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# **SCHOODIC ALGAE FINAL REPORT**

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**Final report 1700-0604-NNS**

**Draft for NPS review and comment**

**May 16, 2009**

## **Final Report (1700-0604-NNS) (Draft for NPS review and comment) (May 16, 2009)**

The primary objective of this research was to evaluate the shore biota of the former Navy Base site on Schoodic Peninsula, which is now part of the Schoodic Education and Research Center. This evaluation is required to determine how distinctive the biota of the SERC shore are, relative to other shores in ANP, and to make management recommendations to the NPS based upon our findings. I first summarize the status of the promised deliverables in the contract. Next, I detail the key protocols used in the research. Finally, there is an executive summary of the findings of the research and my recommendations to the NPS.

### **Deliverables (see 1700-06044-NNS):**

1. *The final report will include an executive summary and recommendations for future research/monitoring.*

This final report includes an executive summary and my recommendations for future research/monitoring. The detailed analysis of the data for the SERC shore and the comparative shores at Little Moose Island (Schoodic Peninsula), the Invertebrate Critical Area (Schoodic Peninsula), Otter Point (MDI) and an area NE of the Bass Harbor Lighthouse (MDI) are included in David Olson's M. S. thesis in Marine Biology. These data are summarized here, and several key figures are extracted as part of the final report. The key protocols used in the research are included in this final report; the NPS may wish to apply these in the future for comparative purposes.

2. *The graduate assistant on the project will complete a M.S. at the University of Maine based upon the proposed work.*

Mr. David Olson successfully defended his M.S. in Marine Biology and M.S. in Marine Public Policy at the University on April 21, 2009. The committee asked for some revisions and additions to his draft thesis before its acceptance. These are nearly completed, and we expect him to file ~ June 1, 2009. His graduation date will be August, 2009.

3. *At least one publication will result from the work (e.g., Ecological Applications)....It is likely that high school students can be guided to a publishable study of Grindstone Neck, near ANP.*

Mr. Olson, Dr. Jim Wilson (advisor for the Marine Public Policy M.S.) and I will prepare Olson's thesis materials for publication in the summer and fall of 2009. *Conservation Biology, Ecological Applications, or Marine Ecology Progress Series* will be the target for some of the descriptive shore data, the experimental trampling study on the SERC shore, and the study of visitors' activities in the intertidal zone/shore area. Dr. Wilson envisions a separate publication with David for policy implications of the marine biological findings.

We tried to engage Sumner High School students in the research, but were relatively unsuccessful in doing so. Students did make a field trip to Grindstone Neck, in which we simulated a more free-form study of trampling on the shore, and Mr. Olson

spent several days in a classroom at Sumner showing students how to press algae and discussing his research and local intertidal ecology. Our lack of proximity to the school created one form of scheduling inflexibility, but the key inflexibility was the school's schedule. Given the lack of a suitable matching course at the high school, and the school's distance from the shore, it was impossible to achieve what we'd hoped with high school students. However, 16 members of the public volunteered regularly to help with the visitor observational study; therefore, public knowledge and interest in the study was achieved in another way.

*4. Raw data in electronic and hard copy will be...given to NPS staff in the final report. This will include digital images of the quadrats in each sampling period and of the high to low shore transects.*

Digital images of quadrats and digital films of the longitudinal transects (4 sets, representing spring and late summer in 2007 and 2008) will be provided to the NPS with a copy of Mr. Olson's M.S. thesis in June, 2009. The NPS had indicated interest in color, hard copies, but the grant did not have funding to permit this. These digital images are likely to be useful to future researchers working in ANP, and I recommend that the digital media be preserved. I need the raw data sheets through winter, 2009, as I prepare the material for publication, but will turn these over to the NPS when the publication is accepted.

*5. GPS locations of all permanent plots will be provided to the Park.*

Maps of the shore with these locations appear in Mr. Olson's thesis. We thank Ms. Karen Anderson of the NPS for providing these maps from our downloaded GPS data files.

*6. Presentations at scientific conferences and at the annual park science meeting will be given by PI Brawley and the graduate student research assistant (Olson).*

Presentations on this work were made by Mr. Olson (with me as a co-author) in the following venues: 1) The North East Algal Society (a regional, annual meeting of Canadian and New England scientists working with algae) in 2007, 2008, and 2009, and 2) The Phycological Society of America (2007) annual meeting. I gave a talk on the research in the Public Lecture Series at the Schoodic Education and Research Center (summer 2008). Ms. Sarah Hall and Mr. Joseph Stachelek (see below) co-presented the SERC lecture with me, and we then helped attendees make herbarium specimens of some algae collected outside (but near) ANP.

*7. A small number of representative (algal) herbarium specimens will be deposited at the Park.*

Some species were present in pieces that were too small for pressing, or are always microscopic; however, we have made herbarium specimens of 42 species of macroalgae found in the sections of shore our study focused on. Multiple specimens are included to show seasonal reproductive phenology for several species. A full list of algal species found on the shore during the study is included with this report.

8. *Two marine sciences' majors at the University of Maine will complete their capstone thesis requirement working on the project.*

Mr. Joseph Stachelek (B.S., 2008, University of Maine) and Ms. Sarah Hall (B.S., 2008, University of Maine) worked on this project in 2007 and 2008, and used components of the research for their senior capstone projects. Ms. Hall is now working as a laboratory manager at North East Labs in Windsor, ME. Mr. Stachelek was hired to an excellent research assistant's position with Dr. Kenneth Dunton at the University of Texas on the strength of his capstone research. Dr. Dunton encouraged him to apply to do graduate research with him this past year, and Mr. Stachelek is now a M.S. student in Marine Sciences at the University of Texas. There is no question that his capstone work in ANP was pivotal in his career path. As a research assistant to Dr. Dunton in fall 2008, Mr. Stachelek worked on conservation projects related to sea grasses and lagoonal algae on the Texas coast.

9. *We will advise and consult with the Park on the design and development of a brochure for distribution to the public.....*

Rather than a brochure, electronic media were developed, with attention to the changing habits of the public. Photographs, micrographs, and text for development of educational materials on marine plants and animals were provided to the ANP staff, edited by the staff, and placed on the ANP home page in fall 2008 and spring 2009. These appear to be attracting attention (as determined by Google hits). A CD on *The Intertidal Algae of Acadia National Park* was developed by Ms. Hall and Mr. Stachelek with close supervision/editing by me. It includes many more photos/micrographs for each species (each species has a page) and information on its biology, a general introduction, glossary to terms, sample life history diagrams and a reference list for additional materials that interested members of the public can access. Ms. Hall and Mr. Stachelek are in conference with ANP staff to try to make this available for purchase by the public beginning in summer 2009, and it was copyrighted to them with ANP permission and reservation by the NPS to be able to use any of these materials in the future in ANP programs, educational materials, etc. Multiple copies of the CD were provided to the NPS in summer, 2008.

10. *A display on the rocky intertidal zone will be designed in consultation with the Park, and as the Park deems appropriate for its interpretative needs.*

ANP staff indicated in spring 2008 that there was no space available in the interpretative center on MDI, and that the web-based materials and CD amply met the intent of this Deliverable. I will be happy to assist the NPS in the future in interpretative tasks based on the research in this contract.

### **Protocols used in research**

Four protocols used in the research are detailed below. These are a protocol for determining the similarity of site topography (Protocol 1), a protocol for determining species diversity and abundance on shores (Protocol 2), a protocol for examining susceptibility to damage of the intertidal biota from human foot traffic (Protocol 3), and a protocol for evaluating visitor activities on the shore and in the intertidal zone.

### Protocol 1 (Site topography, also called rugosity).

This protocol follows Murray et al. (2003).

#### A. Materials required:

1. Nylon string (a spool of kite string is excellent).
2. Chain with small-sized links; 30 m of light zinc chain is suitable.
3. A level (bubble level) that can be attached to a taut string.
4. PVC pipe, about 2 m long and rigid enough to not bend, drilled at top to allow string to be tied.
5. Metric tape (surveyor's tape).

#### B. Measurements required:

1. Surface distance between two areas in the intertidal zone.

Place zinc chain along the contour of the intertidal zone (e.g., from the top of the splash zone to the bottom of the lower intertidal zone), following all small crevices, rises and dips. Do so carefully to avoid damage to biota. Determine the length of chain used from point A to point B. This is surface distance.

2. Linear distance between two areas in the intertidal zone.

Make use of the geometry of a triangle, finding the horizontal and vertical sides and calculating the longer side of the triangle, which is linear distance. The horizontal length is determined by placing the kite string at Point A, bringing the string taut and level to another point where a second person stands. To do so, the free end of the string must be tied to the top of a PVC pipe, whose full or intermediate height is measured to find the small (vertical) side of the triangle. In practice, the range of intertidal vertical distance means that these measurements must be made in steps; there will be multiple measurements made to determine the linear distance from the top of the splash zone to the bottom of the lower intertidal zone.

#### C. Determination of rugosity:

The ratio of linear distance to surface distance constitutes rugosity. If the ratio is 1.0 (no difference between linear distance and surface distance), the topography is so even that there are few microhabitats for the biota, and within a band of vertical and horizontal distance from any point, organisms will experience similar physical conditions. As the ratio approaches 0.0, the rugosity value indicates high heterogeneity of the shore, with many microhabitats available for organisms having different physical tolerances within close physical proximity to each other.

### Protocol 2 (Diversity and abundance of organisms)

This protocol is similar to that used in many other intertidal studies including the 1970s studies by Menge (1976) and Lubchenco & Menge (1978) at adjacent Grindstone Neck, Maine.

#### A. Materials required:

1. Drill with rock carbide bit (~1/4" bit)
2. 0.25 m<sup>2</sup> quadrat (construct out of 0.5 m length PVC pipe and glue together with plastic elbows) strung with nylon string through small, drilled holes in frame to create two sets of parallel strings that cross each other to create regular point

intersections that are evenly spaced within the frame. In this study, 50 such points were as suitable as 100 points for describing species diversity (Olson, 2009).

3. 100 cm<sup>2</sup> quadrat (Made of wire that can be bent into a 10 cm x 10 cm square; wire should be heavy enough to maintain shape of square)
4. calipers
5. digital camera and digital videocamera
6. random numbers' table (from any statistics book)
7. metric tape (e.g., 100 m long surveyor's tape)
8. stainless steel screws (e.g., 1", #10 stainless-steel pan-head screws and 1 " plastic sleeves for marking quadrat positions).
9. PRO-XR GPS unit or similar GPS instrument with sub-meter accuracy.
10. duct tape
11. small plastic screw-top vials containing 3% formaldehyde in seawater, carried in ice chest and kept cool in field.
12. forceps (for picking up small littorinids)
14. dissecting needle
15. 0.25 m<sup>2</sup> quadrat frame without string.

#### B. Site preparation:

1. Establish quadrat locations using a surveyor's tape placed through the middle of the portion of intertidal zone of interest (e.g., splash zone, high zone, mid-zone, low zone). Determine 6 locations for 0.25 m<sup>2</sup> quadrats by selecting random numbers from table (e.g., 6 numbers between 0-100, interpreting these as positions in meters along a 100 m tape). Rule: quadrat locations must fall at least 2 m apart and none can fall over a tide pool or deep crevice [this would create false replicates]; should the rule not hold for selected numbers, pick more.
2. Drill a small hole at the top two corners of each quadrat location and mark it "permanently" with a stainless steel screw that is screwed through a small piece (10 cm long, 2 cm wide) of duct tape (drop the plastic sleeve into the hole before screwing in the screw through the duct tape). Position the quadrat locations so that the quadrat is evenly across the tape with the random number location in the center of the quadrat.
3. Choose 4 longitudinal transects (splash zone to lowest low zone) by using site map, random numbers to find locations, and marking the top and bottom of the transect as above with stainless steel screws. GPS locations for each quadrat were determined by measuring the top, right screw (while facing sea).

#### C. Measurements required:

1. At each "sampling" time, for each quadrat, carry out these measurements:
  - a. Photograph each quadrat with a digital camera with the quadrat lacking string in place to define the quadrat (and frame the photo). Some ecologists use a rectangular quadrat to match the camera's frame (we did not). This records algal canopy (if present) for later analysis.
  - b. Place 0.25 m<sup>2</sup> quadrat frame (50 regularly spaced points) over quadrat location. Record the organism that is underneath each point, gently moving aside canopy to view substratum. A dissecting needle positioned against the point and reaching through the

canopy (carefully) to the substratum is helpful for this if there is substantial canopy cover. (A second set of measurements can be taken on the surface of the canopy, if desired.)

c. Place small wire quadrat within quadrat location at the upper right (facing sea) or as close to this position as possible without removing algae. Photograph quad (to record sessile and non-sessile invertebrates) and then remove, count, and measure all mollusks. Count mollusks < 0.5 cm and list by genus (species determinations can not be made accurately in field on juvenile littorinids) without measuring. Measure length of littorinid snails from spire to bottom of shell.

d. Search quadrat for any organisms that are present but not included in 50 point count. Record these (and assign a 0.5% abundance to them for later quantitative analyses). If algal species can not be identified in field, find a small, adjacent piece of same organism and preserve in numbered vial with fixative for latter identification.

e. Larger invertebrates that can not be estimated by quadrats should be counted by timed searches. A period of 30 minutes of walking along the shore in the lower intertidal zone, while uncovering/recovering stones, looking under crevices, in tide pools etc., is appropriate for counting organisms such as crabs, sea urchins and sea stars.

f. During each "sampling" period, run surveyor's tape from pin at top of splash zone to pin at base of lower intertidal zone of each longitudinal transect. Walk along the tape, top to bottom, recording the tape and adjacent organisms with a digital videocamera held about 0.5 m above tape.

### Protocol 3: Experimental trampling protocol

For additional information on this protocol, see Olson (2009).

#### A. Materials required

a. see Protocol 2

b. two individuals wearing rubber-soled shoes who fit a light-weight (50-60 kg [110-132 lbs]) and heavier-weight (100-120 kg [220-242 lbs]) profile.

c. flexible 2 m tape (to measure fucoid lengths)

#### B. Site preparation:

a. Establish 18 quadrat locations across a large linear distance through the zone of interest (e.g., mid-intertidal zone) using the procedures specified in Protocol 2.

b. Assign two treatment levels (High = 30 steps/heavier person, 90 steps/lighter person; Low = 15 steps/heavier person, 45 steps/lighter person) and a control in interspersed blocks (to avoid pseudoreplication) to the quadrats (e.g., H, L, C). If done as in the original study on the SERC shore, three blocks of 6 quadrats each (n=2/treatment or control) would be sited to maximize the total shore area sampled without artificially separating treatments and controls). This design results in a total n=6 High Treatments, n=6 Low Treatments, and n=6 Controls.

#### Measurements required:

a. Put open-frame quadrat (see Protocol 2) over each plot and photograph it.

b. Place 50-point quadrat frame over each plot and determine what is under each point.

b. Apply appropriate treatment (High, Low, or None [i.e., control]) to each plot/once per month (or more frequently, as reflected by changing visitor conditions, see Olson, 2009).

- c. Gently comb through plot with hands and collect any broken pieces of algal canopy; if any are found, measure lengths (cm) and collect dry wt information after drying to constant weight for several days in a drying oven (65 C) in lab.
- d. Collect information on substratum species composition (see Protocol 2) using 50 pt quadrat, very carefully moving and replacing canopy, as needed, into original position.
- e. Locate and gently measure the longest fucoid (or other component) in quadrat; this is a determination of breakage susceptibility.
- f. Make a final set of foregoing measurements 6 months after last treatment application to look for long-term effects of trampling treatments.

#### Protocol 4: Determination of visitor activities and frequency of visits to intertidal area

For additional information on this protocol, see Olson (2009).

##### A. Materials required

- a. data sheets on clipboard (see Olson, 2009 for the one used here) (Photocopies of table on Rite-in-the-Rain paper are best).
- b. comfortable seating (Pad)
- c. informational sheet explaining study with contact information to an external, supervising party, for further information (to be handed out to interested/concerned visitors)
- d. tide tables
- e. a network of reliable volunteers (the same set of people should make observations throughout the measurement cycle to reduce error).

##### Measurements required:

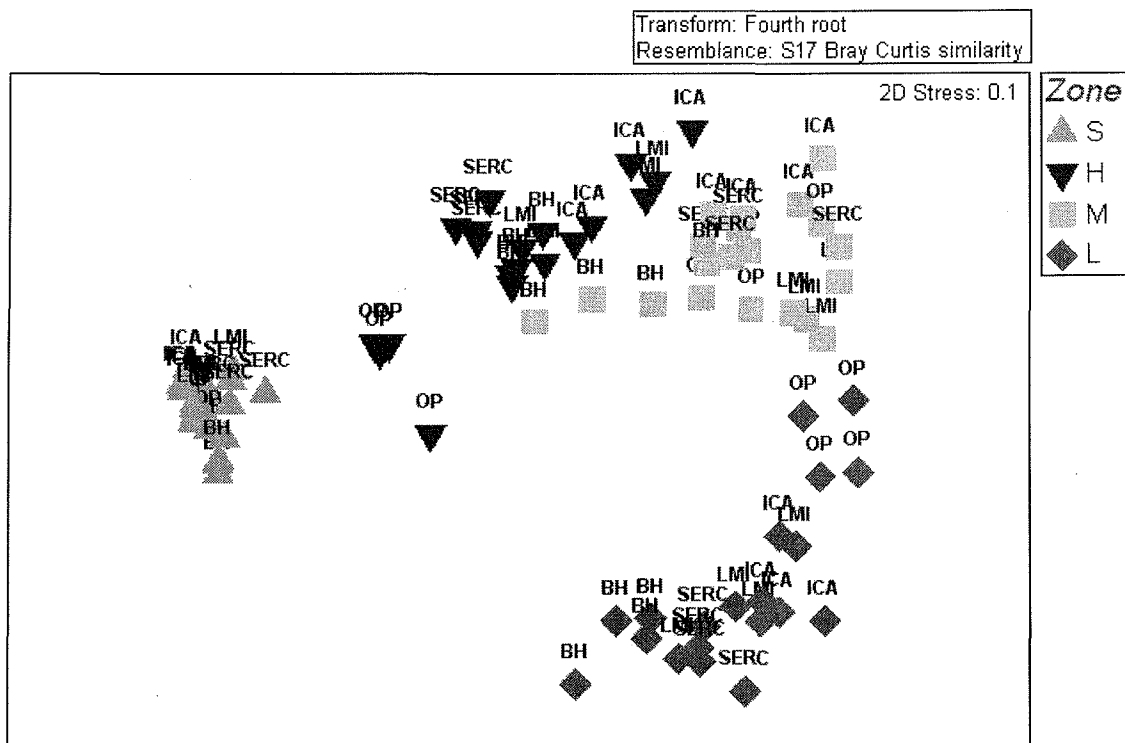
- a. sit (exposed to view of anyone entering area) in a comfortable spot above the splash zone with a full view of intertidal zone.
- b. confine measurement area to the region that encompasses 45° left and right of observer (you) running to shore. That is, the straight line between the observer and the nearest point at the water's edge is one side of a triangle; the boundary lines of the measurement region are the long edges of a triangle to left and right of this.
- c. make measurements during the interval 1 hour before and 1 hour after lowest low tide, using corrected interval for local shore.
- d. for exact sites used in original study at SERC shore, Invertebrate Critical Area, Little Moose Island, Otter Point, and Bass Harbor Lighthouse, see Olson (2009).

#### Executive Summary of Findings

**Key Question:** *Are the biota (species diversity, abundance, etc.) of the SERC shore unique compared to other shores in ANP?*

We find that each of the five shores that we have studied is different from the other at this point in time, despite our efforts to match shores by aspect, rugosity, etc. This is shown by Figure 1, which reduces each shore by zone to an average of individual species abundances and diversity based on data from each quadrat. The closer the

**Fig. 1. Non-metric Multidimensional Scaling (MDS) of abundance data from all sites during all four sampling periods by quadrat (n=6 quadrats/site). See Olson (2009, Fig. 2.21) for more information.**



quadrats are, the more similar quads/site or sites/site are. As demonstrated, the splash zones of each shore are very similar (points overlap each other). Within the high zone, there is some overlap between Little Moose Island (LMI), Bass Harbor Lighthouse (BH or BHL), and the Invertebrate Critical Area (ICA), but SERC emerges as a cluster near LMI, BHL and ICA whereas Otter Point (OP) and the Invertebrate Critical Area are the most different sites. In the mid-zone, SERC and most OP sites cluster centrally with the ICA, LMI and BHL all scaling a bit away from the cluster. In the low zone, SERC resembles the ICA, and LMI with some separation from BHL; Otter Point's low zone is very different from the other sites.

Divergence in species abundance and diversity between sites is greatest in the high zone and the low zone (Fig. 1), and Otter Point is the most different site. Detailed species data appear in Olson (2009) but two facts emerge from our studies. The divergence in MDS (Fig. 1) in the low zone, in which Otter Point is very different from the other sites is a reflection of much less *Chondrus crispus* (Irish Moss) in the lower intertidal zone at this site (Fig. 2.22 in Olson, 2009) than at other sites. Otter Point is the most exposed of our five sites, and we had to choose our workdays at this site carefully to be able to reach the low zone. Lubchenco & Menge (1978) determined that *Chondrus crispus* was less abundant on rocky intertidal shores in New England as wave exposure

increased, and our findings are consistent with this earlier observation. Menge (1976) and Lubchenco & Menge (1978) are particularly relevant to our study, because one of their study sites in Maine was Grindstone Neck (Winter Harbor, Maine), which is near and similar to many of our study sites in ANP. More recent studies of the New England shore focus on more protected sites that are frequently dominated by the furoid alga *Ascophyllum nodosum* (e.g., Bertness et al. 2004 and references therein).

The difference in the high zone at Otter Point is due to it having the lowest cover of barnacles (*Semibalanus balanoides*) and the highest covers of lichen (*Verrucaria* sp.) and cyanobacterial mat (*Calothrix* sp.) (Figs. 2.31, 2.32 in Olson, 2009). Otter Point was the only intertidal site in our study with a high number of visitors. Given that we do not have another site where the visitor traffic was equally high to Otter Point, we can not conclude that foot traffic is responsible for the low barnacle abundance. There are natural cycles of colonization and predation by *Thais lapillus* (dog whelk) that cause barnacle cover to vary. Barnacles, however, are one of the most sensitive components of the intertidal zone to foot traffic. Barnacle hummocks are easily crushed by a single step, and we deliberately did not study such areas where they exist on the SERC shore, to avoid such damage. We observed that on high-profile boulders just a few meters away from the shore (and people) at Otter Point, there are hummocked barnacles, despite the lack of hummocks in the main intertidal zone and the fact that only 10% of the cover of the high zone in our quadrats was *Semibalanus balanoides* (Fig. 2.31 in Olson, 2009). Our considered opinion, therefore, is that damage from foot traffic is responsible for the divergence in the MDS of Otter Point's high zone from other sites.

Lubchenco & Menge (1978) found that only a few categories of habitat (e.g., bare rock) or species described the rocky intertidal zone on the New England shore, including at Grindstone Neck, with distinctive cycles of colonization and succession, and particular importance of the predatory snail *Thais lapillus* (the dog whelk) to competition between barnacles and mussels for space. This is also a finding of our study (Olson, 2009). For example, in the mid-intertidal zone at all sites, most space is held by only four categories (Fig 2): *Fucus vesiculosus*, *Semibalanus balanoides*, *Mytilus edulis*, and bare rock (the latter containing flecks of the red algal crusts *Hildenbrandia rubra* and the sporophytic phase of *Mastocarpus stellatus*). We have observed more algal species in our quadrats (Table 1) than reported by Lubchenco & Menge (1978: 43 species, inclusive of winter species [taxonomic changes in names have occurred in numerous cases since their study, see AlgaeBase at [www.algaebase.org](http://www.algaebase.org)]) but neither their study nor ours was designed to be comprehensive. The best comprehensive checklist to the algae of the central Maine coast is Mathieson et al., (1998). The numbers of herbivorous invertebrates and predators are similar in our study to that of Lubchenco and Menge (1978), although the

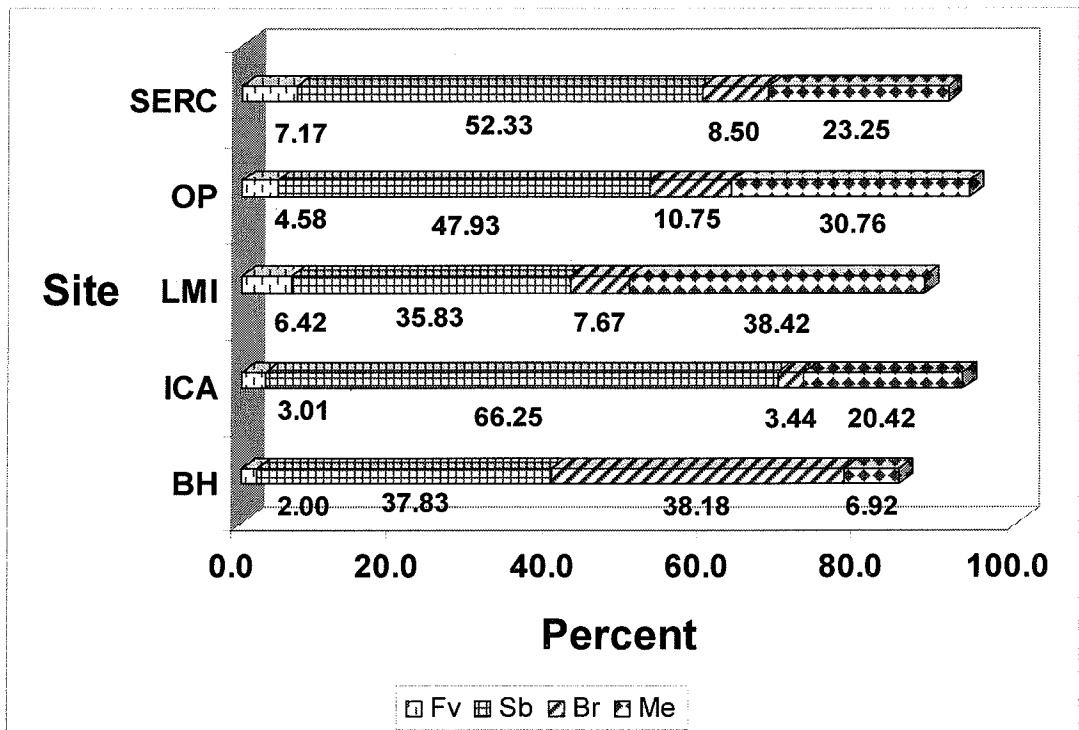


Fig. 2. The amount (%) of substratum occupied by *Fucus vesiculosus* holdfasts (Fv), *Semibalanus balanoides*, Bare rock (see text), and *Mytilus edulis* in the mid-intertidal zone at each of the study sites.

numbers of *Littorina* spp., especially *L. littorea*, are lower (Olson, 2009). Our quadrats were placed on slopes less than  $30^\circ$ , and ones lacking fissures, which unquestionably accounts for our lower numbers. We observed commercial harvesting of *Littorina littorea* by a group of men who rapidly disappeared when we appeared on the SERC shore in one sampling cycle; however, the number of *L. littorea* in pools and fissures at this site is much higher (SHB, pers. obs.) than our quadrat numbers would suggest.

The greatest difference between the SERC shore and most other sites (except LMI) in our study is the large quantity of furoid canopy in the mid-zone. This consists largely of *Fucus vesiculosus*, the furoid species that characterizes most moderately exposed rocky shores throughout New England (e.g., Lubchenco & Menge, 1978). This is demonstrated by the highest number of *F. vesiculosus* holdfasts at the SERC shore (Fig. 2) and by the highest surface canopy cover there (Figure 3, and Olson, 2009). This, combined with the width of the mid-zone at SERC (i.e., much wider than at LMI), gives rise to a distinctive character at SERC. However, the oldest (i.e. longest individual) *F. vesiculosus* on a fine-scale ( $0.25 \text{ m}^2$ ) appears comparable between sites (Olson, 2009), despite the higher furoid abundance at SERC. Because of earlier studies by the PI in ANP, she is aware that there was a major ice scour on the western side of Schoodic Peninsula in 2004; this extended through the ICA area but did not affect the SERC shore. This site may retain a high furoid canopy, even within the natural cycle (i.e., old *F. vesiculosus* are torn away by storms, bare space appears, barnacles colonize, *F.*

*vesiculosus* becomes re-established and out-competes barnacles in mid-zone), for this reason.

**Key question: Will foot traffic damage the SERC shore?**

We find that the mid-intertidal zone of the SERC Shore is the most resilient shore described to date when exposed to foot traffic. There were no differences between treatments and controls (Fig. 3). We hypothesize that this is because of how wet the canopy stays, due to the typical Maine shore climate and also due to the thickness of the canopy, which exposes different individuals on some days compared to others, as current direction changes as water recedes. This could explain our finding of strong resilience of *F. vesiculosus* to breakage when experimental trampling is applied. Many of the other studies of experimental trampling, even when done in areas of comparable furoid cover, are in areas in which the intertidal algae are subject to more drying (e.g., Murray and colleagues, Southern California; see Olson, 2009 for detailed discussion of trampling literature). Very high loss of furoid canopy is observed on shores in the southern hemisphere that are covered by the furoid *Hormosira banksii* after only a few steps, but its thallus is a beaded frond, which may account for its acute sensitivity to foot traffic.

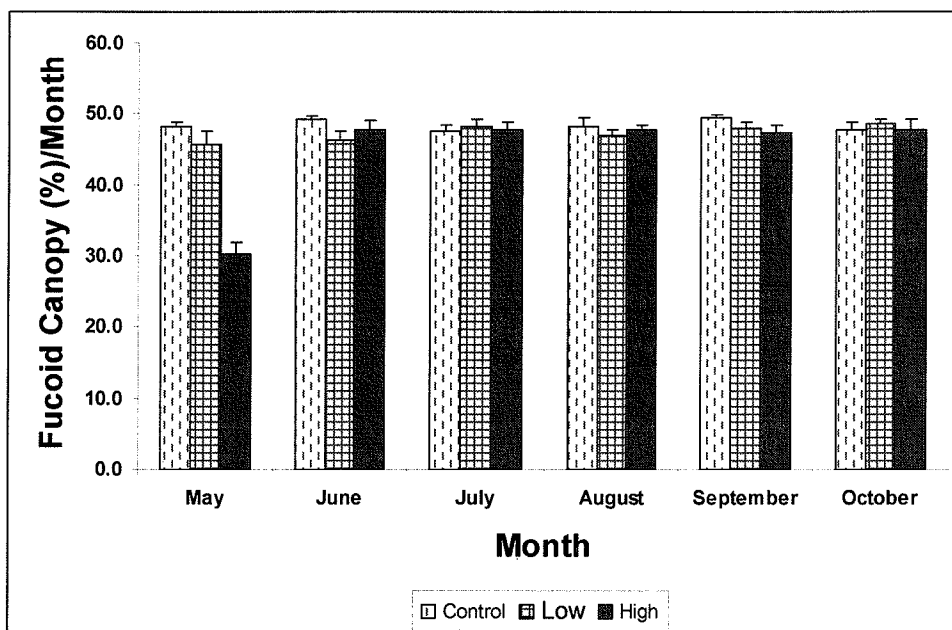


**Figure 3.** Point-count estimate of the percent cover ( $\pm$  SE,  $n = 6$  quadrats) of the *F. vesiculosus* canopy in the mid-intertidal zone on the SERC shore.

The level of foot traffic to which we subjected the *F. vesiculosus*-dominated SERC shore was based upon preliminary observations of visitor numbers and footwear at our study sites in 2006. Should the climate become drier, the number of visitors increase, their typical footwear shift from rubber-soles, etc., repetition of our study might show more damage. We also applied the treatment only once/month, because we expected this

to have adverse effects based upon the literature. This level of foot traffic on a substantially higher number of days in a month might be injurious. We did not establish what the threshold for damage is.

As noted, we did not subject the high zone (barnacles) to a trampling study, and it is easy to demonstrate crushing of barnacles in such areas. However, recolonization by settling larvae in the spring is adequate to compensate for such damage.

### **Key Question: How do visitors use the intertidal zone?**

Most visitors who come to the shore sit or walk in the area above the splash zone, or walk in the intertidal zone, although a total of 18 different activities and 27 different types of items carried onto the site were observed (Olson, 2009). Data were collected monthly from May-October in 2007 and 2008 at each of the five sites, and no statistical difference in visitation was observed on weekdays compared to weekend days during this period; there was a trend to higher visitation on weekend days (Olson, 2009). Most visitors to the shore were older than 18 years of age, with little gender difference. The footwear most commonly worn was some type of soft, rubber-soled shoe (e.g., sneakers). There were more visitors to the shore in 2007 than 2008, possibly due to the increase in gas prices in 2008; interestingly, the number of visitors who entered the intertidal zone at each site remained about the same in the two years (Figs. 4, 5).

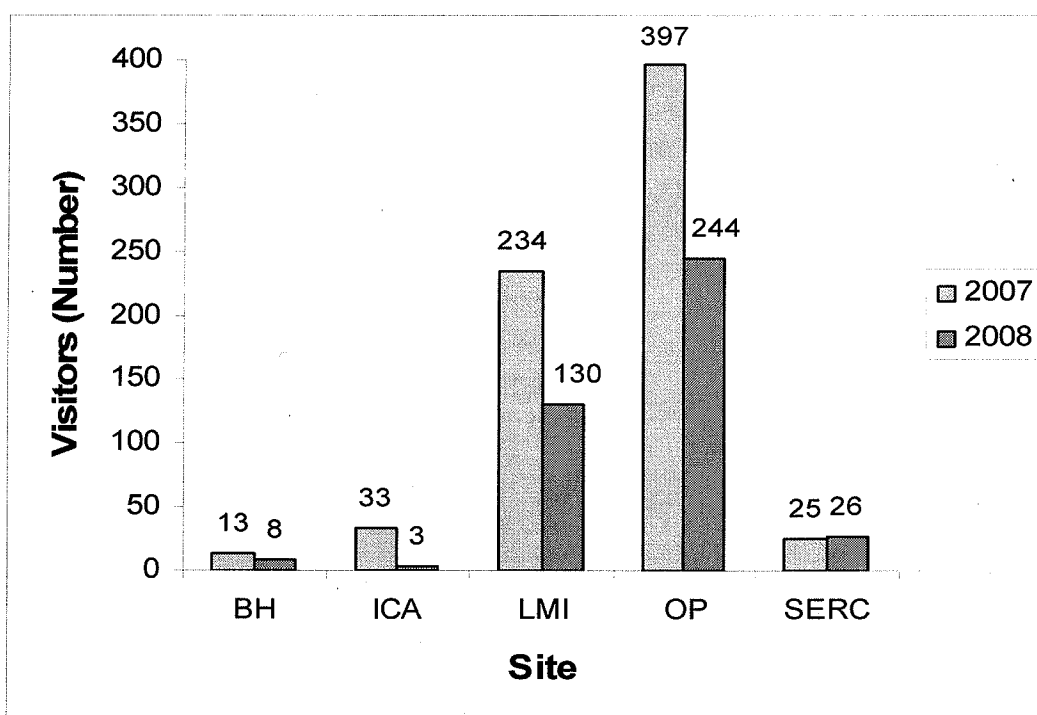


**Figure 4.** Total number of visitors observed in 2007 and 2008 ( $n=24$ ). Data are pooled across month,  $n=6$  (May – October), and days,  $n=4$  (two weekdays and two weekend days/month).

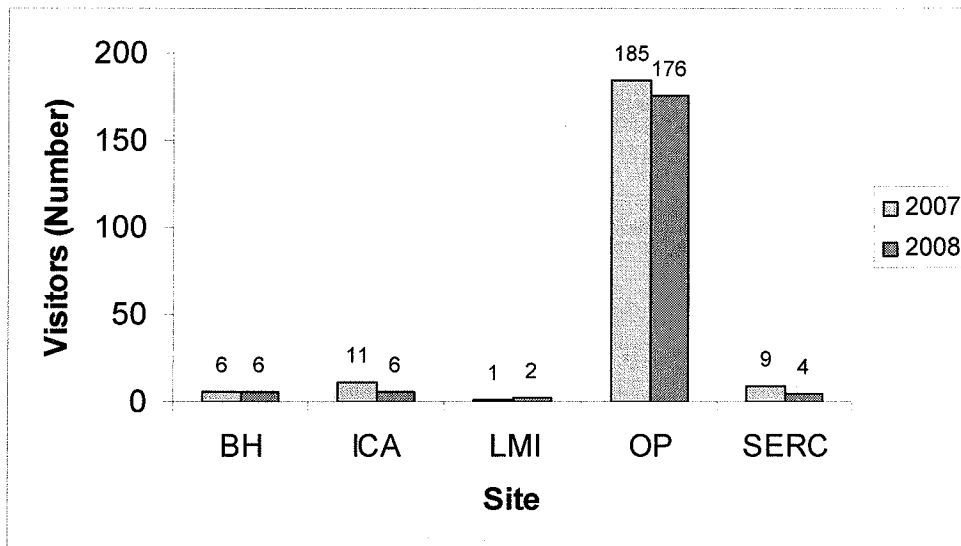


**Figure 5.** Total number of visitors who entered the intertidal zone at each site in 2007 and 2008 ( $n = 24$ ,  $\pm$  SE). Data are pooled across month,  $n=6$  (May – October) and day,  $n=4$  (two weekdays and two weekend days each month).

Our observational area at these sites was a fraction of the total site's visitation, particularly at Otter Point. Here, our observational area is roughly 15 % of the Otter Point intertidal zone. Because visitors on a given day often explored each site beyond our observational area, the AREA multiplier that would be appropriate is unknown, but a DAY multiplier of  $\sim x 6$  should be applied, at least for Otter Point. Our data make clear that the intertidal zone of Otter Point is particularly well visited, with an estimate of  $> 1200$  visitors/year in the tourist season of May-October. In contrast, the other sites have intertidal visitation levels of  $< \sim 100$  persons/year.

We originally hoped to correlate visitation levels on the shore with access based upon the proximity of pull-outs and parking areas to the site. The sites at BHL, ICA, and SERC do not have pull-outs or parking areas that are immediately adjacent to the shore; whereas, Otter Point and LMI do. However, the parking area at Otter Point is larger than that the small pull-out at LMI; it seems likely that other (nearby) parking areas were used by some of the visitors to LMI.

Our BHL site is about a 10 min walk along a social trail by the shore from the Lighthouse with its well-appointed parking lot. We observed that the lot was full on most of our observation days, but visitors tended to visit the Lighthouse and use the nearby stairs for viewing the sea or briefly visiting the shore directly below the stairs. Thus, the parking lot had little effect upon visitation to the study site at BHL. Otter Point is a shuttle drop-off point and has a well-marked parking lot that is large and only  $\sim 70$  meters away from our study area on the Otter Point shore. The SERC shore is about a 10

min walk from a parking area, and the SERC shore has not been advertised to the public in a way that would promote visitation. Most of our volunteers who were residents of Winter Harbor did not know of the Sundew Trail's existence. A pull-out big enough for ~ 3 cars is immediately adjacent to the low tide access to LMI and several other parking lots are nearby (e.g., at the Point, at Blueberry Hill, and in the small lot at the entrance to SERC). However, the walk to our study site on LMI is about a 20 min walk over a high trail and broken rocks; it has the most difficult access of any site. The Invertebrate Critical Area is a 20 min walk away from a small-pull out (for ~5 cars), and the trail to our observational site is a social trail with difficult walking. In summary, we found that the easiest access (Otter Point) among the sites was correlated with the highest visitation rates; despite its harder access, LMI attracted many hikers but very few entered the intertidal zone (except for walking through the *Fucus spiralis* zone to get to the island).

The most important anthropogenic impact on most ANP intertidal zones may be lobstering (and the taking of urchins, although this was so excessive in the 1990s that the populations are just beginning to recover). However, the lobster industry is probably a neutral to positive effect upon ANP shores relative to "natural" conservation. Humans are replacing the role of the large, predatory fishes that inhabited this area before over-fishing severely reduced their numbers.

### **Recommendations:**

1. Repeat the survey of quadrats established by this study in 5-10 years (unless some precipitous event requires this earlier). An earlier repeat (5 years) would help to track appearance of new invasive species, but the overall similarity of our findings to the 1970s-studies of Lubchenco & Menge (1978) show that a longer re-monitoring is probably adequate, absent sharp climate change. Two invasive algae may appear in ANP within a 5-10 year period: *Codium fragile* ssp. *tomentosoides* and *Grateloupia doryphora* (see Sears et al., 2002). Teams of local volunteers might be trained to do the surveys, but would need to be supervised very carefully by a professional biologist on the NPS staff.

2. This study has not provided a complete study of the biodiversity of the SERC shore, even of the algae. If this is desired, two models might be effective: 1) Invite a "crew" of taxonomic specialists to visit SERC for two weeks in a "jamboree" of the sort that has been held in recent years in Cobscook Bay, or 2) Start a "biologist in residence" program along the lines of the "artist in residence" program, and pick different specialists in series to cover all phyla.

2. Because of the resilience of the SERC shore in our trampling study, I believe that the NPS can increase ranger-led excursions into the intertidal zone on the SERC shore, and should not need to restrict intertidal visits by independent hikers as SERC develops. However, I recommend that intertidal excursions be targeted to the second trail-head (where the bolts are), which provides rapid access to the mid-intertidal zone and will minimize damage to the upper intertidal zone. The sign-in log should be maintained. If rangers begin to notice bare spots developing in the canopy, class trips to the intertidal

zone should be relocated for 2-3 years onto the other side of SERC (near the guard house at the entry point) or to the first trail-head. This should allow the shore to recover.

3. There are a number of "best practices" that rangers could convey to visitors on ANP-led visits to the intertidal zone. Few visitors collect organisms (Olson, 2009), which is good, but most visitors will not understand that they need to return stones or canopy to their original positions after "taking a look". Encourage visitors to wear sneaker-style shoes, as most already do; sneakers are easier on the intertidal zone than lug soles. Avoid walking in the most fragile habitats (barnacle covered ones). It is good to encourage visitors' interest in the intertidal zone, which requires being in the intertidal zone.

4. Most of the ANP shore is lightly visited, at present. The NPS appears highly successful at targeting "high exposure and high impact" to a few places on the shore (e.g., Otter Point) by how parking lots, shuttle drop-offs, etc. are arranged. This makes small areas of shore "sacrificial" sites, but as noted above, even at Otter Point there are refuges without human impacts.

5. We overheard numerous visitors at Otter Point saying that they wished they could see underwater. I believe an underwater camera in several locations, especially if hooked to a web-cam, would be an excellent tool to increase appreciation of the shallow subtidal zone, and associated, ecosystem-based educational resources on the marine biota of ANP could be developed for the Visitor's Center.

6. Be vigilant about collectors of organisms on the shore (e.g., *Littorina littorea* collectors).

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**Table 1.** List of algal herbarium specimens prepared for long-term storage in the historical, biological collection of Acadia National Park. \* Species not prepared as herbarium specimens (destroyed during ID of small specimens or heavily calcified)

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**Chlorophyta (green algae)**

*Acrosiphonia arcta* (Dillwyn) J. Agardh  
\**Bryopsis plumosa* (Huds.) C. Agardh  
*Chaetomorpha melagonium* (F. Weber et D. Mohr) Kütz  
*Chaetomorpha minima* (Collins et Herv.)  
“Halicystis” stage of *Derbesia marina* (Lyngb.) Solier  
\**Monostroma grevillei* (Thur.) Wittr.  
*Prasiola stipitata* Suhr ex Jess.  
*Ulothrix laetevirens* (Kütz) Collins  
\**Pringsheimiella scutata* (Rein.) Höhn. ex Marchew.  
\**Pseudendoclonium fucicola* (Rosenv.) R. Nielsen  
*Ulothrix flacca* (Dillwyn) Thur. in Le Jol.  
*Ulva intestinalis* (L.) Nees  
*Ulva lactuca* L.

**Phaeophyceae (brown algae)**

*Agarum clathratum* Dumort.  
*Alaria esculenta* (L.) Grev.  
*Ascophyllum nodosum* (L.) Le Jol.  
*Desmarestia aculeata* (L.) J. V. Lamour.  
*Desmarestia viridis* (O. F. Müll.) J. V. Lamour.  
\**Ectocarpus fasciculatus* Harv.  
*Elachista fuciola* (Vellay) Aresch.  
*Fucus distichus* L. ssp. *distichus* L. emend. H. T. Powell  
*Fucus distichus* L. ssp. *edentatus* (Bach. Pyl.) emend H. T. Powell  
*Fucus distichus* L. ssp. *evanescens* (C. Agardh) emend H. T. Powell  
*Fucus vesiculosus* (L.)  
*Fucus spiralis* (L.)  
*Laminaria digitata* (Huds.) J. V. Lamour.  
*Leathesia difformis* (L.) Aresch.  
\**Mikrosyphar porphyrae* Kuck.  
\**Pilayella littoralis* (L.) Kjellm.  
\**Ralfsia verrucosa* (Aresch.) J. Agardh  
*Saccharina latissima* (L.) C. E. Lane, C. Mayes, Druehl et G. W. Saunders, comb. nov.  
*Scytosiphon lomentaria* (Lyngb.) Link

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**Rhodophyta (red algae)**

*Ahnfeltia plicata* (Huds.) Fr.  
*Bangia atropurpurea* (Roth) C. Agardh [*Bangia fuscopurpurea* in Taylor 1962]  
*Ceramium rubrum* (Huds.) C. Agardh  
*Chondrus crispus* Stackh.  
*Corallina officinalis* L.  
*Cystoclonium purpureum* (Huds.) Batters  
*Devaleraea ramentacea* (L.) Guiry  
*Dumontia contorta* (S. G. Gmel.) Rupr.  
*Euthora cristata* (C. Agardh) J. Agardh  
\**Gloiosiphonia capillaris* (Huds.) Berk.  
*Gracilaria tikvahiae* McLachlan  
\**Hildenbrandia rubra* (Sommerf.) Menegh.  
\**Lithophyllum orbiculatum* (Foslie) Foslie  
\**Lithothamnion glaciale* Kjellm.  
*Mastocarpus stellatus* (Stackh.) Guiry  
*Palmaria palmata* (L.) Kuntze  
*Phycodrys rubens* (L.) Batters  
*Plumaria plumosa* (Huds.) Kuntze  
*Polysiphonia stricta* (Dillwyn) Grev.  
\**Polysiphonia lanosa* (L.) Tandy; also as *Vertebrata lanosa* (L.) T. A. Chr  
*Porphyra amplissima* (Kjellm.) Setchell et Hus. in Hus  
\**Porphyra birdiae* Neefus et Mathieson  
*Porphyra leucostica* Thur. in Le Jol.  
\**Porphyra linearis* Grev.  
*Porphyra miniata* (C. Agardh) C. Agardh  
\**Porphyra purpurea* (Roth) C. Agardh  
*Porphyra umbilicalis* (L.) Kütz  
*Rhodomela confervoides* (Huds.) P. C. Silva

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