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The importance of scale for predicting impacts of stressors in nearshore environments: an example using European Green Crab (*Carcinus maenas*) invasions in British Columbia

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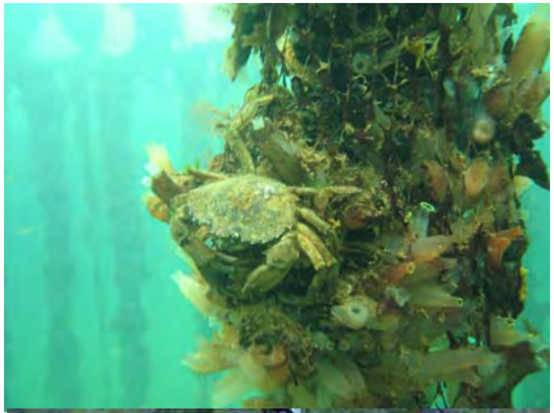
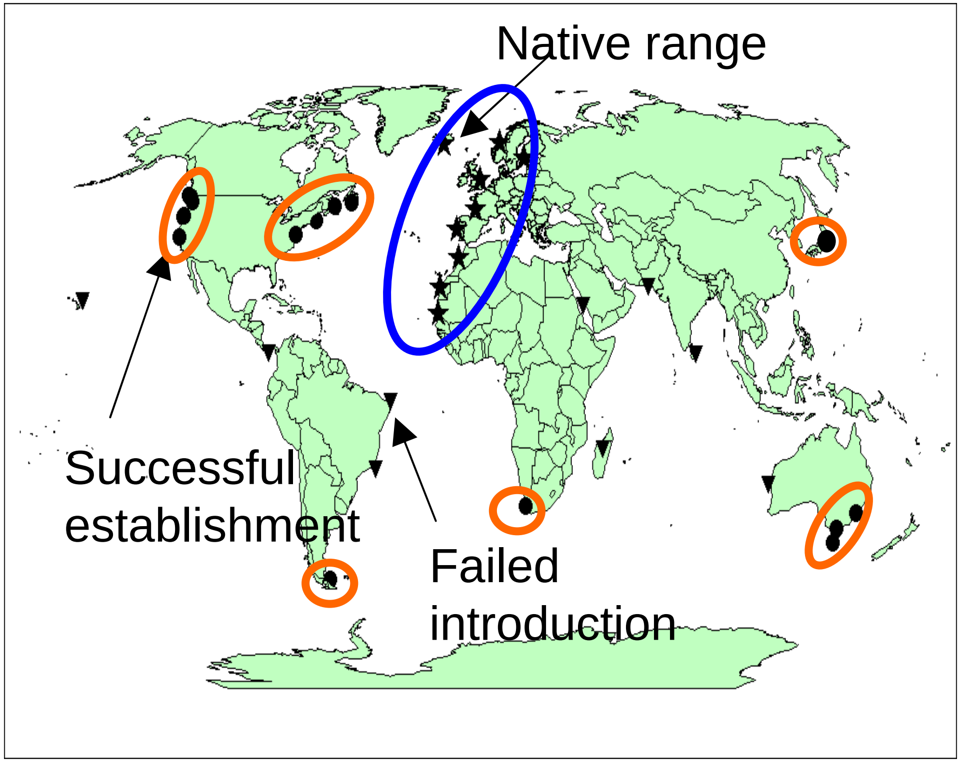
Background



- Biological invasions can represent significant stressors in marine and freshwater ecosystems
- Like all stressors, impacts are not uniform
- Impacts related to invasions are often related to population size of the invader, thus it is critical to identify locations amenable to supporting non-indigenous species at an “invasive” level

European Green Crab (*Carcinus maenas*)



- Ranked on IUCN "100 Worst Invaders" list
- Negative ecosystem impacts include reduced productivity of fisheries and aquaculture
- Range is continuing to expand on both coasts of Canada
- A good example of an ecosystem stressor

Green Crab in British Columbia

- Arrived on the West Coast of North America in 1989 to San Francisco Bay in oyster packing material from the east coast
- Slowly expanded northward along the eastern Pacific Ocean
- Believed to have arrived in BC through larval transport during 1998/99 El Nino
- Relatively few public reports after 1999 and NO directed surveys until 2006 when DFO initiated surveys as part of its AIS Monitoring Program

Research Questions

- Can the distribution of *Carcinus maenas* be predicted in British Columbia?
  - predicting dispersal potential (propagule pressure)
  - predicting suitable environments
- Can the extent of *Carcinus maenas* invasions be predicted?
  - "invasive" levels will be a subset of the overall distribution

Potential Dispersal

- Particle tracking models based on average or El Nino conditions were similar
  - northward movement in winter months
  - southward movement in summer months

Models to Characterize Potential Distributions

- Simple models based on reported environmental variables, primarily temperature and/or salinity
- More complex environmental niche models such as Genetic Algorithm for Rule-set Prediction (GARP)
- Clearly, both have their limitations

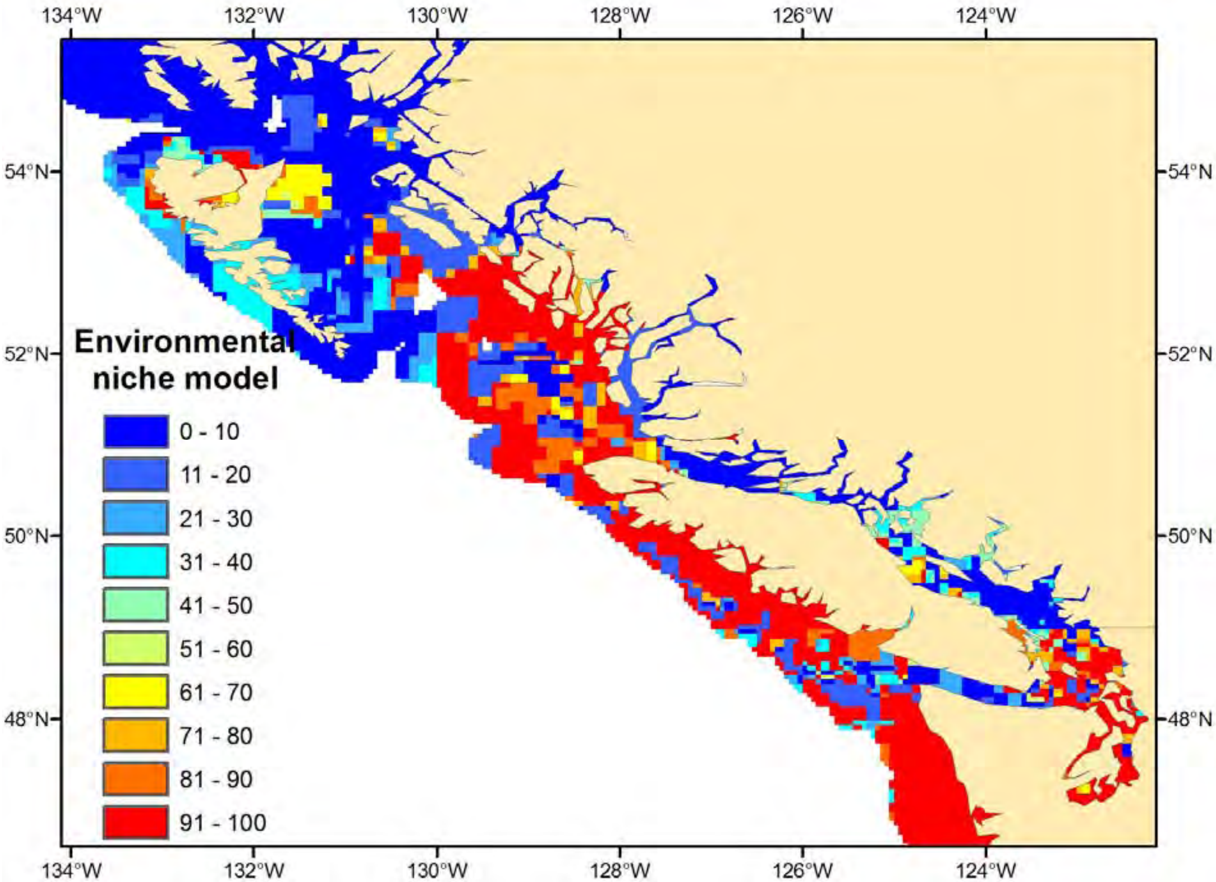
Key Model Limitations

- Simple models
  - reported tolerances might not exist or be accurate
  - could be uninformative for managers
- GARP models
  - don’t rely on species tolerance data
  - do rely on species distribution data that could be limited or inaccurate
  - refined predictions could be more informative

Environmental Variables/GARP Layers

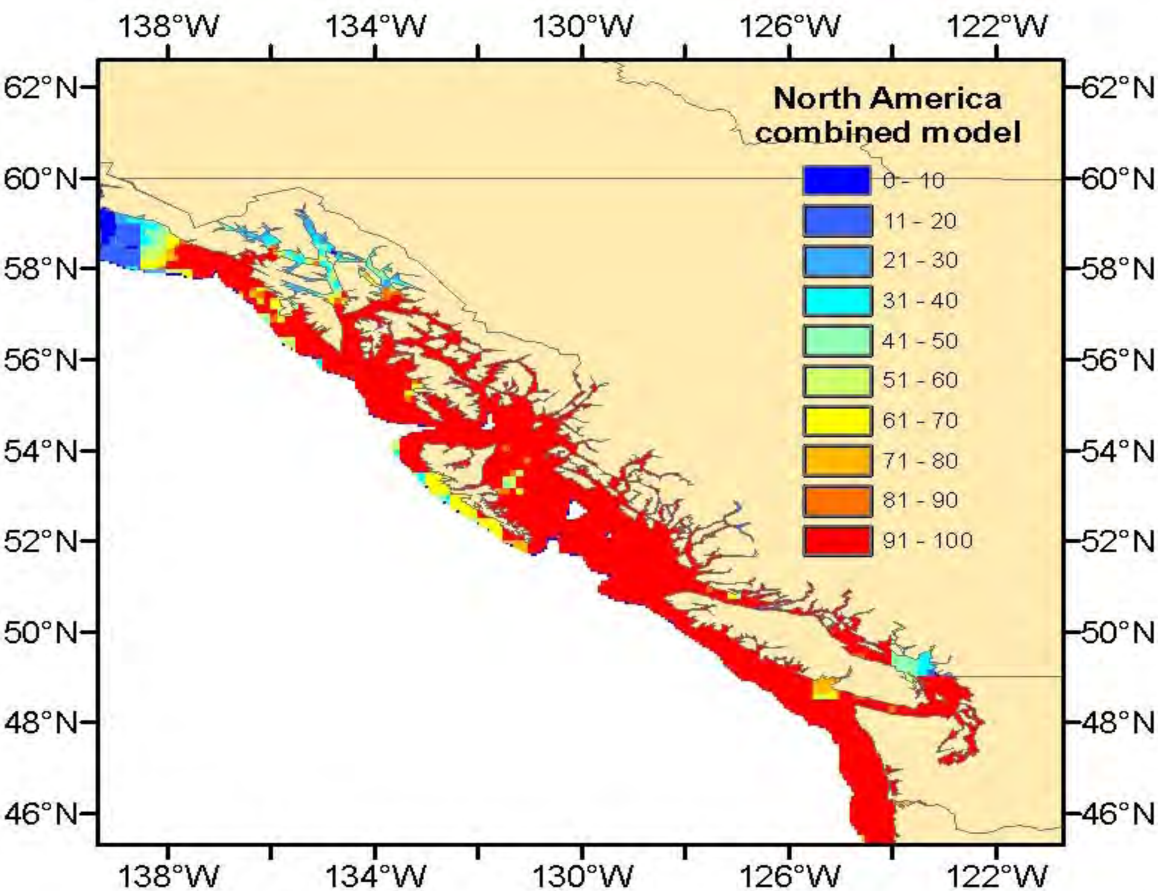
- Seasonal Temperature (4)
- Seasonal Salinity (4)
- Annual Oxygen (1)
- Annual Chlorophyll a (1)
- Depth was bounded at 200m
- All environmental layers were tested for their contribution to model accuracy and only those that improved accuracy were used (here all)

Potential Distribution – 1



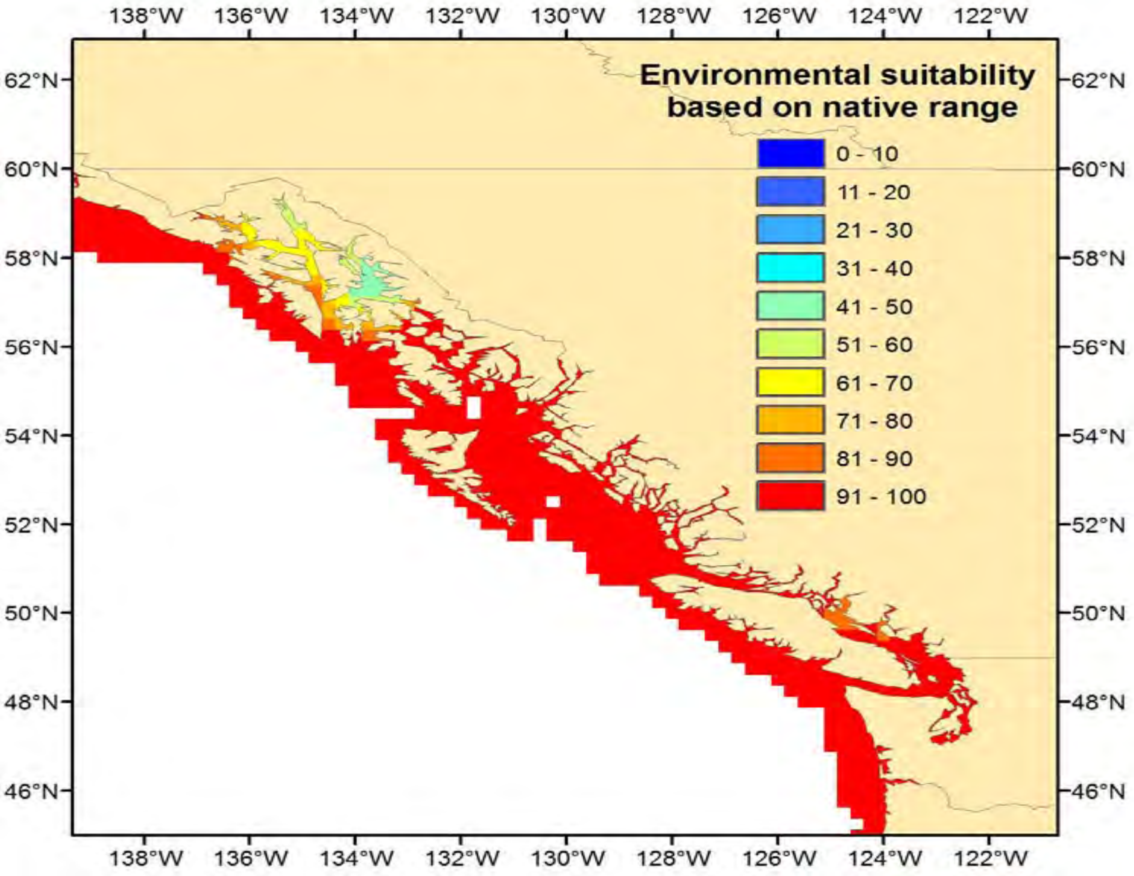
- GARP model based on current west coast distribution ONLY

Potential Distribution – 2



- GARP model based on current Canadian distribution (both east coast and west coast locations)

Potential Distribution – 3



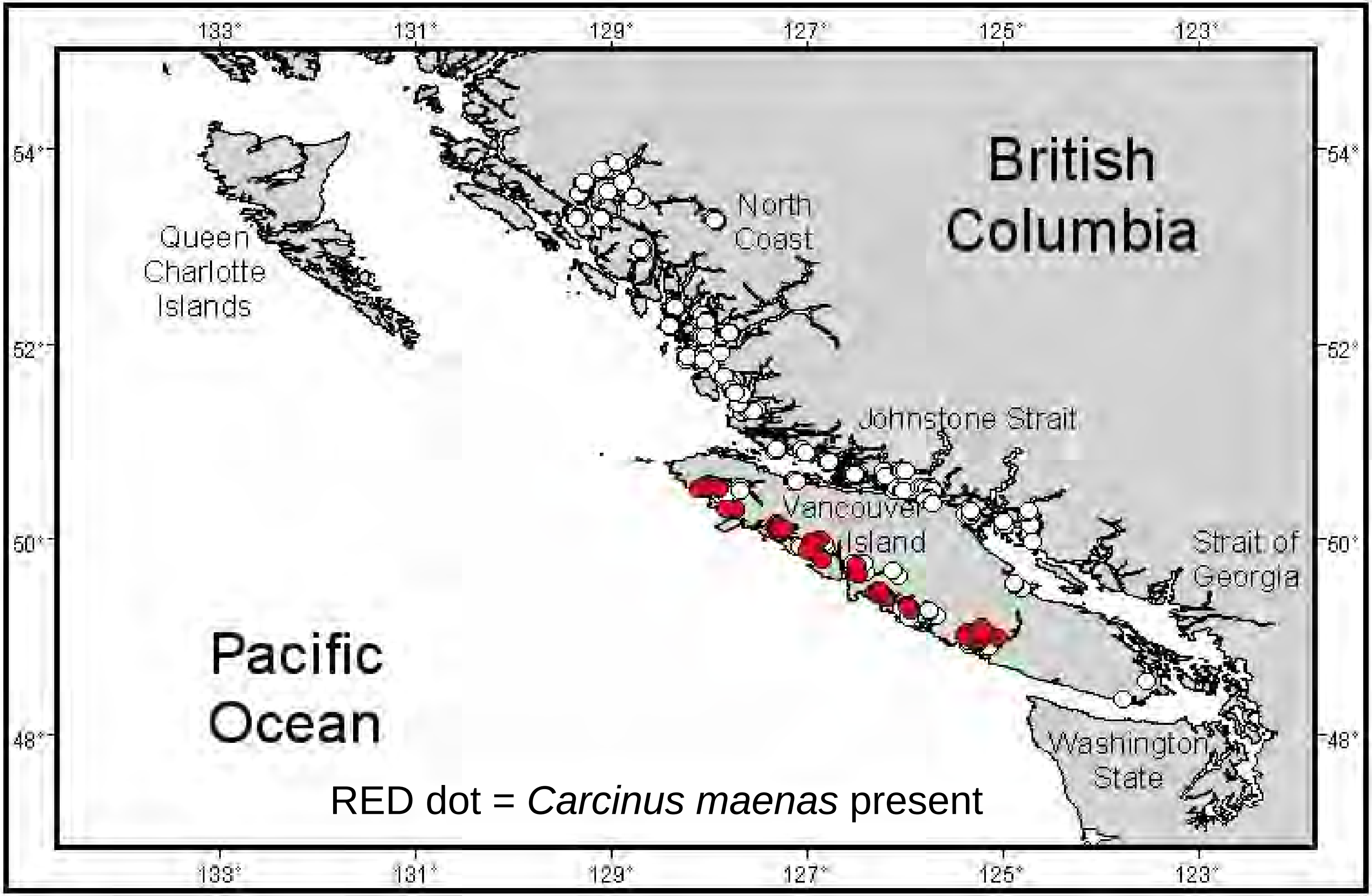
- GARP model based on native range of European green crab (which includes Iceland)

Potential Limitations of GARP Predictions

- GARP models are based on KNOWN distributions such that if green crab is present at locations with significantly different environmental conditions then the predicted distribution would underestimate the actual distribution

- Models do not account for different population sizes in different locations

Geographic Distribution from Surveys



RED dot = *Carcinus maenas* present

Geographic Distribution from Surveys

- Green crabs distributed throughout the west coast of Vancouver Island
  - High density sites at both northern and southern limits
    - Winter Harbour and Pipestem Inlet, respectively
- High catch rates appear correlated with decreased salinity (we tested this)
- No green crabs from inside or mainland waters (the Strait of Georgia)

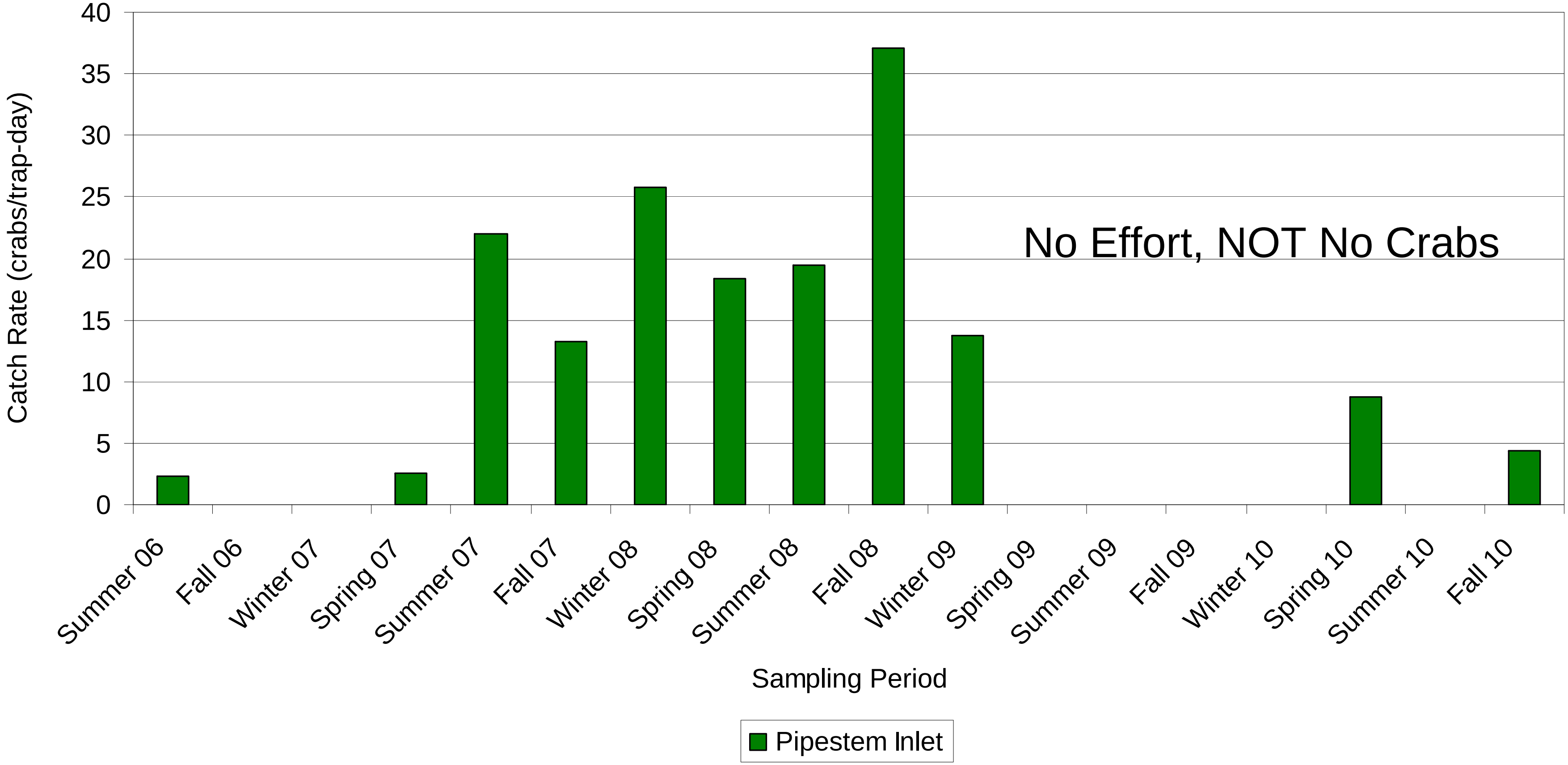
Population Sizes in BC

- *Carcinus maenas* populations show significant differences in population densities based on standardized trapping efforts
  - Hence, differences in “invasion” level
- Evidence of increased abundance (inferred from catch rates) from 2006 to 2008, particularly in Pipestem Inlet, with recent decline in 2010 possibly due to poor recruitment

Green Crab Catch Rates 2006-08

Location	Year	# traps	*Carcinus* /trap
Quatsino Sound	2007	108	0.3
Winter Harbour	2007	96	12.5
Klaskino Inlet	2007	35	1.8
Kyuquot Sound	2007	37	0.4
Mary Basin	2007	36	0.3
Nootka/Esperanza	2006	148	0.4
Tlupana Inlet	2007	30	0.0
Clayoquot Sound	2006	205	0.2
Sydney Inlet	**2006**	**12**	**1.4**
Sydney Inlet	**2007**	**42**	**1.5**
Barkley Sound	2006	162	1.7
Barkley Sound	2008	174	1.2
Pipestem Inlet	**2006**	**120**	**2.3**
Pipestem Inlet	**2007**	**49**	**22.0**
Pipestem Inlet	**2008**	**180**	**21.1**

Pipestem Inlet Population



Factors Affecting "Invasion" Level

- Population sizes could be determined by:
  - biological factors such as prey availability, competition with other species, including native crabs, predation, etc.
  - environmental factors such as temperature, salinity, depth, substrate, beach slope, etc.
  - a combination of both

Spatial Distribution of Green Crab

- Exploratory surveys were conducted throughout Pipestem Inlet
- Five species present
  - European green crab and four native *Cancer* species
- Green crab and *Cancer gracilis* most abundant
  - relative abundance based on CPUE
- Green crabs were concentrated at the head of the inlet

Spatial Distribution of Green Crab

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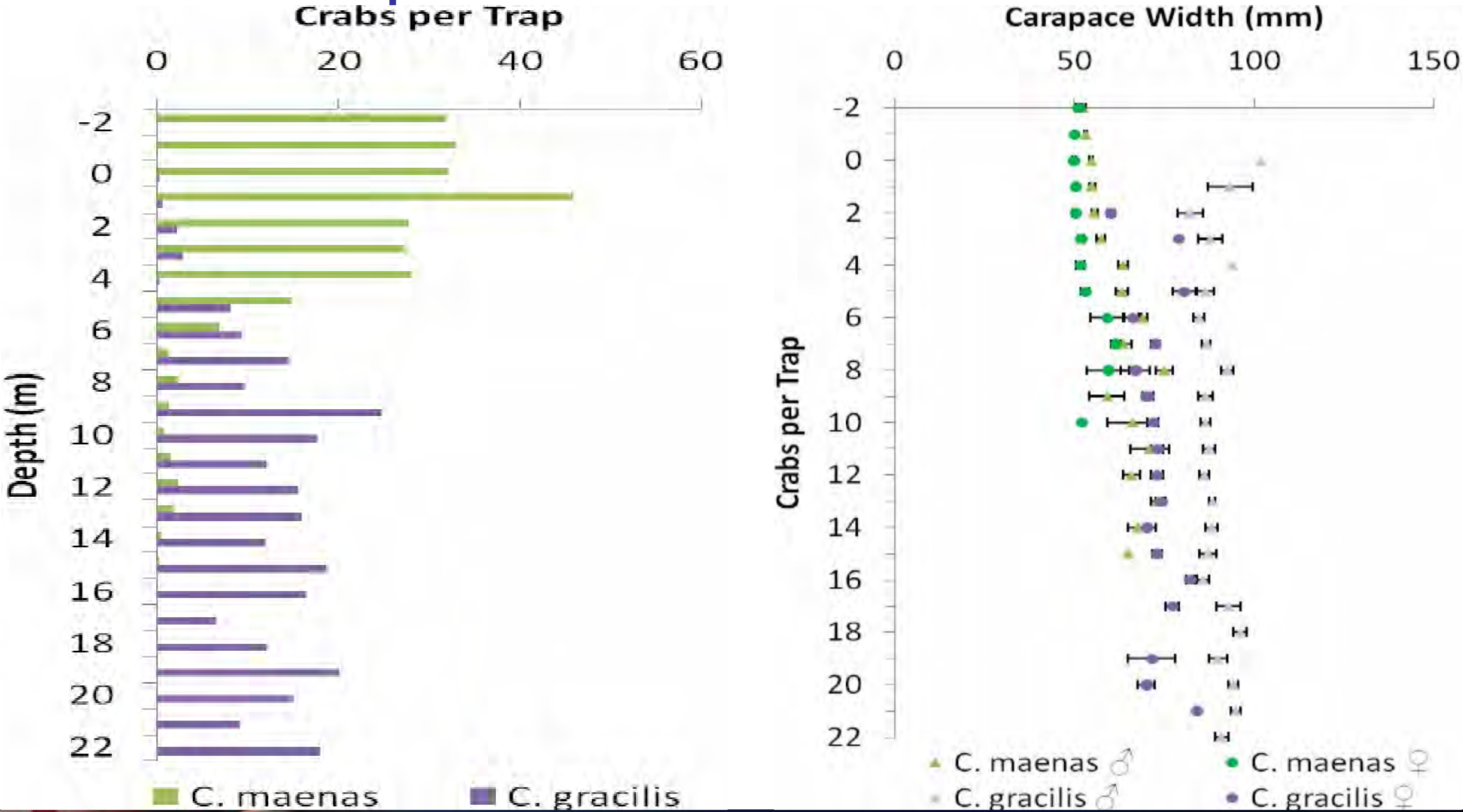
Depth Distribution and Size



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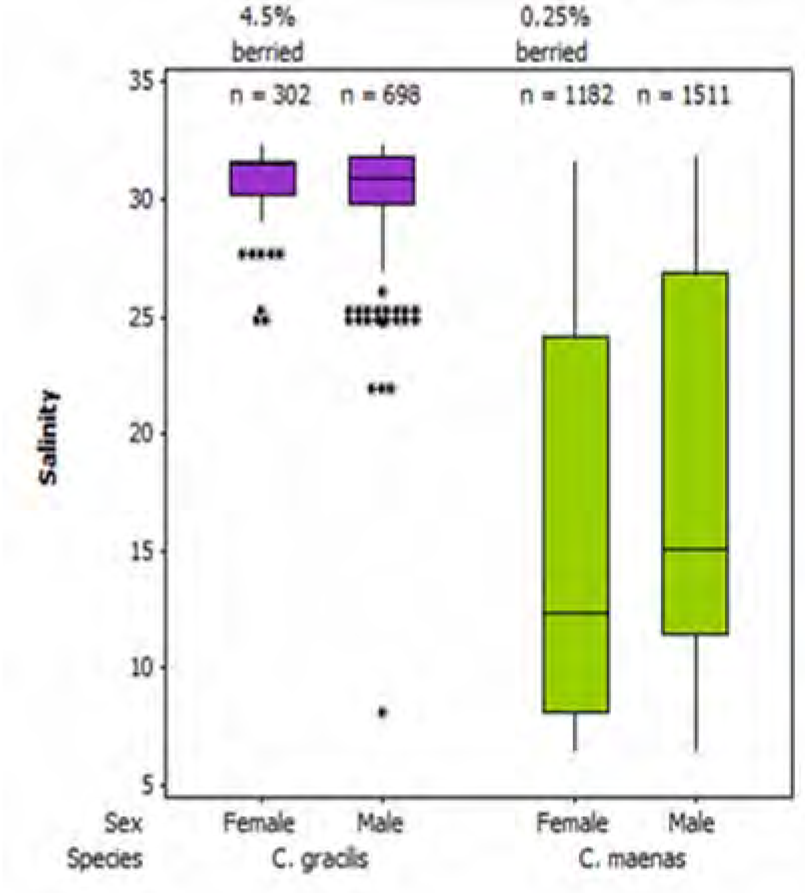
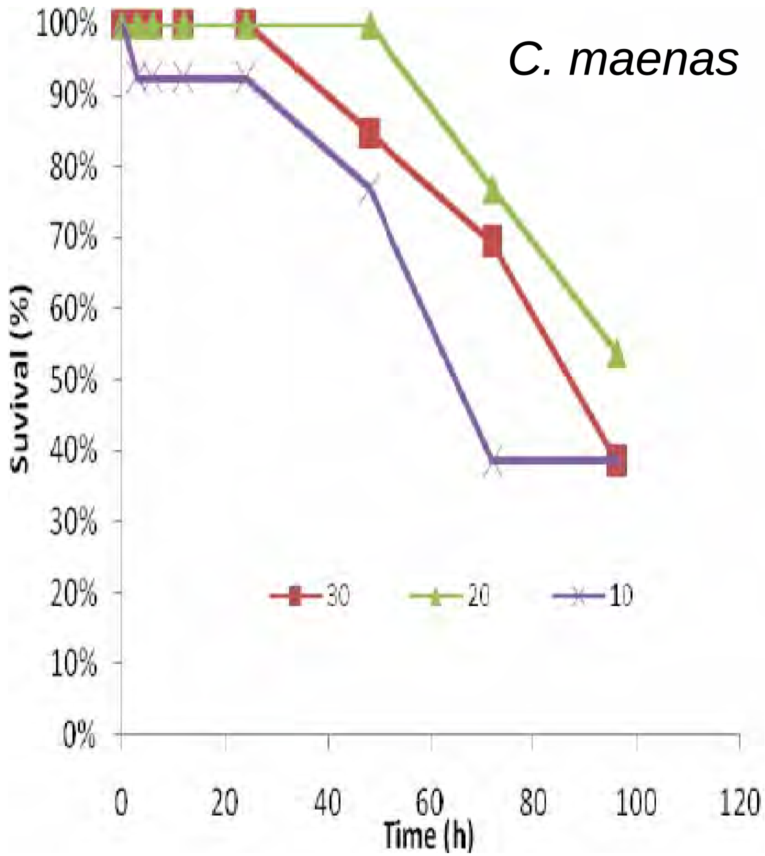
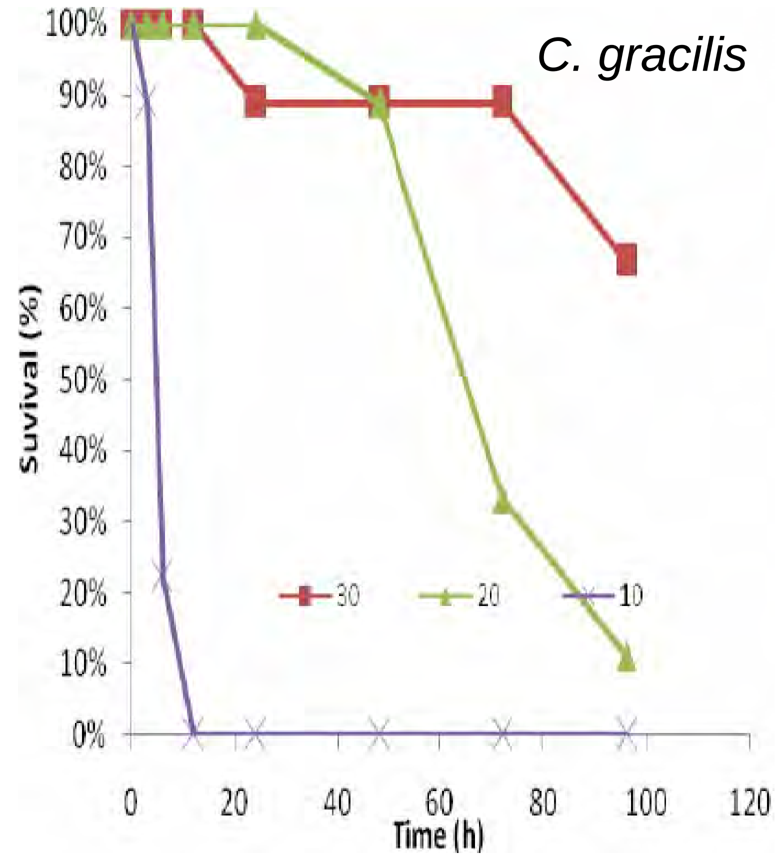
Distribution and Salinity



Experimentally Derived Salinity Tolerance

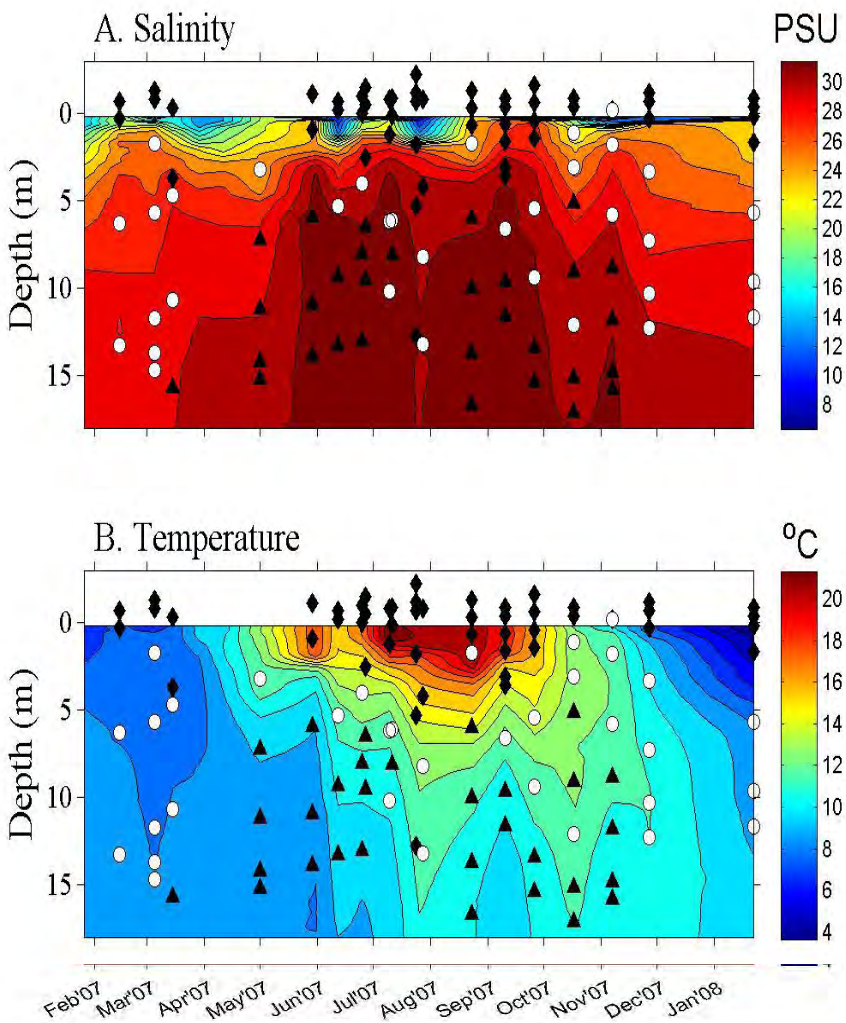




Distribution Summary: Depth, Size and Salinity

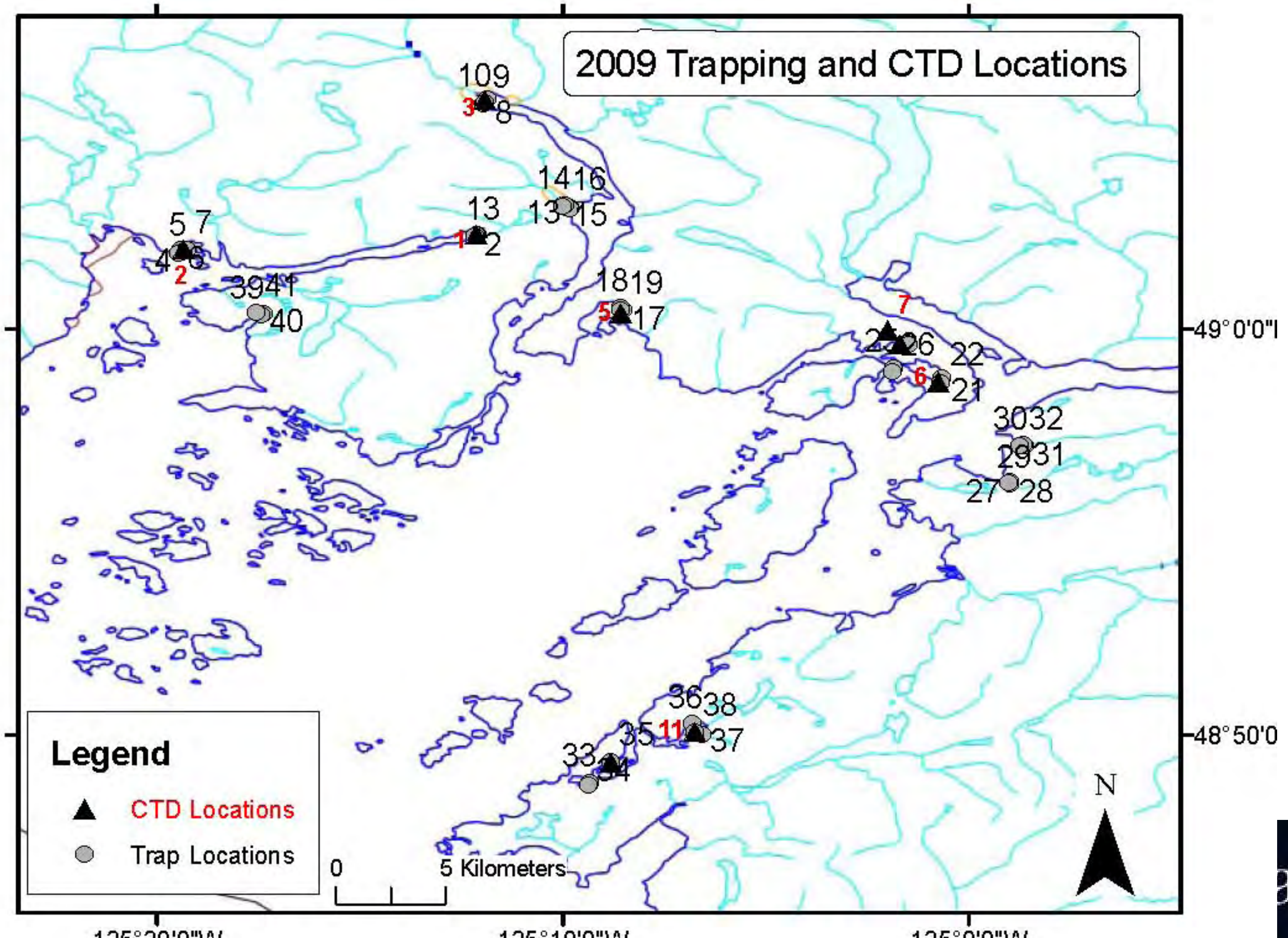
- *C. maenas* and *C. gracilis* distributions overlap
- *C. maenas* are larger in the interaction zone
- No female *C. maenas* below 10m
- *C. maenas* euryhaline
- *C. gracilis* stenohaline

Depth and Salinity/Temperature Interactions

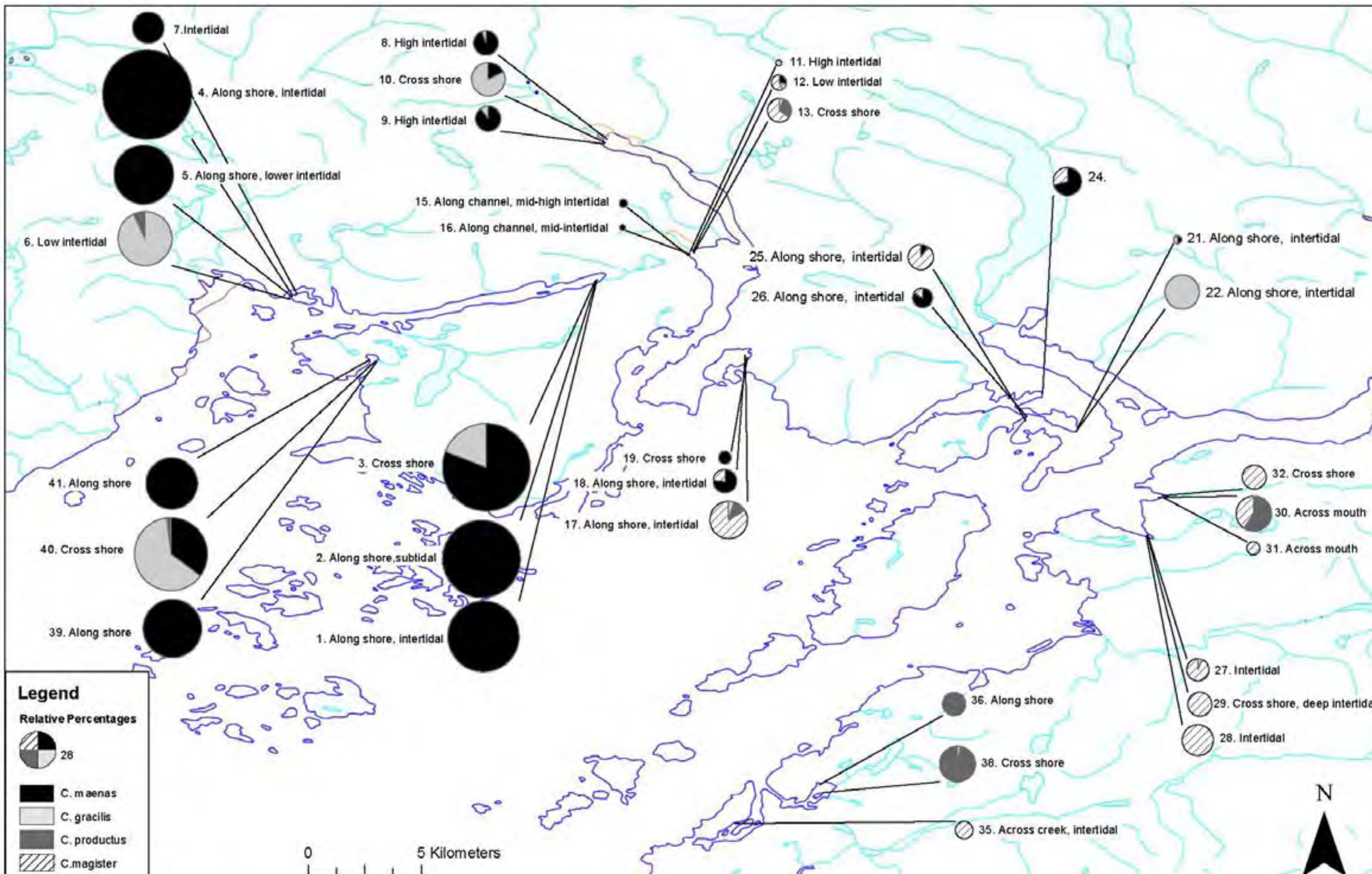


- Salinity more important than temperature or depth in determining catch
  - *C. gracilis* dominates high salinity zones
  - *C. maenas* has expanded range at times of high freshwater influx

What Happens at Larger Scales?

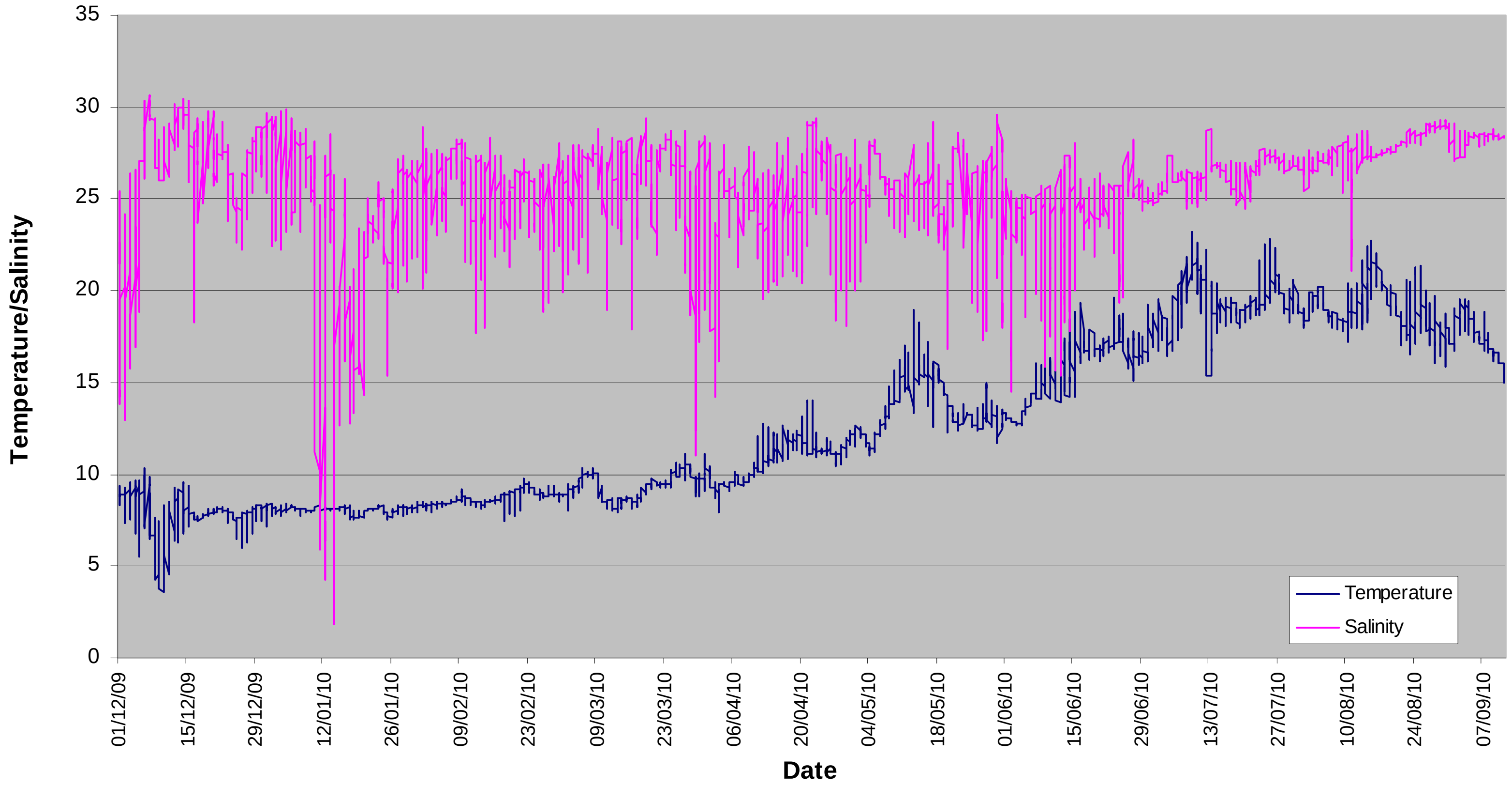


Carcinus maenas Relative Densities



July 2009 trap set locations and relative abundance of catch. Size of pie chart is relative to total catch.

Small-scale Habitat Characteristics



High resolution temperature, salinity and some depth data collected at all 12 sites

Next Steps

- Fully valuate the relationship between small-scale variability in environmental conditions (temperature and salinity) and larger-scale model predictions (e.g., GARP generated predictions) to identify locations amenable to supporting *Carcinus maenas* populations at “invasive” levels

Next Steps

- Evaluate potential refinements based on biological or other environmental measures
  - densities of other crab species
  - densities of potential prey items (primarily bivalves)

- Use this new information to refine predictions and inform potential monitoring/management activities

Preliminary Conclusions

- Identifying the correct spatial (and likely temporal scales) for predictions is critical
  - smaller-scale measurements are hyper-accurate but require dedicated efforts to collect this data
  - larger-scale oceanic surveys provide large amounts of data but resolution is very low, especially in nearshore waters
  - medium-scale might be ideal but needs to be defined

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