Temperature Tolerance of the Kelp *Alaria esculenta*

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INTRODUCTION

The harvest and aquaculture of seaweeds is a multi-billion dollar industry worldwide (FAO 2016). Sea vegetable aquaculture is dependent on a greater diversity of strains that are tolerant to coastal warming attributable to climate change. Market demand and interest in integrated aquaculture offer increased opportunities for development of sea vegetable crops in Maine. This study aims to investigate the temperature tolerance of the edible kelp *Alaria esculenta* (L.) Greville (Laminarales, Phaeophyceae) and to understand its potential as a sea vegetable crop in warming waters.

Strains of *A. esculenta* from Quoddy Head State Park in Lubec, Maine, and Two Lights State Park in Cape Elizabeth, Maine, were isolated and gradually acclimated to 22℃ (Fig. 1). Surviving gametophytes and the corresponding controls were then tested further in an LD_{50} thermal experiment (Exp. 1). Those same gametophytes were also induced for gametogenesis to produce the commercially important sporophyte stage. Resulting sporophytes were grown out and measured (Exp. 2). This work will allow us to determine what the lethal thermal limits of *A. esculenta* seedstocks are and how thermal stress experienced in early life stages may affect crop yield.

We will use information on temperature tolerance to determine the potential of *A. esculenta* as a viable crop in warming waters, providing support to Maine's working waterfront.

Figure 1. Map of gametophyte source locations.

METHODS

Exp. 1) Previously acclimated gametophytes were plated in replicate petris and maintained in a vegetative state. Temperature was increased 2℃/day until 50% of the population died (LD_{50}) or at a 34℃ cut-off. Replicates were monitored daily.

Exp. 2) Previously acclimated gametophytes were sprayed onto spools and grown out at CCAR at 10℃ with a 14:10 L:D cycle. Sporophytes received a modified West-McBride nutrient solution weekly (Andersen, R. A. 2005). After a 3 month grow-out, blades were selected at random to measure blade surface area (ImageJ).

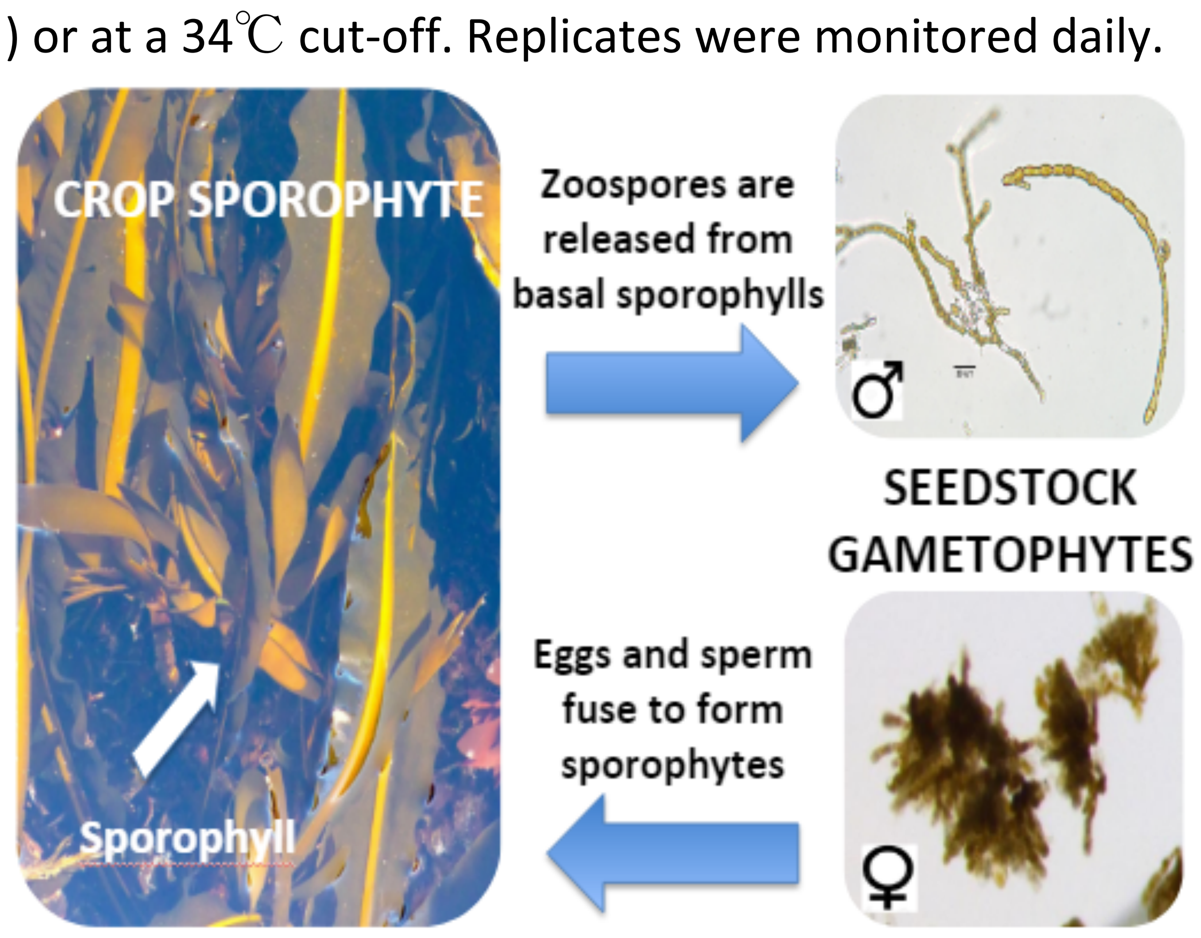

Figure 2. Heteromorphic alteration of generations in *Alaria esculenta*. Both the seedstock gametophyte and the crop sporophyte are critical to kelp aquaculture.

REFERENCES:

1. FAO 2016. *The State of the World Fisheries and Aquaculture 2016*. FAO. Rome.
2. Andersen, R. A.. 2005. *Algal Culturing Techniques*. Elsevier Academic Press.

ACKNOWLEDGEMENTS:
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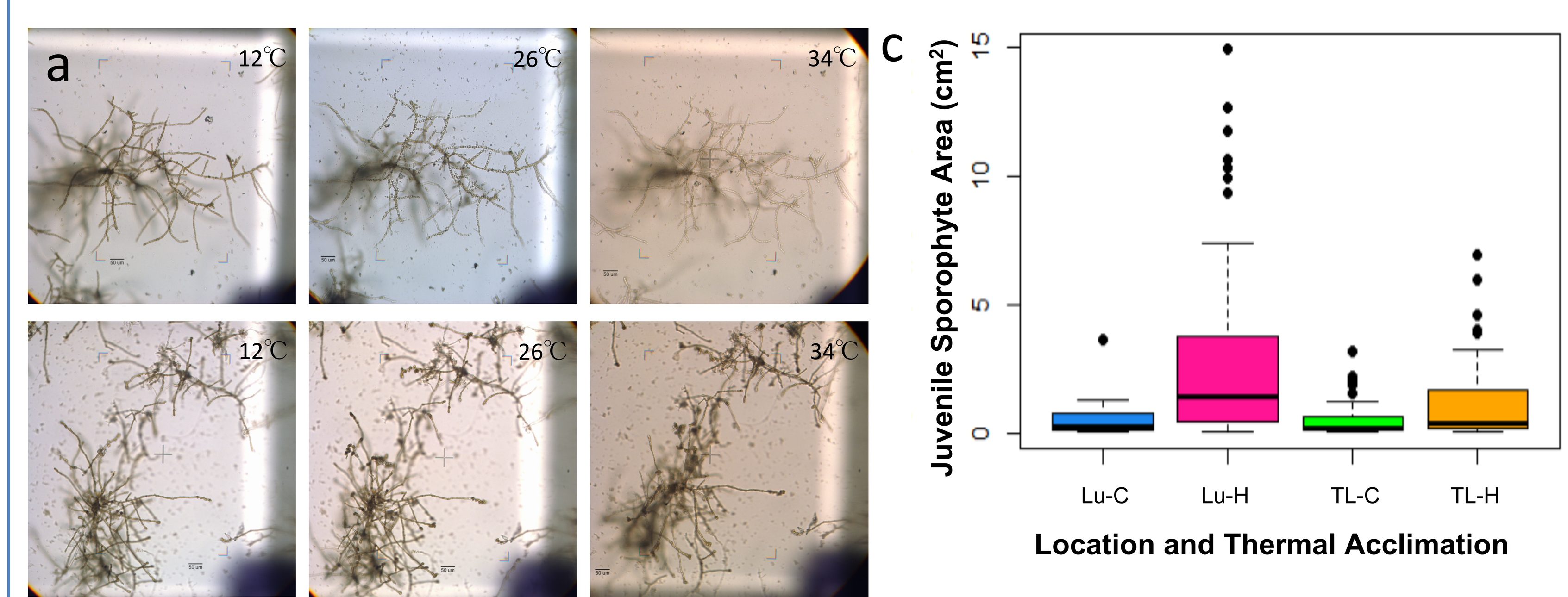
Figure 5. Charlotte Quigley and Margaret Aydlett after collecting at Two Lights State Park in Cape Elizabeth, Maine (left); outplanting *A. esculenta* at a sea farm in Sorrento Bay, Maine (right).

RESULTS

Exp. 1) Individuals from Lubec reached LD_{50} at a lower temperature than individuals from Two Lights. Previously heat- acclimated gametophytes reached LD_{50} at a higher temperature than controls (Fig. 3a and 3b).



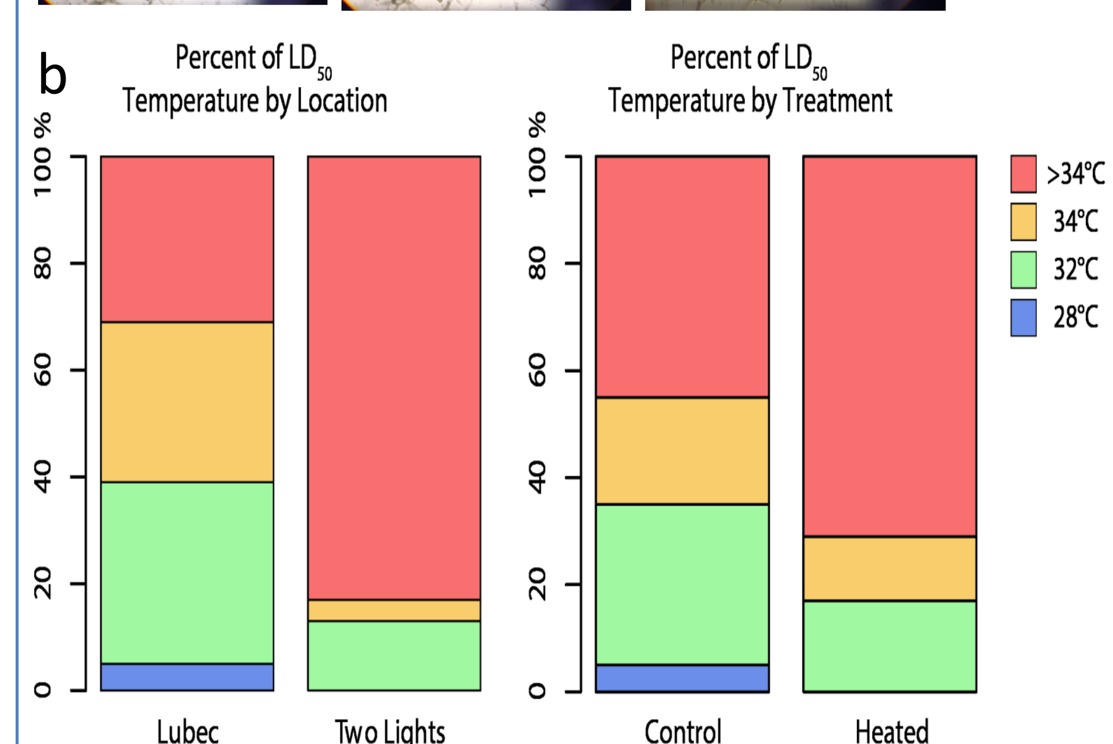


Figure 3a.) Photo sequences showing deterioration of gametophytes from Lubec (top) and Two Lights (bottom) as temperature increased (12℃, 26℃, and 34℃ left to right, scale = 100 μm); b) Stacked bar chart showing the percent of views of LD_{50} temperature by location and thermal acclimation (treatment) on gametophytes; c) sporophyte blade surface area by location and thermal acclimation (C = control, H = heat acclimated, L = Lubec, TL = Two Lights).

Exp. 2) Two-factor ANOVA shows that both location and thermal acclimation have a significant effect on blade surface area on juvenile sporophytes produced from heat-acclimated gametophytes (location: $F(1,49) = 12.7$, $p = 0.00043$, treatment: $F(1,136) = 35.2$, $p = 1 \times 10^{-8}$; R Statistical Software, v. 3.4.1). There is an interaction between factors, but sporophytes from Lubec that were exposed to thermal acclimation grew larger (Fig. 3c).

DISCUSSION

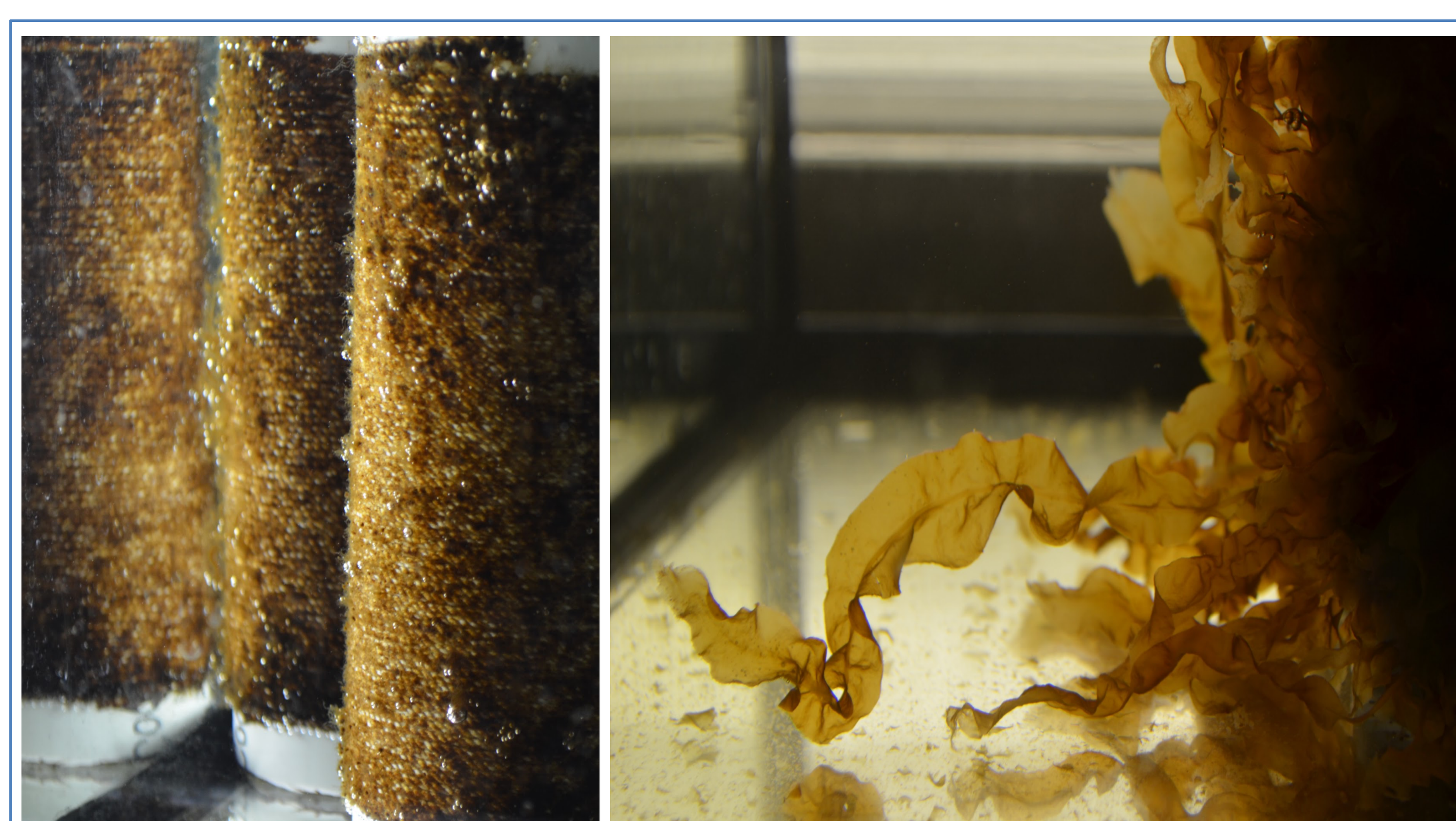


Figure 4. Seeded spools (left) and sporophyte grow-out (right) of *Alaria esculenta* at the University of Maine's Center for Cooperative Aquaculture Research (CCAR).

This research helps us understand the temperature tolerance and lethal limits of *Alaria esculenta* in the Gulf of Maine. The lethal limits of gametophytes appear to differ between sites and be dependent on previous thermal acclimation. Sporophytes derived from the thermally acclimated gametophytes had higher blade surface areas, and those from Lubec had blades up to double the size of their southern counterparts from Two Lights. An important component of sea vegetable aquaculture is crop yield. This research shows that applying our thermal acclimation protocol in the nursery may be able to increase crop yield for farmers; sporophyte grow-out to maturity is being monitored to confirm this. *Alaria esculenta* is an excellent candidate for sea vegetable aquaculture now and in the future.