Integrating Ecology and Education Research to Foster Resilience to Non-native Plant Invasions in Alaska

Katie V. Spellman, Institute of Arctic Biology and Department of Biology and Wildlife, University of Alaska Fairbanks, Fairbanks, Alaska 99775

With the rates of new species introductions and spread of invasive species escalating in Alaska, communities must work rapidly to enhance their capacity to respond to the changes non-native plants could bring to their natural resources and livelihoods. Building this capacity to respond to and shape change, or resilience, requires a multidisciplinary approach. I used ecological research on the impacts of invasive Melilotus albus on native berry resources as a context to conduct education research on the effects that two learning strategies, citizen science and metacognition, could have on social-ecological resilience to non-native plant invasions in Alaska. Using retrospective pre-post surveys, I looked at the impacts participation in a citizen science-monitoring program on the flowering phenology of native berries and M. albus had on the skills, attitudes, social networks and behaviors of the volunteers. I found that volunteers increased the frequency with which they participated in invasive plant control and knowledge-seeking and knowledge-sharing activities, as well as the amount of time they spent observing other changes in nature around them. These effects of citizen science may increase the human and social capital and sense of place required for increased social-ecological resilience. Metacognition, or the ability to reflect upon and regulate one’s own thinking processes, has been proposed as a key cognitive skill in building social-ecological resilience. Using a controlled experiment, I tested the effects of metacognition on the ability of seventh graders to perform complex problem solving on invasive plant issues. I found that structured metacognitive practice enhanced the invasive plant problem-solving ability of most students. These studies suggest that broad-scale education programs that use tools effective at promoting resilience can play an important role in Alaska’s capacity to respond to invasive species.
Integrating ecology and education to build resilience to non-native plant invasions in Alaska

Katie Villano Spellman
Resilience and Adaptation Program
Department of Biology and Wildlife
University of Alaska Fairbanks
What is resilience?

- Capacity to respond and shape change in ways that sustain and develop the fundamental function, structure, identity and feedbacks in a social-ecological system (Chapin et al. 2009)
Overarching Question

How does learning through ecology and education interact to build resilience in the face of accelerating non-native plant invasions in Alaska?

Key learning for tools resilience in my study system:

- Ecological Research
- Citizen Science
- Metacognition
EXTERNAL DRIVERS:
Changes in invasion rates, concern for subsistence resources

Socio-Cultural Template

HUMAN BEHAVIOR
Monitoring, stewardship activities, scientific engagement

HUMAN OUTCOMES
• Social capital (civic engagement, social networks)
• Human capital (understanding, skills, adaptive learning)
• Sense of Place
• Stewardship values
• SES understanding

Bio-Physical Template

ECOSYSTEM STRUCTURE AND FUNCTION
Invasive plants managed in vulnerable areas, Pollinator services intact

PULSES:
Invasive plant identification and control

PRESSES:
Planning processes (vulnerable areas take long-term measures to protect berry habitat)

ECOSYSTEM SERVICES
Supporting (Pollinator services), Provisioning (berries), Cultural (subsistence values)

Adapted from LTER Social-Ecological Research Framework (Collins et al. 2011)
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Metacognition
Citizen science
Ecological Research

Adapted from LTER Social-Ecological Research Framework (Collins et al. 2011)
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**Socio-Cultural Template**

**Bio-Physical Template**

| Adapted from LTER Social-Ecological Research Framework (Collins et al. 2011) | Metropolitan | Citizen science | Ecological Research |
Melibee Citizen Science

2012-2013
- 868 observations
- 106 monitoring sites
- 246 volunteers
Participants
- Ecologists
- K12 educators & youth
- Land managers
- Interested individuals & families
- Alaska Native tribal and traditional councils

Training for Successful Collaboration
- Scientific protocols
- Collaborative problem solving
- Invasive plant ecology & management
- Communication & education approaches

Collaboration Strategies
- High quality email communication between ecologists and volunteers
- Monitoring site visits by ecologists
- Web-based portal to input, share & visualize data
- Team gathering & newsletter

Bestelmeyer, Elser, Spellman et al., in press, Frontiers in Ecology and the Environment
Peak flowering dates (score of 1.1 to 2.9) for focal species in the three ecoregions of Alaska based on two years of citizen science monitoring data (2012-2013). Boxes are average start and end dates from regressions and the whiskers are the earliest and latest observed dates.
Enhancing management planning capacity

- Herbarium-based models for predicting flowering overlap
- Model validation using citizen science data
- Planning tool for concerned communities

\[\begin{align*}
\text{Vaccinium uliginosum} & \quad r = 0.87 \\ n = 262 \\
\text{Melilotus albus} & \quad r = 0.83 \\ n = 91
\end{align*}\]

Predicted Phenophase Score (Herbarium Model)

Observed Phenophase Score (Citizen Science Data)
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Citizen science

Metacognition

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Method for Evaluating Citizen Science Learning

Retrospective pre- / post-survey
- Changes in knowledge and science process skills
- Changes in activity frequency

Written reflections

25 respondents (35 surveys sent out)
- 8 youth
- 17 adults

Box 1
Activities corresponding to different categories of learning outcomes in the Melibee Project volunteer survey. A Likert-scale was used for ranking activity frequency before and after participation in the Melibee Project (6 points: “never,” “once a year,” “a few times per year,” “monthly,” “weekly,” “daily”).

Direct action and prevention
- Pulled invasive plants in your yard or neighborhood
- Attended community weed pull events
- Decided not to plant or buy something because you thought it might be invasive
- Reported invasive plant sightings to land managers or extension agents
- Asked an expert about an unfamiliar plant

Knowledge sharing
- Talked about invasive plants to friends, relatives or acquaintances
- Taught adults or children about invasive plants
- Posted pictures or wrote about invasive plants on social media
- Wrote articles, letters to the editor, listserv emails or creative writing pieces about the issue of invasive plants
- Joined or “liked” environmental or sustainability social media networks

Knowledge and skill seeking
- Attended public lectures on environmental or ecological topics
- Attended courses or workshops on environmental topics
- Participated in other projects where volunteers collect scientific data
- Read magazines, newsletters or online services on environmental issues or ecology
- Volunteered time for an environmental organization or environmental cause

New awareness and curiosity
- Noticed invasive plants around your town
- Noticed invasive plants while travelling away from home
- Paid attention to the changes in plants through the summer
- Paid attention to the changes in animals or fungi through the summer
- Looked up unknown plants in identification books
Learning ecology content and process skills

Figure 2. Learning reported by volunteers who were not engaged in environmental careers that occurred as a result of participation in the Melibee Project phenology monitoring program on key concepts and science process skills on key concepts and science process skills.
Figure 3. Average self-reported activity frequency scores in different outcome categories for volunteers before (pre-) and after (post-) their participation in the Melibee Project Citizen Science Program. Statistical differences between pre- and post- Melibee activity frequency (tested using two-tailed t-tests) is indicated by * (p<0.05).
What did Melibee volunteers like best about the citizen science experience?

**Figure 1.** Word cloud showing frequency of responses to survey question “what did you like best about participating in the Melibee Citizen Science project? The size of the word corresponds with the frequency of the response.
**Socio-Cultural Template**

**Human Behavior**
- Monitoring, stewardship activities, scientific engagement

**Human Outcomes**
- Social capital (civic engagement, social networks)
- Human capital (understanding, skills, adaptive learning)
- Sense of Place
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- SES understanding

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**Bio-Physical Template**

**Ecosystem Services**
- Supporting (Pollinator services), Provisioning (berries), Cultural (subsistence values)

**Ecosystem Structure and Function**
- Invasive plants managed in vulnerable areas, Pollinator services intact

**Presses**
- Planning processes (vulnerable areas take long-term measures to protect berry habitat)

**Pulses**
- Invasive plant identification and control

**External Drivers**
- Changes in invasion rates, concern for subsistence resources

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**Adapted from LTER Social-Ecological Research Framework (Collins et al. 2011)**
Key characteristics of resilient and adaptive thinkers prepared to address climate change issues in social-ecological systems:

<table>
<thead>
<tr>
<th>Thinking Skill</th>
<th>Theoretical Backing</th>
</tr>
</thead>
<tbody>
<tr>
<td>ability to interpret and apply new scientific information</td>
<td>Carpenter 2002, Fazey et al. 2007</td>
</tr>
<tr>
<td>ability to think critically to solve complex problems</td>
<td>Chapin et al. 2010</td>
</tr>
<tr>
<td>ability to envision multiple scenarios and prioritize most probable outcomes</td>
<td>Kofinas 2010</td>
</tr>
<tr>
<td>Ability to view problems within a social-ecological system context</td>
<td>Chapin et al. 2010</td>
</tr>
<tr>
<td>ability to think about future events or future desired ecological states and anticipate the consequences of present actions</td>
<td>Ascher 2009, Tschakert et al. 2010, Tidball &amp; Krasny 2011</td>
</tr>
<tr>
<td>ability to make bold decisions in the face of uncertainty</td>
<td>MEA 2005, Fazey et al. 2007, Chapin et al. 2010</td>
</tr>
</tbody>
</table>

Metacognition may help...
Using Melibee ecological research as a context for learning…

**Research Questions:**

1. Do metacognitive learning interventions improve student metacognitive ability?
2. Do metacognitive learning interventions affect student ability to perform "resilience thinking" tasks?
3. Does the effect of the intervention vary with student ability level?
**Experimental Methods**

- Metacognitive intervention experiment with 108 7th graders (6 weeks)
  - Treatment groups:
    - Inquiry learning
    - Metacognitive inquiry learning

- 3 Standards Based Assessments proficiency levels
  - Advanced, Proficient, Below

- Pre-, Post- and Delayed Post-Assessments:
  - Metacognitive skill survey (Sandi-Urena 2008)
  - Invasive Plant Problem Solving written assessment

- Interviews with 24 students
Change in Invasive Plant Problem Solving Written Assessment Scores

![Bar chart showing the percentage of students improving scores in Inquiry and Metacog categories.]

![Bar chart showing grade level proficiency and treatment for Inquiry and Metacog.]

**Grade Level Proficiency and Treatment**

- Inquiry: Below, Proficient, Advanced
- Metacog: Below, Proficient, Advanced
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How we teach and learn about invasive species are important to our capacity to respond to them in Alaska.

Citizen science and metacognition can be effective learning tools for resilience.

Understanding which learning tools are most efficient in face of rapid invasions is critical.