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Mechanisms by Which Marine Algae Respond to Environmental Variables Affecting Reproductive Success

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Final Report for Period: 02/1997 - 01/2001**Submitted on:** 01/25/2001**Principal Investigator:** Brawley, Susan H.**Award ID:** 9604848**Organization:** University of Maine

Mechanisms by Which Marine Algae Respond to Environmental Variables Affecting Reproductive Success

Project Participants**Senior Personnel****Name:** Brawley, Susan**Worked for more than 160 Hours:** Yes**Contribution to Project:**

I have done half of all of the bench work performed on the project (cryoanalytical work, Bryopsis experiments, construction of molecular probes) as well as designing most of the experiments.

Post-doc**Name:** Speransky, Vladislav**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Dr. Speransky worked on the cryoanalytical studies of K and Cl distribution during gamete release in the fucoid receptacle.

Graduate Student**Name:** Berndt, Mary**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Lynn did her M.S. on objective 3, involving studying estuarine and open-coastal gamete concentrations, polyspermy, and fertilization success. She formulated the first environmental model for reproduction on the Maine coast by these seaweeds using 1982-2000 data

Name: Gordon, Richard**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Rick has been conducting studies under Objective 2; he will finish his M.S. in August, 2001, having tested most of the proposed species and an additional two for responses of reproductive phases (sporophytes and gametophytes) to water motion.

Undergraduate Student**Name:** Black, Christine**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Hansen, Sarah**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** McDougall, Jessie**Worked for more than 160 Hours:** Yes**Contribution to Project:****Name:** Crachan, Heidi**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Organizational Partners

University of Birmingham

Brawley spent a sabbatical here and made monoclonal antibodies needed for project with help of Prof. James Callow's research technician

Carleton University

Brawley and Dr. Speransky used the cryoanalytical SEM at Carleton for the EDX work.

Other Collaborators or Contacts

Activities and Findings

Project Activities and Findings:

1. EDX studies of the fucoid receptacle to study K and Cl distribution during potentiation and gamete release.
2. Studies of gamete release from *Fucus vesiculosus* at Pemaquid Point and the Narraguagus estuary with monoclonal antibodies and immunofluorescence to evaluate fertilization success and polyspermy and time of gamete release during the tidal cycle.
3. Studies of gamete release under calm and turbulent conditions in *Bryopsis*, *Ulva*, *Alaria*, *Dictyota*, *Porphyra* and *Palmaria*.
4. Studies of freezing damage and repair in receptacles of *Fucus vesiculosus*.
5. Model for gamete release by *F. vesiculosus* on Maine shore from 1982-2000 relative to environmental conditions affecting physiological requirements for gamete release.
6. Yearly presentation of abstracts by my laboratory at the Phycological Society of America and 2x at the American Society for Cell Biology meetings.

Project Training and Development:

1. The fucoid receptacle undergoes massive, rapid oscillations of K and Cl efflux into the ECM and reaccumulation by cells during gamete release; less massive fluxes occur during potentiation, but are not found throughout the receptacle.
2. K and Cl distribution vary longitudinally along the receptacle, but are the same between cells and extracellular matrix at any transverse plane.
3. The ECM expands between in the collar between the oogonium and its stalk cell just before the oogonium pops off the stalk cell.
4. Gamete release by *F. vesiculosus* at Pemaquid Point and in the Narraguagus estuary occurs about 2-2.5 h after algae are covered by the incoming tide; this is confined to a period of about 30 min of the ca. 6 h high tide. Gamete release occurs only during calmer high tides on sunny days or calm portions (Narraguagus estuary) of the tidal cycle. All fertilization occurs shortly after gamete release although gametes/zygotes remain in the water column for most of the rest of the tidal cycle (probably due to resuspension).
5. A model based upon 1982-2000 data shows that September is the best month for fucoid reproduction due to it having the most calm, sunny days, on average. Many spring tide series lack even one day appropriate for gamete release; low tide release of gametes and/or hybridization by aged gametes are predictions of this finding.
6. Gamete release is higher under calm versus turbulent conditions in *Bryopsis*, a green alga.
7. Spore release is higher under turbulent conditions in the kelp *Alaria*; gamete release is being tested now.
8. Water motion does not appear to affect the magnitude of gamete release in the red alga *Porphyra* (spermatia) or in the green alga *Ulva*.
9. Freezing damage to *Fucus* receptacles destroys the ECM of the medulla but this recovers in spring and the receptacles begin to release gametes again in late April-May, before undergoing an event that appears to be apoptosis when the new receptacles emerge.

Research Training:

Dr. Speransky learned cryoanalytical electron microscopy and improved his writing skills in English. Ms. Speransky learned English and learned about algal reproduction. Ms. Berndt built equipment to collect gametes in the field, organized a major field project and directed 4 undergraduate helpers (multi-tasking skills), learned immunofluorescence techniques, DNA isolation, and improved her writing and oral presentation skills. She won the Robert Wilce Award for best student oral presentation at the Northeast Algal Society meeting in 2000 based upon this work. Mr. Gordon has learned much about algal reproduction and become skilled at experimental design and microscopic analysis. The undergraduates who worked on this project have learned molecular biology, experimental design, microscopic techniques, etc. and benefited greatly from contacts with graduate students and my postdoctoral associate.

Outreach Activities:

I have presented this research in a simple way in K-12 as lectures and as demonstrations to students. Part of this occurred in the context of my role as P.I. for the University of Maine's NSF GK-12 Teaching Fellows' project.

Journal Publications

- G. Pearson, E. Serrao, S. H. Brawley, "Control of gamete release in fucoid algae: sensing hydrodynamic conditions via carbon acquisition", *Ecology*, p. 1725, vol. 79, (1998).) Published
- V. Speransky, S. Speransky, S. H. Brawley, "Cryoanalytical studies of freezing damage and recovery in *Fucus vesiculosus* (Phaeophyceae)", *Journal of Phycology*, p. 1264, vol. 35, (1999).) Published
- S. H. Brawley, L. E. Johnson, G. A. Pearson, V. Speransky, R. Li, E. Serrao, "Gamete release at low tide in fucoid algae: Maladaptive or advantageous?", *American Zoologist*, p. 218, vol. 39, (1999).) Published
- S. Speransky, S. Brawley, W. Halteman, "Gamete release is increased by calm conditions in the coenocytic green alga *Bryopsis* (Chlorophyta)", *Journal of Phycology*, p. 730, vol. 36, (2000).) Published
- M. L. Berndt, J. A. Callow, S. H. Brawley, "When are sperm limiting in the sea?", *Marine Ecology Progress Series*, p. , vol. , (.) Submitted
- V. V. Speransky, S. H. Brawley, M. E. McCully, "Ion fluxes and modification of the extracellular matrix during gamete release", *Journal of Phycology*, p. , vol. , (.) Submitted

Books or Other One-time Publications

Web/Internet Sites

URL(s):

Description:

Other Specific Products

Contributions

Contributions within Discipline:

After 100 years of conjecture, I have sustained Oltmann's hypothesis for turgor changes in the receptacle being responsible for gamete release in fucoids. Our findings, however, put this original hypothesis in a modern context of ion fluxes and greatly extend data on the receptacle, showing that it is exquisitely engineered for signalling. The results demonstrate a much larger role for the extracellular matrix in gamete release than earlier hypothesized.

This work has demonstrated that release of propagules across algal taxa can be stimulated, inhibited, or not affected by water motion. Thus, the complexity of the response has been defined.

A major concern of marine ecologists is whether sperm competition or limitation occurs at fertilization. The work completed here is the first direct work in any system of a 'broadcast spawner' to define gamete concentrations and sperm:egg ratios during natural fertilization. This demonstrates conclusively that sperm do not limit fertilization in *Fucus vesiculosus*, one of the most abundant organisms in the northern Atlantic intertidal zone. We have developed a novel model for how environmental conditions have affected the frequency of gamete release on a daily basis from 1982-2000. This will give rise to many new ideas about foodweb interactions in September and early October due to massive gamete release and zygote production by fucoids. We have explained why gametes are sometimes released at high tide and at other times at low tide, a controversial subject for a century.

Contributions to Other Disciplines:

My own 'discipline' is very broad! My results contribute to the idea that genetic isolation along the coast is common due to topographic-oceanographic interactions causing fucoids to reproduce at different times on different sides of a point and to hybridize when seaweeds can not release gametes at high tide for at least 14 d due to stormy coastal conditions. This has important implications for local population isolation and speciation. I am following these implications in my recent award, however.

Contributions to Human Resource Development:

I have trained in science, writing and speaking 4 undergraduates, two undergraduates, a technician, and a postdoctoral fellow. All are still engaged in science in Canada and in the U.S.A.

Contributions to Science and Technology Infrastructure:

I give frequent seminars at the University of Maine on these results, and this has broadened the thinking of many scientists about the capabilities of algae to respond to environmental conditions in ways that humans as animals often have dismissed as a possibility.

Beyond Science and Engineering:

Rockweeds are considered an economic resource in Maine. My reputation for expertise in this area is sought out on State panels for managing this crop; my knowledge that helps guide regulatory ideas is based upon this research.

Categories for which nothing is reported:

Any Book
Any Product