Biophysical Modelling of Sea Lice in the Broughton Archipelago, B.C.

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Funding and Support

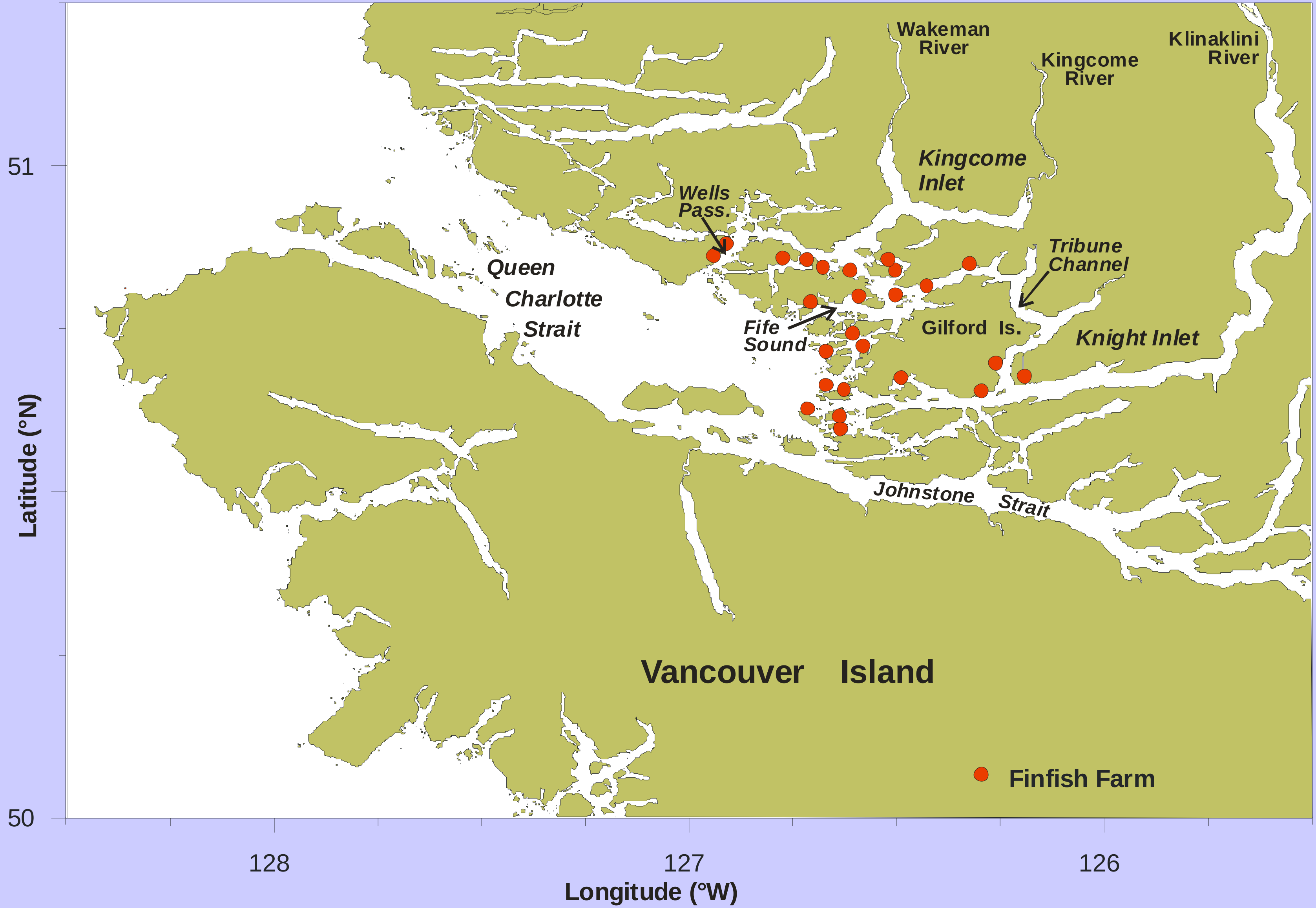
B.C. Pacific Salmon Forum
Marine Harvest Canada

IOS

Fisheries and Oceans Canada   Pêches et Océans Canada

Outline

- **Background**
- **Finite Volume Coastal Ocean Model (FVCOM)**
  - *- setup*
  - *- forcing (tides, runoff and winds)*
  - *- evaluation*
- **Sea Lice Models**
  - *i) farm lice production*
  - *ii) development, mortality and behaviour of planktonic stages*
- **Particle tracking simulations (March-April 2008)**
  - *- comparison with plankton sampling data*
  - *- single farm simulations*
- **Summary/Future Work**



- 26 finfish farm tenures in the Broughton Archipelago
- In 2002, Broughton farms produced about 20,000 tonnes of Atlantic salmon or about 25% of BC farmed salmon production

Sea Lice Controversy

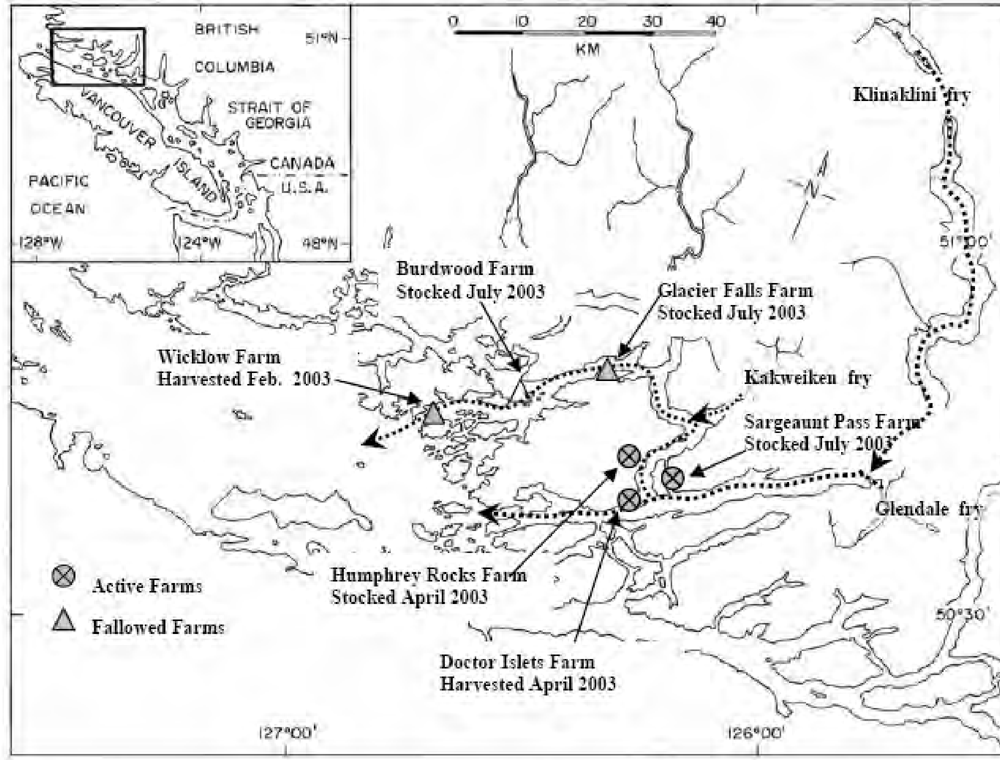
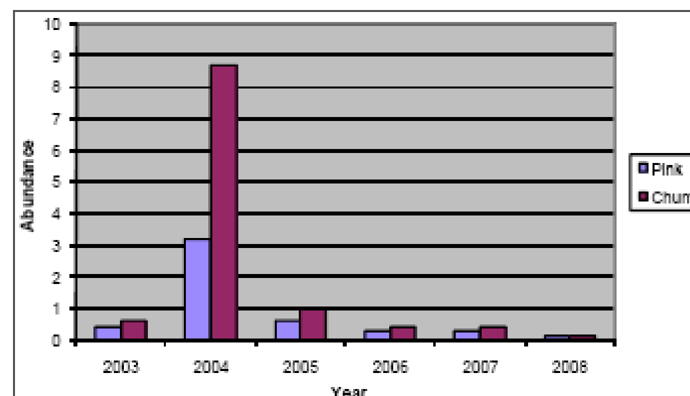


Figure 5. Broughton Archipelago showing two possible migration paths taken by pink salmon fry (dashed lines) and the location of three active salmon farms (Doctor Islets, Sargeaunt Pass and Humphrey Rocks) together with three inactive farms (Glacier Falls, Burdwood and Wicklow).

BC Pacific Salmon Forum recommendation:

No more than 3% of juvenile wild pink & chum salmon of less than 0.5 grams should have more than one pre-adult or later stage L. salmonis between March 1 and May 31.

Figure 3 Sea lice abundance on out-migrating juvenile salmon in the Broughton Archipelago 2003-2008

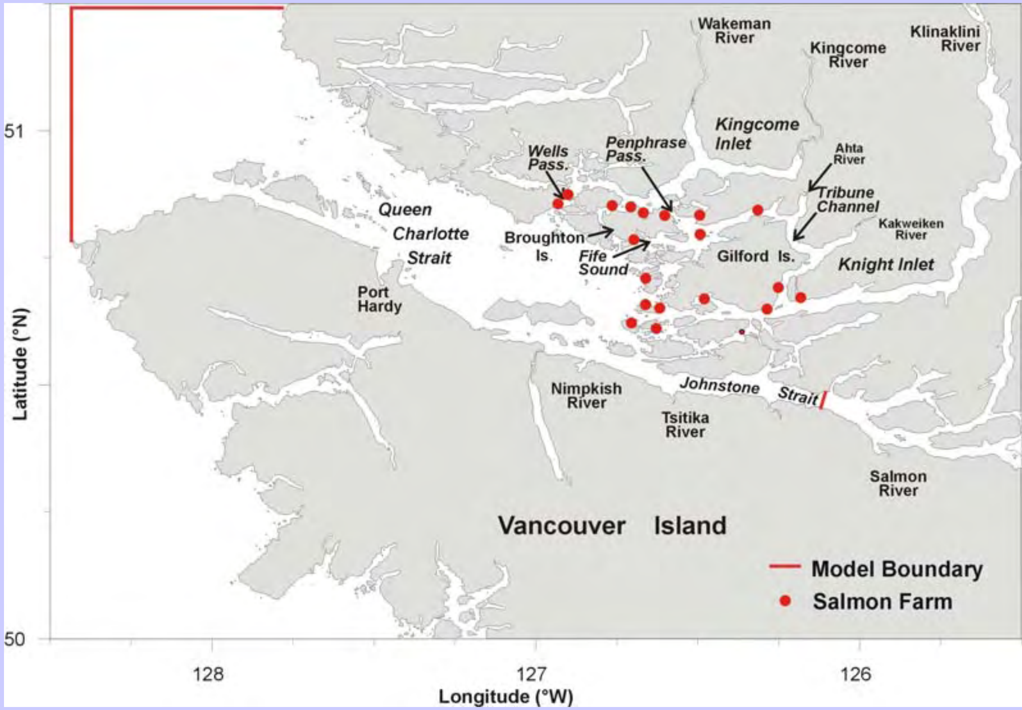


Source: DFO Interim Sea Lice Monitoring Data

Project Objectives

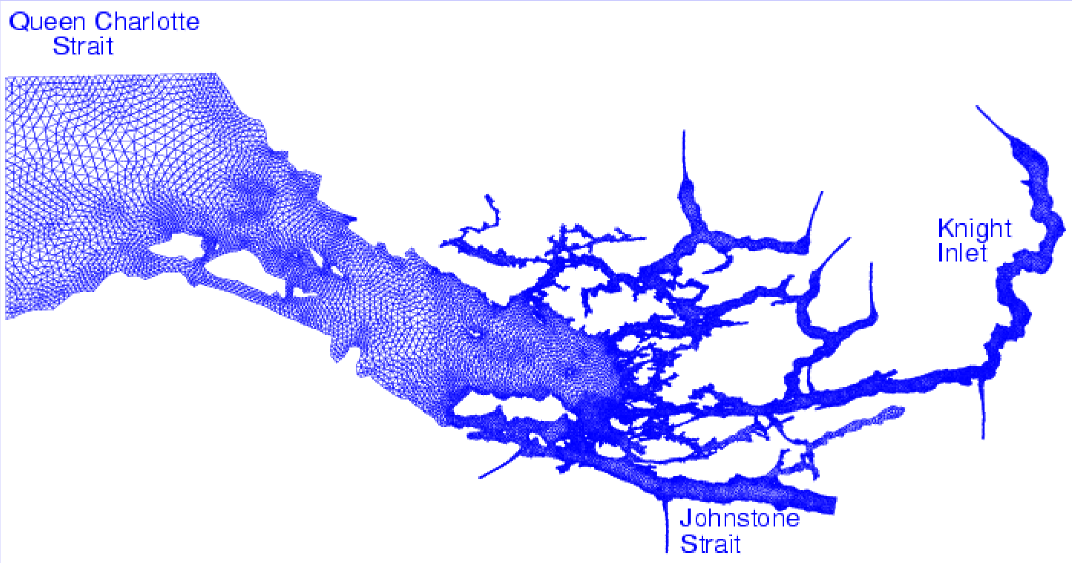
- *Create biophysical models to simulate the production, development, behaviour, and transport of sea lice in the Broughton Archipelago*

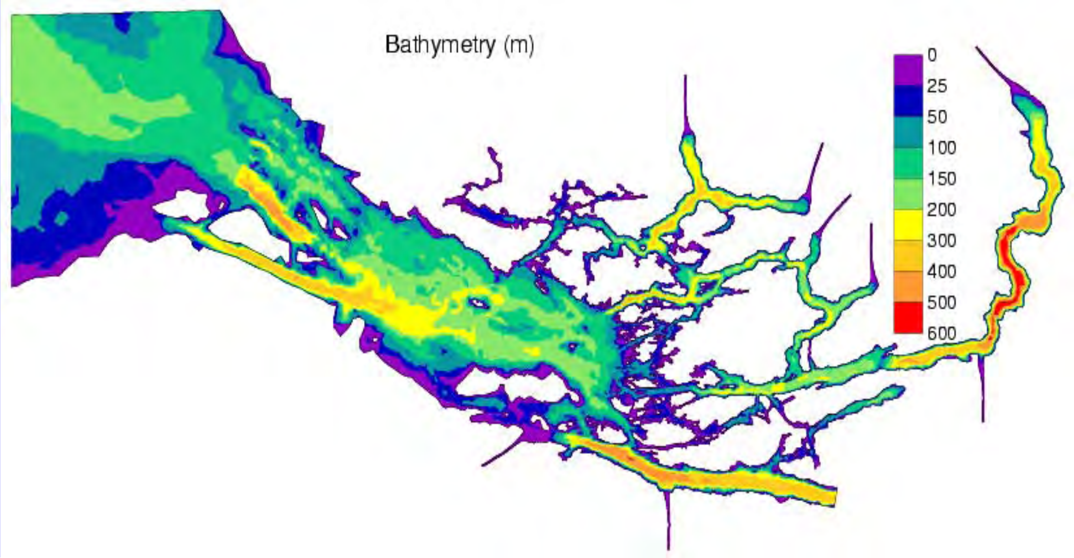
- *Use the models to:*
  - *- hindcast lice concentrations*
  - *- investigate farm management strategies*
  - *- understand sea lice dynamics in the Broughton Archipelago*



Finite Volume Coastal Ocean Model (FVCOM): Grid & Forcing Details

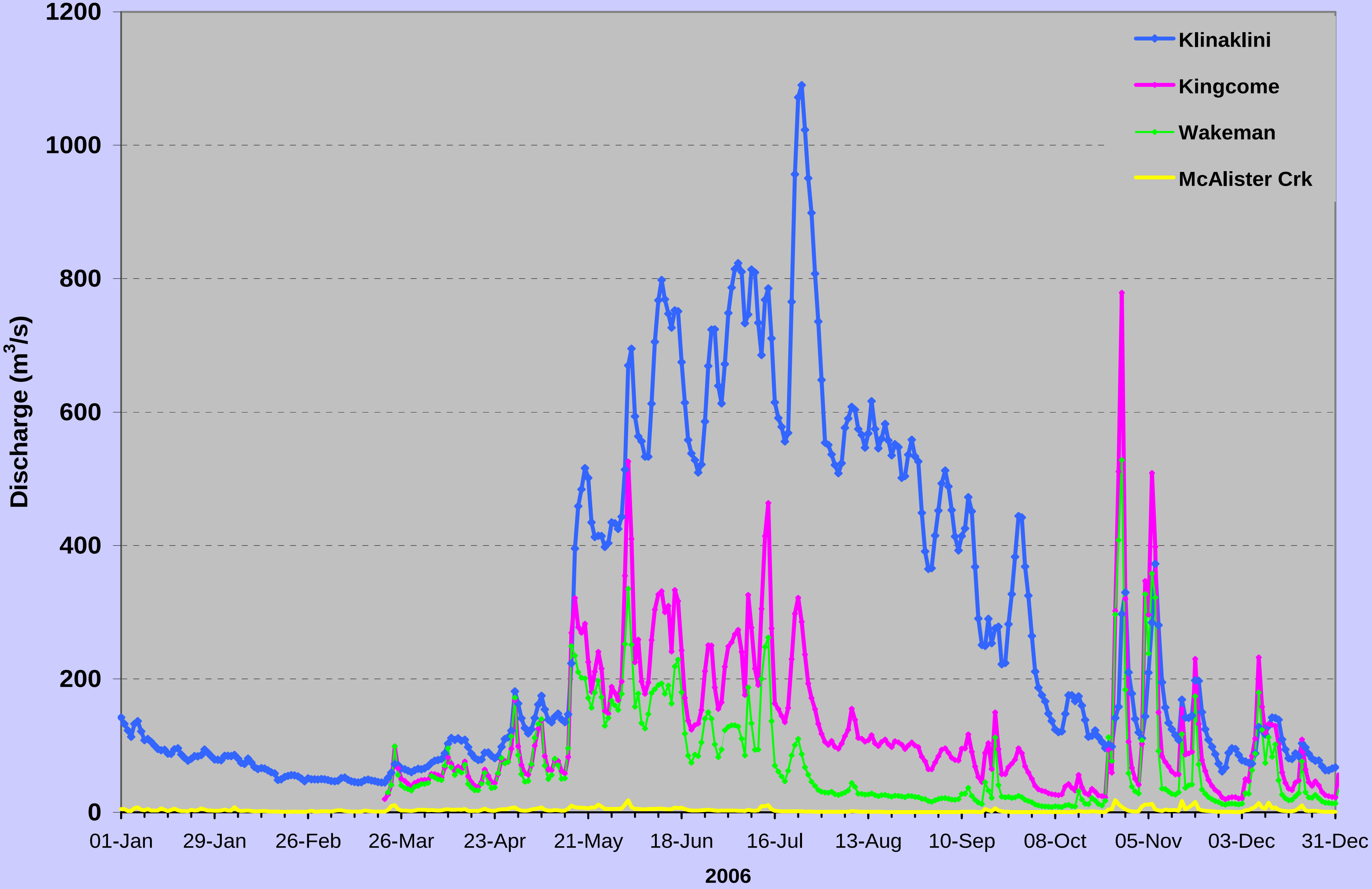
- ~ 43,000 nodes, ~ 75,000 triangular grid elements
- Horizontal resolution: ~ 3km to 50m
- Vertical resolution: 20 sigma-surfaces
- Bathymetry from single & multi-beam surveys
- Tidal forcing at the open boundaries (M_2, S_2, N_2, K_1, O_1 & P_1)
- Freshwater discharges from 8 rivers
- Local wind forcing (9 locations)
- No surface heat flux





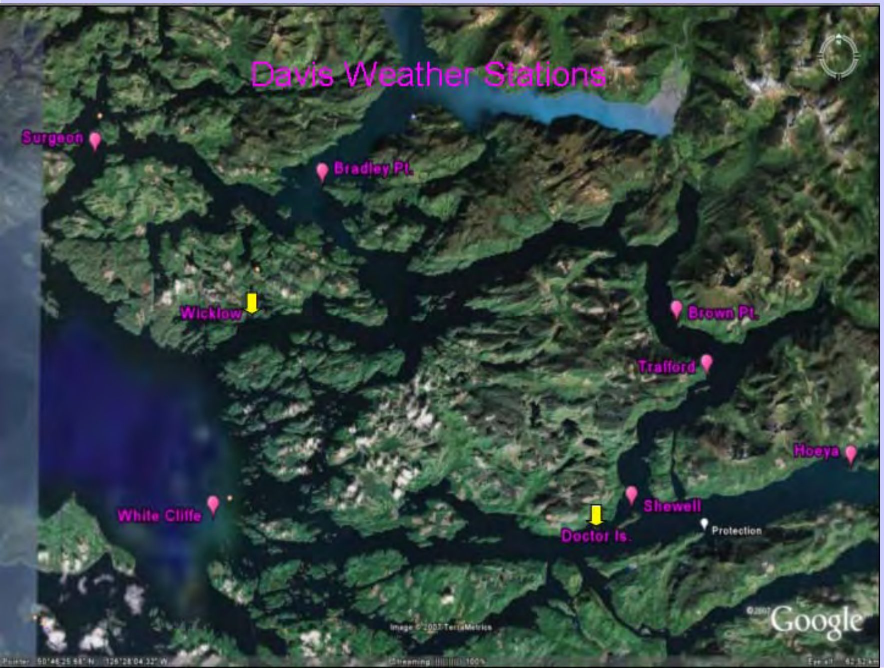
Active River Gauging Stations

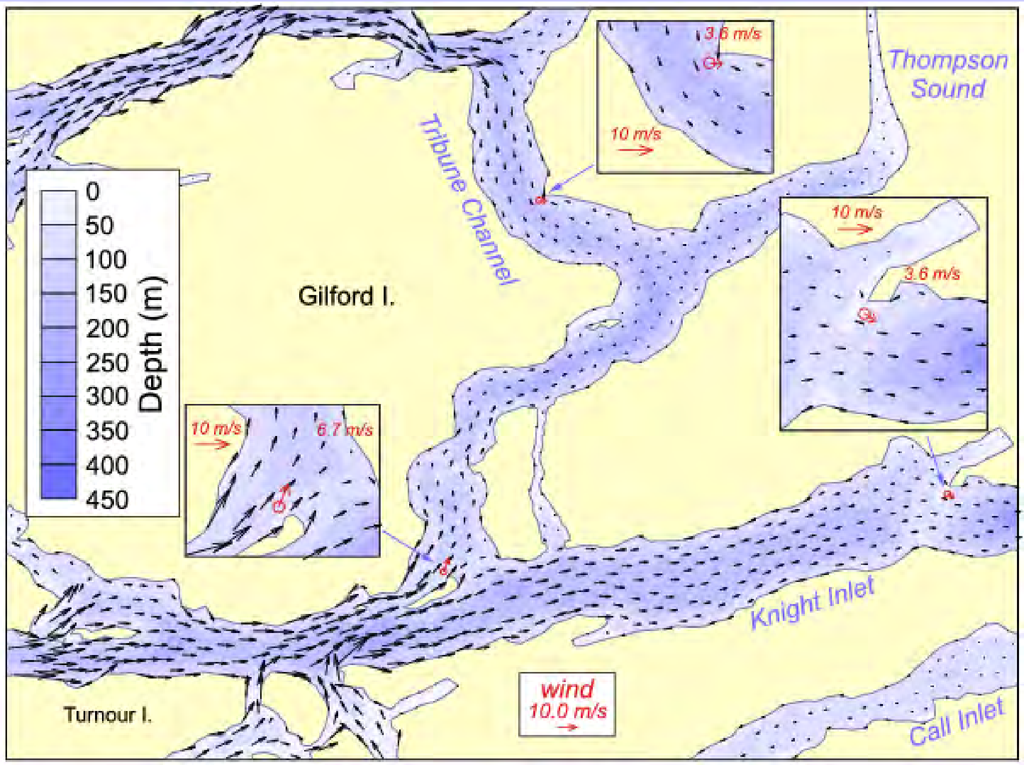
River Discharge



Atmospheric Forcing

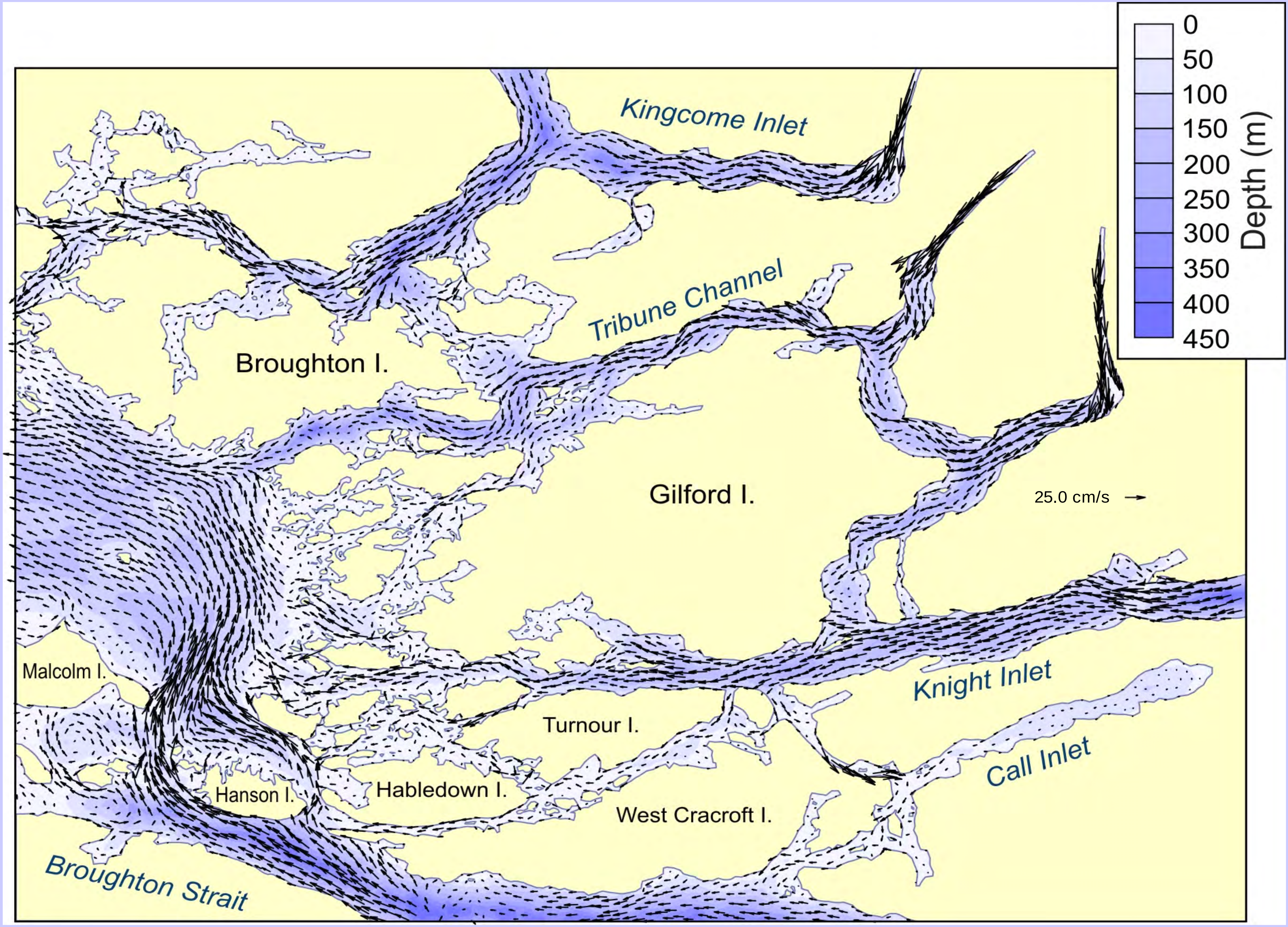
- *No atmospheric meteorological model & terrain too mountainous to interpolate winds from nearest airport (Port Hardy)*
- *Installed 9 weather stations in May 2007*
- *Winds recorded every 30min (when working)*
- *Winds interpolated to model elements via Bennett's (1992, 2002) "representer" data assimilation approach*





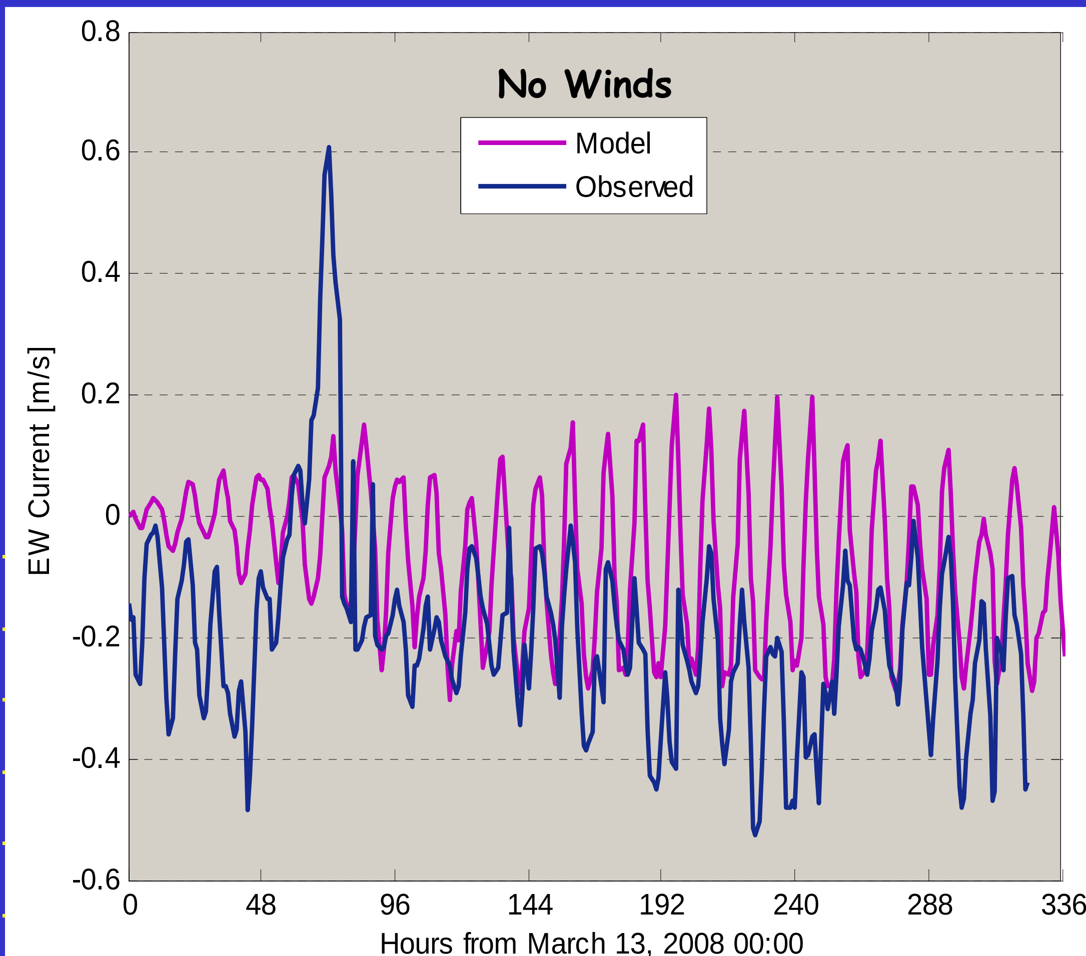
Sample wind field

Average surface flows: March 13 – April 3, 2008



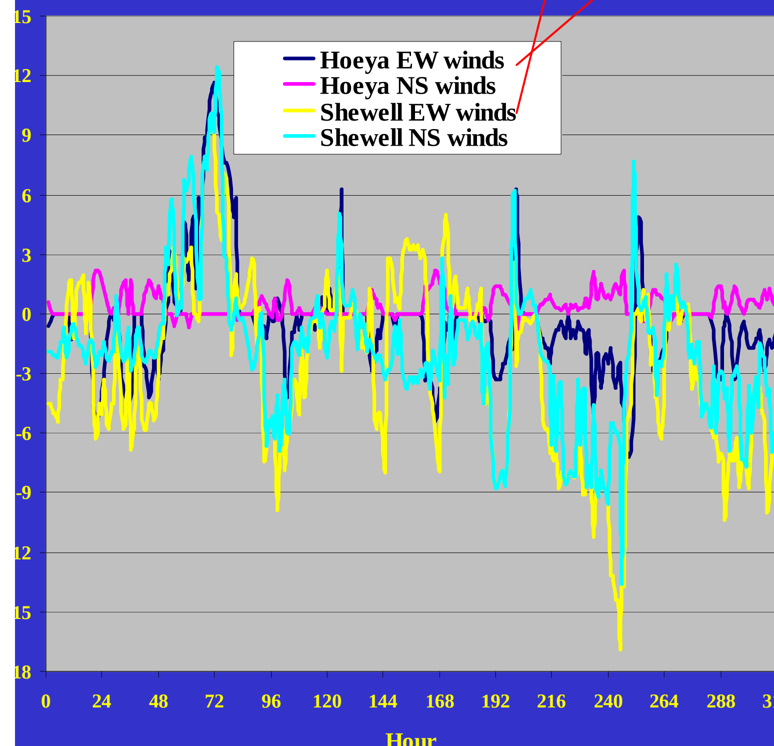
Comparisons at KIW05
March 13-25

KIW05 EW currents at 4.5m

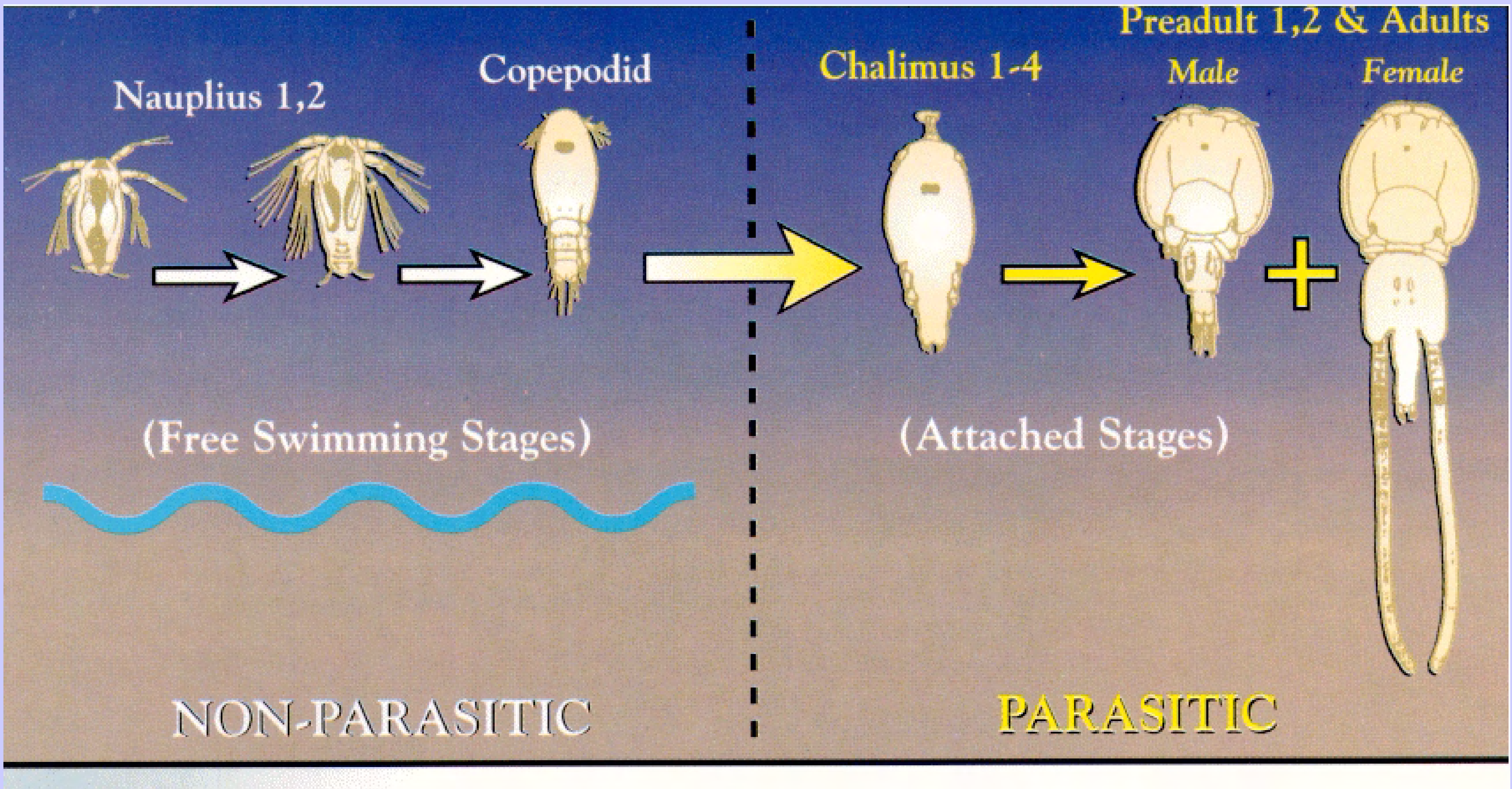


speed (m/s)

Hour



PLANKTONIC CHALIMUS MOBILE



Life cycle (Lepeophtheirus salmonis)

Sea Lice Model

Calculation of Sea Lice (L. salmonis) Egg Production

$$P_E = P_S * E_S * \rho_E$$

Where

P_E is the rate of viable egg production (i.e. produce active nauplii) of an adult female louse [eggs/day]

P_S is the rate of egg string production [egg string pairs/day]
- temperature dependent (Stien et al. 2005)

E_S is the number of eggs per egg string pair
- 580 eggs/string pair – unpublished data from salmon farms in the Broughton

ρ_E is the proportion of viable eggs (i.e. produce active nauplii)
- salinity dependent

Salinity	ρ_E (Johnson & Albright 1991)
<15	0
20	0.2
25	0.51
30	0.55

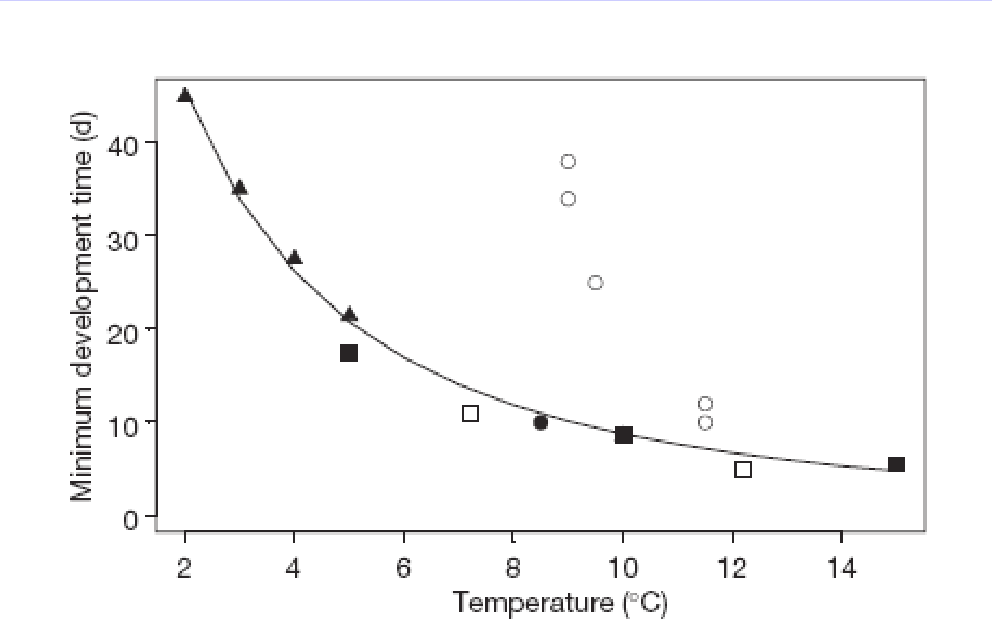
Rate of egg string production [egg string pairs/day]

$$P_S = [\beta_1/(T-10 + \beta_1\beta_2)]^{-2}$$ (Belehradek's function)

Where

T is temperature and

β_1 and β_2 are parameter determined from the best fit to the data in the graph below.



Minimum egg development times to hatching (Stien et al. 2005)

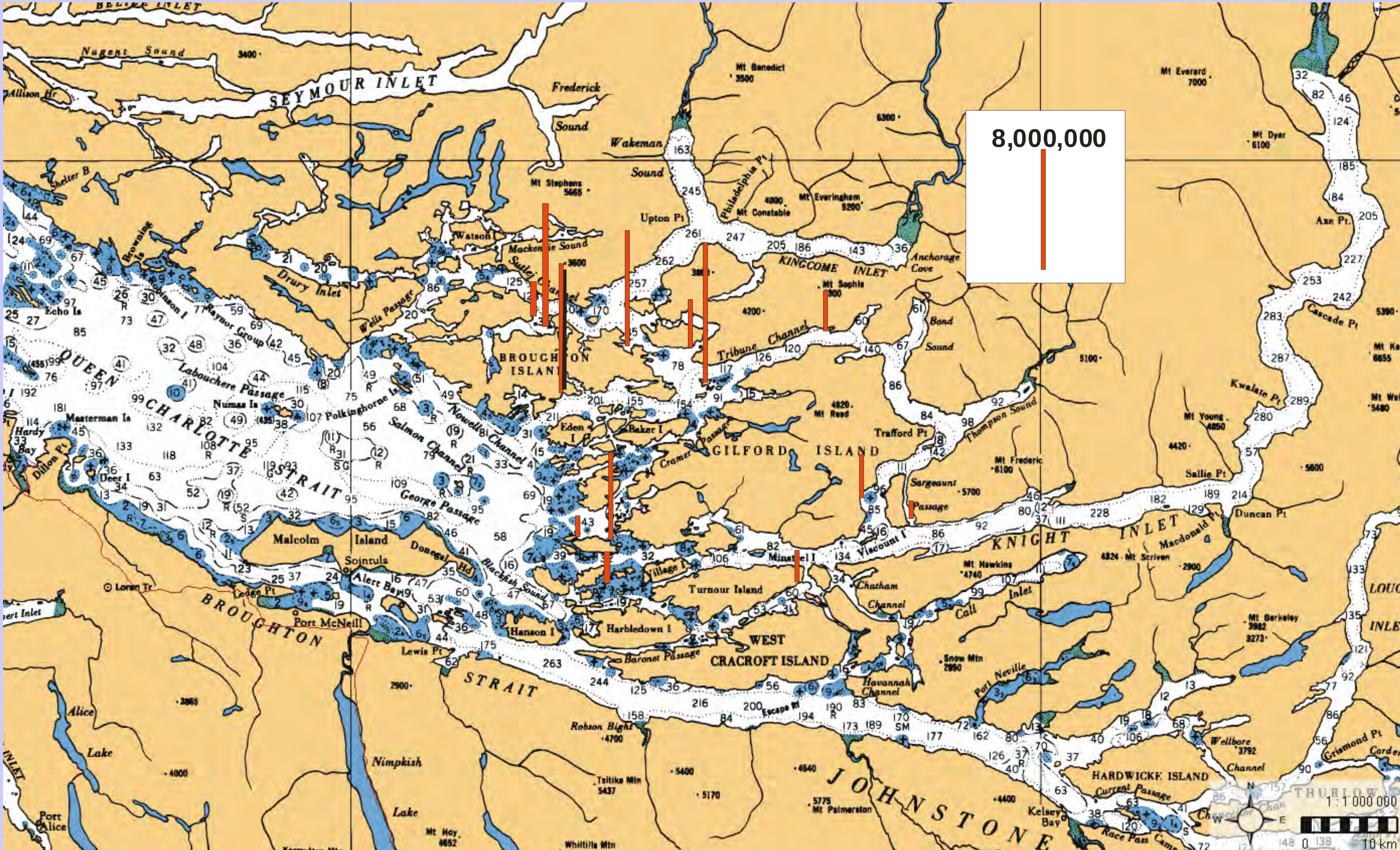
Farm Production of Active Nauplii

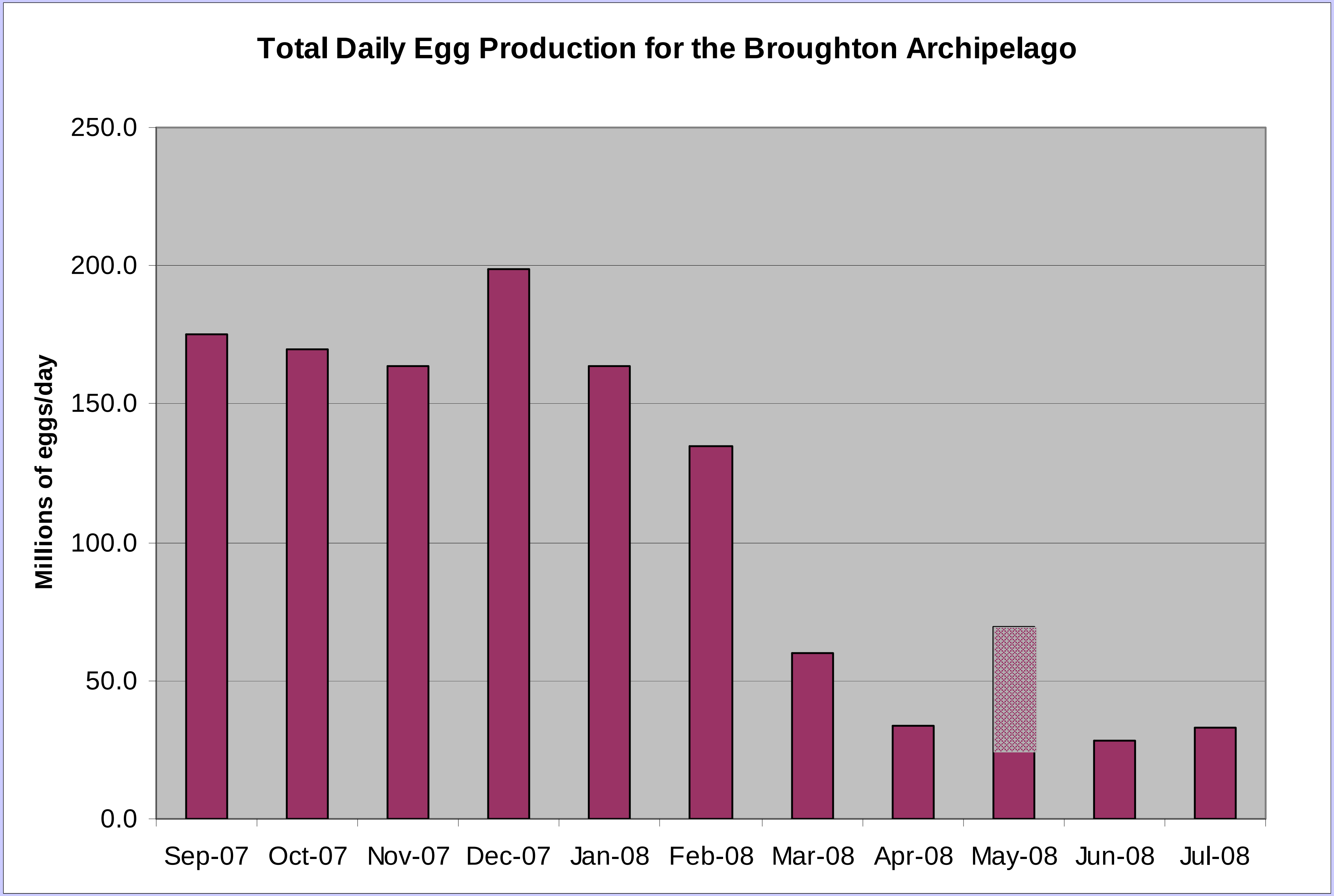
$$T_N = P_E * C_{AF} * N_{Fish}$$

Where

T_N	is the farm's daily production of active nauplii
P_E	is rate of viable egg production (i.e. active nauplii) of an adult female louse [eggs/female-day]
C_{AF}	is the average number of adult females/farm fish (farm monitoring data based on sampling of 60 fish)
N_{Fish}	is the number of fish on the farm (fish inventory provided by farm)

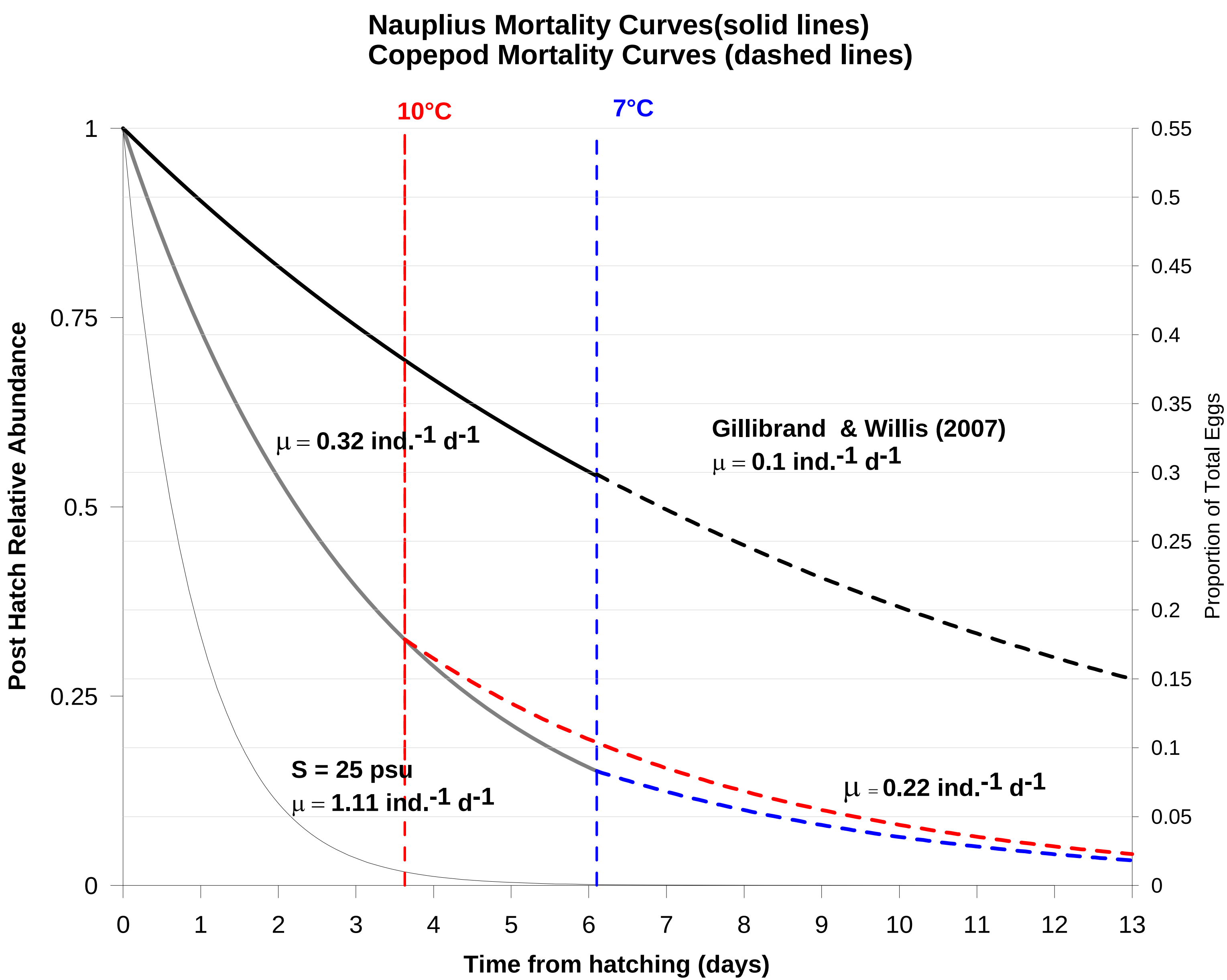
March 2008
Daily Egg Production at Farm sites




Total Daily Egg Production for the Broughton Archipelago
Millions of eggs/day
250.0
200.0
150.0
100.0
50.0
0.0
Sep-07
Oct-07
Nov-07
Dec-07
Jan-08
Feb-08
Mar-08
Apr-08
May-08
Jun-08
Jul-08

Development, Mortality and Behaviour of Planktonic Stages

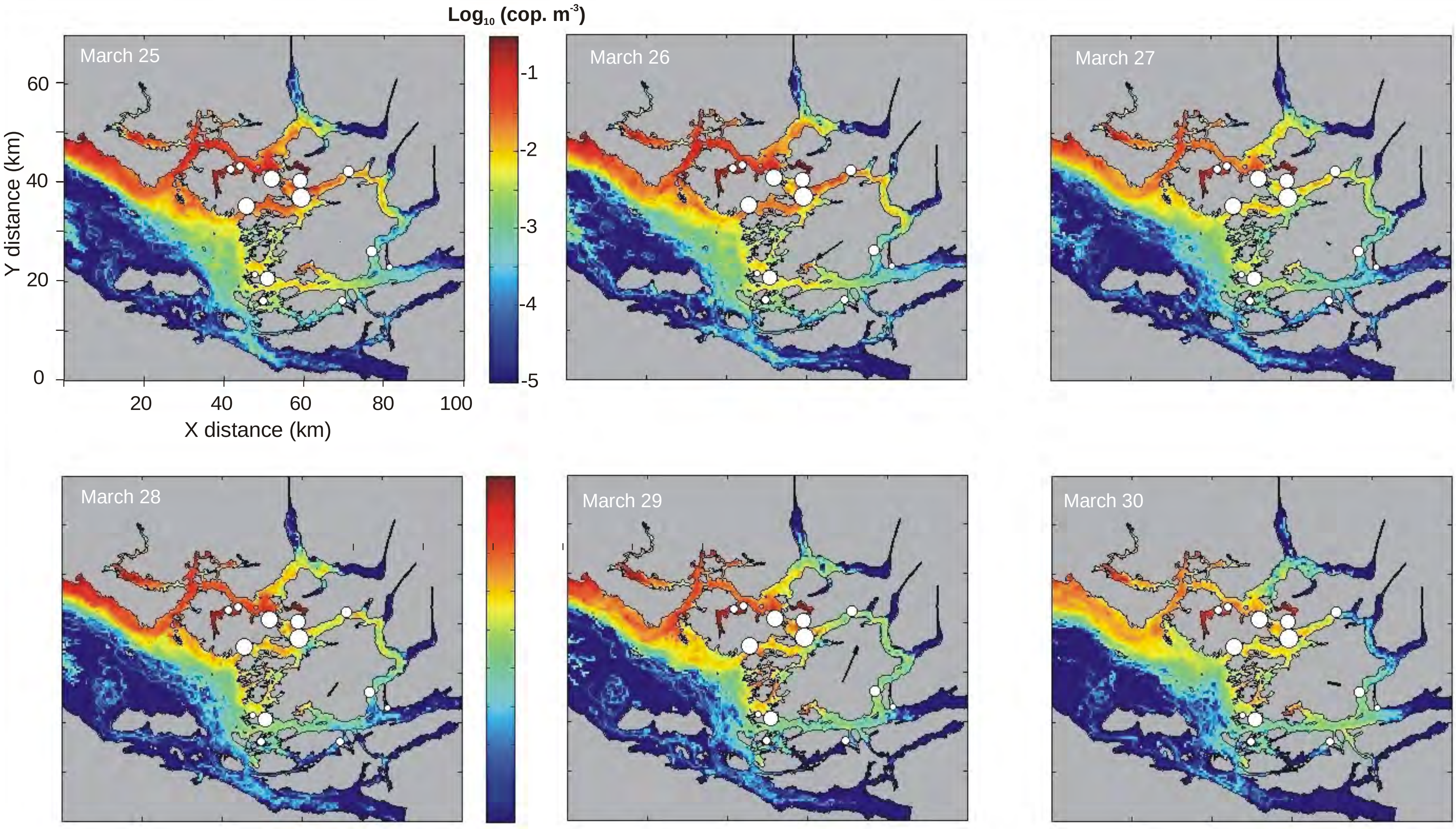
- *Duration of naupliar and copepodid stages are temperature dependant*
- *Mortality of naupliar stages determined from laboratory rearing studies and strongly influenced by salinity (<30 psu)*
- *Diel vertical migration documented in Norwegian study but was not observed in Broughton experiments*


Nauplius Mortality Curves(solid lines)
Copepod Mortality Curves (dashed lines)
10°C
7°C
Post Hatch Relative Abundance
Proportion of Total Eggs
Time from hatching (days)
μ = 0.32 ind.-1 d-1
Gillibrand & Willis (2007)
μ = 0.1 ind.-1 d-1
S = 25 psu
μ = 1.11 ind.-1 d-1
μ = 0.22 ind.-1 d-1

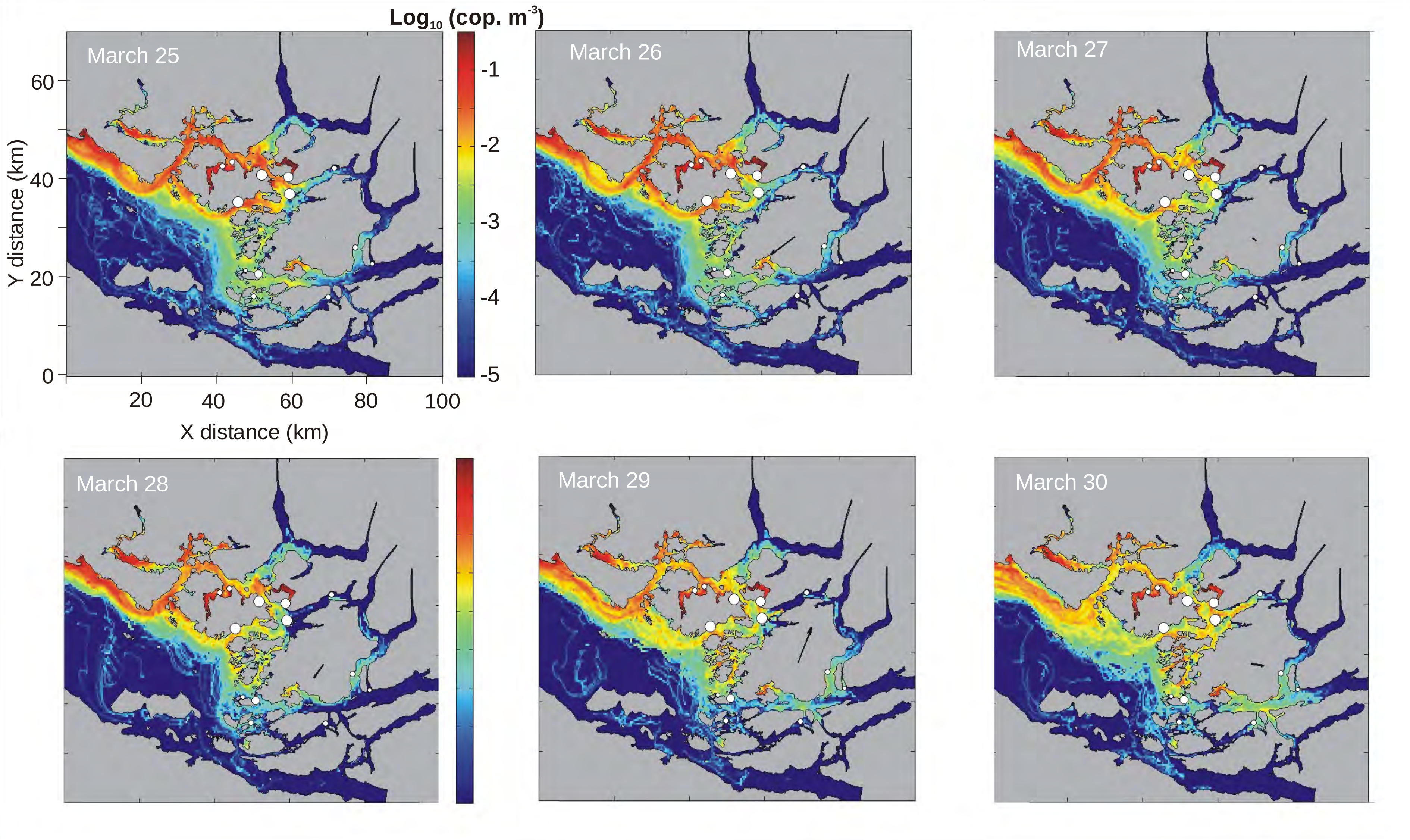
Particle Tracking details

- *Particles (nauplii) are released at random locations within defined-volume box (farm). The box is specified by the center position and its length, width and depth.*
- *At each of 20 farms, 20 randomly located "particles" are released hourly for 10 days starting March 18 (96000 total) and tracked for 10 days.*
- *Number of active nauplii represented by each "particle" is scaled by salinity dependent egg viability and farm egg production.*
- *Nauplii mortality controlled by salinity and time to molt dependent on temperature. Copepod mortality not dependent on salinity*
- *Copepodid behaviour (two types)*
  1) passive or
  2) diel vertical migration - aggregate at the surface in daytime and at 10m depth during the night. Copepodids avoid salinities <20 psu.
- *Coastal boundary condition: when the particle hits a coastal boundary, it stays there until the direction of the current changes or random-walk brings it away from the coast*

Passive Behaviour

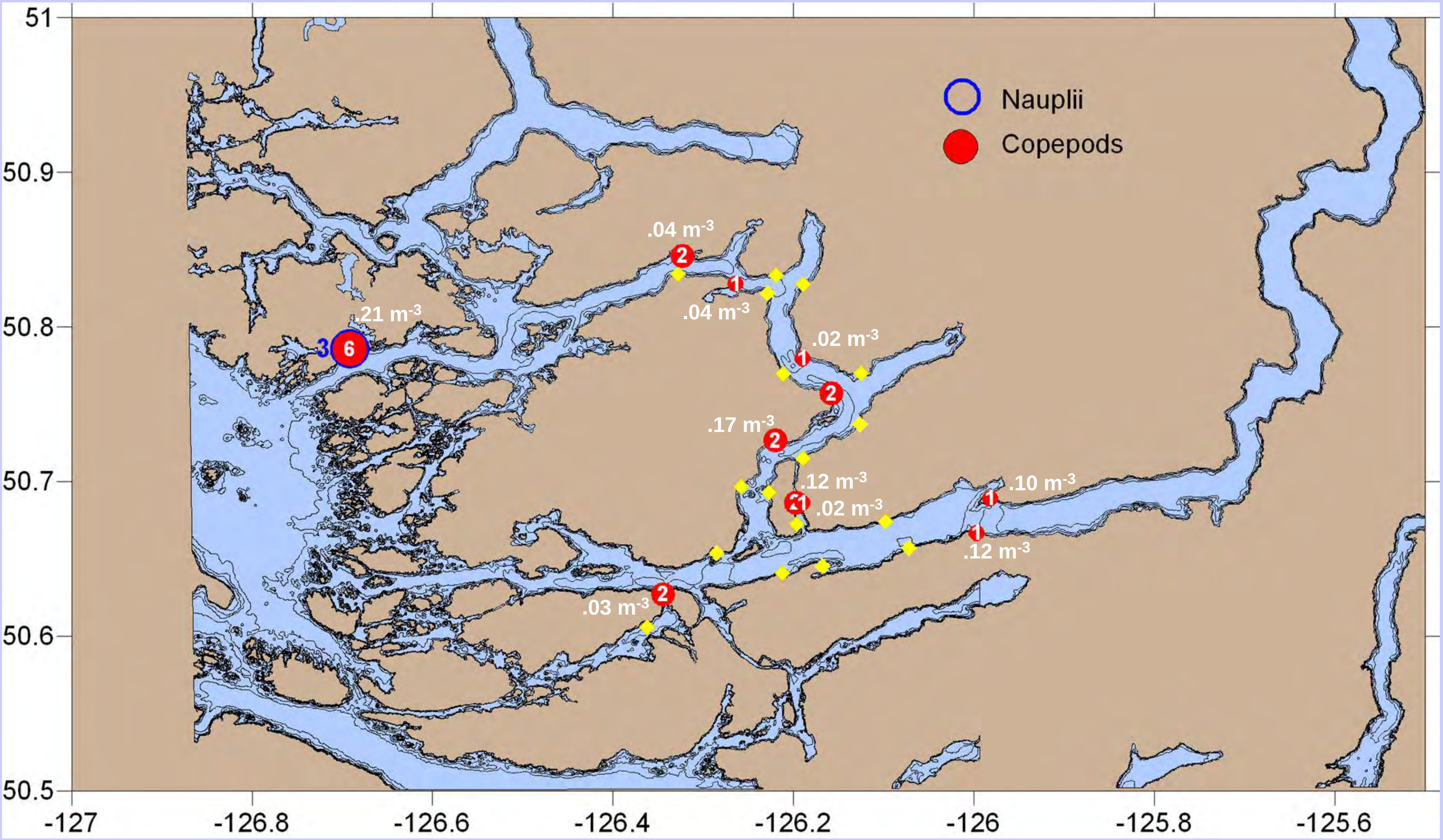


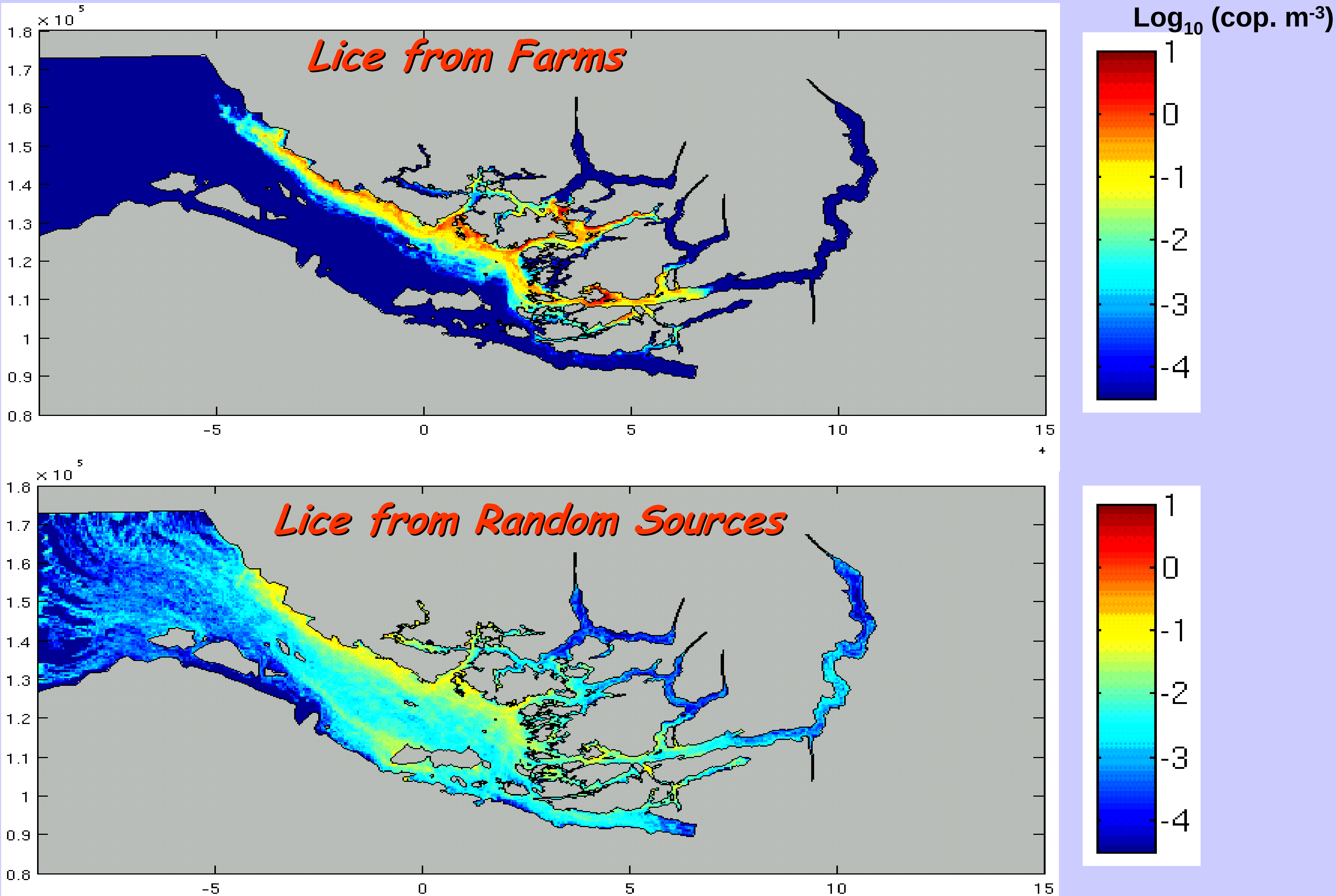
Diel Vertical Migration (0 to 10m)



DFO Plankton Sampling Program

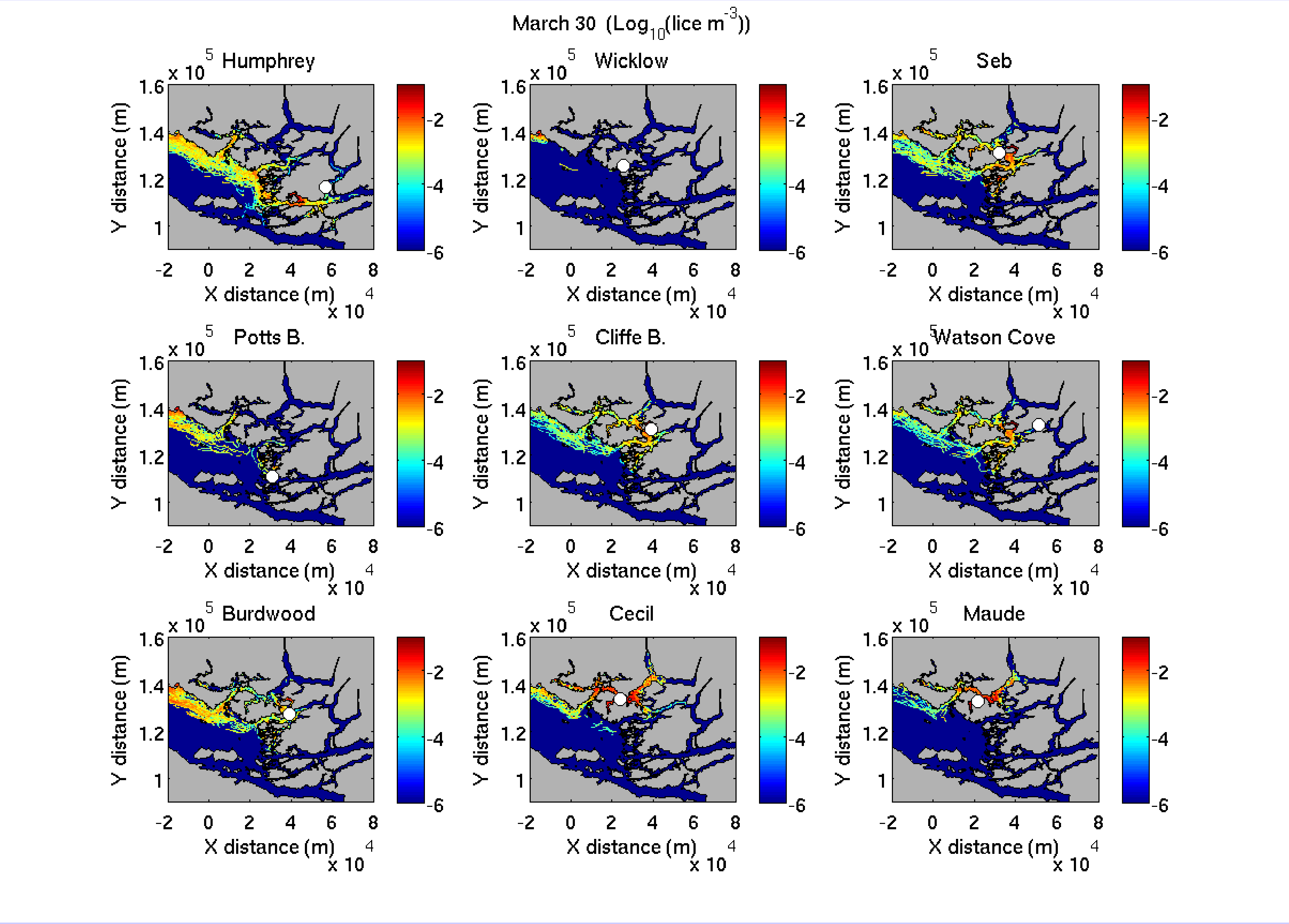
25-29 March 2008





Log10 (cop. m-3)
Lice from Farms
Lice from Random Sources
× 10 5
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
-5
0
5
10
15
1
0
-1
-2
-3
-4

Copepod Concentrations: Passive



Progress/Summary

- *FVCOM has provided reasonable simulation of circulation , temperature, salinity in Broughton Archipelago for March 13 – April 3, 2008*

- *Have created sea lice models that includes:*
  - farm sea lice egg production
  - development, behaviour and mortality of planktonic stages that are controlled by environmental factors (T,S and daylight).

- *Have created active-particle tracking code that uses stored FVCOM (u,v,w,T,S,Kv) variables to transport and develop lice from nauplii to copepodid stages.*

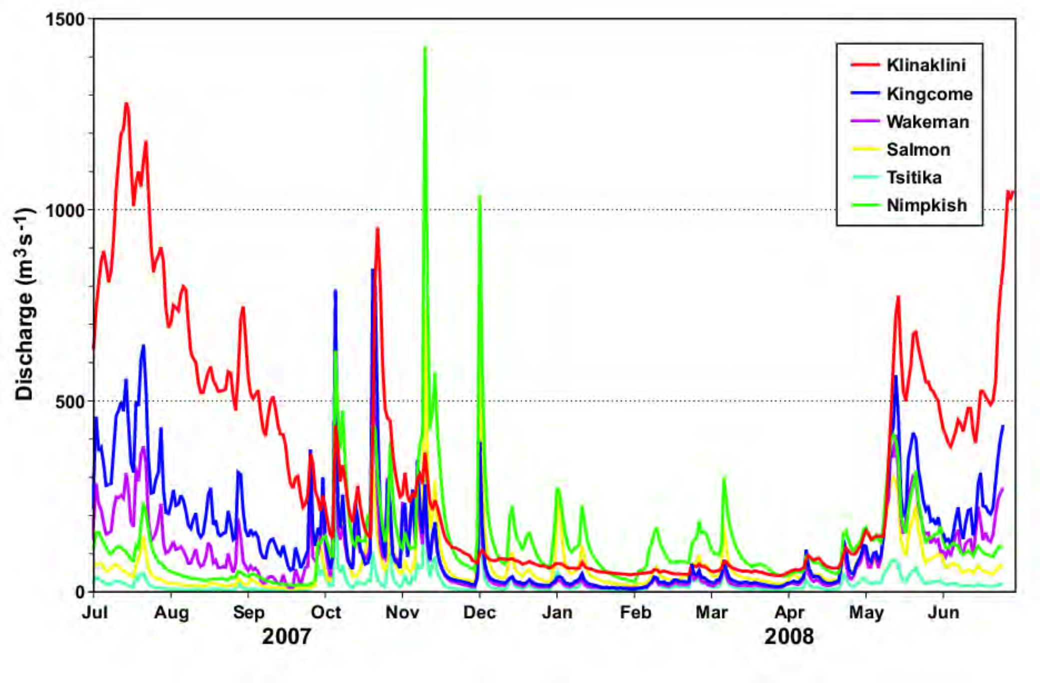
- *Model produces spatial and temporal quantitative estimates of lice concentrations (copepods m^{-3}).*

- *Model predictions of copepodid concentrations are lower than observed concentrations.*

- *Have the modelling tools and observational data to investigate wild/farmed salmon - sea lice interactions and examine ecosystem scale management strategies*

- *Low prevalence of lice on juvenile salmon where lice egg production is low or absent (i.e. area around Knight-Tribune junction)*

Future Work



- *Incorporate surface heat flux forcing (solar radiation, sensible and latent heat)*
- *Conduct simulations for:*
  - *May 20-30, 2008*
  - *June 18-27, 2008*
  - *February 2008*
- *Compare sea lice model concentrations with data from planktonic sampling and wild fish monitoring data*
- *2009 simulations*

Acknowledgments

Data Sharing

Farm Site Sea Lice Monitoring data
Marine Harvest Canada
Mainstream Canada
Grieg Seafoods

DFO Wild Fish Monitoring Data
Brent Hargreaves (DFO-PBS)
Simon Jones (DFO-PBS)

DFO Planktonic Sampling Data
Moira Galbraith (DFO-IOS)
Dave Mackas (DFO-IOS)

Field Operations

Oceanographic Surveys & Moorings
Crews of CCGS VECTOR
CCGS JOHN P. TULLY

Weather Stations
Scott Rogers (Salmon Coast Field Station)
'Namgis First Nations
Mike Berry (ALBY Systems Ltd.)
John Morrison (contractor – IOS)

River Discharge Measurements
Water Survey Branch (Environment Canada)

Changsheng Chen & FVCOM community

Thanks for your interest!