The southern Gulf of St. Lawrence as foraging habitat for the North Atlantic right whale: Role of *Calanus* diapause and regional circulation

Catherine Johnson[1]

Stéphane Plourde[2], Catherine Brennan[1], Laura Helenius[1], Nicolas Le Corre[3], Kevin Sorochan[1]


C. Johnson


NOAA Fisheries

[1]DFO, Bedford Institute of Oceanography

[2]DFO, Institut Maurice-Lamontagne

[3]DFO, Northwest Fisheries Science Centre

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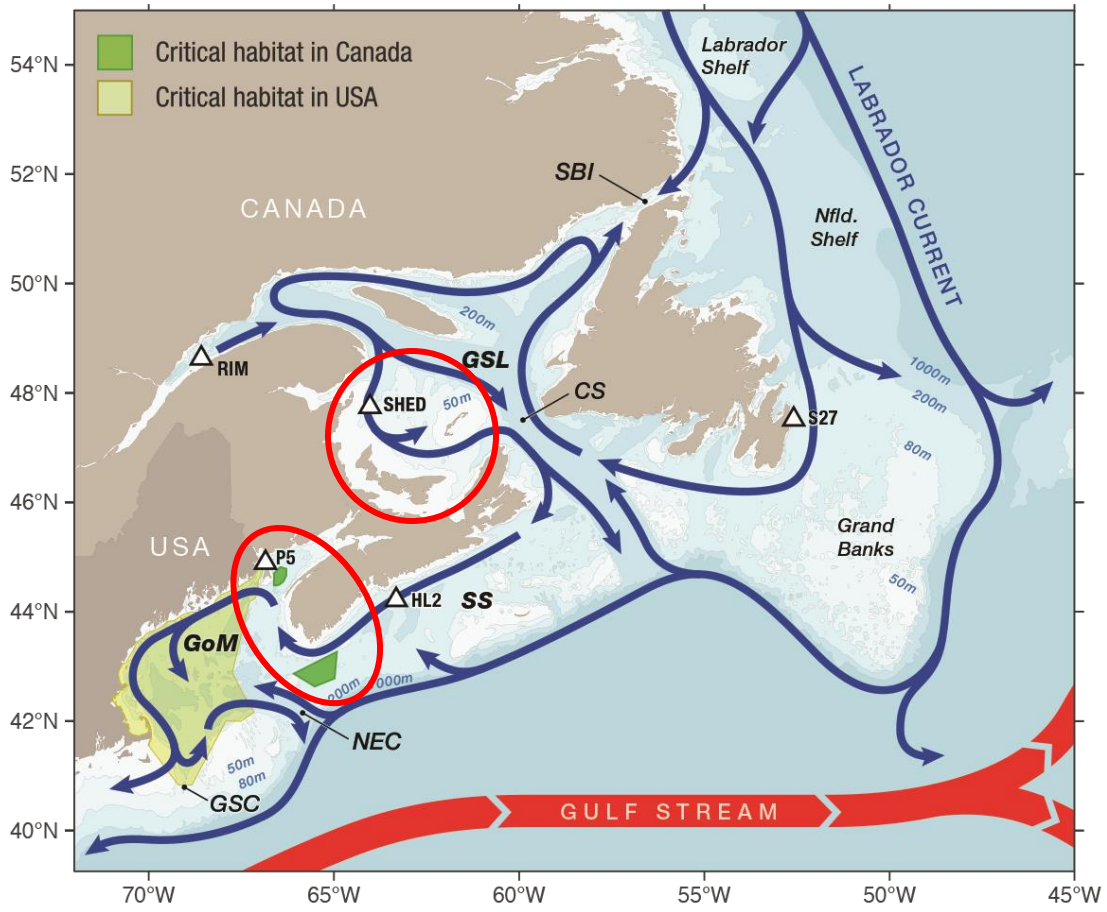
Background

- The primary prey of North Atlantic right whale (NARW) is late stage *Calanus* spp.
- NARW distribution has shifted in response to changes in environment and prey population abundance and distribution
- After 2010, there were fewer sightings in traditional foraging habitats
- After 2015, there was persistent residence of NARW in the southern Gulf of St. Lawrence (sGSL) in spring and summer

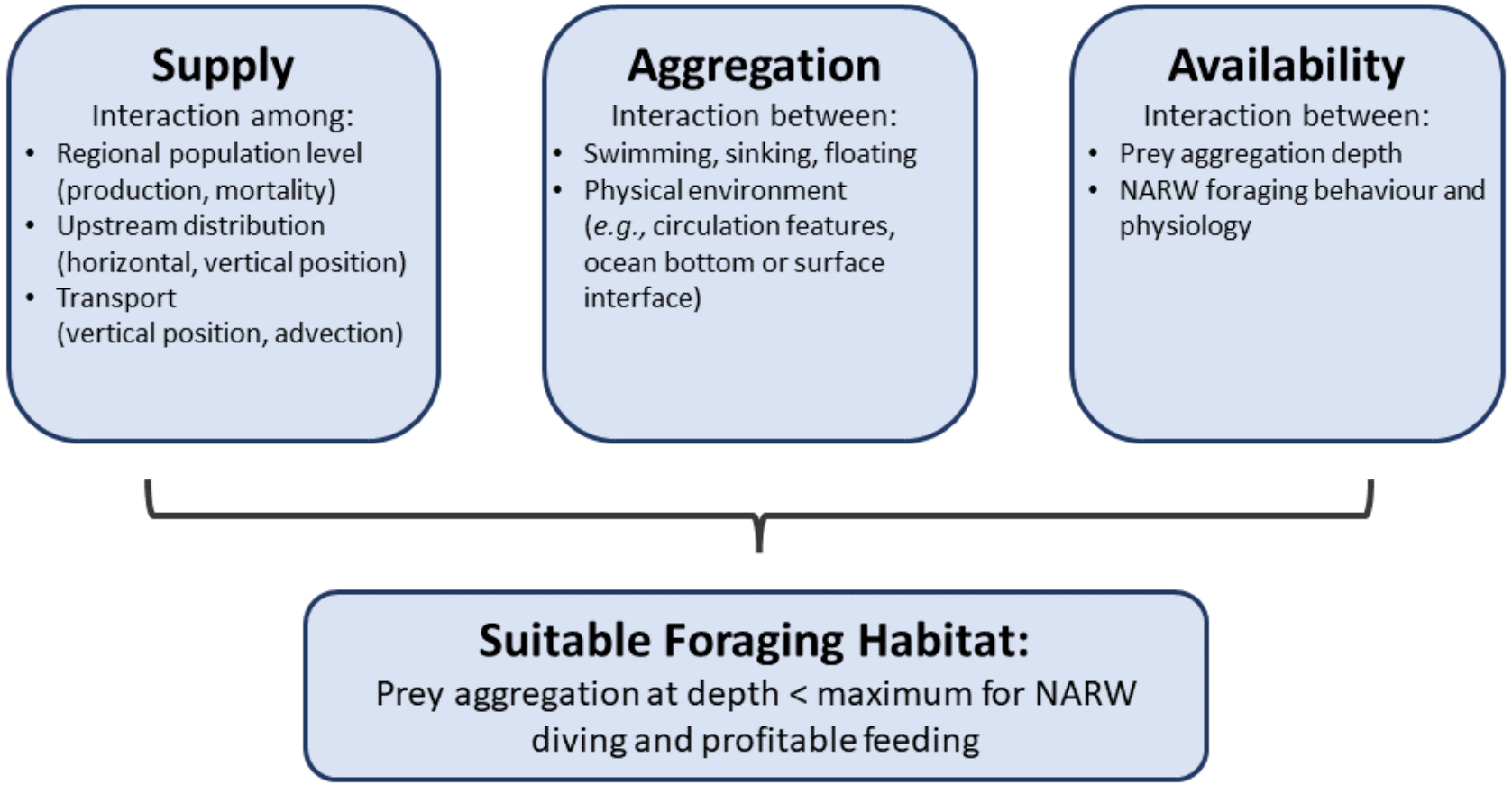
Defined NARW critical habitat and general circulation in the northwest Atlantic



Sorochan et al (2021) ICES J Mar Sci 78(10): 3498-3520

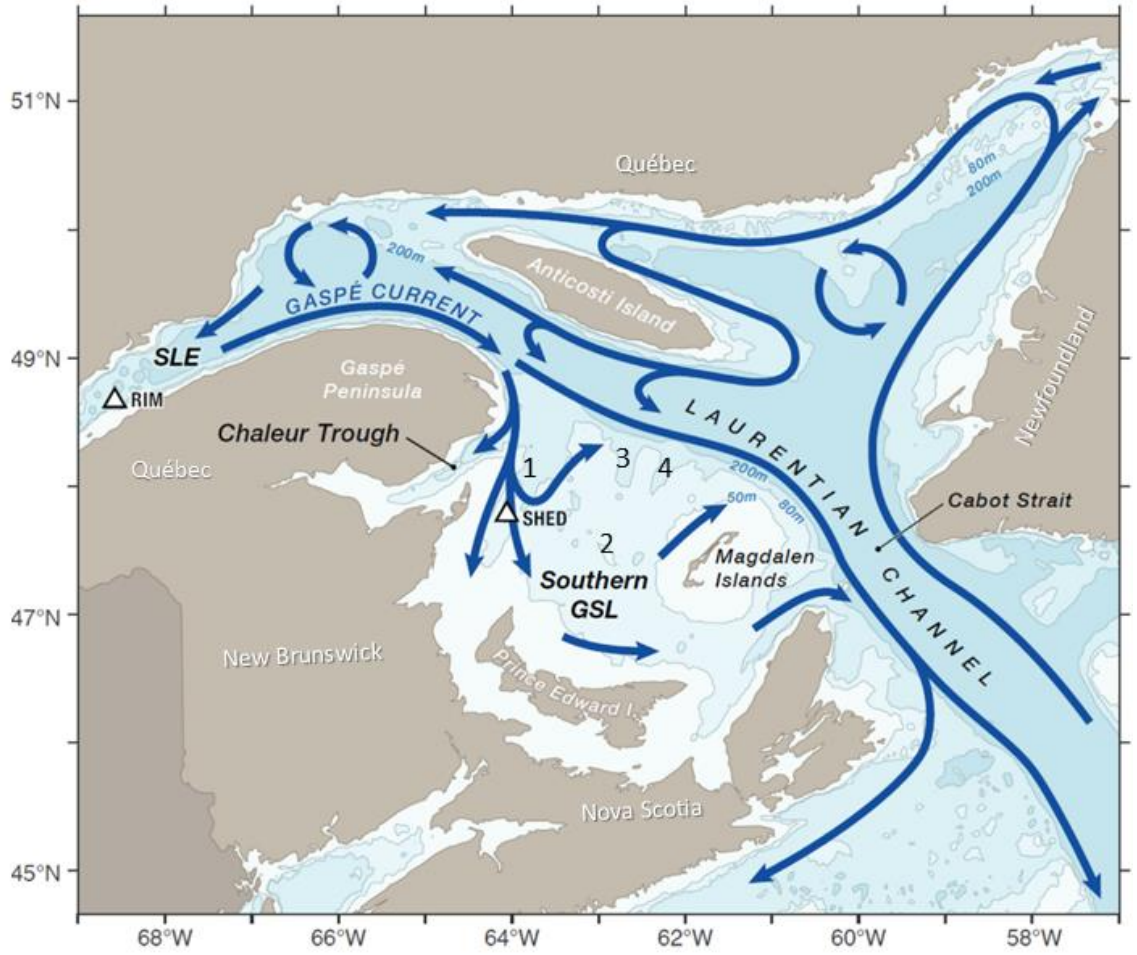
Supply – Aggregation – Availability conceptual model

Formation of suitable foraging habitat requires alignment of adequate Supply and Aggregation processes in locations where prey are Available at depths less than the maximum for NARW diving and profitable feeding



Southern Gulf of St. Lawrence (sGSL)

General Circulation Pattern in the Gulf of St Lawrence



Sorochan et al. (2021)
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Calanus hyperboreus

Calanus glacialis

Calanus finmarchicus

Photo: Dag Altin

Overall Objective

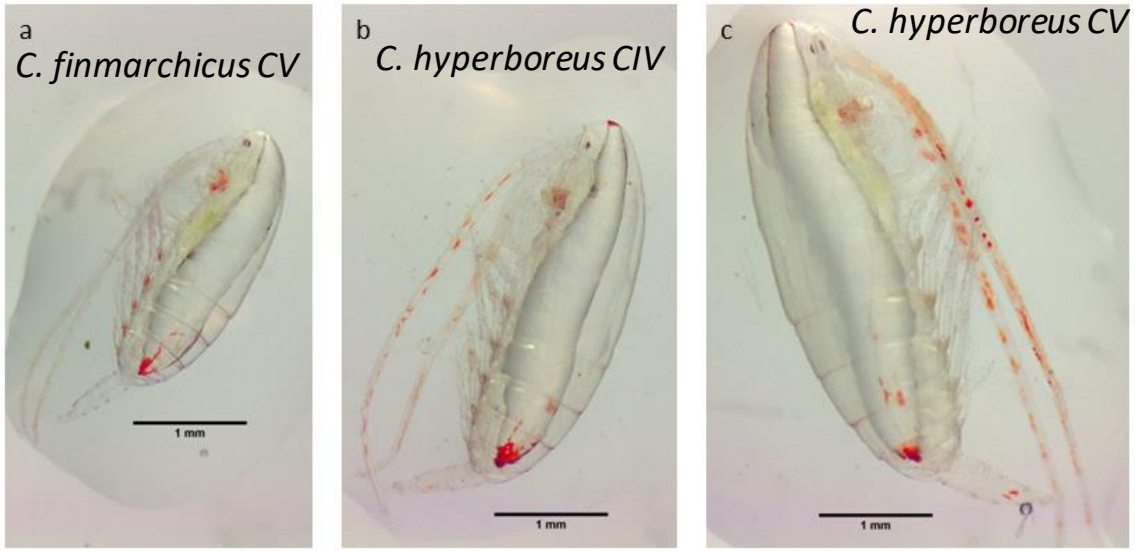
Synthesize key processes and dynamics driving NARW <u>important habitat</u> in the sGSL

DFO NARW Action Plan (DFO 2021)

Key attributes of NARW Adult foraging habitat include

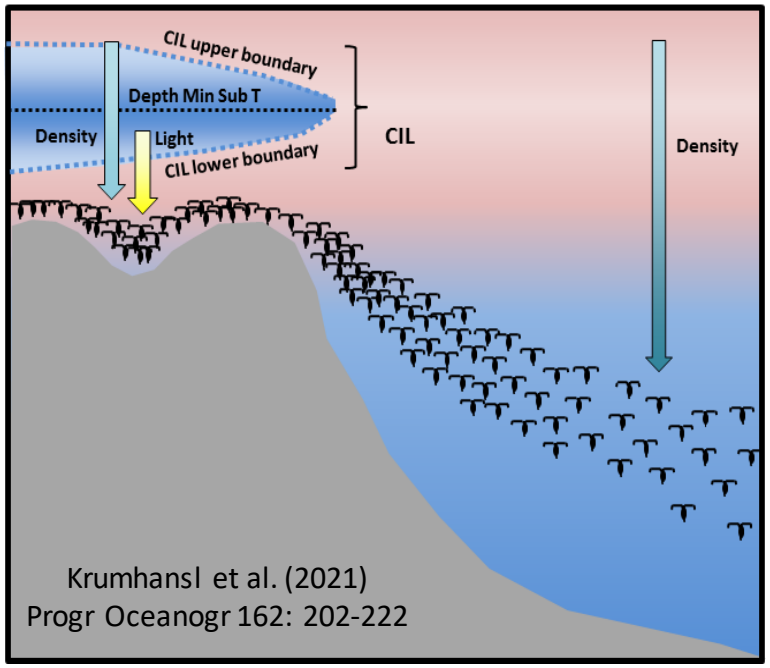
- Presence of sufficient quantities and quality of prey to support the population
- Environmental, oceanographic and bathymetric conditions that support and aggregate concentrations of prey

Primary *Calanus* spp. diapausing stages in the sGSL



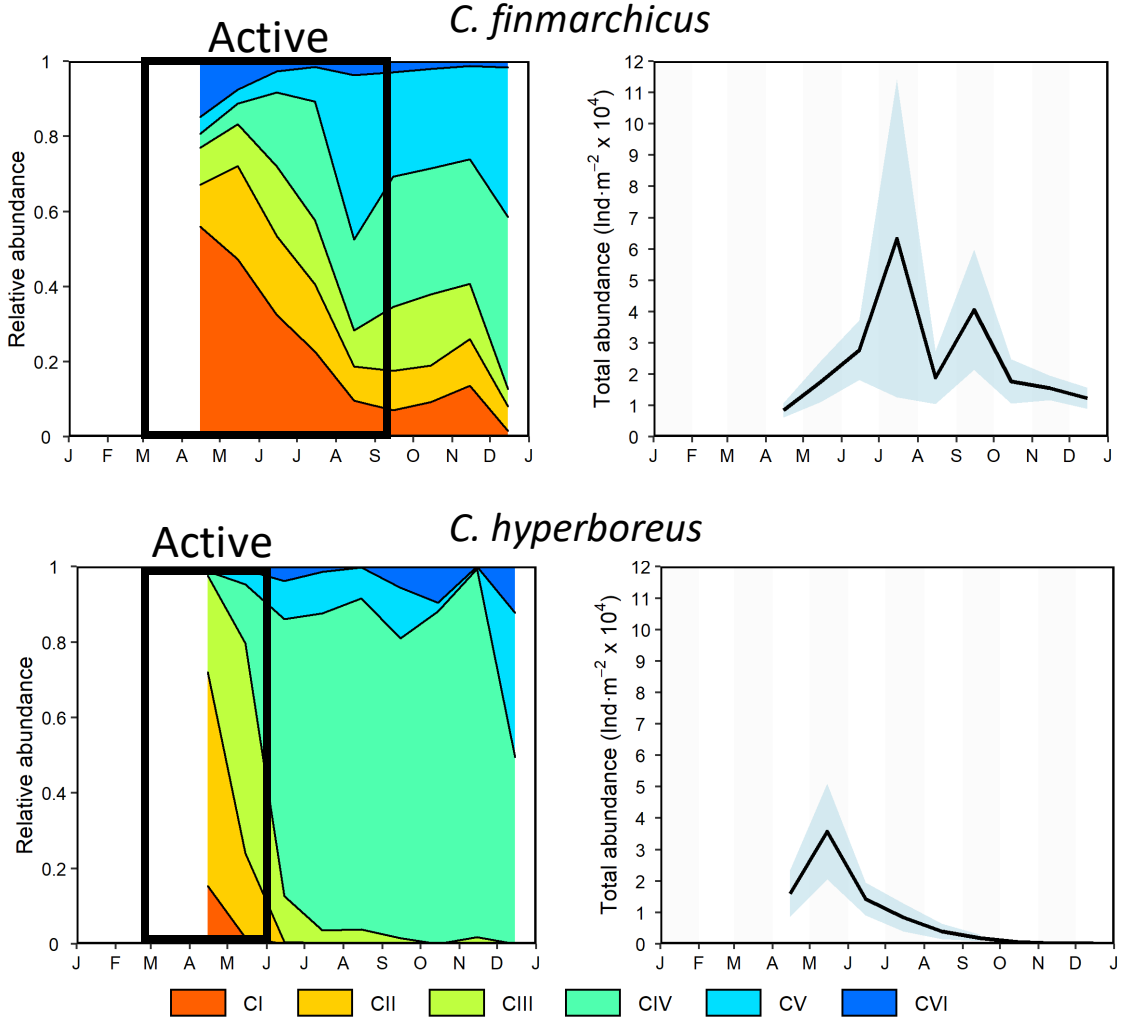
Calanus spp. life cycle in the GSL

Schematic shelf/slope vertical distributions of diapausing *Calanus* spp. in summer-fall



- *C. finmarchicus* active period is ~ March – Sept.
- *C. hyperboreus* active period ~ March – July

Shediac Valley (sGSL) *Calanus* annual development



Blais et al. (2023) Can Tech Rep Hydrogr Oc Sci 357

Multidisciplinary Approach:

Synthesize published and in-progress research in the sGSL

Supply

- Regional prey population levels assessed through DFO ocean monitoring
- Hindcast 3-D coupled *Calanus* population models

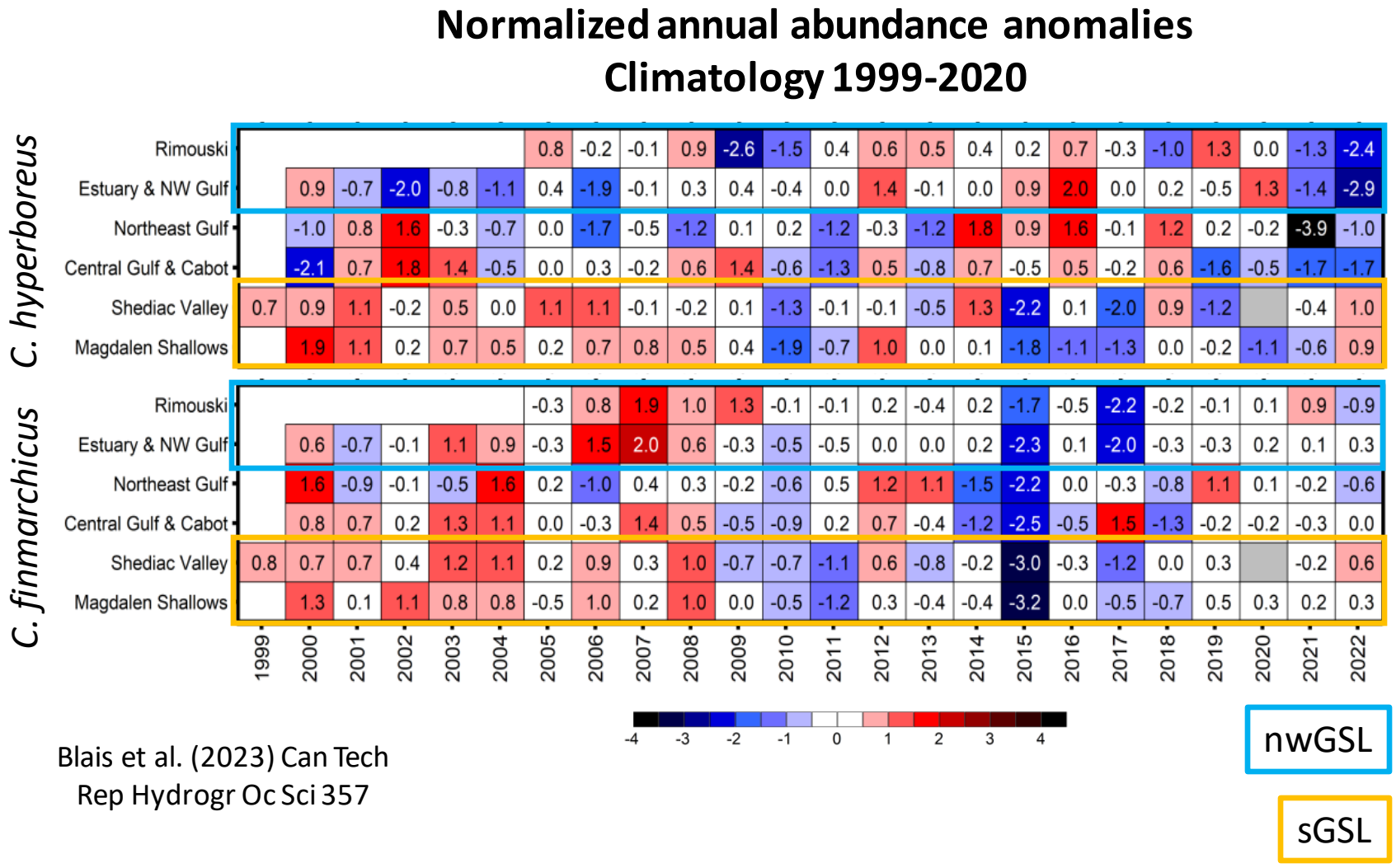
Aggregation and availability

- *In situ* observations of *Calanus* spp. abundance, composition, and vertical distribution in the sGSL using integrated and stratified net sampling, Video Plankton Recorder (VPR) in spring (2022), summer (2019), and autumn (2018)

Prey quality

- Direct observations of *Calanus* individual energy (spring 2022, summer 2019)
- Estimate energy density in prey layers near NARW observations from Max. *Calanus* concentration (VPR) x Species/stage specific individual energy (calorimetry) x Species/stage composition (nets)

Population-levels of dominant *Calanus* spp. in GSL



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nwGSL

sGSL

Northwest Gulf

C. hyperboreus

Strong interannual variability

C. finmarchicus

Mainly low or normal since 2010

sGSL

C. hyperboreus

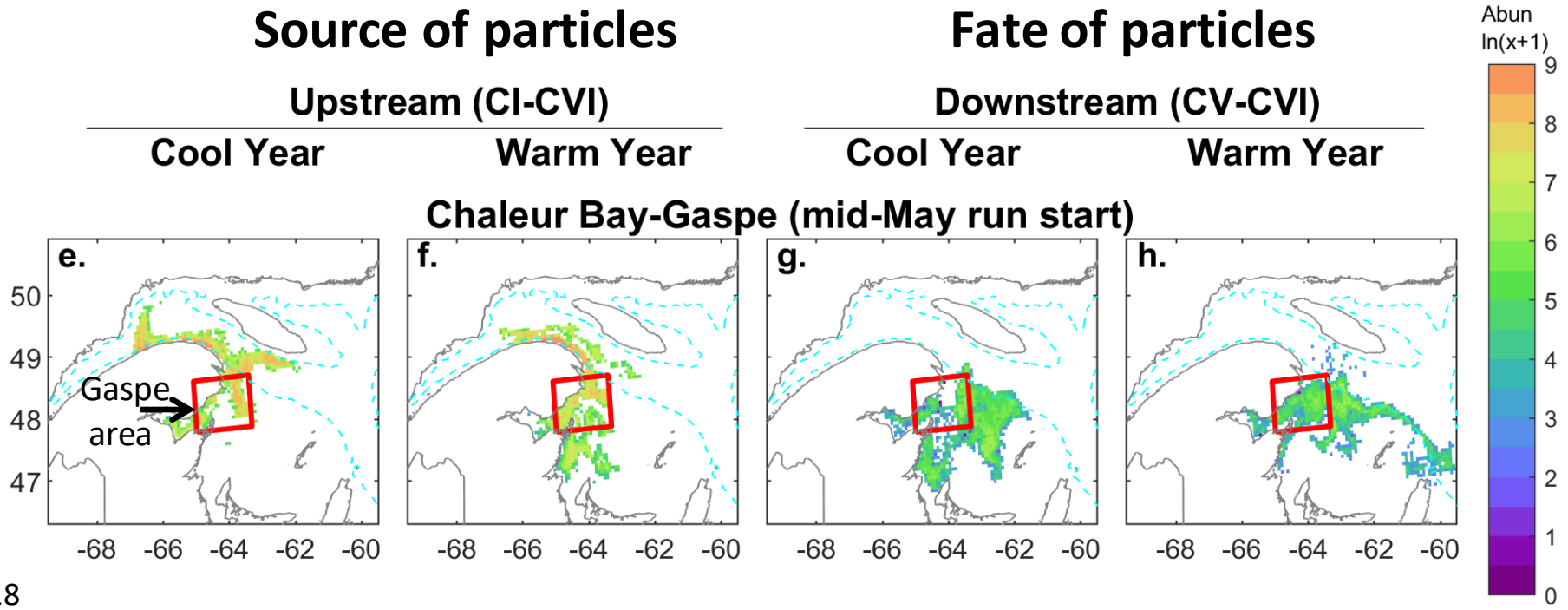
Mainly low but variable since 2010

C. finmarchicus

Mainly low or normal since 2010

Coupled 3D model simulations: *Calanus* supply to the sGSL

- *Calanus* spp. supplied to sGSL from the deep nwGSL, mainly during surface active period
- Particles in Gaspé area can be transported southward into sSGL or along the slope edge
- *C. hyperboreus* contributes to supply mainly in spring and early summer
- Supply is more sensitive to circulation variability in spring and early summer and to upstream *C. finmarchicus* population levels in late summer and fall

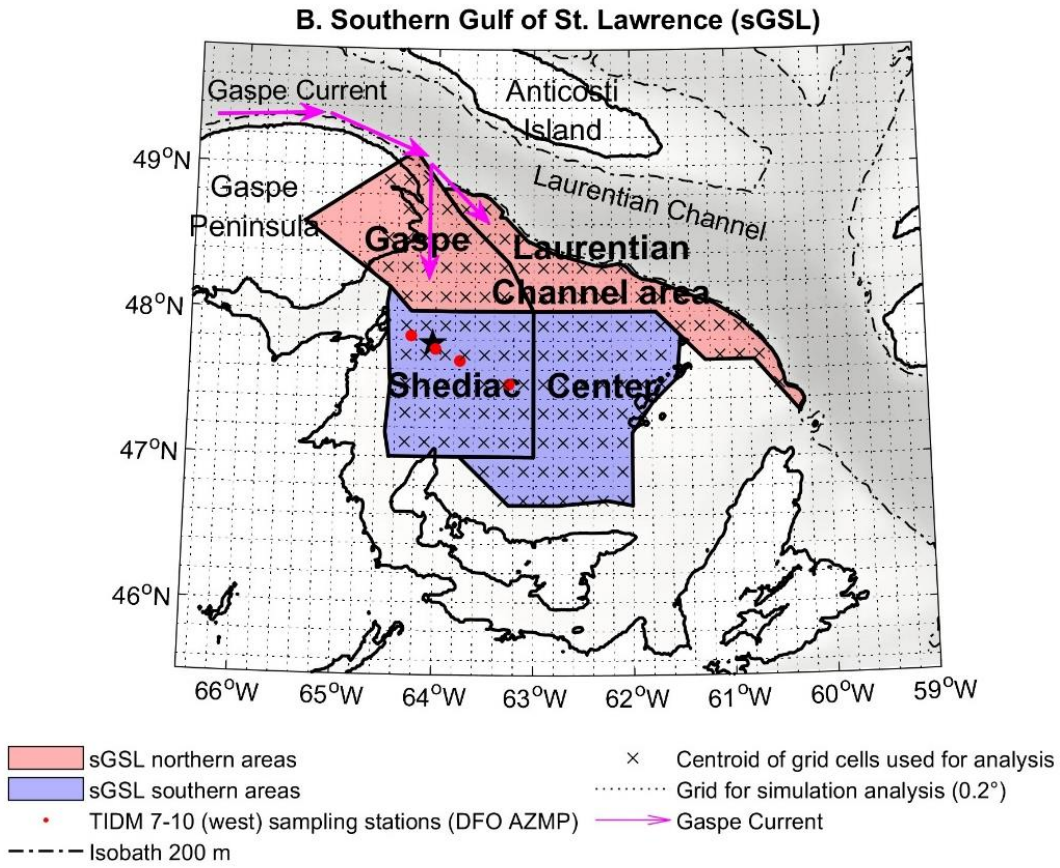


Brennan et al. (2021)
Prog Oceanogr 197:1–18

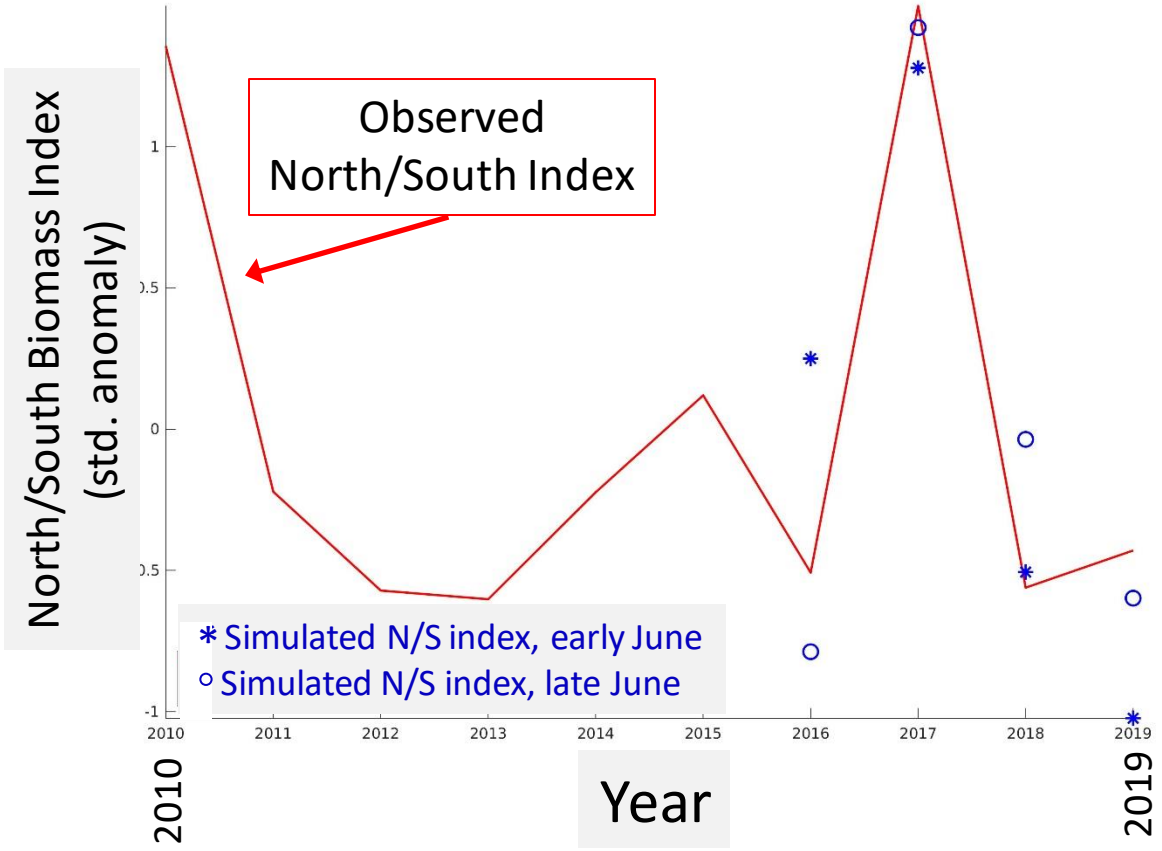
Model simulations of *C. hyperboreus* supply: alternate pathways

Simulations of interactions of new cohort development, vertical distribution, and transport can reasonably forecast interannual variability in spring *C. hyperboreus* phenology and North/South spatial index

Northern and Southern sGSL areas



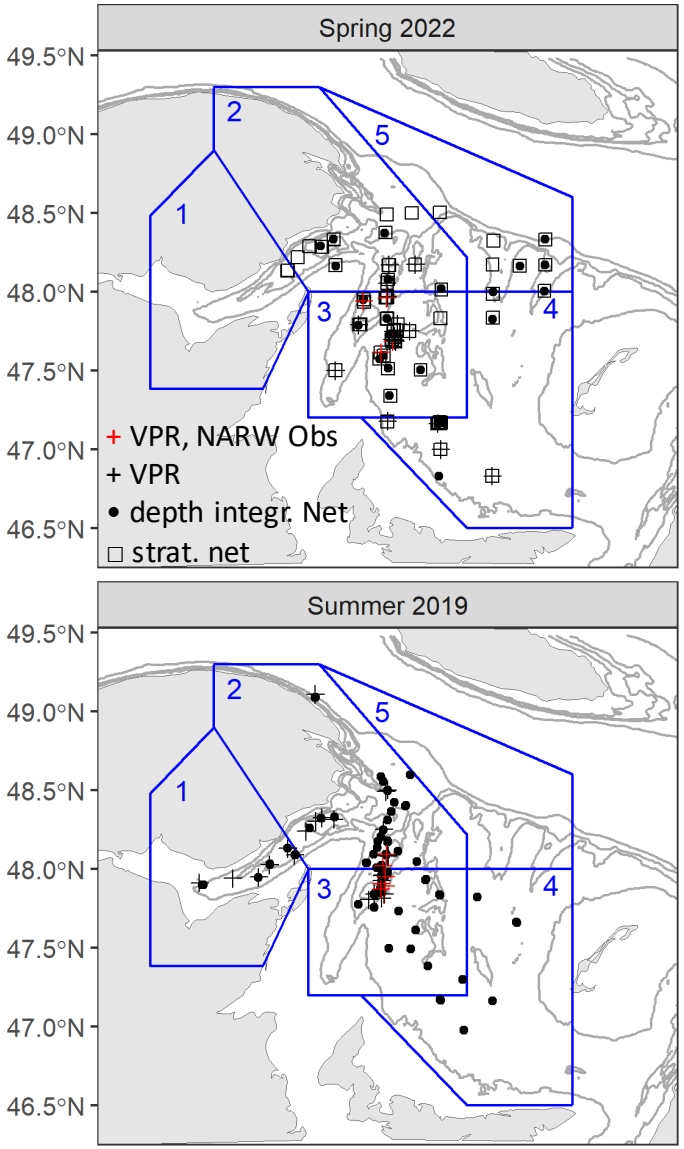
Observed and simulated North/South Index



Le Corre et al. (2023) Prog Oceanogr 219:1–20

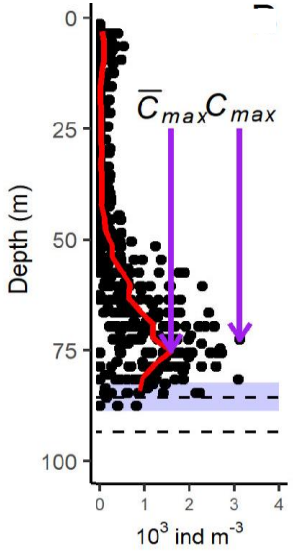
High near-bottom prey aggregations near NARW observations

Sampling sites

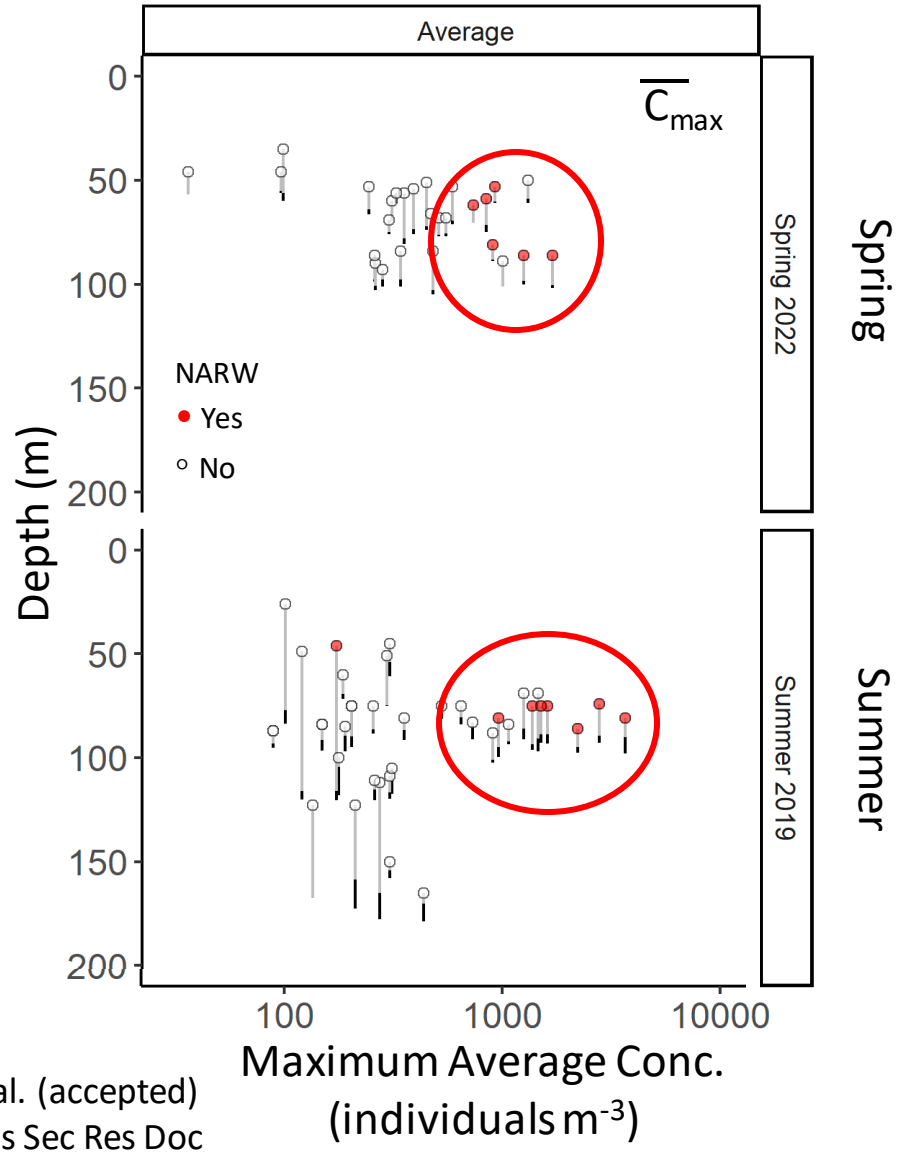


Video Plankton Recorder

Calanus spp. vertical profile



Depth and magnitude of max. *Calanus* layer



Johnson et al. (accepted)
Can Sci Advis Sec Res Doc

Prey aggregations in sGSL have adequate Energy Density for NARW foraging

Compared to traditional NARW foraging habitats, sGSL prey layer energy density (ED) near NARW was…

- Shallower
- Lower in spring 2022
  Similar or higher in summer 2019

Compared to NARW energy requirements…

- Spring 2022: Max ED similar to requirement for resting female NARW
- Summer 2019: Max ED exceeded that of all demographic groups

Estimated energy density in prey layers near NARW observations

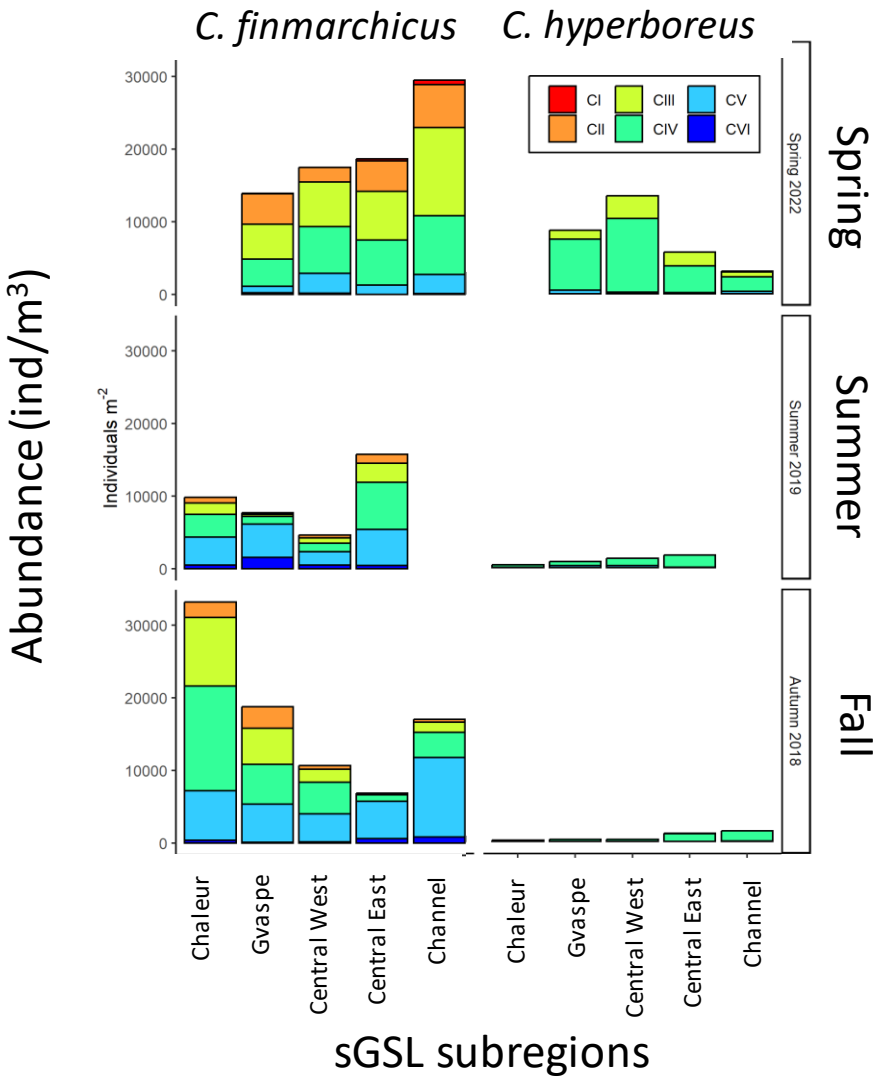
Location, Study	Season, Year	Individual Energy (J ind^{-1})	Depth of max concentration (m)	Maximum Concentration (ind. m^{-3})	Maximum Energy Density (kJ m^{-3})
Southern GSL, Johnson et al (in revision)	Spring 2022	CfinCV, CglaCV (7.9) ChypCIV (12.2) ChypCV(31.9) Weighted avg: 11.8	40-100	Median: 1540 Max:2350	Median: 18 Max: 28
Southern GSL, Johnson et al (in revision)	Summer 2019	CfinCV, CglaCV (9.4) ChypCIV (9.6) ChypCV (65.2) Weighted avg: 15.1	70-90	Median: 3420 Max: 9460	Median: 52 Max: 143
Lower Bay of Fundy; Michaud and Taggart (2011)	Summer 2002	CfinCV (4.5 J)	>140	Median: NA Max: 10000	Median: NA Max: 45
Lower Bay of Fundy and Roseway Basin, Baumgartner and Mate (2003)	Summer 2000 and 2001	CfinCV (6.8 J) [Comita et al. 1966 in UK waters]	100-170	Median: 6220 Max: 20610	Median: 42 Max: 140

Johnson et al. (accepted) Can Sci Advis Sec Res Doc

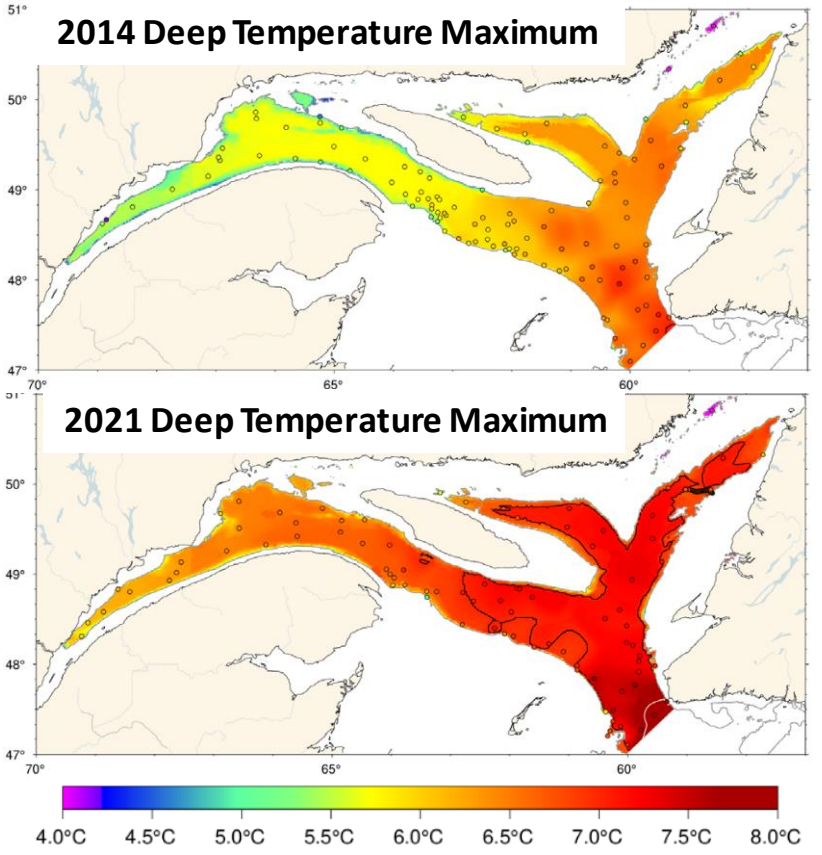
Diapause influence on NARW prey dynamics in the sGSL

- In winter, *Calanus* spp. are depleted in the sGSL and diapausers are mainly in the deep Laurentian Channel
- Transport supplies *C. hyperboreus* during surface active period in ~ March – July
- Both transport and local production supply *C. finmarchicus* during active period ~ March – Sept.
- *Calanus* transport and distribution are sensitive to Gaspé Current variability
- By mid-May, vertical migration concentrates *C. hyperboreus* in near-bottom layers
- *C. finmarchicus* vertical migration contributes to near-bottom layers in late spring to fall
- *Calanus* spp. decline in fall, likely due to mortality, increased wind mixing, and changing circulation

Species-specific stage abundance



Risks to sGSL foraging habitat



Galbraith et al. (2022) Can. Tech. Rep. Hydrog. Oc. Sci. 354

Supply

- Risk of decline in *Calanus* spp. at the southern ends of their range (*C. finmarchicus* – GOM, SS; *C. hyperboreus, C. glacialis* – GSL) under future warming, declining winter sea ice, and strong deep-water warming
- *C. hyperboreus* supply is sensitive to variability in transport to the sGSL during their short active period at the surface

Aggregation and Availability

- Shallow bottom depth (< 100 m) and seasonal vertical migration support prey aggregation and availability across most of the sGSL
- If supply declines, the probability of adequate energy density for NARW would also decline

Acknowledgements

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Travel

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