

CREATING *JOURNEYS*: INTERACTIVE NGSS ALIGNED READING PASSAGES
FOR SECONDARY SCIENCE CLASSROOMS THAT INTEGRATE
CURRENT SCIENCE AND ENGINEERING RESEARCH

by

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When I began traveling last year, my mom and I created a Facebook Tribute Page for the late Dr. Stephen Leatherwood in an attempt to reconnect with scientists whose lives he directly influenced. Her and I found that, as she was his research assistant when I was a child, their work and his legacy in marine mammalogy still impacts dozens of

scientists and filmmakers today. This circular reconnection and outreach to scientists and family friends, with my mom's dedication, has found me in a rewarding future prospect.

<https://www.facebook.com/StephenLeatherwoodTribute>

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ABSTRACT

Science teachers need curricula and resources to support the teaching of the Next Generation Science Standards (NGSS). In order to create interactive reading passages that engage students in scientific literacy and to connect science educators with current science from all over the world through scientist and engineer interviews, I created the *Journeys* concept, pilot and delivery method. I then gauged its NGSS alignment, usefulness and relevance with science teachers based on teacher preliminary surveys, pre-interviews and their resulting feedback using a pilot *Journey* called *Researching Dolphins*. Each *Journey* reading passage focuses on students researching various topics highlighted in NGSS and culminates real and new science issues, engineering education and citizen science opportunities. The pilot *Journey* focuses on High School Life Science and integrates other standards including Science & Engineering Practices. The process and result of my journey to create *Journeys*, or interactive NGSS aligned reading passages that integrate current science and engineering research for secondary science teachers and their classrooms, is provided.

INTRODUCTION

To meet the demand to create current resources for the instruction of the Next Generation Science Standards (NGSS) released in 2013, I invented the concept of interactive reading passages called *Journeys*, developed a pilot *Journey*, implemented a nationwide teacher feedback system, and produced a final, vetted, *Journey* online.

Research Purpose

I want to develop current resources for science classrooms that connect science and education through interactive media. The purpose of this research was to work with a variety of teachers and specialists to produce the concept of *Journeys*. *Journeys* are NGSS aligned interactive reading passages for secondary science classrooms that foster problem-solving skills by integrating multiple scientific concepts in multiple ways, scientific literacy through data analysis practice, and knowledge of current science and engineering issues worldwide through highlighted scientist and engineer case studies. Teacher feedback has been critical in every stage for *Journeys* production and is incorporated in planning, implementation and delivery online, through interactive PDFs and interactive formative assessments called *Waypoints* using the pilot *Journey*:

Researching Dolphins.

To assess the demand that NGSS presents for science educators, I relied in part on my five years of prior experience as a Curriculum Production Manager through Rice University's STEMscopes, now Accelerate Learning, Inc. In that time, I was expected to distill the talents of dozens of teachers, writers, scientists, and other professionals to develop hands-on and literacy-based, standards-aligned, online science curriculum in a

highly condensed timeline. It was this experiences that led me to be a co-inventor of the STEMscopes IDEA model, used for the aggressive K-12 comprehensive curriculum build shortly after NGSS release in 2013.

For my Master of Science in Science Education (MSSE) action research project, I recruited teachers for their feedback of the NGSS alignment, usefulness and relevance of the *Journey* passage, both in structure and in content. According to Carlson (2014), “high-quality curriculum materials... are designed, developed, and field-tested using data about how students learn and how teachers teach” (p. 4). Based on valuable teacher feedback, I completed one *Journey*, titled *Researching Dolphins*, highlighting the research conducted by scientists on dolphins and the effects of tourism on marine mammals in Belize. The production and continued vetting of this *Journey: Researching Dolphins* is the focus of this action research project.

Research Questions

- How will secondary science teachers of all experience levels find NGSS aligned interactive reading passages, or *Journeys* relevant?
- How can secondary science teachers use *Journeys* to incorporate relevant and current science topics with NGSSs in their classrooms?
- How will teachers find these resources useful, and in what ways?

Guidance and Support Team

The guidance needed for a multi-faceted project like this calls for a unique blend of professionals including my graduate advisor, a PhD science reader, PhD educational researcher, science curriculum developers and writers, a web and multimedia designer, and a variety of teachers who are familiar with my online science curriculum

management background. Guidance is provided by, but not limited to, the following individuals:

Dr. Walt Woolbaugh

As an adjunct professor in the MSSE program and full time science teacher in Manhattan, Montana, Dr. Walt has been my graduate advisor since 2014.

Dr. Christian Bahn

My assigned science reader is currently involved with teaching at Montana State University. He was coincidentally my Chemistry in Context professor in MSSE, an incredibly pertinent class.

Dr. Virginia Rangel

Dr. Virginia's educational research experience has been invaluable for reviewing my capstone drafts understanding my previous background in curriculum management.

Kersch

Lisa "Kersch" Kerscher is a long-time colleague and mentor who advises me on my current capstone but also my additional interests in interactive learning platforms. She is actively involved with the writing process and is listed as a co-author of the *Journey: Researching Dolphins*.

Ryan

Ryan is a web and multimedia designer who guides me as we build websites and other interactive projects.

CONCEPTUAL FRAMEWORK

The *Journey* interactive reading passage's structure is consistently sequenced in sections. Each section's purpose is outlined in my Methodology. In addition to fostering

general literacy skills in reading and writing, each section's focus and objective pulls from varied educational features present in the demands of NGSS, among other educational standards. Each section of the *Journey's* interactive reading passage including aspects of NGSS alignment, science literacy, Information and Communications Technology (ICT) literacy, inquiry-based data analysis and interpretation practice, and engineering education. The following conceptual framework provides the pedagogical background and approach to the development of these sections.

The NGSS require integration of multiple dimensions of learning in order to meet the rigor of Performance Expectations, or assessment standards. The dimensions include Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas which are within series of Component Ideas that grow in content sophistication over Kindergarten through 12th grade. The Component Ideas are the main Core Ideas, are delineated by grade span, and represent the content backbone of the NGSS standards directly based on the NRC's *K-12 Science Education Framework*. In addition to the *Framework*, concepts from the American Association for the Advancement of Science (AAAS) Project 2061 *Benchmarks for Science Literacy* are considered in the development of the dimensions and expectations of NGSS. Using the dimensions, NGSS emphasizes the role of students to make sense of and explain scientific phenomena and design solutions to problems (Roseman, 2015, p. 1). Building curriculum from the ground up by "identifying the performances expectations that students should meet, unpacking those ideas, and then creating a coherent storyline to show how those ideas [are] developed" (Roseman, 2015, p. 31) is a practice I am familiar with due to my previous

experience as a Curriculum Production Manager, and have utilized within this project. “Well-designed curriculum materials have the potential to provide secondary teachers with a vision of how to successfully integrate disciplinary concepts, crosscutting concepts, and practices, as well as relate instruction to standards and assessments” (Carlson, 2014, para. 5).

Studies specific to the development of curriculum aligned to NGSS are only now emerging. Curriculum developers, educational researchers and adopting school districts alike now have a rubric called the Educators Evaluating the Quality of Instructional Products (EQUiP) from Achieve, Inc. that gives “the science education research community a new tool for designing and evaluating materials for their fit to NGSS,” (Roseman, 2015, p. 3). Ideally, materials created for NGSS will include not only the met criteria of disciplinary core ideas, science and engineering practices and crosscutting concepts, but also “whether the three dimensions *work together* in the material to help students make sense of phenomena or to design solutions for problems” (Roseman, 2015, p. 3). Using EQUiP, developers from Investigating & Questioning our World Through Science & Technology (IQWST) built and tested hands-on curriculum units for middle school students in 2013 with the intent of reviewing student performance over three years. In this case study, IQWST curriculum builds on scientific concepts, like energy, over time by directly listing the data analysis and modeling strategies used in the unit, along with other literacy strategies, and measure learning through pre- and post- gain benchmark assessments (Roseman, 2015, p. 8). Learning outcome results were high, indicating a “strong contribution to inter-unit coherence on energy to student learning”

(Roseman, 2015, 6). A similar philosophy is within the *Journey* passage scope and sequence plan. The use of the EQUIP rubric, and the IQWST and other developers to measure efficacy in this Research Case Study will be essential for further development of curriculum materials, especially for alignment to NGSS, which is part of my continuing research to build *Journeys*.

Literacy is significant in achieving scientific literacy because literacy is “the importance of being able to understand and explain – in clear language – the meaning of fundamental scientific concepts... central to science literacy” (Glynn, 1994, p. 1058). Scientific literacy is the “knowledge and understanding of scientific concepts and process required for personal decision making, participation in civic and cultural affairs, and economic productivity” (NSES, 1996, p. 22). In 1991, a survey of 215 high school science teachers showed that they “place a high value on the role of reading in learning science” (Glynn, 1994, p. 1069). “The use of literacy to develop conceptual knowledge [is] to seek out relationships among scientific phenomena... they learn science from literacy, and... learn literacy through science” (Moore, 2009, p. 1, 3).

Science learning gives literacy an authentic context. Students learn science concepts and comprehend text best while engaging in authentic inquiry experiences combined with reading, writing, and verbal communication. While many students learn science content through inquiry and classroom instruction alone, students who read, write and talk about science go beyond what's presented in class” (SciMathMn, 2016, p. 1).

Additionally, STEM literacy includes various strategies in reading and writing to engage students in integrated science, technology, engineering and math education:

To accomplish STEM literacy, considerable practice is needed in the selection of appropriate resources that will accomplish the dual purposes of providing content

knowledge but to also provide a glimpse into the authentic world of scientists, engineers, and others who are using these skills in an authentic way (Talley, 2016, p. 204).

Science literacy is reflected in the design of the *Journey* structure and curriculum in general, as “effective curriculum materials must provide and support opportunities for students’ sense-making,” and “analyzing and interpreting data will necessarily push the need for language-rich sense-making” (Carlson, 2014 para. 8). An overlap of standards from NGSS Science and Engineering Practices and Common Core’s English Language Arts exists between “S&E Practice #8: Obtain, Evaluate and Communicate Information” and “ELA #3: Obtain, synthesize, and report findings clearly and effectively in response to task and purpose, respectively” (NGSS@NSTA, 2011). *Seeds of Science – Roots of Reading* is an inquiry-based science curriculum that embeds reading and writing. According to a 2010 review in AAAS’s *Science*, “this experimental curriculum shows advantages on measures of science learning, vocabulary acquisition, and writing fluency” (Pearson, 2016, p. 461). Through reading and writing prompts, a reading passage embeds scientific vocabulary as well as provide case study narratives of scientists and engineers in order to solve problems using data interpretation. Reading and writing prompts allow for students to synthesize science concepts from multiple scientific strands, explore explanations for phenomena that they may not have ready access to, and elaborate on their existing and new knowledge of the phenomena.

If you practice elaboration, there’s no known limit to how much you can learn. Elaboration is the process of giving new material meaning by expressing it in your own words. When you space out practice at a task... you interleave the practice of two or more subjects, retrieval is harder and feels less productive, but

the effort produces longer lasting learning and enables more versatile application of it in later settings” (Brown, 2014, p. 5).

Technology and global literacy are important in general science education as students learn how to solve problems in a growing global economy, especially as citizen scientists. According to the Partnership for 21st Century Skills, “using technology in today’s classroom, students can provide examples of how new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research,” (2009, p. 20). This is just one example of Information and Communications Technology (ICT) Literacy (21st Century Skills, 2009). Both local and global perspectives are included in the theme of the *Journey*, including opportunities for students to reflect on how a research topic is relevant in their region and explore the research conducted by others in the field worldwide. According to the P21 Partnership for 21st Century Learning, key subjects for students must extend beyond science and reading “as schools must promote an understanding of academic content at much higher levels by weaving 21st century interdisciplinary themes into key subjects, including global awareness and environmental literacy.” (21st Century Learning, 2007, p. 2). Citizen science, or the direct contribution or collaboration of students with a scientific community, “refers to efforts in which volunteers partner with professional scientists to collect or to analyze data” (Trautmann, 2013, p. 103). College and Career Readiness standards also play a role in cultivating informed citizens through an emphasis in reading and writing in science:

Much of the work to define college and career readiness to date has focused on the content knowledge and skills high school graduates must possess in English

and mathematics - including, but not limited to, reading, writing, communications, teamwork, critical thinking and problem solving. (Achieve, 2013, para. 1).

The Science and Engineering Practices of NGSS include “Asking Questions and Defining Problems” for each grade span (NSTA, 2012, p. 4). In middle school, students use graphs to identify relationships in data and construct graphs using large data sets. Data analysis in the form of interpreting graphs is required in science education as “students need to make sense of the features of graphs—including labels, scale, shape, noise, and patterns—to describe, depict, and evaluate claims regarding scientific phenomena” (Lai, 2016, p. 1). In a 2016 report, middle school students may be able to “interpret straightforward graphs but not complex graphs... and lack the ability to construct graphs from narrative accounts of scientific phenomena” (Lai, 2016, p. 16). As large sets of data become increasingly easy to store and acquire in a growing technological world, practicing interpretation with real science studies with real data can be an effective problem-solving skill process. New research is being conducted by the Data Nuggets group through Michigan State University (MSU) and Biological Sciences Curriculum Study (BSCS). The goal of the research includes investigating whether the integration of real data from scientific research into grade 6-10 classrooms will increase students’ quantitative reasoning in the context of science (Sculthesis, 2015, p. 1). The Data Nuggets program was designed “in response to teacher requests for lessons that would help students meet quantitative learning skills” and “are built from ongoing research” (Sculthesis, 2015, p.19). MSU received a \$1.1 million grant from the National

Science Foundation and is currently conducting a four-year study on the effectiveness of Data Nuggets (MSU, 2015, p. 1).

“Engineering education has outstanding potential to increase conceptual understanding of STEM disciplines for all P-12 learners while also increasing awareness of and interest in the role engineers play in supporting and advancing humanity” (Brophy, 2008, p. 369). The emphasis of engineering in the form of design challenges is prominent through the Next Generation Science Standards and the *K12 Framework for Science Education* in the Engineering Design Core Ideas for Engineering, Technology, and Applications of Science, ETS1. However, engineering principles from Core Idea ETS2: Links Among Engineering, Technology, Science and Society are also significant, particularly for the influence of engineering and technology through the ETS2.B Influence of Engineering, Technology, and Science on Society and the Natural World Core Idea (Framework p. 212):

The fields of science and engineering are mutually supportive... Advances in technology provide scientists with new capabilities to probe the natural world at larger or smaller scales. In addition, engineers’ efforts to develop or improve technologies often raise new questions for scientists’ investigation (Framework, 2012 p. 211).

Embedding engineering and science concepts in reading passages is a way to include NGSS engineering practices, performance expectations, and disciplinary core ideas. Engineering is Elementary (EiE), an elementary engineering curriculum by the Boston Museum of Science, incorporates reading activities with design projects that link to science content. The program is currently studying possible increases of understanding science concepts embedded in the engineering curriculum and the impacts of this

curriculum. Overall, students “make statistically significant gains on their understanding of engineering and technology concepts when their post-tests are compared to pre-tests” (Brophy, 2008, p. 377).

The sections of a *Journey*, and their multimedia *Waypoints*, correspond to specific categories from the above areas. *Journeys* are built from the ground up to align to NGSS and are intended to culminate all of the above principles of literacy with scientific literacy, research and the significance of various pedagogical features including data analysis, engineering education and citizen science.

METHODOLOGY

I developed the *Journeys* concept, and the pilot for this capstone, with a vision of secondary science teachers using easy-to-read interactive reading passages to supplement their quality hands-on instruction in the classroom. Through an engaging reading and writing passage with data analysis practice sets and multimedia *Waypoint* formative assessments, *Journeys* are designed to foster scientific literacy in students so that they will be involved citizens in their own scientific community and knowledgeable of corresponding careers. *Journeys* elaborate on key points from the NGSS Component Ideas in science and engineering, and are produced by interviewing scientists and engineers with the goal to engage students in their findings, as well as to expose them to phenomena they may not otherwise be exposed to.

As I began travel with NGSS and *Journey* production in mind, I interviewed scientists and engineers in the field and synthesized their stories into various *Journey* drafts. I’ve visited individuals in Iceland, Puerto Rico, Greece, China and, most recently,

various Cayes along Belize's Barrier Reef. Scientists are often asked to focus on one factor of an ecosystem in their scientific research. My goal was to synthesize multiple researchers' results into one *Journey* to give students a background of the whole ecosystem and the research conducted. Additionally, I observed that educators want to highlight more current science issues, especially with NGSS aligned material, but may not have easy access to salient materials of current research. I began to assess these demands in my preliminary research and teacher surveys in April 2015 to help guide and broaden my investigations.

Given the concurrent timeline of my travels, *Journey* production, and teacher interviews and feedback, parts of my methodology are circular. They are outlined first with my scientist interview protocol and then with the overall production of the *Journey* structure. Finally, teacher surveys, interviews and feedback forms were used as an instrument to gather data in order to revise the pilot and final vetted draft of *Journey: Researching Dolphins*.

Scientist Interview Protocol

When my travels began in the spring of 2015, I began interviewing, and then recording, scientists and engineers in the field for an eventual NGSS aligned *Journey*. My approach relied on previous experience in understanding that scientists do not always know how to translate their research into NGSS aligned, grade level-appropriate material. I chose scientists based on a variety of criteria, mainly through word-of-mouth and recommendations by my scientific peers. In addition to interviewing some scientists domestically, I have met with scientists in Iceland, Greece, and most recently Belize,

where I met researchers measuring the effects of cruise ship tourism on dolphin and manatee populations through the Belize's Barrier Reef. While the focus of the pilot *Journey* was on researchers that were not present during my time in Belize, I did meet with supporting groups directly involved with the projects during this trip and corresponded directly with the highlighted researchers, Eric Ramos and Dr. Caryn Self-Sullivan, through email and phone interviews. No set of questions apply from one researcher to the next (there is no attached appendix as a result of this). I've slowly gained experience and sophistication with my technique, including using video and recording technology, in order to build skills and a solid protocol for interviewing both professionals in the field and local citizens. To date, the marine focus of my endeavors is purely coincidental and the scope of production will increase to all fields of scientific research. I just happen to love dolphins.

Journey Structure

Each section of a *Journey* corresponds to a specific pedagogy, content, and/or societal demand present in general science education and NGSS guidelines, and concludes with an interactive formative assessment. The *Journey's* sections are *Job, Opportunity, Unique, Real and New Science, Engineering* and *You!* The sections of a *Journey* are called 'legs' and the multimedia formative assessments are called 'Waypoints,' which are similar to the terms used in an actual nautical journey. These terms are summarized in an at-a-glance glossary in Appendix A. The *Journey* passage is designed to take students through the legs as if they were on a research journey of their own. Students read and respond to the material as though they had conducted the

investigation themselves, which, depending on the region in which they live or the materials available to them, may aid in delivery for teachers.

The *Journey* begins with its first leg called *Job*, which introduces students to the problem that they will solve in the *Journey*, and to the current jobs that are possible in that field of research. It provides an overall context for what the student can expect and the expectations of the student by announcing what the final mission of the *Journey* entails (in the case of *Researching Dolphins*, a report to the Belizean government about dolphins and tourism). Then, in the *Opportunity* leg, students are introduced to other real scientists doing similar research through a case-study narrative approach, and some skills they will need to develop in order to help solve the problem. The *Unique* leg highlights the context of the scientific phenomena with embedded academic vocabulary and why the research is needed and scientifically significant. Here the information is sequenced for the student in such a way that the *Journey* is in context but not all of the information is provided to solve the problem. *Real Science* and *New Science*, the next two legs, together demonstrate some real and new examples of actual research results and provides data in the form of tables, graphs and charts for students to practice analyzing and interpreting. Students also make predictions based on trends in the data in *New Science*. *Engineering*, the next leg, introduces students to some form of engineering needed or used in the current research. This leg emphasizes interactions between innovations and science (Brophy, 2008). Finally, the *You!* leg provides a performance-based assessment and encourages involvement of students to correspond with the scientific community and engage in citizen science. The passage's order, following the consistent JOURNEY

acronym, is designed for consistency in delivery within a wide-spread audience. Most *Journey* legs conclude with multimedia and open-ended questions as formative assessments called *Waypoints*, akin to physical landmarks used in navigation. Examples of *Waypoints* include interactive maps with open-ended questions, quiz-like video clips with open-ended questions, or sketches and thinking maps. A full description of each leg's purpose, the *Waypoint* formative assessment focus, and an example based on the pilot *Journey: Researching Dolphins* is included in Appendix B.

Each *Journey* includes an interactive PDF for students to complete and a teacher document with facilitation notes, standards-alignment information, and answers. Students complete the *Journey* in print or as a fillable PDF that is then turned in electronically to the teacher. A complete, non-interactive version of the *Journey: Researching Dolphins*, reviewed and updated as a result of the treatment, is included in Appendix C.

Instrumentation

Working with teachers through surveys, interviews and feedback for nearly a year, I incorporated a variety of techniques in order to create the structure of the *Journey*, get feedback on the structure and content of the *Journey*, and use the feedback to complete the resulting *Journey: Researching Dolphins*. First, I conducted a preliminary survey in April 2015 to get a snapshot of what teachers know about NGSS and what technology access they had. It was with this background knowledge that I invented the *Journey* acronym and basic structure. I then conducted interviews with other teachers asking for their feedback of *Journey: Researching Dolphins* from December 2015-February 2016. Using their feedback, I incorporated specific revisions into the final draft

of the *Journey: Researching Dolphins*. The below Data Triangulation Matrix Table highlights the process of using the above techniques to answer my research questions.

Table 1: *Data Triangulation Matrix*

Research Question	Curriculum Development	Teacher Survey or Interviews	Teacher Feedback
How will secondary science teachers of all experience levels find NGSS aligned interactive reading passages, or <i>Journeys</i> relevant?	Development of <i>Journeys</i> in the field with scientists	Pre-treatment interview for general background	Feedback Instrument Upon pilot <i>Journey</i> Review and Open Feedback upon review of final <i>Journey</i>
How will secondary science teachers use <i>Journeys</i> to incorporate relevant, current science topics with NGSS in their classrooms?	Development of <i>Journeys</i> in the field with scientists	Preliminary Survey and Pre-treatment interview for general background	Feedback Instrument Upon pilot <i>Journey</i> Review and Open Feedback upon review of final <i>Journey</i>
Will teachers find these resources useful, and in what ways?	NA	Pre-treatment interview for general background	Feedback Instrument Upon pilot <i>Journey</i> Review and Open Feedback upon review of final <i>Journey</i>

Data collection with the survey and feedback form included Likert questions on relevance and usage. This approach yielded quantitative results to accompany the mainly qualitative data I gathered from all three instruments. Coding of qualitative responses were categorized based on the structure and intent of the *Journey* leg the response was made in.

Preliminary Surveys. In April 2015, I sent an email invitation asking peers to complete a voluntary confidential survey based on their background knowledge of NGSS. I used my own website called teachingcontinuum.com (now expired) and an embedded survey tool for teachers to enter their voluntary responses. The survey was designed as preliminary research tool to identify what teachers knew about NGSS, what their technological access was to online material, and what their background in the Earth and Space sciences was. I compiled the responses from 33 teachers into a spreadsheet to get a snapshot of what teachers knew and needed early in NGSS implementation. I also used it to help me understand how technology could be utilized to implement a *Journey* reading passage. The questions, as well as the original action research questions no longer in use, used for the survey are included in Appendix D. The respondents were not reviewers of the *Journey*; they were not interviewed later, yet those that expressed interest in further review may be contacted in a future project.

Teacher Interviews and Feedback. From December 2015 through February 2016, I conducted 16 phone interviews with a variety of teachers in K-12 science representing a dozen US states. The teachers were recruited from email invitations and the MSSE networks on Facebook. Participating teachers were a mixture of peers in the field, MSSE, social media, and all had varied backgrounds. I entered detailed notes in a spreadsheet while voice-recording each 25-minute interview, following my question protocol with as much fidelity as would allow given varying backgrounds in teaching science and NGSS. The interview question set is provided in Appendix E. Participating teachers were then given a draft of *Journey: Researching Dolphins*, with a separate a feedback form, and

asked to return the form within one week. The feedback form is included in Appendices F. I received 11 completed forms, which I compiled into one spreadsheet for quantitative and qualitative comparison in order to understand the merits of the structure and use of the *Journey*, and how it can be improved upon.

Using the working draft of *Journey: Researching Dolphins*, and the compiled suggestions from teachers via interviews and feedback forms, I continually updated the *Journey* to reflect both their expertise and my own discoveries while in the field. The working draft of *Journey* that was sent to teachers is included in Appendix G. Finally, the process of feedback based on the completed *Journey* began in April, 2016, and is expected to be a continual process through onsite development. In order to assure validity, I based conclusions on triangulating responses from teachers on the surveys, interviews, and the peer review on feedback forms. Reliability is maintained through a scoring system in the feedback forms, combined with areas for open-ended responses by the peer review. A complete overview of *Journey* improvements based on specific feedback is included in the Data Analysis section. In best practice, follow up interviews will be scheduled with scientists to assure factual accuracy in writing.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board (Appendix H), and compliance for working with human subjects was maintained.

DATA AND ANALYSIS

The preliminary surveys were used to guide and develop the initial *Journey* structure and the teacher feedback was used to create the final structure. The following

analysis draws from the results of 33 responses from teachers in a survey from April 2015, 16 interviews with teachers through February 2016 and 11 of their resulting feedback forms upon review of the pilot *Journey: Researching Dolphins* through March 2016. Finally, brief updates based on newer reviews from participating teachers based on the final *Journey: Researching Dolphins*.

Preliminary Surveys

The responses from 33 teachers nationwide in April 2015, were compiled into a master spreadsheet and created a snapshot of what teachers knew and needed to know about early NGSS implementation as well as their preferred access to technology.

Overall, teachers were somewhat knowledgeable of NGSS Engineering, Technology and Application of Science Standards (39%), the Science and Engineering Practices (45%), and their current knowledge of NGSS overall (39%). Half (51%) of the teachers received some form of professional development in their districts.

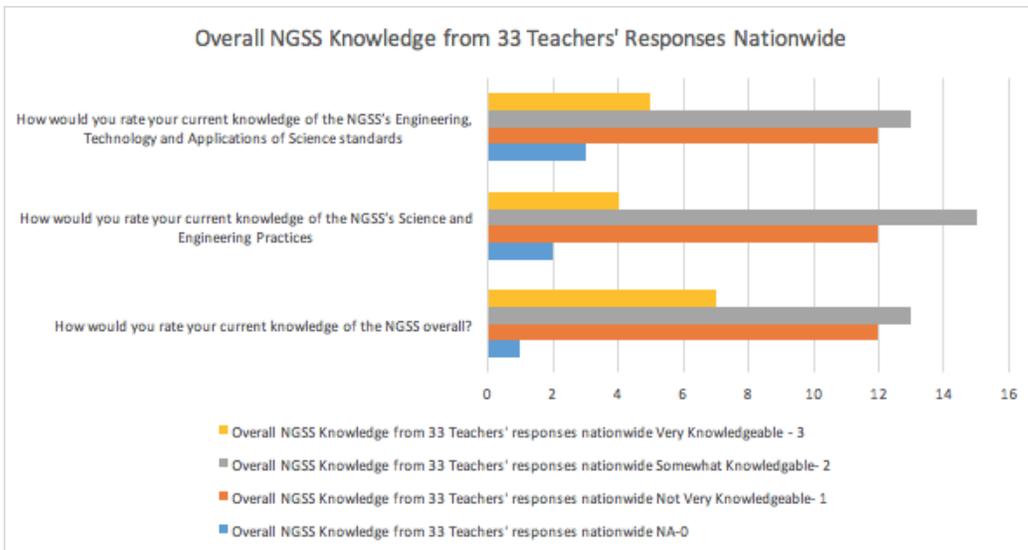


Figure 1: Overall NGSS Knowledge from 33 Teachers Nationwide, (N=33).

Only four (12%) of the respondents reported that their state or district adopted NGSS at that point, including one school in California.

This snapshot of existing NGSS knowledge was helpful to understand what practices the *Journeys* should focus on, including data interpretation and computational thinking, as well as to outline very clearly in a teacher document what standards would be highlighted through the course of the *Journey*. Future *Journey* production would include more teacher facilitation and feedback, especially for the integration of multiple content and process standards.

The wide range of access to technology, and the preferred usage per week, varied greatly across responses. Sixteen teachers had access to a computer lab and preferred to use it once or twice per week. 17 teachers had 1:1 access for students on laptops, and 9 had 1:1 access on tablets. One teacher commented that Chromebooks might be considered in future surveying for technology use within classrooms. Technology and blended-learning, or the varied delivery of curriculum within classroom and online learning, were both surveyed. Teachers were asked about their opinions regarding NGSS and blended-learning, and the results were mixed responses including concerns that students cannot be self-taught through a computer, encouragement that NGSS and blended-learning are headed in the right direction, and “if done well, blended learning can be a huge asset to a class.” The challenging aspect of curriculum development in the early 21st century is finding a balance between all digital vs. all print or some combination thereof. Using this data helped me determine a delivery system that is practical based in today’s secondary science classrooms.

Interviews and Feedback

The 16 participating teachers who were interviewed had an average of 10 years of experience with a mixed background of formal and informal education for grades K-12. Teachers were asked the same set of 12-14 questions depending on how much NGSS applied to their current situation. Most did not have experience teaching under the new NGSS, but some had familiarity with it through curriculum development or professional development in their districts. The secondary teacher from California, a NGSS-adopting state, had no updated material on engineering or NGSS, extremely limited access to technology, and reported that she struggled getting access to data that students can interpret, especially for climate change. The secondary teacher from Arkansas explained that there is a strong emphasis on hands-on instruction through student investigations and data collection, but less on reading or application of the data and investigations' purpose. When asked how they used reading passages in their classrooms, teachers reported various methods including as introductions, weekly-follow ups, and case studies or news clips to elaborate on the current issues in science today. Eight teachers reported students need real-world scenarios they can relate to. When asked about how much their students get to practice with data, most reported that it is not as often as they like (ranging from once every two weeks to once per month if at all), and one teacher emphasized that “students need to be able to think more critically about data, and given more value to numbers. They can read the info, but they can't tell the importance of the data, identify trends in increases or effects on other factors.” These conversations guide the production of a *Journey* to include data analysis practice, especially with graphing, in the *Real* and

New Science legs. Three teachers reminded me about the importance of literacy strategies that support the instruction of English Language Learning (ELL) and to keep English as Second Language (ESL) populations in mind, as well as struggling readers. A K-12 instructor concluded that she is “always looking for ways for students to thinking along a computational way of thinking” and strives for students to “read outside the textbook.”

At the end of each interview, teachers were asked an open-ended question on what they wanted in an ideal science classroom. Their answers ranged from “Give more context and materials so that students can analyze, ask questions, and design experiments,” to “provide materials with more relevance,” to “focus on literature to start, and find an easy way to find what level the students are reading on without a reading specialist.” Many teachers reported that their students need more practice with data and real-world scenarios to connect with science issues. I found this feedback particularly helpful for developing the primary and secondary purpose of each section of the *Journey*’s legs, and further developed the significance of the *Job* leg to reflect real-world scenarios.

Using the 11 feedback forms submitted by teachers regarding their review of the draft *Journey*, I compiled a list possible actionable updates for the *Journey* structure using the salient points from interviews and feedback. The table summarizing feedback by section, the resulting actionable change, and research focus (NGSS alignment, relevance, and usefulness) is included in Appendix J.

Based on my research and subsequent efforts to create a final *Journey* draft, secondary science teachers of all experience levels find NGSS aligned interactive reading

passages, *Journeys*, useful and relevant. They provide context for science and the scientists behind the work. Below is Table Two showing the alignment of the draft passage to the NGSS dimensions, which were combined with open-ended responses of where improvements were needed, including assuring that students create solutions to problems and ask questions about phenomenon, which were included in the highlighted NGSS points for this particular *Journey*.

Table 2: *Teacher Feedback, NGSS alignment of draft Journey: Researching Dolphins (N=11)*

Alignment	Number/Percentage teachers (N=11) reported Aligned
Is the passage aligned to the Performance Expectation?	10
Is the passage aligned to the Disciplinary Core Idea?	10
Is the passage aligned to the Science & Engineering Practice?	9

Teachers reported that the draft *Journey* was 100% relevant, contained current science information, and contributed to student's understanding about current science issues. Pertinent topics for *Journeys* were suggested including climate science education, in which two secondary science teachers reported a lack of resources. "Students are given the opportunity to directly link human activities with what is going on in the environment," reported a secondary science teacher. The relevance of the topic for all science student audiences must be considered, and the inclusion of new research techniques is a possible way to increase this.

Table Three, below, shows responses regarding the usefulness of the pilot and demonstrates a range of opinions on how useful the passage is in its draft state.

Table 3: *Teacher Feedback, Usefulness of draft Journey: Researching Dolphins (N=11)*

Usefulness	Responded Agree	Responded Neutral	No Response
1. Will the students find the passage useful? Why or not?	4	4	3
2. How does the passage contribute to students' skills in data interpretation?	5	1	5
3. How does the passage contribute to students' conceptual understanding of scientific phenomenon?	5	1	5

For question #1, the respondents that agreed were both elementary and secondary teachers and provided additional feedback such as “It’s real world,” and “The passage is engaging with lots of information, visual supports and activities for the reader to use the new information.” Those respondents that responded as neutral commented that additional facts and features would be helpful to make the passage more useful. These include “usefulness is relative and may depend on students’ interest in marine biology,” “videos to give overviews on dolphins and the scientists that research them,” and “students might view it as another worksheet to do at school if not presented well and with enthusiasm.” On the use of data analysis and interpretation, a secondary science specialist in Montana stated it is “simple enough for them to work with, but also important and directly relevant to the study’s finding. I especially like the emphasis on process, critical thinking, and the scientific method which is incorporated throughout the *Journey*.” One teacher was unable to turn in official feedback but reported in a follow up phone call that the passages are unique in that unlike case studies, “they go more in depth and provide rigor to promote critical thinking through problem solving in stages.” He stated that he liked the structure of *Journeys* and that both teacher and student documents

should emphasize the role of small and whole group interactions per leg. All of the above statements are helpful in developing the content of the *Journey* further, and contributed in part to the technology/interactivity suggestions listed in Appendix I and to the actionable changes listed in Appendix J.

Next steps for *Journey* development include further teacher feedback based on the completed draft shown in Appendix C. Note that a continual teacher feedback system on the site development, the final *Journey: Researching Dolphins*, and future *Journeys* is still under production. The following describes the beginning of this process at time of printing. Using formatted and updated material in *Researching Dolphins*, I've asked for updated reviews, with reports as to strengths and weaknesses, from science curriculum specialists who have had limited exposure to this project, if any. A curriculum specialist in the Houston area reported that the *Journey's* strengths include "engaging interactive format with topics that students will want to read more and can be used as an assessment and completed in 1-2 class periods." As for areas of improvement, she reported that a rubric is necessary in both the teacher and student documents and suggested that a full summative assessment accompany the final section for ease of use. Another secondary curriculum specialist in Missoula, Montana performed an in-depth analysis of *Researching Dolphins* and stated that it "is a nice blend of simplicity, scientific method and presentation skills." She agrees that further guidance is needed in defining student performance through rubrics and criteria, like in the *You!* section. Her full review is provided in Appendix K.

Some ways that secondary science teachers can use *Journeys* are with small groups and teams. The majority of teachers (81%) felt that a *Journey* could be completed in small groups. Using a flexible delivery system through interactive PDFs and interactive formative assessments, reading passages help students see a full spectrum of research and the Science and Engineering Practices. Finally, the variety of interactive features can be added at the beginning and middle of the *Journey*, including as a ‘hook’ for students to be engaged in the beginning of the *Journey* (possibly in the *Job* or *Opportunity* legs) as well as in the *Waypoints*, which will be produced and hosted on a website called STEMJourneys.org.

INTERPRETATION AND CONCLUSION

My first research question focuses on how teachers will find *Journeys* both aligned to NGSS and relevant. In order to be properly aligned to NGSS and accompanying standards, such as Common Core ELA/Math, the *Journey* context and multimedia *Waypoints* must include tasks that build student skills for achievement, such as creating solutions to problems and questioning. Three teachers reported that the *Journey’s* NGSS alignment can be increased by assuring that students create a solution to a problem. Relevance can be strengthened by asking students to relate the current research to their own communities. Four teachers commented they liked the backgrounds of the highlighted scientists. The relevance in *Unique* can also be strengthened through student thinking maps and graphic organizers to relate the scientific information to something they know and can relate to. Six teachers reported that using case studies and

science articles, preferably brief and in student language, is a strategy used to elaborate on a science topic.

My next question focuses on how teachers will use *Journeys*. The preliminary survey was a helpful snapshot of teachers' technology access and preferences. Only 10 teachers (30%) reported that they prefer students to use technology at least once per week in the classroom, and the majority preference for usage (laptops vs. tablets for other) was 60% laptops (17 teachers). Given the varied technological access and preferences from this survey, I steered early stages of *Journey* development with versatile delivery in mind and chose to build interactive PDFs until future development of online blended-learning platforms is explored. Interactive PDFs are independent of internet usage or 1:1 laptop/computer lab access and can be emailed/posted for group or individual access. Such flexibility gives teachers and classrooms the ability to complete work collaboratively in small groups, with intermittent whole group discussions and viewings. For example, the majority of teachers reported in feedback that *Journeys* could be used in small groups, and interactive features like videos could be shown in whole group settings. The curriculum specialist reported that she would take this a step further and use the pilot as a performance assessment. Links from the PDF will go to STEMJourneys.org and provide access to the multimedia *Waypoint* formative assessments including introduction videos, interactive maps with popup information, and video quizzes.

Finally, my last question was on how teachers will find *Journeys* useful and in what ways. Overall, teachers reported that *Journeys* are useful and "allow students to participate in finding solutions to a real-world environmental issue and observe first-hand

the approaches, assumptions, and analytical methods used by scientists currently doing this work.” The literature and teacher feedback repeatedly shows that science-literacy resources are useful and at times necessary to emphasize scientific concepts. Strategies include students asking questions, summarizing main concepts, and the “ability to explore a problem from various aspects,” as reported by one secondary science teacher who served as a High School science curriculum developer in her school district. More than one teacher commented on the importance of using general literacy strategies, including alignment to Common Core ELA, in the multimedia *Waypoint* formative assessments and not just the reading passage itself. Graphing was favored in the *Journey’s Real and New* legs, as giving students practice for data analysis was reported eight times in teacher interviews as an area that needs curriculum support, as well as where students struggle. For example, a third grade teacher reported that students “struggle with data,” which is consistent with a high school Biology teacher’s claim that students struggle to look for patterns in data and graphs, and another’s that “it is hard for them to translate book knowledge into chemical and real world knowledge.” In his review of the draft *Journey*, he reported that the “data is presented throughout the passage in a logical manner, and I think it is reasonable to see students understanding how analyzing the data is relevant to understanding the relationships being discussed.” Usefulness can be strengthened by modeling the reading experience as though students were researchers themselves, embedding vocabulary from multiple science strands, and continuing to strengthen the multimedia *Waypoint* formative assessments. Based on the actionable changes and suggestions provided in teacher feedback forms in Appendix J,

the whole *Journey* vocabulary strategies, particularly with open-ended questioning in the *Unique* leg, with more teacher facilitation and performance rubrics, to be even more useful.

The following clarifies the scope of this research assignment, which was to build a supplemental and elaborative NGSS aligned resource based on my field research, teacher correspondence, and writing/media background. Student performance or feedback was not measured in this action research and is planned for future projects. *Journeys* by themselves are not designed to be comprehensive curriculum for hands-on activities in the Exploration or Explanation section of a typical 5E learning cycle developed by Roger Bybee with BSCS. *Journeys* would be used for the Elaboration section as students apply their knowledge to a real-world scenario. While there is no substitute for hands-on learning in the classroom, *Journeys* provide supplemental material to integrate concepts from different strands of science and elaborate on phenomena through data analysis practice. Future production will include integration of Earth and Space Disciplinary Core Ideas, with other topics, in a single *Journey*. Feedback on the final draft completed *Journey: Researching Dolphins*, or any other feedback onsite, is in the beginning stages of implementation within the scope of this capstone. As I continue international travel to meet with scientists and engineers to translate their stories into more *Journeys*, I anticipate making the pilot *Journey: Researching Dolphins* available to teachers online through STEMJourneys.org. Ideally, they will be able to provide feedback on the final draft and new interactive features directly through the website during the 2016-17 school year.

Each *Journey* should go through similar objective feedback systems using the techniques modeled in this action research project, with some improvements. In order to be more effective, I will create more concise action research questions and feedback questions in the feedback form, including yes/no questions in addition to more Likert-based questions for each section of the *Journey*. Now that I'm familiar with the advantages and best practices of this research process, I would likely delegate further research to a third party to keep objectivity and validity in results.

VALUE

This action research project rests entirely on my philosophy that the most effective curriculum is the one that teachers build together, with and for other teachers. This approach naturally leads *Journeys* development to two major areas moving forward. The first is to work with piloting teachers who will implement the *Journey* in their classes to collect student completion data. This group would ultimately form a focus group, composed of science, STEM and ELA teachers that collaboratively adds ideas for complementing *Journey* with hands-on activities and summative assessments. The second is to build the online interactive portion of the project, including all multimedia *Waypoints*, again with teacher feedback regarding access and user experience. Moving forward, I hope each of the members in my guidance team, and the many great individuals who have volunteered their time and expertise to help build this vision, will continue as critical writers and reviewers as we steer production of more *Journeys* and multimedia resources.

Given the glimpse I got into the participating teachers' perspectives, I want to further develop what secondary teachers need, including complementary hands-on activities and summative assessments. For future *Journey* development, I see a news-oriented blog on STEMJourneys.org in which teachers and students interact with interactive media, possibly even the scientists themselves. I see active involvement with classrooms to get feedback from students and collect their questions for scientists to answer, etc., and I aim to produce a similar model that will be effective as an elementary program. I anticipate taking the list of suggested topics that teachers provided, including but not limited to climate science and climate change education, agricultural sciences, pathology and neuroscience, engineering, and evolution education in order to work with credible scientists in the field to produce more *Journeys*. This process should begin after a thorough analysis of the NGSS Science & Engineering Practices and Performance Expectation topics in order to produce and build upon a comprehensive framework.

Similar to my previous experiences in designing and coordinating curriculum programs, I learned that teacher feedback can often be wide-ranging yet include highly specific suggestions that are invaluable to guiding the construction of curriculum. I have built multiple curriculum programs from the ground up, both with and without a provided framework. Teacher feedback was instrumental in my previous projects, usually as a result of teachers using the curriculum and reporting errors. In this particular endeavor, I built an original curriculum design idea and a delivery system around the new NGSS concurrent with teacher feedback, slightly akin to a design-based research approach. As a

result, the *Journey* structure, delivery and content is almost completely designed by the steering of the teachers themselves.

"These 'Journey' projects are quite good and an excellent conceptual way to tie so many things together!"

- Dr. Gerald Nelson, Montana State University

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APPENDICES

APPENDIX A

AT-A-GLANCE *JOURNEY* GLOSSARY

Journey- An interactive NGSS aligned reading passage that integrates multiple science strands' content and brings current science and engineering issues to secondary science classrooms. Each *Journey* is broken into the following sections (called legs) which focus on a practice or skill highlighted in NGSS and general science education:

- J - Job
- O - Opportunity
- U - Unique
- R – Real Science
- N – New Science
- E - Engineering
- Y – You!

Leg- section of a *Journey*, akin to a leg of a race or a journey in a real-world setting.

Waypoint- a formative assessment included at the end of most legs of a *Journey* that can be interactive through multimedia *Waypoints* questions and open-ended responses. They are designed to keep learning on track and help teachers measure learning in action.

APPENDIX B

JOURNEY STRUCTURE, PEDAGOGY, WAYPOINT FOCUS, AND EXAMPLE

<i>Journey Leg</i>	Pedagogy, Primary Purpose	Pedagogy, Secondary Purpose(s)	<i>Waypoint</i> Formative Assessment Focus	<i>Researching Dolphins</i> example
<i>Job</i>	Provides primer for overall context as though the student were a researcher tasked to complete a study. Poses the actual problem to students.	Emphasizes relevance by asking students to list what similar problems and careers they know of in their area.	Students create a graphic organizer based on a list of careers and technologies that are significant in this field, be it marine or terrestrial, and ask questions about the careers listed in this <i>Journey</i>	Students are asked by the government of Belize to conduct a scientific study on the effects of boat tourism on dolphin populations in her Barrier Reef. They are introduced to careers in marine biology/mammalogy, oceanography, and tourism management
<i>Opportunity</i>	Introduces students to the other real scientists doing similar research. Their backgrounds are included to give context just as they were characters in a story.	Begins sequencing pertinent information students will need to understand the current research.	Students list questions about research conducted, including differences of studies conducted in different study areas. Students access an interactive Google Map with preloaded descriptions.	Eric Ramos and Dr. Caryn Self-Sullivan are among one of many scientists who conducts long-term studies in the area.
<i>Unique</i>	Brings context to the scientific phenomenon and topic in ways that the students may not be able to readily access on their own, including descriptions and embedded academic vocabulary. Models scale and overall geographical study area to emphasize the need for regional focus in science.	Highlights why the research conducted is scientifically significant. Emphasizes global awareness and environmental literacy.	Students ask questions about the natural history/science covered thus far, and list facts to elaborate on the organisms, or phenomena highlighted, and the role in the environment. They are provided sketching and open-ended questions when appropriate.	Dolphin behavior and habitat, as well as human activity are introduced together to highlight a potential conflict in tourism and habitat destruction. Concept of scale must be covered as well. Other Earth and Space standards are embedded. Full list of NGSS Life and ESS is included in the teacher page.

<i>Journey Leg, continued</i>	Pedagogy, Primary Purpose	Pedagogy, Secondary Purpose(s)	<i>Waypoint</i> Formative Assessment Focus	<i>Researching Dolphins</i> example
<i>Real Science</i>	Provides actual research results from highlighted scientists including graphs and tables.	Provides data analysis and interpretation practice. Information is sequenced and scaffolded in order to highlight the salient points of the current research.	Students answer open-ended questions after analyzing the data set, label diagrams, and sketch their interpretation of results. Items include strategies such as compare/contrast.	Several studies are reviewed and compared and students create a bar graph relating habitat to dolphin populations and then connect that knowledge to the importance of understanding the factors at play in an ecosystem.
<i>New Science</i>	Focuses on new or emerging studies related to this topic/content and gives students the final "aha" information they need to solve the problem.	Provides some flexibility in <i>Journey</i> construction depending on the topic. Can be a small inset of science facts or a larger part emphasizing a specific study.	Students list and describe possible solutions to the problem, or outline the steps to their scientific study. Students achieve learning goals in a stepwise fashion while using gamified techniques (Haskell, 2013).	Upon discussion with the local Belizean citizens, students (as researchers) find that the biggest direct threat tourism brings to Belize is not the big cruise ships, but the smaller passenger boats that transport cruise passengers to shore.
<i>Engineering</i>	Introduces students to some form of engineering completed for either the studies in question or another feat overall. Provides context of integration of science and engineering in the form of a case study and not an engineering design challenge.	Incorporates description of the significance of using engineering in science or other engineering concepts, including identification of constraints and criteria. Emphasizes interactions between innovations and science. (Brophy, 2008)	Students outline how the engineering used in this <i>Journey</i> can be used in their area, or create their own solution to a problem using the Engineering Design Process, depending on the topic of a <i>Journey</i> .	Introduction to using drones for dolphin studies in tandem with other studies. Ideally this part would include more on the mechanics involved with the drones (camera, GPS location, etc.) and how the data is used in wildlife monitoring.

<i>Journey</i> Leg, continued	Pedagogy, Primary Purpose	Pedagogy, Secondary Purpose(s)	<i>Waypoint</i> Formative Assessment Focus	<i>Researching Dolphins</i> example
<i>You!</i>	Focuses on informing the student of their role as a citizen scientist for either this study or other related projects they can directly contribute to. The purpose of the task and importance is provided for them.	Provides a performance assessment welcoming multimedia and a summary of the main concepts covered in the <i>Journey's</i> topic.	Students complete a multimedia task, such as a Public Service Announcement or slideshow presentation on how they solved the problem from the Job section. They are provided with at least one citizen science opportunity based on the <i>Journey</i> topic, including ways of finding their own data sets to create their own graphs.	Students record a presentation to the Belizean government with their policy recommendations. They go to oceanexplorer.noaa.gov to list other actual research projects currently in progress.

APPENDIX C

COMPLETED, VETTED, *JOURNEY* AS OF JUNE 1, 2016

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Welcome to your Journey! Student Instructions

For each part of your journey, or leg, read the material and answer the Waypoint questions. Follow your teacher's instructions for how to fill in the document and access the interactive Waypoints.



Bottlenose dolphin. Courtesy Eric Ramos, 2012

J is for Job

You've been asked by the government of Belize to conduct a scientific study on the effects of boating tourism on dolphin populations in her **Barrier Reef**. Belize is a small country in between Mexico and Guatemala on the Caribbean Sea. Belize is experiencing a 6000% increase in tourism, especially with large cruise ships. You have some experience observing dolphins from a research boat, and you know how hard it is to spot them because they spend 99% of their time underwater, and they only come to the surface for air. To make scientific observation more difficult, the sun and light have to be just right in order to record the dolphins' dorsal fins in detail. Don't forget that dolphins may come to the boat or veer away from the boat, depending on whether or not they want to play, or if they are hungry and need to leave to find food. How are you going to study the responses of dolphins to boat traffic in a shallow reef if you have so few tools and resources available to you?

Your job is to observe, monitor, and describe the dolphin populations of as many locations of Belize's Barrier Reef as possible, and then prepare a report for the Belizean government. The government will use your report policies to promote tourism and to protect the environment. Your work is significant in science and for the future of the Caribbean Sea, and others around the world will learn from your techniques. You will get more instructions on how to prepare your report at the end of this Journey. Before you start your journey, however, you should know that you're going to need to explain the role of dolphins in this ecosystem and interpret data in order to make a graph.

Waypoint Interactive! ...for the Job leg

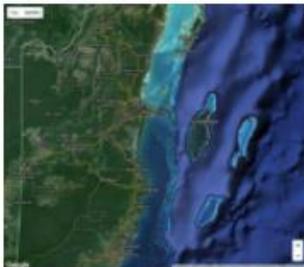


Figure 1: Belize mainland, Ambergris Caye, Turneffe Atoll, Lighthouse Reef, Glovers Reef

Go to [{ \(this link\) }](#) and locate the interactive map for the Job leg. Click on the various pins on the map and read through the descriptions of the types of jobs and research conducted in the area. Then answer these questions on another sheet:

1. What systems do marine biologists study? Marine mammalogists? Oceanographers? Create a T-chart that compares terrestrial ecology and marine ecology.

2. Create a thinking map comparing the tools that the scientists use to observe and monitor organisms in this ecosystem and what they can be used for.

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G is for Opportunity



Image 1: Eric Ramos
OceanicSociety.org

Meet Eric Ramos. He studies dolphin behavior with the Oceanic Society in Belize's Turneffe Atoll outside of the Barrier Reef. Bottlenose dolphins (their scientific name in Latin is *Tursiops truncatus*) have complex communication patterns and he wants to understand their calls to each other, especially when they are looking for food. How does their communication change if their food source is altered? He's got some new techniques for studying this, but we'll get to that soon. What do dolphins eat and why would they want to be in the reef? The corals and reef system, including mangrove and sand islands (called Cayes, pronounced "keys"), provides adequate protection for marine mammals to **forage**, or feed, and reproduce. Imagine that the ocean is a desert, and each Caye is like a tiny oasis for dolphin families.



Image 2: Dr. Caryn Self-Sullivan
Surlean.org

Meet Dr. Caryn Self-Sullivan. She studies manatees and dolphins in the Drowned Cayes inside of the Barrier Reef. She compares populations of both marine mammals in the shallow waters of the reef and makes observations about how tourism affects them. "Ever since I was a small child, I've been fascinated by whales and dolphins. My mom saved my first drawings of whales, which I still have. They are dated 1961... I finally got the opportunity to study marine biology after my kids grew up. I was 39 when I started college for the first time... Finally, as a graduate student, I started a long-term project in Belize in 1998. Today, my own graduate students continue to work on the project, known as "Manatees & Dolphins in the Drowned Cayes of Belize." You can learn more about Dr. Caryn's project on Facebook: www.facebook.com/BelizeManateesDolphins.



Figure 2: Two marine mammal study sites in Belize's Barrier Reef: Drowned Cayes and Turneffe Atoll

Neither Eric nor Dr. Caryn live in Belize, so they must coordinate their research missions with locals in Belize and plan far ahead in order to get as much data as possible in a few short weeks a year. You're going to help them out. Once you visit the Turneffe Atoll with Eric, and the Drowned Cayes with Dr. Caryn, you make some observations about the environment and what is going on.

Waypoint Interactive! ...for the Opportunity Leg

1. Go to this Google Map link { {need to provide, make sure that Belize City, Placencia, State Bank, Turneffe Atoll (Oceanic Society), and Drowned Cayes (Spanish Lookout Caye and Swallow Caye Preservation Area) are highlighted and outlined } } and locate the area of Eric's research and Dr. Caryn's research. What is the latitude and longitude of the Drowned Cayes? What sea is the reef protecting Belize from? What are two other observations you make about the geographic locations of these two field sites?

2. What are two questions that you can ask Eric and Dr. Caryn about their scientific careers?

3. What do you know about dolphins? What are three questions that you have about them or other marine mammals.

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U is for Unique



Image 5: Dolphin's dorsal fins can be used for identification of individuals in a population.
Photo courtesy Dr. Caryn Self-Sullivan

What makes Belize's Barrier Reef unique? It is the most diverse and productive coral reef system in the western hemisphere, with 44 species of reef-building corals and home to more than 700 species of vertebrate fish (Ritz, 2011). The atolls and reefs abundant with sheltered **habitats** for flora and fauna, resulting in a rich **biodiversity** of organisms. Reefs create areas well-protected from the open ocean so there are not a lot of high waves. The reef itself is filled with coral. If you want to see an atoll and scuba dive its limestone formations and unusual walls inside of a reef, then you're going to visit Belize because there are only four atolls in the western hemisphere, and three are located in Belize. Don't forget the Cayes because there are more than a hundred of these sand or mangrove islands throughout the reef. This makes Belize's Barrier Reef the second largest in the world, second to the Great Barrier Reef in Australia.



Figure 3: Dolphin sightings in Turneffe Atoll, 2014

Maybe that's why tourism is increasing in popularity there. From scuba diving, snorkeling, boating and fishing, tours promoting the chances to see manatees and bottlenose dolphins are also very popular in Belize, or "Nature's Best Kept Secret." Tourism is a big economic engine for Central America's Belize and accounts for 18-25% of the nation's economy and about 30% of jobs for local residents. In 2014, more than 1.2 million visitors came to Belize. Between 2013 and 2014, airport arrivals in Belize City increased by about 7%. However, arrivals by cruise ship rose by nearly 43%, bringing more than 968,000 tourists through the Caribbean Sea to the Belize City ports (Belize Tourism Board, 2016). The number of tourists has increased over 6000%! It seems like the secret has gotten out!

How does this affect dolphin populations? As you speak with professionals and locals in the area, you learn that researching dolphins in Belize is just one way to measure the health of an **ecosystem**, or a community of the living organisms and non-living components in an environment. Because dolphins rely on fish found in the **seagrass** and **mangrove** beds in the shallow reef along the Cayes, they are considered indicator species on the health of the entire ecosystem. They are top predators in the area. If dolphin populations remain consistent, then the health of the ecosystem would be considered stable. If their populations decline, then the stability of the ecosystem may be altered because of habitat degradation. According to Eric, this would occur as a gradual change and that's why we need to monitor individual dolphins and populations through long-term studies.

In order to study the dolphin populations in Turneffe Atoll and Drowned Cayes, only two of the areas affected by higher rates of tourism because of their proximity to Belize City, you will need to understand more about the natural history of the area. Turneffe Atoll, just outside of the main reef, is composed of sand, seagrass, corals, and mangrove forests on land and along channels and shorelines. Turneffe Atoll's features shelter and provides reproductive areas for relatively small-sized fish in seagrass. Drowned Cayes is similar, but it is located in the Barrier Reef and has very shallow waters filled with lots of mangrove islands filled with channels, or boggles, that go between them.

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Just because Belize has a protective reef doesn't mean that we shouldn't pay attention to her coastline on the mainland. Habitat degradation along coastlines is a concern because of agriculture and tourism. Overall, destruction of mangrove forests, damage to the sea floor by heavy boat traffic, increase in litter and pollution, and reduction in water quality are the main **anthropogenic**, or human-caused, concerns that face both Belize's coastline and reef habitats.

Waypoint Interactive! ...for the Unique Leg

1. What is an ecosystem? Create a sketch of the various components in a marine ecosystem and label them.

2. What is an indicator species? List an example of an indicator species where you live?

3. Describe the Barrier Reef's corals, atolls, mangrove forests. What makes this habitat unique?

4. Watch this clip for your Waypoint Interactive! and answer the habitat questions in the video.

{ {Insert video of 'daily double' like video quiz for students to answer questions once they see the mangrove roots in movement and brief introduction to the the importance of mangroves. Include manatees even though not highlighted in text, can provide context of them eating the grass which is important. Include co-evolution of reefs and diversity in this area because of the x, y, and z} }

Interactive Question 1 (match to video): Why is seagrass important in this ecosystem? Mangroves?

{ {insert OER field} }

Interactive Question 2 (match to video): Think of two questions you have about the natural history of barrier reefs (it doesn't have to be Belize) and the organisms that use them as habitat.

{ {insert OER field} }

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R is for Real Science

Over the past 25 years, some reefs in Belize have degraded, resulting in their current average coral and fish abundances to fall below the Caribbean average (Marks and Lang, 2006). Scientists have documented a global decline in dolphin populations. Threats to dolphin and wildlife populations include:

- bycatch, or the accidental capture of dolphins, in fishing nets.
- overfishing.
- interference with natural behaviors.
- habitat degradation that impacts prey abundance.

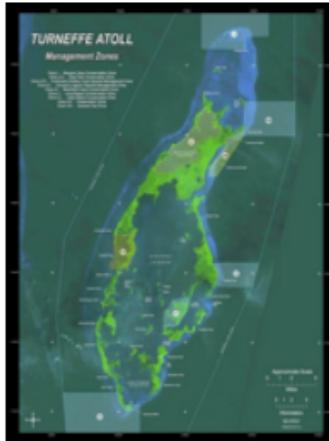


Figure 4 Managed areas in Turneffe Atoll.

You need current science to report to the Belizean government on bottlenose dolphins, including their habitat use, site fidelity and behaviors. But as you'll learn from Eric and Dr. Caryn, research is also done on the existing studies first. That way you know where to start your research. As you research, you conduct a literature review and find the following studies that have been completed in the area.

The Turneffe Atoll (Grigg & Markowitz, 1997):

Researchers E. Grigg and H. Markowitz published a paper on their findings from data collected on the habitat types at the Turneffe Atoll. Their hypothesis was the probability of sighting bottlenose dolphins at a particular site within the dolphins' range can be predicted from the nature of physical and biological characteristics of that site.

Table 5: Grigg & Markowitz's Study on Habitat Types and Dolphin Sightings in Turneffe Atoll, 1997

Environmental Characteristics of the Turneffe Atoll include different mixes of these primary features:	
Physical and Biological Characteristics	Significance to bottlenose dolphin habitat
Sand	
Seagrass substrate	
Coral reef nearby or patches of coral	
Exposure to open sea and tidal movements	
Protection from predators (sharks)	
Proximity to mangrove creek (called a bogue)	

Grigg and Markowitz categorized dolphin sightings by group size: Either 0 (no dolphins), 1-3, 4-6, or greater than 6. Below is a map in *Diagram 1: Site Numbers* where dolphin sighting data was collected during their study.

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Grigg and Markowitz categorized dolphin sightings by group size: Either 0 (no dolphins), 1-3, 4-6, or greater than 6. Below is a map in *Diagram 1: Turneffe Atoll Site Numbers* where dolphin sighting data was collected during their study.

Diagram 1: Turneffe Atoll Site Numbers

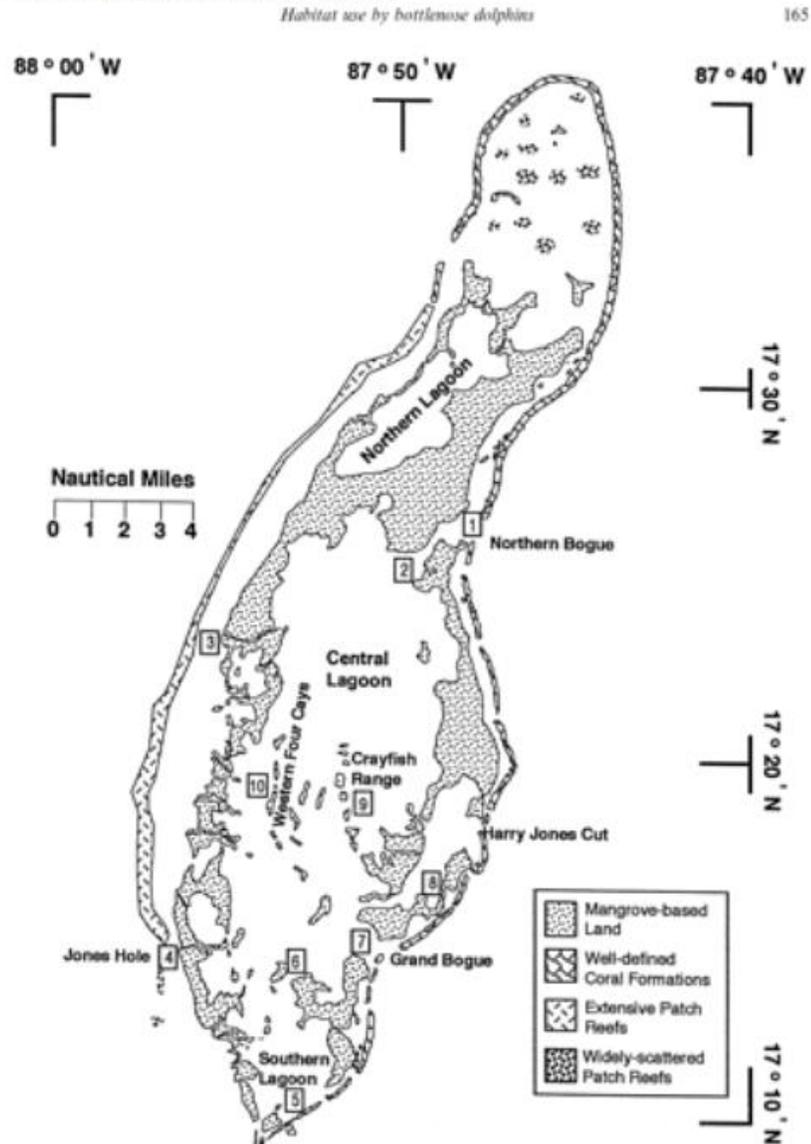


Figure 1. Map of Turneffe Atoll, showing ten focal study sites. (Map courtesy of the Cetacean Behavior Laboratory, San Diego State University.)

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Data Chart 1: Data Collection Results

Dolphin sighting data by site					
Site Number	Site Description	Dolphin Group Size			
		0	1-3	4-6	>6
1	Largely sand and coral substrate; exposed; adjoining coral reef; resort in area; windward side of atoll	17	6	1	0
2	Sand, seagrass, substrate; relatively protected; easy access to bogue/open ocean	14	11	4	1
3	Seagrass substrate; relatively protected; adjoining coral reef; western edge of mangrove creek; leeward side of atoll	16	1	3	2
4	Sand, patch coral, seagrass substrate; somewhat protected; western edge of mangrove creek; leeward side of atoll	12	11	2	5
5	Sand, patch coral, some seagrass substrate; adjoining coral reef; exposed; resort in area; windward side of atoll	14	12	3	1
6	Thick seagrass substrate; protected; easy access to bogue/open sea	19	2	2	3
7	Sand, seagrass, and abundant patch coral substrate; exposed; adjoining coral reef; windward side of atoll	10	17	2	3
8	Seagrass substrate; protected; easy access to bogue/open sea	18	5	4	0
9	Thick seagrass substrate; protected; central lagoon and adjoins lagoon mangrove cayes	16	5	1	2
10	Thick seagrass substrate; protected; central lagoon and adjoins lagoon mangrove cayes	17	3	0	2

Grigg and Markowitz used the Site Characteristics to group sites into Habitat Types with Defining Characteristics – see table below.

Using the sighting data by Site Number above, add up the total number of Dolphin Group Size sightings by Habitat and input those into the table below.

Data Table 1: Defining Characteristics

Habitat Type	Sites Included	Defining Characteristics	Dolphin Group Size			
			0	1-3	4-6	>6
1	9, 10	Central lagoon sites; protected; thick seagrass substrate				
2	2, 6, 8	Easy access to bogue/open sea; protected; thick seagrass substrate				
3	1, 5, 7	Bogues; exposed; windward side of atoll; sand, some seagrass, and lots of patch coral; coincide with reef breaks				
4	3, 4	Creek mouths; leeward side of atoll; seagrass, some patch coral; adjoin reef				

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Waypoint Questions for Real Science Leg

1. What habitat features do you think might make those sites preferred areas for dolphin foraging? Label the Diagram 1: Site Numbers with a colored pencil showing the areas that the highest probability for foraging dolphins.

2. Define the scale of this study. Is it over a large or small study area? How does it compare to studying the Drowned Cayes? Hint, there is no perfect answer to this. Some scientists spend their career studying microscopic habitats, and others massive solar systems within galaxies. Just because we study dolphins in one area doesn't mean that we don't have to study dolphins in multiple areas, especially since dolphins are found all over the world except for the poles. Why do we need to define the scale in our study? Describe scale in terms of the area being studied and its significance to this and other habitats.

3. Create a bar graph that illustrates Data Table 1: Defining Characteristics. On the x-axis is Group Size; on the y-axis is Number of Dolphin Groups. Use four different colors of bars so that each bar within a Group Size represents Habitat Type. Be sure to include a title and key legend.

4. Calculate the probability of sighting foraging dolphins in each Habitat Type. (Assume that foraging dolphins are those in groups of 1-3 and 4-6.)

5. What Habitat Type is the greatest probability that you would sight foraging dolphins?

6. How would you explain the importance of foraging in this Habitat Area? What factors does the ecosystem need in order for dolphins and other mammals to survive in this area?

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Real Science in Drowned Cayes



Figure 5: Drowned Cayes study area with bogues indicated by shading (Petersen 2001).

Swallow Caye Wildlife Sanctuary in the Drowned Cayes (Petersen, 2001):

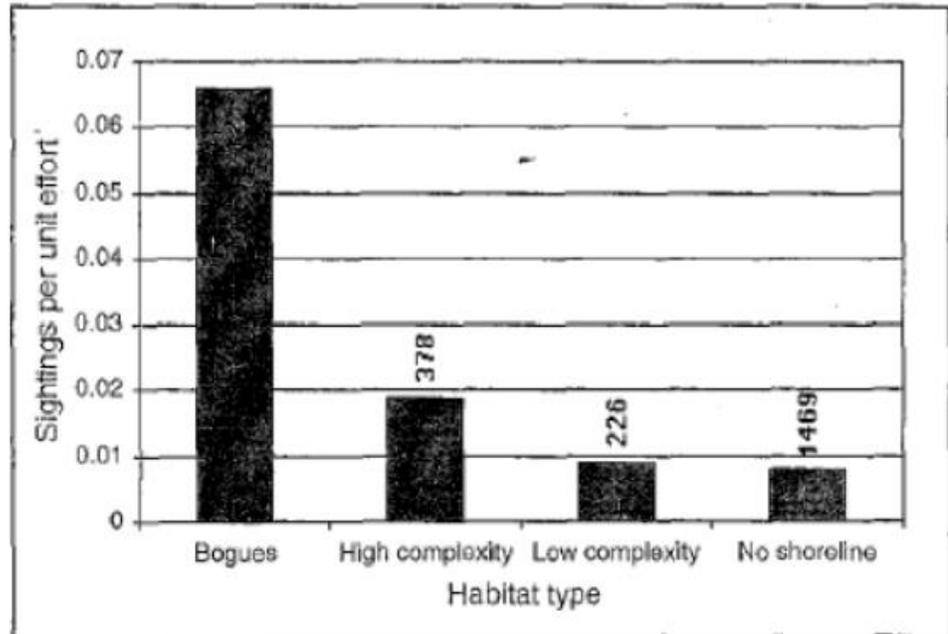
Swallow Caye Wildlife Sanctuary is located in the Drowned Cayes area, has strict tourism regulations in place even though it is relatively close to Belize City, has more boat traffic than Turneffe. In 2001, Heidi Petersen collected data there and reported that potential prey was protected by the barrier reef as well as mangroves, seagrass and coral.

In her study, she recorded the number of dolphin sightings divided by the amount of time spent on the water (not counting the extra time spent watching dolphin behavior), or "per unit effort" and the habitat they were found in. The habitats were bogues and other shorelines. Those results are shown in the bar graph below.



Image 4: Mangrove and bogue in Drowned Cayes, Belize's Barrier Reef. Photo by J. Rowell

Figure 6: Petersen's Dolphin Sightings by Habitat Type, 2001



Recall that mangrove channels, or bogues, are created by mangrove creeks and are common in this shallow Barrier Reef area. If a survey grid with bogue mouths or bordered a bogue, then it was considered to have high complexity; all other shorelines were considered low complexity. Petersen further reported that most all of the sightings were of dolphins foraging. Explain how studying the foraging areas of dolphins is important understanding an ecosystem. What biotic and abiotic interactions are occurring in this

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N is for New Science

You probably already know that dolphins use **echolocation** to communicate, just like bats. The sound waves reflected back and forth using specific calls are how dolphins can hear each other through the water medium. They have really complex communication, even 'accents' or regional dialects depending on where they reside the longest. Eric is studying how boat vessel noise can interfere with dolphin foraging. If a dolphin is hungry, noise from a boat may deter them from their food source further, especially if they can't hear each other. Clarify 2015 study How does he use the hydrophones to study? I didn't realize the disconnect between drones (visual) and hydrophones (aural) until now. Need to clarify and insert, either in here or in Engineering.

In 2015, Dr. Caryn and her team visited the Drowned Cayes to continue previous researchers' findings, as well as work with locals. She wants to find out whether human activities, especially heavy ships and cruise boat for tourism, have negatively impacted dolphin population. Using Experiment.com, she secured funding for the first project of this type since Peterson's 2001 study. She set out to repeat Peterson's study using the same methods to determine if there were changes in dolphin and manatee habitat use, site fidelity, and behaviors. Their final results should be available soon, check out link to see the status. What do you think they found?



Figure 7: Drowned Cayes and mangrove forests with bogues.

As you research more about the area, you start to realize that there are so few places for those heavy ships to go. The water is so shallow (only a couple of feet deep in most parts), and there are few passes in the reef of the big ships to come in from the Caribbean Sea. Cruise ships anchor at State Bank and then dozens of smaller passenger boats, called tenders, move the passengers to the shore at Belize City, back and forth. The big cruise boats are from different companies from all over the world. As you speak with locals, you record a claim that they have directly observed an increase in litter, increased boat traffic overall, and boat-caused damage to the animals themselves, especially during mating season which is usually in the fall.

Waypoint Interactive! ... for the New leg

1. What are the main concerns to dolphin and mammal populations in the above three paragraphs. Are they anthropogenic in nature, and if so, how? Explain.

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2. Using the table below, summarize and compare the scientific investigations. List the scientists' approaches both then and now for the Turneffe Atoll and Drowned Caye locations.

Comparison of Research Conducted at Turneffe Atoll and Drowned Cayes		
	Turneffe Atoll	Drowned Cayes
Research Dates and Scientists		
Variables measured		
Results known to date		
Similarities to these studies and field sites		
Differences in these studies and field sites		

3. How will you explain the changes over time to the Belizean government in your report? What are some possible solutions?

E is for Engineering



Image 8: Eric Ramos and team preparing a drone for observations. OceanicSociety.org

Check this out! You can study wildlife non-invasively with Unmanned Aerial Surveyors, or drones. Just launched in 2015, the Oceanic Society's Turneffe Atoll crew used remotely operated and unmanned vehicles—including aerial quadcopters, autonomous aquatic drones, and a remotely operated underwater vehicle—to collect data on bottlenose dolphin behavior and communication, threats, and habitat use.

The data collected by the drones includes video, audio recordings, and photographs. These are non-invasive methods, along with field observations and acoustic listening are used by the Oceanic Society. During their 2015 field season, participants recorded 15 manatee sightings and hundreds of dolphin sightings, which included two new dolphins they added to their dolphin identification database!

Waypoint Interactive! for the Engineering Leg

1. Think of the equipment you'd like to use to study the natural world in your area. What would you use and why?

2. What are some constraints to using equipment like this in your study, and how would you adjust for this?

3. Go to <https://www.oceanicsociety.org/blog/1356/2015-belize-field-season-in-review> to find summary of the findings from the 2015 field season. What are some of the updates citizens on the current status of dolphin and manatee habitat in the Turneffe Atoll Marine Reserve and Belize Field Station have? Include a description of dolphins and their habitat in Belize and the importance of monitoring in the area.

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Y is for You!

It is time to create your report to the Belizean government. Here is a list of what needs to be included in your multimedia presentation.

In three minutes, summarize what government officials need to know about a) changes in populations, b) changes in studies and b) changes in tourism in the last 25 years.

- List your "Researcher Name," the "Name of your Team," and "Organization"
- Include all of the bolded vocabulary terms in your report.
- List the marine **mammals** that can reside in the Barrier Reef.
- Make three recommendations of policies that locals, tourists, and scientists can follow in order to reduce or eliminate concerns over habitat degradation in the area. Remain objective.
- Include specific examples that you are aware of that might be similar to where you live.

Follow all of your teacher's guidelines for assignment production and submission, including this completed journal.

Good luck in your Journeys and safe travels.

Going the extra mile...

A great place to learn more about current research conducted in oceanography is oceanexplorer.noaa.gov.

You might be able to help identify individual dolphins for a comprehensive bottlenose dolphin database that researchers have been working on. It is important to monitor individual dolphins in a population, and using a **dorsal fin** identification system with photographs, this is possible. Because funding is limited, scientists like Dr. Caryn are always looking for volunteers to help with this process. To learn more about the ways you can directly contribute to this project, go to STEMJourneys.org and post your questions online!

Journey: Researching Dolphins
Teacher Page, Draft June 1, 2016**Objectives & Learning Outcomes**

Journeys are integrated, interactive reading passages and data analysis practice sets designed for students to elaborate on their understanding of scientific phenomena through literacy exercises in real-world scientific scenarios.

The purpose of this *Journey* is to lead students through a research mission in the field research on marine mammals and effects of tourism. They experience of variety of data collection methods, emphasize the role of dolphins in a reef ecosystem, and identify concerns of tourism on natural habitats. After reading the passage and watching the video, students will:

- Explain the role of dolphins in an ecosystem consisting of barrier reef habitat.
- Use information from different data tables to create and interpret a graph.
- Analyze some effects of human activity on the biodiversity of an ecosystem, including tourism.
- Create a plan and multimedia report for long-term monitoring of organisms in an ecosystem.

Estimated Time Required

1-2 class periods, depending on data interpretation and analysis and final report.

Technology and Materials Needed

1 Student Page per student, Internet access for provided links, including Google Maps

Safety Considerations

Follow school and district policies for safe and responsible internet usage.

Implications for Instruction

After reading through the passage's Student Page, decide on method for student groups vs. individual work. Any hands-on activities that need to be administered should be completed before the beginning of this elaboration reading passage.

A *Journey* can be completed in print or using an interactive PDF using current Adobe software. If using a PDF, make sure students can receive and send the completed file. Links to videos are provided in each *Waypoint* for each leg of the *Journey*. Make sure students have access to the links or project the interactive components for each *Waypoint* when appropriate. While not required, students and teachers are invited to post and answer questions on STEMJourneys.org blogs.

In addition to the completed Student Page, teachers are encouraged to create a small quiz or ask students to create a portfolio segment based on what they have learned. The portfolio segment can include a brief presentation, illustration, infographic, or other demonstrative form of assessment.

Academic Vocabulary Terms: ecosystem, indicator species, barrier reef, mangrove forest, forage, biodiversity, seagrass, echolocation, anthropogenic, water column, dorsal fin, mammal carrying capacity, habitat, feedback, biosphere, coevolution.

Strand and Reading Level: NGSS Life Science, High School 10th grade

Find
habitat
Previous

HS.Interdependent Relationships in Ecosystems		
<p>HS.Interdependent Relationships in Ecosystems</p> <p>Students who demonstrate understanding can:</p> <p>HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. [Clarification Statement: Emphasis is on quantitative analysis of relationships among interdependent factors including boundaries, resources, climate and competition. Examples of mathematical comparisons include graphs, charts, histograms, and population changes gathered from simulations or historical data sets.] [Assessment Boundary: Assessment does not include deriving mathematical equations to make comparisons.]</p> <p>HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. [Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.]</p> <p>HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. [Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.]</p> <p>HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]</p> <p>HS-LS2-8. Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. [Clarification Statement: Emphasis is on: (1) distinguishing between group and individual behavior, (2) identifying evidence supporting the outcomes of group behavior, and (3) developing logical and reasonable arguments based on evidence. Examples of group behaviors could include flocking, schooling, herding, and cooperative behaviors such as hunting, migrating, and swarming.]</p> <p>HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]</p> <p style="font-size: small; text-align: center;">The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i>.</p>		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Using Mathematics and Computational Thinking Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> ▪ Use mathematical and/or computational representations of phenomena or design solutions to support explanations. (HS-LS2-1) ▪ Use mathematical representations of phenomena or design solutions to support and revise explanations. (HS-LS2-2) ▪ Create or revise a simulation of a phenomenon, designed device, process, or system. (HS-LS4-6) <p>Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> ▪ Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-LS2-7) <p>Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.</p>	<p>LS2.A: Interdependent Relationships in Ecosystems</p> <ul style="list-style-type: none"> ▪ Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. (HS-LS2-1),(HS-LS2-2) <p>LS2.C: Ecosystem Dynamics, Functioning, and Resilience</p> <ul style="list-style-type: none"> ▪ A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2),(HS-LS2-6) ▪ Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS-LS2-7) <p>LS2.D: Social Interactions and Group Behavior</p>	<p>Cause and Effect</p> <ul style="list-style-type: none"> ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS2-8),(HS-LS4-6) <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> ▪ The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (HS-LS2-1) ▪ Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. (HS-LS2-2) <p>Stability and Change</p> <ul style="list-style-type: none"> ▪ Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6),(HS-LS2-7)

NGSS & Common Core Standards Alignment (HS-Life Science focus)

Performance Expectation

HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

Science & Engineering Practice: Using Mathematics and Computational Thinking

Use mathematical representations of phenomena or design solutions to support and revise explanations. Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

Disciplinary Core Idea LS2.A Interdependent Relationships in Ecosystems

Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance number of individuals) of species in any given ecosystem.

Crosscutting Concept: Scale, Proportion, and Quantity

Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Performance Expectation

HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Science & Engineering Practice: Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Disciplinary Core Idea LS4.D Biodiversity and Humans

Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity

through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate changes. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes for recreational or inspirational value.

Crosscutting Concept: Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable.

Common Core ELA

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS2-1), (HS-LS2-2)

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Reading Level information – estimated 11th grade

Highlighted Scientists

Eric Ramos is a PhD Candidate in Animal Behavior and Comparative Biology at the University of New York. He conducts research on dolphins in the Turneffe Atoll off the coast of Belize and has been teaching with the Oceanic Society since 2010.

Dr. Carol Self-Sullivan and Jazmin Garcia are scientists with the Nova Southeastern University's Oceanographic Center. Their dolphin and manatee studies in Belize's foraging and nursery habitat near the Drowned Cayes began in the 1990s and continue through 2015 to include tourism and land use impacts. Her research is conducted out of the Hugh Parky Adventure Lodge in Spanish Lookout Caye on the southern end of the Drowned Cayes in the Belize Barrier Reef.

Journey Authors

Jess Rowell researches current science, as well as research in action, by traveling around the world and creating the vision for *Journey* passages for secondary science educators. Jess Rowell is a science curriculum writer and coordinator focusing on the Next Generation Science Standards and science literacy in the 21st century.

With a background in biology, chemistry, and journalism, Lisa “Kersch” Kerscher

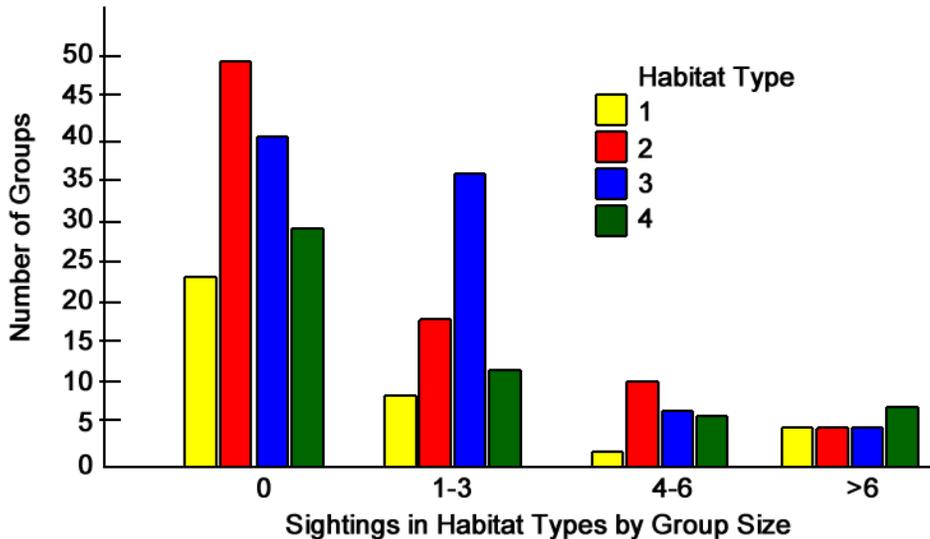
specializes in her passion to synthesize research and real-world challenges into digestible and deliverable science curriculum for our next generation of emerging scientists and engineers.

Answer Key

R is for Real Science

Habitat Type	Sites Included	Defining Characteristics	Dolphin Group Size			
			0	1-3	4-6	>6
1	9, 10	Central lagoon sites; protected; thick seagrass substrate	23	8	1	4
2	2, 6, 8	Easy access to bogue/open sea; protected; thick seagrass substrate	49	18	10	4
3	1, 5, 7	Bogues; exposed; windward side of atoll; sand, some seagrass, and lots of patch coral; coincide with reef breaks	41	35	6	4
4	3, 4	Creek mouths; leeward side of atoll; seagrass, some patch coral; adjoin reef	28	12	5	7

Waypoint



Calculate the probability of sighting *foraging* dolphins in each Habitat Type. (Assume that foraging dolphins are those in groups of 1-3 and 4-6.)

Probability = desired outcome/total outcomes = foraging group sightings/total sighting opportunities

Habitat Type 1: $9/36 = 0.250$

Habitat Type 2: $28/81 = 0.346$

Habitat Type 3: $41/86 = 0.477$

Habitat Type 4: $17/52 = 0.327$

What Habitat Type is the greatest probability that you would sight foraging dolphins?

47.7% probability of foraging dolphin sightings in Habitat Type 3, "Bogues; exposed; windward side of atoll; sand, some seagrass, and lots of patch coral; coincide with reef breaks."

How would you explain the importance of foraging in this Habitat Area? What factors does the ecosystem need in order for dolphins and other mammals to survive in this area?

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APPENDIX D
SURVEY INSTRUMENT

Research Questions and Survey conducted April 15-May 15, 2015

The following bulleted questions were created in order to get a baseline understanding and to attempt to answer the following, original, Action Research question(s):

- “What support and tools do teachers need to implement effective STEM education, including NGSS Earth and Space standards, as well as Science and Engineering Practices?”

“How would you rate your current knowledge of the NGSS overall?”

“How would you rate your current knowledge of the NGSS Science and Engineering Practices?”

“How would you rate your current knowledge of the NGSS Engineering, Technology and Applications of Science standards?”

Participation is voluntary and you can choose to not answer any questions you do not want to answer and/or you can stop at anytime.

Teacher Information for 2014-15 School Year

Date Initial Survey Taken:

Name (FIRST NAME, LAST INITIAL):

Email (optional):

School and Grade taught:

How long have you taught?

What subjects have you taught?

Highest Degree you have earned?

District and City:

Number of students in subject (total):

Subjects taught and time of subject instructional time per week:

Gender ratio of students, on average:

Would you like to participate in an interview and follow-up survey? Yes No

Possibly, contact me for more details (please list email address).

Part I: Professional Development

1. Are you interested in receiving professional development in space education? Why or why not?

2. Are you interested in receiving professional development in the NGSS Science and Engineering Practices?

What training have you already had?

- 3. Are you interested in receiving professional development in the NGSS Earth and Space standards?
- 4. Are you interested in curriculum development? What topic?
Please complete this sentence. Regarding professional development, what would be important to me is.....

Part II: Next Generation Science Standards

- 5. How would you rate your current knowledge of the Next Generation Science Standards overall? Please indicate one choice

Very knowledgeable
Somewhat knowledgeable
Not knowledgeable
NA

If you have knowledge, through what means did you get it?

- 6. Has your state adopted the Next Generation Science Standards? Please indicate one choice.

Yes No

- 7. Are you in a decision-making or coordination role for choosing and implementing curriculum, and the NGSS, if applies? Please indicate one choice.

Yes No

Please explain your answer.

- 8. How would you rate your current knowledge of the NGSS's Science and Engineering Practices? Please indicate one choice.

Very knowledgeable Somewhat knowledgeable Not knowledgeable NA

- 9. How would you rate your current knowledge of the NGSS's Engineering, Technology and Applications of Science standards? Please indicate one choice.

Very knowledgeable Somewhat knowledgeable Not knowledgeable NA

- 10. Please list any other comments from Questions 5-9 here, if applicable. Good question.

Part III: Earth and Space Education

- 11. Please indicate the preferred length of an Earth and Space unit in your classroom, using a topic of your choice.

12. To your knowledge, what are your state/district/school's current guidelines for incorporating Earth and Space education? Please include information about scope and sequence. If secondary, please indicate if Earth and Space is incorporated in each grade or as separate courses.

13. Please list any other comments from Questions 11 and 12 here, if applicable.

Part IV: Blended Learning

For Questions 14 -17, the term blended learning will be defined as “a formal education program in which as student learns at least in part through online delivery of content and instruction with some element of student control over time, place, path and/or pace and at least in part at a supervised brick-and-mortar location away from home.” (Staker, 2012).
Period goes here

14. What is your current technology availability in your classroom? Please select the option that best describes your availability for the subject that you teach.

- My school does not have any technology for students to use.
- My school has a computer lab that students access 1-2 times per week.
- My school has a computer lab that students access 3-5 times per week.
- My school has 1x1 technology for students using laptops (each student has a laptop).
- My school has 1x1 technology for students using tablets.
- Not applicable.

To what degree do your student have access to a computer at home?

15. What is your preferred method of using technology in the classroom?

- I prefer that technology is not available for students to use.
- I prefer a computer lab that students access 1-2 times per week.
- I prefer a computer lab that students access 3-5 times per week.
- I prefer 1x1 technology for students using laptops.
- I prefer 1x1 technology for students using tablets.
- Not applicable.

16. Using the scale below, please indicate to what degree you feel blended learning can be utilized for all learners in your classroom, with 0 meaning not effective and 5 meaning highly effective. 0 1 2 3 4 5

Please explain why you answered the way you did on the above question.

17. Please list any other comments from Questions 14-16 here, if applicable.

Is there anything else you can think of that you wish to tell me about NGSS and/or blended learning?

APPENDIX E
INTERVIEW INSTRUMENT

Interview Questions

What state do you teach in?

What grade?

What subject(s)?

How long have you taught?

Have you taught using the NGSS before? Explain.

What types of curriculum materials have you used to teach NGSS?

Follow up question: What types of materials do you use to teach science and engineering practices?

How do you use reading passages in your teaching? At what stage of a typical learning cycle do you use reading passages?

How much practice do your students get practicing data analysis? Do you wish it to be more? Explain what you feel is most needed.

What do you want in your classroom or educational setting?

APPENDIX F
TEACHER FEEDBACK FORM

Teacher Name and Date Review Completed:	Score	Comments
Participation is voluntary and you can choose to not answer any questions you do not want to answer and/or you can stop at anytime.	1 = Agree 2 = Neutral 3 = Disagree	Please be specific. All constructive feedback, including praise, welcome.
“How will secondary science teachers of all experience levels find NGSS aligned literacy resources relevant and useful?”		
Alignment		
1. Is the passage aligned to the Performance Expectation(s)?		
2. Is the passage aligned to the Disciplinary Core Idea(s)?		
3. Is the passage aligned to the Science & Engineering Concept(s)?		
4. Is the passage aligned to the Crosscutting Concept (s)?		
5. Suggestions for improvement? (open response)		
6. Overall passage comments regarding alignment (open response)		
How will secondary science teachers incorporate current science topics with the NGSS in their classrooms?		
Relevant		
1. Do you feel the passage is relevant and contains up to date science information? Please elaborate.		
2. How does the passage contribute to students’ understanding about current science issues? Please elaborate.		
3. Overall passage comments relevance (open response)		
How will these teachers find literacy resources useful?		
Usefulness		
1. Do you think that students will find the passage useful? Why or why not?		
2. How does the passage contribute to students’ understanding of the science concept through the use data interpretation and analysis? Please elaborate.		
3. Suggestions for improvement?		
4. Overall passage comments regarding usefulness (open response)		

APPENDIX G

WORKING DRAFT OF *JOURNEY*

FOR TEACHER REVIEW, JANUARY 21, 2016

JOURNEY**Researching: Bottlenose Dolphins *Draft for Teacher Review: January 21, 2016*****Teacher Page****Objectives & Learning Outcomes**

Journeys are integrated, interactive reading passages and data analysis practice sets designed for students to elaborate on their understanding of scientific phenomena through literacy exercises and real-world scientific scenarios.

The purpose of this *Journey* is to describe how current field research on marine biology can be done with a variety of methods, to emphasize the role of dolphins in the ecosystem, and to identify the importance of data collection and engineering in science. After reading the passage and watching the video, students will be able to:

- Explain the role of dolphins in the ecosystem.
- Complete a graph using data from two data charts.
- Evaluate affects of human activity on biodiversity.
- Determine a plan for long-term monitoring of organisms in an ecosystem.

Estimated Time Required

1-2 class periods, depending on data interpretation and analysis and final assessment.

Technology and Materials Needed

1 Student Page per student, Internet access (no specialized software or maps are needed)

Safety Considerations

Follow school and district policies for safe and responsible internet usage.

Preparation

After reading through the passage and material, decide if there is any portion of the activity that would best be done in partners or small groups, depending on individual teaching styles. This activity can be done independently as well.

Scientific Vocabulary: ecosystem, indicator species, barrier reef, mangrove forest, forage, biodiversity, carrying capacity, habitat.

Procedure

Please see the Researching Dolphins: Student Page for specific instructions for students to read, proceed, and research internet information.

Assessment Suggestions

In addition to the completed Student Page, teachers are encouraged to create a small quiz or ask students to create a portfolio segment based on what they have learned. The portfolio segment can include a brief presentation, illustration, infographic, or other demonstrative form of assessment.

NGSS & Common Core Standards Alignment

Performance Expectation

HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

Science & Engineering Practice: Using Mathematics and Computational Thinking

Use mathematical representations of phenomena or design solutions to support and revise explanations. Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

Disciplinary Core Idea LS2.A Interdependent Relationships in Ecosystems

Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance number of individuals) of species in any given ecosystem.

Crosscutting Concept: Scale, Proportion, and Quantity

Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Performance Expectation

HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Science & Engineering Practice: Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by

multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Disciplinary Core Idea LS4.D Biodiversity and Humans

Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate changes. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes for recreational or inspirational value.

Crosscutting Concept: Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable.

Common Core ELA

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS2-1), (HS-LS2-2)
 RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Reading Level information – estimated 11th grade

About the Scientists

Dr. Carol Self-Sullivan and Jazmin Garcia are scientists with the Nova Southeastern University's Oceanographic Center. Their dolphin and manatee studies in Belize's foraging and nursery habitat near the Drowned Cayes began in the 1990s and continue through 2015 to include tourism and land use impacts.

About the Authors

Jess Rowell researches current science and research in action by traveling around the world and creating the vision for Journey passages for secondary science educators. Jess Rowell is a science curriculum writer and coordinator focusing on the Next Generation Science Standards and science literacy in the 21st century.

With a background in biology, chemistry, and journalism, Lisa Kerscher specializes in her passion to synthesize research and real-world challenges into digestible and deliverable science curriculum for our next generation of emerging scientists and engineers.

Student Page

Job

Have you ever wondered what it would be like to study dolphins in the wild? How do you know where they are, and if you find them, what kind they are? Is it easy to count them and monitor their population? What do you need to know about their habitat? What kind of technology would you use, and why would you even study dolphins and other marine mammals to begin with?

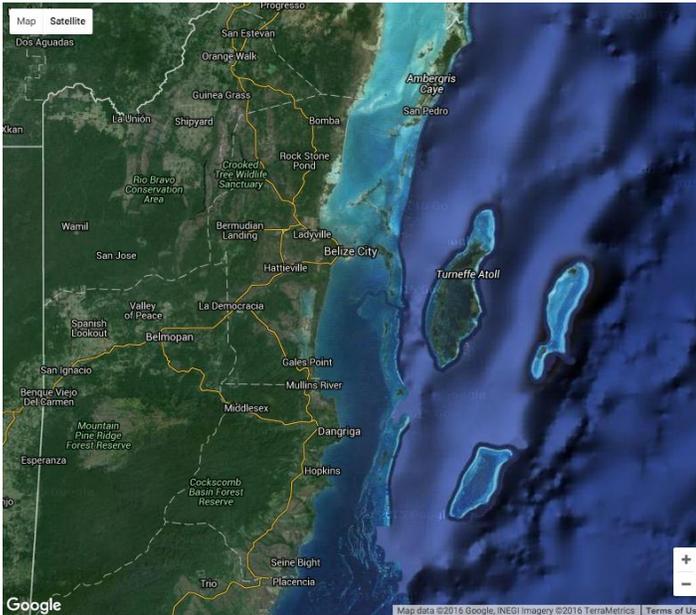
Insert images of dolphins. Mine from Greece are striped dolphins

Bottlenose dolphins (*Tursiops truncatus*) are found throughout the world, except around the poles. This is because these cetaceans go where the food is. Since their distribution ranges along coastal areas worldwide, the habitats where they live and travel, and where the prey is, drives what's on the menu (Shane et al., 1986). This makes them opportunistic feeders, and they rely on areas like Belize's barrier reef for foraging and reproduction. Since feeding is done underwater, monitoring dolphin's foraging is a challenge.

Dolphins are considered indicator species of fish habitats (Torres and Urban 2005). If the habitats they frequent are healthy, then fish populations remain abundant and dolphin populations are stable. If the habitats degrade, then fish populations decline and dolphin numbers decrease or disappear completely from an area.

In general, scientists have been noticing a global decline in dolphin populations. Threats to dolphin populations include:

- bycatch, or the accidental capture of dolphins in fishing nets.
- overfishing by humans.
- human activities that interfere with natural behaviors.
- habitat degradation that impacts prey abundance.



more than 700 species of vertebrate fish (Ritz, 2011). Over the past 25 years, reefs in Belize have degraded, resulting in their current average coral and fish abundances to fall below the Caribbean average (Marks and Lang, 2006).

Opportunity

Insert images of Caryn in the field. Jess visiting in March.

Dr. Caryn Self-Sullivan studies manatees and dolphins in Belize, and she needs your help. She's taking the history of the research that has been done in the area and reporting on the current status of dolphin populations in several areas of Belize's shores. "Ever since I was a small child, I've been fascinated by whales and dolphins. My mom saved my first drawings of whales, which I still have. They are dated 1961... I finally got the opportunity to study marine biology after my kids grew up. I was 39 when I started college for the first time... Finally, as a graduate student, I started a long-term project in Belize in 1998. Today, my own graduate students continue to work on the project, known as "Manatees & Dolphins in the Drowned Cayes of Belize."

Learn more about Dr. Caryn's project at <https://experiment.com/users/cselfsullivan1> and on Facebook: <https://www.facebook.com/BelizeManateesDolphins>)

Unique

What makes Belize and studying manatees and dolphins there unique? Situated in Central America, Belize is about the size of New Hampshire and bordered by Mexico, Guatemala, and the Caribbean Sea. It was a British colony until it gained its

independence in 1981. It is home to a rich diversity of habitats and abundance of flora and fauna across the nation's variable elevations and environments. And, the tourism business has been booming there quickly over a relatively short period of time.

The marine environment includes the world's second longest barrier reef and more than a hundred Cayes, pronounced "keys." These sets of islands make it a dream destination for outdoor recreation, such as scuba diving, snorkeling, boating, and fishing, with tours promoting chances to see manatees and bottlenose dolphins.



Tourism and agriculture are the nation's top economic engines. With its official tourism motto as "Nature's Best Kept Secret," tourism accounts for about 18-25 percent of the nation's economy, providing jobs for nearly one-third of its residents. In 2014, more than 1.2 million visitors came to Belize. Between 2013 and 2014, airport arrivals increased by about 7 percent. However, arrivals by cruise ship rose much more dramatically – by nearly 43 percent – bringing more than 968,000 tourists through the Caribbean Sea to the Belize City ports (Belize Tourism Board, 2016). The number of tourists has increased over 6000%! Agriculture and fisheries sectors also employ about one-third of the nation's work force and contribute about 22 percent to its economy (Ministry of Agriculture & Fisheries).

Two areas of study interest, specifically for dolphins, are the Turneffe Atoll and the Drowned Cayes. The Turneffe Atoll is composed of sand, seagrass, corals, and mangrove forests on land and along channels and shorelines. Some areas are well-protected from the open ocean. While there are not conclusive studies yet about what dolphins prey on here, Turneffe Atoll's features shelter and provide reproductive areas for relatively small-sized fish in seagrass. Both the Turneffe Atoll and Drowned Cayes area have tourism regulations in place, however, the Drowned Cayes area is closer to Belize City and due to its proximity to the city, port, and coastline, it's subject to more boat traffic and effects from pollution.

Checkpoint

1. Describe dolphins and the habitats found in this area. What activities, both natural and human-caused, can disrupt this ecosystem?

Real Science

In order to help Dr. Caryn, we need to go over the studies that have already been done on dolphins and their habitats in Belize. Even more research needs to be done in Belize to

better understand bottlenose dolphin habitat use, site fidelity, and behaviors, and here are a few studies about the Turneffe Atoll, Drowned Cayes, and a few other areas offshore.

The Turneffe Atoll (Grigg & Markowitz, 1997): Researchers E. Grigg and H. Markowitz published a paper on their findings from data collected on the habitat types at the Turneffe Atoll. Their hypothesis was the probability of sighting bottlenose dolphins at a particular site within the dolphins' range can be predicted from the nature of physical and biological characteristics of that site.

Environmental Characteristics of the Turneffe Atoll include different mixes of these primary features:

- Sand
- Seagrass substrate
- Coral reef nearby
- Patchy coral
- Exposure to open ocean and tidal movements
- Protection from predators (largely sharks)
- Proximity to mangrove creek

Grigg and Markowitz categorized dolphin sightings by group size:

- 1-3
- 4-6
- >6

Below is a map in Diagram 1: Site Numbers where dolphin sighting data was collected during their study.

Diagram 1: Site Numbers

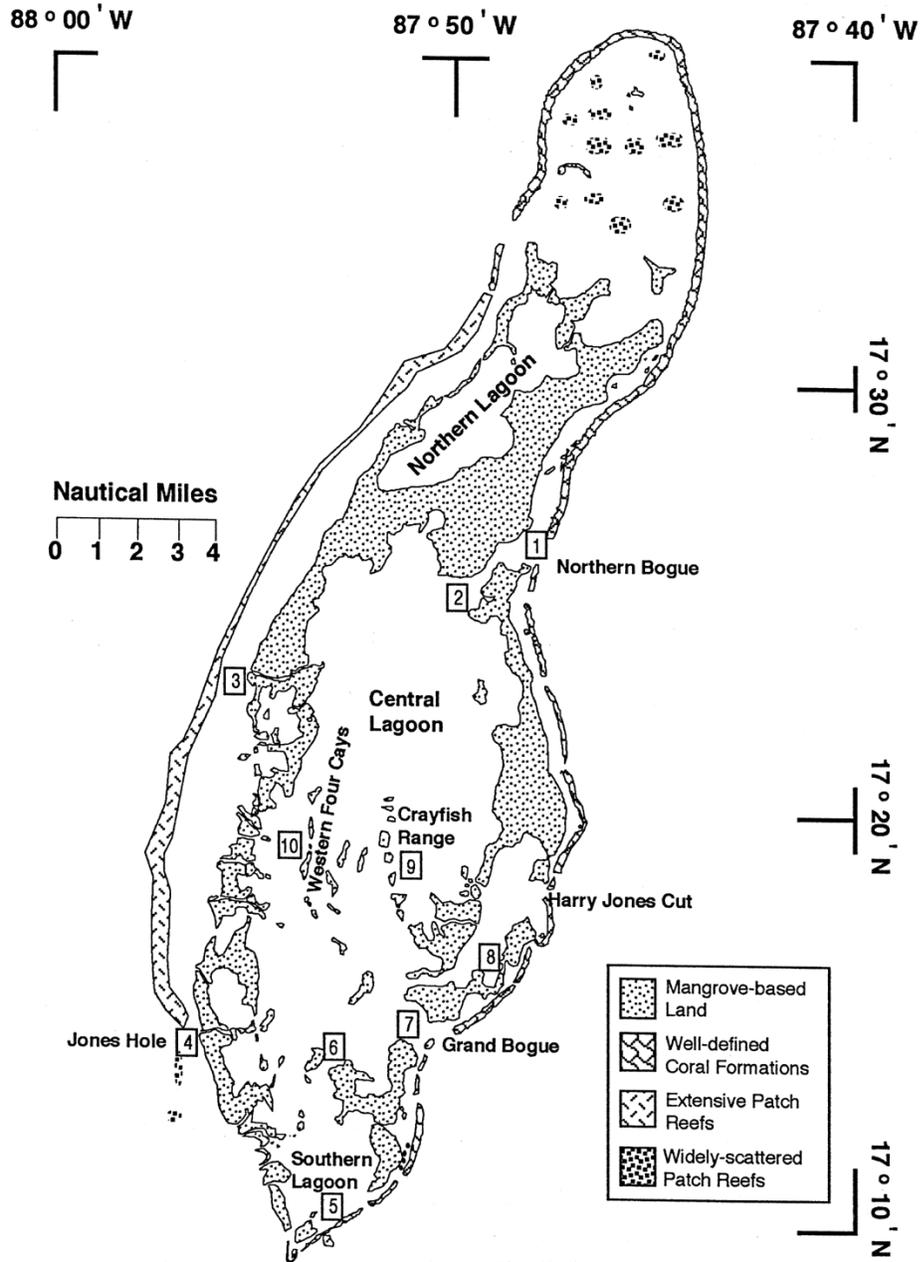


Figure 1. Map of Turneffe Atoll, showing ten focal study sites. (Map courtesy of the Cetacean Behavior Laboratory, San Diego State University.)

Data Chart 1: Data Collection Results

Dolphin sighting data by site	
Site Description	Dolphin Group Size

Site Number		0	1-3	4-6	>6
1	Largely sand and coral substrate; exposed; adjoining coral reef; resort in area; windward side of atoll	17	6	1	0
2	Sand, seagrass, substrate; relatively protected; easy access to bogue/open ocean	14	11	4	1
3	Seagrass substrate; relatively protected; adjoining coral reef; western edge of mangrove creek; leeward side of atoll	16	1	3	2
4	Sand, patch coral, seagrass substrate; somewhat protected; western edge of mangrove creek; leeward side of atoll	12	11	2	5
5	Sand, patch coral, some seagrass substrate; adjoining coral reef; exposed; resort in area; windward side of atoll	14	12	3	1
6	Thick seagrass substrate; protected; easy access to bogue/open ocean	19	2	2	3
7	Sand, seagrass, and abundant patch coral substrate; exposed; adjoining coral reef; windward side of atoll	10	17	2	3
8	Seagrass substrate; protected; easy access to bogue/open ocean	18	5	4	0
9	Thick seagrass substrate; protected; central lagoon and adjoins lagoon mangrove cayes	16	5	1	2
10	Thick seagrass substrate; protected; central lagoon and adjoins lagoon mangrove cayes	17	3	0	2

Grigg and Markowitz used the Site Characteristics to group sites into Habitat Types with Defining Characteristics – see table below.

Using the sighting data by Site Number above, add up the total number of Dolphin Group Size sightings by Habitat and input those into the table below.

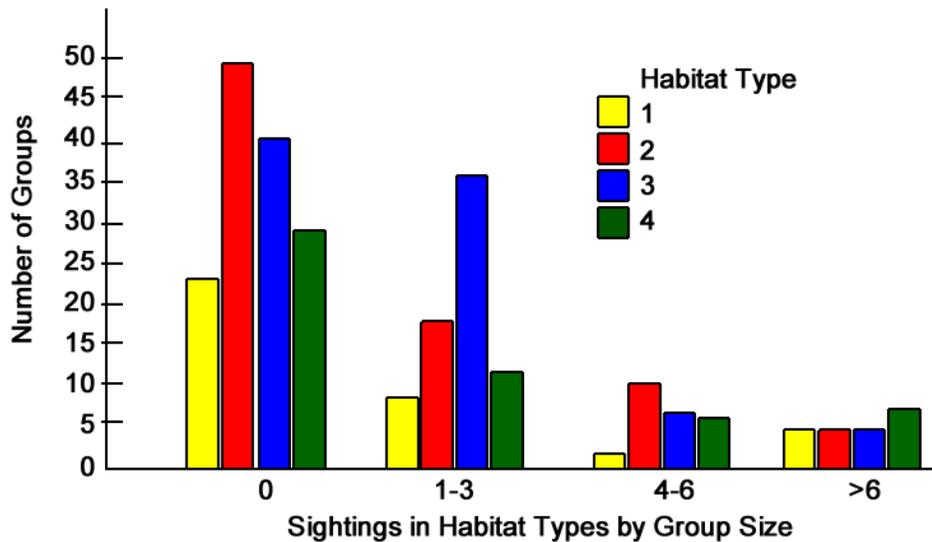
Habitat Type	Sites Included	Defining Characteristics	Dolphin Group Size			
			0	1-3	4-6	>6
1	9, 10	Central lagoon sites; protected; thick seagrass substrate	23	8	1	4
2	2, 6, 8	Easy access to bogue/open ocean; protected; thick seagrass substrate	49	18	10	4

3	1, 5, 7	Bogues; exposed; windward side of atoll; sand, some seagrass, and lots of patch coral; coincide with reef breaks	41	35	6	4
4	3, 4	Creek mouths; leeward side of atoll; seagrass, some patch coral; adjoin reef	28	12	5	7

Checkpoint

1. Create a bar graph that illustrates this data. On the x-axis is Group Size; on the y-axis is Number of Dolphin Groups. Use four different colors of bars so that each bar within a Group Size represents Habitat Type.

Answer Key



2. Use the space below to calculate the probability of sighting *foraging* dolphins in each Habitat Type. (Assume that foraging dolphins are those in groups of 1-3 and 4-6.)

Probability = desired outcome/total outcomes = foraging group sightings/total sighting opportunities

Habitat Type 1: $9/36 = 0.250$

Habitat Type 2: $28/81 = 0.346$

Habitat Type 3: $41/86 = 0.477$

Habitat Type 4: $17/52 = 0.327$

4. What Habitat Type is the greatest probability that you would sight foraging dolphins?

47.7% probability of foraging dolphin sightings in Habitat Type 3, "Bogues; exposed; windward side of atoll; sand, some seagrass, and lots of patch coral; coincide with reef breaks."

5. What habitat features do you think might make those sites preferred areas for dolphin foraging? Label the Diagram 1: Site Numbers with a colored pencil showing the areas that the highest probability for foraging dolphins.

6. Based on this hypothesis, how would you explain the importance of foraging in this area? What factors does the ecosystem need in order for dolphins and other mammals to survive in this area?

The Drowned Cayes (Petersen, 2001):



Image 1: Credit Jess Rowell

The Drowned Cayes area lies between Belize City and the Belize Barrier Reef and is open to the public for tourism activities, but the Swallow Caye Wildlife Sanctuary within that region of the sea is a protected area with strict tourism regulations in place. Even so, compared to the Turneffe Atoll area, it is less sheltered from human impacts, especially boat traffic and pollution. Drowned Cayes is unique because it has mangrove channels, or bogues, created by mangrove creeks.

Heidi Marie Petersen collected data in this area through 2001. She explained that potential prey was protected by the barrier reef as well as mangroves, seagrass and coral throughout the study area.

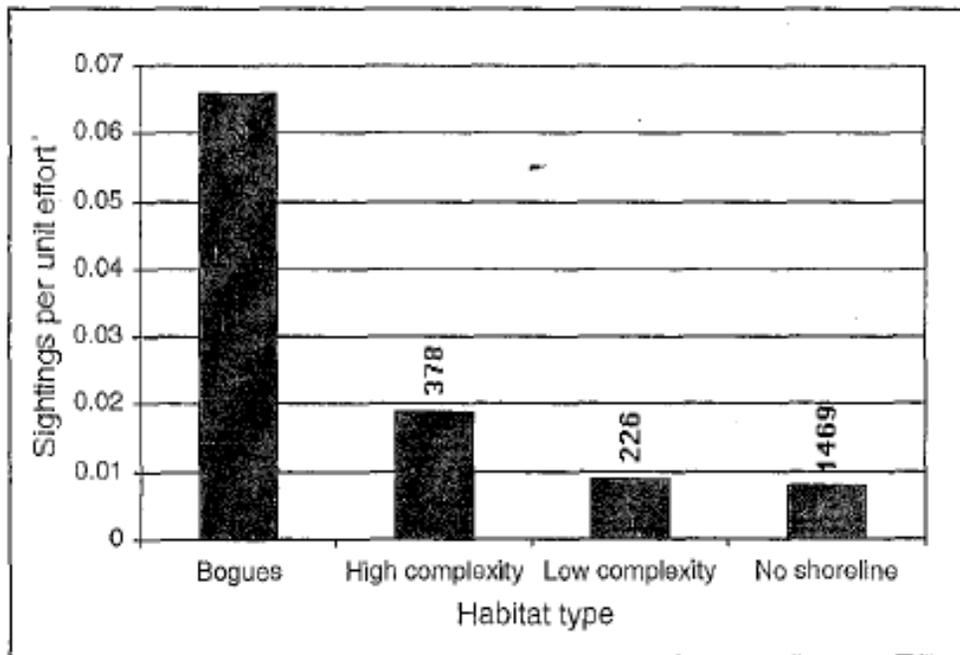


Image 2: Mangrove area in Belize. Jess Rowell

In her study, she recorded the number of dolphin sightings divided by the amount of time spent on the water (not counting the extra time spent watching dolphin behavior), or "per unit effort" and the habitat they were found in. The habitats were bogues and other shorelines. Those results are shown in the bar graph below.



The Drowned Cayes study area with bogues indicated by shading (Petersen 2001).



A survey grid area with bogue mouths or bordering a bogue was considered to have high complexity; all other shorelines were considered low complexity. Petersen further reported that most all of the sightings were of dolphins foraging.

Checkpoint

1. Explain how studying the foraging areas of dolphins is important understanding an ecosystem. What biotic and abiotic interactions are occurring in this ecosystem?

The chart shows a concentration of sightings and foraging behavior near mangrove creeks, both within the bogues and outside them (in areas of highly complex shoreline), suggests that these areas provide important foraging grounds for bottlenose dolphins. The combination of factors including the physical environment, predation, and other interactions of organisms can influence the populations that rely on these areas for survival.

2. Compare and contrast the findings in the Grigg and Markowitz study (1997) with the Petersen study (2001). Describe and explain similarities and differences.

New Science

In 2015, scientists Dr. Caryn Self-Sullivan and Jazmin Garcia secured funding for a research study to discover whether the increases in human activities have negatively impacted bottlenose dolphin populations.



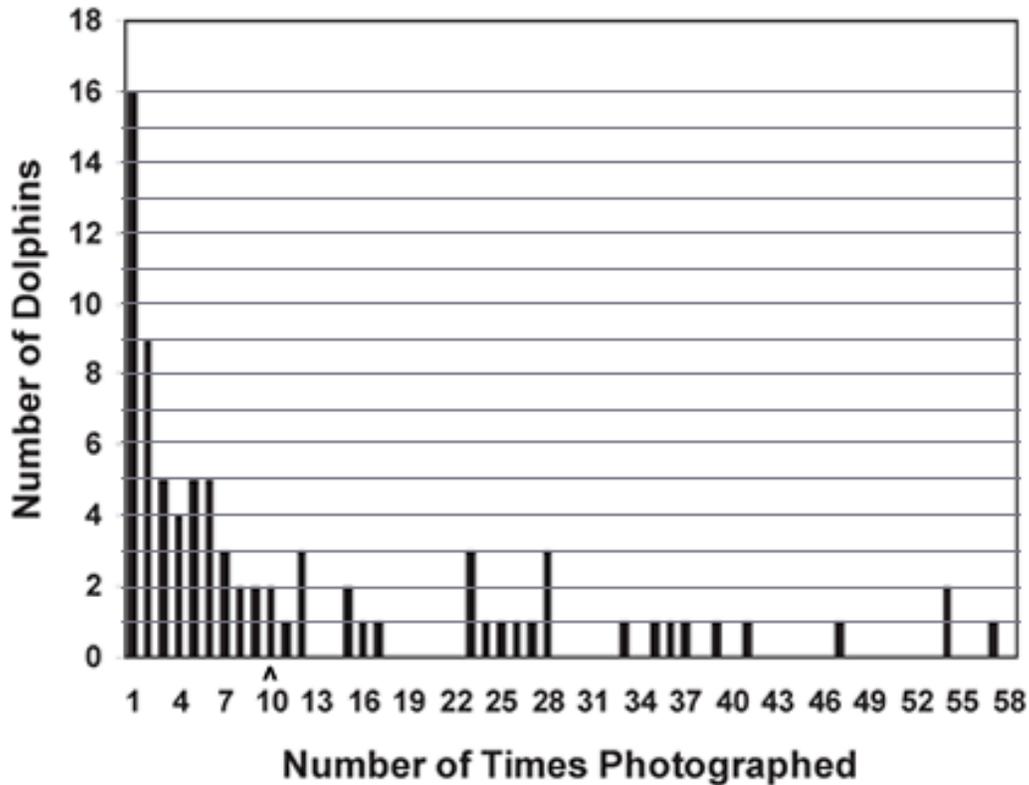
Image 3: Dr. Self-Sullivan Project

On the crowdfunding website Experiment.com, these scientists explained that their project is important and should be funded because no one has gone out to survey the bottlenose dolphin population in Drowned Cayes since Petersen's 2001 study. Their project goal was to repeat Peterson's study and to determine any change in the ecology, behavior and habitat use by the population. Their study observes and records data using the same methods to see if there have been changes to Petersen's observations. What do you think they found? How can you help contribute to this recent study?

Scientists researching dolphins commonly use photographs to not only capture numbers of dolphins and group sizes, but also to be able to specifically identify individuals. Like a human thumbprint, a dolphin's dorsal fin is unique. Identifying individuals can help determine whether dolphins tend to be residents in the area or transients that are merely traveling through.

Photographs have traditionally been taken from boats during survey sessions, while more modern techniques, such as using drones, are being tested for viability and broader usability. Regardless of photographic survey method, however, not all photos are created equal. Meaning, every photo requires careful review for whether it is of high enough quality to be used for accurate individual identification.

Criteria to determine whether an individual should be considered a resident: Individual must be photographed two times or more in at least three of the four study years.



Checkpoint

1. What percentage of individuals were photographed 10 times or more over the study's four-year period? What does the percentage represent?
 $30/81 = 37.0\%$ of the total individuals identified were photographed at least 10 times. This means that over 30% of the dolphins spotted are considered residents and not transients of the area and hence rely on the resources there for reproduction and survival.
2. If you were asked to determine a plan for the long-term monitoring of this ecosystem, how would you include this information? In your plan, what other variables would you measure?

Engineering



Image 4: Eric Ramos © Kathi Koontz

Check this out! Here is a really cool way to study dolphins. Drones. Just launched in 2015, the Oceanic Society's Turneffe Atoll crew used remotely operated and unmanned vehicles—including aerial quadcopters, autonomous aquatic drones, and a remotely operated underwater vehicle—to collect data on bottlenose dolphin behavior and communication, threats, and habitat use.

The data collected by the drones includes video, audio recordings, and photographs. These are non-invasive methods, along with field observations and acoustic listening are used by the Oceanic Society. During their 2015 field season, participants recorded 15 manatee sightings and hundreds of dolphin sightings, which included 2 new dolphins they added to their dolphin identification database!

You!

The Oceanic Society is working with researchers, such as those focused on Turneffe Atoll and the Drowned Cayes, to create a comprehensive bottlenose dolphin database of individuals. This database will include data on individuals, such as dorsal fin identification, previously reported locations and dates, etc. Dr. Caryn and Jazmin will also be using photo identification as part of her current research study in the Drowned Cayes area, with their data contributing to that database. Because funding is often limited, scientists are turning to the public for other kinds of contributions: data. You can help Dr. Caryn and Jazmin identify the dolphins' dorsal fins for the photographic database by contacting them at jg2288@nova.edu.

Finally, you will create a public service announcement that updates citizens on the current status of dolphin and manatee habitat in the Turneffe Atoll Marine Reserve and Belize Field Station. This script or recorded audio/visual message will include a summary of the findings from the 2015 field season found on <https://www.oceanicsociety.org/blog/1356/2015-belize-field-season-in-review>. Include a description of dolphins and their habitat in Belize and the importance of monitoring in the area, and follow all of your teacher's instructions for the submission of this assignment.

Good luck in your Journeys and safe travels.

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APPENDIX H
IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
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MEMORANDUM

TO: Jessica Rowell and Walt Woolbaugh
FROM: Mark Quinn, Chair *Mark Quinn CJ*
DATE: December 7, 2015
RE: "Journeys: Producing NGSS-aligned Interactive Reading Passages Connecting Scientists and Secondary Science Educators with Real Events and Issues in the Field" [JR120715-EX]

The above research, described in your submission of December 7, 2015, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX I

TECHNOLOGY & INTERACTIVE SUGGESTIONS

Suggestion Summary (Teacher)	Section (Leg)	Actionable Update to <i>Journey</i> draft	Code: Research Focus
Students should feel as though they are on their own research journey. (Jess, as a result of conducting research directly in Belize)	Whole <i>Journey</i>	Change ‘Interactive Checkpoints’ to ‘ <i>Waypoints</i> ,’ ‘sections’ to ‘legs,’ and make a concerted effort to sequence each leg so that students must use information and solutions from previous sections in order to solve the next problems. This models an actual research process in the field and will hopefully add more interest and relevance to align to the NGSS Standards.	NA
<i>Journey</i> should integrate more than just one science strand, at least secondarily (Jess, as a result of conducting research directly in Belize).	Whole <i>Journey</i>	Add appropriate NGSS Earth and Space standards, at least the Disciplinary Core Ideas. Special Note: This was not a part of the original research design and was not included in the teacher feedback system, therefore not technically a part of this study. However, It will be added and reviewed in future settings.	Alignment
<i>Journey</i> should be interactive with videos, maps, etc. (Various)	Whole <i>Journey</i> , especially in engagement.	Included here for purposes of <i>Journey</i> organization and general feedback: <ul style="list-style-type: none"> - Video as introduction to hook students - Video as elaboration for main concepts - Video of research in action - Use video before <i>Waypoint</i> questions - Use maps early and often, interactive maps - Links in passage to online material - Simulations to explain natural study area - Simulations to manipulate variables - Include Facebook connections of scientists 	Usefulness
<i>Journey</i> should include cultural sensitivity (Jess, as a result of conducting	Unique	This comes as an observation that science is not just done by scientists but that all citizens are invested in their environment. In fact, the scientists themselves may only visit their study area once per year and work with locals in order to pull their research	NA

research directly in Belize).		missions together. I feel this should at least be mentioned in a <i>Journey</i> .	
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APPENDIX J

ACTIONABLE CHANGES BASED ON

RESEARCHING DOLPHINS JOURNEY DRAFT

Section (Leg)	Actionable Update to <i>Journey</i> Structure	Based on Feedback/Interview/Survey Synthesis (Reviewer Initials)	In order to support or answer which Research Question?
Whole <i>Journey</i>	Assure that there are open-ended response questions for students to describe and list what they know. Assure that student handout has Cornell writing space for topic note taking	More opportunity to "write informative/explanatory text," open-ended written responses, and note-taking guidance (M.Ha.)	Usefulness #2
Whole <i>Journey</i>	Create vocabulary list for teacher and use bolded terms throughout passage. Possibly include glossary at the end for easy student reference.	Increase vocabulary support with a preview section or bolded terms. (J.S.)	Usefulness #2
Whole <i>Journey</i>	Create a teacher page that includes the standards, teacher facilitation, and background.	Include more teacher facilitation and background, including answers for the student data analysis. (M.S.)	Usefulness #2
Whole <i>Journey</i>	Review open-ended response questions and strengthen stems to include all levels of Bloom's taxonomy. Review Common Core ELA.	Work in Common Core ELA standards into the makeup of questioning. (J.T., et. al)	Alignment #1
<i>Job</i>	Student will have a basic grid of some example careers for them to reference and fill out.	May not be relatable to students who are inland, especially regarding career opportunities (M.S.)	Usefulness #2
<i>Job</i>	Students create a proposal to report to the Belizean government on the surge of tourism and how it is affecting marine mammal populations, particularly during mating season. Include the mating season info in the New so students connect boat traffic and dolphin populations.	Students should be creating a solution to solve the problem (J.S., M.Ha., J.T., et. al)	Alignment #1

<i>Unique</i>	Students will fill in a brief table that will compare dolphins as an indicator species with other species they may be aware of in their own environment.	Increase relevance as students who are not impacted by dolphin populations may not see relevance (especially for High School Students). (J.S., M.Hu.)	Relevance #3
<i>Unique</i>	Students will be given the context of how dolphin natural history is studied in one area, but that study areas may be similar or different in other parts of the world depending on the habitat, research significance, and other geographical differences.	The concept of scale is implicit in the data, but not explicitly addressed. The concept of stability and change is not explicitly explored in any detail; though it is inherent in habitat degradation. (M.Ha., S.V., et. al)	Alignment #1
<i>Unique</i>	Write about the habitat and marine mammal reliance on the mangroves in the area.	Include specific facts about dolphins in general and in Belize, including specific threats to them or their habitat. (M.Ha.)	Alignment #1
<i>Unique</i>	Include this with the open-ended responses as a result of other teacher feedback as well.	Could include opportunities for students to ask some of their own questions about dolphins. (S.K.)	Usefulness #2
<i>Unique</i>	See previous notes about natural history of reefs and indicator species, etc.	May want to elaborate more on the role of the organism. (S.V.)	Alignment #1
<i>You!</i>	Possibly send students to a site where they can download their own data on a similar topic, area and direct they create their own graph and solution. This would go under <i>You!</i> Leg.	Students find their own data set and create their own graph? (M.M.)	Relevance #3, focus on environmental impact topics and the impact of human activity on ecosystems
<i>You!</i>	Develop a rubric for common performance standards for use by teacher and student.	Combined with a future summative assessment, this will make the whole <i>Journey</i> more useful. (S.H.)	Usefulness #3.

APPENDIX K

TESTIMONY OF *FINAL JOURNEY: RESEARCHING DOLPHINS*

“So often, science students don’t have the opportunity to learn about real, large-scale investigations in any detail and to work with actual data from these projects. This *Journey* allows students to “participate” in finding solutions to a real-world environmental issue and observe first-hand the approaches, assumptions, and analytical methods used by the scientists currently doing this work. The data analysis and interpretation done by the students is simple enough for them to work with, but also important and directly relevant to the study’s findings. I especially like the emphasis on process, critical thinking, and the scientific method which is incorporated throughout the *Journey*. The sections on *Opportunity*, *New Science*, *Engineering*, and *You!* also offer a refreshing, broad perspective to the scientists’ work and give students a context for directions they may want to pursue (and how to get there) in their own future careers. The final presentation to non-scientific policy-makers also hones communication skills which are critical to science-based decision making. One suggestion I would make in this portion of the curriculum would be to guide students a bit more in how to start their presentation where their audience is, in this case, how big is the problem, how healthy is the reef habitat, how important are the dolphins, both for the ecosystem and as an indicator species, and how fast do policy-makers need to act? Then proceed to their scientific data and conclusions. This is all icing on the cake in a solid experience of a scientific research project, but one that lends itself to interdisciplinary communication and problem-solving. I would anticipate other *Journey* projects which lend themselves to written, structured scientific reports, such as would be submitted to a scientific journal, an engineering design document, a photo- or drawing-based presentation of observations, etc. *Researching Dolphins* is a nice blend of simplicity, scientific method, and presentation skills.”

(M.Hu.)

May 20, 2016