N.H. Sea Grant Research Project Post Completion Report

Today's date: 6/15/12

Project number: AISR-05-094

Project title: Aquatic Invasive Species Research: tracking origins, examining population structure and economic impact of the invasive green alga *Codium fragile* in the Northwest Atlantic.

Project initiation date: Sept. 30, 2007*
* This project was initially funded in June 2005, just as the PI began a two year leave of absence to work with the National Science Foundation. The National Sea Grant Office gave permission to delay the project’s initiation and permit a no-cost extension. Research was not started until the fall of 2007, when the PI returned to University of New Hampshire, recruited and then trained new graduate students.

Project completion date:

Principal investigator: Anita Klein

Affiliation: Department of Biological Sciences, University of New Hampshire

Impacts to date:

The major impacts of this research project are three fold:

1) Scientific:
   a. Continued monitoring of the status of *Codium fragile* populations in the Canadian Maritimes and Gulf of Maine documented significant declines of *C. fragile* in the Northumberland Straits area near Prince Edwards Island, while *C. fragile* populations are either stable or expanding in the Gulf of Maine and Long Island Sound.
   b. Morphological variation was observed for ‘diagnostic’ characters of *C. fragile* subspecies. Statistical analysis suggested that *C. fragile* populations from Long Island Sound differed from more northern *C. fragile* populations. Most plants evaluated to date have chloroplast haplotypes consistent with the *C. fragile* subsp. *fragile* haplotype, which is common to Kochi, Sagami Bay, and Nakagi in Japan, and to invasive populations from the Northeast Atlantic. A second distinctive haplotype of *C. fragile* subsp. *fragile* was identified in Malpeque Bay PEI.

2) Economic: The potential impacts of *C. fragile* to shell-fisheries and urchin harvesting were modeled for the Gulf of Maine. Continued expansion of *C. fragile* would have a multi-million dollar effect on shell-fisheries and urchins in the Gulf of Maine economy.

3) Educational: A website ([www.Codium.unh.edu](http://www.Codium.unh.edu)) and educational materials were developed to inform the public about the ecological and economic impacts of invasive seaweeds, especially *Codium fragile*.
Accomplishments:

1. (Art Mathieson, Anita Klein and graduate students Chris Benton and Lucy Pleticha) During the summer and early fall of 2008, collections of *C. fragile* were made at 24 sites from the Canadian Maritimes south to Long Island Sound. Significant reductions in *C. fragile* populations were noted for the Northumberland Strait area near Prince Edwards Island (C.S. Benton, L. Pleticha pers. comm.), as compared to previous surveys (cf. Mathieson et al. 2003; Rhodora 105:1-53; Garbary and Hubbard 2002, op.cit.). This population decline was confirmed during a follow-up survey by Garbary and Benton during August 2009. However in the summer of 2010, Garbary noted rebounding of *Codium* populations along the shores of PEI (pers. Comm)

2. (Lucy Pleticha, Art Mathieson, and Anita Klein) Over 330 plants were collected. Representative plants from each population were pressed and deposited in the Albion Hodgdon Herbarium (NHA). The swollen terminal portion or utricle of the plant’s thallus was evaluated microscopically. Different subspecies of *C. fragile* are commonly distinguished by morphometric measurements of the utricle: length, width at narrowest point; width at widest point, the length of its pointed tip, the mucron, and presence and size of gametangia (Maggs and Kelly 2007, op.cit.). Utricle attributes were evaluated for each population. While there was significant variation within and between different plant populations, various statistical analyses of utricle features indicated that the plants from the Canadian Maritimes and the Gulf of Maine were more similar to each other, and distinct from plant populations in Long Island Sound. At this time it is unclear whether this subtle phenotypic variation is due to environmental or genetic differences between populations.

3. (Chris Benton, graduate student Renee Eriksen, undergraduate Matt MacKenzie, and Anita Klein) Provan and coworkers (Provan et al. 2005, Molecular Ecol. 14: 189-194; Maggs and Kelly 2007, op. cit.; Provan et al. 2008, op.cit) identified polymorphisms in two chloroplast genes that distinguished *Codium fragile* subspecies (*rps*3-*rpl*16) and/or populations of *C. fragile* subspp. *fragile* (*trnG*). DNAs were extracted from 107 accessions, covering the full geographic range of surveyed sites. The DNAs were split into two tubes and stored at -80°C for additional studies.

A subset of the plants that were evaluated morphologically were screened for their chloroplast haplotype at these two loci. The chloroplast haplotype for the *rps*3-*rpl*16 gene region was determined for 50 individuals representing populations from Nova Scotia Canada to Long Island Sound. All plants had identical haplotypes (GenBank accessions FJ754465-FJ754478), which closely matched the chloroplast haplotype for *C. fragile* subsp. *fragile* (GenBank accession EU045560). A single polymorphism that distinguished NW and NE Atlantic haplotypes, was determined to be a sequencing artefact in Provan and coworkers original studies(Benton and Provan pers. comm.) Sequence analysis revealed a single *trnG* haplotype in the Northwest Atlantic for 26 *Codium* individuals (Figure 3,GenBank accessions GQ274899-GQ274924) spanning the entirety of our study region. This matches the *C. fragile* subsp. *fragile* haplotype from Northeastern Atlantic and Japanese populations from Kochi, Sagami Bay, and Nakagi (Provan et al., 2005, op. cit.). This is the same haplotype of *C. fragile* subsp. *fragile* that is common in Northern Europe.

Recently a second chloroplast haplotype was identified for *C. fragile* collected from PEI in the summer of 2009, and 2010. This haplotype varies by 3 nucleotides (insertion/deletion) compared to the most common chloroplast haplotype found for *C. fragile* subsp. *fragile*. Samples collected in Malpeque Bay have the insertion while samples collected along the southern coast of PEI have the common *C. fragile* subsp. *fragile*. Either
the C. fragile populations from Malpeque Bay represent a new mutation localized to the Canadian Maritimes or they represent a separate introduction of C. fragile subsp. fragile. Although we’ve not observed much genetic variation for the two chloroplast genes in the NW Atlantic, this does not necessarily mean that C. fragile populations in are genetically homogenous. A much earlier study (K. C. Malinowski. Codium fragile- the ecology and population biology of a colonizing species. Yale University. -127+, 1974) screened isozymes from C. fragile populations in Long Island Sound and Boothbay Harbor ME. The populations in Long Island Sound had a single heterozygous genotype while those from Boothbay Harbor had several distinct alleles. Additional genetic evaluations are in progress.

4. (KGC) The potential economic impact of expansion of Codium fragile in the Gulf of Maine was modeled by Assoc. Prof. Cullen. The focus was on shell-fisheries and urchin operations; data on landings and values were obtained from Maine’s Department of Marine Resources, Massachusetts’ Division of Marine Fisheries and the New Hampshire Department of Fish and Game. Impacts included not only direct effects on shellfisheries and urchin but also indirect effects for example to suppliers and induced effects on employees, and regional tax base. The direct effects of further expansion of Codium fragile populations to the Gulf of Maine economy could be as high as $154 million, based on 2007 landing values; combined with indirect effects, the impact could exceed $333 million. See the attached detailed report by Prof. Cullen: Region Economic Impacts of Codium fragile in the Gulf of Maine.

5. Additional ecological and genetic investigations are ongoing; when these studies are complete we will make recommendations to prevent further spreading of Codium; these recommendations will be disseminated as a report to managers of coastal and estuarine reserves.

6. In an effort to engage the public’s help to identify new populations of C. fragile in the NW Atlantic, a web site ([www.Codium.unh.edu](http://www.Codium.unh.edu)) describing this project was launched in May 2008. To date the web site has attracted 62 visits and 204 page views. To enhance contacts with the public, an educational pamphlet modeled on the web site was distributed to NH and ME Fish and Game Departments, Seabrook Science and Nature Center, plus the Great Bay Discovery Center, Pemaquid Watershed Association, and the Casco Bay Estuary Partnership. In 2011 the population data was transferred to VitalSignsme.org. VitalSignsme.org is based in the Gulf of Maine Research Institute; they work with student groups and environmental volunteers to monitor biodiversity and track invasive species. Combining resources with Vital Signs Me organization will improve the tracking of Codium in the Gulf of Maine.

Related grants and contracts (Other grants and contracts that funded this research or that were obtained as a result of this research.):
NH Agricultural Experiment Station H499 2007-2010.

Publications to date received by N.H. Sea Grant:
Additional Publications:

Peer reviewed publications:
Klein, A. ????. *Botanica Marina*. UNHMP-JR-SG-11-11. 12/11 Based on new data, revising manuscript and resubmitting summer 2012

Theses/Dissertations:

Other communications products (non peer-reviewed pubs, manuals, tech reports, videos, etc.):
An educational web site [www.codium.unh.edu](http://www.codium.unh.edu) was launched in May 2008 and similar pamphlet has been distributed to the public. NHU-I-09-001

A technical report on the regional economic impacts of *Codium* has been prepared by Prof. Cullen. The report is attached.

Presentations to date, with published abstract citation if applicable:


3) Joint meeting American Society of Plant Biology and Phycological Society of America July 2009 Molecular and morphological variation in *Codium fragile* in the NW Atlantic Christopher S. Benton, Lucy E. Pleticha, Anita S. Klein, and Arthur C. Mathieson; [P04034](http://www.e-neas.org/NEASabstracts1.html); Plant Biology 2009 Final Program pg.120

Students Supported (see next page)
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<th>Student Name</th>
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<th>Duration of support</th>
<th>Type of support (stipend, travel, supplies, etc.)</th>
<th>Type of degree: Undergrad Master's PhD</th>
<th>Year degree awarded</th>
<th>Title of thesis/dissertation if supported by N.H. Sea Grant</th>
<th>Where is he/she now?</th>
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<tr>
<td>Lucy Pleticha</td>
<td>UNH-Dept. of Plant Biology</td>
<td>Jan – Dec 2008</td>
<td>stipend, travel, supplies</td>
<td>MS</td>
<td>in progress</td>
<td>Morphological variation in <em>Codium fragile</em> in the Northwest Atlantic</td>
<td>continuing student</td>
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<td>Chris Benton</td>
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<td>Renee Eriksen</td>
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<td>Sept. – Dec 2008</td>
<td>partial stipend</td>
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<td>Matt MacKenzie</td>
<td>UNH-Biochemistry and Molecular Biology</td>
<td>July-Dec 2008</td>
<td>part-time salary, supplies</td>
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