Green Eggs and Sand: A Collaborative Effort of Scientists, Teachers, Resource Managers, and Stakeholders in Educating About *Limulus polyphemus*

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Abstract The highly successful *Green Eggs & Sand* (GE&S) project is a joint effort of educators, scientists, resource users, and managers engaged in building a unique workshop/field experience, a wealth of educational video, and a series of associated activity-based learning modules, centered on the current horseshoe crab/shorebird phenomenon and management controversy on Delaware Bay. Over the past 8 years, more than 800 teachers, non-formal educators, scientists, resource users, and managers from 20 states and 3 foreign countries have taken part in GE&S workshops, which are now offered up and down the Atlantic coast each spring around lunar event peak times for horseshoe crab spawning. These workshops are intensive, spanning 2–3 days, and feature a mix of hands-on field experiences, presentations by experts, and demonstration of curricular components. This article provides a case-study overview of how GE&S was developed and implemented, with an eye to how this approach might be adapted and modified for use elsewhere.

1 Introduction

1.1 Background and History

Green Eggs & Sand was initiated in 2000, in response to an interest in developing educational modules around the mid-Atlantic horseshoe crab/shorebird phenomenon and the complex and challenging management issues it presents.

A steering committee was subsequently formed, comprising a unique coalition of environmental educators, natural resource agencies, and nonprofit organizations from Delaware, New Jersey, and Maryland. Over the next several months, this group planned and presented a special workshop for the spring 2000 spawning season, inviting 14 master teachers from the three states. The objectives of the first Green Eggs & Sand (GE&S) workshop were to (1) immerse educators

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in experiencing this phenomenon first hand; (2) expose them to the issues and experts: the scientists, managers, and other individuals who are directly involved in these resources; and (3) explore the feasibility of, and chart directions for, developing educational modules around the phenomenon and issues (Fig. 1).

Along with the steering committee, the 14 teachers who convened at the Mallard Lodge in Smyrna, Delaware for that weekend became the "think-tank" for GE&S. The initial tasks were to respond to surveys, exchange countless emails, and meet to hash out priorities, plan strategies, and ultimately form the module writing teams that produced the draft/pilot curriculum. These same teachers then assisted in planning and presenting the second GE&S workshop in May 2001 as a vehicle for exposing a new group of educators to the phenomenon and issues. The second workshop also served as a venue for distributing draft curriculum modules to the collective group for piloting during the school year ahead. Feedback on the draft curriculum was used to develop a more finished product for 2002.

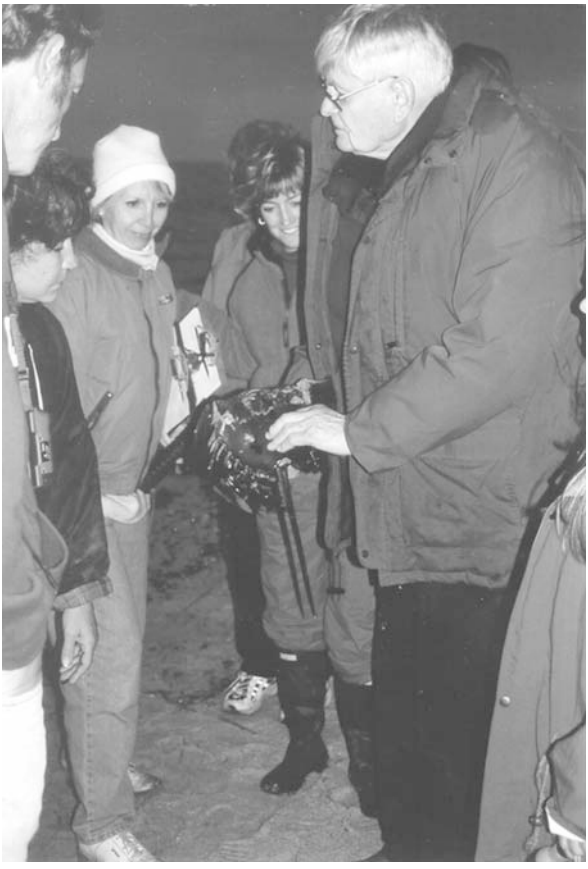

Fig. 1 Horseshoe crab expert and GE&S contributor, Dr. Carl N. Shuster, shares his knowledge of horseshoe crab anatomy with teachers at the pilot Delaware Bay workshop

To distribute the curriculum to a wider audience, two workshops per year were held on Delaware Bay in 2002 and 2003, using the same structure as in past workshops: presentations by experts, field trips to view shorebirds and horseshoe crabs, and orientation to the educational modules.

As awareness of and interest in GE&S grew, the project team began to receive requests to offer additional workshops at locations beyond the Delaware Bay. To meet this demand, in 2004, along with the traditional workshop in Delaware, the project team organized special 1-day sessions in Massachusetts, New Jersey, and Virginia. These workshops still offered presentations by local experts, but did not include much of the field component that was key to the Delaware workshop. Nevertheless, the 1-day sessions were positively received by participants.

In 2005, the full weekend Delaware workshop was supplemented by 1-day sessions in New Jersey, Massachusetts, Virginia, and Georgia, due to continued requests for workshops. Upon completion of those five spring workshops, the team re-designed the GE&S program. It was decided that in 2006, three regional workshops would be offered, but that each of these would span a full weekend to include field experiences comparable to the Delaware sessions. So, in addition to the traditional Delaware weekend workshop 2-day workshops were scheduled for 2006 for Cape Cod, Massachusetts, and the Georgia Coast to offer a regional focus because each area has unique horseshoe crab/shorebird issues.

In 2005, the GE&S team started to be recognized for the program's success. In April 2005, the team received the Northeast Association of Fish and Wildlife Agencies "Communicator of the Year" Award for "exemplary leadership in conservation communication." Later that year, "Green Eggs & Sand: The Horseshoe Crab/Shorebird Education Project" was awarded first place in the curriculum category at the National Association for Interpretation's annual conference in Mobile, Alabama. The National Association for Interpretation (NAI) is dedicated to the advancement of the profession of natural and historic interpretation, including all aspects of environmental communication and education. Its membership encompasses 4,500 professionals from the United States, Canada, and 30 other nations. With such stiff competition as Yellowstone National Park, Bandelier National Monument, and others, the project team, needless to say, was very proud.

Green Eggs & Sand has continued to expand its reach. As of August 2007, GE&S team has hosted 18 workshops reaching over 800 participants from 20 states and 3 foreign countries. More than 50 expert presenters have contributed to those sessions, many returning year after year to share their respective areas of expertise. Along the way, the project team has presented GE&S at conferences far and wide, from Japan to Puerto Rico, and all over the United States.

1.2 Educational Design

Green Eggs & Sand is composed of four educational modules, which systematically guide students through an understanding of the horseshoe crab, its connection to a larger ecosystem (through shorebirds), its use by man, and

human's attempts to manage this resource given limited science and multiple stakeholders. Yet, while GE&S offers multi-faceted learning opportunities, it has been designed by teachers to be flexible and adaptable for use at various grade levels in both the classroom and the field. Hence, the four educational modules can be taught as sequential learning blocks or independently of one another (Fig. 2). For example, a teacher of the lower grades interested primarily in science and math can use Modules 1 and 2 to engage children with a focus on anatomy, ecology, and hands-on activities about the crabs and birds. Conversely, those interested in higher level exploration of the issues and impacts on the human use and management side of this topic may wish to focus their studies on the material provided in Modules 3 and 4.

Video segments are used to introduce all four modules and to supplement specific lessons where appropriate. In the earlier modules, these clips provide background, context, and a "feel" for what it is like to be out on the beaches experiencing the birds and the crabs. In Module 4, video segments are infused throughout the lessons.

Since there is still much more to understand about this phenomenon, educators are encouraged to adapt these exercises or develop their own as new scientific data is published.

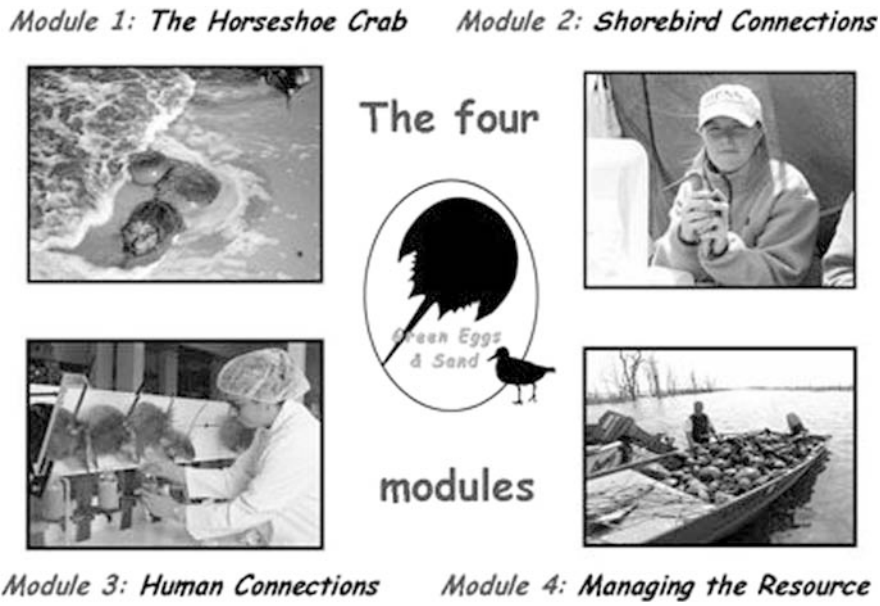

Fig. 2 The four Green Eggs & Sand learning modules

1.3 Module Highlights

Module 1, "The Horseshoe Crab", provides a strong foundation for the curriculum. In addition to interactive lessons on horseshoe crab anatomy, life history, and ecology, one of the highlights of this module is the companion "Horseshoe Crabs in the Classroom" piece provided by the Maryland Aquatic Resources Education Program. As part of this project, teachers attend a 1-day workshop to receive training in the methods and materials needed to care for juvenile horseshoe crabs. In the classroom, students raise juveniles throughout the year, feeding them, collecting water quality data, and recording observations. Experiments are conducted on topics such as substrate, salinity, lighting, and feeding. Students are required to submit data from their experiments to a project manager. Maryland is currently the only state with a formalized program on rearing juvenile horseshoe crabs. Although the lessons can be conducted in any classroom, teachers must check with their individual states regarding regulations on the collection of eggs.

Module 2, "The Shorebird Connection", introduces shorebirds into the curriculum. Several stimulating lessons on shorebird biology, natural history, and interactions with horseshoe crabs are offered. One of these, called the Red Knot Olympics, combines physical activities and mathematical word problems to promote numerous kid to bird comparisons and provides students with a more at-their-level grasp of the magnificent feats and amazing adaptations these migratory shorebirds exhibit during their long-distance flights

Module 3, "Human Use," introduces man's relationship to this natural phenomenon while also introducing social science activities such as history, economics, and statistics. It makes clear mankind's increasing dependence on an animal that the larger ecosystem depends upon.

Module 3 is highlighted by a lesson entitled "Limulus Amebocyte Lysate Lab: Bacteria, Blood, & Biomedical Testing." An accompanying video, power point presentation, and lab activity engage students in the use of a gel-clot test for detecting endotoxins in various waters. The lab uses past-shelf-life test vials of LAL donated by a biomedical company whose employees have served as expert presenters and contributors to the curriculum (Fig. 3).

Module 4 addresses how human use of a resource is managed when there is limited science and politics influences management. This module is noteworthy because the real data sets that fisheries managers grappled with to develop the management plan and the insights of actual stakeholders, scientists, and managers were used as material on the lessons on the horseshoe crab harvesting controversy. Ultimately, students are asked to examine their own values and beliefs regarding this resource by developing and justifying their own management plan.

The strong point of Module 4, "Managing a Resource", is the wealth of video it uses to chronicle the horseshoe crab management controversy in the mid-Atlantic region over time. Video segments go hand-in-hand with lesson plans, weaving a story-line that plays off the various activities provided. An example

LAL-LAB: BACTERIA, BLOOD & BIOMEDICAL TESTING

Developed by: Tricia Coseby, Melissa Pierce & Gary Kreamer, Delaware Aquatic Resources Education Center, with special thanks to Dr. Ronald Berzofsky of Cambrex Bio Science, for his substantial input to, and review of, this lesson. Assistance from Glenn Gauvry of Ecological Research and Development Group (ERDG) and Dr. Gary DuMoulin of Genzyme Bio Surgery is also appreciated.

Class Time: 2-3 class periods

Grade Level: targeted for High School, but could be used also at Middle School level

Materials: TV/VCR; Projection system or student access to computers (to view Powerpoint presentation), vials of LAL media* (for gel-clot reaction demo/experiment), samples of distilled water, tap water, bottled water and aquarium/stream/pond/ditch water (for endotoxin testing); small plastic pipettes (for adding water samples to LAL media), graphic organizers and LAL challenge sheets (for focusing student learning while viewing video and powerpoint), student transparency markers and worksheets for lab instructions and observations (one per team).

* Samples of single-test LAL vials - past shelf-like for pharmaceutical use, but fine for conducting the LAL gel-clot experiments described in this lesson - have been made available on a limited basis to *Green Eggs & Sand* workshop participants through the generous donations of Cambrex BioScience. To replenish supplies, contact: gary.kreamer@state.de.us

OVERVIEW

This combination video/powerpoint/lab activity is designed to deepen student understanding of the use of horseshoe crab blood in biomedical testing. The video piece introduces students to the basics of this process, including: how horseshoe crabs are collected and bled, how the blood is centrifuged to collect the amoebocytes used to make the LAL media, and how the end product is used to test all vaccines and other injectable materials that are put into the human body. The powerpoint presentation to follow approaches this subject in greater depth, including such aspects as: how the clotting properties of HSC blood were discovered; the nature of the crab's immune system in comparison to humans; what endotoxins are; and why we need to detect them. The presentation also introduces some basics on how the gel-clot tests are carried out, which leads into a culminating lab activity/demo, during which students test and compare water samples for the presence of endotoxins, using the same LAL media used by the pharmaceutical industry.

CONCEPTS

- the blood of the horseshoe crab has special cells that induce a distinctive clotting reaction in the presence of certain disease-causing bacteria
- this property of HSC-blood is the basis for a special test that is used to ensure the sterility of all vaccines, injectable medicines and other medical objects placed inside the human body

Fig. 3 Opening page of the biomedical use-focused LAL-Lab lesson plan, from Module 3 of the GE&S curriculum

of this is the "Identifying the Stakeholders" lesson, where after watching "talking head" clips of 10 real-world stakeholders in the horseshoe crab resource, students are challenged to use an accompanying worksheet to identify the role, values, and points of view that each of those people represent. Module

4 video clips include (1) interviews with scientists, stakeholders, and managers; (2) chronological highlights of the management process and the challenges it entailed; and (3) a closing piece that showcases approaches that are helping address the conservation need.

2 Elements of Success

2.1 A Management Module

A major strength of the GE&S curriculum, which sets it apart from many other environmental education materials, is that one module is dedicated specifically to the management aspects of a natural resource issue. In doing so, GE&S does not advocate or instruct its users to follow the views of a certain "side" of the story, but rather presents the differing viewpoints of all stakeholders and stresses the importance of gathering rigorous scientific data to base decisions. The management module addresses the challenges faced by managers seeking to balance the needs of diverse user groups and encourages students and teachers to understand and become involved in public processes that provide input to the management of natural resources.

2.2 Expert Involvement

One of the key elements of GE&S has been the ongoing interaction of scientists, stakeholders, and educators. Biomedical professionals, commercial fishermen, fisheries and natural resource managers, environmental educators, and horseshoe crab and shorebird researchers have all contributed to GE&S. They made presentations at workshops and contributed to video pieces. They have provided data and information useful to lesson plan development and have reviewed lessons for accuracy and fairness. Their dedication, passion for their field, and willingness to share their expertise with educators continues to play a vital role in the success of GE&S.

2.3 Using "Real" Data

Hand-in-hand with the expert involvement came the utilization of "real" scientific data in the curriculum. Students use data provided by the experts to learn about trends, look for flaws in data and data collection, and learn how data are used to guide management strategies. The same data sets managers struggled with in developing the fisheries management plan for the horseshoe crab are used for these exercises – we do not "fix" the data to meet our needs or show a certain story.

2.4 Training Workshops

From its inception, the GE&S project team has held that the only way to obtain a complete copy of the GE&S curriculum is to attend a GE&S workshop endorsed by the team. This is due in large part to the complexities of the horseshoe crab/shorebird phenomenon and controversy. Teachers who are immersed in the issues through field experiences, get hands-on training in the use of the curriculum and hear from topic experts are much better suited to teach this curriculum in an accurate and balanced way. The curriculum is not sold. A modest registration fee covers some of the costs, and the balance is covered with operational funds from the GE&S project team's respective agencies. Workshops are open to classroom teachers and non-formal environmental educators, with a focus on middle and high school levels.

2.5 The Importance of Video

The GE&S curriculum is rich in video material. Each of the four modules opens with an introductory video clip, followed by multiple supplementary segments that complement, enrich, and provide focus for the respective lessons within the modules. Video segments are particularly important in Module 4, where specific clips capture the real-life chronology, stakeholder perspectives, and numerous factors that have and continue to drive efforts to manage the horseshoe crab resource. In crafting the curriculum, its developers realized the challenges that many classroom educators have with arranging field trip opportunities. Video allows students to see the horseshoe crab/shorebird phenomenon first hand and "meet" some of the players involved in the issues. In certain lessons, video is used to simulate real-world field experience, such as in Module 2: "Be Shore About Your Birds" where students identify and quantify flocks of shorebirds using a dichotomous key, while watching video footage of shorebirds on the beach. While not a primary objective of using video, the developers have now recognized the value of students seeing "real" scientists in action, steering them away from the stereotypical lab coat scientist, to one who might go to work in sneakers and cutoff shorts.

2.6 Curriculum Standards

In today's standards-and-testing-focused educational landscape, the curriculum developers recognized the importance of addressing education standards in the lesson plans. Due to the regional/cross-states interest in this curriculum, the decision was made to forego making correlations with individual state curriculum standards in favor of using the national ones. These were completed by an independent consultant with expertise in applying the standards and are

presented in easy-to-view formats at the beginning of each module section, as well as in the appendix to the overall curriculum. The lessons were correlated to National Education Standards for Math, Science, Social Studies, and Language Arts for the middle and high school levels. Individual states have begun to correlate the curriculum to their standards as funding has allowed.

2.7 Tracking, Assessment, and Evaluation

Tracking, assessment, and evaluation help to improve GE&S and to document success and effectiveness to current and potential funding sources. Pre- and post-tests are given to training workshop participants to assess their level of knowledge at the start of the workshop and document change through the workshop experience. These participants also complete a workshop evaluation to comment on presentations, field experiences, and logistical items. The curriculum includes evaluations for each individual lesson and for the module as a whole. In 2005 and 2006, the GE&S project team conducted a survey of past workshop participants to determine the extent of the use of the curriculum. The 2006 survey of persons trained in the GE&S curriculum showed that in that year alone GE&S activities reached over 22,000 students.

2.8 Supporting Pieces

The success of GE&S has spawned several opportunities to offer enriching pieces to the curriculum. In 2004, special grant funding from the US Fish and Wildlife Service "Eco-Teams" enabled the GE&S team to produce a high-quality, information-packed horseshoe crab poster. The quality of this effort was much enhanced by partnership with the Ecological Research Development Group (ERDG), a nonprofit dedicated to the conservation of the world's four remaining species of horseshoe crab. Thousands of copies of this poster were reproduced and have been distributed through special events, educational conferences, the ERDG web site, and other outreach venues. Also during 2004, the curriculum and video segments were converted to a CD/DVD, product which is now distributed to workshop participants in lieu of a notebook and VHS tapes.

In 2006 the project team produced a special learning and tribute piece featuring Dr. Carl N. Shuster, Jr., who was instrumental in the development of the project, participating in all but one of the GE&S training workshops. The piece entitled "Dr. Carl Shuster and the Horseshoe Crab" is distributed as a learning tool for teachers who attended a workshop, met Carl, and want to share his extensive knowledge of horseshoe crabs with their students.

In the spring of 2007, a GE&S Sampler CD was created to spark additional interest in the curriculum and to give interested persons a "taste" of the lessons. Background information about the curriculum and a sample lesson from each

of the first three modules is included on the Sampler CD. The intent is that the Sampler CD will encourage educators to attend a full GE&S workshop.

3 Looking Toward the Future

The GE&S project team has tentatively set three workshops for the spring of 2008: Georgia, Delaware, and New York. The curriculum is now 7 years old and the group is looking to update and add to the modules in the years ahead. Opportunities for partnerships across the United States will also continue to be explored as a vehicle for strengthening and expanding the project's reach. For more information on any aspect of the Green Eggs & Sand workshop and curriculum, contact any of the GE&S team members/authors.