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Temperature effects on snow crab (*Chionoecetes opilio*) growth rate and size after terminal molt

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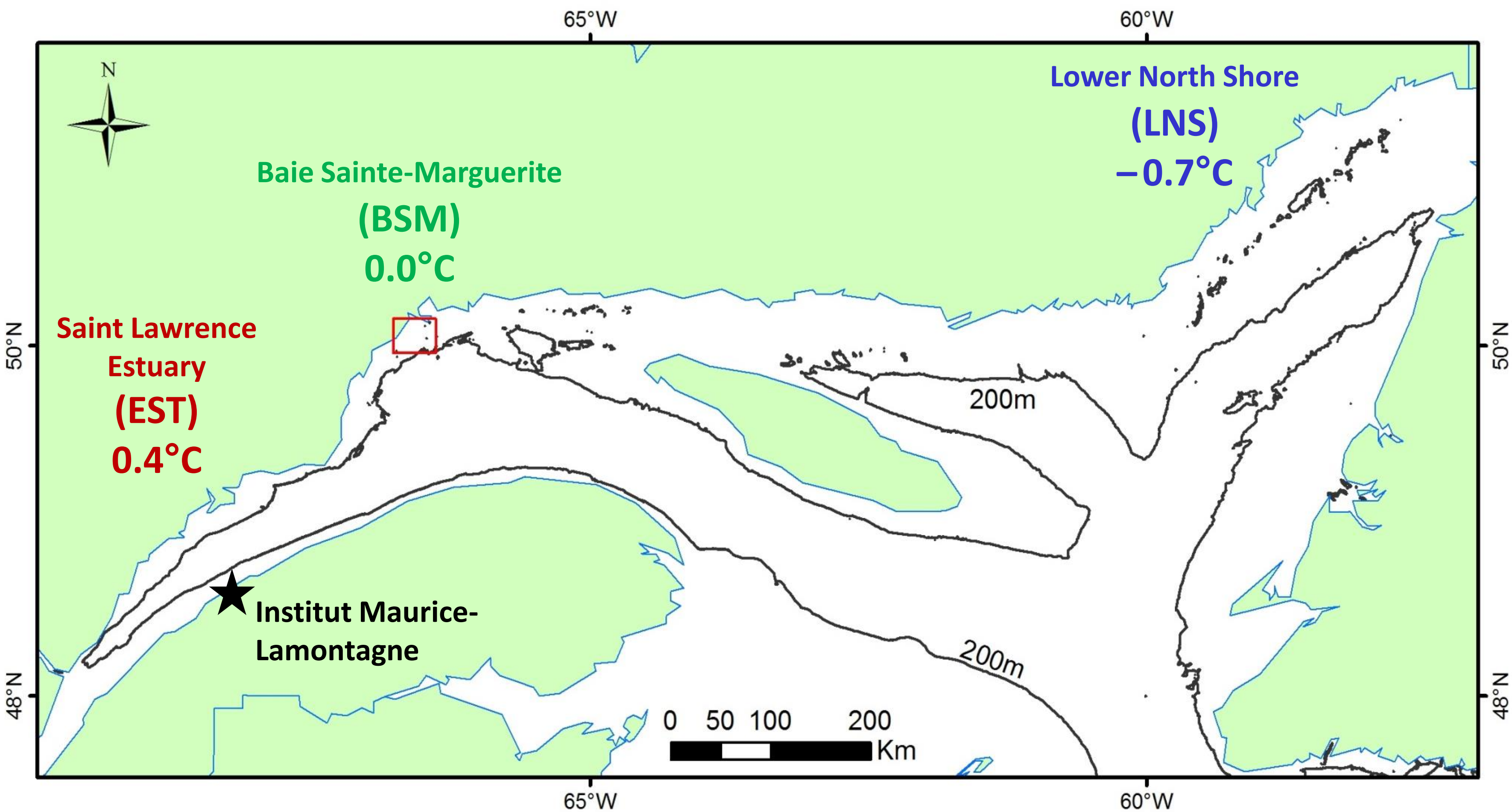
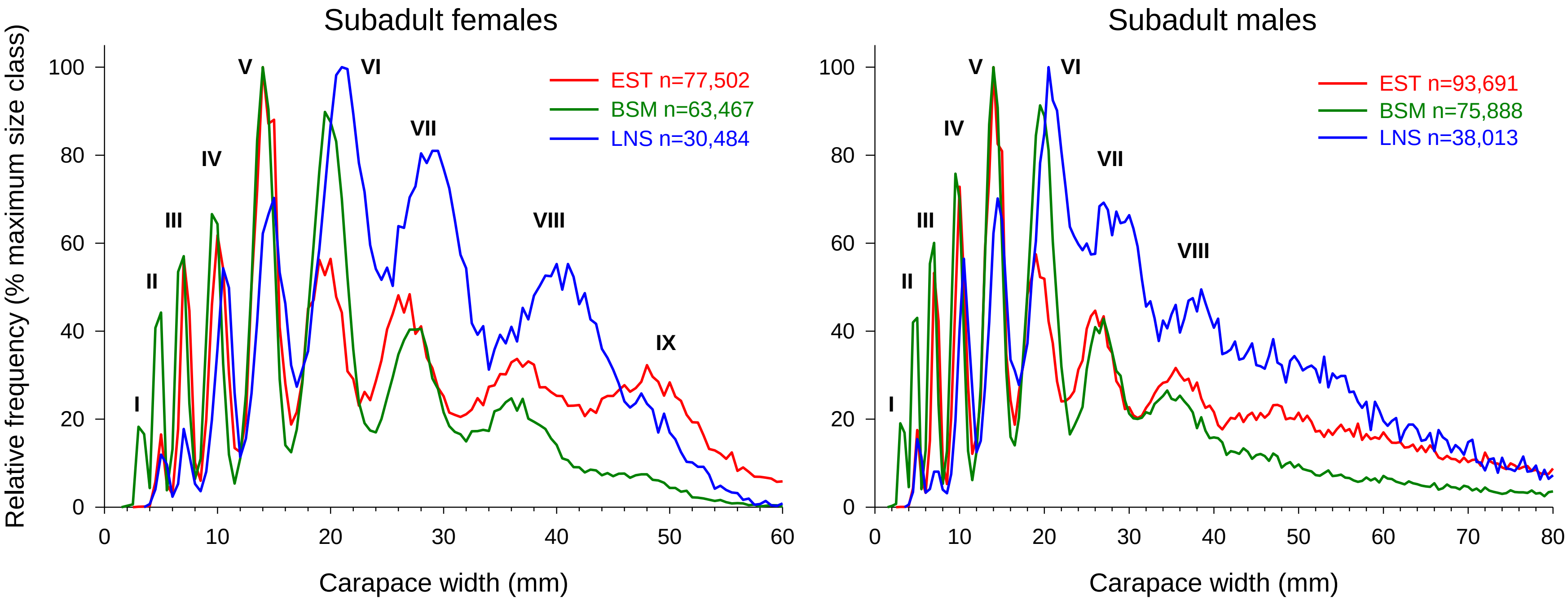
Introduction

- Snow crab, *Chionoecetes opilio*, has a terminal molt leading to full maturity (= adult) and final size (size after terminal molt, SATM).
- Snow crab stands apart from most other northern marine ecotherms in showing a smaller-colder spatial cline of adult body size.
- If temperature is the principal driver of spatial patterns of SATM in snow crab, it is also likely to be a driver of temporal patterns in SATM.
- This presentation reports work in progress on:
  - effects of temperature on growth rate (molt increment and intermolt period);
  - a longitudinal (temperature) cline in female and male SATM;
  - interannual variability in recruitment and SATM of females and males, and sources of variability in SATM (temperature and density).

North Gulf of Saint Lawrence (nGSL) regions: 1992-2013



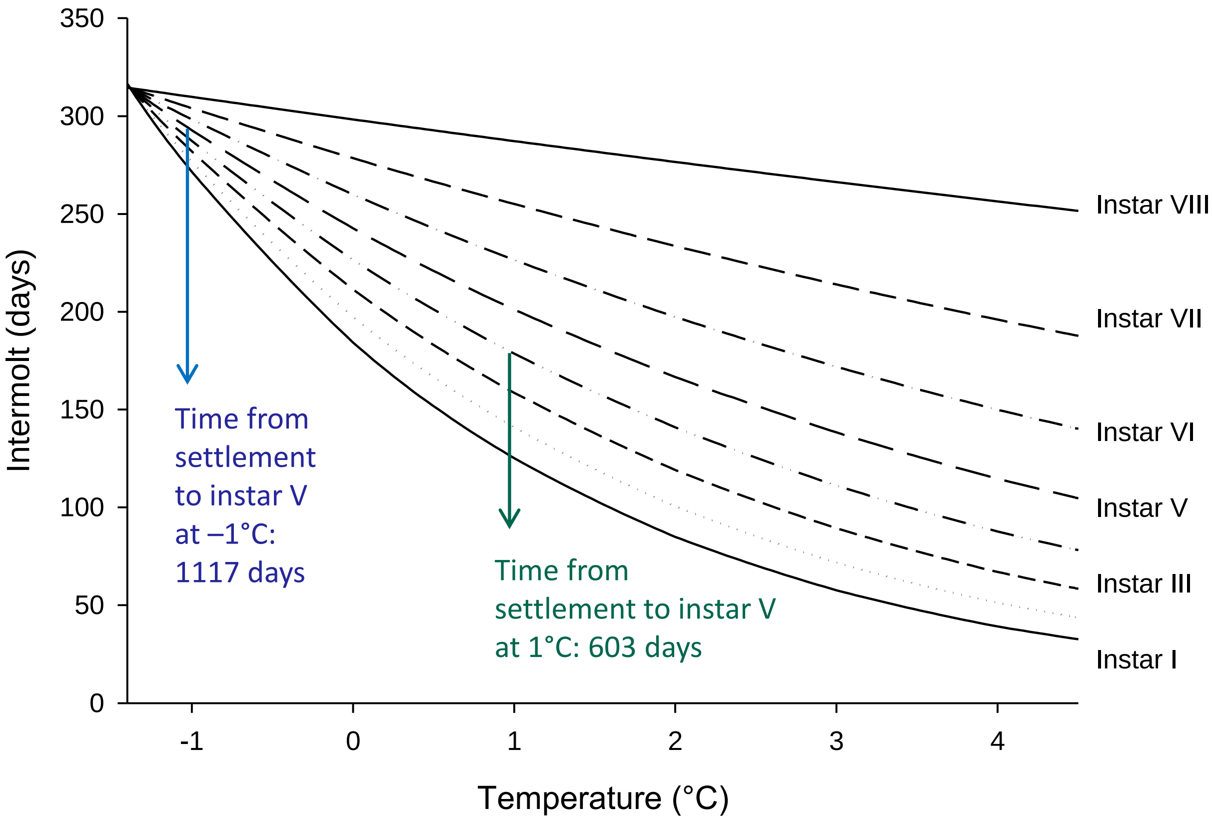
Subadult size frequency distributions in nGSL



Easily discernable modes representing instars I to VIII (males) or IX (females); mean carapace width (CW) at instar resolved by modal analysis to produce molt increments.

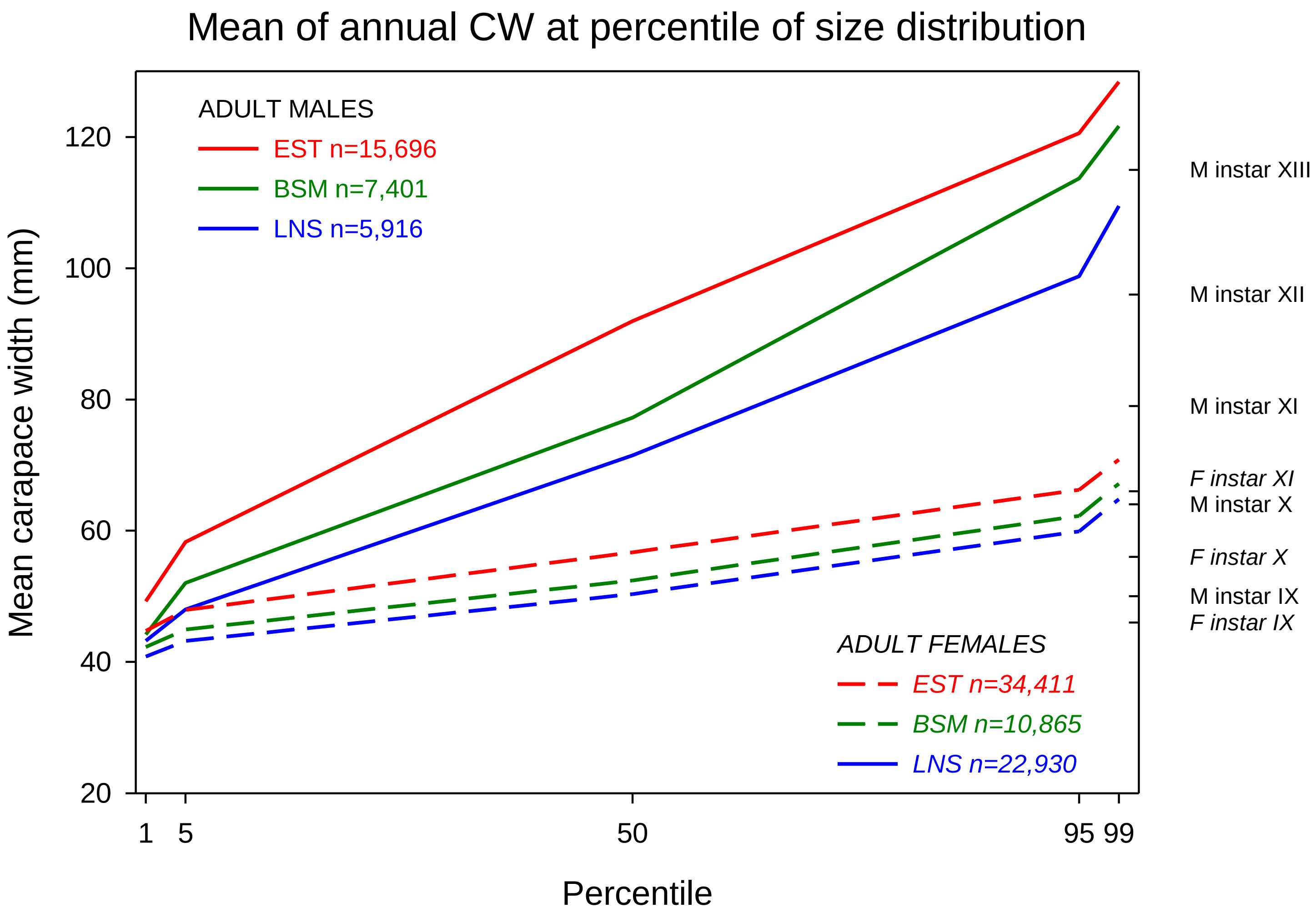
Effect of temperature on subadult growth rate

Regression of molt increment against instar number did not differ across nGSL regions; corroborated by lab work showing only very small temperature effects on molt increment.



- Temperature sensitivity declines with instar number and intermolt duration converges to 320 days for all instars from warm to cold.
- Instars I–IV are poorly mobile and endure local temperature; larger instars are hghly mobile and can be exposed to other temperatures by movement/migration.

Size after terminal molt (SATM) in nGSL regions



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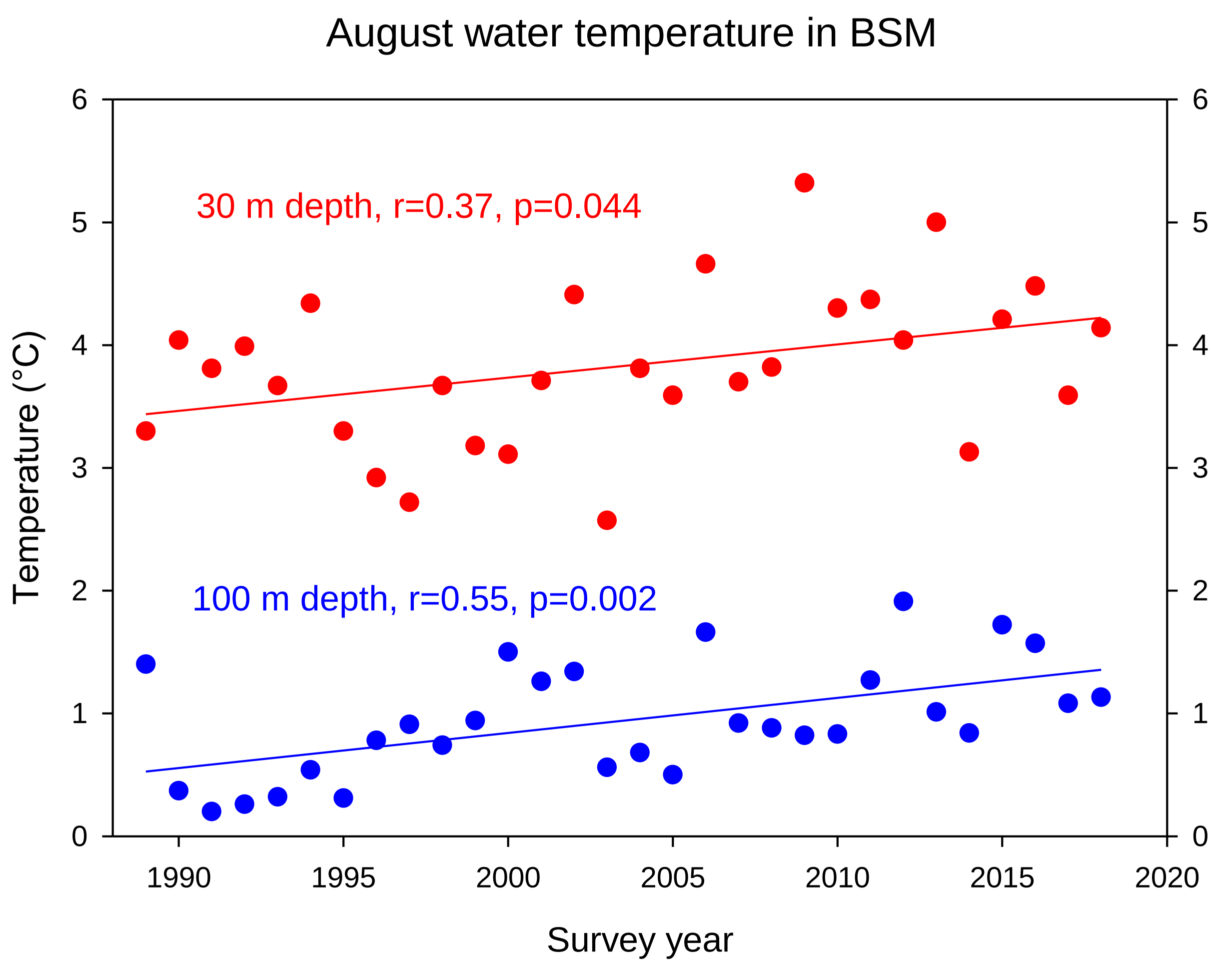
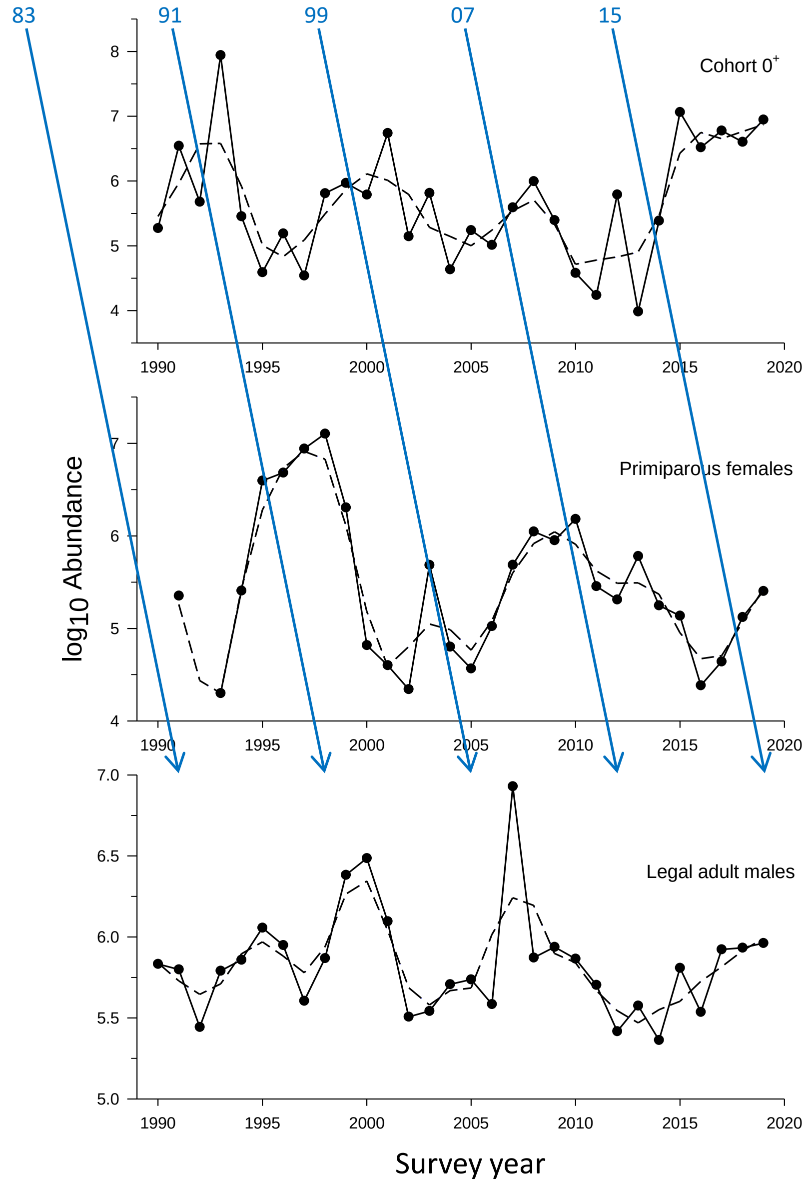
Interannual variability of water temperature in BSM



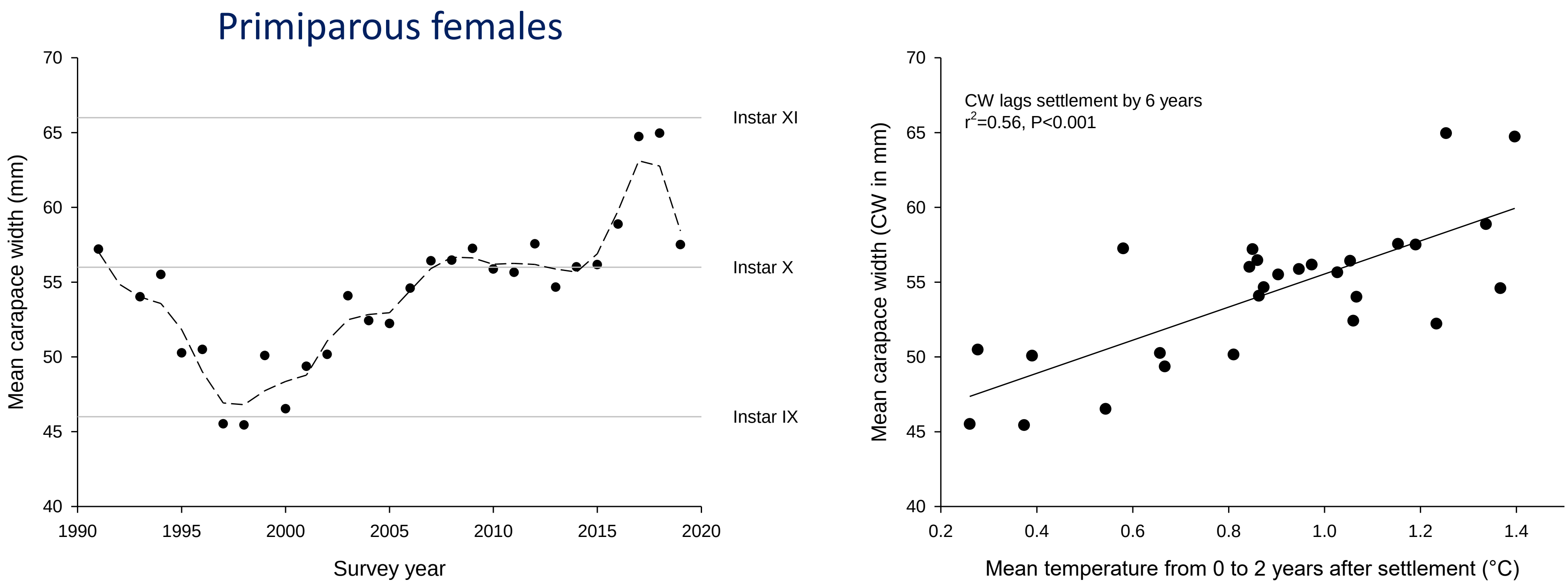
Recruitment dynamics in BSM

- Cohort 0+ (<5.5 mm CW) shows significant ≈8-yr cyclic abundance pattern.
- Abundance of primiparous females (newly recruited adults) and of legal adult males (i.e. ≥95 mm CW) is positively correlated with cohort 0+ abundance at lags of 5 yrs ($p=0.017$) and 7-8 yrs ($p=0.063$-0.080), respectively.
- Because molt increment does not vary with temperature, and mean time from settlement to TM is not highly variable, any interannual variability of SATM may mainly reflect a change in number of molts prior to TM. That change is likely to occur because crabs grow more or less quickly through instars I–IV, so we expect to find a positive relationship between temperature in early life and SATM.

Abundance of cohort 0+ (<5.5 mm CW), primiparous females and legal adult males (≥95 mm CW) in BSM by survey year

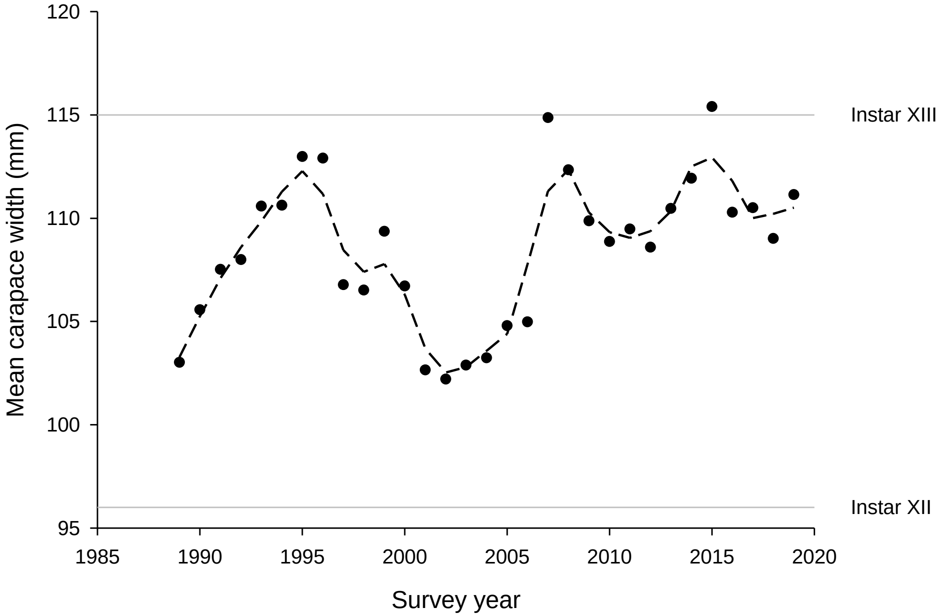


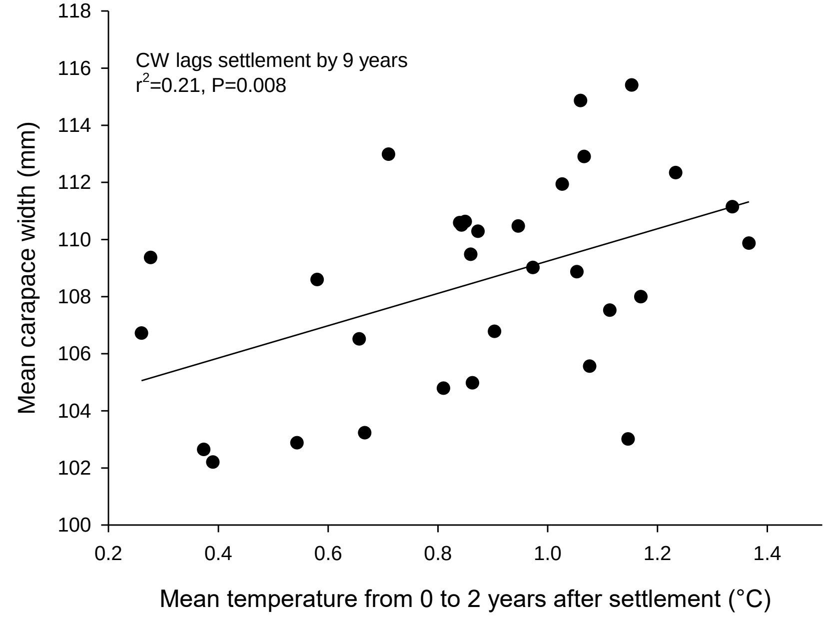
Interannual variability of female SATM in BSM



- 17,865 eggs at 45.4 mm CW and 51,460 eggs at 65.0 mm CW: a 2.9-fold increase.
- Strong effect of temperature 0-2 yrs from settlement on SATM at 6-yr lag; temperature from 3-5 yrs after settlement is marginally not significant (p=0.051).
- SATM not related to cohort 0^+ abundance at appropriate lag (p>0.2).

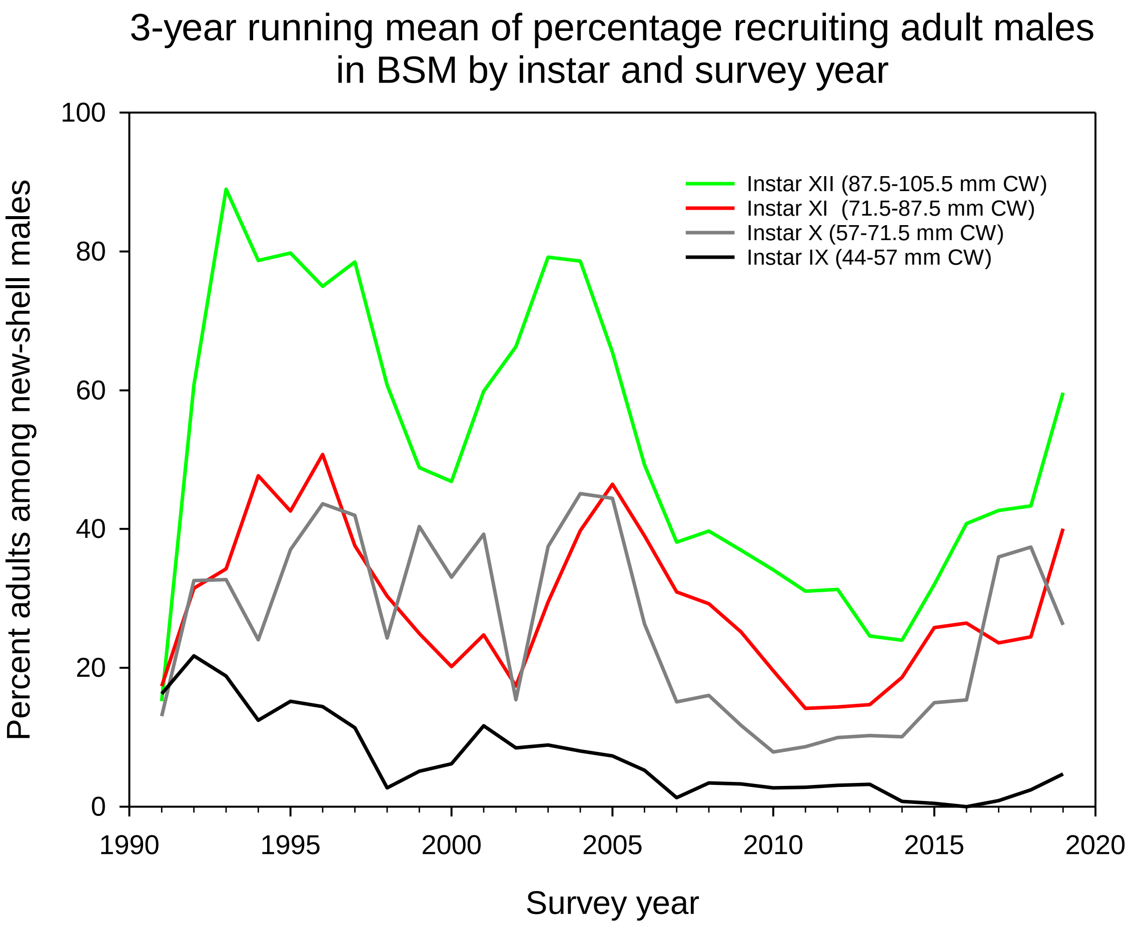
Interannual variability of legal (≥95 mm CW) male SATM in BSM





- Mass 0.45 kg at 102.2 mm CW and 0.65 kg at 115.4 mm CW: a 1.4-fold increase.
- Moderate effect of temperature 0-2 yrs from settlement on SATM at 9-yr lag; no effect of temperature from 3-8 (or 3-5) yrs after settlement on SATM (p>0.5).
- SATM not related to cohort 0^+ abundance at appropriate lag.

Male terminal molt schedule is variable



- Percent terminal molters negatively correlated to temperature 0-2 yrs from settlement in instar IX at 6-yr lag (p=0.003) and instar XII at 9-yr lag (p=0.029).
- Cause of variability in TM schedule for other instars: population density, mating opportunity?
- Proportion settlers reaching instar XII (legal size):
  - min 25% for 1997 y-c;
  - max 74% for 2004 y-c.
- Proportion of settlers reaching instar XIII:
  - min 6% for 1986 y-c;
  - max 56% for 2004 y-c.

Conclusion

- Potential for predicting spawning biomass and fishery recruitment from first benthic instars, based on year-class strength and better understanding of TM schedule, especially if early juvenile habitat is known/monitored.
- Changes in SATM alter egg production and commercial productivity (proportion males reaching legal or commercial size and mean mass of recruited males).
- Efficacy of minimum legal size (MLS) or constant exploitation rate for protecting against recruitment overfishing will change with temperature:
    - female sperm demand increases with warming (greater per capita fecundity and increased reproductive tempo);
    - a greater proportion of males become vulnerable to exploitation with warming – exploitation rate (or MLS) needs to be adjusted.

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