Modeling the environmental effects of marine aquaculture operations

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Background

- Modeling approaches towards aquaculture management
  - Application of the Scottish aquaculture waste sedimentation model **DEPOMOD**

Napier University

SAMS Scottish Association for Marine Science

Cromey *et al.*

SEPA Scottish Environment Protection Agency

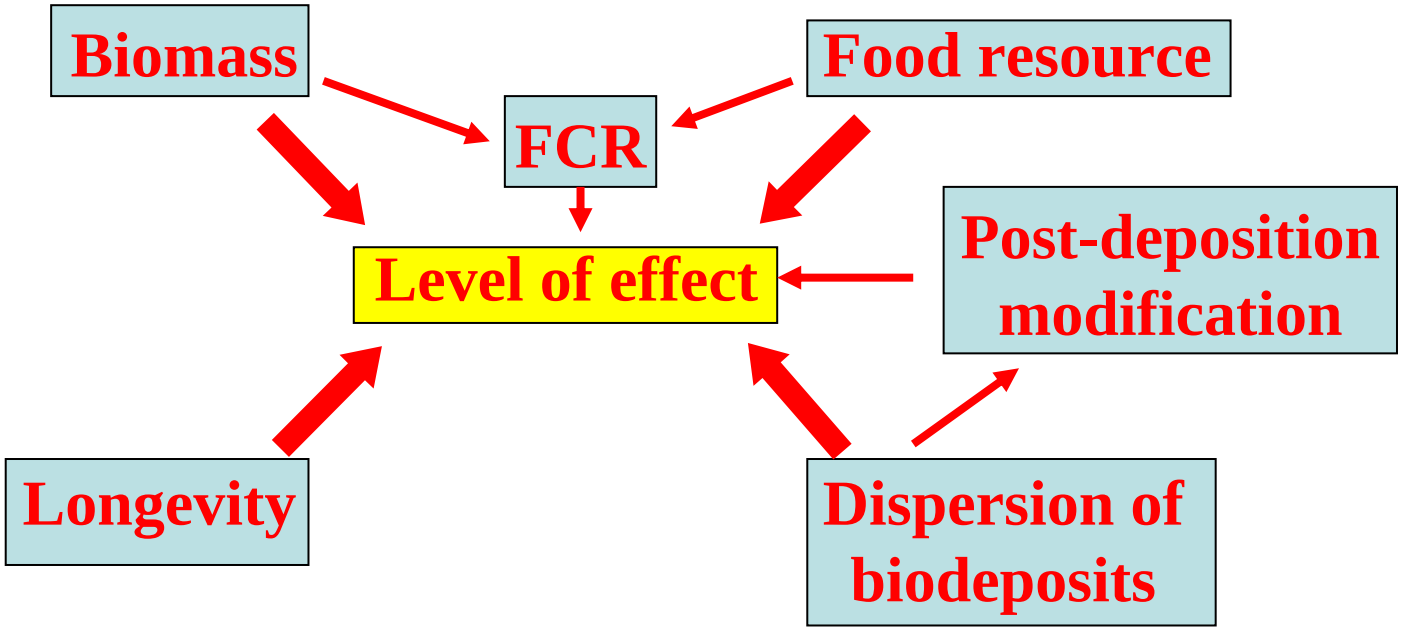
Fisheries and Oceans Canada | Pêches et Océans Canada

British Columbia

Introduction

- Minimizing the impact to the benthic environment a central element in the monitoring and regulation of marine aquaculture operations in many countries.
- Stakeholder desire for predictive capability in assessing potential effects of ‘change’
- Aquaculture – controversial, polarized arguments
- Needs:
  - Transparency and openness within decision making process
  - Objective management framework

Factors affecting the potential degree and scale of effect



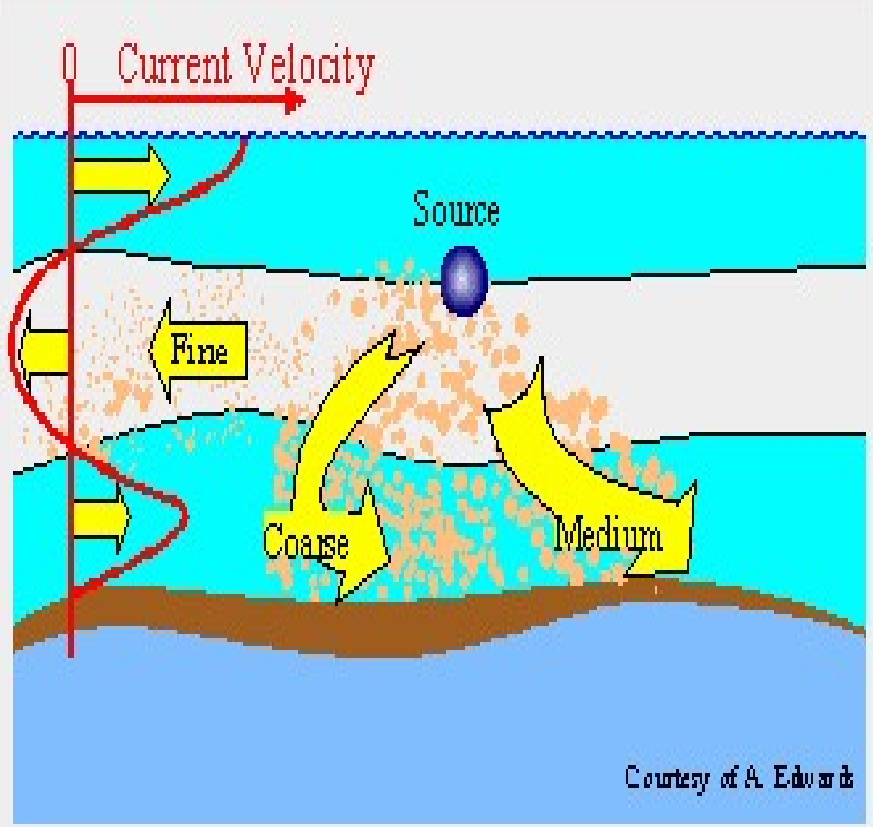
Can these factors be simulated and/or parameterized to predict the flux of material to the benthic environment?

Introduction - DEPOMOD

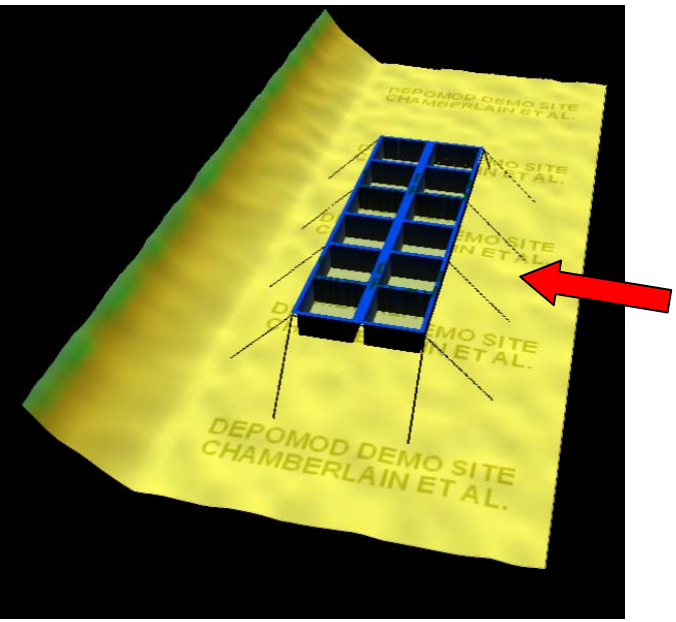
"To enable a better predictive capability of the input of large marine cage finfish farms on the benthos and improved objectivity in the regulatory decision making process"

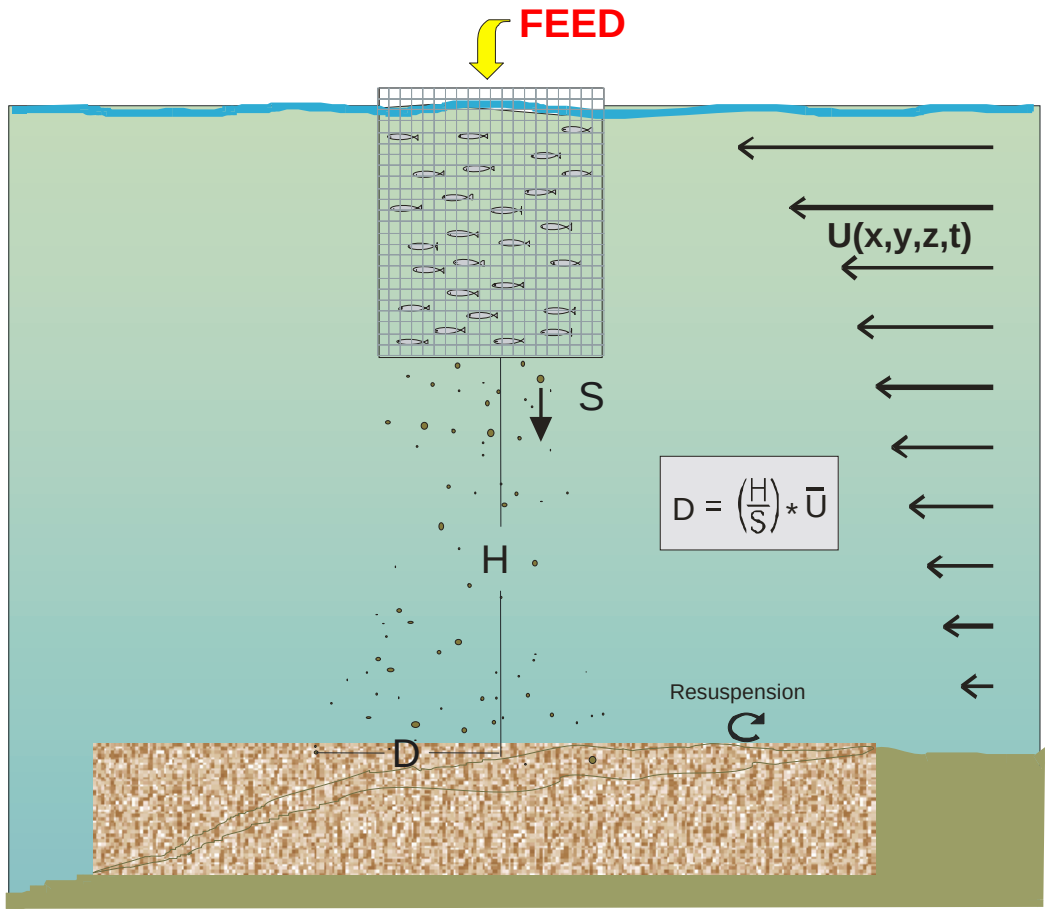
What is DEPOMOD?

- Marine aquaculture waste sedimentation/particle tracking model
- Predicts deposition of waste material to the seabed
- NOT Hydrodynamic model
- Achieved levels of validation in Scotland and B.C. Canada



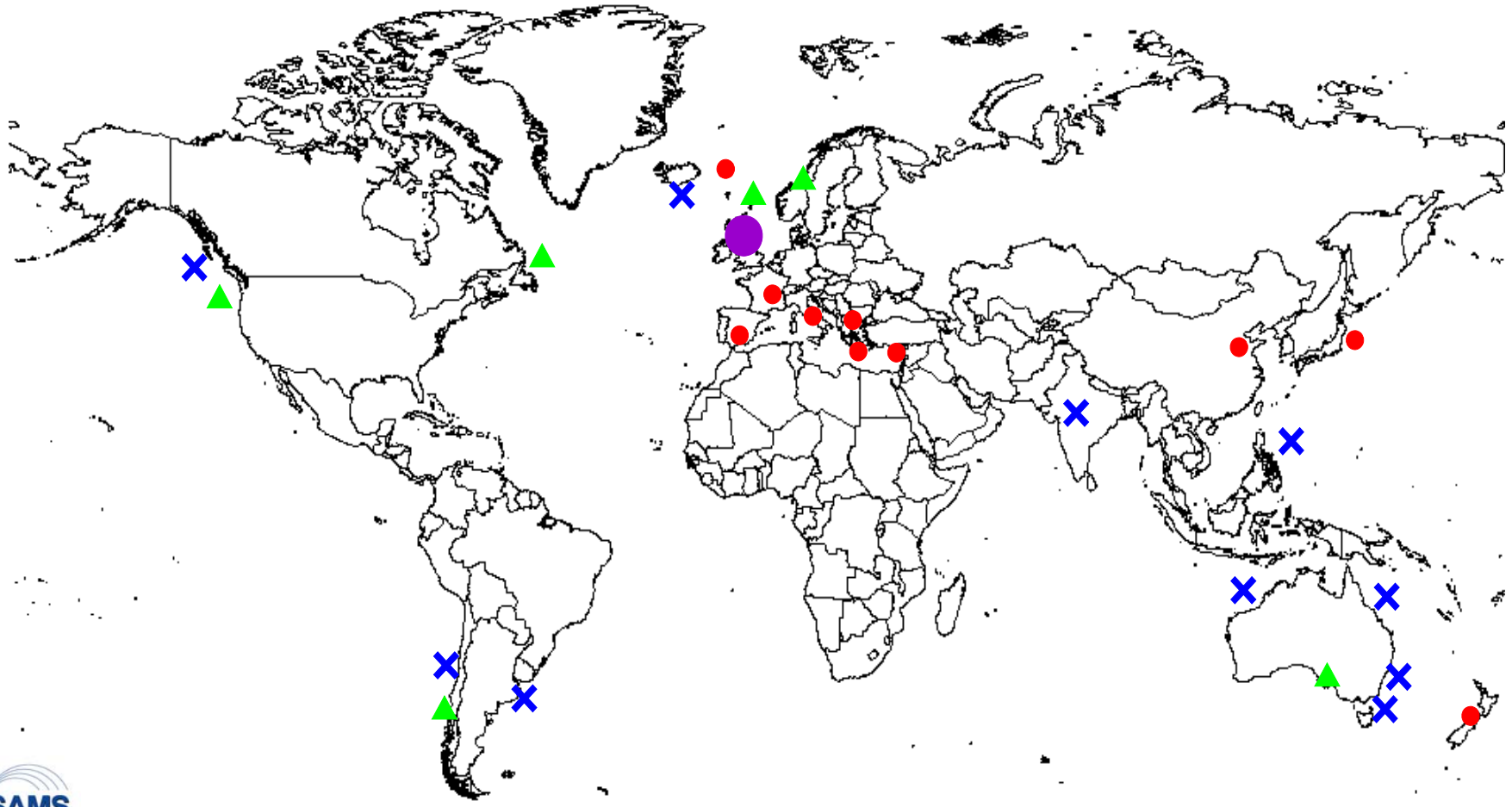
What is DEPOMOD?





History

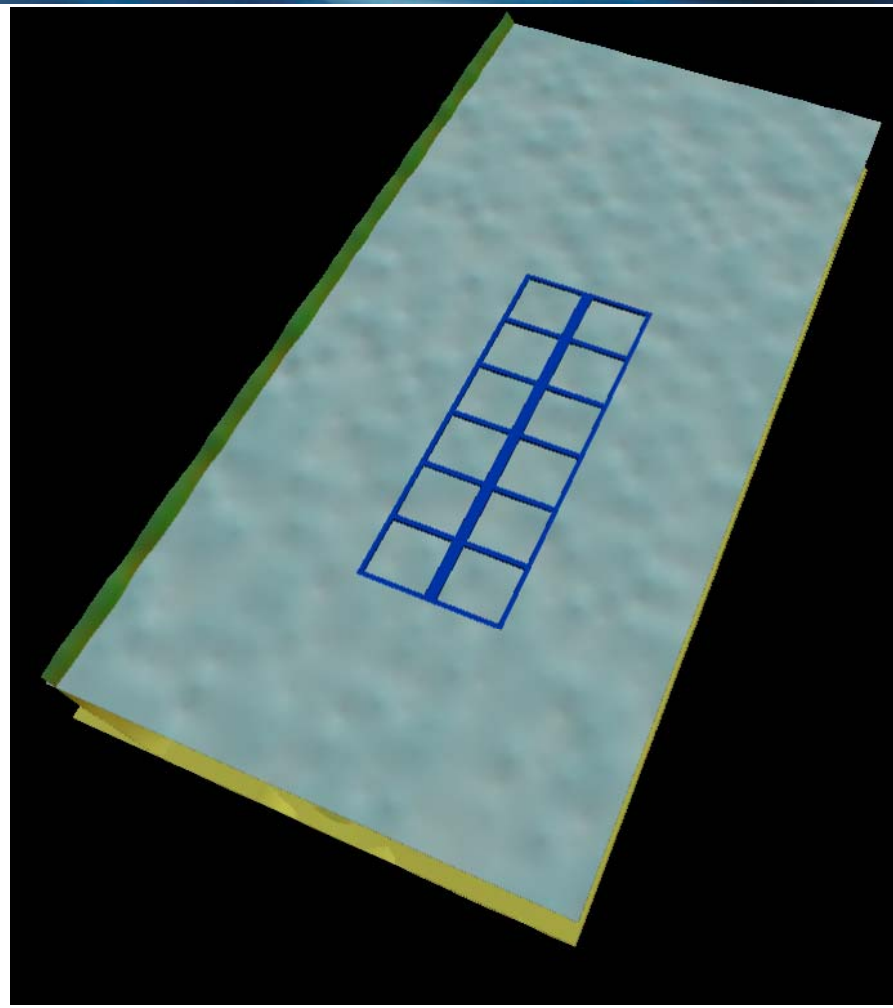
- BenOss – Biological effects and organics solids sedimentation (Cromey et al, 1998)
  - Long sea sewage outfalls
- DEPOMOD
  - Modifications for particle release point, organic loading, gradients of enrichment, typology
  - Multiple versions (v1.5, v2.0, AutoDEPOMOD, Meramod, CodMod
  - All based on same basic algorithms
  - Licences sold around the globe – widely accepted



Data supplied by Chris Cromey (SAMS)

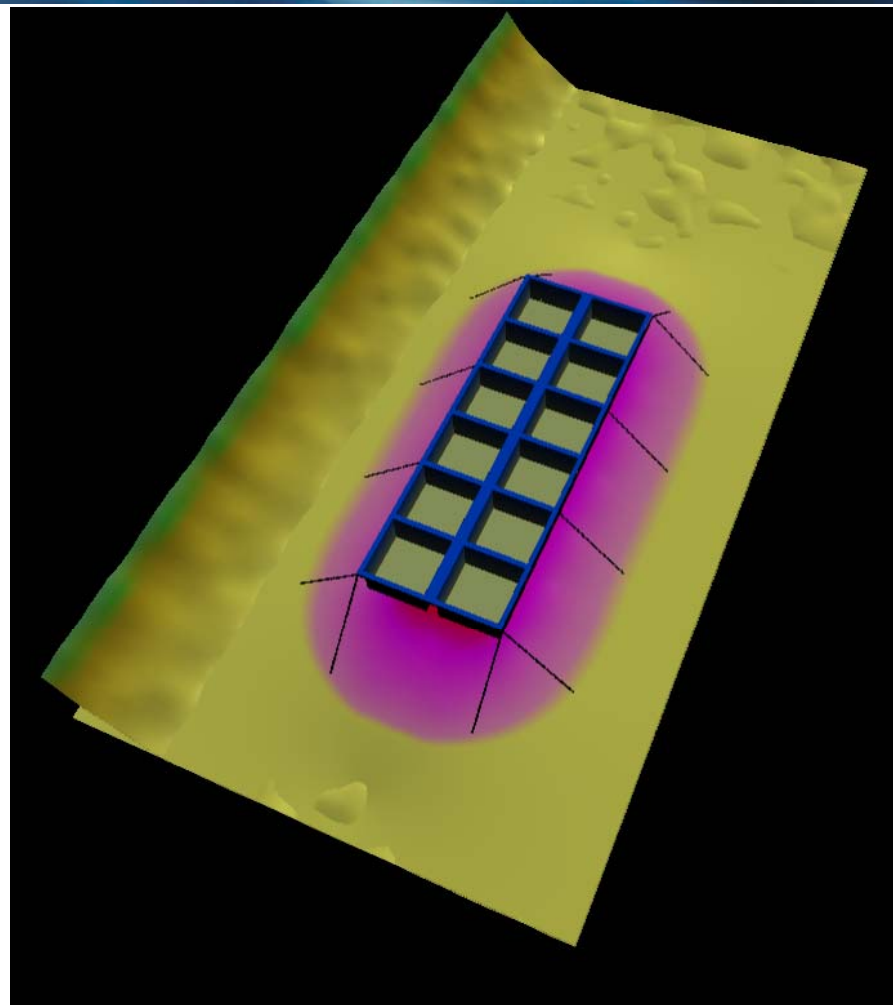
DEPOMOD

- Site specific information



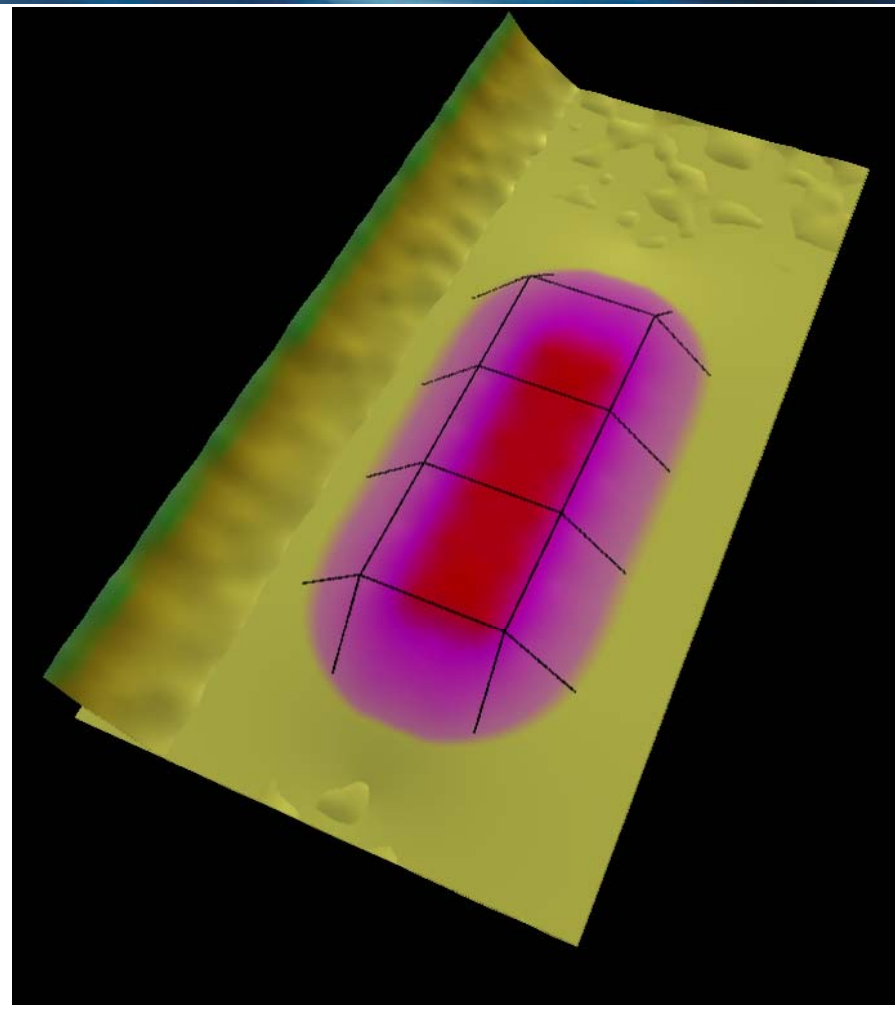
DEPOMOD

- Site specific information
- Predicts the flux of material to the benthos (quantitative)



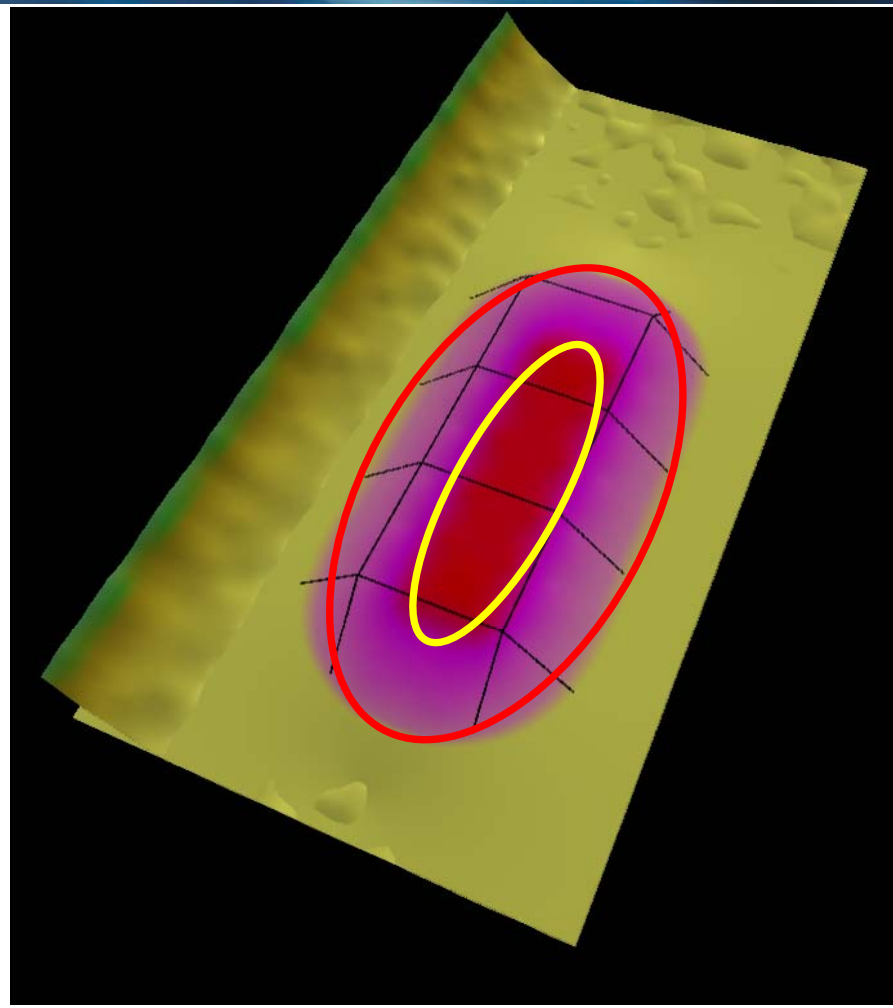
DEPOMOD

- Site specific information
- Predicts the flux of material to the benthos (quantitative)
- Post deposition modification
  - Resuspension (model)
  - Consolidation (parameter)
  - Degradation (model/parameter)
- Predictions of the location, areal extent and scale of flux to the benthos



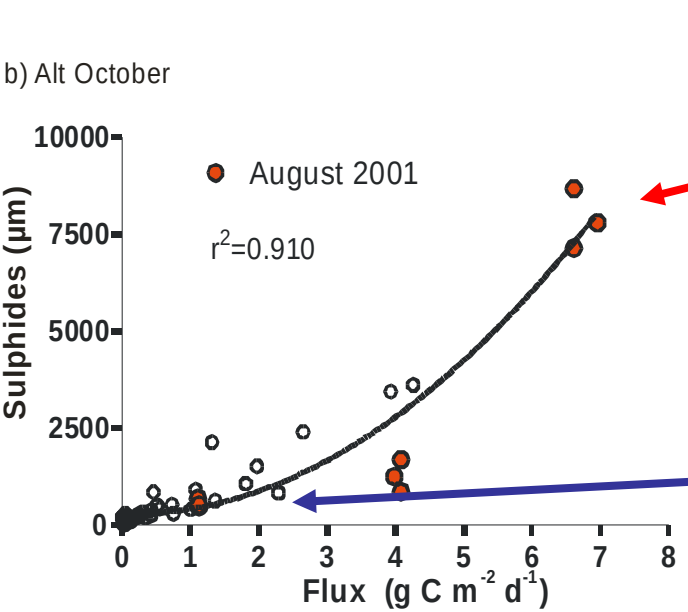
DEPOMOD - Output

- Useful information source to all stakeholders
- “What is the relationship between flux of material and benthic status?”
- Semi-empirical model on effect of solids loading on benthic infauna (Scotland only)
- Other relationships with measures of benthic status
- Complex and varied – numerous factors (hydrography, bottom type, temperature, O_2 delivery…)
- “Can useful model predictions be made with this uncertainty?” – **YES!** – through validation exercises



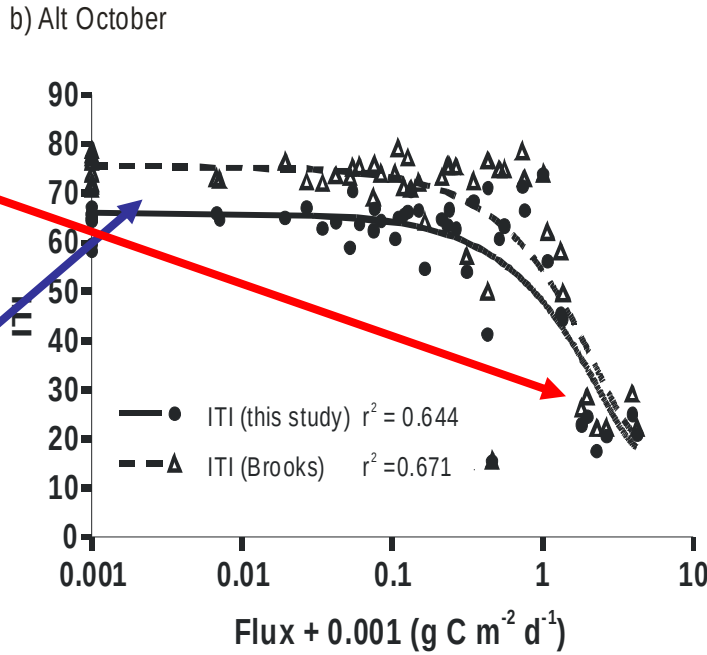
DEPOMOD – Management tool

Chamberlain et al 2005



HIGH

LOW



RELATIVE — RISK OF IMPACT — RELATIVE

- Management decisions may be made at far ends of scale
- Intermediate risk may be described through back-extrapolation

DEPOMOD – How may model outputs be used?

Scotland – In-feed anti sealice chemotherapeutant consent

DEPOMOD used to predict the benthic loading of TFBZ (Calicide) and EmBZ (Slice) for consents to discharge.

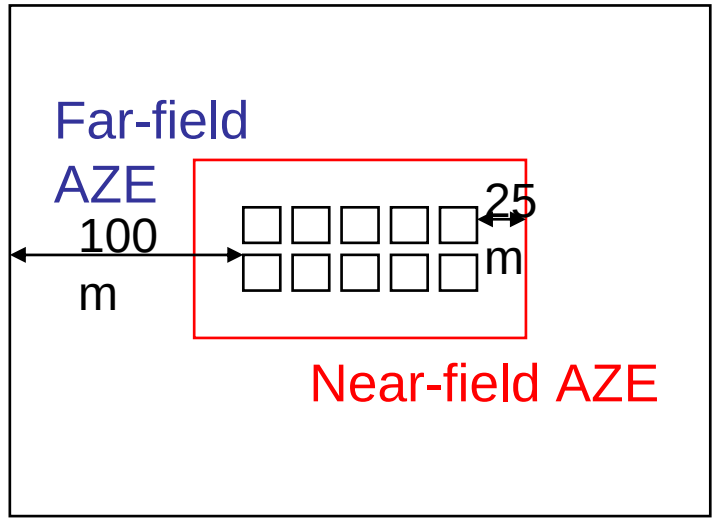
Simulations involving multiple application of chemical bound to waste feed and faecal material with specific degradation characteristics

DEPOMOD – How may model outputs be used?

Scotland – 'old' AZE approach

RISK - Acceptance that FF will have benthic effect – should be within fixed distance

EQS at 25m – benthic status measure



"SEPA policy has clear preference to dispersive locations"

"….it is impossible for deep and [or] dispersive sites to retain the majority of deposited loads within 25m [of the farm]….."

DEPOMOD – How may model outputs be used?

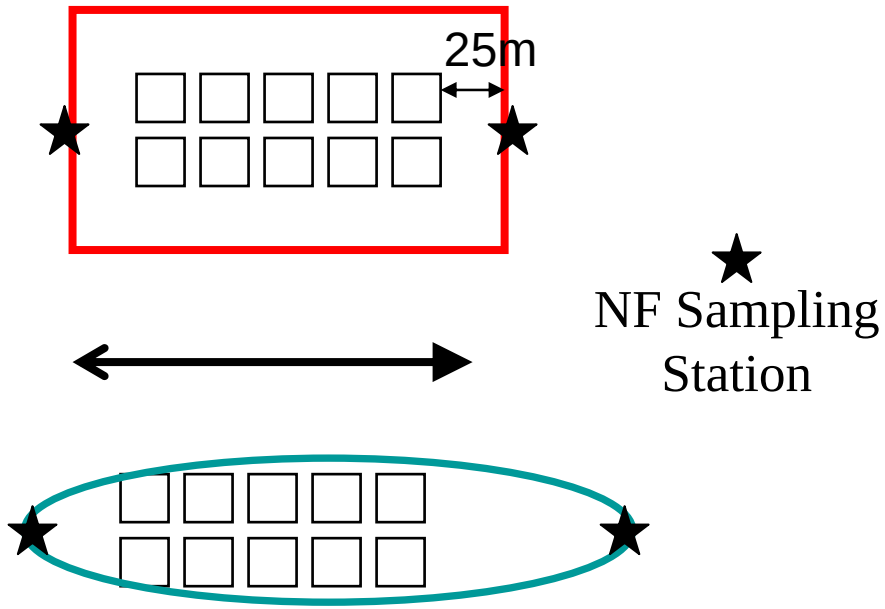
Scotland – alternate strategy

Use DEPOMOD to model site and produce footprint

- Maintain 25m 'value' - Equivalent Area approach

Result

- Sites in deeper and/or more dispersive locations have greater 'distance' to attain EQS
- Overall allowable AREA of impact remains the same



DEPOMOD – How may model outputs be used?

Hypothetical scenario

Using predetermined benthic environmental quality threshold
(e.g. benthic community measure, [sulphide], anoxic sediment)
and allowable zone

- None
- Specified distance from farm
- Area measurement (m^2)
- Area enclosed based on percentage of particles (50%, 90%)

Model can be applied to investigate

- Maximum biomass that will not exceed EQS
- Best site location for reduced impact
- Best site configuration for reduced impact

DEPOMOD – How may model outputs be used?

Model may be used for scenario testing to

- Redesign
- Relocate
- Mitigate….the effects on the near field benthic environment

2005 – Scottish Environment Protection Agency

AutoDEPOMOD – used for assessing appropriate biomass and monitoring stations

DEPOMOD – How may model outputs be used?

Canada - Aquaculture policy

- Industry competitiveness
- Public confidence
- Sustainable aquaculture industry

Habitat Management Objective:
No Net Loss of productive capacity of fish habitat supporting Canada's fisheries resources

Modeling approach applies to *new* finfish aquaculture sites and historic sites that make changes that result in *new* impact.

DEPOMOD – How may model outputs be used?

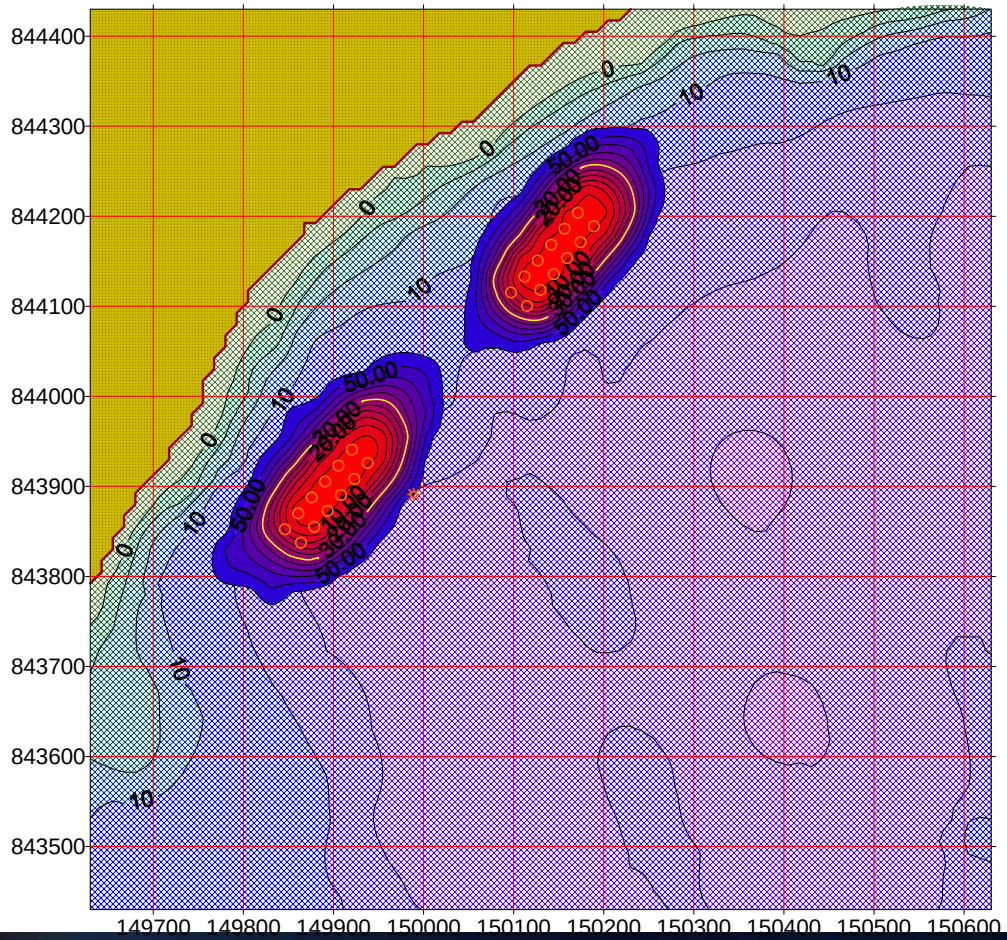
DEPOMOD used to predict the area and location of initial flux at MAX and AVERAGE feed input rates

Maximum – "worst case scenario" representing maximum daily food input for the maximum permitted biomass
Average – represents a longer term estimate of carbon flux to the seabed

Management framework
Use predicted 5g C m^{-2} d^{-1} as Authorization threshold
Ensure that predicted 5 g C m^{-2} d^{-1} does not overlap critical habitat
Use the predicted 1g C m-2 d^{-1} contour as a siting buffer for critical habitat and use as a siting guideline for sensitive habitat
Purpose of this framework: To ensure that the Section 35(2) provision of the Fisheries Act is applied in a **consistent manner** among aquaculture applications

DEPOMOD – How may model outputs be used?

INCREASING BIOMASS



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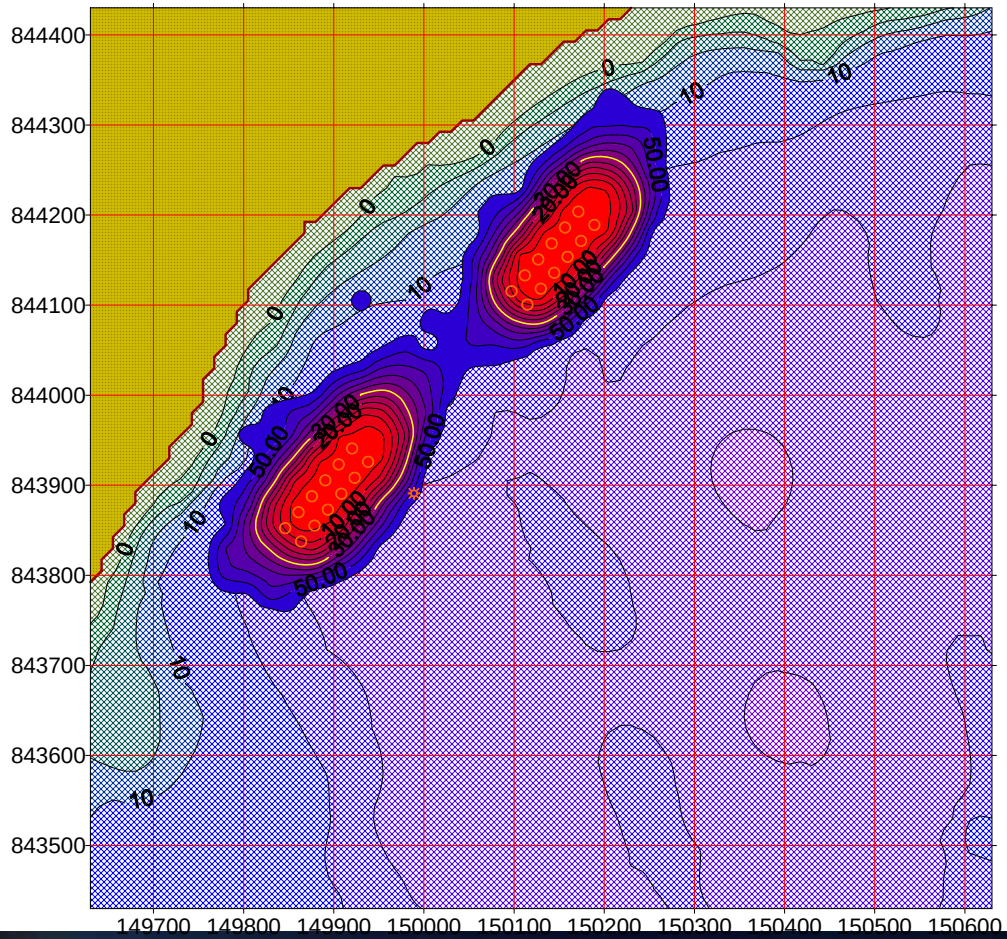

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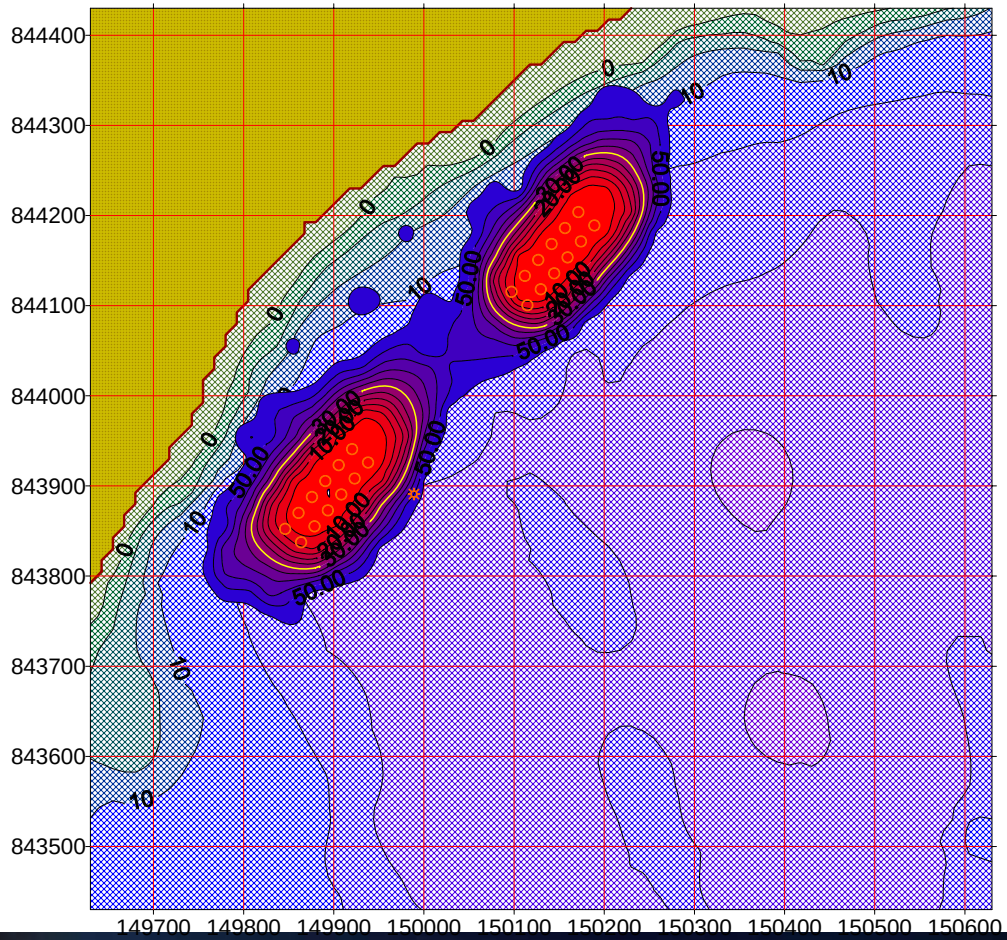

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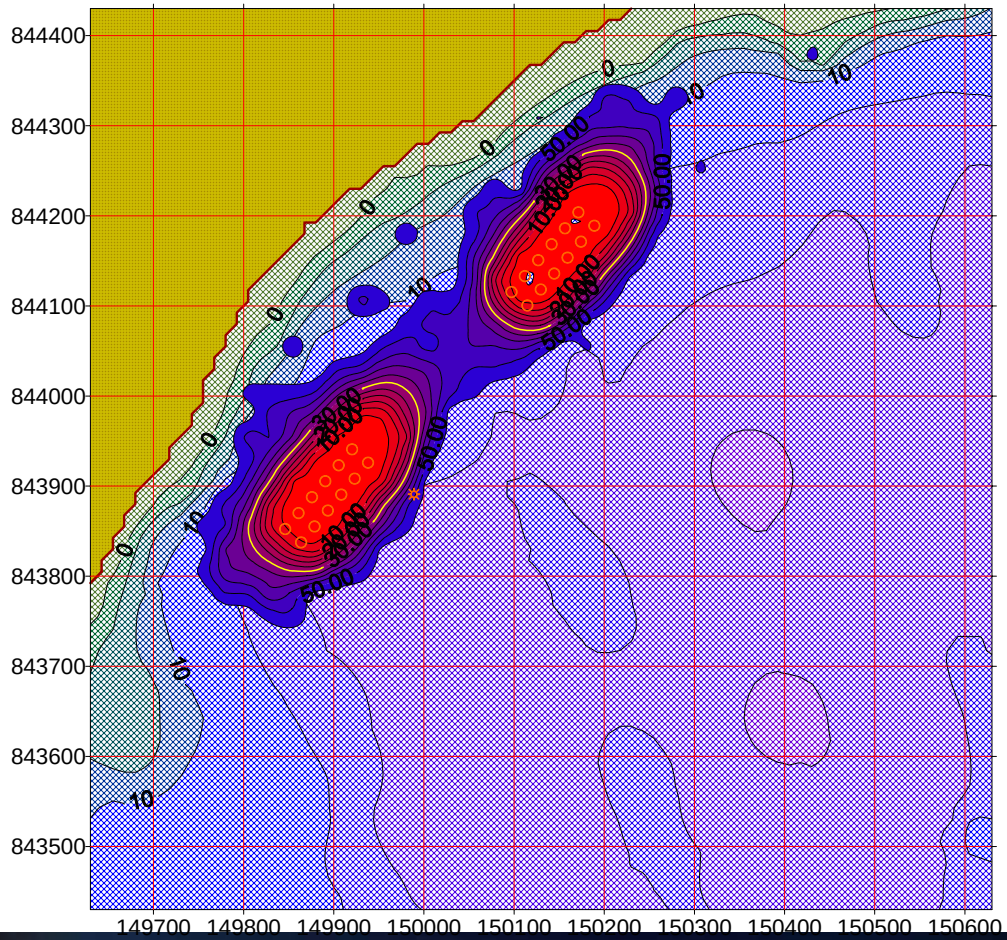

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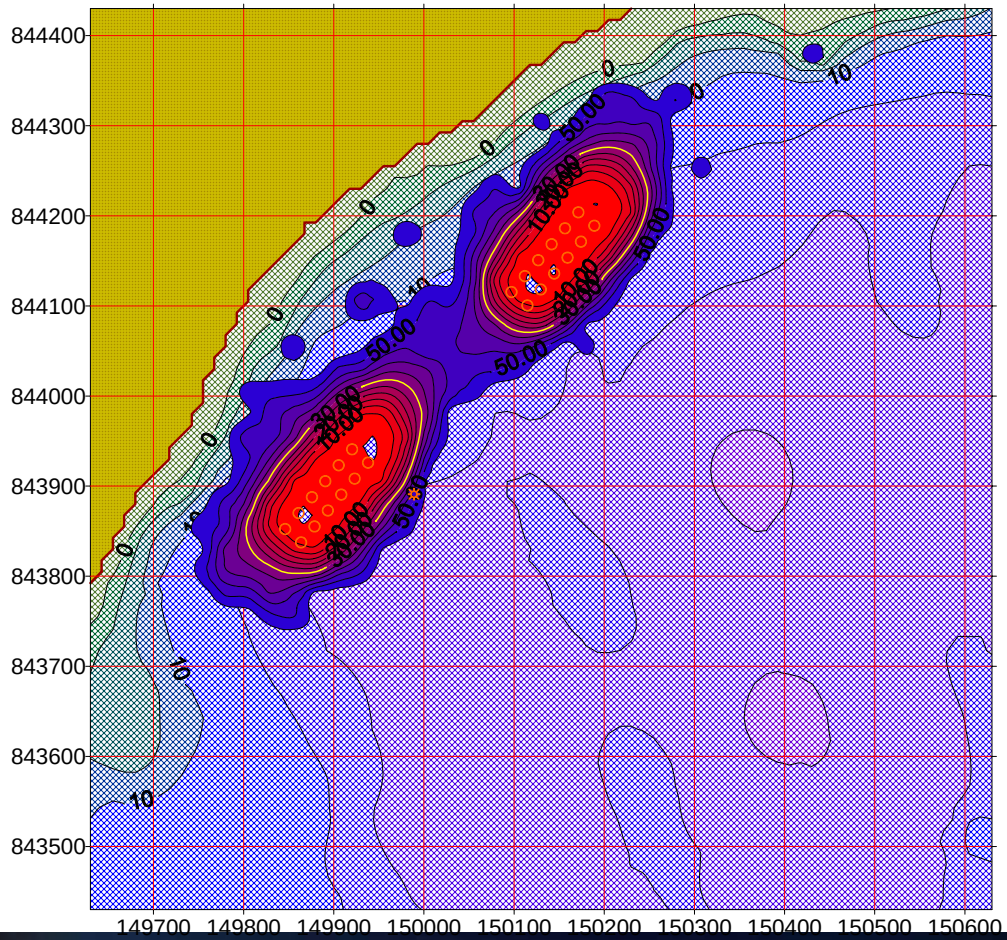


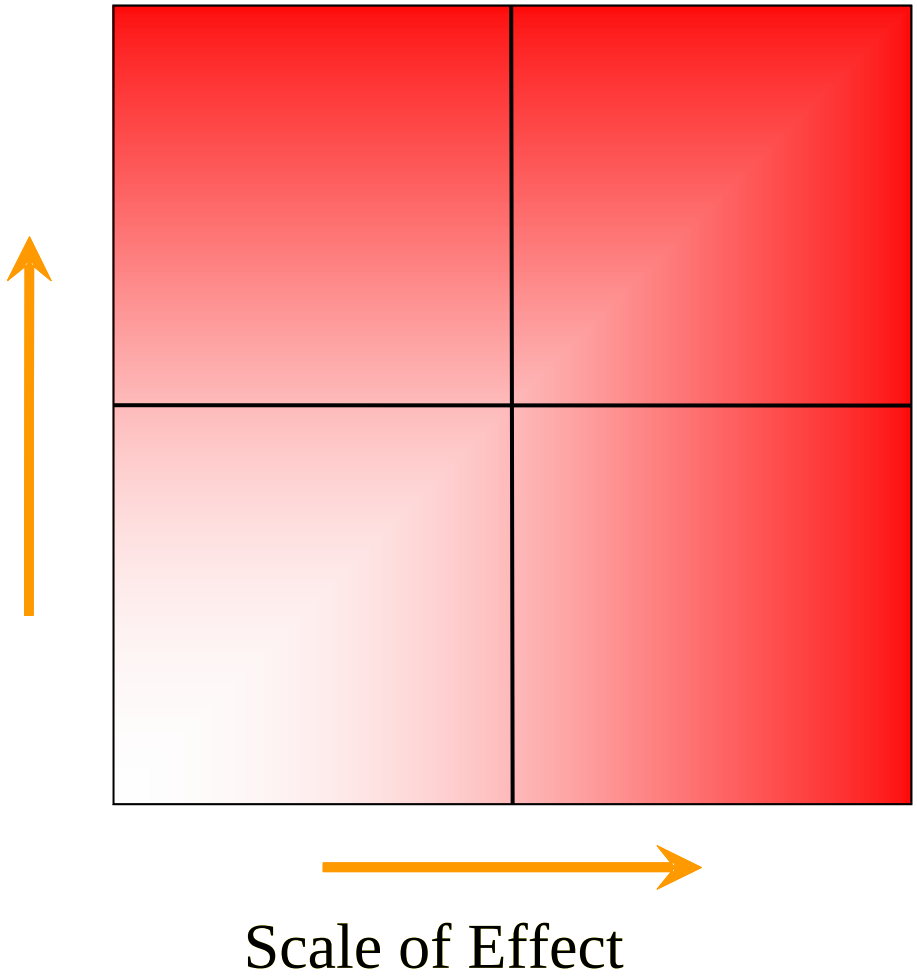
DEPOMOD

Benefits of approach

- Transparent and objective tool for provision of advice to all other stakeholders – confidence and trust in decision making framework
- Site specific management tool:
  - Predict when (biomass) and where “impact” is *likely*
  - Predict when “impact” is NOT likely
- Scenario testing tool – Redesign, Relocate, Mitigate effects
- *A priori* assessment of potential impacts and effects on sensitive/critical habitats – new site *or* application to change
- Assessment of risk
- Targeted monitoring – reduced costs

DEPOMOD

Benefits of approach

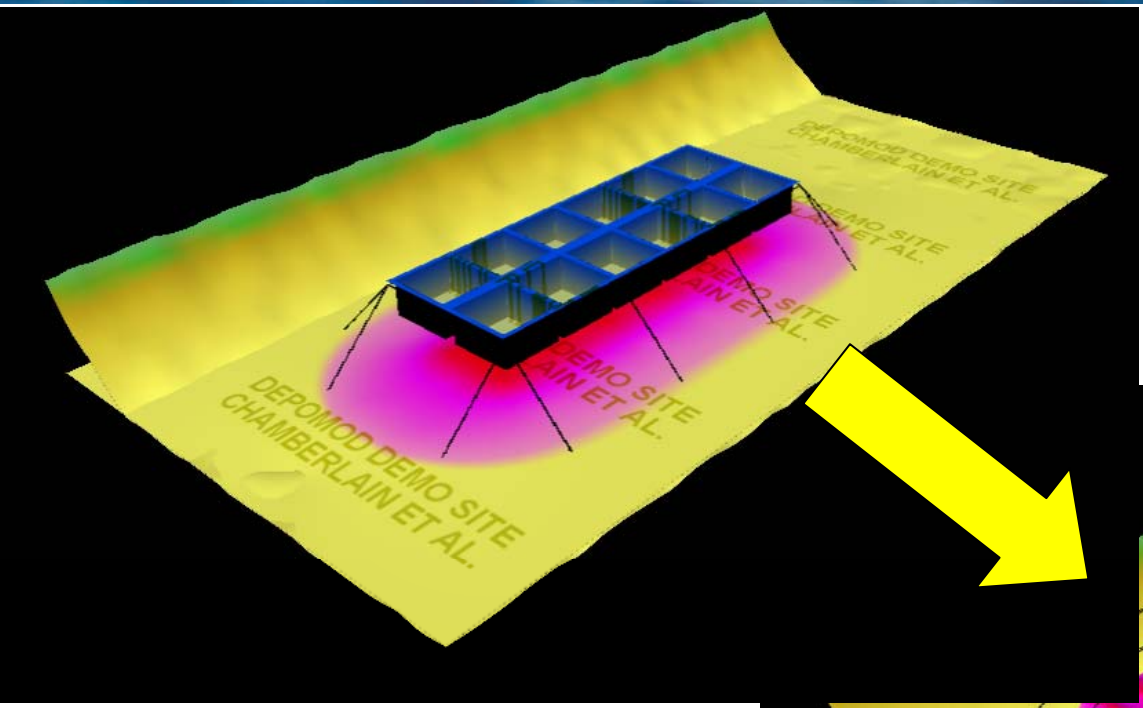


DEPOMOD can provide guidance on best location and management

DEPOMOD

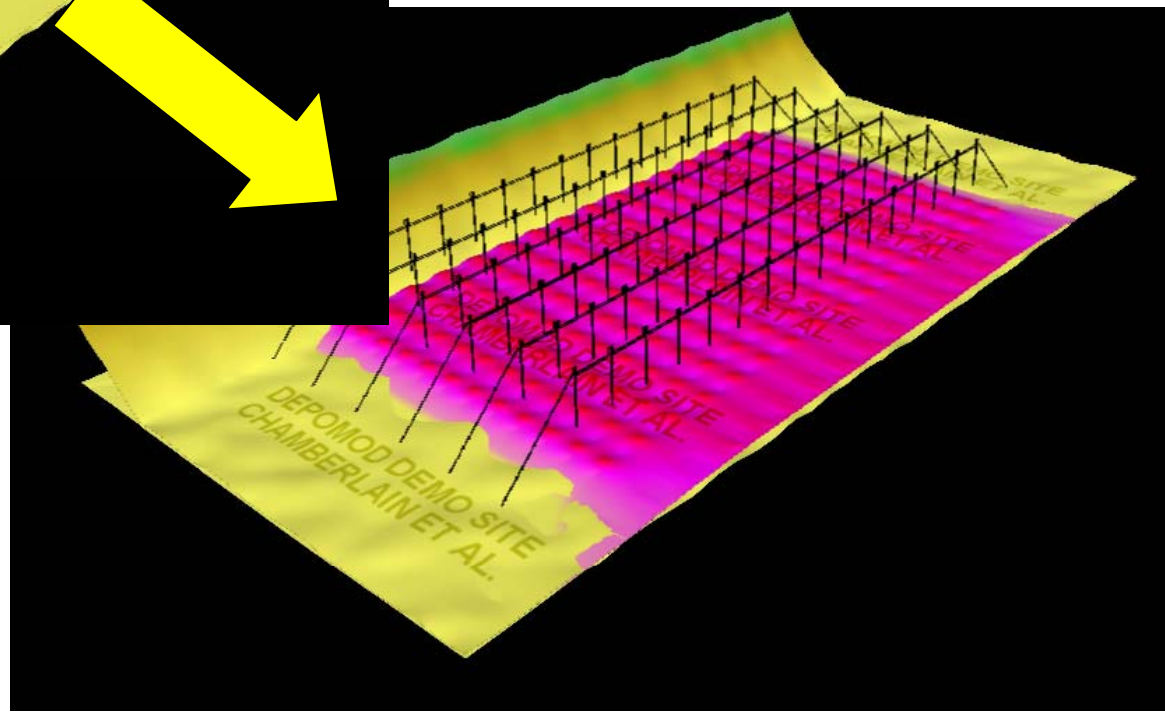
Drawbacks/Limitations of approach

- All models have assumptions and limitations
- Accuracy of predictions determined by suitability of model to test environment, model configuration and quality of input data
- Model validation for areas where it is being applied – always ongoing
- Small area modeled – mass balance issues
- Storm events - Shetland factor? - difficult to include
- Complex and Expensive? – relatively low
- Open to abuse? Requirement for auditing



Ongoing development..

Chamberlain et al 2006



Modeling approaches towards aquaculture management

- Potential utility of modeling tools in the regulation and management of aquaculture operations (Henderson et al 2001)
  - Indicators (or warning signs) for adaptive monitoring strategies
  - Descriptors of well understood processes
  - Tools for all sectors to achieve best practice [for sustainability]
  - Cost effective alternative to extensive field studies
  - Derive fast predictions of potential impacts
  - Aid in transition from reactive to proactive management

- Powerful information tools for all users to promote best practice and sustainable futures.

Acknowledgements

GOBIERNO DE CHILE
SUBSECRETARÍA DE PESCA

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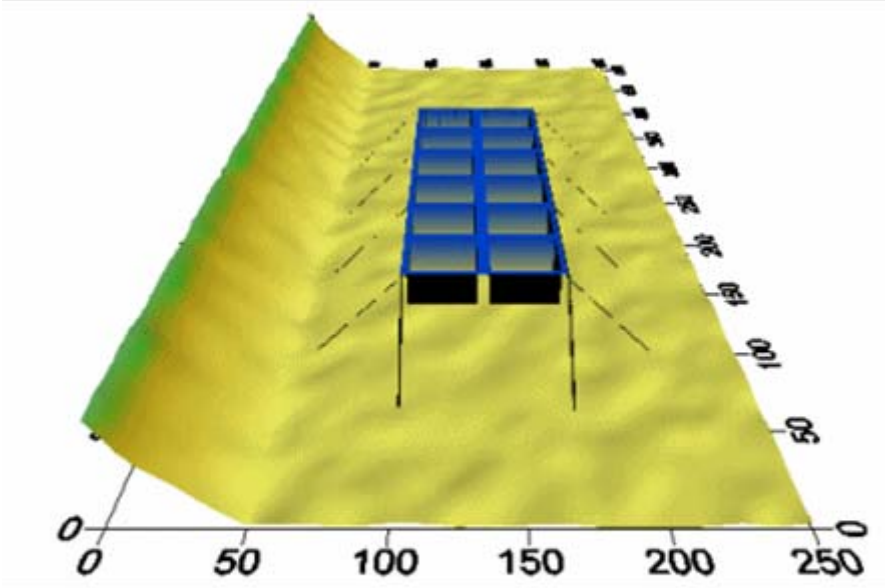
SAMS
SCOTTISH ASSOCIATION FOR MARINE SCIENCE




Canada