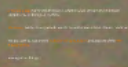



Mixing chronobiology, phenology and evolutionary biology in the study of deep-sea organisms: a look at patterns and drivers of life cycles and species interactions

Annie Mercier

Department of Ocean Sciences
Memorial University



A five-armed starfish is positioned on the left side of the frame, resting on a dark, textured surface. The starfish is light-colored, possibly orange or pinkish, with a slightly mottled appearance. Its arms are spread out, and it casts a soft shadow to the right. The background is a dark, almost black, surface with a fine, grainy texture, possibly sand or a rock face. The lighting is soft, highlighting the contours of the starfish.

Chronobiology examines behavioural, physiological, cellular and molecular components of biological rhythms.

Phenology relates those periodic events to environmental and climatic conditions.

We use both to explore the **evolution of reproduction** and aspects of the **life-history theory**.

Among other things...

Main Foci

Research in my lab examines the interactions between benthic organisms and environmental factors at various scales, focusing on endogenous and exogenous drivers of gamete synthesis, spawning, larval development, settlement, growth and associations from functional and evolutionary perspectives.



Breadth/depth of broad significance to biology, ecology, evolution and communication made by our teams

- Evidence of lunar rhythms in the reproduction of deep-water taxa
- Demonstration of a seasonal functional relationship between fish larvae and deep-sea corals



We address research questions through a wide spectrum of approaches and techniques, typically combining field samplings and experimental trials with microscopical/cellular analyses



Our trademark is the study of live deep-sea animals



Through realistic long-term lab experiments



It would be a great benefit to make parallels with studies conducted in situ

Main interests include cycles of activity (circadian, monthly, seasonal, annual) relative to:

- Feeding
- Gamete production
- Gamete release
- Symbiotic associations
- Trophic interactions

We seek to clarify how environmental factors mediate periodic reproductive cycles and how those cycles align among conspecifics to enhance synchronous gamete maturation and epidemic spawning.

Research in my lab examines the interactions between benthic organisms and environmental factors at various scales, focusing on endogenous and exogenous drivers of gamete synthesis, spawning, larval development, settlement, growth and associations from functional and evolutionary perspectives.

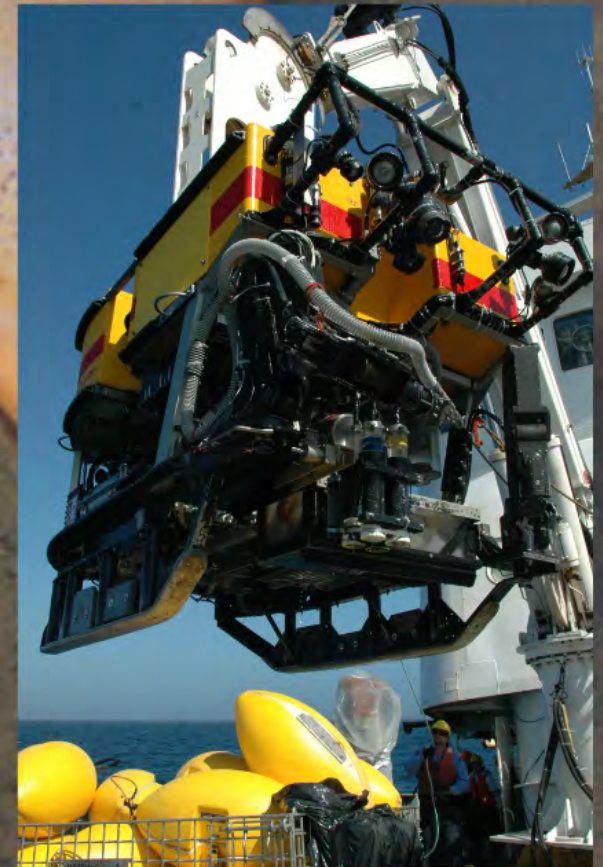


Breakthroughs of broad significance to biology, ecology, evolution and conservation made by our team :

- Evidence of lunar rhythms in the reproduction of deep-water taxa.
- Demonstration of a seasonal functional relationship between fish larvae and deep-sea corals.



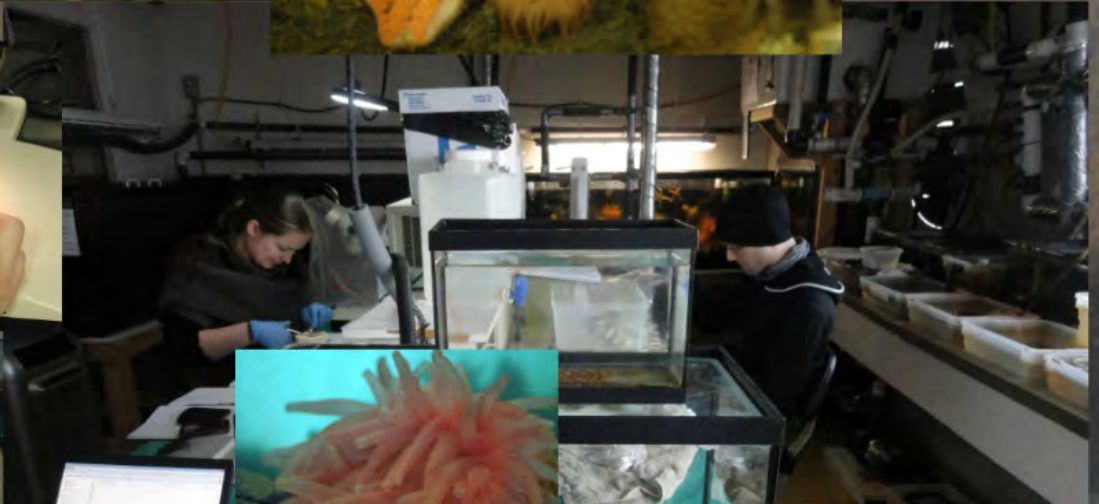
We address research questions through a wide spectrum of approaches and techniques, typically combining field samplings and experimental trials with microscopic/cellular analyses



Our trademark is the study of live deep-sea animals



Through realistic long-term lab experiments



It would be a great benefit to make parallels with studies conducted in situ

Main interests include cycles of activity (circadian, monthly, seasonal, annual) relative to:

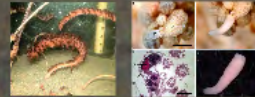
- Feeding
- Gamete production
- Gamete release
- Symbiotic associations
- Trophic interactions

We seek to clarify how environmental factors mediate periodic reproductive cycles; and how those cycles align among conspecifics to achieve synchronous gamete maturation and epidemic spawning.

Research Results

Deep-sea corals

Gamete development and breeding periodicity in octocorals



Lee, C. J., E. S. Riebel & M. S. Riebel (2010) Periodicity of gamete development in the deep-sea coral *Desmarestia* sp. *Journal of Experimental Marine Biology and Ecology*, 383, 1-10.
 Lee, C. J., E. S. Riebel & M. S. Riebel (2010) Periodicity of gamete development in the deep-sea coral *Desmarestia* sp. *Journal of Experimental Marine Biology and Ecology*, 383, 1-10.
 Lee, C. J., E. S. Riebel & M. S. Riebel (2010) Periodicity of gamete development in the deep-sea coral *Desmarestia* sp. *Journal of Experimental Marine Biology and Ecology*, 383, 1-10.

Deep-sea corals

Gamete development, breeding periodicity, and seasonal growth in octocorals



Hansen, L. P., Z. S. Glick & M. S. Riebel (2011) Influence of day and seasonal factors on the growth of the deep-sea coral *Desmarestia* in mesocosm. *Journal of Experimental Marine Biology and Ecology*, 383, 1-10.

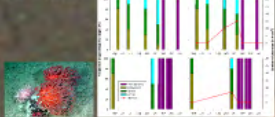
Deep-sea corals & other taxa

Life cycles

Reynolds, T., S. J. Wilson & J. J. Wilson (2011) Deep-sea corals and other taxa: life cycles and reproductive periodicity of anemone corals. *Journal of Experimental Marine Biology and Ecology*, 383, 1-10.

Deep-sea corals

Reproductive strategies



Reynolds, T., S. J. Wilson & J. J. Wilson (2011) Contrasting reproductive strategies in deep-sea corals and other taxa. *Journal of Experimental Marine Biology and Ecology*, 383, 1-10.

Deep-sea corals

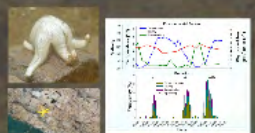
Species interactions



Reynolds, T., S. J. Wilson & J. J. Wilson (2011) Deep-sea corals and other taxa: species interactions. *Journal of Experimental Marine Biology and Ecology*, 383, 1-10.

Deep-sea sponges

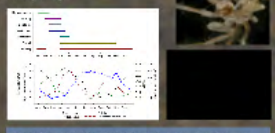
Life-history strategies



Reynolds, T., S. J. Wilson & J. J. Wilson (2011) Deep-sea sponges and other taxa: life-history strategies. *Journal of Experimental Marine Biology and Ecology*, 383, 1-10.

Deep-sea sponges & molluscs

Life-history strategies



Reynolds, T., S. J. Wilson & J. J. Wilson (2011) Deep-sea sponges and molluscs: life-history strategies. *Journal of Experimental Marine Biology and Ecology*, 383, 1-10.

Deep-sea sponges, molluscs and siphonarians

Trophic interactions



Reynolds, T., S. J. Wilson & J. J. Wilson (2011) Deep-sea sponges, molluscs and siphonarians: trophic interactions. *Journal of Experimental Marine Biology and Ecology*, 383, 1-10.

Deep-sea corals

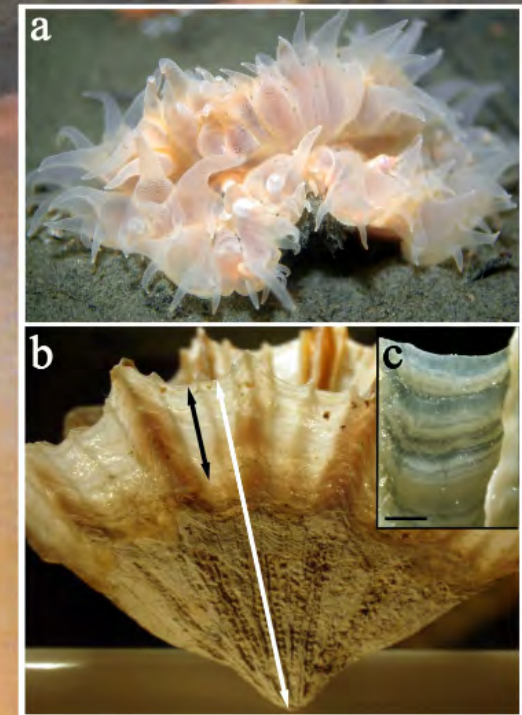
Gamete development and breeding periodicity in octocorals



- Sun, Z., J.-F. Hamel & A. Mercier 2009. Planulation of deep-sea octocorals in the NW Atlantic. *Coral Reefs* 28(3): 781.
- Sun, Z., J.-F. Hamel & A. Mercier 2010. Planulation periodicity, settlement preferences and growth of two deep-sea octocorals from the northwest Atlantic. *Marine Ecology Progress Series* 410: 71-87.
- Sun, Z., J.-F. Hamel, E. Edinger & A. Mercier 2010. Reproductive biology of the deep-sea octocoral *Drifa glomerata* in the Northwest Atlantic. *Marine Biology* 157: 863-873.
- Baillon S., J.-F. Hamel & A. Mercier 2014. Seasonality in reproduction of the deep-water pennatulacean coral *Anthoptilum grandiflorum*. *Marine Biology*, 161: 29-43.
- Baillon S., J.-F. Hamel & A. Mercier. Protracted oogenesis and annual reproductive periodicity in a deep-sea octocoral. *Marine Ecology*, early view.

Deep-sea corals

Gamete development, breeding periodicity and seasonal growth in scleractinians



Hamel, J.-F., Z. Sun & A. Mercier 2010. Influence of size and seasonal factors on the growth of the deep-sea coral *Flabellum alabastrum* in mesocosm. *Coral Reefs* 29(2): 521-525.

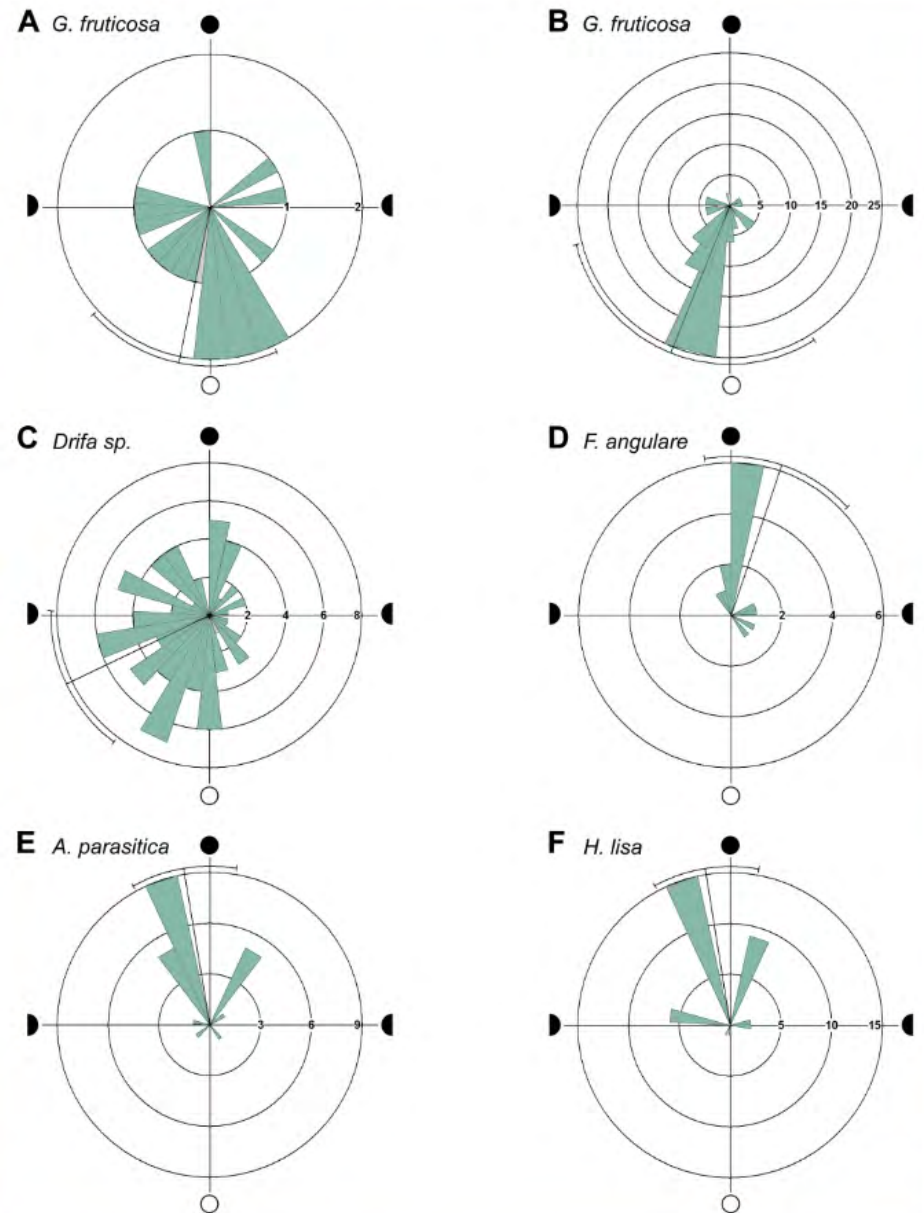
Mercier A., Z. Sun & J.-F. Hamel 2011. Reproductive periodicity, spawning and development of the deep-sea scleractinian coral *Flabellum angulare*. *Marine Biology* 158, 371-380.

Deep-sea corals & other taxa

Lunar cycles

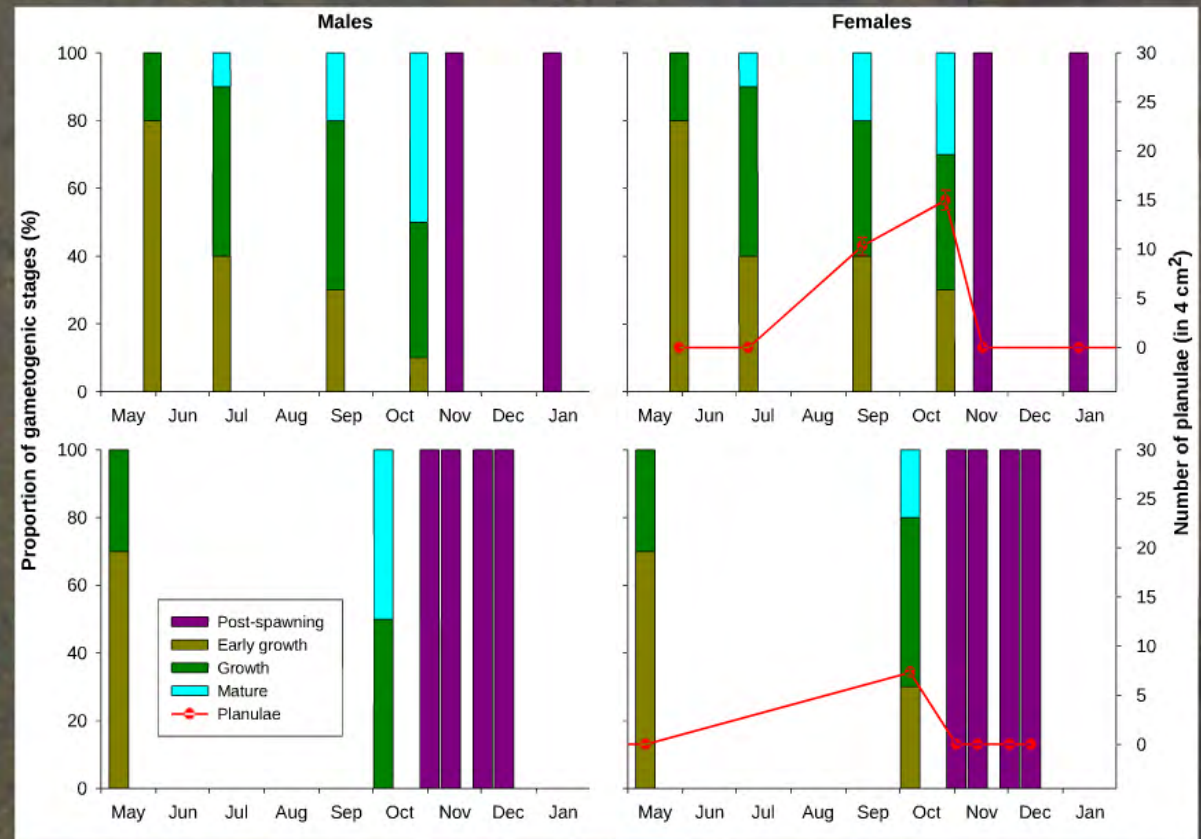
Mercier A., Z. Sun, S. Baillon & J.-F. Hamel 2011. Lunar rhythms in the deep sea: evidence from the reproductive periodicity of several marine invertebrates. *Journal of Biological Rhythms* 26, 82-86.

Mercier A. & J.-F. Hamel 2014. Lunar periods in the annual reproductive cycles of marine invertebrates from cold subtidal and deep-sea environments. In *Annual, lunar and tidal clocks: Patterns and mechanisms of Nature's enigmatic rhythms* (ed. H. Numata and B. Helm), pp. 99-120. Springer.



Deep-sea corals

Reproductive strategies



Mercier A. & J.-F. Hamel 2011. Contrasting reproductive strategies in three deep-sea octocorals from eastern Canada: *Primnoa resedaeformis*, *Keratoisis ornata* and *Anthomastus grandiflorus*. *Coral Reefs* 30, 337–350.

Deep-sea corals

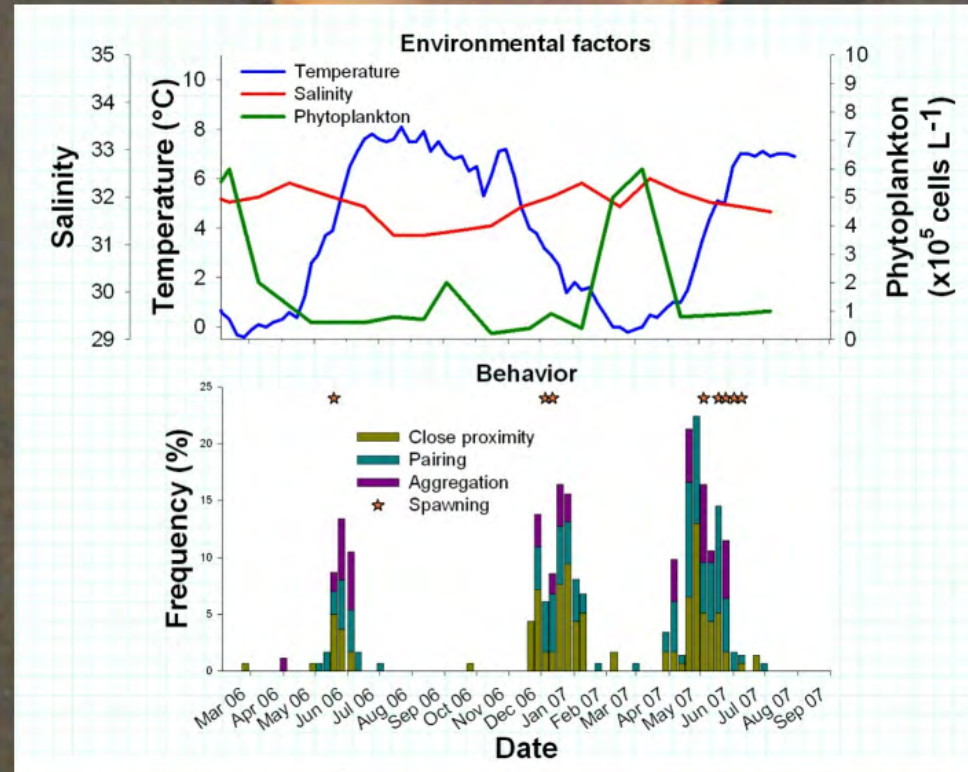
Species interactions



Baillon, S., J.-F. Hamel, V.E. Wareham & A. Mercier 2012. Deep cold-water corals as nurseries for fish larvae. *Frontiers in Ecology and the Environment* 10(7): 351-356.

Deep-sea echinoderms

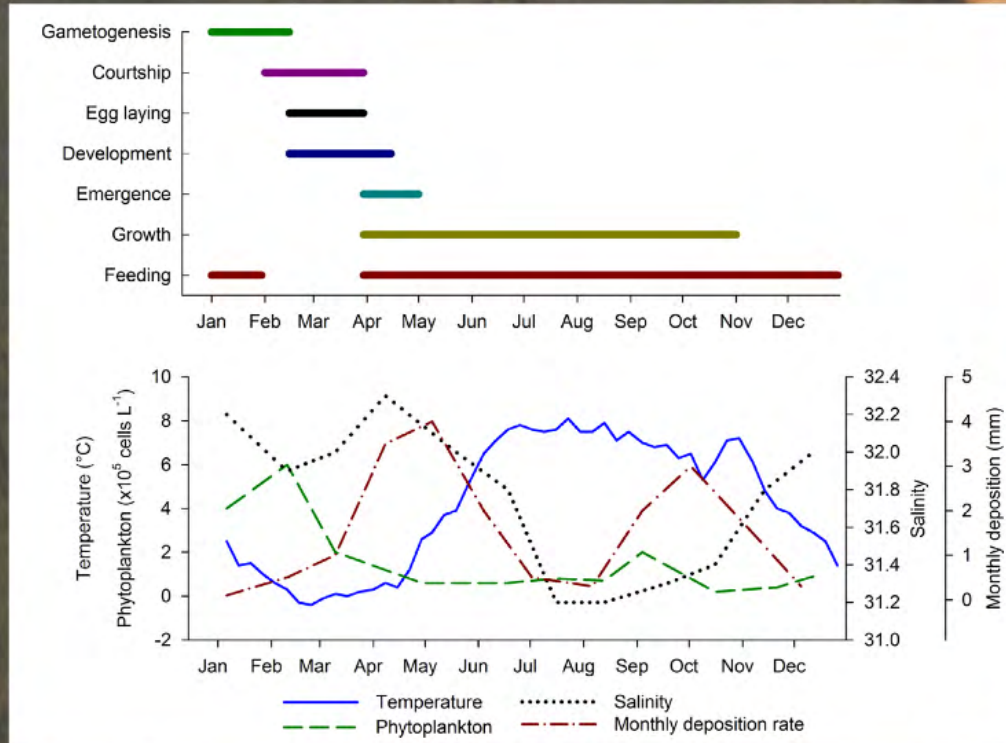
Life-history strategies



Mercier, A. & J.-F. Hamel 2008. Depth-related shift in life history strategies of a brooding and broadcasting deep-sea asteroid. *Marine Biology* 156: 205-223.

Deep-sea pycnogonids & annelids

Life-history strategies



Mercier, A., S. Baillon, and J.-F. Hamel. 2014. Life history and seasonal breeding of the deep-sea annelid *Ophryotrocha* sp. (Polychaeta: Dorvilleidae). *Deep-Sea Research Part I*, 91: 27-35.

Mercier A., S. Baillon & J.-F. Hamel. Life history and feeding biology of the deep-sea pycnogonid *Nymphon hirtipes*. *Deep-Sea Research Part I*, in press.

Deep-sea cnidarians, molluscs and echinoderms

Trophic interactions



- Mercier, A. & J.-F. Hamel 2009. Reproductive periodicity and host-specific settlement and growth of a deep-water symbiotic sea anemone. *Canadian Journal of Zoology* 87: 967-980.
- Mercier, A., M. Schofield & J.-F. Hamel 2011. Evidence of dietary feedback in a facultative association between deep-sea gastropods and sea anemones. *JEMBE* 396: 207-215.
- Gale, K.S.P., J.-F. Hamel & A. Mercier 2013. Trophic ecology of deep-sea Asterozoa (Echinodermata) from eastern Canada. *Deep-Sea Research Part I*, 80: 25-36.
- Gale, K.S.P., K. Wilkinson, J.-F. Hamel & A. Mercier 2015. Patterns and drivers of asteroid abundances and assemblages on the continental margin of Atlantic Canada. *Marine Ecology*, 36: 734-752.

Team members



Ongoing projects

Emaline Montgomery (PhD Marine Biology)

Comparative study of characteristics and abilities of pelagic propagules in marine invertebrates

Camilla Parzanini (PhD Marine Biology)

Food webs at bathyal depths along the continental slope of eastern Canada

Katie Verkaik (MSc Marine Biology)

Impact of CO₂-driven ocean acidification on reproduction in marine invertebrates

Matt Osse (MSc Marine Biology)

Effect of hydrocarbons on reproductive processes in benthic marine invertebrates

Bruno Gianasi (PhD Marine Biology)

Fisheries and aquaculture of the sea cucumber *Cucumaria frondosa*

Justine Ammendolia (MSc Marine Biology)

Response of marine invertebrates to multiple stressors at depth

Leah Robertson (Biology Honours student)

Biology of deep-sea sponges

Jiamin Sun (PhD Marine Biology)

Behavioral and feeding ecology of the sea cucumber *Cucumaria frondosa* relative to IMTA



Acknowledgements

Department of Fisheries and Oceans (DFO)

Canadian Coast Guard for sampling with

- *CCGS Teleost*
- *CCGS Templeman*
- *CCGS Hudson*

ROPOS team for ROV operations

OSC Field Services

Research partly funded by grants from:

- Natural Sciences and Engineering Research Council of Canada (NSERC)
- Canada Foundation for Innovation (CFI)
- Department of Fisheries & Aquaculture of NL (DFA)
- Research & Development Corporation of NL (RDC)
- Canadian Centre for Fisheries Innovation (CCFI)



