation (ponds)	Integrated model systems, risks, welfare, disease. Holistic indicators LCA: inefficiencies and eco-labelling Mechanistic and statistical models Data assimilation models
Shellfish farming	Large areas Focus on production and social carrying capacity NIMBY, NIMTO	Economic sustainability, ecology and economics Coupled GIS expert systems including xenobiotics HAB, etc Model uncertainties in yield Early warning
Integrated Multi-Trophic Aquaculture	Optimise production Reduce negative externalities	Integrated Coastal Zone Management. Simulate species combinations Full economic assessment. Combine GIS, remote sensing, and modelling

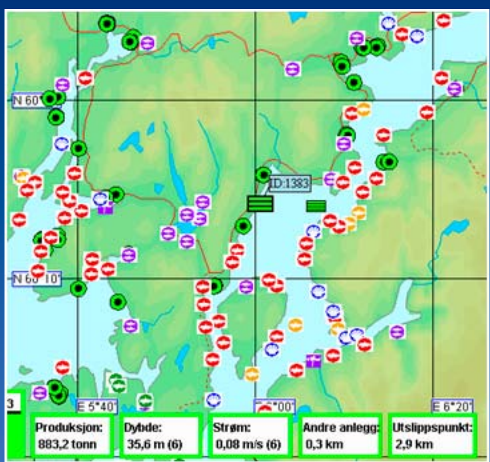
Case study: ecological carrying capacity



Prince Edward Island, system-scale carrying capacity

Filgueira & Grant. 2009. A box model for ecosystem-level management of mussel culture carrying capacity in a coastal Bay. Ecosystems 12: 1222-1233.

Case study: AqvaVis expert system

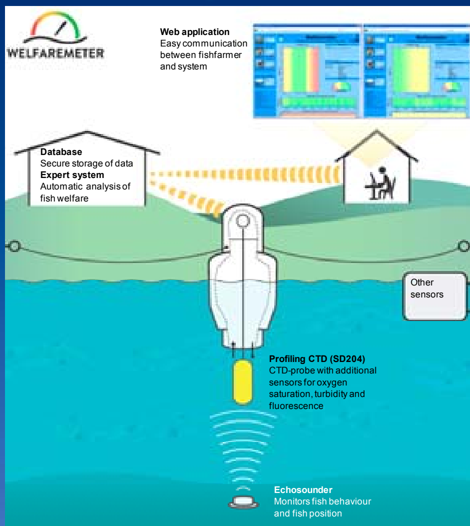


- Applied for mussel and finfish farming
- Three modules share the same databases but apply information for different purposes
- Siting module identifies potential farm sites, simulates carrying capacity
- Management module compiles information needed by the authorities for aquaculture management
- Application module promotes efficient application and ensures that all relevant information is provided

Norwegian fjords, site selection

Ervik A, Døskeland I, Hageberg A.A., Strand, Ø., and Hansen P.K. in prep. Virtual decision support tool (AkvaVis) for integrated planning and management in aquaculture.

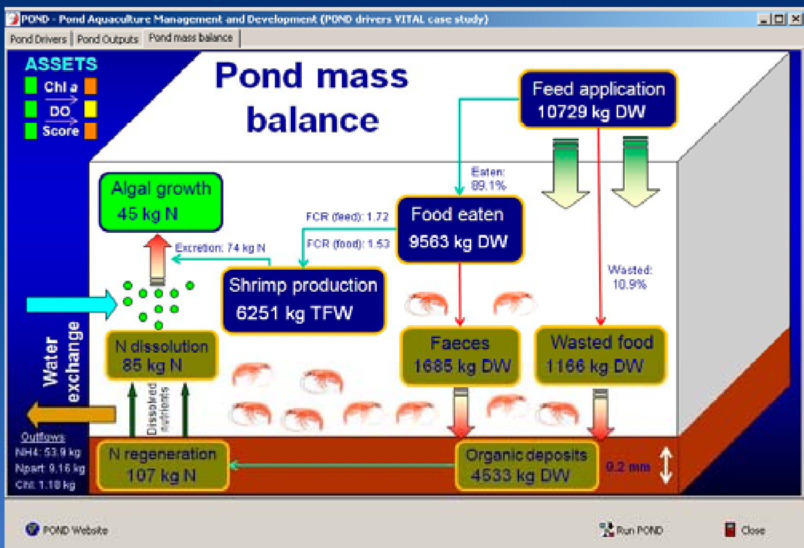
Case study: Welfaremeter operational model



- Coupled monitoring and modelling for finfish cages
- A cage can contain one million USD of fish, but little investment in monitoring of environment and fish behaviour
- Automated assessment of fish welfare in sea cages
- Instrumentation such as profiling CTD, DO, echosounders
- Database for secure data storage and retrieval
- Expert system software for data analysis and modelling
- Web interface for easy visualisation of data and expert system outputs
- Similar systems developed for gilthead and bass in the east Mediterranean

Oppedal F., T. Dempster, L. H. Stien, 2010. Environmental drivers of Atlantic salmon behaviour in sea-cages: a review. Submitted to Aquaculture.

Case study: POND for land-based culture



Franco, A. R., J. G. Ferreira, A. M. Nobre, 2006. Development of a growth model for penaeid shrimp. Aquaculture, 259, 268-277.

Key recommendations

- Innovations will drive aquaculture as virtual technologies become more widespread and aquaculture becomes increasingly competitive;
- Information exchange and networking will accelerate the use of virtual technology and decision-making. Web -based access to real time information will accelerate this growth;
- Links between industry and research need to be more effective to create objective-led demand for virtual technology-driven RTD;
- Collaboration must be strengthened between developed and with developing countries, mainly through educational and research programmes;
- Strategic alliances for implementation of virtual technology for aquaculture in developing countries;
- Virtual technology tools need to be more production- and management-oriented, and adapt to local realities and conditions.

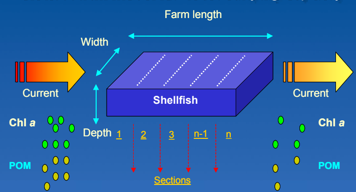
The way forward: constraints and actions for developing nations

- Aquaculture has special importance for developing countries: healthy food, important source of income;
- Which developing countries should be priorities for implementation of virtual technologies? EAA: those with the most impact on the environment;
- Which tools will be most appropriate for a given country? Analyse the potential impacts by species and culture systems;
- Should dissemination of virtual technology tools be passive or active?

Emerging issues

- Disease
  - Probabilistic models, e.g. SIR model
  - Risk assessment
  - Sentinel fish
- Harmful algal blooms
  - Sensors such as targeted RNA probes
  - Improved remote sensing algorithms for HAB
- Certification and traceability
  - Sensor arrays, e.g. Welfaremeter
  - Fish “bar-coding” for monitoring and certification
- Modelling with data scarcity
  - High quality data at suitable resolution is expensive
  - Remote sensing, models for uncertainty and risk
- Progress in information technology
  - Web 2.0. YouTube
  - Software As a Service (SAAS) e.g. Google Apps, FARM, WinShell
  - Mobile computing: stay tuned…

Above: bivalve physiology experiments, China
Below: FARM model for local carrying capacity



Is the planet of the apps ready for an aquaculture app?

Tilapia aquaculture GIS displayed on a mobile platform (South China)

- Mobile computing is increasingly ubiquitous;
- The stand-alone server is being rapidly replaced by “the cloud”;
- Data circulation is easier, faster and cheaper;
- We need to define workable business models;
- Mobile computing will help bridge the gap between richer and poorer nations in access to information technology.