Climate Change and Snow Crab in the Bering Sea:
Connectivity Between Larval Release Sites and Potential Settlement Areas

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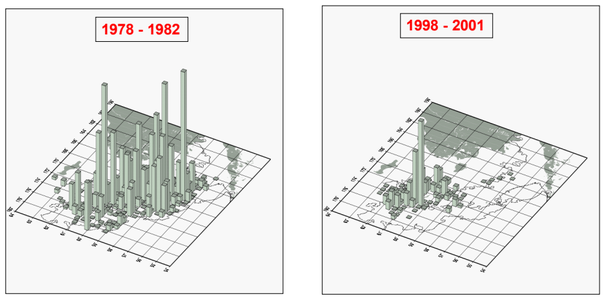
Introduction

Snow crab *(Chionoecetes opilio)* has supported one of the most lucrative fisheries in the southeastern Bering Sea (EBS), but landings have recently declined to historically low levels.

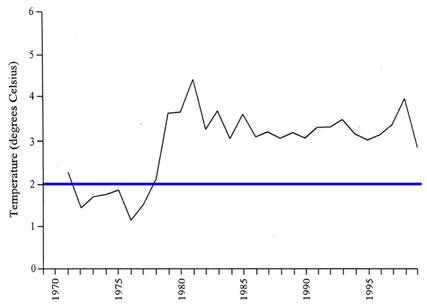
Survey results show that the distribution of adult female snow crabs between 1978-1982 and 1998-2001 has contracted and shifted to the northwestern parts of the eastern Bering Sea.

Figure 1. Change in the geographic range of snow crab to the northwest. Aggregated abundance of mature females is shown.



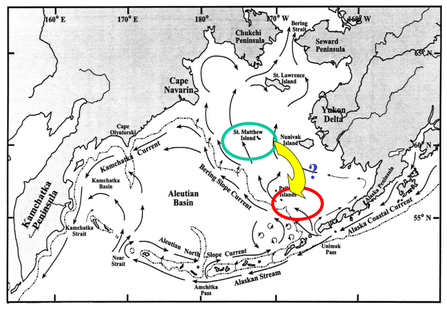
This northward contraction coincides with warming of near bottom temperatures over the EBS, and reduction in size of the "Cold Pool" (the area over the middle shelf with temperatures ≤2˚C).

Figure 2. Mean near bottom temperatures in the southern range of the historic eastern Bering Sea distribution of snow crab around the Pribilof Islands, from survey data.



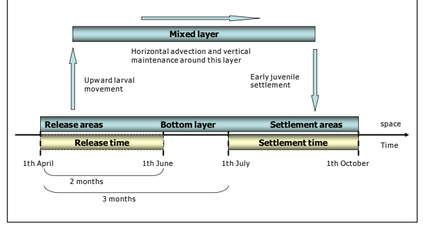
There is concern about whether or not it is possible for the southeast shelf to be repopulated via larval advection from the new spawning areas over the northwest shelf and slope.

Figure 3. Will the range of snow crab shift back from the present northwest center of distribution (green circle) to the southeast Bering Sea (red circle)?



Methods

Figure 4. Snow crab conceptual model



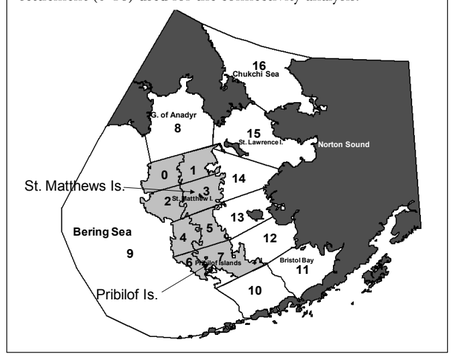
A biophysical model coupling the hydrodynamic model ROMS (Curchitser et al., 2005) with an Individual-based Model for Snow Crab (Parada et al., in press), was implemented to study larval transport and environmental effects.

Virtual particles were released near the bottom and soon afterwards migrated upwards to the mixed layer, remaining there until they reached the megalops stage, became hyperbenthic, and eventually settled. Release time was set to occur between April 1st and June 1st; "settlement" took place ~90 days later.

In our analysis, we examined the near bottom temperature (NBT) at the locations of settlement and compared these to data on NBT collected by the NOAA/AFSC groundfish surveys.

We also compared the distribution of settlers from the model to the distribution of primiparous females, ie. first-time spawners, 5-7 years later (from NOAA/AFSC surveys) to ground truth our model.

Figure 5. Regions of larval release (0-7, shaded) and potential settlement (0-16) used for the connectivity analysis.

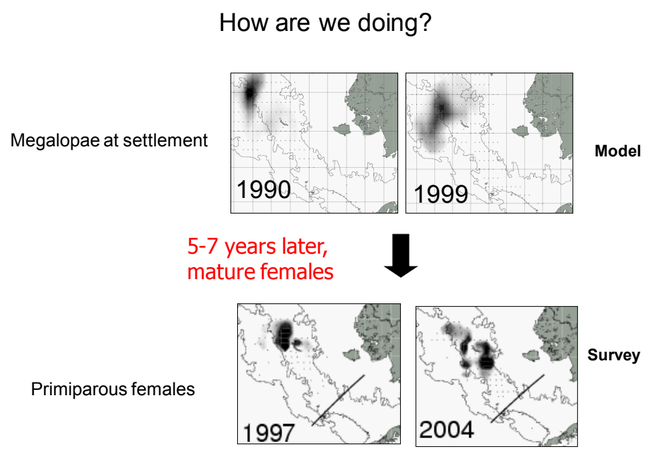


We examined the connectivity between areas of larval release and potential settlement in the Bering Sea. The geographical areas used to investigate connectivity are shown here.

Results

Model Validation: The distributions of modeled megalopae at settlement were quite similar to the distribution of primiparous females from surveys 5-7 years later. Small differences were seen, this may be attributed to adult female active movement and site specific mortality.

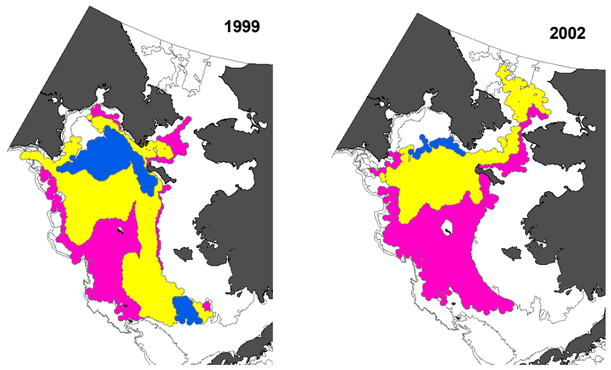
Figure 6. IBM model results compared with data.



Temperature: Juvenile snow crab are said to prefer settlement in areas where the bottom temperature is between 0 and 2 °C (Dionne, et al., 2003).

The cold year (1999) produces a larger "optimal" settlement region (0 - 2 °C) than the warm year (2002). This pattern is consistent for model hindcasts from 1978 to 2004.

Figure 7. Temperature in settlement areas for a cold (1999) and a warm (2002) year. The potential settlement areas are color coded by temperature (blue <0 °C, yellow 0 - 2 °C, fuchsia 2-4 °C.



Connectivity - Major Results

- Substantial northward transport along the Middle Domain and limited transport from the Middle Domain (areas 3 and 5) to the Outer Domain (areas 0 and 2)
- Consistent northeastward (onshore) transport from the northern parts of the Outer Domain (areas 2 and 4) to the northern parts of the Middle Domain (areas 1 and 3).
- Significant retention in two areas of the Middle Domain: NW of St. Matthew (area 1), and east of the Pribilof Islands (area 7).
- Some transport from the core region (areas 0-7) to the Coastal Domain (areas 12-14), and to sub-arctic regions north of St. Lawrence Island (area 15), even into the Chukchi Sea (area 16).
- Substantial transport from the NW core region (areas 0 and 1) to the Gulf of Anadyr (area 8) (>55-60% in the case of transport from area 1 to area 8).
- No offshore transport (i.e. to area 9) from the core region.
- Southward (including southeastward and southwestward) transport was never observed throughout the entire geographic region of interest for all years simulated.

Figure 8. Connectivity matrix between larval source areas (0-7) and settlement areas (0-16). Figure shows mean connectivity over the period 1978-2004.

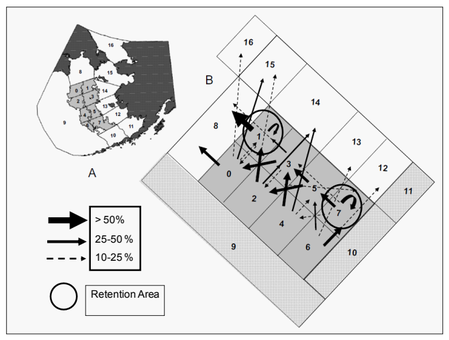
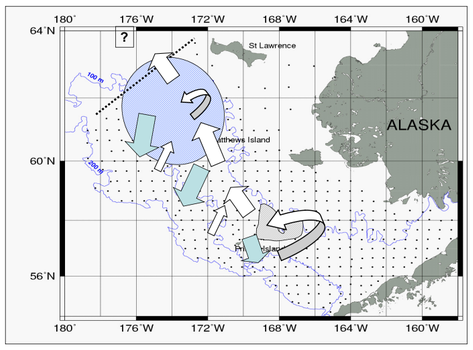


Figure 9 shows a conceptual model of crab life history in the EBS. The conceptual model shows the northward shift in distribution of snow crab in recent decades, as informed by this work and by the NPRB funded FERO project. Shown is the larval transport to the north and the retention in the areas near St. Matthews and the Pribilof Islands.

Also shown are the later offshore ontogenetic movements, as demonstrated by the FERO project. Primiparous females located over the Middle Domain in the region near St. Matthews Island release eggs in this area (which are retained) and then move offshore to the Outer Domain where they reproduce as multiparous females.

As the connectivity analysis indicates, offspring released in the offshore areas move mainly to the northeast onto the middle shelf, where they settle and mature. Very few females are left in the retention area around the Pribilof Islands, so the population life cycle is maintained via these movements in the northern areas.

Figure 9. Conceptual spatial life history of snow crab. Clear arrows: direction of larval transport towards, and retention within, the Middle Domain. Shaded arrows: ontogenetic migrations. Cross-hatched area: main region of recruitment to the adult stock.



Conclusions

1. Our model successfully forecast the distribution of primiparous females by simulating the distribution of newly settled juveniles.
2. In cold years, the habitat for juvenile settlement may be larger and further to the south than in the warm years.
3. Two retention areas were seen: near the Pribilof Islands (where the population of adults is almost gone) and near St. Matthews Island.
4. No larvae were transported towards the south, in warm or cold years.
5. This study indicates that the southeast Bering Sea may not be repopulated with snow crab coming from the northwesterly adult females, via larval transport.
6. A new conceptual model of spatial crab life history shows how this northern population is maintained.

→ We need to simulate the last several years, which have been cold, to see what might happen where there is a run of consecutive cold years.

References

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Acknowledgments

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