Direct Economic Inputs from Internationally Funded Science Projects to the Abaco Islands, The Bahamas

Craig A. Layman[1,*], Olivia Patterson Maura[2], Sean T. Giery[3], Jacob E. Allgeier[4], and Andrew L. Rypel[5]

[1]Center for Energy, Environment, and Sustainability, Wake Forest University, Winston-Salem, NC, 27106. [2]Friends of the Environment, Marsh Harbour, Abaco, The Bahamas. [3]Department of Biology, Pennsylvania State University, University Park, PA, 16802. [4]Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, MI, 48109. [5]Department of Biology, Pennsylvania State University, University Park, PA, 16802.

*Correspondence: laymancraig50@gmail.com

Abstract - International expenditures for scientific research are important for small island developing nations, especially for those local communities that directly support research activities. We used the Abaco Islands, The Bahamas, as a case study to quantify the direct monetary inputs to a local economy via internationally-funded scientific research. We found that over two years the external monetary influx was $995,310, via 24 research teams, that was spent across diverse business sectors on Abaco. A direct survey approach ensured this was a conservative estimate, leaving out numerous indirect economic impacts, thereby suggesting the actual monetary infusion was significantly higher. The highest expenditures were for services (e.g., local salaries and boat guides), lodging, food/drink, and major equipment (e.g., vehicles). In addition to the research-based contributions that give rise to conservation and management decision-making, scientific activity brings benefits through the injection of money into local island economies. This relationship warrants study at larger regional scales, including across The Bahamas archipelago.

Introduction

Quantifying the value of ecosystem services is a primary tool for developing natural resource conservation approaches and promoting environmental sustainability for human well-being (Kubiszewski et al. 2017, Paul et al. 2020). This approach can provide frameworks for regional conservation planning, as has been done for the Caribbean (Schuhmann and Mahon 2015, Hernández-Blanco et al. 2020). Core to assigning a dollar value to ecosystem services is translating ecosystem "functions" (e.g., fishery yields or shoreline protection) into a unit (money) that people can recognize and relate to, providing a guide to how ecosystems support local and regional economies. This valuation approach is now commonly used to link ecosystems and economics—via science—yet it is only one aspect of the complex interplay between the two. For example, local economic expenditures are necessary to support the research, yet local economic activity derived from scientific research is rarely quantified. This dynamic leads to a counterintuitive scenario where estimates of the abstract value of a region's ecosystems are available, whereas quantifications of concrete monetary flows to local economies from scientific research are not.

Science-based expenditures are especially relevant for the local communities that support internationally-funded research—research often focused on the ecosystems that local communities depend on. In the Commonwealth of The Bahamas, an estimated 84% of the $13 billion economy is service-based (estimate from *The Economist* 2019), driven by the tourism industry. Directly or indirectly, natural resources form the base of the tourism industry, and thus the economy and the well-being of the Bahamian people. At least partially because of the fundamental importance of the environment to the national economy, scientific research flourishes in the country. This is highlighted by recent studies with direct economic relevance, including on recreational fisheries (Adams et al. 2019, Ruga et al. 2019), coral reefs (Rogers et al. 2014), fishery species (Harborne et al. 2008, Sherman et al. 2018, Arkema et al. 2019), marine protected areas (Wielgus et al. 2008), and mangroves (Micheletti et al. 2016), as well as the study of events affecting natural resources, such as hurricanes (Wallace et al. 2019, Winkler et al. 2020, Wallace et al. 2021).

We use the Abaco Islands, The Bahamas, as a case study to quantify direct monetary inputs to a local economy from internationally-funded environmental research. We aimed to depict one component of the multidimensional links between science and society (Penfield et al. 2014, Weisshuhn et al. 2018, Fryirs et al. 2019). In The Bahamas, the complex interrelationship between science and local communities was thoughtfully reflected on by Moore (2019), and here we extend information specifically regarding ties between science and economics. We take a conservative approach in that only direct influxes of money are included, providing a figure that defines the minimum economic impact. We then discuss ways in which collaborations between Bahamian and international scientists, as well as with Bahamian non-governmental organizations (NGOs) and the Government of The Bahamas, drive additional local economic activity. This study builds on previous reflections of the relationships between science and society for other small island developing nations—countries that share many common challenges for sustainable development (Wong 2011, Lowitt et al. 2015, Mycoo 2018, Walshe and Stancioff 2018, Moore 2019, Rao and McNaughton 2019).

Methods

The Commonwealth of The Bahamas consists of hundreds of islands and cays encompassing a territory of 470,000 km^2 of ocean space. The population was around 390,000 in 2019 (The Economist 2019), of which approximately 70% of people are found on the island of New Providence, with the rest of the population spread across other islands. The Abaco Islands comprise the main islands of Great Abaco and Little Abaco along with several smaller barrier cays

(Figure 1); it is the third most populated island after New Providence and Grand Bahama. The Abacos were impacted by Hurricane Dorian in 2019, one of the strongest landfalling Atlantic hurricanes on record, causing catastrophic damage. The ongoing sustainable development challenges following Hurricane Dorian provide one background context for this study.

Researchers supported by international funding sources who visited the Abaco Islands from the 1st of August 2017 to the 1st of August 2019 were included in this data compilation. The primary contact list was generated through Friends of the Environment (FRIENDS), an environmental education-driven NGO in the most populated settlement, Marsh Harbour. Many of the researchers stayed in the Kenyon Centre (administered by FRIENDS), a facility established in 2015 to facilitate research and education by providing affordable accommodations and basic lab capabilities for scientists, with specific intentions to build connections between scientists and the local community. Additional researchers were contacted for the survey based on other projects known to the authors of this study. In June 2020, an email invitation to participate was sent to all researchers identified. Some researchers provided itemized expenditure lists which allowed for a more specific assessment of how money was spent.

Results

Twenty-four research groups responded to the request; 18 of the 24 (75%) were from the United States and the others from the United Kingdom, Continental Europe, or Bahamas-based organizations supported by international funding. Eight additional groups responded and said that they had researched in the country but not during the time frame of this study. Groups included university professors and students, NGOs, independent research groups, and conservation organizations. Research topics ranged widely across terrestrial and aquatic systems, including threats to coral reefs, mangrove die-off, artificial reef deployment, recreational fisheries, geological structures unique to the island, paleoecology, and threatened bird species. All of the researchers received necessary permits from the Bahamian government and developed programs with non-commercial outcomes—the fundamental purpose of the research was knowledge acquisition and applying that information toward the development of conservation or management strategies. Other respondents noted that they had expenditures on Abaco for environmental education activities during the period; these data were not included, thus rendering our estimated expenditure values conservative. Further, we are aware of research teams that did not respond to the survey, again indicating that the actual science-based expenditures are higher than the values reported here. Thus, this study provides a minimum baseline value from which to infer impacts international funding has on the local economy via research activities.

Total recorded expenditures for the two years were $995,310 (Supplementary Table 1). For international academic research teams (the most common researcher category) the average expenditure was $30,621. Twenty of the respondents provided itemized estimates allowing us to assess areas where expenditures were targeted (Figure 2). Fifteen sub-categories were identified representing money spent in diverse sectors of the economy. Four categories accounted for 73% of all expenditures: services (primarily salaries and boat guides), lodging, meals, and major equipment.

Discussion

The Bahamas is a country fundamentally dependent on its natural resources, and science-based approaches are necessary to protect and manage these resources. Although science contributions can be quantified through output metrics (such as the number of publications stemming from research in the country) and they form a direct basis for policy-making (as can be seen in codified environmental regulations), science has multidimensional societal outcomes that are often less appreciated and difficult to quantify (Weisshuhn et al. 2018, Moore 2019, Chams et al. 2020, Marti et al. 2020, Williams 2020). These outcomes include direct economic impacts associated with scientific research, the focus of the present study. The minimum estimated direct monetary input was $995,310 over two years, and a more complete estimate would be higher because of the caveats outlined above and the reasons discussed below.

We identified only one somewhat similar study in the primary literature (Royuela et al. 2019). This study analyzed the Safe Islands for Seabirds project on Corvo Island—the smallest, most remote, and least populated island in the Azores Archipelago. The project was coordinated by Sociedade Portuguesa para o Estudo das Aves (a BirdLife International partner), in partnership with the municipality of Corvo, the Secretary of Environment and Sea (on behalf of the Azores Regional Government), and the Royal Society for the Protection of Birds. It comprised 35 actions related to the conservation of bird species and habitats, scientific research, and science communication to the public. The science revolved around the eradication of invasive mammalian species (cats, rodents, goats, and sheep) and assessing the impact of these mammals and alien plant species (e.g., cane and tamarisk) on seabird breeding success and their natural habitats. Over three years, the estimated direct external expenditures on the project were €344,212 (equivalent to ~400,000 USD depending on the exchange rate used). The authors noted that there is no standardized method to assess such economic impacts of scientific activities (because such studies are so rare), so we drew from their study in designing the present project.

As in Royuela et al. (2019), an advantage of the present economic assessment for the Abaco Islands was that expenditure information was compiled directly from researchers. Collecting data directly from scientists obviates the need for indirect inferences and assumptions regarding visitors to The Bahamas that other studies have employed (e.g., Maycock 2015). Since university-based scientists primarily fund their research activities with grants from public money (e.g., the National Science Foundation) or private foundations (e.g., National Geographic Society), their budgets are readily available and expenditures well-documented. Fedler (2019) used a similarly direct survey approach to estimate the economic impact of the recreational bonefishing fishery for The Bahamas. Specifically, they compiled data from bonefishing lodges and independent bonefish guides through in-person interviews, e-mail, or telephone calls. They collected information on the number of fishing days and number of anglers serviced by each lodge or independent guide, focusing on their direct expenditures locally. Such direct approaches provide a reliable way to estimate actual expenditures instead of inferring potential economic activity through alternative means.

Our conservative approach yielded the minimum economic impact, namely, we did not provide estimates that incorporated multiplier effects. A multiplier is a measure of how dollars brought into a community are re-spent, thereby leading to additional economic activity. The output multiplier measures the combined effect of a $1 change in money spent on the output of all participants in a specified economy (Hughes 2018). This framework is often broken into three components: direct, indirect, and induced effects. Direct effects are the number we report, i.e., the sum of all money spent by scientists that was sourced from international funding agencies—external money transferred to local businesses, organizations, or individuals. Indirect effects refer to the increase in economic activity that occurs when the recipient of the external money re-invests it into other local goods or services that support their business (e.g., a fishing guide paying a mechanic to service a boat engine). Induced effects are changes in spending patterns that are caused by the increased income of those persons directly and indirectly supported by the initial spending (e.g., the boat mechanic has more money to dine in a local restaurant). These effects together are represented by the multiplier that is applied to direct expenditures (direct effects) to yield a total estimated economic impact. Multipliers are not available for the type of scientific economic activity we quantified, and any multiplier assumptions, such as for tourism (Crompton et al. 2016), are wrought with challenges. One analog we can use is ecological restoration, for which multipliers ranging from 1.6 to 2.6 have been applied (BenDor et al. 2015). Taking the midpoint of this range (a multiplier of 2.1) would suggest that the minimum economic impact of scientific research on Abaco is more than double the dollar value we estimate in this paper—more than $1 million annually.

The application of multipliers alone does not include other contributions that can be parlayed into additional economic returns. Direct partnerships between Bahamian scientists and international researchers open possibilities for ongoing project development, drawing heavily on local knowledge complemented with international support. NGOs benefit by using scientific research for procuring additional grant dollars and to support fundraising (such as building and maintaining the Kenyon Research Centre on Abaco). Local organizations also benefit from research through capacity building and enhancing existing projects, thereby allowing those organizations to direct more of their funds to the local economy. Other activities involving researchers include working with Bahamian students to move into STEM fields, developing educational materials, assisting with the justification for new protected areas, participating in the scientific review of conservation and development projects, and providing expertise for community-based habitat restoration projects. While some of these activities are incorporated in permitted research projects and thus encompassed by the direct economic assessment outlined in this study, many represent additional "hidden" economic value to local economies. Educational and applied science activities are now further emphasized in the Bahamas scientific permitting process, which will further solidify and extend external monetary inputs to local communities.

Research facilitates network development between Bahamian and international scientists, leading to future research projects, and attracting funding to the country to advance natural resource management. Science has led to internationally-recognized documentaries, e.g., through National Geographic (Todhunter 2010), that are promotional tools for the Ministry of Tourism. Science- and conservation-based research trips introduce people to the island and to local colleagues, and these people may return subsequently (for scientific research or as tourists), generating future revenue. Although money can "leak" out of the economy, e.g., some businesses are internationally-based (e.g., many airlines) and supplies (e.g., food) are imported from other countries, research activities still provide support for job creation locally. We acknowledge we are using simple monetary values to represent a complex interrelationship of science and society, and we do not consider various other important sociological perspectives (Moore 2019). Regardless, the external economic stimulus is an emergent outcome that should be considered.

An obvious next step is to scale this project beyond Abaco to the entire country. Such a project would encompass research centers supporting science, including the Cape Eleuthera Institute, Gerace Research Centre, Bimini Biological Field Station, and Forfar Field Station. Research on other islands is supported by The Bahamas National Trust, The Nature Conservancy, and The Bahamas Reef Environmental Education Foundation, among other organizations. Likewise, funding from international organizations, such as the United Nations and the Inter-American Development Bank, that is directed to the Government of The Bahamas and earmarked for science and conservation efforts, should be considered as additional sources of international support that eventually have concrete, local economic impacts. Quantifying the broader economic impacts of research activities, from both national and international funding sources, will reveal a more complete picture of the benefits of scientific research for The Bahamas and other countries in the region.

Literature Cited

Adams, A. J., J. S. Rehage, and S. J. Cooke. 2019. A multi-methods approach supports the effective management and conservation of coastal marine recreational flats fisheries. Environmental Biology of Fishes 102:105-115.

Arkema, K. K., L. A. Rogers, J. Toft, A. Mesher, K. H. Wyatt, S. Albury-Smith, S. Moultrie, M. H. Ruckelshaus, and J. Samhouri. 2019. Integrating fisheries management into sustainable development planning. Ecology and Society 24:24.

BenDor, T., T. W. Lester, A. Livengood, A. Davis, and L. Yonavjak. 2015. Estimating the Size and Impact of the Ecological Restoration Economy. PloS One 10:e0128339.

Chams, N., B. Guesmi, and J. M. Gil. 2020. Beyond scientific contribution: Assessment of the societal impact of research and innovation to build a sustainable agri-food sector. Journal of Environmental Management 264:12.

Crompton, J. L., J. Y. Jeong, and R. M. Dudensing. 2016. Sources of Variation in Economic Impact Multipliers. Journal of Travel Research 55:1051-1064.

Fedler, T. 2019. The 2018 Economic Impact of Flats Fishing in The Bahamas. Bonefish and Tarpon Trust.

Fryirs, K. A., G. J. Brierley, and T. Dixon. 2019. Engaging with research impact assessment for an environmental science case study. Nature Communications 10:10.

Harborne, A. R., P. J. Mumby, C. V. Kappel, C. P. Dahlgren, F. Micheli, K. E. Holmes, and D. R. Brumbaugh. 2008. Tropical coastal habitats as surrogates of fish community structure, grazing, and fisheries value. Ecological Applications 18:1689-1701.

Hernández-Blanco, M., R. Costanza, S. Anderson, I. Kubiszewski, and P. Sutton. 2020. Future scenarios for the value of ecosystem services in Latin America and the Caribbean to 2050. Current Research in Environmental Sustainability 2.

Hughes, D. W. 2018. A Primer in Economic Multipliers and Impact Analysis Using Input-Output Models. University of Tennessee Institute of Agriculture.

Kubiszewski, I., R. Costanza, S. Anderson, and P. Sutton. 2017. The future value of ecosystem services: global scenarios and national implications. Ecosystem Services 26:289-301.

Lowitt, K., A. Saint Ville, P. Lewis, and G. M. Hickey. 2015. Environmental change and food security: the special case of small island developing states. Regional Environmental Change 15:1293-1298.

Marti, T. S., R. Flecha, J. A. Rodriguez, and J. L. C. Bosch. 2020. Qualitative inquiry: A key element for assessing the social impact of research. Qualitative Inquiry:7.

Micheletti, T., F. Jost, and U. Berger. 2016. Partitioning Stakeholders for the Economic Valuation of Ecosystem Services: Examples of a Mangrove System. Natural Resources Research 25:331-345.

Moore, A. 2019. Destination Anthropocene: Science and Tourism in The Bahamas. University of California Press, Oakland, California.

Mycoo, M. A. 2018. Beyond 1.5 degrees C: vulnerabilities and adaptation strategies for Caribbean Small Island Developing States. Regional Environmental Change 18:2341-2353.

Paul, C., N. Hanley, S. T. Meyer, C. Furst, W. W. Weisser, and T. Knoke. 2020. On the functional relationship between biodiversity and economic value. Science Advances 6:17.

Penfield, T., M. J. Baker, R. Scoble, and M. C. Wykes. 2014. Assessment, evaluations, and definitions of research impact: A review. Research Evaluation 23:21-32.

Rao, L. L., and M. McNaughton. 2019. A knowledge broker for collaboration and sharing for SIDS: the case of comprehensive disaster management in the Caribbean. Information Technology for Development 25:26-48.

Rogers, A., J. L. Blanchard, and P. J. Mumby. 2014. Vulnerability of Coral Reef Fisheries to a Loss of Structural Complexity. Current Biology 24:1000-1005.

Royuela, J. B., S. H. Parejo, A. de la Cruz, P. Geraldes, L. T. Costa, and A. Gil. 2019. The socio-economic impact of conservation: the Safe Islands for Seabirds LIFE project. Oryx 53:109-116.

Ruga, M. R., D. L. Meyer, and J. W. Huntley. 2019. Conch fritters through time: human predation and population demographics of *Lobatus gigas* on San Salvador Island, The Bahamas Palaios 34:383-392.

Schuhmann, P. W., and R. Mahon. 2015. The valuation of marine ecosystem goods and services in the Caribbean: A literature review and framework for future valuation efforts. Ecosystem Services 11:56-66.

Sherman, K. D., A. D. Shultz, C. P. Dahlgren, C. Thomas, E. Brooks, A. Brooks, D. R. Brumbaugh, L. Gittens, and K. J. Murchie. 2018. Contemporary and emerging fisheries in The BahamasConservation and management challenges, achievements and future directions. Fisheries Management and Ecology 25:319-331.

The Economist. 2019. World in Figures 2020. Profile Books Ltd, London.

Todhunter, A. 2010. Deep Dark Secrets. National Geographic Magazine.

Wallace, E. J., J. P. Donnelly, P. J. van Hengstum, C. Wiman, R. M. Sullivan, T. S. Winkler, N. E. d'Entremont, M. Toomey, and N. Albury. 2019. Intense Hurricane Activity Over the

Past 1500 Years at South Andros Island, The Bahamas. Paleoceanography and Paleoclimatology 34:1761-1783.

Wallace, E. J., J. P. Donnelly, P. J. van Hengstum, T. S. Winkler, K. McKeon, D. MacDonald, N. E. d'Entremont, R. M. Sullivan, J. D. Woodruff, A. D. Hawkes, and C. Maio. 2021. 1050 years of hurricane strikes on Long Island in The Bahamas, Paleoceanography and Paleoclimatology. 36:e2020PA004156.

Walshe, R. A., and C. E. Stancioff. 2018. Small island perspectives on climate change. Island Studies Journal 13:13-24.

Weisshuhn, P., K. Helming, and J. Ferretti. 2018. Research impact assessment in agriculture—A review of approaches and impact areas. Research Evaluation 27:36-42.

Wielgus, J., E. Sala, and L. R. Gerber. 2008. Assessing the ecological and economic benefits of a no-take marine reserve. Ecological Economics 67:32-40.

Williams, K. 2020. Playing the fields: Theorizing research impact and its assessment. Research Evaluation 29:191-202.

Winkler, T. S., P. J. van Hengstum, J. P. Donnelly, E. J. Wallace, R. M. Sullivan, D. MacDonald, and N. A. Albury. 2020. Revising evidence of hurricane strikes on Abaco Island (The Bahamas) over the last 700 years. Scientific Reports 10.

Wong, P. P. 2011. Small island developing states. Wiley Interdisciplinary Reviews-Climate Change 2:1-6.

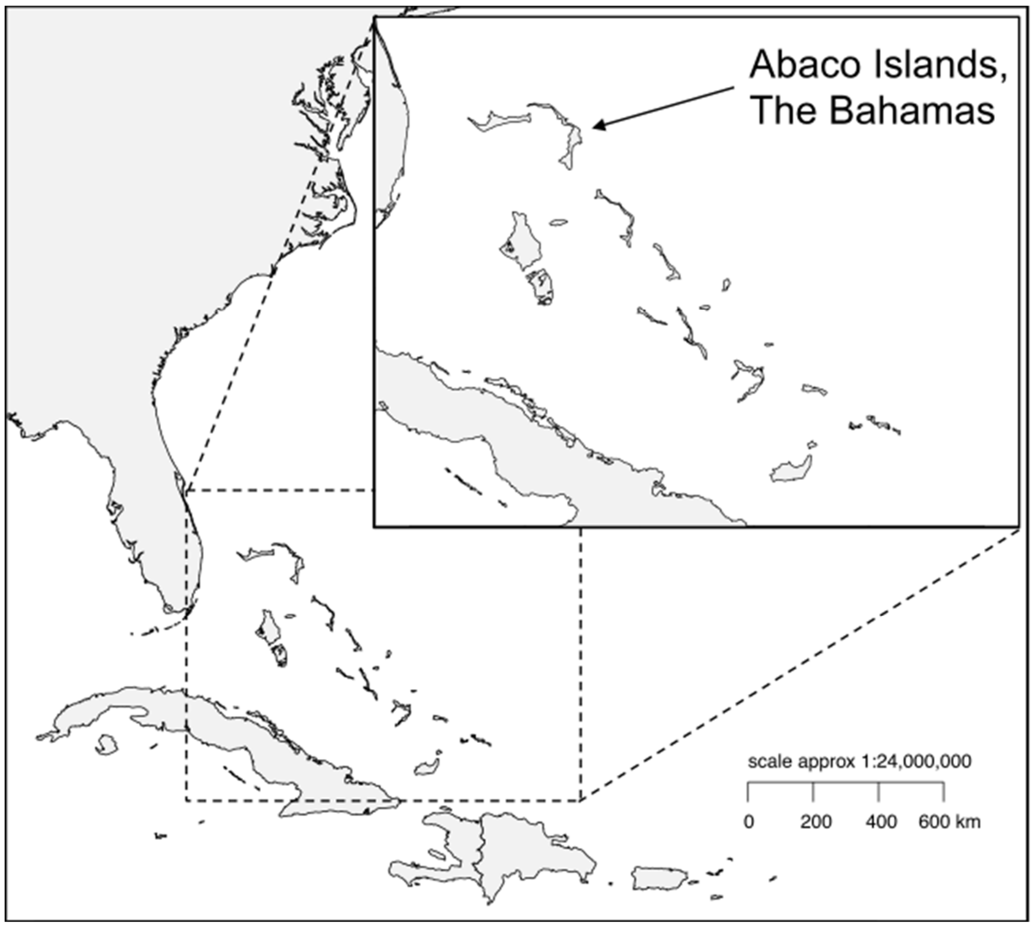

Figure 1. The Abaco Islands are in the northern portion of the Lucayan Archipelago (inset). The Abaco Islands comprise the main islands of Great Abaco and Little Abaco along with several smaller barrier cays.

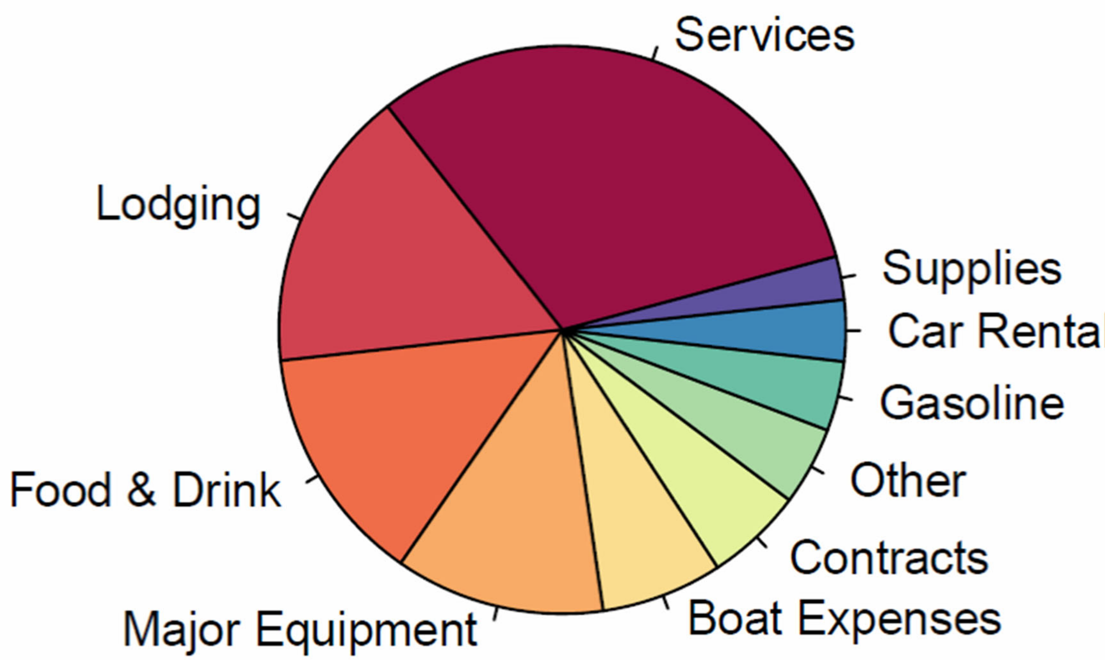

Figure 2. The relative proportion of expenditures by scientists on Abaco Island from August 1st, 2017 to August 1st, 2019.