CAWTHRON

ICM COASTAL WORKSHOP

Modeling Update

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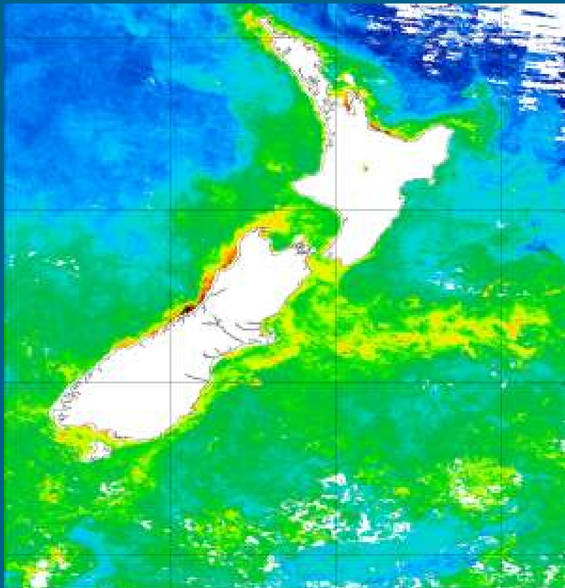
Topical Marine Themes in Tasman Bay

1. *Introduction/expansion of aquaculture*

2. *Performance of current fishery*

3. *Changing land-use effects on catchment*

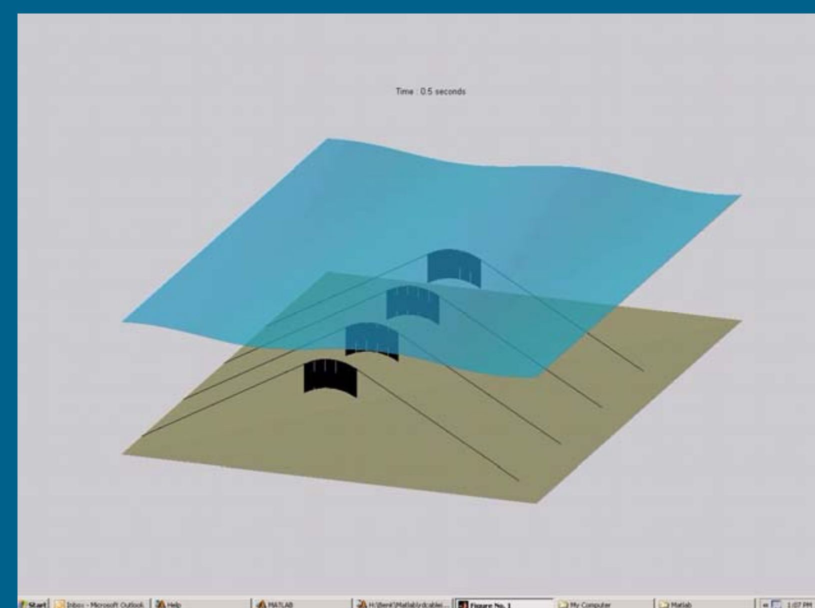
4. *Coastal erosion/accretion*



Questions We Have Addressed….

- *Carrying capacity of the Bay for aquaculture-is the proposed level sustainable?*

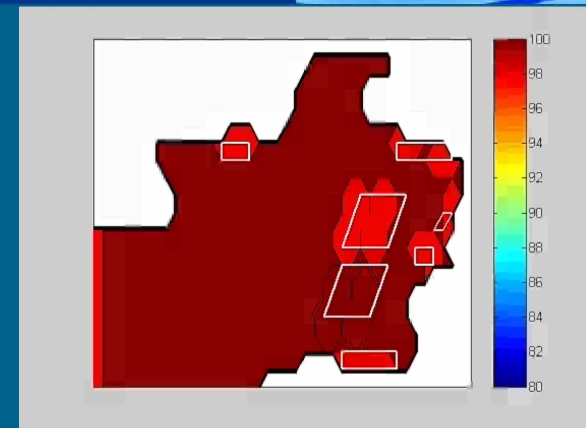
- *What is the scale of influence of the Motueka Plume?*



Aquaculture Carrying Capacity (Biophysical)

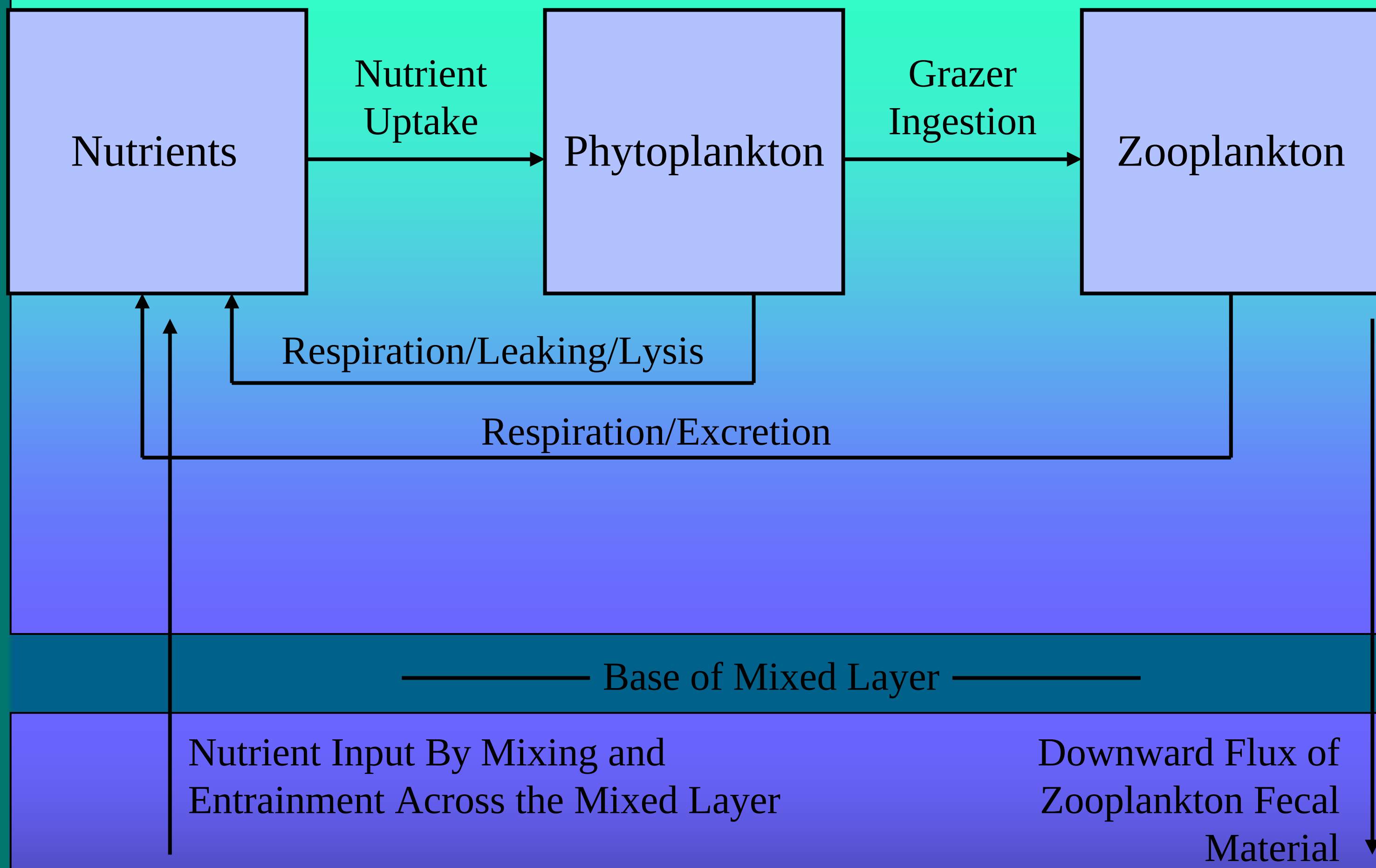
- Predicting carrying capacity not straightforward
- Predictions = model
- Several modeling options available

NPZ models



- Simulates nutrient and phytoplankton dynamics in space and time. Straightforward to include bivalve culture
- Obvious scientific way forward.
- Opportunity to learn a lot about the system

NPZ models


Nutrients
Nutrient Uptake
Phytoplankton
Grazer Ingestion
Zooplankton
Respiration/Leaking/Lysis
Respiration/Excretion
Base of Mixed Layer
Nutrient Input By Mixing and Entrainment Across the Mixed Layer
Downward Flux of Zooplankton Fecal Material

NPZ models

Marine Ecosystem Model of ***Evans & Parslow (1985)***

$$\frac{dM}{dt} = \zeta(t)$$

$$\frac{dN}{dt} = -\alpha(t)\left(\frac{N}{j+N} - r\right)P + \frac{m+\zeta^+}{M}(N_o - N)$$

$$\frac{dP}{dt} = \alpha(t)\left(\frac{N}{j+N} - r\right)P - \frac{c(P-P_o)}{K+P-P_o}H - \frac{m+\zeta^+}{M}P$$

$$\frac{dH}{dt} = f\frac{c(P-P_o)}{K+P-P_o}H - gH - \frac{\zeta}{M}H$$

M - Mixed Layer Depth
N - Nitrate Concentration
P - Phytoplankton Concentration
H - Herbivore (Zooplankton) Concentration

$\zeta = \zeta(t)$ rate of mixed layer deepening or shallowing
$\zeta^+ = \zeta(t)$ rate of mixed layer deepening
m = turbulent mixing rate

$\alpha = \alpha(t,M,P)$ low light photosynthetic rate
j = phytoplankton nutrient uptake half saturation
r = phytoplankton respiration rate

f = grazing efficiency
K = grazer half saturation
c = maximal grazing rate

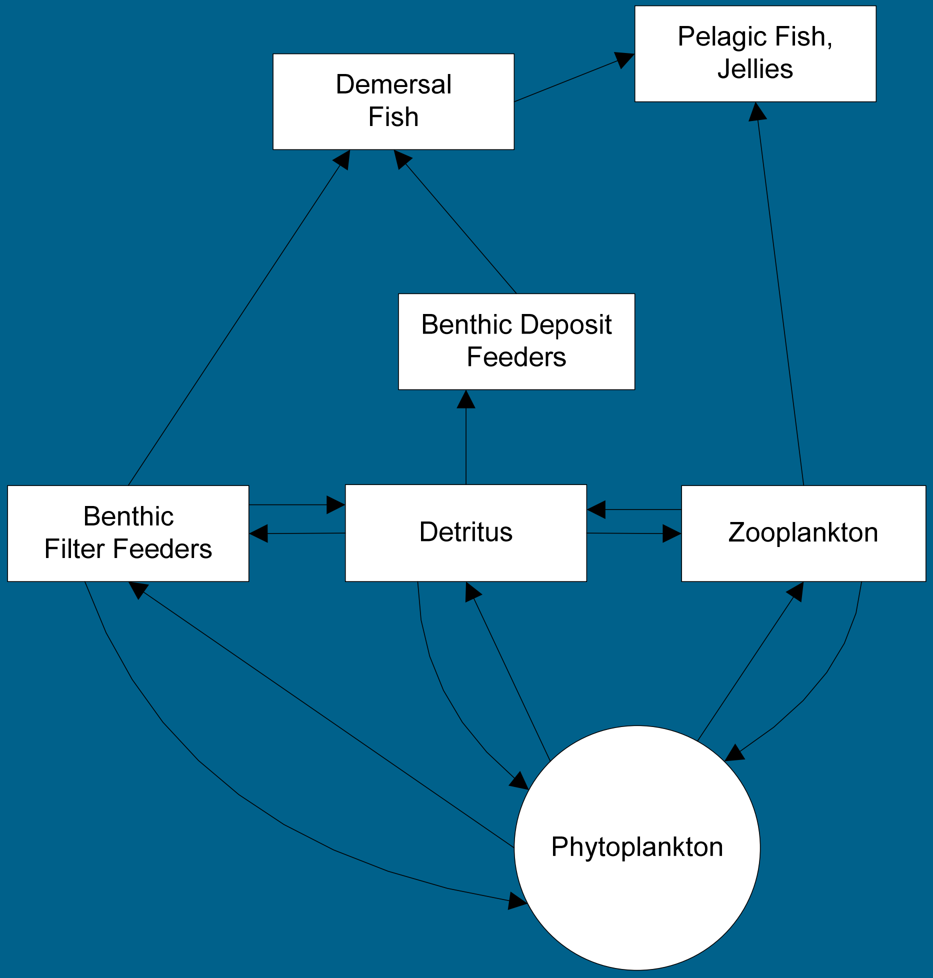
Growth efficiency, large zooplankton	Growth efficiency, large zooplankton
Growth efficiency, small zooplankton	Growth efficiency, small zooplankton
Half-saturation of SG N uptake in the sediment	Half-saturation of SG N uptake in the sediment
Half-saturation of SG P uptake in the sediment	Absorption coefficient of a PS cell
Linear mortality rate, large phytoplankton (in sediment)	Maximum growth rate of MPB at Tref
Linear mortality rate, small phytoplankton	Radius of the microphytobenthos cells
Linear mortality rate, macroalgae	Absorption coefficient of a MPB cell
Linear mortality rate, seagrass	Maximum growth rate of MA at Tref
Quadratic mortality rate, microphytobenthos	Nitrogen specific absorption cross-section of MA
Quadratic mortality rate, large zooplankton	Maximum growth rate of SG at Tref
Quadratic mortality rate, small zooplankton	Nitrogen specific absorption cross-section of SG
Fraction of large zooplankton growth inefficiency	Maximum growth rate of ZS at Tref
Fraction of large zooplankton mortality lost to detritus	Radius of the small zooplankton cells
Fraction of small zooplankton growth inefficiency	Swimming velocity for small zooplankton
Fraction of small zooplankton mortality lost to detritus	Maximum growth rate of ZL at Tref
Fraction of labile detritus converted to detritus	Radius of the large zooplankton cells
Fraction of labile detritus converted to DOM	Swimming velocity for large zooplankton
Sediment net respiration rate at which nitrification	Dissipation of turbulent kinetic energy in the water
Sediment net respiration rate of denitrification	Drag coefficient of the benthic surface
Max efficiency of the removal of N by nitrification	Velocity at the top of the benthic boundary layer
Ntrogen to Chlorophyll a ratio in phytoplankton	Sand-grain roughness of the benthos
Background light attenuation coefficient	Fraction of refractory detritus that breaks down
DON-specific light attenuation coefficient	Rate at which TSS flocculates above 10 PSU
Detrital N specific light attenuation coefficient	Rate at which P reaches ab/desorbed equilibrium
Secific light attenuation coefficient	Phosphate buffering capacity of sediment 26
Fraction of incident solar radiation that is PAR	Phosphate absorption coefficient 2
Temperature coefficient for rate parameters	Breakdown rate of labile detritus at 106:16:1
Maximum growth rate of PL at Tref	Breakdown rate of labile detritus at 550:30:1
Radius of the large phytoplankton cells	Breakdown rate of refractory detritus
Absorption coefficient of a PL cell	Breakdown rate of dissolved organic matter

Water-column interactions

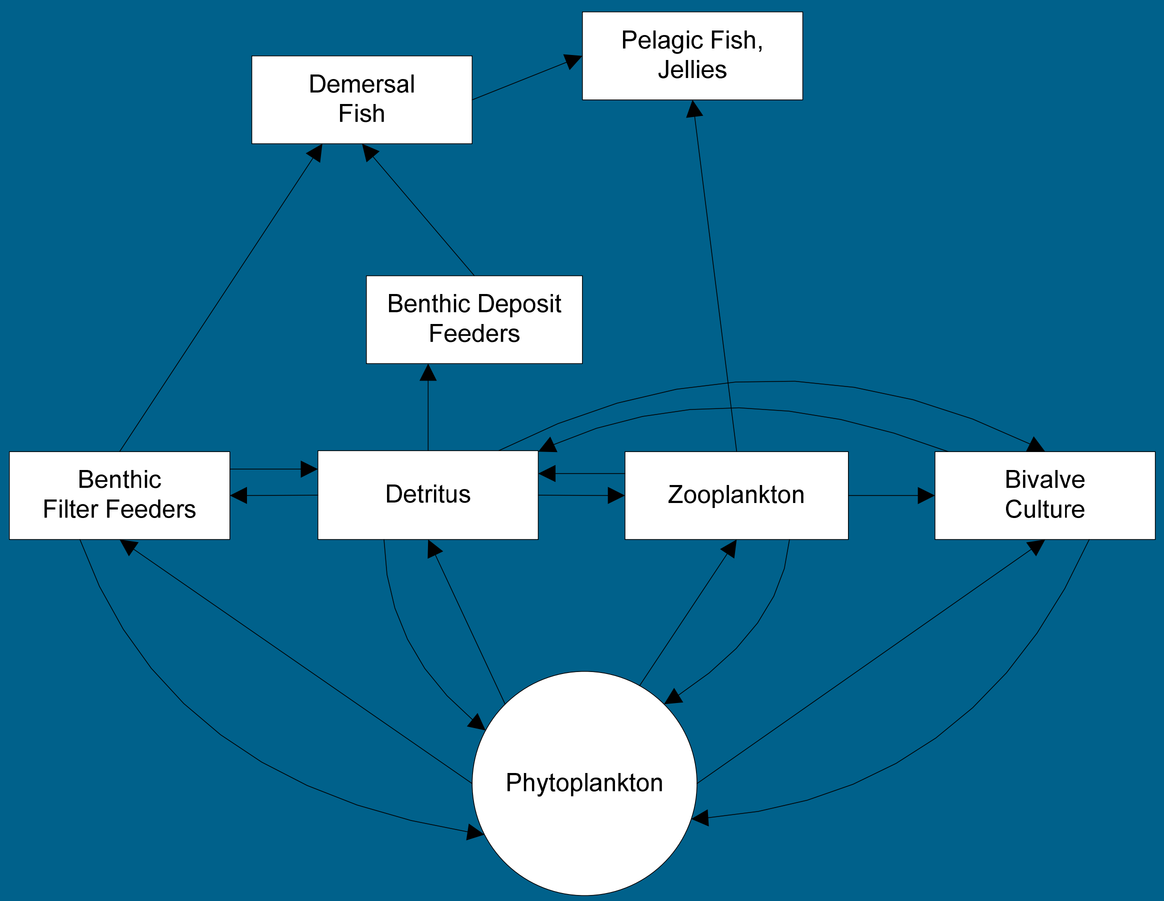
- Bivalve filter feeders extract suspended particulate matter from the water column.

- Production foregone and predation foregone

Water-column interactions



Water-column interactions



Theoretical production carrying capacity

The theoretical production carrying capacity occurs when the system collapses down to a culture-phytoplankton-detritus-nutrient system (Gibbs, 2004)

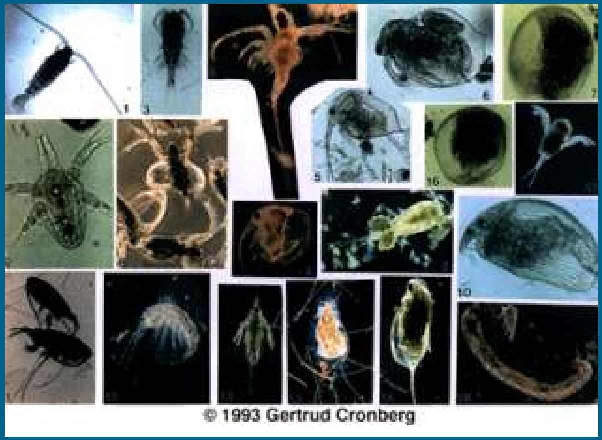
Thinking about fish: food web modeling

Attributes:

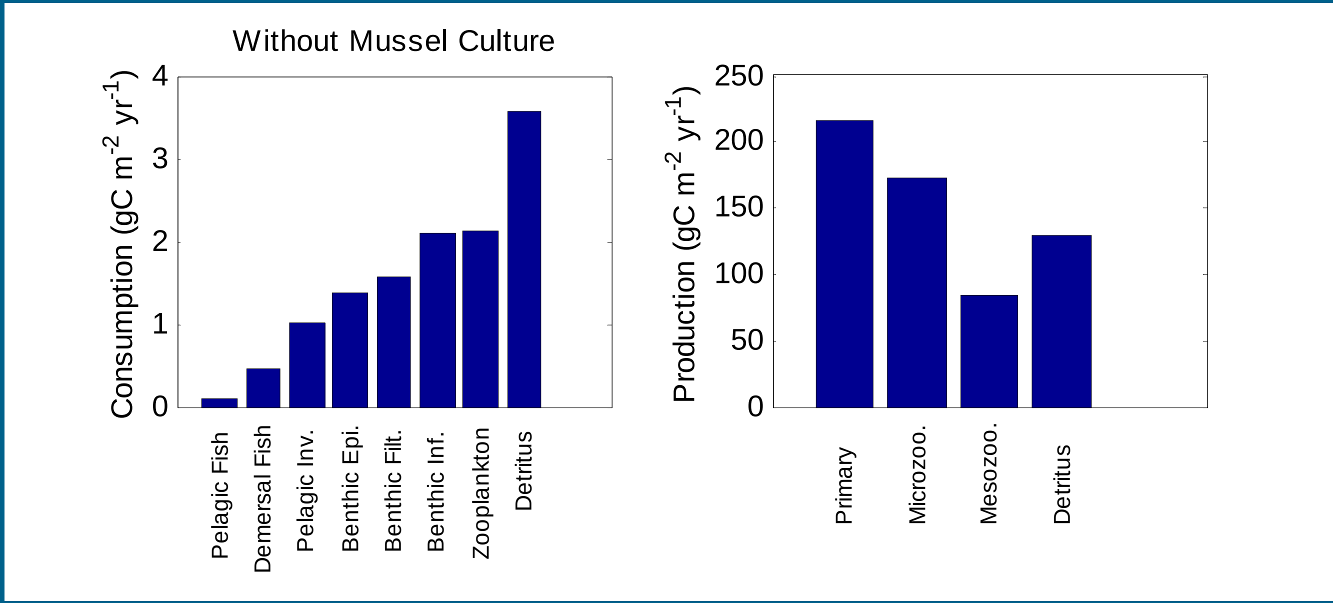
- Encompasses whole ecosystem
- Mostly equilibrium methods
- Not spatially explicit
- Data hungry (like NPZ models)
- Mathematically unrobust (like NPZ models)
- Does fish!

Using food webs to investigate carrying capacity

- Difficult to predict (model) exactly how system will respond after the culture is introduced,
- But, we can estimate theoretical production carrying capacity (boundary condition)

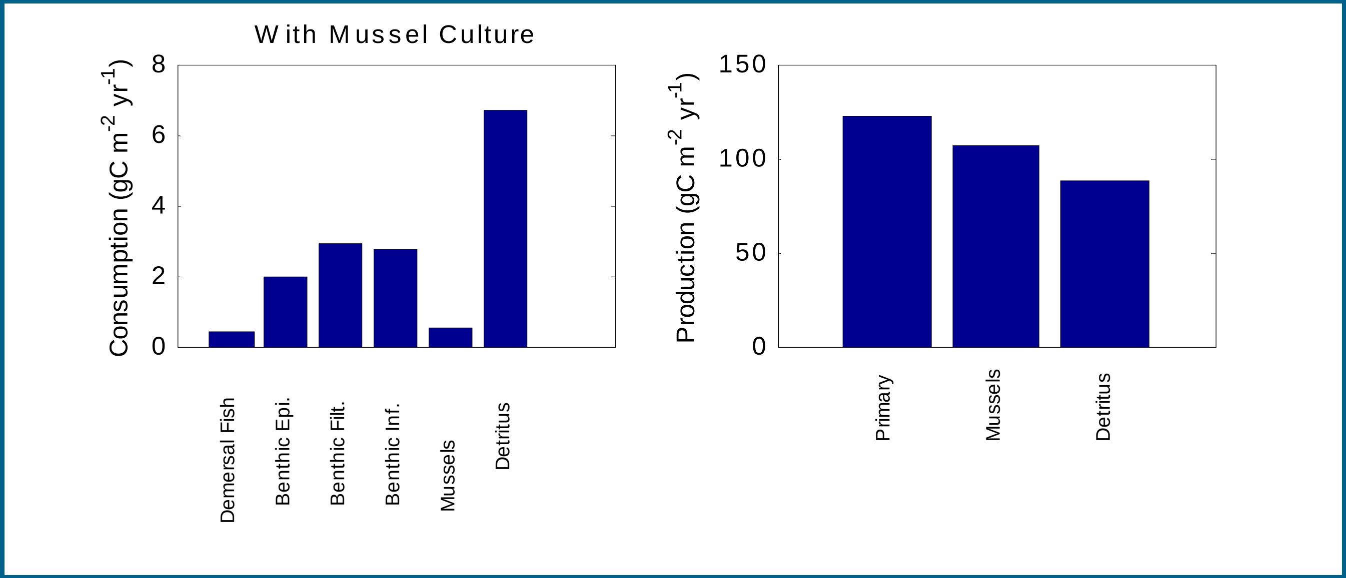


Results: Marlborough Sounds



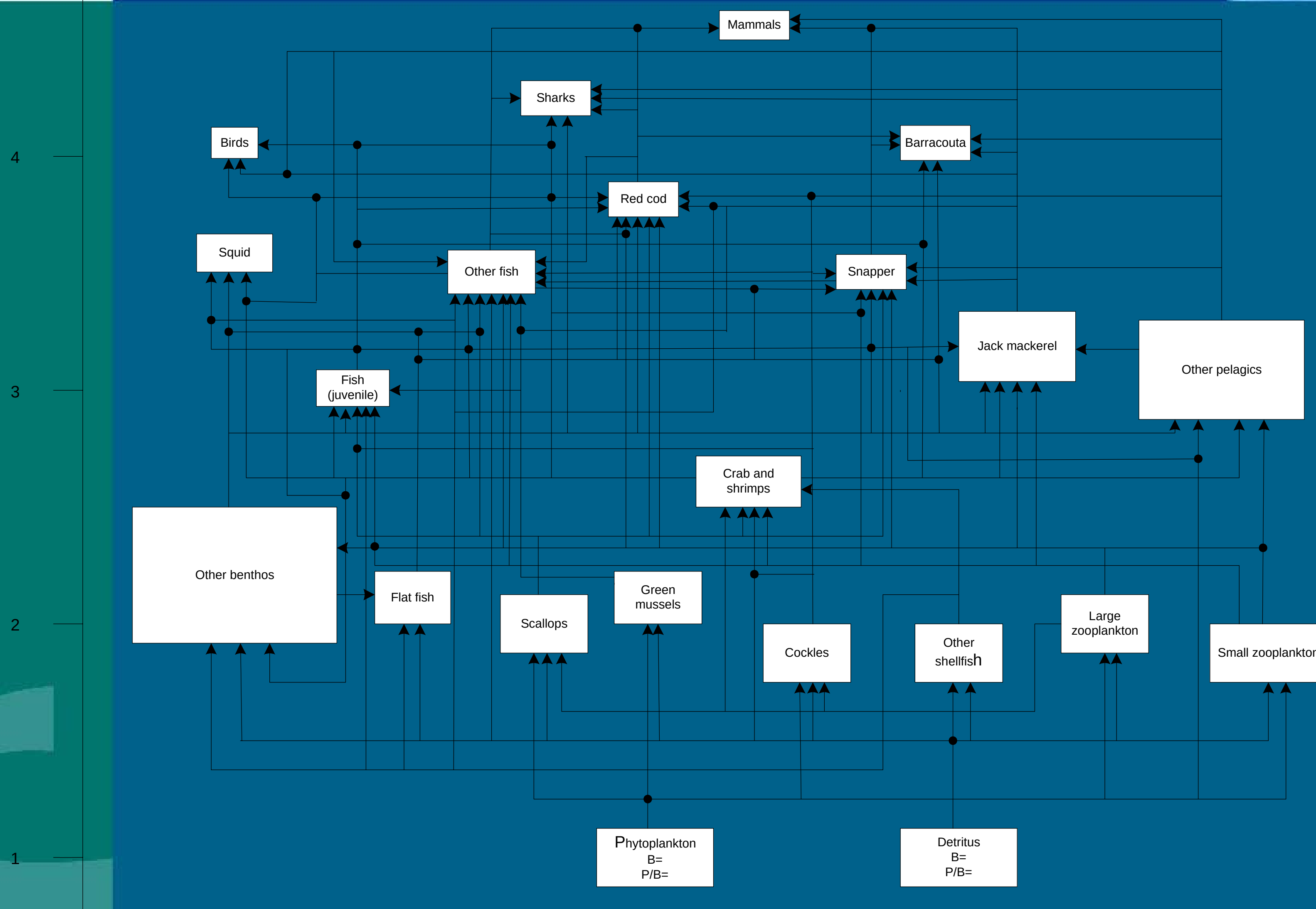
Gibbs (2004a) *Aquaculture*

Results: Marlborough Sounds

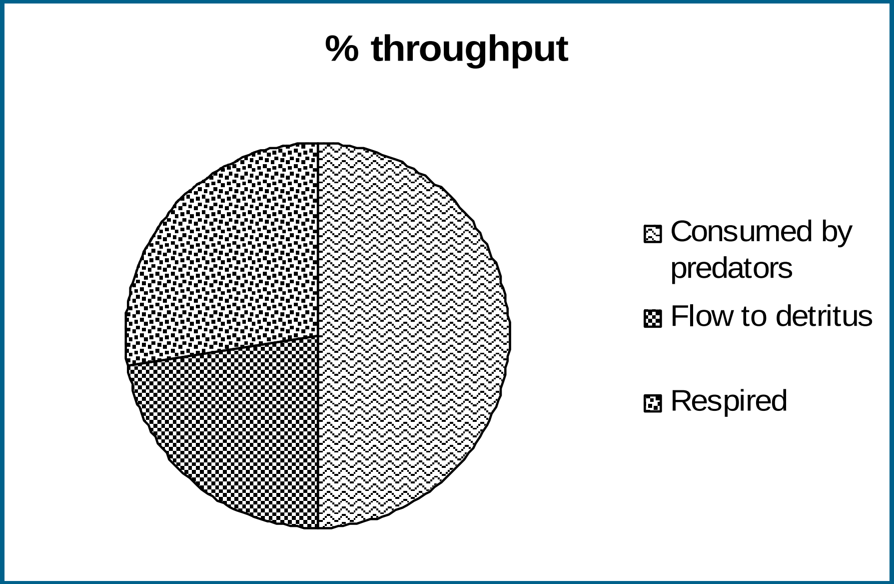


- Replacing zooplankton with mussels would result in a production yield of 20 000 t
- The present yield is around 5 000 t

Results: Tasman/Golden Bays



Results: Tasman/Golden bays



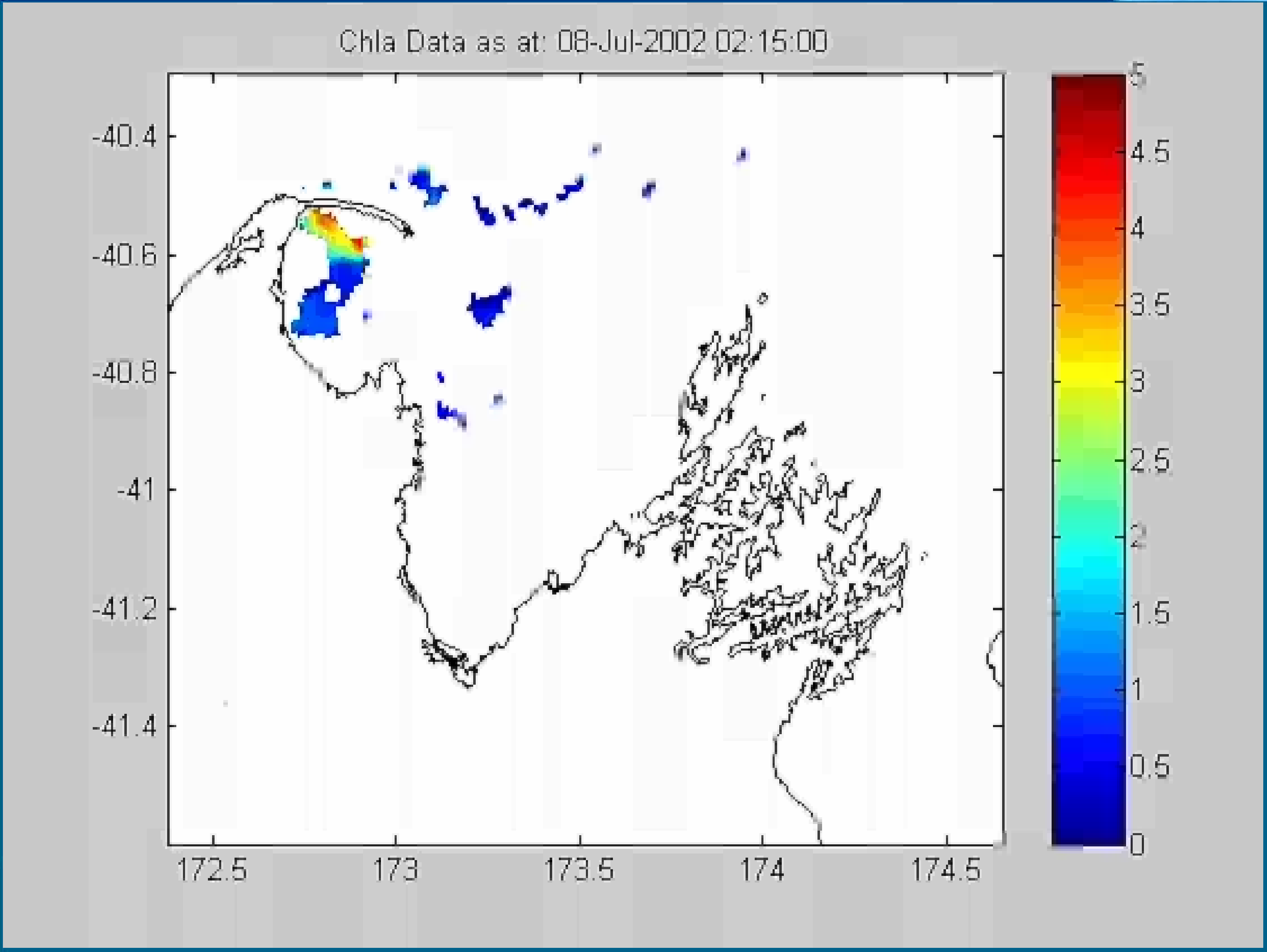
- Production carrying capacity possibly 310 t/km^2
- Ecological carrying capacity possibly 65 t/km^2

Jiang and Gibbs (2005)

Results: Tasman/Golden bays

- The mean trophic level of the ecosystem decreases
- The total yield (wetfish and shellfish) increases (normative but not equitable?)
- Efficiency of the foodweb increases

Extent of Influence of Motueka Plume



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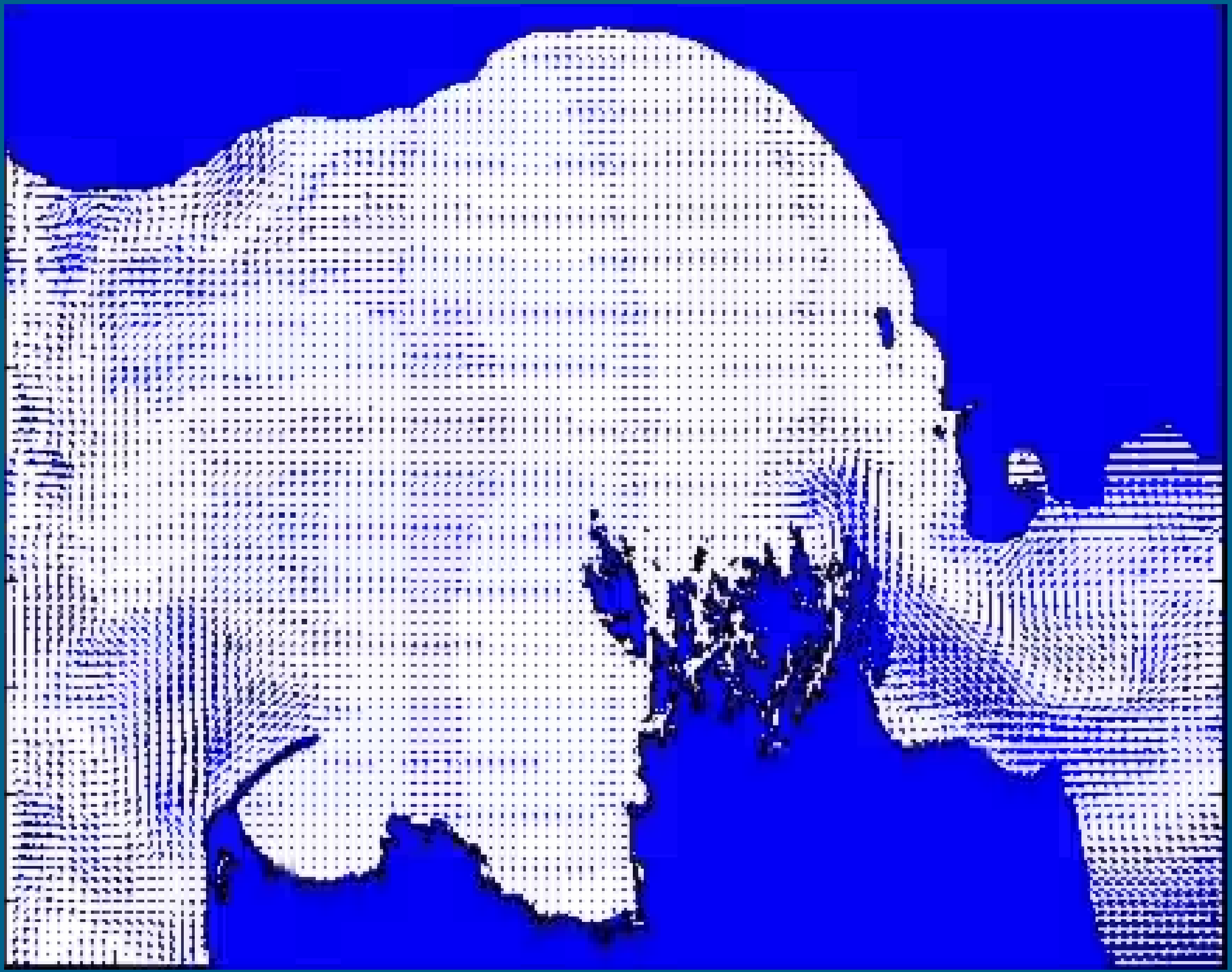

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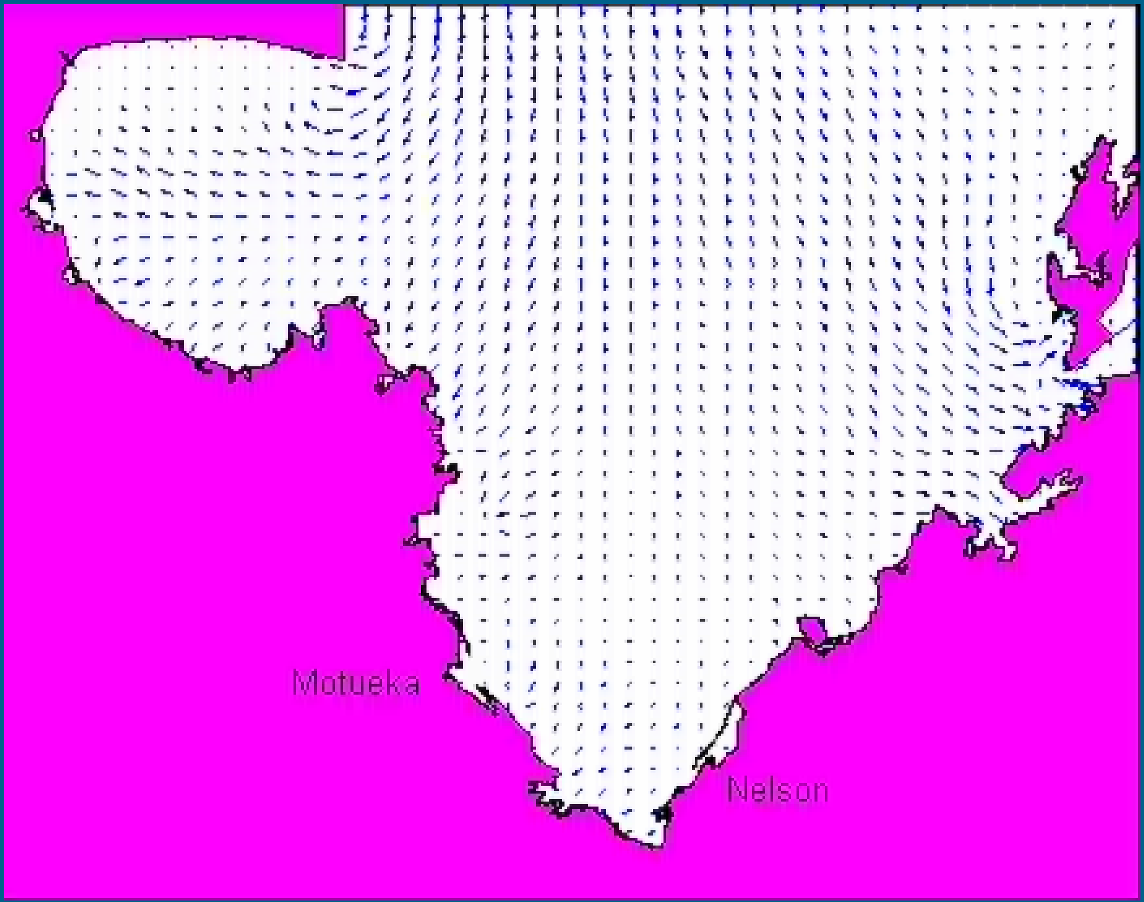

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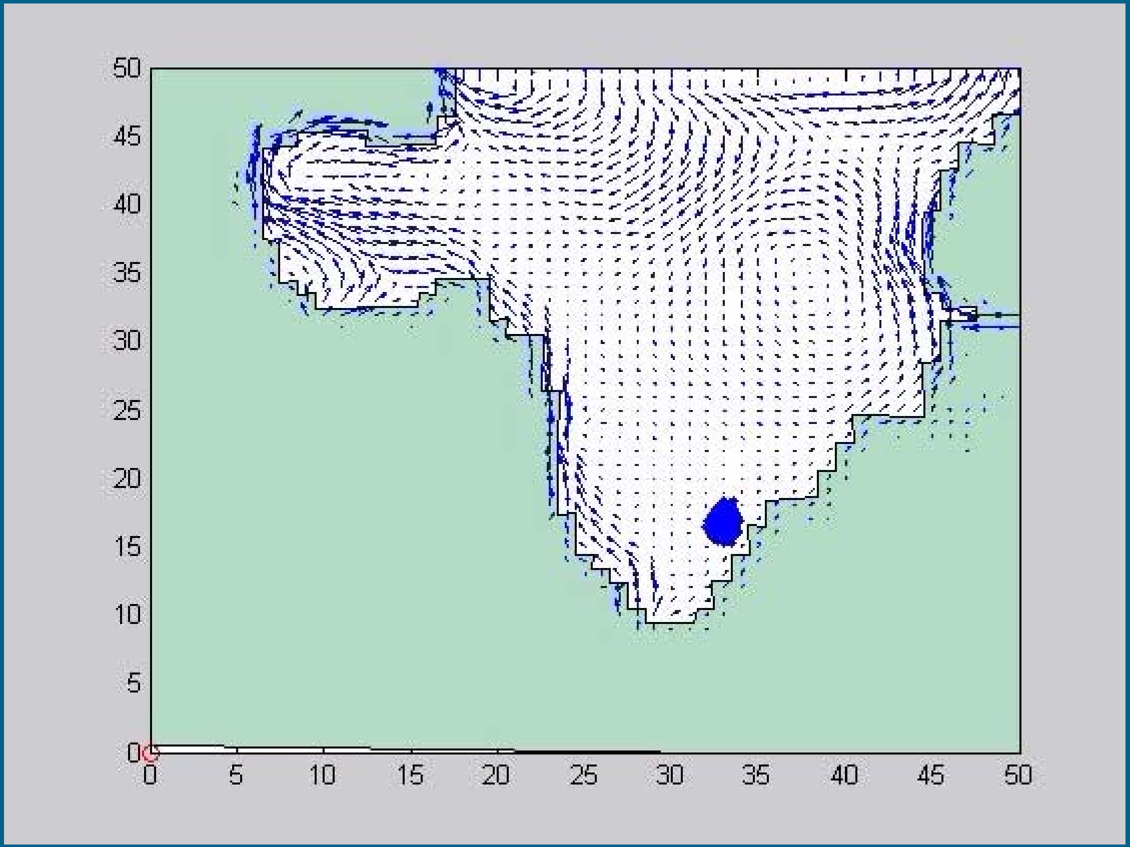

Extent of Influence of Motueka Plume