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## Background

### The Benefits of Paid Undergraduate Ecological Research

- Ecological literacy is critical for making informed decisions ranging from what flowers to plant in one's backyard to how to best tackle global climate change (Jordan et al. 2009).
- Ecological literacy differs among socio-demographic groups, and may be particularly lacking among adults who grew up in urban communities (Pitman et al. 2018).
- Undergraduate research, particularly starting as college freshmen or sophomores (Jones et al. 2010, Thiry et al. 2012), improves students' critical thinking abilities and their interpretation of scientific knowledge (Thiry et al. 2011).
- Undergraduate research experiences require significant time, but are often unpaid, and so can exclude lower income or otherwise financially burdened students (Fournier and Bond 2015).
- Underrepresented minorities in life sciences may disproportionately benefit from a paid undergraduate ecological research internship (Hansen et al. 2018, Emery et al. 2019), and in an urban community college, even students who do not pursue an ecology-related career will improve their abilities to "think and work like scientists" (Seymour et al. 2004).

### Massasoit STEM Research Internship Program Goals

- Support the development of resilience, personal responsibility, and critical-thinking skills among diverse community college STEM students to improve their chances for success upon transfers to higher degree programs or careers.
- Conduct publication-quality, contemporary ecological research not only to further our collective understanding of the natural world, but also as a means to improve scientific literacy among students in an urban community college.
- Through rigorous data collection and literature review, allow students to organically develop an appreciation for the complexity of ecosystems and the integral role humans play in them.

## Methods

### Paid Research Internship Personnel Structure

- Up to 20 high-performing students recruited from science, math, and engineering academic programs are paid to work 10 h/wk during spring and fall semesters and up to 30 h/wk over the summer.
- One full-time STEM Program Manager oversees the Research Internship.
- Part-time faculty and/or staff serve as laboratory supervisors, mentors, and direct reports for student interns.
- Full-time faculty mentors can be paid hourly to contribute expertise as they are available, particularly in summer.
- Alumni from the program (typically enrolled at a 4-yr transfer school) may return over the summer to train interns and ensure continuity in methods for data collection.

### Research Framework

- We provide student interns with a conceptual framework (Fig. 1) within which they generate independent lines of inquiry.
- This encourages scientific creativity and establishes inherent ownership and personal responsibility of each student for their specific aspect of the larger study (Emery et al. 2019).
- As we amass related conclusions from students' individual projects, we ask interns to synthesize results and try to communicate the more comprehensive findings in oral presentations.

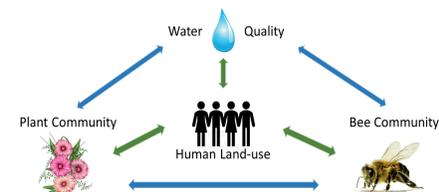


Fig. 1 The conceptual framework for ecological inquiry we have developed with the help of prior student interns. As students gain experience in our research internship, they are encouraged to individually develop testable hypotheses that focus on some impact of human land-use on markers of ecological integrity.

### Journal Club

- College science professors often report that reading and interpreting primary scientific literature is among the most important skills for undergraduates to develop (Coil et al. 2010).
- However, these skills take a great deal of time and practice to develop (Kershaw et al. 2018), and professors have difficulty incorporating primary literature into introductory biology courses (Coil et al. 2010).
- As a mandatory part of our research internship program, students select primary scientific research articles related to their inquiries, read and interpret them with the help of peers and mentors, and lead discussions of salient points with peers and faculty.
- In this way, students not only gain the benefits of guided early exposure to scientific literature (Sandefur and Gordy 2016), but also help to keep our methods in-line with published standards.
- After transferring and experiencing upper-level undergraduate biology courses, alumni to our intern program often report that their experience in journal club was the most helpful preparation they received.

### Our Current Research: Land-use and Bees

- Within the broad framework of our research (Fig. 1), our current work focuses on three nested aspects of the interplay of land-use, the bee community, and the plant community. We are investigating...
  - ...the effects of land-use deemed as 'sustainable' on bee community structure in urban and suburban settings.
  - ...the relationship of the plant community (as nesting habitat or foraging resources) to the bee community across differing land-uses.
  - ...development of a genetic barcoding technique capable of quantitatively defining the foraging resources of various bee species based on pollen collected from bees or their nests.

### Scientific Rigor and Professional Integrity

- Student interns are *not* given specific testable hypotheses, they must generate them (Linn et al. 2015).
- Primary literature must justify any method or rationale interns employ.
- Our bee community sampling represents a powerful long-term database we make accessible to interested professionals; we plan to publish results in the future.
- Interns can and have been dismissed for underperforming or not adhering to professional standards of conduct.

# Ecological research promotes critical-thinking, science literacy, and data-driven eco-centrism among diverse STEM student-interns at a community college

## Results

### Student-driven Method Development and Data Collection

- Currently in our fourth year of quantitative bee community sampling with consistent, student-developed methods
  - 7,867 individual bees identified to genus (Fig. 2)**
  - 40 species identified and recorded that were not previously known to inhabit southeastern Massachusetts**
- As senior interns train new interns, long-term monitoring will continue
- Students have developed and continue to test quantitative plant sampling protocols for future long-term monitoring
- Advancing DNA metabarcoding techniques for identification of pollen carried or provisioned by bees
  - Successful pollen identification confirmed (proof of concept)
  - Quantitative and qualitative metabarcoding methods currently under development by mentor-guided interns

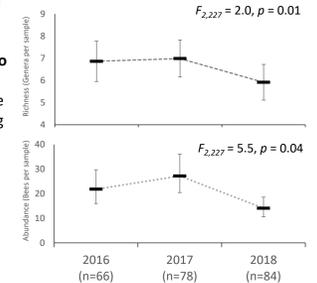


Fig. 2 Summary of intern-collected bee community data for southeastern Massachusetts. Genera richness and total abundance vary over years (ANOVA,  $\alpha = 0.05$ ; 95% confidence intervals shown).

### Scientific Communication Fosters

#### True Scientific Literacy

Table 1. Summary of academic presentations given by Massasoit student-interns since 2015. The Massasoit STEMposium is an annual college event in which interns present past and current posters followed by a platform presentation for invited faculty and guests.

Year	Venue	Platform Presentations	Poster Presentations	No. Students Participating
2015	Massasoit STEMposium	1	7	7
2016	Massasoit STEMposium	1	8	8
	ESA Baltimore, MD	-	1	3
2017	Massasoit STEMposium	1	7	12
	BSU* Symposium on Sust. & Env.	-	6	6
2018	BSU* Symposium on Sust. & Env.	1	5	10
	ESA New Orleans, LA	-	6	6
2019	Massasoit STEMposium	1	8	12
	ESA Louisville, KY	1	7	8

\*Bridgewater State University, MA



Fig. 3 Ten student-interns and a mentor (far left) at Bridgewater State University's Annual (2018) Symposium on Sustainability and the Environment.

### Community Engagement: Ecological Data Goes Public

- On average, Massasoit interns organize four local community outreach presentations or activities per year.
- Examples include:
  - Hands-on activities with elementary through high-school students
  - Educational talks for local community garden clubs or senior centers
  - Updates on our research to administrators and our college Board of Trustees
- No one delivers messages of environmental stewardship with more enthusiasm and hope than students.



Fig. 4 Interns interacting with the public at a local library (above) and an elementary school (right).

### Organic Inclusivity

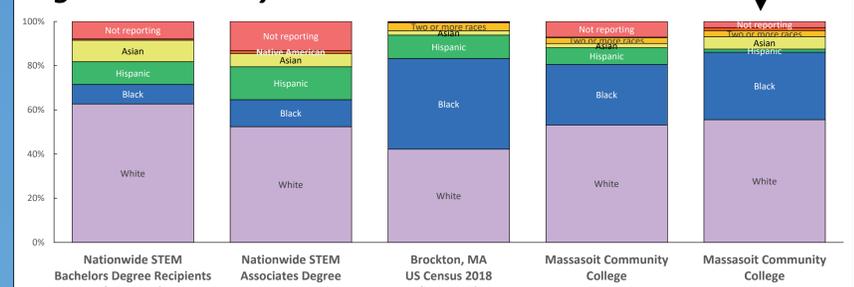


Fig. 5 Racial and ethnic distributions for Massasoit student-interns since 2015 (far right) and for other selected comparator groups.

### Transfer Success and Merit-Based Scholarships

- 56% of Massasoit interns who transferred in a STEM major to 4-year colleges report conducting scientific research in their chosen field as juniors or seniors; 12% report plans to join a research lab.
- Many intern alumni report about the benefits of journal club: "Students may not like it now, but eventually they will appreciate it." -Qiao Li
- The overall message from intern program alumni is that high-standards, focused advising, and real research experience, equate to increased confidence and a professional work ethic.

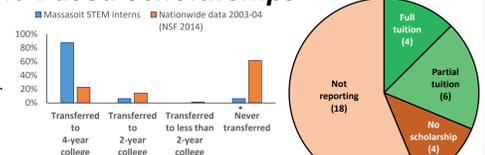


Fig. 7 Self-reported merit-based academic scholarship data for Massasoit intern alumni (n=32).



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