14th International Larval Biology Symposium

September 27 - October 1, 2026

Woods Hole, Massachusetts, USA

THE UNIVERSITY OF CHICAGO
MARINE BIOLOGICAL LABORATORY

WHOI

Sponsors & Acknowledgements

Special thanks to Dexter Davis (LBS26 designs and generated proceeds) and Martha Duda (LBS logo). Additional funds were donated by numerous individual contributors who we appreciate immensely.

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Welcome & Conference Overview

The purpose of the International Larval Biology Symposium is to bring together an international community of scientists from academic and professional institutions and across professional levels to exchange information and ideas about marine larvae across taxonomic groups. The symposium presents the opportunity to learn from one another, create and renew collaborations, foster the next generation of larval biologists, promote educational opportunities in the field, and network across a broad community of scientists from around the world.

Code of Conduct & Community Standards

The Larval Biology Society (LBS) is committed to establishing a safe, productive, and welcoming Symposium environment in which all attendees can participate without discrimination, harassment, or disrespect.

Expectations

All participants are expected to create a respectful and welcoming environment for scientific exchange. Specific expectations include:

- Treating all participants, staff, and venue facilities with respect and consideration.
- Respectful and constructive critique of ideas, not individuals. Avoid personal attacks.
- Adhering to the rules and policies of the meeting venues, hotels, and local businesses, whether contracted for the Symposium or not.
- Maintaining academic integrity and ethical professional conduct, including but not limited to:
    - Use of images, graphics, and other media only with proper permission and credit
    - Respect for other participants' "no sharing" or "no photography" policies.
    - Disclosure of AI use
- Anyone who is asked to stop an unacceptable behavior is expected to comply immediately

LBS promotes open access of data and ideas for broad dissemination of scientific knowledge. LBS promotes diversity and inclusivity in all professional and educational activities.

Unacceptable Behavior

- **Harassment and Discrimination:** Harassment or discrimination based on gender or gender identity, ethnicity, sexual orientation, disability, physical appearance, race, religion, or nationality will not be tolerated.
    - Harassment includes, but is not limited to, unwanted verbal attention or touching, shaming, stalking, intimidation, or bullying.
- **Retaliation**: Threats or intimidation for reporting.
- **Disruption**: Interruption of sessions, talks, or other conference activities.
- **Unwanted Photography**: Taking or sharing (e.g., on social media) photographs of participants without their knowledge or consent.

Reporting

Any person who believes that he or she has been unlawfully or sexually harassed should bring his or her concerns to the attention of management immediately. This can be done in writing or orally. If you experience or observe harassment or unacceptable behaviors, you may contact one of the Society's Board members or email Larval Bio Society larvalbiosociety@gmail.com. You may also report such conduct to the MBL EEO Coordinator (Homestead 109, x7378, eeo@mbl.edu) or the Human Resources Director (x7422). These people are available to discuss any concerns you may have and to provide information to you about this policy and the complaint process.

If you feel unsafe or threatened on the MBL campus, notify conference venue security or call 911 for medical or police assistance. MBL Campus Security provides 24-hour security services for the MBL Campus and MBL Community. Campus security is located on the first floor of the Swope Center and can be reached for non-emergencies at 508-289-7217. In an emergency, dial 911 or contact campus security at 508-289-7911. We suggest you put these important numbers in your cell phone. Security is available after hours to help you if you get locked out of your housing.

Consequences

LBS Board will hold sole discretion to determine consequences for violations of the Code of Conduct. Consequences may include a written warning (at minimum), reporting to the violator's Title IX office, ejection from the symposium, and/or banishment from future meetings. In the case of ejection from the Symposium, a refund of registration fees will not be offered.

Process used to create this Code of Conduct

The following Code of Conducts were reviewed to use as a guide for this Code: Western Society of Naturalists, Benthic Ecology Meeting, Society of Integrative and Comparative Biology, and Deep-Sea Biology Society. The draft was reviewed and approved by the LBS Board.

Plenary Talks

Craig M Young, University of Oregon

The Larval Biology Meetings, and four decades of larval studies in the deep sea

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The larval biology meetings, a brainchild of the late Stephen Morgan, came to fruition in a pact between Stephen and the present author in a Dauphin Island, Alabama seafood restaurant, around 1984. With the aid and encouragement of 19 postdocs, 36 graduate students, a literal army of undergraduate assistants, 8 submersibles, 6 ROV's and too many collaborators to count, we focused our lab on the fundamentals of reproduction and larval biology in the deep sea. This talk will review a few of the highlights, mostly discoveries by our students and postdocs, ending with recent collaborative work on vertical migration, long-distance dispersal, and a bet-hedging dispersal strategy of deep-sea mussels in the Gulf of Mexico.

Monday, 28 September, 9:00-10:00

Meike Stumpp, Christian-Albrechts-University Kiel

Ecophysiology of marine larvae: key mechanisms for coping with ocean change

The physiological performance of an individual to their current environment determines its fitness and survival, and thus cements its potential to influence the population structure and evolutionary path of its species in future. Thus, understanding physiological performance and mechanisms are key for predicting future performance potential of a species. Function rules survival – and survival rules the future.

Over the past two decades, my research group and I have focused on understanding underlying physiological principles of invertebrate larvae that shape their performance, resilience, or vulnerability to changing ocean conditions. Using integrative approaches that combine organismal physiology, cell biology, bioenergetics, and developmental biology using a range of different echinoderm species, my group revealed how specific processes such as calcification, growth, metabolism and energy management are impacted by environmental stress. We also demonstrated that especially the physiological characteristics of the larval digestive system play a key role in species-specific larval performance to ocean acidification.

In this talk, I will present an overview on the most fascinating features of the sea urchin larval biology, integrating knowledge from the beginnings of my research almost 20 years ago as PhD student with present projects and current data focusing on larval responses to seawater acidification or feeding conditions.

Tuesday, 29 September, 8:30-9:15

Sarah C Donelan, University of Massachusetts Dartmouth

The case for legacy: past experiences affect organisms and ecosystems across marine systems

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Phenotypic plasticity is a critical mechanism that allows organisms to respond to sudden changes in their current environment. Growing evidence from across systems also suggests that past environments experienced by an individual either directly (i.e., early in life) or indirectly (e.g., by previous generations) alter phenotypes via plasticity. These “legacy effects” matter not only for individuals by impacting fitness but can also influence processes at the population, community, and ecosystem scale. Here I present results of legacy effects experiments across three marine systems – rocky shores, oyster reefs, and invasive barnacles – in response to a variety of stressors. My talk highlights the universality of legacy effects as a mediator of organism performance in marine systems and their potential to alter food chains, species invasions, and ecosystem function.

Tuesday, 29 September, 9:15-10:00

Mary A Sewell, University of Auckland

Maternal investment in echinoderms, with a focus on lipids

Mary A. Sewell (University of Auckland) & Maria Byrne (University of Sydney)

In the complex life cycle of marine invertebrates (pelagic larva, benthic juvenile), the extent of maternal provisioning, in addition to determining fecundity, has a profound influence on development, as seen in the major dichotomy between feeding planktotrophic larvae that depend on exogenous nutrients to achieve the juvenile stage and non-feeding lecithotrophic larvae, where egg nutrients support development to the juvenile stage. Here we review research on lipid provisioning in both planktotrophic and lecithotrophic echinoderms, primarily using the Iatroscan TLD/FID (thin-layer chromatography-flame ionization detection) instrument, which allows separation of the energetic and structural lipid components. In a meta-analysis of published papers and unpublished theses, we show a clear distinction between planktotrophs and lecithotrophs in the amounts and lipid classes present in their eggs. Specifically, both planktotrophs and lecithotrophs show a significant positive natural-log relationship between egg volume and the amount of energetic lipids, with greater maternal provisioning in lecithotrophs. Additionally, in planktotrophs, the dominant energetic lipid class is triacylglycerol (TAG), while in lecithotrophs, this is diacylglycerol ether (DAGE). Multivariate analyses separate the four echinoderm classes (no data available for crinoids) by developmental type and maternal investment level. We also discuss the utilization of lipid during larval development, where planktotrophs use their energetic lipids to build the larval body and feeding structures, while lecithotrophs retain a significant proportion of maternal lipids into the benthic juvenile. A detailed examination of lipid provisioning and utilization during development reveals new patterns that we encourage the next generation of larval biologists to explore.

Thursday, 1 October, 8:30-9:30

Jesús Pineda, Woods Hole Oceanographic Institution

Larval transport and dispersal: observations, predictions, and small-scale, short-term processes

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A major goal in ecology is knowledge of larval processes influencing population dynamics and spatial distributions, and researchers have used a variety of approaches for understanding these processes. For example, little known processes can be uncovered by empirical research, or larval distribution can be predicted from biological traits interacting with physical processes. Regardless of the approach, small-scale, short-term biological-physical processes important to larval dynamics and distribution tend to be understudied, and their study remains a challenge. I will consider these approaches and problems while discussing larval transport and dispersal of crustaceans in nearshore environments, including recent work on American lobster larvae. Overall, the conclusions are not new; knowledge in larval transport and dispersal is best gained by observing processes and by empirically testing predictions and assumptions.

Thursday, 1 October, 15:30-16:30

Schedule at a Glance

SUNDAY, September 27 . . . . MBL Swope Center

14:00-20:00 . . . . Registration

MONDAY, September 28 . . . . Clapp Auditorium, MBL

07:30-08:30 . . . . Registration
08:30-09:00 . . . . Opening Remarks
09:00-10:00 . . . . Craig Young Plenary
10:00-10:30 . . . . Coffee break
10:30-12:15 . . . . Session 1: A Larval Legacy. A Session in Honor of Craig Young
12:15-13:30 . . . . Lunch break
13:30-15:00 . . . . Session 2: Unraveling Settlement, metamorphosis, and recruitment
15:00-15:30 . . . . Coffee break
15:30-17:00 . . . . Session 3: Advances in Larval Methods and Other Diverse Topics
17:00-18:00 . . . . Larval Biology Society Open Meeting
19:30-21:00 . . . . *Born in the Abyss* Pre-release Screening

TUESDAY, September 29 . . . . Redfield Auditorium, WHOI

08:30-09:15 . . . . Meike Stumpp Plenary
09:15-10:00 . . . . Sarah Donelan Plenary
10:00-10:30 . . . . Coffee break
10:30-12:15 . . . . Session 4: Larval Performance Under Stress I
12:15-14:00 . . . . Lunch break
14:00-15:30 . . . . Session 4: Larval Performance Under Stress II
16:00-18:00 . . . . Poster Session & Social at **MBL Swope Center**

WEDNESDAY, September 30 . . . . Redfield Auditorium, WHOI

08:30-10:15 . . . . Session 5: Ecophysiology, Behavior, Development, & Evolution
10:15-10:45 . . . . Coffee break
10:45-12:30 . . . . Session 6: Importance of Early Life Stages in Population Dynamics

THURSDAY, October 1 . . . . Speck Auditorium, MBL

08:30-09:30 . . . . Mary Sewell Plenary
09:30-10:00 . . . . Coffee break
10:00-12:00 . . . . Session 7: Larval Transport, Dispersal, and Population Connectivity I
12:00-13:30 . . . . Lunch break
13:30-15:00 . . . . Session 7: Larval Transport, Dispersal, and Population Connectivity II
15:30-16:30 . . . . Jesús Pineda Plenary
16:30-17:00 . . . . Closing Remarks & Student Presentation Awards
18:30-22:00 . . . . Closing Banquet

Presenter Guidelines

Oral Presenters

Oral presentations are slotted for 15 minutes each (including questions and transitions), so please aim for a ~12 minute talk to leave time for questions. Please aim to submit presentations by the evening of Sunday September 27, but presenters have until 24 hours prior to their session to upload. Presenters may upload either a pptx or pdf.

Poster Presenters

Poster presentations are on Tuesday at 4-6 pm. If you have a poster, you can hang it up anytime starting Tuesday morning in the Swope Center. The assignment of poster locations will be available on-site, as well as all materials to put them up. Posters can be a maximum of 30” W x 60” H and must be removed by the end of the evening.

Venue Information

WiFi & Technical Information

On MBL campus:

- MBL-GUEST, pw = mblguest
- Eduroam

On WHOI campus:

- WHOIguest
  - September pw = sponge4856
  - October pw = sponge7242
- Eduroam

Emergency & Accessibility Information

- For emergencies, dial 911
- MBL Campus Security: +1 (508) 289-7217, securityofficers@mbl.edu
- WHOI Campus Security: +1 (508) 548-1401, security@whoi.edu

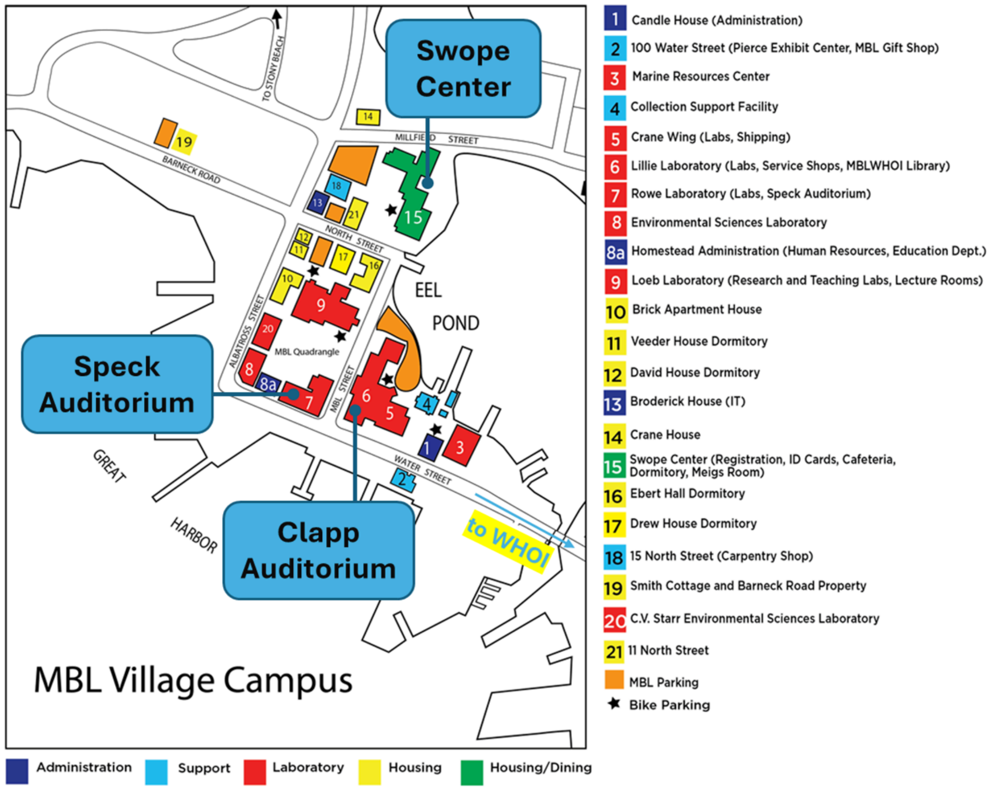
In an emergency, dial 911 or contact MBL campus security at +1 (508) 289-7911.
Security is available after hours to help you if you get locked out of your housing.

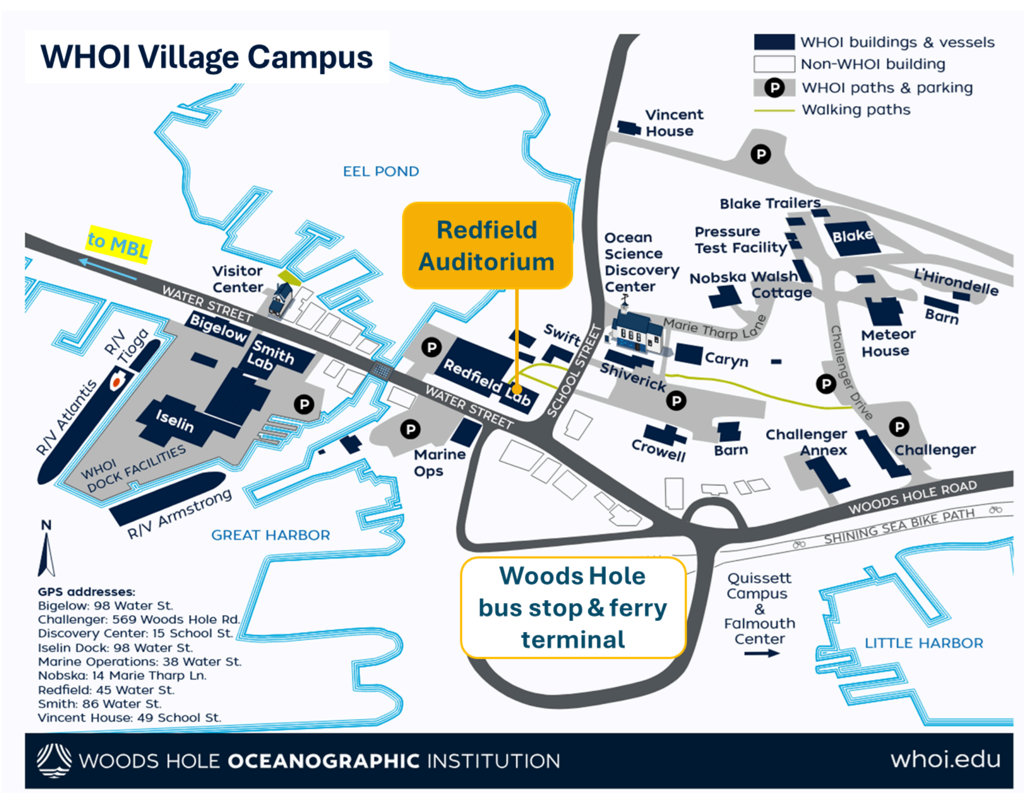
Your keycard should give you access to all relevant buildings at MBL.

Parking & MBL Dorm Housing

If you are driving to campus, you can get a parking pass from MBL when you register in the Swope Center. If you are staying in MBL dorm housing, you will also check in for housing when you register. **If you arrive after 8:00 PM on Sunday and need to access your MBL housing, you can ring MBL Campus Security for a late check-in.**

Campus Maps


Swope Center
Speck Auditorium
Clapp Auditorium
to WHOI
EEL POND
GREAT HARBOR
MILLFIELD STREET
BARNECK ROAD
NORTH STREET
ALBATROSS STREET
MBL STREET
WATER STREET
TO STONY BEACH
MBL Quadrangle
MBL Village Campus
1 Candle House (Administration)
2 100 Water Street (Pierce Exhibit Center, MBL Gift Shop)
3 Marine Resources Center
4 Collection Support Facility
5 Crane Wing (Labs, Shipping)
6 Lillie Laboratory (Labs, Service Shops, MBLWHOI Library)
7 Rowe Laboratory (Labs, Speck Auditorium)
8 Environmental Sciences Laboratory
8a Homestead Administration (Human Resources, Education Dept.)
9 Loeb Laboratory (Research and Teaching Labs, Lecture Rooms)
10 Brick Apartment House
11 Veeder House Dormitory
12 David House Dormitory
13 Broderick House (IT)
14 Crane House
15 Swope Center (Registration, ID Cards, Cafeteria, Dormitory, Meigs Room)
16 Ebert Hall Dormitory
17 Drew House Dormitory
18 15 North Street (Carpentry Shop)
19 Smith Cottage and Barneck Road Property
20 C.V. Starr Environmental Sciences Laboratory
21 11 North Street
MBL Parking
Bike Parking
Administration
Support
Laboratory
Housing
Housing/Dining


WHOI Village Campus
WHOI buildings & vessels
Non-WHOI building
WHOI paths & parking
Walking paths
EEL POND
to MBL
Visitor Center
WATER STREET
Bigelow
Smith Lab
R/V Tioga
R/V Atlantis
Iselin
WHOI DOCK FACILITIES
R/V Armstrong
GREAT HARBOR
Redfield Auditorium
Redfield Lab
Swift
Marine Ops
SCHOOL STREET
Vincent House
Blake Trailers
Pressure Test Facility
Blake
Ocean Science Discovery Center
Nobska Walsh Cottage
L'Hirondelle
Barn
Meteor House
Marie Tharp Lane
Caryn
Shiverick
Challenger Drive
Crowell
Barn
Challenger Annex
Challenger
WOODS HOLE ROAD
SHINING SEA BIKE PATH
Woods Hole bus stop & ferry terminal
Quissett Campus & Falmouth Center
LITTLE HARBOR
N
GPS addresses:
Bigelow: 98 Water St.
Challenger: 569 Woods Hole Rd.
Discovery Center: 15 School St.
Iselin Dock: 98 Water St.
Marine Operations: 38 Water St.
Nobska: 14 Marie Tharp Ln.
Redfield: 45 Water St.
Smith: 86 Water St.
Vincent House: 49 School St.
WOODS HOLE OCEANOGRAPHIC INSTITUTION
whoi.edu

Things to Do in Woods Hole

Quick Bite to Eat

Coffee Obsession, 38 Water St., Woods Hole, MA
Pie in the Sky, 10 Water St., Woods Hole, MA
Maison Villate, 20 Luscombe Ave., Woods Hole, MA
Quicks Hole Taqueria, 6 Luscombe Ave, Woods Hole, MA
Woods Hole Market & General Store, 87 Water St., Woods Hole, MA

Sit-Down Meal

Water Street Kitchen, 56 Water St., Woods Hole, MA
Landfall Restaurant, 9 Luscombe Ave., Woods Hole, MA
Captain Kidd Restaurant and Bar, 77 Water St., Woods Hole, MA
Leeside Pub, 29 Railroad Ave., Woods Hole, MA
Shuckers, 91 Water St., Woods Hole, MA

Local Activities

Stony Beach
Nobska Lighthouse
Shining Sea Bikeway
Martha's Vineyard (via Woods Hole ferry terminal)

Greater Cape Cod Recommendations

Aquatic Brewing, 661 Main St., Falmouth, MA
Cape Cod National Seashore
Provincetown, MA

LBS26 ABSTRACTS:
Talks

Does larval food supply drive reproductive seasonality in the deep ocean? An experimental test of Crisp's Rule with the bathyal echinoid *Strongylocentrotus fragilis*

Lauren Rice (University of Oregon, Oregon Institute of Marine Biology)
Caitlin Q. Plowman (University of Oregon, Oregon Institute of Marine Biology)
Avery E. Calhoun (University of Oregon, Oregon Institute of Marine Biology)
Matt DePaolis (University of Oregon, Oregon Institute of Marine Biology)
Larry Bash (University of Oregon, Oregon Institute of Marine Biology)
Craig M. Young (University of Oregon, Oregon Institute of Marine Biology)

Temperate echinoderms in the northern hemisphere spawn most commonly during the spring, coinciding with the main seasonal bloom of phytoplankton. Noting this pattern, Crisp (1954) hypothesized that, irrespective of the specific proximal cues for spawning, spring reproductive cycles evolved because food for planktotrophic larvae is inadequate at other times of the year. Surprisingly, echinoderms living in virtual darkness at bathyal depths often have spawning patterns similar to those of shallow species living in the euphotic zone. We tested Crisp's Rule experimentally by manipulating photoperiod in the bathyal echinoid *Strongylocentrotus fragilis* off Oregon to obtain viable gametes and larvae both in-phase and out-of-phase with the normal spring reproductive season. In each season, larvae were cultured in surface water changed on alternating days and coarsely filtered to remove larger zooplankton. Larvae reared on natural plankton during the spring phytoplankton bloom grew significantly faster (19.57 μm/day) than those fed and cultured in winter conditions (5.02 μm/day). Higher rates of abnormal development were also observed in the winter cultures. While settlement was attained in both treatments, larvae reared on spring phytoplankton settled at higher rates, grew larger, and lived longer past settlement than those reared on winter phytoplankton. Our results support the hypothesis proposed by Crisp, namely that surface productivity can serve as an ultimate selective pressure to drive the reproductive timing of species like *S. fragilis*. We suspect that Crip's Rule would apply to other deep-sea echinoderms with planktotrophic larvae.

Embryo and Larval Development during the Polar Winter

Mary A. Sewell (University of Auckland)

Polar marine environments exhibit pronounced seasonality in the light:dark cycle, primary productivity, and the extent of sea-ice cover. Thorson's Rule, predicting reduced meroplankton diversity at high latitudes, was based on the perceived difficulties in completing larval development at low temperatures and within the short summer period of phytoplankton production. However, meroplankton and settlement studies in both the Arctic and the Antarctic are revealing higher larval diversity and abundance during the polar winter than Thorson (1936, 1950) might have predicted. In this talk, I consider our year-round sampling in the High Antarctic using the Scott Base desalination plant (Sewell and Jury 2011), which showed high larval diversity and many morphologically distinct egg and embryo Operational Taxonomic Units (OTUs) during the austral winter. Recent winter sampling in the fjords of Norway and Svalbard has also shown eggs and early embryos (e.g. trochophores). The appearance of larvae during winter may result from extended larval life, as observed in many echinoderms, but the presence of early embryos provides strong evidence for winter spawning in many polar marine invertebrates.

Bigger changes, bigger risks: lessons on developmental mortality from crustacean larvae

Paul Dunn (Utah Valley University)

Mortality risk during the larval stage of aquatic organisms has always been understood to be high. Causes of this high risk have been hypothesized to include extrinsic factors (e.g., predation, environmental stress, larval waste) as well as intrinsic factors (e.g., developmental failures). One may assume that the relative importance of the intrinsic factors might decrease over time due to selection against phenotypes that do not develop into functional, reproductive individuals. However, this may not be the case if this mortality is associated mostly with developmental transitions that are simultaneously dangerous and necessary. The importance of developmental transitions to larval mortality is reviewed through examples of crustaceans that exhibit metamorphic development with both major and minor developmental transitions as well as those that exhibit anamorphic development with only minor developmental transitions.

First estimates of gamete subsidies from a deep chemosynthetic ecosystem to the pelagic food web

Caitlin Q. Plowman (Oregon Institute of Marine Biology, University of Oregon)
Shawn M. Arellano (Shannon Point Marine Center, Western Washington University)
Craig M. Young (Oregon Institute of Marine Biology, University of Oregon)

Bathymodiolin mussels often form expansive, dense beds around methane seeps and are among the dominant macrofauna at many hydrothermal vents. These large-bodied mussels have high fecundity, and most reproduce seasonally. The resulting "egg boons" from spawning, followed by larval mortality in the plankton, release pulses of energy into surrounding systems, potentially representing a significant, unquantified energy flux out of chemosynthetic systems. Using gonad histology and bomb calorimetry of lab-spawned eggs, we investigated variation in maternal investment in *Gigantidas childressi*. We also estimated energy released by mussels at the Brine Pool methane seep in the Gulf of Mexico and the Baltimore Canyon and Chincoteague seeps in the western Atlantic. We found high variability in fecundity across sites and egg size and energy content increased with depth. At Baltimore Canyon (500 m), eggs contained about 1.35 mJ, within the range reported for shallow-water mussels. Brine Pool 650 m) eggs had 7.25 mJ, and Chincoteague (1060 m) eggs had 18.76 mJ. Total energy release depended on bed size and mussel density, with beds at the Brine Pool and Chincoteague capable of releasing about 16 MJ m^{-2} yr^{-1}, exceeding surface-water photosynthetic primary productivity in the oligotrophic North Pacific Gyre. This is the first quantitative estimate of fecundity and egg energy for a large bathymodiolin mussel and the first estimates of energy fluxes from reproductive products in chemosynthetic ecosystems. Results suggest that gametes are a vital component of energy flux in deep pelagic food webs and should not be overlooked.

Larval migration from deep-sea hydrothermal vents to the euphotic zone

Takuya Yahagi (Atmosphere and Ocean Research Institute, The University of Tokyo)
Kotaro Shirai (Atmosphere and Ocean Research Institute, The University of Tokyo)
Junya Hirai (Atmosphere and Ocean Research Institute, The University of Tokyo)
Yasunori Kano (Atmosphere and Ocean Research Institute, The University of Tokyo)

Larval migration plays an essential role in determining the distribution and evolution of invertebrates endemic to hydrothermal vents — disjunct and ephemeral habitats in the deep sea. However, technical obstacles have prevented field observation or tracking of their free-swimming, microscopic larvae. Our geochemical analyses of pre- and post-metamorphic parts of shells reconstructed that the planktotrophic larvae of vent-endemic limpets of the genus *Shinkailepas* migrate to upper layers, in or near the euphotic zone (0–200 m) (Yahagi et al. in press, Science Advances). Oxygen isotopes indicated that the larvae experienced warm temperatures approximating conditions in the euphotic zone above the vent sites, whereas Ba and Mn concentrations as proxies for hot vent fluids were much higher in post-metamorphic than in pre-metamorphic shells, dismissing retention under hydrothermal influence. These findings are fully consistent with the larval swimming behavior, thermal preferences, and phytoplankton feeding observed in culture experiments (Yahagi et al. 2017, Ecology). We further present unpublished metabarcoding results detecting larvae of a deep-sea vent mussel species in plankton-net samples from 0–200 m depth in the northwestern Pacific, providing direct evidence of larval migration to euphotic waters. Our results demonstrate the importance of surface currents and temperature in shaping the geographic distribution of chemosynthesis-based vent communities in the deep sea. Other vent-endemic animals await similar integrated studies to understand the role of the euphotic zone in their dispersal, population dynamics, and evolutionary histories.

Components of the microbial biofilm predict larval settlement at hydrothermal vents

Shawn M. Arellano (Western Washington University)
Tanika M. Ladd (Western Washington University)
Olivia Cannon (Rutgers University)
Costantino Vetriani (Rutgers University)
Nadine Le Bris (Sorbonne University)
Lauren S. Mullineaux (Woods Hole Oceanographic Institution)

Many marine invertebrates use microbial biofilms to choose settlement sites, though the exact cues remain unclear. Hydrothermal vents are ideal systems to study questions about the roles of biofilms in larval settlement because vent biofilms are relatively simple; vent animals depend on chemosynthetic microbes for primary productivity, sometimes through symbiotic partnerships acquired at settlement; and variations in habitat types and geochemical gradients are present within a common larval pool. We performed a field experiment to test whether microbial biofilms provide settling larvae with a signpost indicating suitable habitat. We deployed sets of paired settlement surfaces with established and fresh biofilms and monitored abiotic and biotic factors for each pair during short-term (~10-day) experiments. The larvae of at least four vent endemic species (2 annelids, 1 gastropod, and 1 bivalve) settled in higher abundance on the established vent biofilms, including those larvae of the chemosymbiotic foundational mussel *Bathymodiolus thermophilus*. The microbial community composition varied between established and fresh biofilms, and we identified groups of amplicon sequence variants both positively and negatively associated with larval settlement, depending on larval taxon. Interestingly, the symbiont of the *B. thermophilus* was not significantly associated with their larval settlement. We are using generalized additive mixed models to examine settler abundance dependent on abiotic (site chemistry and temperature) and biotic (microbial and faunal diversity and community composition metrics) factors. Ultimately, we will follow our modeling with metagenomics and proteomics to identify factors that predict larval settlement at hydrothermal vents.

Efficacy of diets in commercial bath sponges

Noah Gorman (Florida Atlantic University - HBOI)
Andia Chaves Fonnegra (Florida Atlantic University - HBOI)

Commercial bath sponge populations faced substantial declines over the last century within Florida Bay due to overfishing and recurring cyanobacterial blooms. To avoid population collapse, *in situ* and *ex situ* aquaculture restoration efforts have been implemented. Restoration initiatives can be bolstered via *ex situ* culturing of sponges utilizing larvae; however, dietary and husbandry challenges remain. Our research identified viable diet sources and conditions for increased growth and survival of yellow bath sponge (*Spongia barbara*) recruits within FAU HBOI's land-based nursery. Sponge recruits were fed microalgae *Tisochrysis galbana*, crystalline amino acids, *Laurencia* sp. macroalgal concentrate, and biofloc as single and paired diets across a series of trials. Amino acid and macroalgal concentrate exposure promoted significant growth in recruits but showed no synergistic effects when paired. Biofloc diets promoted no significant growth paired or unpaired. *T. galbana* diets offered no significant growth. Alongside dietary trials, amino acid profiles were generated for the *S. barbara* holobiont and *Laurencia* sp. macroalgae. Utilizing insights gleaned from trials and nursery husbandry a new *ex situ* sponge nursery system was modeled. These trial results and the modeled *ex situ* nursery can support restoration of Florida's iconic commercial bath sponges and advance *ex situ* sponge aquaculture.

Optimizing coral larval stocking density to increase production for reef restoration

Rachel Ionata ((Nova Southeastern University)
Liam Abrams (Nova Southeastern University)
Joana Figueiredo (Nova Southeastern University)

Coral larval settlement and post-settlement survival are the main constraints to the success of *ex situ* sexual propagation for coral reef restoration. To optimize production, we assessed the effect of larval stocking density on percent settlement and the effect of initial settler density on post-settlement survival up to eight weeks — the time-point at which the corals are typically large enough to be isolated and grown on individual tiles. The average percent settlement of *Colpophyllia natans* was 46% and it increased as the larval stocking density increased. For *Orbicella faveolata*, average percent settlement was 51% and was only significantly higher when the larval stocking density was approximately 4 larvae/cm^2 of settlement substrate compared to lower densities (down to 2 larvae/cm^2). Post-settlement survival over time was not significantly affected by initial coral settler density. From a production perspective, the aim is to obtain about 1.5 coral spats/cm^2 at 8 weeks post-settlement, as a density higher than that would prevent spats from being able to be isolated. To achieve this density, we recommend providing 6 larvae to each cm^2 of settlement substrate since larval settlement was approximately 50% and post-settlement survival at 8-weeks was at least 50%. From a labor efficiency perspective, this larval stocking density would lead to an initial settler density of 3 settlers/cm^2 which is also manageable to clean manually.

Desperate Larva or Death Before Dishonor: can old coral larvae replenish degraded reefs?

Joana Figueiredo (Nova Southeastern University)
Nepsis García (Nova Southeastern University)
Margaret Miller (SECORE International)
D. Abigail Renegar (Nova Southeastern University)

The recovery of coral populations depends largely on larval recruitment. Coral larvae settle in response to environmental cues that indicate habitat quality. In the absence of suitable cues, lecithotrophic larvae may delay settlement until they die (Death Before Dishonor strategy) or become increasingly less discriminatory (Desperate Larva strategy). To examine which of these strategies corals follow, we used larvae from three broadcast spawning reef-building corals, *Diploria labyrinthiformis*, *Pseudodiploria clivosa*, and *Orbicella faveolata*, and one brooding coral, *Agaricia agaricites*. Settlement behaviors of larvae of different ages, specifically 0, 7, 14, or 21 days after becoming competent, were examined in response to inducing (crustose coralline algae) and inhibitory (*Dictyota* sp.) settlement cues. Potential latent effects of delaying metamorphosis on post-settlement survival and growth were also assessed. As larvae got older, broadcast spawning species decreased selectivity, doubling to quadrupling their settlement in tiles with *Dictyota* sp. (i.e. followed the 'Desperate Larva strategy'), whereas the brooding species' larvae never did (i.e. followed the 'Death Before Dishonor strategy'). Delayed settlement of *A. agaricites* produced latent effects on post-settlement survival (up to 50% reduction) and growth (sixfold decrease), while *O. faveolata* displayed latent effects to growth only (reduced by 50% or more). No latent effects of delayed settlement were observed in the other species. Our results suggest brooding corals may have evolved to disfavor dispersal and maximize local retention. In contrast, "old" coral larvae from broadcast spawners have the potential to disperse widely and replenish degraded reefs. Hence, albeit at a lower rate, disturbed reefs can recover through larval replenishment.

Developing hatchery production and optimizing microalgal diets for Atlantic Purple Sea Urchin (*Arbacia punctulata*) for integrated oyster aquaculture

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There is an emerging demand for the hatchery production of Atlantic Purple Sea Urchin (*Arbacia punctulata*) in the Northeastern USA, especially in the state of Rhode Island; however, larval production methods have not yet been established for this species. Demand originates from shellfish farmers, who manage biofouling on farms which heavily increases operational costs, farming effort, and can be met with negative public perceptions and acceptance. Pilot studies have shown significant benefits to co-culturing the native and unexploited *A. punctulata* with Easter Oysters (*Crassostrea virginica*), with reduction of biofouling accumulation on oyster gear up to 90%. To support the long-term implementation of this co-culture aquaculture approach, reliable hatchery production methods for *A. punctulata* are needed. This project focuses on developing hatchery protocols and optimizing larval feeding regimes. Adult broodstock were acclimated and spawned under controlled hatchery conditions to determine fertilization success, larval development, settlement, and early juvenile growth. Differing microalgal diet combinations were evaluated for their effects on larval growth and performance. Developing sustainable hatchery for *A. punctulata* will support further scaling of co-culture urchin aquaculture while reducing the reliance on wild populations. This work advances understanding of larval culture, settlement, and recruitment in sea urchins and supports environmentally sustainable biofouling management strategies in shellfish aquaculture.

Optimizing settlement of green sea urchin *Strongylocentrotus droebachiensis* larvae for commercial seed production and aquaculture

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The green sea urchin *Strongylocentrotus droebachiensis* is considered a highly promising aquaculture candidate in Europe and North America. In the Northeastern United States, hatchery seed production for this species was first established in 1998 to support research and commercialization, following Japanese hatchery methods developed since the 1970's for other urchin species. However, post-settlement survival rates are relatively low and annually fluctuate between and within Northeast hatcheries, in contrast to the higher and more consistent production reported for Japanese hatcheries. In part, this may be attributed to the lack of access to both the Japanese namiita plate rack systems used for settlement and to *Ulvella lens*, a microscopic green macroalgae that serves as a foundational food source and substrate for sea urchin larvae in Japan, but which is considered non-native to the Gulf of Maine. The green sea urchin hatchery at the University of Maine's Center for Cooperative Aquaculture Research (CCAR) has been working to address these issues since 2006. Here, we report on the use of bio barrel filter media conditioned with native diatom growth as an alternative to namiita plates, leading to the production of over 60,000 seed urchins for aquaculture trials. However, variable diatom growth on the bio barrels and other settlement surfaces, along with predatory micro fauna, continues to be problematic. Future efforts investigating the use of native macroalgae species as an alternative substrate, along with simple control measures to limit the presence of predatory micro fauna, are also reported.

Small-scale spatial variability in coral reef fish settlement

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Larval fish dispersal and recruitment processes are essential to the overall health, persistence and resilience of coral reef ecosystems. Yet the magnitude and importance of spatial variability in fish settlement to reef habitats are still poorly understood. Here we investigate small-scale (1-10km) spatial variation in larval settlement in the context of potential biological and physical drivers. Larval settlement was surveyed across ten sites within a ten-kilometer stretch on the south coast of St. John, USVI. Sites comprised relatively higher and lower quality reefs, and one sandy bottom habitat. Associated biological data (e.g. adult fish abundance, coral cover, habitat integrity, diversity of resident taxa) and physical measurements (e.g. near-shore currents) were used to investigate correlations with settlement. Multivariate analyses reveal significant among-site differences in reef fish settlement and high inter-taxon variability in settlement patterns. Given the rapid rate of coral reef decline worldwide, understanding the mechanisms behind reef fish settlement on a small scale could provide insight into how coral reef ecosystems will respond in the face of continuing global change, informing future conservation management efforts.

The energetic shifts in zooplankton of the Northeastern US Shelf amidst a changing climate

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The energy density of copepods can vary greatly by species, with high lipid concentrations reported in species such as *Calanus finmarchicus* and lower energy densities in *Centropages* spp. and *Pseudocalanus* spp. The primary component of this research compares the energy density of highly abundant copepod species in the Gulf of Maine and southern New England regions using bomb calorimetry techniques. We found that *C. finmarchicus* have consistently higher energy densities, $\bar{x}$ = 26.5 kJ/g, compared to other copedpod taxa *Pseudocalanus* spp. ($\bar{x}$ = 15.25 kJ/g) and *Centropages* spp. ($\bar{x}$ = 16.57 kJ/g). Current climate modeling and research is predicting large reductions in *C. finmarchicus* abundance in the Northeastern U.S. Shelf. This depletion in abundance could be detrimental for the endangered North Atlantic Right Whale (*Eubalaena glacialis*) populations and several important commercial fish species which rely on *C. finmarchicus* as an important prey source. For further examination of alternative food sources, the energy density of several other abundant plankton taxa, Cumacea, Mysidae, Hyperiidae, were also compared to *C. finmarchicus* with mean energy densities similar to that of *Centropages* spp. and *Pseudocalanus* spp. For future analysis we plan to explore the relationship between the energy densities of plankton taxa to environmental factors including season, location, and temperature.

Larval diagnostic playbook: development of a workflow to determine causes of larval crashes in Atlantic coast bivalve hatcheries

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Widespread recent increases in larval crashes in bivalve hatcheries along the Atlantic Coast of the United States showcase the need for cross-institution collaboration, standardized sampling, high throughput sample processing, and the use of a comprehensive set of diagnostic assays to identify potential causes and develop targeted management tools. The Bivalve Hatchery Health Consortium (BHHC) has developed a screening assay using healthy larvae exposed to hatchery-collected samples to identify the type of disease-causing agents that could be present in the water or larvae from hatcheries experiencing low larval performance. In 2024 and 2025, more than 30 BHHC hatcheries collected incoming water (before hatchery treatment), larval tank water, and larval samples from more than 60 production runs experiencing unusual losses, as well as from normal runs (control samples). Preliminary results from the screening of whole and size-fractionated water samples from a subset of 21 hatcheries experiencing poor larval performance indicate that causes and factors leading to the low larval performance are heterogeneous. A portion of these 21 samples of incoming and tank water caused mortality in healthy larvae after filtration through 0.22-micron filters, indicating the presence of toxin/s and/or viral agents. Results also indicate that mortality in water-exposed larvae was affected by salinity. Additional samples are in the process of being tested using the larval screening assay. Results from these assays will be used by the BHHC pathology working group to develop more specific diagnostic tests and make management recommendations.

How heritable is food-conditioned plasticity in ciliated band length in sand dollar larvae?

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Most feeding larvae of echinoderms develop long ciliated bands (which serve as food-capturing structures) when reared in low-food environments, and short ciliated bands when reared in high-food environments. This phenotypic plasticity has been studied for ~40 years, but because of limits to replication imposed by traditional culture methods, the shape of this reaction norm and its sensitivity to additive genetic variance and maternal effects are poorly understood. We used a paternal half-sib mating design and a novel method of rearing of larvae in individual containers to describe the shape and inheritance of the reaction norm in larvae of the sand dollar *Dendraster excentricus*. Each of 20 males was mated to two unique females (total of 40 females), and offspring from all crosses were exposed to the alga *Rhodomonas* sp. at concentrations ranging from 1000-10,000 cells/mL for four days. We used an animal model analysis to estimate genetic and maternal components of variation in body size and ciliated band length. Plasticity was strong, with a ~17% decline in ciliated band length over the full range of food concentrations. Additive genetic variation (slope and shape of reaction norm) explained ~18% of variation in ciliated band length, while 13% was attributable to maternal effects. The reaction norm for larval phenotypic plasticity in *D. excentricus* thus seems likely to be moderately responsive to natural selection. The methods introduced here will be useful in future work testing hypotheses on among-population and among-species variation in reaction norms in echinoderm larvae.

Advances in collection, identification, and analysis of larval Atlantic sea scallops (*Placopecten magellanicus*)

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The Atlantic sea scallop (*Placopecten magellanicus*) is a bivalve that commonly occurs along the northwest Atlantic continental shelf. With commercial landings in over $360 million/year, the sea scallop consistently ranks among the five most valuable fisheries in the United States. Numerous fishes and invertebrates also consume sea scallops, forming key trophic linkages. Despite their economic and ecological importance, the life history of sea scallops is not well defined. As the distribution of mature sea scallops is primarily dependent on larval dispersal and settlement, understanding these dynamics is critically important to managing the fishery. The last known survey of larval sea scallops occurred in the 1980s. Thus, efforts to model their dispersal, and the potential impacts of offshore wind development, rely only on data derived from adults. In this study, we reestablished a depth-discrete collection method using an electric centrifugal pump system deployed at 10-meter intervals to target larval bivalves. We simulated sea scallop larval dispersal in the Middle Atlantic Bight using an Individual Based Model and collaborated with commercial sea scallop fishermen to sample during the predicted peak in larval biomass. Then, we quantified larval sea scallop abundance by utilizing polarized light microscopy called a Bivalve Larval Imaging System (BLIS) to identify species-specific birefringent patterns from the aragonite crystal orientation in larval shells. Preliminary results show that a pump system paired with automated BLIS identification offers a cost-effective and accurate pipeline to survey the abundance of several larval bivalve species which will aid in future modeling and management efforts.

2025 Slope Sea Atlantic Bluefin Tuna (*Thynnus thunnus*) larval sampling results and use cases, including close-kin mark-recapture

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Close Kin Mark Recapture studies rely on the frequency of genetically determined kinship pairs (Parent-offspring or sibling) to estimate population abundance and other demographic parameters. These types of studies rely on large sample sizes from multiple life stages. Targeted sampling in the Slope Sea, off the northeast U.S., during mid July 2025 resulted in catch numbers of Atlantic bluefin tuna larvae, higher than any previous western Atlantic sampling. Method and equipment adjustments maximized catch and efficiency onboard. Sample processing to date has yielded >10,000 bluefin tuna larvae, including genetically confirmed yolk sac larvae. Slope Sea larvae will be included in the existing Close-Kin Mark-Recapture project to help estimate the size of the western Atlantic spawning population of bluefin tuna and the nature of Slope Sea spawning. These individuals will also be an important input for multiple studies on bluefin tuna population structure and life history. The number of larvae caught allows for multiple studies to be pursued from fish caught on the same spawning ground, a unique opportunity in the Atlantic.

Larval Communities at Hydrothermal Vents Following the 2022 Hunga Eruption in the Lau Basin

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Hydrothermal vent ecosystems are spatially fragmented, island-like habitats that rely on larval dispersal to maintain connectivity, enable colonization, and support recovery following natural or anthropogenic disturbances. We examined larval communities across multiple vent fields in the Lau Basin following the 2022 Hunga Tonga eruption, which caused widespread mortality of foundation invertebrate species on the seafloor. We assessed larval communities at ash impacted and unimpacted sites using a McLane large volume system pump to sample within vent fields and the SyPRID plankton collector on the AUV Sentry to sample above vents and in the vent periphery. This multi-platform approach provided a vertically and horizontally resolved view of larval assemblages in recently disturbed habitats. Larval communities across the Lau Basin were generally dominated by trochophores, zoea, nectochaetes, and gastropods across all vent fields and sampling locations. Across vent fields there were no significant differences in larval community composition between ash impacted and unimpacted sites. However, larval communities differed by sampling location; larval communities were significantly more abundant within vents than communities above vents and in the vent peripheries. Notably, we also found *Alviniconcha* spp. larvae — key foundation species that were severely impacted by the 2022 eruption — throughout the vent fields and across sampling locations. Together, this work provides a framework for understanding how larval communities and vertical structure interact to influence connectivity in deep sea ecosystems following disturbances. Ongoing work from Spring 2026 will extend this effort by continuing sampling of larval communities across the Lau Basin four years after the original disturbance.

Larval performance under stress: Impacts of changing climate, pollution, and multiple stressors

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Assessing the thermal tolerance of Atlantic sea scallop (*Placopecten magellanicus*) early life stages

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Ocean warming affects numerous traits in early life history stages of invertebrates and fishes, which may reduce recruitment and harvestable biomass. A prime example is the Atlantic sea scallop (*Placopecten magellanicus*), which supports the most valuable U.S. fishery in the northwest Atlantic. This fishery may be at risk due to its high sensitivity to projected future ocean conditions. Prior research has identified decreases in recruitment, growth, biomass, and shifts in abundance across the Mid-Atlantic Bight (MAB); however, few studies have examined the response of planktonic larvae to future conditions. To address this knowledge gap, we conducted fully factorial experiments to evaluate the physiological response of larvae across a range of current and future environmentally relevant temperatures. Preliminary results suggest that warmer temperatures increase growth which decreases larval stage durations. At higher temperatures, increasing clearance rates were offset by more drastically increasing respiration rates, resulting in a lower scope for growth and faster mortality rates. This study provides empirical physiological data which can be incorporated into bio-physical model parameterizations and used to improve predictions of future population dynamics in the MAB under expected temperature escalations. The results of this study will help sustain stock biomass and aid in adaptive fisheries management under future temperature projections.

Thermal stress response in larval and post-larval of *Dendraster excentricus*

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Temperature fluctuations in marine environments can affect biological processes at the population, species, and community levels, with important consequences for ecological dynamics such as larval dispersal and survival, population connectivity, and recruitment success. *Dendraster excentricus* (Eschscholtz, 1831) is a filter-feeding echinoderm that inhabits intertidal and subtidal sandy habitats along the Pacific coast. This sand dollar has been widely used as a model organism for studies of cell differentiation and early developmental processes.

In the present study, we evaluated the thermal tolerance and physiological responses of 4-, 6-, and 8-armed pluteus larvae, as well as competent post-larvae, of *D. excentricus*. Responses were assessed through measurements of survival, body size, and the expression of seven genes associated with stress response, metabolism, apoptosis, antioxidant defense, and cytoskeletal structure (hsp70, hsp90, AIFM2, GDH, GSTO1, Cu-Zn SOD, and CyIIb cytoskeleton actin). Larvae and post-larvae were exposed for 6 h to four atypical temperatures (4, 13, 26, and 29 °C), and their responses were examined at both physiological and molecular levels.

The results demonstrated that thermal stress affects developmental stages differently, although temperature treatments significantly influenced most of the variables analyzed. Significant mortality was observed in 8-armed pluteus larvae exposed to 4 and 29 °C and in post-larvae exposed to 29°C. No significant differences were detected in overall body size among treatments; however, molecular responses were evident in all developmental stages subjected to elevated temperatures. Overall, 4-, 6-, and 8-armed pluteus larvae appeared to be more sensitive to thermal extremes, than later developmental stages.

Effects of adult acclimation and larval rearing temperature on reproduction and early development in the Arctic sea urchin *Strongylocentrotus droebachiensis*

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The Arctic is warming at more than twice the global average rate, yet the consequences of increasing temperatures for reproduction and early life-history stages of Arctic benthic invertebrates remain poorly understood. The green sea urchin *Strongylocentrotus droebachiensis* is a dominant herbivore in Arctic coastal ecosystems, where shifts in reproductive success and early development may have cascading effects on macroalgal habitats and benthic community structure under ocean warming.

To investigate the effects of temperature increase on reproductive performance and larval development, adult *S. droebachiensis* from Kongsfjorden, Svalbard (Kongsfjordneset; 78°58.50′ N, 011°31.20′ E), were acclimated for seven months to High Arctic (2 °C) and projected future temperatures (5°C and 8°C). Three independent biological replicates were established for each temperature. Adult reproductive output was quantified after thermal acclimation by counting spawning individuals and enumerating egg numbers per female. Larvae were subsequently reared across the same temperature treatments in a fully crossed experimental design. Larval survival, developmental progression, and growth were monitored until an early pluteus stage, when lipid storage, respiration rates, and transcriptomic responses were assessed.

Preliminary analyses indicate that larval rearing temperature strongly influences developmental progression, with warmer temperatures accelerating development. This pattern was modestly influenced by adult acclimation temperature, with larvae tending to perform better under developmental temperatures matching adult thermal history, suggesting parental carry-over effects on offspring performance. Together, these findings suggest that direct and transgenerational effects of warming may interact to shape the resilience and future population dynamics of Arctic *S. droebachiensis* and thus Arctic ecosystems.

Transcriptomic responses to ocean acidification in embryos of Northern sand lance (*Ammodytes dubius*)

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Northern sand lance (*Ammodytes dubius*) embryos are unusually sensitive to ocean acidification (OA), with previous work showing reduced hatching success under elevated pCO_2 conditions projected for the Gulf of Maine this century. OA appears to interfere directly with the hatching process, as exposed embryos show prolonged hatching duration and many normally developed embryos fail to hatch. We hypothesized that elevated pCO_2 disrupts embryonic gene expression, particularly the expression of choriolytic hatching enzymes required to pre-digest the egg membrane before mechanical hatching. To test this, we reared embryos under two pCO_2 treatments, 400 and 2,000 µatm, crossed with two dynamic temperature regimes, 10→7°C and 10→5°C. Embryos reared under 2,000 µatm pCO_2 exhibited delayed hatching and a 62% reduction in average cumulative hatching success, with stronger effects under the warmer treatment, −73%, than the cooler treatment, −43%. However, high-frequency qPCR measurements showed no OA effect on hatching-enzyme expression, indicating that altered expression of these enzymes does not underlie hatching failure. RNA-seq instead revealed broad OA-induced transcriptional shifts, with enrichment of pathways related to cell adhesion and signaling, biosynthesis, immune function, lipid metabolism, cytoskeletal organization, and proteolysis, and reduced enrichment of transcriptional, chromatin, DNA repair, and neural developmental processes. These results suggest that OA-induced hatching failure in Northern sand lance reflects broad developmental and cellular disruption, with important implications for the future reproductive success of this foundational forage fish.

Knowing the limits of your model organism: Thermal performance of *Lytechinus pictus* larvae under low pH

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Larval development in marine echinoderms is constrained by lower and upper critical temperature limits that define the thermal performance range of early life stages. However, interactions between temperature and additional environmental stressors in sea urchin larvae remain poorly resolved. To better understand physiological performance under stress in the emerging model sea urchin *Lytechinus pictus*, we examine how seawater pH interacts with temperature to influence larval survival and developmental success.

Larvae were reared under fully factorial combinations of temperature (9–27°C) and seawater pH (7.2–8.2) and monitored throughout development. Survival patterns across temperatures allowed us to characterize the thermal performance range and identify developmental limits of L. pictus larvae. Within this range, decreasing seawater pH consistently reduced peak survival without substantially altering thermal breadth, indicating reduced performance rather than a shift in thermal limits.

Differences among pH treatments became most apparent after the onset of feeding and were strongest at the lowest pH. This divergence coincided with the transition from maternal energy reserves to digestion-dependent energy acquisition from microalgae, suggesting increased sensitivity to reduced pH once larvae depend on external energy sources and feeding-associated physiological complexity increases.

We therefore propose that reduced seawater pH may interfere with digestive processes, potentially limiting nutrient assimilation and energy availability for development. Future work will investigate physiological mechanisms underlying energy acquisition and allocation to key processes, including midgut pH regulation and digestive enzyme production. This approach will help explain how energetic constraints shape larval performance across environmental stress gradients.

Spinning Off Course: How Future Oceans Affect Stone Crab Larvae

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After larval release, stone crab larvae respond to abiotic cues to direct their vertical movements. Earlier larval stages swim toward the surface, while later larval stages elicit swimming behaviors that promote a relatively deeper depth distribution. Little is known about how these vertical swimming behaviors may shift when larvae are exposed to warmer, more acidic conditions that are increasingly characterizing coastal environments. This is especially problematic during the rainy season and summer months in Florida when stone crabs are reproductive. We tested the klinokinetic (changes in direction and turning rate) and geotactic (orientation to gravity) responses of larval stone crabs raised under combinations of forecasted temperatures (28°C, 30°C, 32°C) and pH levels (8.0, 7.8, 7.6) in a fully crossed experiment. Klinokinetic behavior of downward swimming larvae showed no trend among the different combinations of temperature and pH. However, upward swimming larvae exhibited increased turning behavior in the warmer and more acidic treatments, resulting in 37% more turns relative to the control. The frequency of turning in upward swimming larvae also increased with age, with later stages turning more often than newly hatched larvae. Geotactic responses promoted upward swimming under contemporary conditions, but this response reversed to downward swimming in warmer, more acidic treatments. The increased turning behavior and reversal in geotactic swimming in the warmer and more acidic treatments may result in larval stone crabs having a relatively deeper depth distribution earlier in their larval development, potentially exposing individuals to slower currents at depth and reducing the populations' dispersal.

Stage-specific responses of Eastern oyster larvae exposed to multiple coastal stressors

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Coastal ecosystems worldwide are facing an increasing number of anthropogenic stressors, yet their concurrent and cumulative impacts remain poorly understood, particularly during vulnerable early life stages. In shallow estuarine environments, two prevalent and often coupled stressors are hypoxia, or low dissolved oxygen (LDO), and coastal acidification (CA), both of which are driven by diel cycles. Pulses of freshwater are also observed, causing short-term low salinity (LS) conditions and altering carbonate chemistry. Global climate change is expected to intensify these disturbances by increasing the frequency, magnitude and duration of LDO and CA events, while altering estuarine salinity regimes. We investigated the phenotypic and genotypic responses of larval Eastern oysters (*Crassostrea virginica*) exposed to four treatments: (1) control, (2) combined LDO and CA (1 mgO2/L and 7.0 pH units), (3) LS (10 ppt), and (4) combined LDO/CA + LS treatment. Oyster larvae were produced from four independent spawns of wild adults collected from Narragansett Bay between 2023 and 2025. For each spawn, both early-stage (pediveliger) and late-stage (eyed-pediveliger) larvae were exposed to each experimental treatment for 24 h, allowing comparisons of stage-specific sensitivity to multiple stressors. Larvae were sampled for growth, survival and genomic analyses to evaluate phenotypic performance and identify genes under selection in response to stress exposure. Preliminary results from these experiments will be presented at the meeting. Ultimately, this study will improve our understanding of how short-term exposure to multiple stressors influences larval performance and shapes the distribution of genomic diversity across Eastern oyster populations.

Environmental marine microbes drive larval host gene expression and immune responses

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Marine microbial communities can be altered by warming, both through increasing bacterial loads and pathogen spread, but it is still unclear whether these complex microbial communities, especially in combination with abiotic stressors, create an adaptive or immunosuppressive immune response in larvae. We examined the effects of early exposure to high temperature and environmental microbes on the larval gene expression, morphology, and immune system function in the purple sea urchin (*Strongylocentrotus purpuratus*). Embryos were reared in four conditions–ambient or elevated temperatures (14 ºC or 18 ºC) and two microbial conditions (low or high microbial richness (LMR or HMR))–and then larvae were infected at 6 dpf with *Vibrio diazotrophicus*, a known marine pathogen. Before infection, larval size and gene expression were largely driven by the microbial environment during development, with distinct differences in the expression of genes related to epigenome modifications, metabolism, and cellular anatomy. Following 24 hour exposure to *V. diazotrophicus*, larval gene expression patterns differed based on both temperature and microbes, with a shift towards genes related to stimulus response and regulation of molecular functions. Additionally, during infection, larvae in HMR lost pigment cells (an antimicrobial cell), while the larvae in LMR increased their pigment cell numbers, possibly reflecting a delayed immune response in larvae that had been exposed to lower microbial diversity (LMR) during development. Thus, we show that unique environmental conditions lead to different molecular landscapes within the larvae, ultimately leading to differences in immune response which could impact survival in the changing ocean.

Synergistic selection across the genome of eastern oyster larvae under coastal acidification and sewage effluent: a CASE study

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Coastal marine organisms encounter multiple anthropogenic stressors simultaneously, and the combined effects are hard to predict from single-stressor studies. In urbanized estuaries, eutrophication from sewage effluent drives coupled low dissolved oxygen and coastal acidification, conditions expected to worsen with climate change. Eastern oyster (*Crassostrea virginica*) larvae are vulnerable during their pelagic stage, yet no prior study had measured differential mortality and the genomic response to coastal acidification and sewage effluent together. Here, we used expressed exome capture sequencing of pooled larvae exposed to a factorial stressor design across three independent spawns. Larvae from wild broodstock were exposed for 24 h to control, coastal acidification (CA, ~2800 μatm pCO2), sewage effluent (SE, 5% v/v treated effluent), or the combination (CASE). Pooled allele frequencies were estimated before and after exposure, and outlier loci identified with Cochran-Mantel-Haenszel tests across replicate spawns, with control-treatment outliers removed. Combined CASE conditions produced the lowest larval survival, with greater-than-additive mortality in the highest-survival spawn, and a synergistic genomic response: more loci responded to the combination than to coastal acidification and sewage effluent combined, enriched for protein folding, the ubiquitin-proteasome system, and ciliary function. Selection drew on standing genetic variation and was repeatable across independent spawns, with the strongest and least reproducible response under the combined treatment. Combined stressors therefore recruit a larger and partly distinct set of genomic targets than either stressor alone, and rapid, repeatable selection on standing variation operates across independent genetic backgrounds, supporting the possibility of adaptive resistance to multiple stressors.

Commonly co-occurring stressors in industrialised estuaries disrupt larval development in blue mussels.

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Frances Orton (Heriot-Watt University)
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Recent, substantial declines in blue mussel (*Mytilus edulis*) beds in northern European estuaries are hypothesised to be caused by poor recruitment success. Estuaries are sinks for contaminants, and now climate-driven warming and salinity shifts have emerged as additional pressures which may interact to affect larval development in mussels. In this study, we investigated the interactive effects of a representative, environmentally relevant pollutant mixture, water temperature and salinity on mussel embryo-larval development. We used a full factorial design with a pollutant mixture concentration range of 0.015–15 μg/L (organic compounds) and 20–20,000 μg/L (dissolved metals) and in the presence of two different temperatures (15 or 18°C) and two different salinities (25 or 35 ppt) over a 48-hour exposure duration. Under control conditions (15°C, 35 ppt, no pollution), larvae exhibited high normal development with few malformations. Increasing temperature alone enhanced normal development by 15.9% ($p \leq 0.01$), whereas reduced salinity alone decreased normal development by 28.7% ($p \leq 0.01$). Combined high temperature and low salinity, did not significantly alter normal development from the control but induced shell malformations in the D-stage ($p \leq 0.05$). Pollutant mixtures produced a strong concentration dependent decline in normal development and an increase in malformations, with high concentrations arresting most larvae in the trochophore stage. Detrimental pollutant effects were intensified under low salinity but were modestly alleviated by elevated temperature. These findings demonstrate that climate change may alter environmental contaminant effects on mussel larval development, which if replicated in wild mussels, could severely compromise recruitment.

Cumulative impacts of climate change and crude oil pollution on blue mussel larvae across populations

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Coastal marine ecosystems are increasingly exposed to multiple stressors due to climate change and human activities. Blue mussels (e.g., *Mytilus edulis*) are key species in these systems, performing important ecosystem functions such as the bentho-pelagic coupling and creation of biogenic habitats. This study evaluated how early developmental stages of *M. edulis* from Denmark and Greenland are affected by individual and combined exposure to different temperatures (17, 19 and 21.5°C for the Danish and 2, 3.5 and 5.3°C for the Greenlandic population), salinities (24 and 33 psu) and crude oil (0, 1, 10 µL L^{-1}). Fertilization, larval development, and growth were assessed. Results showed that high temperature and oil exposure negatively affected fertilization and development, while low salinity sometimes mitigated these effects. The Greenlandic population showed greater resilience during fertilization and early survival than the Danish population, suggesting local adaptation. However, larval development failed under laboratory conditions for the Greenlandic population. The veliger stage in the Danish population was particularly sensitive to the combination of high temperature and oil. We found complex interactions between the three stressors, leading to additive, synergistic and antagonistic effects. Our findings highlight the vulnerability of blue mussel larvae to multiple environmental stressors and the importance of understanding how multiple stressors affect larval stages to predict future impacts on populations and the ecosystem.

Cumulative effects of real life nanoplastics and climate change on sea urchins and brittle stars larvae

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Nanoplastics (NPs) are emerging contaminants of concern in marine ecosystems, yet their effects on sensitive early life stages remain poorly understood, particularly when derived from environmentally realistic sources. This study investigated the impacts of tire wear particle (TWP), commercial polystyrene (PS), and polyethylene terephthalate (PET) nanoplastics on fertilization and larval development of two ecologically relevant echinoderms, the sea urchin *Strongylocentrotus purpuratus* and the brittle star *Amphiura filiformis*, under ambient (8°C, pH 8.0) and climate change (12°C, pH 7.6) scenarios.

Our results demonstrated strong treatment specific responses. Fertilization success was markedly reduced up to 40% in TWP and TWP leachate treatments. During larval development, TWP NPs caused the highest proportions of abnormal larvae and mortality, with cumulative mortality reaching 90–100%. In contrast, PS and PET NPs generally produced weaker effects. Climate change conditions increased the negative effects of nanoplastics in larval development. These findings indicate that nanoplastics derived from realistic sources such as tire wear pose substantially greater risks to marine invertebrate early life stages than commonly used commercial particles. In addition, it also emphasizes the need to consider multistressors approaches for improving ecological risk assessments under future ocean conditions.

Determining whether sea urchin phenology and reproductive success changes with environmental temporal change

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Environmental and temporal changes are significantly impacting animal physiology, altering the ways in which we produce seafood, particularly when, where, and how it is done. Despite extensive research efforts, most studies have focused on short-term heat and chemical change experiments, leaving critical knowledge gaps about the medium- and long-term effects on production practices. We will overview several ongoing projects that aim to address these gaps, with a particular focus on commercial sea urchin production. As wild fisheries decline, aquaculture has emerged as a promising alternative for sustaining the sector. We will present work on multigenerational breeding and high-frequency field sampling to explore how heat and chemical change affect sea urchin physiology and reproduction, key factors influencing production output and the timing of practices. While this research focuses on sea urchin species produced in the Atlantic, these insights have broad implications for other commercially important species and production practices in both aquaculture and fisheries.

Thermal sensitivity and aerobic scope in paralarvae of *Octopus tetricus*

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Temperature strongly influences metabolic performance and survival during the early life stages of cephalopods, yet the thermal requirements of octopus paralarvae remain poorly defined. This study examined the effects of temperature on metabolic rates and aerobic scope of gloomy octopus (*Octopus tetricus*) paralarvae to identify an optimal rearing temperature during the first four days post hatch. Oxygen consumption was quantified using closed system respirometry at six temperatures (12, 15, 18, 21, 24, and 27°C) in paralarvae aged 0, 2, and 4 days post hatch. Standard (SMR), routine (RMR), and maximum metabolic rates (MMR) were measured, and used to calculate aerobic scope (AS). Metabolic rates varied significantly with temperature, with both low and high thermal extremes depressing performance. AS exhibited a clear temperature dependent parabolic pattern, peaking at 3.34 mg O_2 gDW^{-1} h^{-1}. Quadratic modelling identified an optimal temperature (T_{o}□□) of 18.98°C. Behavioral observations aligned with physiological trends as paralarvae at cooler temperatures showed reduced activity and delayed exhaustion, whereas elevated temperatures increased metabolic demand and reduced aerobic capacity. Temperature dependent Q10 analyses revealed exceptionally high thermal sensitivity immediately post hatch, which moderated rapidly by 4 dph, indicating strong early developmental constraints and a narrowing of physiological vulnerability with age. These findings indicate that rearing *O. tetricus* paralarvae at ~19°C maximizes aerobic performance during a critical developmental window when individuals transition from yolk utilization to active predation. This study provides the first empirically derived T_{o}□□ for any octopus paralarva and establishes a physiological basis for refining aquaculture protocols while informing predictions of early life sensitivity to ocean warming.

To eat and not be eaten: Hydrodynamic adaptations of velum morphology in molluscan veligers

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Many mollusks develop through a planktonic veliger larval stage, during which a ciliated velum supports both locomotion and suspension feeding. However, veliger morphology and body size vary widely across taxa. Veligers of the eastern oyster *Crassostrea virginica* (Bivalvia) have a single-lobed velum and range from ~70 to 350 μm during larval development, whereas veligers of the slipper limpet *Crepidula fornicata* (Gastropoda) bear a bilobed velum and grow from ~300-400 μm at hatching to ~1 mm before metamorphosis. Using a high-speed microscale imaging system (HSMIS) and micro-particle image velocimetry (μPIV), we quantified the feeding currents generated by free-swimming veligers of both species. Both species produced feeding currents that yielded similar body-volume-specific clearance rates (on the order of 10^6 body volumes per day). Nonetheless, the absolute volumetric flow generated by *C. fornicata* veligers was up to an order of magnitude higher, consistent with their larger body size. *C. virginica* larvae generated a single-branched feeding current using their single-lobed velum, whereas *C. fornicata* larvae produced a two-branched feeding current aligned with their bilobed velar structure. Despite these differences in branching configuration and flow magnitude, both species exhibited comparable hydrodynamic disturbance areas. These findings suggest that the bilobed velum of *C. fornicata* represents a hydrodynamic adaptation that enables a two-branched feeding current, allowing the larvae to maintain high clearance rates while potentially reducing predation risk from flow-sensing predators. This comparative study highlights the functional significance of velum morphology in shaping feeding mechanics and mitigating predation risk in molluscan veligers.

Neural modulation of swimming in a gastropod veliger

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Veliger larvae of molluscs are so named because they possess a velum, a ciliated swimming and feeding organ whose loss during metamorphosis marks the end of the larval period. The velum is richly innervated by central efferent neurons that modulate the rate of ciliary beating, as well as the frequency of ciliary arrest (an electrically-mediated event in which all of the prototrochal swimming cilia simultaneously stop beating). We investigated the effects of the velar neuromodulators serotonin (5-hydroxytryptamine) and FMRFamide (a neuropeptide) on the kinematics of swimming in precompetent and competent veligers of the gastropod *Crepidula fornicata*, to complement earlier studies of these modulators done in static electrophysiological preparations. Serotonin at micromolar concentrations increased swimming speed, especially in precompetent larvae and especially in the horizontal component of swimming velocity. FMRFamide had an opposite effect, stopping swimming at 10 μM and showing graded inhibitory effects at micromolar and lower concentrations. Double-labeled immunohistochemical preparations revealed serotonin and FMRFamide-like immunoreactivity in velar lobes of precompetent and competent larvae, with labeled nerve terminals for both modulators adjacent to cell bodies of prototrochal cilia. Surprisingly, although most nerve fibers appeared to express only one modulator or the other, some fibers expressed both antagonistic modulators in the same terminal axon branch. The finding of such mixed-phenotype neurons suggests that, rather than distinct circuits for excitation and inhibition of swimming, there may be a dynamic developmental balance between these influences at the level of single cells.

Acoustic enrichment enhances coral recruitment under favorable ecological conditions

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As coral reefs decline worldwide, developing strategies to support recovery after mortality is a critical priority. Reef recovery depends on the arrival and settlement of coral larvae, which rely on environmental cues (e.g., chemical, light, and acoustic) to locate suitable habitat, as well as on post-settlement survival shaped by local conditions, including competition with fast-growing fauna. Acoustic enrichment (AE) can promote larval settlement, but its effects on early post-settlement survival in natural settings remain unclear. We conducted a 2-month field study in Maui, Hawaiʻi, using wild, free-swimming coral larvae and a Reef Acoustic Playback System to enrich soundscapes with healthy reef sound. Coral recruitment was 66% higher at the site with the least bivalve growth. At the other sites, where recruits were frequently overgrown or adjacent to bivalves competing for space, no AE effect was detected. These results show that AE can enhance coral settlement, but its effectiveness for post-settlement survival depends on environmental context.

Spawning, paternal care, and larval development of an Antarctic colossendeid sea spider

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The family Colossendeidae contains some of the largest and most conspicuous species of sea spiders, yet until recently, reproduction and embryonic development had never been described for any member of the family. This was particularly surprising because paternal brooding is a distinctive and famous feature of pycnogonid biology, but no adult colossendeid, male or female, had ever been observed carrying embryos or larvae. During fieldwork at McMurdo Station, Antarctica, we documented spawning in the laboratory and subsequently located naturally occurring egg masses in the field, allowing us to reconstruct development of *Colossendeis megalonyx* from early cleavage through hatching. Females released negatively buoyant eggs embedded in a sticky gelatinous matrix and departed soon afterward, while an inferred male remained associated with the egg mass for over 48 h, grooming and compacting the eggs into a sheet attached to the substrate. Embryos remained substrate-associated throughout development and hatched after 7–10 months as tiny, typical protonymphon larvae. We also present new SEM images of larval morphology, including observations of cheliphore segmentation, and discuss several comparative questions that arise from these observations.

Genetic regulation of a larval dimorphism

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Evolutionary change originates from differences that arise during development resulting in phenotypically divergent adults. Yet development is also a conserved and often constrained process. The first steps of evolutionary transitions to new developmental modes are crucial to understand, but difficult to pinpoint at the genetic level, even across closely related species. Therefore, organisms with dimorphic development — where two developmental modes occur within a species — have long held the interest of biologists because they offer a unique insight into the microevolutionary changes necessary to switch major developmental and life-history traits. We investigate gene expression difference during embryonic and larval development between two alternative larval types of the polychaete *Streblospio benedicti*. This worm can produce two distinct offspring types that drastically differ in egg size, embryogenesis, and larval development. These differences are maintained by selective pressures in the environment resulting in a larval dimorphism. Despite the heritable genetic differences that give rise to the two larval types, *S. benedicti* is a single species and represents the earliest evolutionary stage of developmental divergence. We uncover genes whose expression is linked with one of the developmental morphs and find candidate genes that dramatically change larval morphology. We determine that developmental morphologies arise from gene regulatory differences rather than mechanistically distinct pathways and report the first set of genes that contribute to morphological differentiation within a species that has multiple developmental modes.

Single-cell atlas of the human-infective *Schistosoma mansoni* cercaria larva highlights novel cell types and transcriptional programs underlying mammalian host invasion

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Schistosoma mansoni is a parasitic flatworm that causes schistosomiasis, a neglected tropical disease affecting an estimated 250 million people worldwide. Its complex life cycle includes molluscan and mammalian parasitic stages, bridged by two transient free-living freshwater larval stages. The cercaria, the second larval stage, emerges from the snail intermediate host and has approximately 48 hours to find and infect a mammalian host. Propelled by its tail, the cercaria penetrates host skin, sheds its tail, and transforms into a schistosomulum, which migrates through the host vasculature and ultimately develops into an adult worm. To define the molecular and cellular programs that drive cercarial invasion and adaptation to the definitive host, we generated a single-cell RNA-seq whole-body atlas of the *S. mansoni* cercaria. We identified 24 cell types and spatially validated populations using HCR in situ hybridization. This revealed that 11 cell types were specific to the cercarial body and 5 were specific to the tail; using phylostratigraphy, we found that tail-specific cell types are evolutionarily more recent innovations, providing insight into the evolution of the cercarial tail and active host infection. Comparative analyses with cell atlases from other *S. mansoni* life stages and flatworm species revealed cell types that are conserved across development and evolution, as well as populations unique to the cercarial stage. Finally, by comparing cercarial and schistosomulum cells, we identified dynamically regulated genes associated with the transition from freshwater to the warm, osmotically distinct, immune-active environment of the mammalian host, which could inform therapeutic strategies.

Genes vs. environment: Larval body size plasticity may lead to carryover effects in Dungeness crab

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We investigated the striking seasonal variation in body size among Dungeness crab megalopae throughout their long settlement season in Washington inland and coastal waters. Our approach combined whole-genome sequencing data from hundreds of megalopae collected across the settlement season and region with sea-surface temperature records prior to their capture. This allowed us to test two alternative hypotheses: that size variation results from genetically distinct larval sources, or from environmentally-induced plasticity following the temperature-size rule that governs body size among the vast majority of ectotherms. Our results, along with the additional context provided by prior studies brought to new light, support a dominant role for environmentally-driven phenotypic plasticity in body size variation among crab larvae. Persistent size differences previously observed between early and late settlers into adulthood suggest that this environmentally-driven plasticity during early life history stages may result in a carryover effect that has significant demographic implications for population dynamics and fishery management. More broadly, we hypothesize that other species whose reproductive and/or larval periods extend over multiple seasons or regions may also experience variability in body size that may lead to consequential carryover effects into adulthood.

Diverging phenology of lobster larvae and their zooplankton prey in a warming ocean

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We build on our previous research describing correlative links between changes in the abundance of the copepod *Calanus finmarchicus*, a foundational zooplankton species of the pelagic food web, and diminishing recruitment of young-of-year lobster to benthic nurseries in the Gulf of Maine. Using parallel 31 year time series of lobster larvae and zooplankton collected on the New Hampshire coast between 1988 and 2018, we investigated how changes in phenology of stage I larval lobster and their putative copepod prey, *Calanus finmarchicus*, affects their temporal overlap and potential to interact during the larval season. We found that over the time series both the lobster egg hatch and first appearance of larvae trended earlier in the season, a trend significantly correlated with ocean warming. The last appearance of larvae in late summer has been delayed, however, thereby extending the larval season. Even with the longer larval lobster season, the *C. finmarchicus* season has increasingly been ending before the peak abundance of stage I lobster larvae. The net effect is a widening mismatch in phenology of the two species, an outcome consistent with the hypothesis that changes in abundance and phenology of *C. finmarchicus* have contributed to recent declines in lobster recruitment.

Early life-history barriers to connectivity for thermally-tolerant corals in Palau

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Recovery of coral reefs following disturbance depends on dispersal of coral larvae, subsequent settlement, and survival of newly-settled corals. Thermally-adapted corals living on extreme (naturally high-temperature conditions) reefs have been considered a genetic bank that could reseed other reefs following disturbance. However, multiple barriers in the early life-history stages could limit connectivity of classic (typical conditions) and extreme reefs. Here, we investigate larval and settler stages of *Porites* spp. sourced from extreme and classic reefs in Palau's Rock Island Southern Lagoon. We aim to understand whether larvae spawned from thermally-tolerant parents on extreme reefs in semi-enclosed lagoons could disperse out of the lagoons, settle, and survive on outer classic reefs. About 1% of *Porites* larvae were still swimming 17 days after fertilization, suggesting they could escape a Rock Island lagoon. For coral settlers, both temperature and light stress had significant effects on survival. While extreme reefs had higher temperatures, classic reefs had higher light intensities. These results suggest that environmental stressors may restrict survival of corals that settle away from their natal reef; however, a field transplant showed no difference in survival between corals outplanted at their home reef versus an away reef. Corals that were forced to delay settlement as larvae had lower survival after settlement compared to individuals that settled directly after reaching competency, and this effect was exacerbated by thermal stress. Overall, this study shows that multiple early life-history barriers restrict the connectivity of *Porites* populations in the Rock Islands of Palau.

Pioneer species arriving after a 2025 seafloor eruption near 9ºN on the East Pacific Rise

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Communities at hydrothermal vents on fast-spreading ridges experience catastrophic destruction during frequent seafloor eruptions. Our group has observed the 1991, 2006, and 2025 eruptions near 9ºN at the East Pacific Rise (EPR) and is investigating which species arrive as pioneers and how they may influence succession. The arrival times and composition of foundation species (e.g., siboglinid tubeworms and bivalves) were similar between the 1991 and 2006 events but differed for smaller invertebrates (macrofauna). After the 2006 eruption, the gastropod *Ctenopelta porifera*, which had never been detected in the region, arrived in large numbers and persisted for several years. Monitoring over the next 19 years revealed continued shifts in species composition and function, but long-term data sets from prior eruptions were not available for comparison. The 2025 eruption provides an opportunity to investigate temporal variation in initial colonists and determine how those pioneers influence later succession. We sampled and imaged colonists using ROV Jason in January 2026, approximately 8 months after the 2025 eruption. Preliminary analyses from one site (V-vent) have revealed typical pioneer foundational species (the siboglinid *Tevnia jerichonana* and mussels), but, so far, no *C. porifera*, suggesting that initial macrofaunal pioneers may differ from the 2006 event. Analyses from other vents are underway and future cross-disciplinary investigations will explore the influences of larval supply, microorganisms, fluid chemical composition, and physical habitat on early recovery. Long-term monitoring will assess the influence of the 2026 pioneers on subsequent succession.

Tracking larval connectivity using genetic tools

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Marine invertebrates commonly produce free-swimming larvae that disperse away from adult populations. Distance and direction that larvae disperse rely on physical (tides and currents) and biological (larval swimming and growth) conditions, resulting in trajectories of dispersal dependent on where and when the larvae originate. This means that some areas of an estuary will act as a better larval source than others. These potential patterns of metapopulation connectivity are often predicted using dynamic ocean models that disperse particles with biological behaviors. Measurement and confirmation of these dynamic dispersal and recruitment processes are more challenging; however, recruitment from source populations into sink populations can be detected with genetic markers such as microsatellites and single-nucleotide polymorphisms (SNPs). The power of detection depends on the number and type of genetic markers used and the genetic divergence between the two populations. Recent development of a high-density SNP arrays for eastern oysters and hard clams provides a powerful tool for studying recruitment and possible introgression of selectively bred hatchery strains raised on aquaculture farms into wild populations. In two related studies, we are using these SNP arrays to test for recruitment of larvae spawned from farms in wild populations of oysters and clams in two estuaries in New Jersey. Locations of farms are known, and wild populations to be sampled will be targeted using previously estimated dispersal patterns predicted from dynamic biophysical models. Results from this study will provide unique insights into realized connectivity patterns in metapopulations of oysters and clams.

Do larvae play a role in adapting to change?

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The marine environment is often characterized by its spatial heterogeneity. Suitable habitat and food resources are distributed in patches, creating a challenge for the vulnerable offspring of many marine organisms. One common adaptation to address this issue is the production of a plethora of dispersive larvae, enhancing the odds that a small number may encounter the necessary conditions for survival. In the modern era marine organisms must contend with an environment which varies not just in space, but more rapidly over time due to climate change. Individual larvae are generally regarded as sensitive rather than robust, and so rapid climate change may be especially difficult for these early life-stages to overcome. On the contrary, adaptations which allow a large pool of larvae to produce a small number of survivors when faced with spatial heterogeneity might also allow them to react quickly to changes over time. In order to assess the ability of larvae to adapt rapidly to novel climates we conducted laboratory experiments acclimating the model copepod species *Acartia clausi* to ambient and warming conditions. Larval respiration rates exhibited greater variation but less plasticity compared to later life-history stages. Lower plasticity may limit individual survivorship, but broad phenotypic variance within the larval pool could lead to the production of individuals adapted to a wide range of conditions. Results from a complementary Individual Based Model and secondary data analysis also suggest that the high fecundity exhibited by larval bearing organisms may provide a buffer against environmental change.

Benthic lecithotrophic development restricts connectivity in the tropical sea cucumber *Holothuria floridana*

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Understanding how life history traits shape population connectivity is central to marine ecology. Although a pelagic larval phase drives dispersal in most marine taxa, some species exhibit alternative developmental strategies that may greatly restrict dispersal. The tropical sea cucumber *Holothuria floridana* is a commercially important fishery species with entirely benthic development. It has negatively buoyant gametes and lecithotrophic larvae that develop within gelatinous capsules on the seafloor. We investigated whether these early life history traits constrain population connectivity throughout Belize's Mesoamerican Barrier Reef System. Using 3D GBS, we genotyped 183 individuals collected from all major fishing zones at 6,986 SNPs. *H. floridana* displays strong hierarchical genetic structure. There are highly divergent populations in southern Belize that are likely isolated by a gyre and other localized seascape features. These southern populations also exhibit a small reduction in heterozygosity that could reflect increased drift in isolated populations. Within central and northern Belize, additional genetic differentiation was identified among populations within and between fishing zones, further supporting limited connectivity and restricted gene flow. Collectively, these findings indicate that *H. floridana* exhibits high local retention owing to its benthic development, which, in turn, may limit recovery after localized overexploitation. Our results can inform resource management of genetically distinct sea cucumber populations in the region.

Flow, function, and fate: Larval behavior and connectivity in a changing ocean

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The dispersal and connectivity of coastal and marine species – and ultimately their persistence – will be increasingly shaped by anthropogenic change over the coming century. Thermal stress has the potential to reduce reproductive output, alter larval development and survivorship, and modify ontogenetic patterns of larval behavior. Ocean acidification may further influence larval performance through synergistic effects on physiology, behavior, and survival. Hydrodynamic models provide our best representation of the physical forces governing larval transport, and their spatial and temporal resolution continues to improve rapidly. Yet our understanding of larval behavior and responses to environmental change at the fine scales relevant to these flows remains limited, constraining our ability to translate increasingly sophisticated ocean models into accurate predictions of dispersal and connectivity. As a result, the biological realism of biophysical models now lags behind advances in physical oceanography. Using cnidarian and crustacean systems, we are generating high-resolution datasets describing larval vertical swimming and buoyancy in changing oceans, and integrating these observations with high-resolution coastal circulation models. This approach allows us to disentangle the interacting effects of environmental change, larval behavior, and ocean circulation on retention, dispersal, and connectivity. Our results suggest that climate change may truncate dispersal kernels and favor short-distance dispersers across diverse taxa, with important consequences for population persistence, community structure, fisheries, and ecosystem resilience.

Environmentally mediated behavior influences the recruitment of simulated stone crab larvae

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For many benthic invertebrates, the pelagic larval phase is the greatest opportunity for dispersal, connectivity, and migration. During this phase, these early life stages may be particularly vulnerable to environmental stressors. For example, in larval Florida stone crabs, acidification and elevated seawater temperatures significantly alter larval swimming behavior, accelerate development, and reduce survival in laboratory experiments. While laboratory experimentation is a valuable method to discern larval behaviors, it is nearly impossible to track and observe larval stone crab behavior *in situ*. We coupled laboratory behavioral and developmental data with the hydrodynamics simulated by the Regional Ocean Modeling System (ROMS) into ROMSPath, a Lagrangian particle simulation, and tracked larval trajectories for 23 years. Through simulations, we attempt to estimate how environmentally influenced larval swimming behaviors influence patterns of dispersal and connectivity in larval stone crabs throughout the West Florida Shelf. Simulated recruitment was subsequently compared with the Florida Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring Program juvenile sampling data along the West Florida Shelf to determine the model's effectiveness in estimating recruitment patterns. Incorporating dynamic larval swimming behavior into ocean hydrodynamics revealed that coastal water temperatures shaped recruitment patterns for simulated individuals. The frequency of marine heat waves and future ocean temperatures are expected to increase, potentially reshaping pelagic larval swimming behavior, development, and dispersal, and ultimately impacting recruitment patterns along the coast.

Heterogeneous regional distribution of the barnacle *Chthamalus fragilis* across a biogeographic barrier: relation to circulation and water temperature

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Chthamalus fragilis competes for space in western Atlantic rocky intertidal habitats with the more boreal *Semibalanus balanoides*. Along the NE US, the abundance of the warmer-water *Chthamalus* declines dramatically in the area of Cape Cod, MA, going from very high densities in Buzzards Bay to very low densities further north in the cooler water of Cape Cod Bay (CCB). These two water bodies are connected by a 12-km navigation canal, enabling two-way larval transport. Recent and historical survey data reveal a distinct geographic pattern of *Chthamalus* in CCB. Small *Chthamalus* populations are found along the eastern CCB shoreline, while *Chthamalus* is rare or absent along the western CCB rocky shores, north of the canal entrance, where *S. balanoides* is abundant. Larval transport modeling suggests that this pattern is not associated with coastal circulation. During the June–August period, when *Chthamalus* larvae disperse, coastal flow in CCB is frequently poleward, carrying larvae emerging from the canal entrance northward to the area where *Chthamalus* juveniles and adults are absent. However, the *Chthamalus* distribution in CCB may be linked to water temperature. Analyses of satellite-derived sea surface temperatures show that the coastal waters in western CCB and areas further north tend to be significantly cooler, by up to 8°C, than nearshore waters in eastern CCB. The higher temperatures in the eastern bay likely allow the persistence of *Chthamalus* populations, whereas the cooler thermal regime in western CCB and further north may favor the cold-adapted and competitively dominant *Semibalanus*.

Limited dispersal of clones and sexually produced larvae in two co-distributed Caribbean sponges

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Sponge dispersal patterns have far-reaching ecological consequences given that sponges serve as hosts to many other species and are key to ecosystem functioning. The extent to which sponge connectivity is driven by the dispersal of sexually produced larvae versus asexually produced fragments remains understudied in most taxa. Here, we disentangled rates of sexual and asexual reproduction in two conspicuous Caribbean sponges, *Aplysina archeri* and *Neofibularia nolitangere*, and inferred their generational dispersal distances. We mapped the locations of hundreds of sponges around the fringing reefs of Curacao and genotyped them at 1,039 (*A. archeri*) and 5,147 (*N. nolitangere*) SNPs using 3D-GBS. Clones were exceptionally rare among sampled individuals in both species, representing <0.03% of all intraspecific pairs. The few clone pairs detected were less than 1 m apart, on average, demonstrating that successful cloning is highly spatially restricted. Considering only unique multilocus genotypes, we detected clear signals of genetic isolation by distance along the island in both species. Indirect dispersal estimates revealed that the mean generational axial dispersal distance is just tens of meters, concordant with the limited movement capacity of species with short-lived, lecithotrophic larvae. Taken together, these results show that sexual reproduction is the predominant reproductive mode, but neither clones nor larvae travel far from their origin. Because many Caribbean reefs are increasingly sponge-dominated, elucidating sponge larval dispersal patterns will be key to predicting future reef dynamics.

Seasonal patterns of larval distribution and connectivity dynamics for *Crassostrea virginica* in Apalachicola Bay, Florida

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The Eastern oyster *Crassostrea virginica* has declined throughout its range, in some cases to the point of total ecological collapse. Numerous restoration efforts using various strategies have been implemented, with mixed success. Important metrics in restoration planning are larval supply and reef connectivity, which depend on larval dispersal patterns among populations. This study used a high-resolution, unstructured mesh Estuarine Coastal Ocean model coupled with an individual based biophysical model to simulate larval growth and mortality. A Lagrangian transport scheme was used to simulate larval transport for two 60-day periods corresponding with peak spawning times. This was also conducted under environmental conditions representing anomalously dry (drought) and anomalously wet (flood) scenarios. Particles were released from areas that correspond with natural oyster reefs and advected until reaching settlement size or random mortality, then evaluated for survival and connectivity metrics. We found distinct changes in larval distribution patterns between the seasonal peak spawns, as well as changes between climate scenarios. The spring spawn showed greater retention over the originating reefs, with low connection between reef complexes more than ~6km distant. Fall larval transport patterns showed increased westward advection, highlighting greater directional connectivity across the study domain. Anomalous climate scenarios showed overall decreases in survival, with a Wet Fall showing the greatest change. These changes in larval supply and connectivity dynamics can be used to inform more effective selection of oyster reef restoration or rehabilitation sites. Further work includes validation of larval supply and suitability modelling for adult oysters to emphasize the importance of incorporating seasonality into restoration planning.

Temporal variation in source-sink dynamics of eastern oysters at the Virginia Coast Reserve

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Metapopulation persistence depends in part on successful dispersal among fragmented habitat patches. For sessile marine organisms, connectivity across habitat mosaics is mediated by larval dispersal during a pelagic phase. Temporal variation in reproductive output, spawning phenology, and hydrodynamic conditions can generate highly dynamic patterns of recruitment and connectivity, yet the consequences of this variability for source-sink dynamics remain poorly quantified in natural metapopulations. Here, we integrate long-term monitoring data with a coupled biophysical modeling framework to quantify source-sink dynamics of the eastern oyster (*Crassostrea virginica*) at the Virginia Coastal Reserve Long Term Ecological Research (VCR LTER) site—a network of shallow, tidally forced bays along the US Mid-Atlantic coast. We reconstructed annual variation in oyster larval production across 21 years and 92 reefs using an extensive size-composition dataset and coupled these estimates with hydrodynamic simulations from Delft3D and a biologically informed Lagrangian particle-tracking model to estimate larval connectivity. Model predictions were evaluated using an independent dataset of standardized recruitment estimates collected from a subset of VCR reefs. Our results quantify the magnitude and timescales of variation in oyster source-sink dynamics and identify the relative roles of reproductive and physical processes in shaping connectivity. We conclude by discussing how these dynamics can inform oyster restoration and management, including opportunities to improve the effectiveness of ongoing large-scale restoration efforts within the VCR.

Latitudinal variation in the seasonal cycle mediates population differences in barnacle reproduction phenology and connectivity

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The timing of life history events around reproduction and early development is critical in population dynamics, and it can determine recruitment success, species dispersal, and population connectivity. In ectotherms, phenology is mediated by the nonlinear effects of temperature on physiology and development, meaning that spatiotemporal variation in temperature can exert powerful controls on the timing of local reproduction and recruitment. Here, we examine reproduction phenology (fertilization of embryos, duration of embryonic development during brooding, and larval release) of the intertidal acorn barnacle *Semibalanus balanoides* in 2002–2004 and in 2019–2024 at up to eight sites along a steep temperature gradient in the northwest Atlantic Ocean. At each site and year, we assessed how phenology varied with intertidal temperature, estimated with a hybrid atmosphere–ocean data assimilation model. Although within-site reproduction was delayed due to interannual and decadal fall warming (3.7 days per 1°C), fertilization at all sites in all years still occurred within a 1-month timeframe. In contrast, latitudinal differences in intertidal temperature resulted in substantially different brooding durations (up to 95 days difference) and, by extension, larval release timing (e.g., Dec 18 vs. Apr 4). These different larval release times likely result in regional differences in temperature-mediated larval development, impacting regional connectivity.

Environmental selection across life-history stages and genomic architectures drives adaptive divergence in oyster populations

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Investigating the adaptive divergence of marine populations in highly urbanized estuaries can help us understand the potential for species to persist in highly stressful, heterogeneous environments. For many marine species, like the eastern oyster (*Crassostrea virginica*), the larval stage is the only mode of dispersal, and therefore the only means of gene flow across the seascape. Therefore, the larval stage plays a crucial role in shaping the genomic structure of populations. Because larvae are generally more sensitive to environmental stressors, they can also be important drivers of adaptive divergence in populations. This study used expressed exome capture sequencing, generating capture probes from mRNA of larval oysters exposed to multiple coastal stressors to capture genomic DNA of adult oysters sampled from localities in Narragansett Bay with varying environmental profiles. This approach selectively enriched exon sequences in adult DNA corresponding to genomic regions expressed in larvae during coastal stressor exposure, directly incorporating information about larval stressor response into a seascape genomics framework. We identified environmentally driven signatures of local adaptation corresponding to different genomic regions. Notably, we found unique environmental associations with candidate loci within large inversions in *C. virginica*, supporting the role of inversions in driving adaptive divergence in highly connected systems. In loci putatively under selection in larvae exposed to coastal stressors, we found stressor-specific associations with environmental conditions in Narragansett Bay that aligned with adult candidate loci. This work demonstrates the complex influence of the multivariate environment on adaptation across life stages of oysters.

Genomic data illuminates a disconnect between dispersal and realized connectivity across a major biogeographic boundary in the acorn barnacle *Semibalanus balanoides*

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In many widespread marine species, larval dispersal is necessary but not sufficient to maintain connectivity across populations. New settlers typically experience very high rates of mortality due to selection, priority effects, and other environmental filters that vary over both space and time, ultimately shaping adult populations. Here, we use an abundant, widespread barnacle (*Semibalanus balanoides*) to contrast adult genetic structure with the origin of newly-settled cyprids across the Cape Cod biogeographic boundary in the northwest Atlantic. Settlement was monitored weekly: we used cyprids from the "peak" settlement window at each of three sites in 2021-2023. DNA was extracted from individual adults and cyprids and genotyped with double-digest restriction-site associated DNA sequencing; ultimately, we used 10,130 putatively neutral, unlinked single nucleotide polymorphisms to examine population structure. Genetic structure in adult barnacles showed a clear divide between sites south of Cape Cod and those substantially to the north; the three sites in Cape Cod Bay (immediately north) included a mix of genetic signatures from both sides of Cape Cod. By contrast, cyprids from three locations (north, south, and Cape Cod Bay) predominantly shared the genetic signature of their settlement site, indicating substantial self-recruitment, though this varied by year and included evidence for north-to-south dispersal not reflected in the adult data. Overall, we observed a mismatch between the origin of larval supply during peak settlement and genetic structure in adults surviving longer-term. This suggests that dynamics throughout the extended dispersal and settlement window may be critical to shaping long-term population connectivity.

Does nearshore thermal stratification mediate coupling between larval supply and settlement?

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Determining the relative importance of pre-vs. post-settlement processes in structuring benthic marine populations is a fundamental goal in marine ecology and requires understanding the relationship between larval supply and settlement. In southern California (USA) nearshore waters (within 1 km from shore), thermal stratification constrains larvae of the acorn barnacle, *Chthamalus fissus*, with higher late-stage larval abundance closer to shore when waters are stratified. Here, we tested the hypothesis that thermal stratification proximity to the shore mediates the coupling between offshore larval development areas and rocky intertidal habitats by altering the 'zone of larval accumulation,' a region offshore the surfzone where waters are well mixed (unstratified). The hypothesis was tested with combined high-resolution measurements of temperature and currents with vertically-resolved sampling of barnacle larval distributions along a cross-shore transect extending from 4-12 m water depth in La Jolla, California, USA. We also calculated thermal stratification to identify the zone of larval accumulation. Larval supply was calculated as the density of late-stage barnacle larvae in the zone of accumulation, and we quantified daily settlement using plates deployed in rocky intertidal habitats. Thermal stratification varied with depth, with the shallowest stations consistently less stratified than deeper, offshore stations. We observed a significant positive relationship between larval abundance in the zone of larval accumulation and settlement, with the strength of this relationship increasing with stratification. Our results support the fundamental importance of biological and physical nearshore processes in influencing larval transport to intertidal adult habitats.

Late summer distribution and abundance of larval snow crab (*Chionoecetes opilio*) and pelagic crab communities in the U.S. Pacific Arctic Gateway

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Juvenile snow crab (*Chionoecetes opilio*) are known to prefer relatively cold (<2°C) bottom waters in the Pacific Arctic. It is unknown if larval stages share this cold-water preference that may impact the timing of egg hatch and pelagic larval duration and dispersal. This multi-year study is an assessment of late summer pelagic snow crab and larval communities relative to environmental conditions in the northern Bering and Chukchi Seas in Alaska (USA). Interannual variability in the distribution and composition of larval crab communities was relatively low and largely driven by the timing of the survey and water mass location. Snow crab was the most abundant and widely distributed taxon and all stages were associated with colder bottom waters. A higher proportion of advanced developmental stages occurred in warmer years (2013 and 2017) compared to the colder year (2012). Species-specific abundances were generally higher in 2012, most notably snow crab and rare blue king crabs (*Paralithodes platypus*) in the Chukchi Sea. Snow crab found on the North Chukchi Shelf were a mix of late-stage zoeae and megalopae presumably from the northern Bering Sea and early-stage zoeae presumably from the Chukchi / Beaufort Slope. We hypothesize cooler conditions with remnant sea-ice and ice-melt waters may promote increased dispersal of slope originating snow crab larvae on to the shallow shelf. The North Bering Sea appears to be an important post-larval settlement area for snow crab and advection from both eastern Bering Sea and western Gulf of Anadyr likely delivers settlers to the Chirikov Basin.

Assessing spatiotemporal patchiness in meroplanktonic assemblages in two high-Arctic fjords

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Marine invertebrates dominate seafloor communities and constitute the vast majority of biomass in polar regions. Fjords are ubiquitous along Arctic coastlines, and factors including glacial melt, sedimentation, and intrusion of oceanic water drive strong environmental and biological gradients in glacially-influenced fjords. These factors cause a diversity gradient of benthic invertebrates along the fjord axis. Unfortunately, little is known about the processes governing early life-history processes of benthic invertebrates and how they might control the observed biodiversity gradients. Filling in this black box is critical for understanding how climate change impacts marine invertebrate communities in the Arctic. Here, we investigated how the distributions of benthic invertebrate larvae vary on temporal and spatial scales within two fjord systems in Svalbard, Norway (Kongsfjorden and Rijpfjorden) using morphological and molecular techniques. We found stark differences in composition and quantity of meroplanktonic larvae among summer and fall sampling, as well as spatial patterns within each fjord, suggesting seasonality and dispersal impact adult communities, and traditional summer sampling is likely vastly underestimating the richness of the meroplanktonic community. By identifying when and where organisms disperse, we begin to identify the role meroplankton plays in setting up adult communities and diversity gradients.

Did the established fauna know? Abundance of hydrothermal vent larvae peaked prior to two cycles of volcanic eruptions

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Hydrothermal vents on the East Pacific Rise near 9°N host a unique fauna that is found only at vents. These sites are disturbed by eruptions every 15-20 years, which destroy large portions of the existing animal communities, even though venting may continue. Since many of the animals have limited mobility as adults, they must recolonize these sites as planktonic larvae. We have used high volume plankton pumps to collect these larvae at 9°N since 1998, including before and after the last two eruptions in 2006 and 2025. We found that the abundance of vent gastropod and polychaete larvae increased more than threefold over the mean of the previous five years two months prior to the 2025 eruption and remained high nine months after. Looking back to the previous eruption, we found a similar pattern of an abundance spike a year before the eruption, compared to the previous eight years, and high numbers nine months after, followed by a drop off over the next year. In both cases, the richness of species and morphotypes also increased dramatically around the time of the eruptions. Using the larval data and observations of vent habitat and benthic communities, we evaluate possible explanations, including environmental triggers for spawning, enhanced production by local sources, and subsidized supply by remote populations. We believe that the most likely explanation is that there is increased production of larvae by local populations, triggered by physical or chemical changes in vent fluids.

Life history strategies of marine wood boring invertebrates are shaped by an energy rich but dispersed and transient niche

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Marine wood borers excavate tunnels that protect them from predators, and certain isopod and amphipod crustaceans, plus bivalves of the families Teredinidae and Xylophagaidae, derive nourishment from the wood. Wood tends to be widely but sparsely scattered in the sea and tunnelling eventually causes wood disintegration. The borers have diverse life history strategies that enable them to disperse and maintain connectivity despite their transient and dispersed niche. Some bivalve borers are broadcast spawners of large numbers of small eggs that develop into larvae with a long planktonic phase, intromission avoiding sperm dilution is known in one teredinid, others brood larvae to the D veliger stage, which are released for a shorter planktotrophic period before settlement. Others brood larvae until the settlement-ready pediveliger stage. Many xylophagaids have dwarf males that attach to the much larger females and their larval dispersal period may be much longer than that of shallow water teredinids. Wood borers of the isopod Limnoriidae and the amphipod Cheluridae brood a small number of embryos and have no larval phase. Juveniles are retained within the parental tunnel and may form side tunnels when capable of boring. Adults can disperse by swimming. All borers may also disperse in floating wood, in some cases crossing oceans in this way. The existence of borer species specialising in wood found in estuarine, mangrove, open ocean flotsam or deep-sea settings indicates use of cues during dispersal, though the cues that stimulate settlement remain to be characterised.

LBS26 ABSTRACTS:
Posters

Discovery of brooding in reef-forming deep-sea coral *Enallopsammia profunda* off the southeastern U.S.

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Scleractinian corals form some of the most important deep-sea habitats, creating complex reef structures that serve as refuge for diverse assemblages of marine species. Despite the importance of these reefs, little is known about their reproduction relative to shallow corals. This study focused on the reproductive biology of the deep-sea coral *Enallopsammia profunda*, which forms bioherms along the western North Atlantic, primarily in the southern region. Coral samples were collected from the southeastern United States over several months in 2009, 2010, 2018, and 2019 and gametogenesis was described using histological techniques and polyp micro-dissection. Our analysis shows that *E. profunda* is gonochoric with a 3:2 female: male sex ratio. Males contained all stages of spermatocysts and females contained multiple stages of oocytes and larvae, suggesting a continuous reproductive cycle. Average oocyte feret diameter was 567.62μm (SD = 415.48μm) and average larval feret diameter was 1263.21μm (SD = 162.24μm). Fecundity was low, with an average of 0.70 larvae/polyp (SD = 0.96). The presence of larvae in female polyps indicates this species has internal fertilization and embryogenesis. This is only the second known instance of brooding seen in reef-forming deep-sea Scleractinia. Brooding species generally produce fewer larger larvae with shorter lifespans than broadcast spawners, which produce many small planktonic larvae. Most other deep-sea reef-forming corals reproduce through broadcast spawning and have much broader distributions than *E. profunda*. Understanding their reproductive strategy can provide insights into the complex factors that influence deep-sea coral distributions and ecosystem resilience.

Born in the Abyss Outreach and Education

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Born in the Abyss is a giant screen movie that takes the audience on an expedition to study the larvae of deep-sea animals. Using the famous Alvin submersible, teams including college students visit the deep ocean in the Atlantic, the tropical Pacific, and the Gulf of Mexico to investigate how nearly invisible larvae renew and sustain life in some of the most extreme conditions on the planet. The film highlights an adventure of exploration and sends the message that collaborative high-tech science is within the reach of dedicated students. In addition to the movie itself, our team has developed online resources for viewers to extend their exploration. This additional content includes a Larval Quest activity that invites participants to become larval biologists and search for microscopic babies. The larvae are “hidden” around the center showing the movie, in a school, or any other room, as printable wall tiles. Once a larva is found, the quest leads participants to different pages on the website via QR codes, where they learn the basics of larval biology and about twelve larval forms found in the deep sea. The website also includes personal stories from scientists, engineers, sub pilots, and others who, together, conduct expeditions that enable the discovery of deep-sea animals and their ecology. Larval art and K-12 lesson plans, designed with consideration of the Next Generation Science Standards and Ocean Literacy Principles, are also featured on the *Born in the Abyss* website as additional resources to help viewers learn more about larvae.

Implications of parental size and specific environmental scenarios on the reproduction and larval development of *Mytilus galloprovincialis*

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Mussel seed scarcity has become a widespread concern along the European Atlantic coast, particularly affecting aquaculture in NW Spain. Climate-driven factors such as rising seawater temperatures and irregular upwelling events are likely contributing to this issue. Additionally, recent reductions in commercial size standards have shortened harvesting cycles, potentially limiting mussel seed production. Together, these factors may be reducing the reproductive capacity of *Mytilus galloprovincialis*.

To investigate this, early-stage reproductive performance was assessed during the spring spawning season. Adult mussels were collected from two contrasting environments—an outer, exposed site and an inner, sheltered site—and categorized into three size classes: small, medium, and large. Spawning was induced under controlled conditions, and reproductive success was monitored from fertilization to the 72-hour D-larval stage.

Preliminary results show that female size strongly influences oocyte production, with larger individuals consistently producing more oocytes regardless of origin. However, origin also plays a significant role: mussels from the exposed site yielded higher oocyte numbers than those from the sheltered site. This suggests that both population size structure and environmental conditions affect overall gamete availability.

Conversion rates to D larvae differed between sites. Larger females from the exposed site exhibited the highest success rates, while those from the sheltered site showed more variability, possibly reflecting environmental stress affecting gamete quality. These findings highlight the importance of considering both environmental origin and broodstock size when evaluating reproductive resilience under changing climatic and management conditions.

Life history consequences of asexual reproduction by sea star larvae (Echinodermata: Asteroidea)

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The distributions of teleplanic ("far wandering") larvae studied by Rudi Scheltema and later Mary Rice indicated that larvae of gastropods and sipunculans could survive transatlantic dispersal. The life history benefits afforded to benthic invertebrates that produce teleplanic larvae have largely focused on the consequences of prolonged dispersal made possible through an apparent delayed metamorphosis. Supported initially by funding to Craig Young and Kevin Eckelbarger, we have studied larvae of sea stars from the tropical and subtropical western Atlantic Ocean that reproduce asexually. Because of their wide distribution and abundance in oceanic currents, these larvae are also potentially teleplanic. This hypothesis is supported by results of DNA barcoding studies that have assigned the two prevalent cloning larvae to adult taxa (*Valvaster striatus* and *Mithrodia clavigera*) that are primarily known from the Indo-Pacific Ocean. The number of copies and the dispersal of the genomes of cloning larvae is increased by the production of new individuals through asexual reproduction. As attractive as hypotheses of the functional benefits of larval cloning might be, there are many unknowns about this unusual life history strategy. Among these are (1) what and where are the source adult populations of the clonal larvae?, (2) do populations of clonal larvae persist without significant recruitment of sexually produced individuals?, and (3) what functional properties of cloning larvae promote their persistence in oceanic waters? Answers to these could provide insights into our understanding of life history evolution, long distance dispersal and speciation of benthic invertebrates.

Brittle stars in the plankton: Descriptions of larvae and developing juveniles of the northeastern Pacific Ocean, with a key for their identification

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We describe 19 species of ophiuroid larvae from the southern coast of Oregon, showing a broad range of planktonic forms including feeding ophioplutei, reduced plutei, vitellaria, and pelagic direct developers. We report molecular, developmental, morphological data for identifying the planktonic stages of brittle stars from the northeastern Pacific Ocean.

We identified embryos, larvae, and juveniles from plankton using mitochondrial COI and 16S compared with public databases and our own adult ophiuroid sequences. The 19 species include many types of development: 11 planktotrophic ophioplutei from four families, from the genera *Ophiothrix* (1 sp.), *Ophiopholis* (2 spp.), *Amphiodia* (2 spp.), *Amphipholis* (1 sp.), *Ophiacantha* (1 sp.), *Ophiopteris* (1 sp.), *Ophiocten* (1 sp.), and *Ophiura* (2 spp.); eight species with abbreviated development, including four reduced plutei from *Amphiodia* (3 spp.) and *Ophiura*, a vitellaria from *Amphioplus*, and three pelagic direct developers from *Amphiodia*, *Amphiura*, and *Gorgonocephalus*. Using identifications made by barcoding, we describe morphological characters useful for the identification of each species. We include descriptions, photos, and a key for the identification of ophiuroid plutei, nonfeeding larvae, and planktonic juveniles. In addition, we report plankton collection records that show brittle stars in the region spawn primarily in winter months (January–March).

Larval performance under stress: Impacts of changing climate, pollution, and multiple stressors

Can you take the heat? Dropping embryos, larval death, and shooting blanks in response to heat shock in the spot shrimp (*Pandalus platyceros*), a harvested Alaskan species

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High latitude regions are experiencing temperature increases at double the global average, imperiling some of the most productive fisheries in the world. Several Alaskan stocks are experiencing declines, and even periodic crashes, due to direct and indirect effects of increasing environmental variability.

The spot shrimp (*Pandalus platyceros*) is the target of shrimp pot fisheries in Southeast Alaska (SEAK) and Prince William Sound and is a favored species for sport and subsistence harvest. This fishery has been experiencing a decline since the 1990s, forcing closures and changes to the guideline harvest levels set by Alaska Department of Fish and Game (ADFG). Life history information on spot shrimp in SEAK is limited, hampering the state's ability to track and respond to population-level changes that impact management. Spot shrimp are protandric hermaphrodites with a complex life cycle, but life history parameters such as lifespan, number of female reproductive seasons, and the effects of rising temperatures on growth and reproduction remain unknown for this region.

Here we report preliminary lab observations of spot shrimp reproduction that will be used in size-structure models for fisheries management. In collaboration with ADFG, shrimp collected from SEAK were kept in the wet lab from September 2025 to August 2026 and observed for size, sex, fecundity, and larval hatching. We opportunistically documented the effects of heat shock, which included the premature release of unhatched embryos and larval death, a partial recovery by a week later, and possible female cessation of next year's brood two months post heat shock.

Larval thermal tolerance and sensitivity of the intertidal gastropod *Nucella ostrina*

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Increasing temperatures alter metabolic rates of marine larvae, accelerating their development and reducing the size and performance of juveniles. This study investigates the thermal tolerance and range of early life history stages of the intertidal gastropod *Nucella ostrina*, which has encapsulated larval development and crawl-away juveniles. *N. ostrina* is an important predator that helps maintain biodiversity on rocky shorelines of the NE Pacific by regulating barnacle and mussel populations. This work will produce an ecologically relevant thermal performance curve, investigating inflection points and thermal limits that can be used to predict species distributions and population dynamics. We are rearing *N. ostrina* egg capsules from individual mothers distributed across a 9℃ to 17℃ temperature gradient and measuring time to hatching, number of hatchlings per capsule, and hatchling size. We will also use these hatchlings to examine the effects of temperature on other key fitness traits like shell calcification, susceptibility to crushing predators, and post-hatching survival and growth. Preliminary results of rearing experiments have revealed fine-scale thermal sensitivity. Larvae reared at 14.5-16.0℃ hatched in 60-65 days, those reared at 13.5-12.5℃ hatched in 68-74 days, and a capsule reared at 12℃ has hatched after 92 days. We also found evidence for upper long-term thermal limits between 15℃ and 17℃. The results of this study will inform predictions of *N. ostrina* population dynamics and be used in future modeling approaches to understanding predator-prey dynamics in warming environments.

Interannual Variation in Larval Lobster Phenology and Environmental Drivers in the Gulf of Maine

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The reproductive cycle and early life stages of the American lobster (*Homarus americanus*) are seasonally regulated processes influenced by both intrinsic and extrinsic factors, particularly temperature, that affect the timing and duration of egg extrusion, hatching, larval development, and settlement. Long-term time-series data from a New Hampshire monitoring program in the southern Gulf of Maine has shown that earlier larval hatching is associated with increasing spring bottom temperatures. This suggests that climate-driven shifts in phenology may alter recruitment patterns and impact the effectiveness of existing monitoring programs that track population dynamics. Missing key phenological transitions or changes in larval phase timing and duration schedules could lead to inaccurate assessments of population abundance estimates and recruitment potential. Since 2018, the Maine Department of Marine Resources Larval Lobster Survey has monitored four fixed stations near Boothbay Harbor, generating an eight-year time series of larval lobster abundance and concurrent environmental conditions. This study is characterizing seasonal larval phenology across the time series by quantifying annual timing of first appearance, peak abundance, season end, and season duration across larval stages. Additionally, the study is evaluating the influence of environmental and ecological variables, including temperature, seasonal transition dates, salinity, zooplankton abundance, and convergence zones on larval density and phenological timing within and among years. A primary product of this study is to identify ecological indicators that may predict early, average, or late onset of the larval season. These indicators could improve survey efficiency and help optimize personnel and financial resources for long-term larval monitoring efforts.

Unraveling settlement, metamorphosis, and recruitment: From basic understanding to aquaculture

Settlement of the Atlantic surfclam (*Spisula solidissima*) in New Jersey state waters from the 1970s through the 2010s

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The Atlantic surfclam (*Spisula solidissima*) is a commercially important bivalve in the Northwest Atlantic Ocean that disperses in the water column as larvae before settling to the benthos. Post-settlement surfclams have been monitored annually in state waters from the 1970s through the 2010s by the Rutgers University Haskin Shellfish Research Laboratory (HSRL) and the New Jersey Department of Environmental Protection (NJDEP). This study examines the changes in the settlement timing of the juvenile surfclam recruits using benthic grabs from the annual HSRL and NJDEP state surfclam surveys that lasted from 1972 to 2019. The number of juvenile surfclams caught in benthic grab samples varied over time and space; however, the number of juveniles caught on average declined from the 1970s to the 2010s. An age in days for individually measured surfclams was calculated by dividing the size measurements of post-settlement juvenile surfclams (<30 mm) by an average growth rate (0.037 mm/day). Individual ages were subtracted from the collection dates of each juvenile for each sampling year to estimate a settlement date. The mode(s) of the settlement dates were calculated for each year that settlement was estimated. These modes showed distinct spring and fall settlement timing for different years, with most years having one settlement season and 6 years having two settlement seasons (1 spring and 1 fall). Oceanographic conditions such as sea surface and bottom temperature may reveal information about settlement throughout this time series. This work highlights the use of long-term studies to reveal settlement patterns in the field.

Species-specific optimization of light spectra for post-settlement grow-out of Caribbean reef-building corals

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The land-based sexual propagation of reef-building corals for restoration remains to be fully optimized, particularly the grow-out phase. This study optimized the post-settlement survival and growth (up to 7 months old) of the Caribbean reef building corals *Colpophyllia natans*, *Pseudodiploria strigosa* and *Montastraea cavernosa* under three light spectra: (1) near-surface sunlight, typical in outdoor grow-out tanks; (2) reef-mimic (using LED aquarium fixtures to replicate wavelengths at 10 m depth); (3) blue-shifted (using LED aquarium fixtures peaking between 400-450 nm). The study was conducted concurrently at four *ex situ* nurseries using the same larval cohorts. All treatments started at 25 μmol photons m^{-2} s^{-1} and experienced equal gradual increases until reaching 200 μmol photons m^{-2} s^{-1} on day 133. The light spectra tested yielded comparable survival, but artificial lighting promoted higher growth than the near-surface sunlight spectrum. There were species-specific differences in optimal light spectrum: *C. natans* grew up to two times larger under the reef-mimic spectrum, *M. cavernosa* grew up to five times larger under the blue-shifted spectrum, and *P. strigosa* performed equally well under both the blue-shifted and reef-mimic spectra, being up to 0.3-0.4 times larger than the ones reared under the near-surface light spectrum. For all species, corals reared under the near-surface spectrum reached full pigmentation at a later age than the artificial light. The species-specific differences in light spectrum did not seem to be explained by algal symbionts. This study suggests that the optimal light spectrum is species-specific and can be manipulated to maximize growth.

Larval biology and culture of marine invertebrates: insights for conservation and aquaculture in Hong Kong

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Many local wild populations of commercially and ecologically important invertebrates in Hong Kong are severely depleted. Species such as pearl oysters, Babylon snails, tiger cowries, and horse conch snails, which were historically found in local subtropical waters of Hong Kong, are now sparsely distributed, with few records in marine biodiversity surveys. The decline of these populations can be attributed to historical overfishing, coastal reclamation, and decades of marine pollution that have devastated their natural habitats. Exploring their larval biology and culture offers a promising opportunity to develop and enhance aquaculture management and conservation efforts in Hong Kong. This study investigates the reproductive and developmental processes of these species, focusing on their early life stages, which are critical for successful cultivation and sustainability. By understanding the specific requirements for larval growth and survival, culture techniques can be optimised to support local aquaculture industries while also contributing to the conservation of these species and the restoration of marine ecosystems. Additionally, this research highlights the potential for these invertebrates to serve as indicators of environmental health, thereby helping to inform conservation strategies. The findings also underscore the importance of integrating scientific knowledge with community engagement to promote sustainable practices that benefit both local farmers and the broader ecological landscape of Hong Kong.

To Sequence or Sort? Comparing eDNA Metabarcoding with Traditional Sampling Methods for the Detection of Hydrothermal Vent Larvae

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Hydrothermal vents host some of the most unique biological communities in the world's oceans, almost entirely reliant on chemically enriched fluids commonly driven by submarine volcanism. These communities are characterized by high biomass, low biodiversity, and long-term stability. However, occasionally submarine eruptions, such as the one observed in 2022 at the Hunga Submarine Volcano off the coast of the Kingdom of Tonga, provide a rare opportunity to observe the resilience of hydrothermal ecosystems to disturbance. Numerous studies have examined both the immediate and long-term impacts of submarine eruptions on benthic communities; however, few have sought to characterize the potential impacts on local zooplankton communities and associated larval populations around hydrothermal systems, despite their importance as both a food source, component of the biological pump, and as a source of new recruits for vent ecosystems . This project aims to answer three primary questions: 1) Are there significant differences in the zooplankton communities around hydrothermal vents in the Lau-Back Arc Basin at sites heavily impacted by ashfall from the 2022 Hunga eruption and those unimpacted by ashfall?, 2) Are there significant changes in the zooplankton communities moving away from vents in the vertical/horizontal? and 3) Are eDNA-based methods effective at characterizing zooplankton communities in the deep ocean compared to traditional methods such as plankton tows? Answers to these questions will help inform the resilience of hydrothermal systems to disturbance, which is critical in an age when human presence in the deep ocean is increasingly common. In addition, this study will help establish the efficacy of eDNA-based sampling for the study of Metazoan communities, which may provide a superior approach (both in terms of time and resources) for monitoring biological communities in the deep ocean.

The state of larval Scombridae identification in the North Atlantic

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The Scombridae family is a group of highly migratory fish species (tunas and mackerels) that garner a lot of international interest. Abundance and distribution patterns of the egg and larval stages of several of these species are used in fisheries management, and there is extreme political, commercial, and scientific interest in these data. Further, many of these highly migratory species are found over a wide range (for example, bluefin tuna range the entire North Atlantic from Canada to the Gulf of America to the Mediterranean). While parts of the larval stages of all North Atlantic scombrids have been described, these descriptions are incomplete and sometimes misleading. Comparisons of larval morphology across their wide range is rarely described. And, similarities among species can make confident identification difficult to achieve. However, morphological identification is still the most practical and cost-effective way to collect species-level data. We are collecting images and physical specimens of larvae from all species of Scombridae that occur in the North Atlantic, from all regions of their spawning range, and at all larval stages for morphological comparison and description. A subset of morphological identifications for each species will be verified through genetic identification. The final result of this project will be a comprehensive guide to the Scombridae of the North Atlantic.

Corals Across Habitats: Understanding coral survival in non-reef habitats in Turneffe Atoll Marine Reserve, Belize

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Climate change, coastal development, and emerging diseases are causing global declines in reef corals, disrupting ecological functions, and reducing ecosystem services. But many generalist reef corals are thriving in non-reef habitats such as mangroves and seagrass lagoons. Because these habitats often present harsher environmental conditions compared to reefs (e.g., high and variable temperatures, low light levels), they may serve as resilience reservoirs. We studied the Mustard Hill coral, *Porites astreoides*, a generalist “weedy” coral that plays a crucial role in maintaining benthic coral cover throughout the Caribbean. On Turneffe Atoll, Belize, *P. astreoides* is distributed across coral reefs, seagrass meadows, and the mangrove epibiont community. To elucidate whether these populations are locally adapted or acclimating to variable environments, we conducted a reciprocal transplant experiment across Turneffe Atoll’s mangrove-lagoon-reef mosaic. Preliminary evidence suggests that corals perform differently in each environment, exhibiting variation in survival, growth, and morphology. This implies different acclimatory capacities of populations across these systems, with the natal habitat strongly impacting their acclimatory responses across the seascape. Since *P. astreoides* is a brooder that purportedly vertically transmits microbes to its larvae, our next step is to explore how microbiomes vary across habitats. Taken together, these data will provide insight into whether non-reef corals could eventually rescue reef populations as environmental conditions continue to change. Our next steps are to explore fine-scale patterns of connectivity and characterize spatial variation in microbiomes across habitat types.

There’s no place like home: effects of adult crab, salinity, and habitat cues on molting of fiddler crab megalopae

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Three species of fiddler crabs co-occur in North Carolina: *Leptuca pugilator*, *Minuca pugnax*, and *Minuca minax*. Larvae of all species export as zoeae to coastal waters and reinvade estuaries as megalopae; they occupy different but sometimes overlapping habitats as adults. Previous studies indicated that some degree of selective settlement is involved in this habitat separation. However, these studies were conducted using laboratory-reared animals because megalopae of these species are morphologically identical. Molecular tools now allow us to identify individuals to species, so studies of behavior and physiology of field-caught megalopae are possible. We examined molting of field-caught megalopae in response to chemical cues from adult crabs of each species in multiple estuarine salinities, and cues from sand and marsh habitats at ocean salinity. *L. pugilator* megalopae molted in response to cues from all three species at all test salinities, and many molted without any cues. *M. pugnax* molting increased in response to odors of conspecifics and to a lesser degree *L. pugilator*; this difference was strongest at low salinity. Most of the very few *M. minax* that molted in the experiments did so in conspecific odor. Cues from sand and marsh habitats also appear to stimulate molting in these species. Because some of these results differ from those obtained using lab-reared larvae, fully understanding settlement site selection in these species will require further studies using field-caught megalopae.

Exploring the energetic value of Northeast U.S. shelf zooplankton: preservation effects and the roles of community composition and environment

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As prey for organisms ranging from larval fish to baleen whales, mesozooplankton communities are a key intermediate trophic link in ocean food webs. NEFSC's Ecosystem Monitoring Survey (EcoMon) is one of the longest-running surveys of the Northeast U.S. shelf, but there has been little exploration into the energetic quality of zooplankton samples collected on this survey. We used mixed-species EcoMon samples to investigate two questions: how preservation affects estimation of energy density, and how community composition and environment explain energy variation. Samples were split to compare proximate-composition energy density of dried (reference), frozen, and formalin-preserved samples. Frozen samples did not differ significantly from dried, however formalin samples differed in all biochemical components and overall energy density. Linear regression was used to propose a correction for energy density of formalin-preserved bulk samples. When comparing community biomass and energy, we found that high energy density matters, but high biomass can still drive high localized water-column energy. Though total community abundance was a poor predictor of water-column energy density, abundance of specific lipid-rich taxa tracked it closely (*Calanus finmarchicus*). Variance partitioning attributed most explained variation in energy density to composition and environmental conditions jointly, with composition also contributing significantly on its own, consistent with environment influencing energy through its effect on zooplankton composition. Further analyses will model relationships between specific environmental conditions and key taxa to better resolve their relationship with community energy. This work establishes a foundation for incorporating zooplankton quality, not just abundance, into assessments using EcoMon data.

Ichthyoplanktonic vertical distribution and ingress in the Aransas Pass Inlet System

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Desalination plants have been proposed as a solution to water usage problems for coastal communities. However, briny discharge from these plants creates plumes of water with higher salinities and temperatures which may have adverse effects on marine communities if discharged into critical areas that act as bottlenecks for fish recruitment (e.g., estuarine inlets). This study examined the vertical distribution of larval fish in the Aransas Pass Inlet, near the vicinity of a proposed desalination plant. The goal was to assess how environmental conditions (season, tides, day or night) influenced transport of larvae through the Inlet system and evaluate potential exposure risks to brine effluent. Several multivariate analyses were conducted to compare the relationship between larval density and these environmental variables. Analysis of the GLS model showed larval densities were greatest in the deepest stratum and at night. While an RDA found September, October, November, outgoing tide, night hours, surface depths to be significantly ($P > 0.001$, $P > 0.01$) correlated with changes in larval density. Currently there are no specific regulations addressing desalination plant discharge, but the results presented here suggest those regulations should limit both the location and timing of discharge to mitigate potential negative impacts on local ichthyofauna.

Using real-world data to inform larval dispersal modelling for invasive species management

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Most animals living in the ocean have a relatively sessile benthic adult phase and a dispersive pelagic larval phase. The larval dispersal phase is highly influenced by both physical (e.g., current velocities and directions, temperature) and biological (e.g., behavior, survival) factors. For benthic marine invasive species, larval dispersal plays a critical role in shaping their distribution, posing significant challenges for effective management. For instance, each female of the invasive European green crab (EGC, *Carcinus maenas*) releases upwards of 185,000 eggs twice a year which are then transported by ocean currents as larvae. On the West Coast of the United States, controlling the invasion of this species is a high priority due to their impacts on marine ecosystems. EGCs prey on small invertebrates that support valuable fisheries and their foraging behavior has been associated with the degradation of eelgrass habitat. We predict the spread of the invasive EGC in the Salish Sea, Washington, using a larval dispersal model that couples a model of hydrodynamic circulation with an individual-based model of ichthyoplankton dynamics. Preliminary model results highlight distinct larval distribution patterns of EGC within the Salish Sea due to its unique circulation. From these preliminary findings, specific connected areas were identified to inform EGC management. Further, EGC trapping data collected by state agencies, Tribal Nations, and private groups in the area were gathered. These data were used for model comparison and to refine our management recommendations and understand the physical conditions that led to the current status of EGC invasion.

Variation in the dispersal range of deep-sea hydrothermal vent barnacle larvae – possible ecological shift in late larval stages

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Deep-sea hydrothermal vent animals face a changing environment, from natural and anthropogenic disturbances. Most animals associated with hydrothermal vents are endemic to this environment, distributed only in limited locations such as the plate boundaries. Due to upcoming deep-sea mining, many vent animals have been recognized as Endangered on the IUCN Red List. The basic information of their ecologies, including larval dispersal capability and genetic connectivity, are important in identifying and estimating source-sink populations and dynamics – key factors to guide their conservation. This information has not been available for most species, leading to difficulties in shaping conservation strategies in most areas.

In the western Pacific vent fields, barnacles are one of the dominant megafaunas and distributed widely. We focused on two vent barnacles with different distributional ranges, *Ashinkailepas seepiophila* in a limited basins in the northwestern Pacific and *Leucolepas longa* with a trans-equatorial distribution, and compared their genetic connectivity and larval ecology to identify the larval character(s) influencing their dispersal capabilities.

The larval characteristics of the two species are almost comparable until the 4th larval stage, and we were unable to rear the larvae of *L. longa* beyond this stage due to limitations in the field. No clear genetic subdivision was found among the local populations in each species when analyzing their mtCOI sequences, however the regional metapopulations were not genetically homogeneous. Differences in later larval stages may be the key in determining their dispersal and distributional ranges, and further experiments to obtain the larval characteristics in the later stages are required.

More adept at depth? Larval vertical positioning interacts with cross-shelf circulation to shape biogeographic patterns along the West Coast of North America

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In regions with strong vertically structured circulation, small differences in larval vertical position can produce large differences in dispersal, even for species with similar pelagic larval durations (PLDs). In upwelling regions, larvae in the surface Ekman layer are rapidly transported offshore, whereas larvae at greater depths may be advected onshore within subsurface return flow. These depth-dependent transport pathways can generate strong differences in offshore larval loss and coastal recruitment among organisms with different vertical behaviors. Because the strength of cross-shelf transport and the depth of the return flow can vary significantly alongshore, the larval behaviors that maximize coastal return also vary spatially, potentially creating sharp biogeographic transitions.

We used a modeling approach to examine how this alongshore variation in cross-shelf flow can interact with larval vertical behavior to establish range boundaries in coastal species with obligate planktonic dispersal. We simulate idealized larval vertical behavior within and below the surface Ekman layer using circulation fields from a high-resolution global circulation model. Resulting connectivity patterns were used to parameterize dispersal in a simple two-species population model to identify where depth-dependent dispersal differences may translate into range limits. We compare results to observed biogeographic boundaries and species occurrence data, and find that spatial varying, depth-driven differences in larval return to the coast strongly influence the location of biogeographic boundaries along the west coast of North America. We suggest that this mechanism is likely to be a general driver of biogeographic zonation in coastal upwelling systems worldwide.

Model effects of phenologic shift in spawning on larval dispersal of the mud snail *Ilyanassa trivittata*

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Climate change may affect larval dispersal through phenological shift of spawning times. I am studying the possible effects by using a previously run ROMSPath dispersal model. I will analyze model data reflective of three release conditions in the Northwest Atlantic Ocean: modern temperatures (2015), projected warming due to climate change, and cooler past conditions. The ROMSPath model used tracked particles with behaviors representative of larval gastropod *Ilyanassa trivittata* in addition to neutrally buoyant passive particles. These snails spawn in the spring when temperatures reach 8 degrees centigrade. The model generated particles in the mid-Atlantic bight from multiple static cross-shore transects when water temperature first reached 8 degrees for normal conditions, 6 degrees for projected warming, and 10 degrees to imitate estimates of cooler waters in the mid-20th century. I am investigating whether the difference in time of release has a significant impact on dispersal and the nature of the effects. Based on shifting ranges of benthic invertebrates, larvae are likely to be carried southward and shoreward into warmer waters due to stronger alongshore currents earlier in the year.

Population structure and genetic diversity of the European sea lemon (*Archidoris pseudoargus*), an invader in the northwest Atlantic

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Biological invasions due to anthropogenic activity are of growing concern globally and remain understudied in marine systems. In 2017, the European sea lemon (*Archidoris pseudoargus*) was noted in Massachusetts and has since been found at multiple localities from Connecticut to Nova Scotia. It is hypothesized to have been transported to North America in ballast tanks during its pelagic larval phase. Single gene studies suggested that the invasion originated in northern Europe, but the data lacked resolution to confidently determine the provenance. Here, we used genomic data from individuals across the native and non-native ranges to 1) elucidate the origin of *A. pseudoargus* in its non-native range and 2) investigate population structure and genetic diversity across the full species' range. We uncovered two populations, albeit with weak structure, concordant with expectations for a species with pelagic larval dispersal and limited swimming capabilities. One population was comprised of individuals from Scandinavia and North America, and a second was comprised of individuals from the UK and Ireland. Our results indicate that Scandinavia is the likely origin of the invasion. Genetic diversity estimates were similar within regions, but slightly higher in the non-native range, indicating high larval propagule pressure and/or multiple invasion sources. Together, this research characterizes a recent marine invasion facilitated by an invertebrate larval phase and contributes to our current understanding of Atlantic invasion pathways.

Behind the capsule wall: proboscis development in lecithotrophic larvae of *Admete viridula* (Gastropoda: Neogastropoda) from the White Sea

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The study is focused on comparative morphological analysis of larval stages and foregut development in the lecithotrophic member of the Cancellariidae – *Admete viridula*. A starting point was provided by several hypotheses concerning this family, which belongs to the order Neogastropoda, a group of predatory gastropods known for their remarkable proboscis that enables successful hunting. In most Cancellariidae, feeding type is unknown; several genera (including *Admete*) lack a radula, raising questions about their hunting strategy and the potential for complete radula loss during embryogenesis. Using *A. viridula* collected below the thermocline as a model, we describe proboscis development to test whether its formation is shaped by developmental mode and differs between planktotrophic and lecithotrophic larvae. Live observations (2.5 months, cold-water aquaria) were combined with SEM, TEM, and semithin sections for 3D reconstructions to examine morphology across all stages.

Development of *A. viridula* includes eight intracapsular stages up to the juvenile and lasts approximately 3 months. Embryos rely entirely on yolk throughout; adelphophagy is absent. The earliest stages are vulnerable, but the early veliger is active and resilient. No radula was found at any developmental stage. However, heterochrony is evident in the formation of the jaw – a modified chitinous structure that in cancellariids is thought to participate in feeding. In *Admete*, the jaw consists of a chitinous layer lining the buccal cavity that continues to grow the whole life through microvillar secretion. Remarkably, proboscis formation follows the same mechanism as in planktotrophic neogastropods, regardless of developmental mode or complexity.

Hybridization chain reaction *in situ* revealed novel data on neurogenesis in phoronid *Phoronopsis harmeri*

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Phoronids (Phoronida) are marine animals, which nervous system undergoes great transformation during life cycle: pelagic larva possesses well-developed nerve centre, the apical organ, whereas the adult nervous system is transformed into a diffuse intraepidermal plexus. The replacement of the larval nerve center to the definitive nerve plexus arises question which type of the nervous system organization is primary for bilaterians. Here we provide the first molecular and ultrastructural description of larval and metamorphic neurogenesis in phoronid *Phoronopsis harmeri*. We applied *in situ* hybridization chain reaction (HCR) and mapped the expression of three evolutionarily conserved neuronal markers: PhaNgn, PhaElav, and PhaSyt1. The ultrastructure of the identified neural elements was examined by transmission electron microscopy. Postmitotic neuroblasts and mature neurons labelled by PhaElav and PhaSyt1 are distributed throughout the larval body. We describe several previously unknown larval neural elements: dorso-lateral clusters of perikarya at the base of the preoral lobe, peritoneal perikarya and neurites in tentacles, intertentacular groups of perikarya, and paired PhaElav-positive cords running within the coelomic lining of the metasomal sac. At all examined stages, marker-positive cells remain within the epithelial layer, indicating that, in contrast to other spiralians, phoronids lack stage of migratory neuroblast. From early larval stages to metamorphosis, neural progenitors that expressed PhaNgn are detected only in four discrete domains, which probably correspond to the elements of central nervous system of other bilaterians. The study is supported by RNF (23-14-0020-P).

Constructing a dynamic energy budget model for the larvae of the Pacific Sand Dollar

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In response to food availability, larvae of the sand dollar *Dendraster excentricus* exhibit morphological and physiological plasticity, yet no mechanistic model exists to describe the underlying energy dynamics. Dynamic Energy Budget (DEB) theory provides a unifying framework for comparing metabolic strategies across species by representing shared processes with species-specific values. The DEB framework can be used for *D. excentricus* to create a holistic view of the diverging strategies between low- and high-fed larvae, answering questions about the relationship between food availability, structure as a reverse energy source, and metamorphic competency. The first aim is to gather data for a robust model. To model protein biomass growth rates as a function of food availability, measurements are taken across a range of feeding levels. To quantify structural reabsorption under starvation, measurements for the change in rudiment, post-oral arm length, and midline body length are taken. The second aim is to incorporate published data with new data to create a DEB model. Preliminary results for aim one show that a well-developed rudiment does not shrink under starvation, but that the larval body (eg. Midline body length and post-oral arms) does overall. Initially, post-oral arms increase in length, consistent with a response to a low-fed environment, before shrinking below their length pre-starvation. This dynamic response will feed into the first DEB model for *D. excentricus* larvae, providing a realistic and mechanistic framework linking food availability to larval physiological state and development, establishing a foundation for integrating independent data.

Assessing the efficacy and biochemical underpinnings of reversible phenotypic plasticity in larvae of the Pacific sand dollar, *Dendraster excentricus*

Troy Stern (California State University, Long Beach)
Douglas Pace (California State University, Long Beach)

My research focuses on phenotypic plasticity during planktotrophic larval development of echinoid echinoderms. These larvae feed on unicellular algae using ciliary bands on their larval arms. Larvae are known to change the length of their arms in response to food availability: high food concentrations result in shorter arms, while low food concentrations result in longer arms. In particular, I study larvae of the sand dollar *Dendraster excentricus*. They can induce the short arm phenotype throughout larval development when switched from low to high food conditions. My current research has 2 goals. The first is to evaluate if this response can be reversed (i.e., switching from short arms to long arms) when larvae are switched from high to low food concentrations. By switching larvae from high to low food conditions at 4, 8, and 12 days post-fertilization, I will determine if there is a discrete critical window when morphological remodeling is possible. The second goal is to determine what biochemical reserves (i.e., protein and/or lipid) are used to fuel the rapid arm growth that occurs upon switching larvae to low food conditions. Although there are numerous studies confirming food-induced plastic responses in marine invertebrates, most of them focus on changes which occur during or before the development of feeding ability. My research expands on this by focusing on the occurrence of plastic responses in larvae in variable feeding conditions after the attainment of feeding ability. Additionally, my research will define the biochemical energetic reserves that fuel such important morphological remodeling.

Evolutionary transitions in modes of larval development associated with terrestrial invasions in the gastropod family Ellobiidae

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Invasion of the land by aquatic animals is one of the most remarkable transitions in the history of life. While many marine invertebrates possess a pelagic larval phase, successful colonization of land often requires its abbreviation or loss, especially for taxa with low adult mobility. The gastropod family Ellobiidae provides an excellent system for investigating the evolutionary shifts in developmental modes associated with terrestrialization because it includes both marine and fully terrestrial lineages. Among the five recognized subfamilies of Ellobiidae, all species of the subfamily Carychiinae and several in the genus Pythia (Pythiinae) are fully terrestrial and are thought to have independently colonized the land.

To explore the relative timing of the ontogenetic transition and succeeding terrestrialization, we reconstructed molecular phylogenetic trees covering all subfamilies and habitat types in Ellobiidae. New observations of eggs, hatchlings, and protoconchs (pre-metamorphic shells) were obtained for nine species representing seven genera and four subfamilies. All eight marine species exhibit pelagic larval development, including seven planktotrophic and one lecithotrophic species, whereas the single terrestrial species examined exhibits direct development. Population genetic analyses revealed distinct degrees of genetic differentiation and hence dispersal capability, even among the planktotrophic species. Mapping newly obtained and existing ontogenetic traits and estimated dispersal capabilities on the ellobiid phylogeny suggests successive transitions from ancestral, long-lived planktotrophs to short-lived planktotrophs or lecithotrophs, and finally to direct development. Independent terrestrial invasions in Carychiinae and Pythia appear to have followed the acquisition of direct development, suggesting that ontogenetic transitions paved the way for terrestrial invasion.

Changes in Gulf of Maine ichthyoplankton community composition and abundance between 2009-2014 and 2019-2022

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Ichthyoplankton represent the larval forms of fish species present in an ecosystem. Despite their importance as population indicators of spawning productivity and recruitment, ichthyoplankton have been poorly monitored in the Gulf of Maine (GOM). This limits understanding of how major system changes have affected development schedules and abundance as conditions have undergone regime shifts. This study analyzed a previously unpublished long-term ichthyoplankton dataset collected using bongo nets at the Central Maine Time Series (CMTS) station, located eight kilometers offshore of the Damariscotta River Estuary in mid-coast Maine, USA. The study aim was to compare the ichthyoplankton community composition between 2009-2014 and 2019-2022. These two time periods represent distinct thermal regimes in the GOM. Annual and monthly comparisons revealed shifts in the number of species present and overall abundance. During the first time period, the most abundant species were *Sebastes fasciatus* (Atlantic Redfish), followed by *Enchelyopus cimbrius* (Four-Beard Rockling), *Tautogolabrus adspersus* (Cunner), and *Clupea harengus* (Atlantic Herring). The second time period saw a shift, with *T. adspersus* being the most abundant species, followed closely by *Ulvaria subfurcata* (Radiated Shanny), *E. cimbrius*, and *Merluccius bilinearis* (Silver Hake). *Clupea harengus* and *S. fasciatus*, species of regional economic value, saw a significant decrease in abundance between the earlier and later time periods, while *M. bilinearis*, another species of regional economic value, saw a significant increase of 2,614% in seasonal abundance. Continued monitoring is needed to characterize ongoing population changes as the ecosystem continues to experience rapid change.

Eat, Prey, Land: early life ontogeny of age-0 Bristol Bay red king crab (*Paralithodes camtschaticus*) from pelagic to benthic habitats

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Recruitment limitation has been hypothesized as the cause of the continued decline of Bristol Bay red king crab in the southeastern Bering Sea (Alaska, USA). An early life bottleneck in survival may be occurring during vulnerable pelagic and early benthic phases. Successful source-sink dynamics for age-0 red king crabs requires favorable currents and environmental conditions to deliver healthy larvae to sea floor nursery habitats with adequate food and shelter. We conducted field surveys in 2024 and 2025 across Bristol Bay to capture and enumerate age-0 crabs and assess potential source-sink areas and habitats for larval recruits. Spring zooplankton net tows, seasonal post-larval collectors, and benthic sampling utilizing a towed camera sled (Alaska CamSled) were utilized across three depth strata (20, 50, and 70 m). We compared stage-specific catch indices and conducted spatial regression to assess crab response to habitat covariates including temperature, salinity, and benthic substrate type. Spring, early-stage larvae cluster in cooler waters within central Bristol Bay (50 – 70 m depths) and overlap with spawning adults. By mid-summer, recently settled crabs overwhelmingly occur in nearshore collectors (< 50 m, and presumably in underlaying habitats). We hypothesize that offshore larval delivery to nearshore settlement habitats is an important source of successful recruits due to prevailing north and easterly currents toward complex shallow substrates (i.e., large gravel, cobble, shell habitat) that settlers are known to prefer. This information will be useful to stock managers by informing area closures and other habitat protections to increase juvenile red king crab survival.