ENVIRONMENTAL COUNCIL ANNUAL REPORT
STATE OF HAWAIʻI
2014

INTRODUCTION

There has never been a more critical moment for people who care about Hawai‘i to come together, to address environmental and sustainability issues, to make the economy and the environment work hand-in-hand and to protect our quality of life. Today, we face daunting uncertainties and risks linked to climate change, ocean acidification, and rising sea levels, to name a few. Numbers and statistics help express the magnitude of some changes, but comprehending the meaning of staggering numbers, percentages and predictions, or deciding what we should do to respond, is not easy. For example, if we know the world's oceans are 30% more acidic than they were 100 years ago, what does that mean for Hawai‘i; what should we do?

Fortunately, more and more people are thinking and talking about these issues, especially our keiki, and taking action, particularly our kupuna, reminding us all to think of the next generation. Fortunately, many of our predecessors thought about sustainability issues and set up systems to ensure we take care of our water and land. Fortunately, we live in a place with aloha, where there is a community spirit to help one another as well as dedicated emergency responders willing to take action at a moment's notice.

High stakes, risk and challenge often lead to innovation and adjustment, and we already are witnessing exciting ideas emerging here in Hawai‘i. Just last year the state legislature passed the Aloha + Challenge resolution (**Senate Concurrent Resolution 69 Senate Draft 1**), setting six statewide sustainability targets to achieve by 2030, in clean energy transformation, local food production, natural resource management, waste reduction, smart growth, climate resilience, green job creation and education. These targets provide a shared framework to set priorities, take action, and track progress. In July of 2014, our mayors and the state's chief executive formally endorsed and signed the Aloha + Challenge.

Similarly, the **Hawai‘i Green Growth** (HGG) initiative has taken root and is becoming an established collaboration among government, non-profit organizations, business and academia to advance action with an integrated approach to sustainability. The partnership honors Hawaiian cultural values and focuses on the interdependence of food, energy, natural resources, waste, smart growth, climate change, workforce development and education. HGG is working to build a diversified green and blue economy for a more resilient, sustainable future in Hawai‘i.

Last but not least, preparations have begun for September 2016, when the International Union for Conservation of Nature (IUCN) World Conservation Congress (WCC) will be held in Hawai‘i, providing us with a window of opportunity to collaborate with leaders around the world, learn about and share solutions, and prepare to create a better future. With this one event, we have a chance to showcase the best of Hawai‘i and influence global decisions. There is a lot of work to do.

OEQC, THE EC, AND THE ANNUAL REPORT

Way back in 1970, the state legislature passed groundbreaking legislation to create the Office of Environmental Quality Control (OEQC) in recognition that our economy and environment are equally important. In fact, they are inextricably intertwined, and our economy depends on our environment in more ways than we can imagine. Also, the Environmental Council ("EC") was created to advise the governor, all state agencies, and the legislature on environmental issues. Now, and every year, the EC publishes an Annual Report to provide information on the state of the environment to help identify priorities for the people of Hawai‘i—decision makers in particular.

SUSTAINABILITY VISON

This year's Environmental Council Annual Report provides an overview of the most critical sustainability issues for our state, including invasive and endangered species, water management and policy, energy use, food security and the need to create a more efficient government structure to address these issues. Based on much of the work done at the EC Strategy Session in August 2014, OEQC staff and volunteers discussed, debated, and worked tirelessly to create the EC's 2015 Sustainability Vision, providing a simple path, in black and white, for us to create a better future.

THE EC STRATEGY SESSION FOCUS: Climate Change, Invasive Species, and the 2016 WCC

The Annual Report also includes three briefings from expert panelists who presented findings at the Environmental Council's Strategy Session in August of 2014. Chipper Wichman shared stories to inspire us all to be persistent and provided proof positive that a few people in Hawai'i, working together, can create major, unexpected successes. He also helped us understand how we can and must be prepared for the IUCN WCC, happening here in Hawai'i September 2016. Dr. Thomas Giambelluca from the University of Hawai'i (UH) at Mānoa, gave an excellent summary of recent climate change findings specific to Hawai'i that can help us prepare for the future, identifying drought as an increasing result in some areas, and educating us all about the latest scientific findings relating to climate change specific to Hawai'i. We were also fortunate to hear from Christy Martin, who works on the front lines fighting invasive species, and Rick Barboza, who owns a nursery business and runs non-profit organizations that promote restoration of Hawaiian plants. Christy and Rick summarized some of the rapid and dramatic changes that have occurred on our islands, now including the Little Fire Ant, Coconut Rhinoceros Beetle, Macadamia Nut Coccid, and the Coffee Borer Beetle.

MEASURING THE RIGHT NUMBERS FOR THE RIGHT REASONS: THE GPI PROGRESS INDICATOR

For the third year in a row (see the **2012** and **2013** Annual Reports), the bulk of the EC Annual Report is the State of Hawai'i Genuine Progress Indicator (GPI) report by Dr. Regina Ostergaard-Klem and Dr. Kirsten L.L. Oleson, presenting data and information on values for ecosystem services that support the economy. The most commonly used measure of economic health is gross domestic product (GDP). GPI is designed to offer a more holistic view of the economy than GDP by including social and environmental, as well as economic, factors.

This year's report builds upon previous years, adding a new layer of specificity by focusing on the ever-increasing invasive species throughout all of the Hawaiian Islands. This analysis will become increasingly important as decision makers look more closely at how best to spend limited funds to address myriad needs for the economy and environment. The details in this section will help move forward the discussion on how to prevent and manage existing risks, and spend our dollars wisely; it leaves no doubt that when it comes to invasive species, we must not be penny wise and pound foolish.

MAHALO

Thank you for reading this far. I hope you are able to take the time to read the full Environmental Council Annual Report; it is not only really interesting, it also reflects the work and minds of many, and will help us all make better decisions.

In closing, I want to express my gratitude to all who have contributed to this report. It has been an honor to work as the Director, to serve the people of Hawai'i, and I simply can't thank the staff, volunteers, EC members, and all who have influenced this report enough. MAHALO A NUI LOA!

Jessica Wooley
OEQC Director, EC Member *Ex Officio*

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Cover photo: Wiliwili seed, Forest and Kim Starr

In 2005, a tiny new invasive wasp was spread across the state, laying its eggs inside wiliwili leaves, which weakened and killed wiliwili trees. Biologists statewide quickly collected as many of the seeds of native wiliwili as possible in the hopes that they could someday be replanted. Hawai‘i Department of Agriculture’s Biocontrol Program worked quickly to find, study, and release a natural enemy, saving the wiliwili from extinction.

INTRODUCTION TO THE COUNCIL

The EC serves as the liaison between the Director of the OEQC and the general public on issues concerning "ecology and environmental quality." The EC consists of 14 dedicated and conscientious volunteers appointed by the Governor and confirmed by the Hawai'i State Senate. Currently the EC has nine members, among which is the Director of the OEQC, who serves as an *ex officio* member and makes the total number of members to be 15.

Members of the EC represent "a broad and balanced representation of educational, business, and environmentally pertinent disciplines and professions, such as the natural and social sciences, the humanities, architecture, engineering, environmental consulting, public health, and planning; educational research institutions with environmental competence; agriculture, real estate, visitor industry, construction, media, and voluntary community and environmental groups (Chapter 341-3(c), Hawai'i Revised Statutes).

The EC is responsible for promulgating the administrative rules for Chapter 343, Hawai'i Revised Statutes, codified as Hawai'i Administrative Rules 11-200, Environmental Impact Statement Rules and 11-201, Rules of Practice and Procedure. The EC also reviews and provides concurrence on agency exemption lists.

Mark Ambler, Chair

Mark has been a member of the EC since May 2012 and currently serves as its Chair. Born and raised in Kailua, Hawai'i, Mark received degrees from 'Iolani High School and the University of Illinois at Urbana-Champaign. Mark's career has been devoted to pursuit of innovative and sustainable environmental engineering. He is a Professional Engineer registered in Hawai'i and a Project Management Professional. These certifications represent a career demonstrating technical and leadership training as well as professional experience. Mark has championed implementation of sustainable concepts, such as Green Roofs and Green and Sustainable remediation in Hawai'i, and has had the opportunity to share those positive examples across the country.

Scott Glenn, Vice Chair

Scott has served on the EC since 2011 and serves as Vice Chair of the Council. He served as Chair of the Council in 2013. He is a project manager at Cardno. He received his Master's Degree in Urban & Regional Planning from UH in 2009. Scott specializes in asset management, environmental planning and compliance, environmental review, and climate change adaptation planning. Scott helped create better data and data analysis tools such as the Genuine Progress Indicator as well as enhance the Council's role in communicating the public's concern about environmental quality to decision makers. As the Rules Committee Chair, Scott leads the Council's effort to modernize the EIS administrative rules.

Jessica Wooley, Member *Ex Officio*

Jessica is Director for the OEQC. Before, she was the state Representative for District 48 (Windward Oahu), and most recently served as Chair of the Committee on Agriculture in the State House. She was elected in 2008, after 5 years working closely with community and family organizations and raising her two children. Director Wooley also worked as an attorney at Legal Aid (1998-2000), an economist at UH (1999), and at the Office of the Attorney General as a Deputy Attorney General under Governors Cayetano and Lingle (2000-2003). Wooley graduated with a B.A. in Economics from the University of California, Santa Cruz, and received her M.S. in Agricultural and Resource Economics and her J.D. from the University of California at Berkeley. Throughout her personal academic and professional career, she has maintained a consistent focus on the connections between the environment and the economy, including issues relating to agriculture, land use, poverty, and water resources.

Koalani Kaulukukui, Member

Koalani was raised on Hawai‘i Island and then attended Kamehameha Schools, Kapālama Campus, received her B.A. from the UH Environmental Center. She earned a J.D. and Certificate in Environmental Law from the William S. Richardson School of Law in 2006. She has worked as an associate attorney for Earthjustice and as a policy advocate for the Office of Hawaiian Affairs (OHA). She is currently Counsel for Environmental Law and Native Rights at the OHA. As a member of the Environmental Council, Koa hopes to help shape environmental policy that ensures a robust future for our keiki without compromising the cultural and natural resources of our islands.

Charles Prentiss, Member

Chuck is city manager and a retired city planner with the City and County of Honolulu. He holds degrees in economics, planning, and government management. He is a former Executive Secretary of the Honolulu City Planning Commission, a Vietnam veteran pilot, and a retired Lieutenant Colonel of the Hawai‘i National Guard. Chuck is also President of Hawai‘i’s Thousand Friends and Chairperson of the Kailua Neighborhood Board. Chuck possesses a strong belief in citizen participation in government. For him, “participation aids in government openness and honesty, and provides a countervailing force to special interests in government decisions. In Hawai‘i, the environment is our economy.”

John Richards, Member

John was born and raised on a cattle ranch on Hawai‘i Island. John has lived in different parts of the world for both schooling and military service, which lent him a unique perspective on sustainable land and resources use. As the sixth generation of his family here, John has a desire to see the islands thrive: “The Council offers the opportunity to help the systems that protect the islands. A careful balance must be found to ensure business has what it needs to function well, while protecting the spirit, lands and people of Hawai‘i. Laws and their application can either make us greater or limit our potential. The Council has the opportunity to facilitate the former.”

Joseph Shacat, Member

Joseph attended Miami University (Ohio), where he studied philosophy and environmental science. He moved to Hawai‘i in 2001, where he earned a M.S. degree in Oceanography and an Executive MBA from the UH Shidler College of Business. He currently works as the Environmental Compliance Manager for Grace Pacific LLC. He has advocated for improving environmental performance in the construction industry through cooperation with government agencies and active engagement with industry associations, including the General Contractors Association of Hawai‘i, Associated General Contractors of America, and National Asphalt Pavement Association. Also, Joseph volunteers on the boards of Honolulu Clean Cities, the Hawai‘i Yacht Racing Association, and the Waikiki Yacht Club.

Mary Steiner, Member

Mary has served in a variety of roles on the EC, including as past Chair. Having spent almost 20 years as CEO of The Outdoor Circle, Mary is now the policy advocate for the Hawaiian Humane Society. She also acts as the Hawai‘i Campaign Manager for the non-profit Compassion and Choices, an organization that works to improve care and expand choice at the end of life. Mary has several goals before completing her term with the Environmental Council. These include helping OEQC to obtain proper staffing levels and funding, providing support to demystify the environmental review process so that the grassroots, project proponents and developers alike are able to understand the procedures. Mary strongly believes that a strong economy goes hand-in-hand with a healthy environment.

Glenn Teves, Member

Glenn has been a County Extension Agent for the UH College of Tropical Agriculture and Human Resources on Moloka‘i for the last 32 years. He also serves on the UH Professional Assembly Board of Directors and Moloka‘i Community Services Council. He is involved in agriculture, water, and land use issues on Moloka‘i. Glenn has served as a member of the DLNR Water Working Group and also the Maui Community Plan Advisory Committee. He is a Hawaiian Homestead farmer in Ho‘olehua and grows fruits, taro, and other vegetables for the local market. ”What makes Hawai‘i special are its unique environment, and especially its island communities. These are inextricably connected, and we must preserve both equally. This only comes through deliberate and diligent planning.”

INTRODUCTION TO THE OEQC

The OEQC (clockwise from top left): Linda Hijirida, Herman Tuiolosega, Les Segundo, Director Jessica Wooley, and Genevieve Hilliard.

The OEQC was established in 1970 to stimulate, expand, and coordinate efforts to maintain the optimum quality of the state's environment. The OEQC implements Chapter 343, Hawai'i Revised Statutes, which governs the environmental review process. Office planners review hundreds of environmental disclosure documents and respond to thousands of inquiries each year from agencies, the public, and the private sectors.

Twice a month, the OEQC publishes the Environmental Notice, which announces the availability of Environmental Assessments and Environmental Impact Statements undergoing public review, as well as other local, state, and federal activities of public interest.

Jessica Wooley, as OEQC Director, provides advice and assistance to private industry, government agencies, and community groups regarding Chapter 343, Hawai'i Revised Statutes. The OEQC is also empowered by law to conduct research, develop legislative initiatives, do public outreach, and recommend programs for the long-range implementation of environmental quality control.

The OEQC staff also provides support to the EC regarding amendments to the administrative rules, exemption lists, and the Council's annual report. The OEQC is attached to the Hawai'i Department of Health for administrative purposes.

This year, the OEQC released its new **EA and EIS Map Viewer** and its **Citizen's Guide to the Hawai'i Environmental Policy Act**. These tools help proponents and the public better engage the environmental review process.

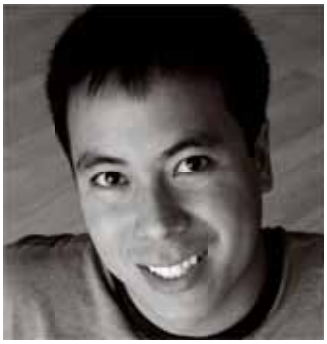
VOLUNTEERS

OEQC Volunteers

Peter Myung
I am currently volunteering for OEQC. I think improving the earth's environment is very important for our next generations. I am working willingly and happily with our staff.

Nourah Abualsaud
I am currently a graduate student at Hawai'i Pacific University, majoring in Global Leadership and Sustainable Development, focusing on sustainable development issues. I am planning to pursue a Ph.D. in Environmental Policy and Development.

Kelsey Anderson
I am a third year law student attending the William S. Richardson School of Law, University of Hawai'i at Mānoa. My coursework included classes such as Environmental Law, Environmental Clinic, Administrative Law, and Land Use Management & Control. Mahalo for the opportunity to build on my in-class education by volunteering with OEQC!



Kaimana Pine
Love, respect and the willingness to work. I believe that people can affect change living by those words. The OEQC mission inspires me to help grow its relationship with communities in Hawai'i through my passion for art and technology.

Liam deClive-Lowe
I am very passionate about contributing to the progress of environmental legislation, streamlining state government, and helping to make Hawai'i a more sustainable place. I feel so grateful for the opportunity to volunteer at OEQC.

Meg DeLisle
I moved back to Hawai'i after pursuing my Master's degree in Environmental Science at University of Colorado, Denver. I received my B.S. in Marine Biology from UH. I am very passionate about the environment and conservation of our natural resources. Volunteering at OEQC has given me a chance to be part of the solution as Hawai'i navigates its environmental policies towards a more sustainable future. I am so happy to be part of any effort that helps save and protect our precious 'āina!

GPI Research Assistants

Brandon Tao

Brandon is an undergraduate student majoring in Environmental Studies at Hawai‘i Pacific University, where he is also pursuing a graduate certificate in Environmental Policy and Leadership. He aspires to continue his education in environmental policy, with concentrations in resource management and marine conservation. In addition to his education goals, he hopes to eventually work in the public sector or with a non-governmental organization.

Monique Schafer

Monique is completing her B.S. in Environmental Science at Hawai‘i Pacific University. She plans on continuing work in the environmental field by going to graduate school to pursue a master's degree in Environmental Science and Management. Her research interests include water resource management, ecological restoration, and land-use policy.

Lisa Hinano Rey

Lisa will graduate from the College of Tropical Agriculture and Human Resources (CTAHR) at UH with a B.S. in Natural Resource and Environmental Management in May of 2015. Previously she attended Windward Community College where she earned a Certificate in the Marine Options Program. She helps to preserve and protect the land the ocean and the culture by engaging in environmental restoration projects at several levels, policy, education, outreach as well as hands on in-field community based restoration. She grew up in Kāne‘ohe and speaks English, Tahitian and French.

Ben Southwell

Ben Southwell is a veteran and a graduate student at Hawaii Pacific University in the M.A. in Global Leadership and Sustainable Development (GLSD) program. He has an undergraduate degree in political science and international affairs. For his capstone project in GLSD, he is interested in game theory and climate change. Upon graduating, Ben intends to remain a student, eventually acquiring a Ph.D. in political science.

Also thank you to Jade McMillen.

Introduction

Solutions for the future of Hawai‘i

Hawai‘i faces a number of environmental challenges, and solutions will not be quick or easy as global warming, sea level rise, food insecurity, land and water scarcity, skyrocketing energy costs, and invasive species take their toll on our environment and economy. One might hope that government could change quickly to become more relevant and responsive, or at least, less massive and wasteful. The reality is that even minor adjustments in government take time and too often, easy solutions do not happen for the wrong reasons.

Given Hawai‘i’s remote location and today’s challenges at both the global and local level, there simply has never been a better time to rethink our government from a sustainability perspective, to lay the foundation for a better future.

At the 2014 Environmental Council Strategy Session, environmental priorities were set forth and agreed upon by the Environmental Council. Based on research on past legislation, as well as discussions with field experts, the Environmental Council created this report to communicate its vision of key priorities that should be addressed through legislative action and public policy.

Not only does this report put forth a broad vision for sustainability in Hawai‘i, but it also lays out a comprehensive series of strategies to fulfill that vision. The Aloha + Challenge plays an integral role in this vision, as it outlines Hawai‘i’s top six sustainability goals for the next fifteen years. If implemented, actions proposed in this report would take us another step closer to reaching those goals. By increasing government efficiency and decreasing costs in the long-term, these strategies can lead us towards a brighter future that will benefit the people of Hawai‘i for generations to come. In short, this vision grants Hawai‘i the opportunity to reach its full potential and become truly sustainable.

Natural Resource Management

Protect Hawai‘i’s unique environmental landscape

Invasive species have become a very serious problem for our endangered Hawaiian ecosystems as well as our economy. Unfortunately, our modern global economy has led to many new vectors for invasive species to be introduced. Preventing new species from arriving on our shores, and preventing their spread, requires better restrictions on imports from abroad and regulation of intra-island transportation.

At the same time, endangered species protections need to be improved upon as Hawai‘i’s uniqueness and our environmental and economic potential permanently disappears whenever a species goes extinct. With so many of our very special endemic and endangered species facing a bleak future, it is important to maintain a high level of protection and to continue to provide funding to help save these unique plants and animals.

II. Freshwater and Nearshore Water Management

Hawai‘i is the most isolated chain of islands anywhere on the planet. While our remote position in the center of the Pacific makes us highly vulnerable to the dangers of climate change, we also have a great opportunity before us. Hawai‘i, perhaps unlike any other place in the world, is perfectly poised to illustrate how to effectively prepare for, and ultimately confront, climate change. We must strive to be the example for other states and nations, by implementing clear policies that will ultimately conserve our unique natural resources for centuries.

Science has consistently demonstrated that freshwater availability will decrease in the coming decades. As one of the most essential resources necessary for human survival, we must improve our water management and make sure we can ensure the conservation of clean, safe drinking water for the future generations of Hawai‘i. These potential initiatives could include incentives to install gray water recycling systems and decrease household water usage, ultimately motivating both businesses and families to make more sustainable decisions. Science has also shown that our near shore waters face multi-faceted challenges, ranging from alien species, rising sea levels, ocean acidification, and higher temperatures. Private, non-profit organizations, community leaders, and all levels of government must move more quickly to better manage human activities and actions that affect these sensitive, priceless, and potentially bountiful resources.

III. Renewable Energy

70% locally-generated renewable energy by 2030

According to recent reports, the State of Hawai‘i is the top consumer of fossil fuels (per capita) in the nation, using more fuel per capita than any other state. Due to our extreme isolation, importing products uses an inordinate quantity of fuel, which accounts for a substantial portion of the pollution for our islands and the broader Pacific. While we may not be able to reduce imports any time soon, we can begin to tackle this ever-growing energy crisis by dramatically increasing our utilization of renewable energy. Given that Hawai‘i is the only location on Earth where it is possible to create all four main types of renewable energy (solar, wind, geothermal, wave), we now have an opportunity to lead the nation in the global movement to make our planet more sustainable and resilient for generations to come. We endorse two simple strategies, described below.

Definition: renewable energy ~ energy from a source that is not depleted when used

Renewable Portfolio Standard

The state can support the 100% Renewable Portfolio Standard for electric generation & transportation fuels. These possible initiatives have the potential to not only further the transition to renewable energy, but also provide attractive incentives to citizens to invest in this transformation through tax credits.

Sustainable & Efficient Transportation Initiatives

Transportation in particular needs to develop comprehensive policies and procedures to reduce the use of fossil fuels. Potential policy changes are easy to find by looking at states that have needed to meet federal Clean Air Act mandates, such as congestion management tools, public-private partnerships to discourage single-occupancy vehicle trips, increased pedestrian bicycle and public transit options, and parking limits and offset fees to promote the use of alternative transportation.

IV. Local Food Production

30% locally produced food by 2030

The Aloha + Challenge sets forth an ambitious goal; by 2030, 30% of the food consumed in the state must be produced locally. While this goal is attainable, if we wish to achieve this standard in time, we must understand the underlying importance of local food production and its fundamental benefits for disaster preparedness, human health, the economy, education, and our worldwide carbon footprint.

Disaster Preparedness

As of today, Hawai‘i only grows about 10% of its food locally; the remaining 90% is imported, which contributes heavily to our exorbitant fossil fuel emissions and hurts our economy and environment in multiple ways, exposing us to potential risks and uncertainty. Imagine if the entire state were to lose access to imported foods, due to a sudden natural disaster that cut off trade with the mainland. Forced to continue off the locally produced foods, we could only feed our population for 10 days, after which, we would have limited food left to survive.

Health

All citizens of Hawai‘i deserve to have food that is fresh, healthy and local. However, the bulk of the food that is imported into Hawai‘i is processed; even those imported foods that are not processed likely end up losing nutrients during the importation process. Not only are locally grown foods nutritious and fresh, more importantly, they also establish a direct connection between the farm and the plate, thereby promoting a culture of respect for the ‘āina. Issues such as economic disparity and food deserts also should be exposed and eliminated, wherever and whenever they occur.

Economy

As demand for locally-produced food increases, new local agriculture operations will be formed and existing small agricultural businesses strengthened, in turn creating hundreds of middle-class jobs. As the supply of local food increases, competition will increase as well—thereby driving and stimulating the local economy. Reduced dependence on imported food supplies will also stimulate the local economy and protect us from unwanted price or supply changes.

Education

Public schools provide one of the most effective and potentially far-reaching methods for delivering locally-produced food to the citizens of Hawai‘i. Our keiki should have the chance to build a connection with the food they consume. By teaching our students about local food at a young age, we will pave the way for the future farmers, chefs, and agricultural entrepreneurs of Hawai‘i.

Carbon Footprint

Not only does increasing our locally produced food benefit Hawai‘i’s environment, it also decreases our carbon emissions. When we import our foods from elsewhere across the world, every bite we consume has traveled thousands of miles to reach our mouths. This takes a toll on the global atmosphere, and hence, contributes to the crisis of our ever-warming planet.

With each of these issues playing an essential role in the vision for local foods in Hawai‘i, we now have an opportunity to build a sustainable future for Hawai‘i and make the Aloha + Challenge a reality. To accomplish this seemingly unconquerable feat, we must implement positive incentive-based strategies that will increase the demand for local agriculture, support innovative agribusinesses, and create comprehensive farm-to-school programs.

V. Department Of Sustainability

The implementing force behind the Aloha + Challenge

Sustainability issues must be better organized in government to reflect critical and myriad environmental and economic needs in Hawai‘i. Existing relevant agencies should be consolidated and united in a Department of Sustainability, thereby eliminating inefficiencies created by programs that are now scattered among multiple agencies, making government more responsive, and providing authorization for an agency to implement the Aloha + Challenge.

The Department of Sustainability would focus on coordinating and advancing all of Hawai‘i’s environmental initiatives, most notably, the Aloha + Challenge. Based on the fundamental goals of efficiency, collaboration, and action, the Department of Sustainability would provide a single, unified agency directly responsible for coordinating environmental projects between state agencies, local businesses, and the public. As the implementing force behind the Aloha + Challenge, the Department of Sustainability would have the ability to help execute the six sustainability goals, thereby giving Hawai‘i the best chance at a sustainable environment for generations to come.

There is a real need to consider consolidate existing environmental and sustainability programs in Hawai‘i that are now scattered and often disconnected. Currently, for example, our Environmental Health Administration lies within the Hawai‘i Department of Health (HDOH). Also, the OEQC is an attached agency to the HDOH, and the EC is an independent advisory board but also attached to HDOH. At the same time, there are programs within the Hawai‘i Department of Land and Natural Resources (DLNR), the Hawai‘i Department of Agriculture (HDOA) (pesticides) and the Department of Business, Economic Development, and Tourism that focus on the environment and sustainability.

It was a common practice in the early 1970s for states to organize environmental programs within health departments. However, as the need for more environmental prioritization grew over the following decades, states began to unify their environmental offices under new departments—ones that were dedicated to the mission of environmental sustainability.

The time has come for Hawai‘i to do the same. Due to our unique geographic isolation at the center of the Pacific, critical issues such as climate change and sea-level rise will have a major impact on Hawai‘i’s environmental landscape. It is of the utmost importance that we confront these monumental challenges before they become crises we cannot solve. If we are to take on these seemingly overwhelming obstacles, we must advance swiftly in a unified and coordinated effort. The establishment of the Department of Sustainability is perhaps our best chance at tackling these challenges effectively.

Efficiency

Reorganizing the Environmental Health Administration as the core of the new Department of Sustainability would increase the state’s responsiveness to environmental issues, business interests, and the general public. Not only would the increased responsiveness lead to vastly improved efficiency, it would also promote more accountability and effectiveness.

Collaboration

The Department of Sustainability would be uniquely positioned to coordinate with other agencies by interconnecting the environmental efforts of transportation, land use, water management, development, city planning, health, agriculture and education. Through deeper and broader collaboration, Hawai‘i would be better prepared to take on environmental challenges, promote sustainable and green growth, and find real solutions that will last for generations.

Action

The Department of Sustainability would be the implementing force behind the Aloha + Challenge. This new, agile, and collaborative department is exactly what the Aloha + Challenge needs to reach its full potential for sustainability in Hawai‘i. Over the coming 15 years until 2030, the Department of Sustainability would be responsible for launching sustainability initiatives to help Hawai‘i reach the six sustainability goals of the Aloha + Challenge.

The Journey of a Lifetime – How the World Conservation Congress was awarded to come to Hawai‘i in 2016

In early 2009, Penny Levin from Maui and Christopher Dunn from Honolulu and myself (from Kaua‘i) indulged in a casual conversation about how great it would be for the world if the IUCN would consider Hawai‘i as the location for its World Conservation Congress (WCC).

For those not familiar with the IUCN, it is the International Union for Conservation of Nature (IUCN) and it is based in Switzerland as a symbol of its international importance and neutrality. The IUCN is the world's oldest and largest global environmental organization, with more than 1,200 government and Non-governments (NGO) Members and almost 11,000 volunteer experts in some 160 countries. Every four years, IUCN holds the WCC which is the world's largest and most inclusive nature conservation forum that inspires member organizations to improve their management of the natural and cultural environment for human, social, and economic well-being. The WCC hosts 8,000–10,000 delegates from around the world to discuss, debate, and decide on environmental and development issues and policy.

Back to our taro patch…over the next few days as our conversation continued to grow more intense it got us more and more inspired—we could close our eyes and clearly visualize the value both to Hawai‘i and to the global conservation community. It was a dream, in fact it was almost a laughable dream, but it inspired us to take action and to see how far we could go. And go we did! To our amazement, and the amazement of many around the world, on May 21, 2014 at the IUCN Council meeting in Gland, Switzerland (just outside of Geneva) the Council made up of representatives from around the world voted unanimously to award the 2016 World Conservation Congress to Hawai‘i.

Chipper Wichman, President, Chief Executive Officer and Director National Tropical Botanical Garden, Kaua‘i, United States

For his entire adult life, Chipper has worked to preserve the precious natural and cultural resources of Hawai‘i where he was born and raised. He began work at the National Tropical Botanical Garden (NTBG) in 1976 conducting botanical surveys of Limahuli valley and the Nā Pali coast where he discovered several new species of plants and helped to pioneer methods of rappelling down cliffs to hand pollinate the species threatened with extinction. Over the past 39 years, Chipper has held various leadership positions at the NTBG including being director of two of their five gardens before being appointed the Acting Director in 2003. In 2005, Chipper was appointed as the Director and CEO and in 2014 he was given the additional title of President.

Some of Chipper's many accomplishments include the creation of the award winning Limahuli Garden and Preserve and in 1994, Chipper and his wife Hau‘oli donated this 1,000 acre Limahuli Valley to the NTBG in order to create ahupua‘a-based management program that has been successful in restoring rare plant communities as well as cultural sites and traditional knowledge and practices.

In 1999, Chipper was honored by the State Legislature for his leadership in as the Director of Kahanu Garden in Hana where he empowered local Hawaiian stoneworkers from Hana to undertake the restoration of the massive Pi‘ilanihale Heiau, the largest stone structure and one of the most sacred cultural sites in all of Hawai‘i.

In 2008, Chipper successfully completed a $15 million capital campaign to build a new 21,000 square foot LEED Gold botanical research center at NTBG which was the first LEED certified green building built on Kaua`i.

In 2013, Chipper received the Outstanding Leadership award from the Hawai‘i Conservation Alliance for his role in leading the effort to bring the IUNC World Conservation Congress to Hawai‘i in 2016.

Chipper has been able to accomplish all of this thanks to the steadfast support from his wife Hau‘oli who serves as his Executive Assistant.

The story of how this came to be is a testimony of "taro-roots" tenacity, passion and commitment—of a growing army of people who agreed never to say "we give up" because we believed in a vision so potent that it engaged the hearts and minds of the most powerful people in our country including the Governor of Hawai'i and the President of the United States!

The story of how this came to be is a testimony of "taro-roots" tenacity, passion and commitment

While I soon become the elected leader for this effort, it took an army of dedicated people from the conservation, environmental, and foundation community to pull it off. To list all of their names would be folly as the list would be pages long and I would leave someone out! Year after year, we worked at building support in Hawai'i and Washington DC and developing a strategy to overcome the political resistance within the US Department of State (DoS), which had kept the WCC out of the United Stated since the IUCN's founding 70 years ago!

This was a mammoth undertaking and there were not only the countless trips to Washington, but in 2010, my wife Hau'oli and I flew to Switzerland to meet with the leadership of IUCN and to begin building the relationships that would become allow us to come to intimately understand this large and complex organization and what they wanted to get from holding the world's largest conservation gathering on earth every four years. From Switzerland we flew to Barcelona to meet with the hosts of the 2008 WCC and to hear first-hand what it took to host a WCC and what they felt they got out of it. It was an amazing trip and as we flew back halfway around the world on our way home I knew then that if we were given the opportunity we could host the best WCC that IUCN would ever see and that it would energize and inspire conservation efforts in Hawai'i and around the world.

In September 2012, as the world gathered in Jeju, Korea for the 2012 WCC our efforts seemed to reach a crescendo. In the summer months leading up to the 2012 WCC, our committed partners opened their checkbooks and we raised close to $250,000 in funding from various sources including foundations, state government, NGOs, and individuals. As the funding came in, we were able to put together an amazing delegation of close to 60 people that included 40 members of our science/conservation community (including 3 from Micronesia and Palau and 2 from San Diego Zoo), 12 native Hawaiian hula dancers, 3 VIPs with 3 support staff, and four support staff including two Koreans (one also spoke Spanish) to help with translations. We built the five most beautiful booths at the Congress for outreach and conducted two significant outreach events including a VIP reception for over 250 dignitaries and a traditional hula performance by Unukupukupu (a traditional dance troupe) conducted on the world stage and attended by thousands of delegates from around the world. Over 20 members of our delegation were participants and/or moderators in 10 Workshops, 4 Knowledge Cafes and numerous poster sessions. Each of these individuals also presented a unique perspective on how Hawai'i is playing a leading role in the global conservation community.

As 2012 came to a close, we felt really good about our strategy and our prospects of success and eagerly anticipated the call from IUCN for "An Expression of Interest" that would solicit proposals from countries wanted to host the 2016 WCC. Then, on a rainy day in December, Senator Inouye died and our whole world seemed to fall apart. Both Senator Inouye and Akaka had been our champions encouraging us on year after year and assuring us that when the time came they would help to secure the support of the DoS. Its support was essential—without it we could not submit a bid to IUCN—as only IUCN member counties (there are over 160 of them) could host a WCC according to the IUCN's bylaws.

This requirement was logical since a host had to 1) ensure access and visas for all qualified IUCN delegates from around the world and 2) provide the substantial financial resources needed to host this massive global event.

Overnight, our vision went from being bright and powerful to being a dim flickering light—it seemed to me that it was like a candle that was sputtering trying desperately to stay lit.

Overnight, our vision went from being bright and powerful to being a dim flickering light—it seemed to me that it was like a candle that was sputtering trying desperately to stay lit.

Our darkest moment was in February 2013 when all seemed lost, but it was then that Dr. Steve Montgomery came to our rescue and with his bold and embracing character and die-hard attitude. He almost single-handedly reignited our flame and pulled us up and out of the dark hole of despair.

With that new burst of energy, we sought and found a new champion in the honorable Governor Neil Abercrombie. The Governor realized what this could mean for Hawai‘i and for his own vision of pushing Hawai‘i to become a global model of sustainability. The Governor was already a champion of the Hawai‘i Green Growth Initiative that had been inspired by Audrey Newman and the Global Island Partnership and he had appointed a State Sustainability Coordinator to facilitate his vision so…it was not too much of a stretch for him to grasp that this was an opportunity for Hawai‘i that would never be presented again.

At the 11th hour the Governor agreed to sign a letter of “Expression of Interest” and put the full weight of his administration behind our effort. This was a transformational moment, as it signified the transition from a completely organic “taro-root” effort to one led by a government entity. When I realized that the Governor now “owned” it, I knew that we had turned the corner and we were back on track and that our dream was still very much alive. The Governor appointed Esther Kia‘aina to be the First Deputy to the DLNR and the person to lead this effort for his administration. Eventually through his connections and efforts the Governor secured a passionate letter of support from President Obama and the support of Patrick Kennedy the Under Secretary of State for Management at the DoS. Hawai‘i’s successful hosting of APEC was one of the key factors that came into play in securing this high-level support.

What was interesting looking back was that over the years our focus and effort was directed at developing a strategy that would allow us to be able to submit a bid to IUCN. We never really thought about what we would have to do if we were allowed to submit a bid!

As amazing as that seems to me now, I think that is because we were so confident that if that time ever came that we would blow the competition away just because we have so much to offer here, from the best convention center and hospitality industry in the world to a deeply committed and innovative conservation community. We knew in our heart of hearts that hosting 10,000 delegates from 160 counties was something we could do better than anyone else.

While we clearly believed this, when we saw the competition it was intimidating as it included some spectacular locations and countries willing to put up huge amounts of money to host this prestigious event. The completion included: Abu Dhabi (UAE), Hungary, Istanbul (Turkey), Liverpool (UK), Northern Ireland (UK), Panama, and Rio de Janeiro (Brazil). Eventually the competition narrowed down to Hawai‘i and Turkey and IUCN scheduled site visits to each location. In February 2014, a team from IUCN’s headquarters in Switzerland arrived in Hawai‘i to inspect our facilities and test the commitment of our state.

What they experienced over the week they were with us transformed their views of Hawai‘i and took them far beyond the false vision of Hawai‘i as a land of surf and shopping to one of deep cultural connections that fuel some of the most amazing conservation work on the planet.

They saw rainbows, whales jumping, the volcano erupting, and the most beautiful landscapes on earth. They also met with the Governor and other political leaders as well as the leaders of our conservation community. When they left we knew that Turkey could not stand a chance!

While this story has up to this point been about the journey of bringing the WCC to Hawai‘i, what is important now is for the citizens of Hawai‘i to begin to engage in the process of hosting the WCC and to create your own dream of what it can leave behind as a legacy.

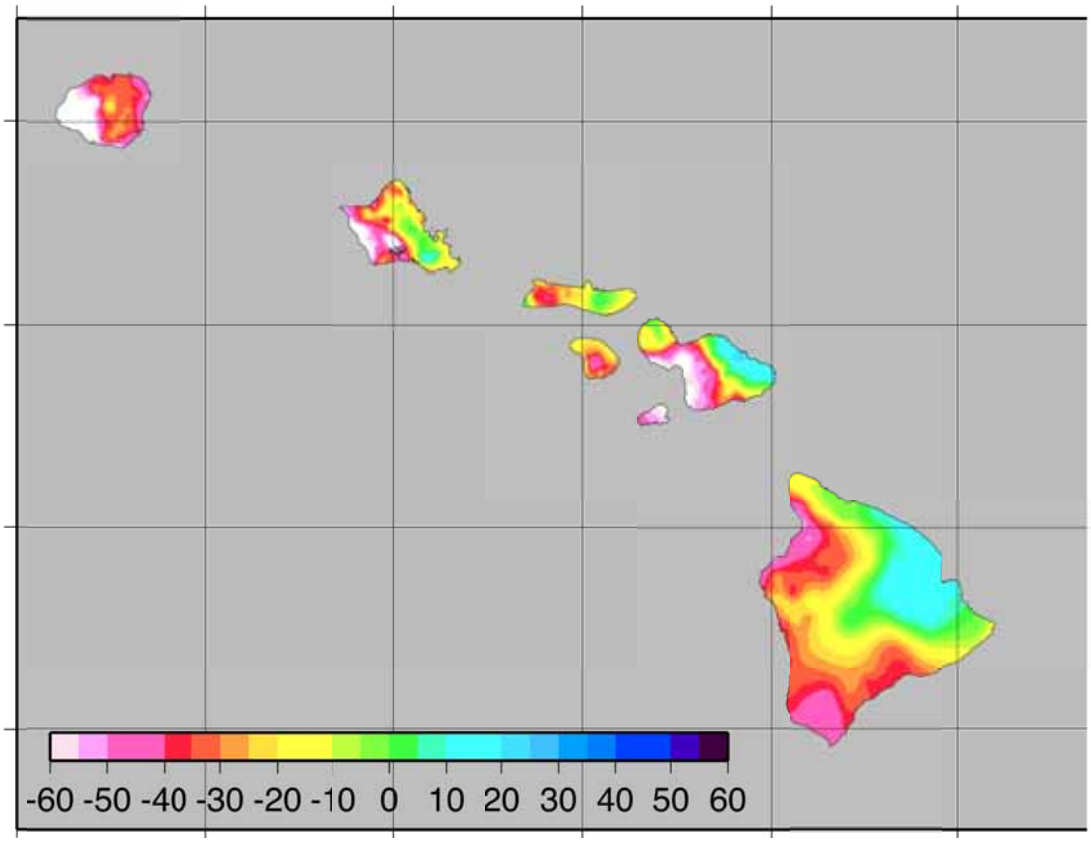
If all we do is host the best WCC the world has ever known and we do not create catalytic and transformational change, then I would say we will have missed the opportunity of a lifetime.

I encourage everyone to get involved now and to find out how to participate and to begin thinking about big ideas that will be a legacy that is left when the 2016 WCC is over and the delegates have all gone home. What are the commitments that our local, state and federal governments can make when the world is here that will transform the way we do business and care for the precious environment that makes Hawai‘i so unique in the world?

What lies before us is an uncharted ocean and it is up to us to navigate our canoe to the destination we envision. It is not by accident that the Hōkūle‘a is embarking on its own unprecedented voyage around the world that will share our values and commitments with far flung communities and peoples. Our planet is hurting and we need to lead and inspire others so they too can care for island earth. Together we can do it.

Recent historical data indicate that climate is already changing in Hawai'i. Temperatures are rising, especially at higher elevations (Giambelluca et al. 2008), where most of the remaining native forest is found. Precipitation is declining (Diaz and Giambelluca 2012), and solar radiation on the upper slopes of the highest mountains is increasing due to reduced cloud cover (Longman et al. 2014). These changes are consistent with an observed change in the atmosphere over Hawai'i. The trade wind inversion (TWI), a layer of air at around 7,000 ft above sea level, acts as a cap on the growth of clouds.

The TWI can occur with or without trade winds, but it always tends to limit clouds and rainfall. The number of days per year with a TWI present over our islands has increased (Cao et al., 2007). This seems to be associated with a change in large-scale circulation of the tropical atmosphere, which has resulted in more descending air over the islands (Longman et al. in review). Whether or not these changes are the result of global warming is not yet known (Frazier et al. 2014). But, projections of future climate in Hawai'i based on statistical downscaling of global climate models (Timm and Diaz 2009, Elison Timm et al. 2011, Elison Timm et al. 2013, Elison Timm et al. in press) indicate that changes in precipitation will continue throughout this century (see the figure below). Wet season rainfall is expected to decrease severely in the drier areas of the islands, where most people live, where resorts and golf courses are located, and where irrigated agriculture is found. This projected change in rainfall, if it becomes reality, will have large impacts on natural ecosystems and people in Hawai'i in the coming decades.



Change in wet season rainfall for the Hawaiian Islands based on statistical downscaling of the ensemble median of 32 CMIP5 RCP8.5 global model runs for the 2071-2099 average (Elison Timm et al. in press).

Thomas Giambelluca is a professor of Geography at the University of Hawai‘i at Mānoa, who specializes in climatology and hydrology of tropical environments. Dr. Giambelluca received B.S. and M.A. degrees in Geography from the University of Miami (Florida), and a Ph.D. in Geography from the University of Hawai‘i at Mānoa. Dr. Giambelluca’s research is focused on land-atmosphere interaction under changing land cover and changing global climate. In Hawai‘i, one aspect of his work aims at improving understanding of Hawai‘i’s climate, how it has changed over the past century, how it is likely to change in the future, and how the changes have and will affect hydrological processes and terrestrial ecosystems. He also studies the effects of biological invasions in Hawai‘i, particularly by alien tree species, on water, soils, and carbon storage.

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Focus on Invasive Species

The Hawaiian archipelago is the most isolated group of islands in the world, with the nearest continent more than 2,400 miles away. For more than 70 million years, the volcanic islands of the archipelago have been created as the earth's crust moves over 'hotspots', or holes in the middle of ocean floor, which are then conveyed away to weather and erode. Unlike other islands, the Hawaiian Islands were never close to any land mass, a key factor that limited the arrival and successful establishment of many common continental species.

Christy Martin, project manager and public information officer for CGAPS, the Coordinating Group on Alien Pest Species. CGAPS's mission is to coordinate and catalyze action among government and non-government partners to prevent and manage invasive species in Hawai'i, as well as communicate key issues to the public.

Despite this isolation, the first plant and animal species were able to arrive and colonize millions of years ago, carried by the wind, ocean currents, and even within or attached to birds. Millions of years, extreme isolation, and diverse physical habitats led to more than 18,000 native Hawaiian species, many of which are found only in Hawai'i. In fact, Hawai'i has the highest number of endemic species in the world.

Today, Hawai'i's isolation provides limited protection against the arrival of new species, as the purposeful and accidental transport of new species via planes and ships is a daily occurrence. From being 100% food self-sufficient little more than 200 years ago, Hawai'i now imports 80-90% of the food consumed locally, and is equally dependent on imports for goods and energy. Each plane or ship—its people, its cargo, or the vessel itself—can bring with it new, potentially harmful species alongside the useful or benign new species.

There are steps that we can and should take to protect Hawai'i from invasive species, and they fall generally into the categories of prevention, early detection/rapid response, and control or mitigation of the most harmful non-eradicable pests to reduce their impact.

Prevention (Pre-entry and Port of Entry)

The most cost-effective measures are pre-entry agreements and laws to keep unwanted pests from being legally or intentionally imported. One example of such an agreement is the Hawai'i Department of Agriculture's request to have Christmas trees grown in Oregon and Washington physically shaken to remove pests before being loaded and shipped to Hawai'i. An example of a law is the law restricting the importation and possession of snakes. It should be a priority to regularly identify and set in place agreements, laws, and procedural measures that can keep pests offshore, and laws or measures that could prevent a pest from moving from one island to another.

For the most part, federal and state agencies are not inspecting for the same things and are restricted from sharing interception information with each other. Once shipments arrive at ports, inspection of foreign goods is conducted by federal agencies looking for pests of national significance, while inspection of domestic goods is the responsibility of the Hawai'i Department of Agriculture, The State's actionable pest list is more comprehensive and targeted to pests of Hawai'i than the Federal list.

A second major problem is that the HDOA does not have adequate, much less optimal, inspection facilities at most sea and air ports. Until very recently, boxes were inspected on the tarmac at some ports, where potential invasive species could easily escape. Unless we get serious and address these gaps with better inter-agency cooperation and better facilities, we will very soon be overwhelmed.

Early Detection & Rapid Response

Invasive species can get through even the most rigorous prevention networks, and this is to be expected. A consistent and properly funded early detection system should be the next line of defense. In the past, there have been successful detection programs that have greatly aided the response to an invasion:

HDOH used to maintain hundreds of mosquito surveillance traps at ports of entry and throughout the islands to monitor for diseases like West Nile Virus and new mosquitoes such as the Anopheles species that could reintroduce malaria to the islands. Despite the 2009 budget cuts which resulted in the loss of 40 staff and the and dismantling of the surveillance system, four traps kept at Honolulu International Airport detected *Aedes aegypti* mosquitoes at least five times since. These mosquitoes are the most efficient transmitters of dengue fever.

Early detection also proved important in finding the coconut rhinoceros beetle in December 2013. Survey traps for several different pests that were not known to occur in Hawai‘i, but that were highly likely to arrive were placed around the state in 2013. Just a few months later, one of those traps captured a coconut rhinoceros beetle, which set in motion the rapid response team with the goal of eradication. However, funding for such early detection surveys are largely via soft funds. If funding for such a survey had been received in 2012, the infestation may have been detected at an earlier stage.

Invasive Species Potential and Current Effects to Hawai‘i

Upon arrival, some species remain benign or beneficial, but others become invasive —they reproduce and spread quickly, causing harm to the environment, the economy, agriculture, or public health. The multi-faceted costs of just a few unwanted invasive pests are staggering:

- If brown tree snakes (*Boiga irregularis*) were to become established in Hawai‘i, economists estimated a $2 billion dollar annual impact to the power infrastructure, public health, and visitor industry alone. Yet brown tree snakes have also caused the extinction of 10 of 12 of Guam’s native forest bird species, and the ongoing lack of birds on the island has cascading effects, such as a reduction in natural seed dispersal and forest regeneration, and an increase in insects and their impacts on agriculture.
- In the ocean, invasive seaweeds overgrow and smother near shore reefs, reducing the food, habitat, and shelter space for a wide variety of fish and invertebrates that depend on the reefs. Hawai‘i’s reefs also generate $800 million annually and protect the shoreline from storms and the impacts of climate change.
- The arrival and subsequent discovery of the plant disease commonly known as ‘ōhi‘a rust (*Puccinia psidii*) in 2005 was a wake-up call to resource managers as the disease spread across the state, sickening and killing large tracts of rose apple, skipping over its very close cousins, ‘ōhi‘a trees. Research now shows that any additional imports of this plant disease could attack ‘ōhi‘a instead, a critical blow to 1 million acres of watershed forests and the most sacred of Hawaiian cultural plants.
- The arrival and establishment of mosquitoes carrying human diseases like malaria, dengue fever, or chikungunya would have a huge impact on residents, businesses, and the visitor industry.
- Existing invasive species, such as strawberry guava (*Psidium cattlianum*), continue to spread into watershed forests statewide, outcompeting and replacing native forest plants and reducing habitat for the animals that rely on native forests. Strawberry guava forests also transpire up to 50% more water into the atmosphere compared to native ‘ōhi‘a forests, which impacts water resources.

The island-based Invasive Species Committees also focus on early detection and rapid response of plants and animals that no single agency has the authority or capacity to address. They work across jurisdictions and property lines, to focus on early detection and control or eradication of high-risk invasive species that may otherwise become established.

In 2014 the Invasive Species Committees have provided critical capacity to HDOA in the little fire ant and coconut rhinoceros beetle responses, while continuing work detecting and controlling priority pests like miconia (*Miconia calvescens*), pampas grass (*Cortaderia spp.*), and devil weed (*Chromolaena odorata*). Despite clear examples of what these species can do if allowed to become widespread, these committees continue to rely on grants year to year.

One unique attribute that Hawai‘i has is an opportunity to reduce or stop the spread of pests from one island to the next. This has historically not been a focus or priority, and will require additional effort on every island. Each pest that arrives and spreads from island to island by commerce and travel is a clear indicator of need.

Control of Widespread Pests

It is often said that an ounce of prevention is worth a pound of cure. However, this should not be used as a reason to pay less attention to those invasive species that are already present, yet if allowed to continue to multiply and spread unfettered, would impart unacceptable levels of damage on natural resources or public health. Two examples illustrate the spectrum of effort required to control widespread pests:

The spread of little fire ants into watershed forests, agricultural crops, and communities statewide will have an unacceptably high cost on nearly every aspect of our lives in Hawai‘i. It is irresponsible to not do everything in our power to slow or stop the spread of these invasive stinging ants. This type of infestation may take great effort and funding over time to properly manage.

On the other hand, for certain widespread invasive plants and insect pests, it is possible to find one or two natural enemies that keep that invasive species' population under control in its native range. The most recent success of finding the natural enemy for the wiliwili gall wasp (*Quadrastichus erythrinae*) was an example of what can and should be done to find long-term suppression of 100 additional widespread invasive species. The cost of finding and studying potential natural enemies, or biocontrol, was relatively low and upfront, and the ongoing control of the gall wasp is allowing native wiliwili (*Erythrina sandwicensis*) to survive, at no additional staff or control costs. However, continuing or expanding capacity to do this work will require the state to invest in a new quarantine containment facility for testing the efficacy and environmental safety of natural predators.

The agencies responsible for managing widespread pests and ultimately minimizing their impacts have a number of mandates that they are asked to prioritize for limited funds. Positions cut over the past several decades, most recently in 2009, must be reinstated, funded, and filled to continue this cost-effective work.

We can also support the sustainability goals outlined in the Aloha + Challenge, including increasing local agriculture and clean energy production, and ensuring the resiliency of watersheds and reefs.

Having a well-rounded invasive species program is possible, but success is attainable only if decision makers, business leaders, and we the people place a higher priority on protecting our islands. For more information, visit **www.cgaps.org** .

GENUINE PROGRESS INDICATOR-HAWAI‘I GPI-HI

Gross domestic product (GDP) was originally designed solely as a measure of economic activity in order to gauge the health of an economy. Yet now, any rise in GDP is assumed to be an increase in what is good for society overall. GDP overlooks incidental costs to society, such as environmental pollution or income inequality, as well as unrecognized benefits, such as unpaid housework or volunteerism. In some cases, environmental harm can actually increase GDP (i.e., via clean up expenditures).

The Genuine Progress Indicator (GPI) goes “beyond GDP” to more fully capture what is good for society. The GPI framework, first designed in 1997, is a holistic measure, consisting of multiple factors spread across three categories: economic, environmental, and social. GPI acknowledges costs that economic growth imposes on society, whether a loss of forests or a loss in leisure time, and adjusts the measure of progress accordingly. The costs and benefits are assigned dollar values for easy comparison. At times when it is difficult to calculate direct values, best available estimates are used instead. The objectives are not to calculate precise numbers, but rather to illustrate the overall trends in true progress. Moreover, GPI raises awareness of the importance to society of other values besides the economic activities used to calculate GDP.

For Hawai‘i, a recently developed “Island Style” GPI goes even further beyond GDP, to capture the costs of economic growth relevant to our unique island setting. As the Island Style GPI develops further, the framework will be modified to reflect costs associated with the loss of coral reefs, the spread of invasive species, or even homelessness.

For more information on GPI and GPI Island Style:
http://oeqc.doh.hawaii.gov/Shared%20Documents/Environmental_Council/Annual_Reports/Annual-Report-2013.pdf

Above: Ohia lehua blossom, CCAGPS
Below: Kappaphycus spp. (Invasive algae), Jennifer Smith

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Dr. Ostergaard-Klem teaches in both the undergraduate Environmental Science/Studies program and the master's program in Global Leadership and Sustainable Development. Her teaching is concentrated in the fields of environmental economics, ecological economics, industrial ecology, environmental policy, and natural resource management. Her research interests are focused on alternative measures for social welfare, and the nexus between the two disciplines of ecological and environmental economics.

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Natural capital, such as land, water, and biodiversity, supports human well-being, yet this crucial capital is depleted and degraded because it is generally unaccounted for in standard decision-making frameworks. Dr. Oleson's research addresses this by integrating economics and the environment along three related tracks:

- Building "green accounting" methods to improve the metrics we use to signal economic "progress." These accounting tools seek to include environmental and social changes; e.g., loss of forested land or gains in education, rather than focusing solely on the economy's productive sector. They also aim to track global impacts of consumption.
- Linking watershed-scale ecological modeling with economic models to assess the outcomes of resource development alternatives.
- Studying coastal communities' natural resource management.

Introduction

In Hawai‘i, a close tie exists between invasive species and the economy. The introduction (whether intentional or unintentional) of a harmful invasive species is often a byproduct of economic activity, particularly when the trade of economic goods provides the vector and pathway for its spread. Once a harmful invasive species establishes itself, however, the biological invasion (bioinvasion) damages the environment, society, and/or the economy and presents high costs to prevent, control, or mitigate further harm. Nowhere are the impacts of bioinvasions more pronounced than within an island setting; interestingly enough, those islands with the highest Gross Domestic Products (GDPs) have the highest number of invasive species (Meyers, 2014). Likewise, the influx of invasive species to Hawai‘i has potential to affect or involve nearly all activities within the state (OTA, 1993).

The 2012 and 2013 Environmental Council Annual Reports showcased the Genuine Progress Indicator (GPI) as a holistic approach to more fully capture the economic as well as social and environmental costs and benefits within the state. The GPI framework recognizes costs, such as pollution or loss of leisure time, or benefits like volunteerism, that are not incorporated into conventional measures such as gross domestic product. Through our experience of applying GPI to the island setting of Hawai‘i, we identified unique local features and recommended changes to the standard framework to incorporate them (Ostergaard-Klem & Oleson, 2014). To build upon the GPI in the two previous annual reports, this current report explores the ways in which GPI could be further applied to the unique circumstances of Hawai‘i through a specific issue – invasive species

The framework for GPI includes indicators tracking the loss of acres of wetlands, forest, and farmland, i.e., the change in a quantity. GPI does not incorporate invasive species per se. Through GPI, we propose a further examination of this significant issue to track not only the quantity (acres), but also the quality (native versus invasive) of those land types. When ecosystem functions are damaged due to invasive species, the ecosystem services provided by those areas are compromised. The drop in ecosystems services has an associated cost to society that is not captured by other measures. Through a review of existing literature and interviews with experts in Hawai‘i, the following report provides background on invasive species in Hawai‘i, an introduction to ecosystems services, relevant examples from four different ecosystem types, and next steps aimed at incorporating the economics of invasive species into broader discussion and actions.

Background

As defined by the IUCN, an invasive species is an animal, plant, or other organism introduced by humans to an area outside its naturally occurring location, where it becomes “established and disperse, generating a negative impact on the local ecosystem and other species” (IUCN, n.d.). According to the UN Convention on Biological Diversity (CBD), to become invasive, the species must “arrive, survive, and thrive.” (UN CBD, n.d.). Bioinvasions typically entail four stages: introduction, establishment, naturalization and spread, and damage creation (Marbuah, et al., 2014). Certain characteristics of the invading species, such as tolerance to climatic conditions, rapid growth and reproduction rates, or wide ranges of dispersal, make it particularly well suited to the new location and lead to successful bioinvasion.

In the US, researchers estimate that over 50,000 alien (i.e., non-native) invasive species have already been introduced and the number continues to rise (Pimental, et al., 2005). Some non-natives species, such as wheat, rice, and livestock, are staples in our economy, while others have led to major economic impacts on agriculture, forestry, and the environment.

Generally, researchers estimate that as few as 10% of introduced species become harmful (Marbuah, et al. 2014), but even a small proportion can lead to large damages. A 2005 study across a set of non-native species within the US estimated that the combined damages and control costs resulting from invasive alien species reached upwards of $120 billion per year (Pimental et al., 2005).

Bioinvasions threaten the biodiversity in the area of impact. Declines in native species can result from multiple interacting threats, yet invasive species are considered the second greatest contributor to species extinction behind habitat destruction, with speculation that invasive species are the first contributor in island settings (IUCN, n.d.). Moreover, greater than 40% of the species listed as threatened or endangered under the Endangered Species Act in the US are at risk due to competition with and pressure from non-native species. (Pimental et al., 2005).

Currently there is no official state designation of invasive species.

Invasive Species and Hawai‘i

Hawai‘i is the most geographically isolated island chain in the world. The flora and fauna that arrived in the islands prior to human contact via the wind, waves, or migratory birds, are generally considered native species. Due to Hawai‘i’s extreme geographic isolation, many of the native species are endemic and can be found only in Hawai‘i. According to the Hawai‘i Biological Survey (HBS), of nearly 24,000 known species of Hawaiian biota, approximately 40% are considered endemic to Hawai‘i (Eldredge & Evenhuis, 2002). Nonnative species, though, are introduced to the islands via human means.

Many of the species introduced to Hawai‘i are not considered harmful to the surroundings. However, those competitive species that are both nonnative plus currently or potentially causing negative economic, environment and/or human health impacts within the state are deemed “invasive.” The term “invasive species” takes on a range of meanings depending on the contexts, but can be synonymous with pests, nuisance species, noxious species, or weeds (CGAPS, n.d.).

Currently there is no official state designation of invasive species. However, the HDOA regulates a number of activities related to plant pests and noxious weeds. HDOA defines noxious weeds as “any plant species which is, or which may be likely to become, injurious, harmful, or deleterious to the agricultural, horticultural, aquacultural, or livestock industry of the State and to forest and recreational areas and conservation districts of the State, as determined and designated by the department from time to time” (“Official Designation of Invasive Species,” 2014). Plant pests are further defined by HDOA as any pest that “could cause significant damage to agriculture, our environment, and quality of life” (“Official Designation of Invasive Species,” 2014).

There are an estimated 300 serious invasive species in Hawai‘i (Kraus & Duffy, 2010). At least one half of the wild species in Hawai‘i are non-native and no other area in the US has a greater percentage of non-indigenous species established in the wild (OTA, 1993). Some estimates of the rate of new, unwanted species arriving in the Hawaiian Islands is two million times greater than the natural rate (HEAR, n.d.). Additionally, Hawai‘i is known as the “extinction” or “endangered species” capital, having the greatest concentration of threatened and endangered species and the highest number of extinct species in the US. Over 30% of the species on the Federal endangered species list are in Hawai‘i, including over 40% of the listed endangered birds; this is astounding considering Hawai‘i makes up a mere 0.2% of the total land area of the US (Eldrege & Evenhuis, 2002).

In Hawai‘i, ongoing measures aim to control the invasive species that are already introduced to or established in Hawai‘i. In addition to the species that currently threaten the islands, there are other potentially invasive species that could be detrimental to Hawai‘i’s environment and economy if they were to be introduced to the island chain; this is the case for the brown tree snake and the West Nile virus. Today, invasive species continue to be introduced to the islands, despite efforts to prevent them. Actions across all stages of bioinvasions, from prevention, to rapid response, to control, result from the coordinated efforts across government agencies and other institutions within the state (Table 1) as well as Federal agencies.

Two unique and notable partnerships include: the Hawai‘i Invasive Species Council (HISC) and the Coordinating Group on Alien Pest Species (CGAPS).

HISC is comprised of individual invasive species committees at the county level; its goal is to “protect Hawai‘i’s unique economy, natural environment and the health and lifestyle of Hawai‘i’s people and visitors from the impacts of invasive species” (HISC, 2014).

CGAPs is a voluntary public-private partnership involving state and Federal agencies, non-profits, academia, and HISC, all working to protect Hawai‘i from invasive species.

Table 1. Major Players Involved with Invasive Species in Hawai‘i

Agencies and Major Players	Programs and Responsibilities
Hawai‘i Invasive Species Council (HISC)	• Policy level direction, coordination, and planning amongst the state departments, federal agencies, and local organizations • Fund dispersal for prevention, control, outreach, and research • Funding and support for island invasive species committees
Hawai‘i Department of Land and Natural Resources (DLNR)	**Division of Forestry and Wildlife (DOFAW)** • Invasive species removal on state lands, wildlife resources management, and game management • Management of Watershed Partnership Programs • Management of Natural Area Reserves **Division of Aquatic Resources (DAR)** • Removal of invasive algae • Aquatic invasive species detection • Policy development for ballast and hull fouling
Hawai‘i Department of Agriculture (HDOA)	**Plant Pest Control Branch** • Responsible for containment and control of plant pests which cause potential economic damage to agriculture • Research and regulation of biocontrol agent • Management of apiary program **Plant Quarantine Branch** • Monitors imports and exports of plant and animals • Inspection of cargo and vessels, responsible for enforcing regulations against the importation of regulated species • Intrastate inspection, monitoring, and quarantine **Pesticides Branch** • Regulation and development of pesticides in the state
Hawai‘i Department of Health (DOH)	• Disease prevention and vector control • Issue permits for use of pesticides near water resources
Coordinating Group on Alien Pest Species (CGAPS)	• Public-private partnership of federal and state agencies and non-governmental organizations • Works with above agencies and other organizations to improve interagency work and coordination

Table 1: Major agencies and players and their responsibilities in regards to the issue of invasive species in Hawai‘i. Agencies coordinate with each other, as well as with the University of Hawai‘i and other organizations to fulfill responsibilities and mandates (Coordinating Group on Alien Pest Species, 2009, 2014; State of Hawai‘i, Department of Land and Natural Resources, Division of Forestry and Wildlife, & Hawai‘i Invasive Species Council, 2014)

Overview of Ecosystem Services

Ecosystem services are the "goods" and "services" provided by an ecosystem that humans rely on not only for physical health and survival, but also mental health and happiness. The Millennium Ecosystem Assessment, prepared by the Millennium Assessment (MA), in 2005, brought worldwide attention to the links between ecosystem services and the factors of human well-being that rely upon them (Figure 1 Ecosystem Services). These services represent both the tangible and intangible benefits that humans derive from functioning ecosystems (MA, 2005). While ecosystems function with or without humans, ecosystem services are only derived at the point of interaction with humans.

The seminal study on ecosystem services, the Millennium Ecosystem Assessment, divides them into four categories: provisioning, regulating, cultural, and supporting. Provisioning services include food, wood, fuel, fiber, fresh water, and medicinal resources as well as raw materials for human use. Regulating services include local flood regulation, water purification, carbon sequestration, erosion control, and pollination. Cultural services include recreation, tourism, aesthetics, and those services that are inspirational or traditional. Supporting services, such as nutrient cycling, soil formation, and primary production, underpin the other three categories of services, and give the necessary structure and function to furnish habitats for important or native species and support genetic diversity. Different from provision, regulating, or cultural services, supporting services indirectly relate to humans yet are necessary for the production of all other ecosystem services (MA, 2005).

Provisioning services are closely related to economics goods, those that can be bought and sold on a market, and are more likely to be included when assessing the value and importance of a given ecosystem. The other services are more difficult to quantify, and are therefore not commonly included in ecosystem valuation. Nevertheless, they all are important for sustaining the health of ecosystems for the happiness and health of residents and visitors of the Hawaiian Islands (Brauman, Daily, Duarte, & Mooney, 2007).

By threatening Hawai'i's biodiversity and outcompeting native species, invasive species could be undermining the provisioning, cultural, regulating, and supporting ecosystem services on which Hawai'i's citizens are dependent. Moreover, invasive species have significant impacts on forests, farmlands, wetlands, and near shore coastal areas throughout the state; we discuss several examples below.

Impacts to forests caused by invasive species such as strawberry guava, Miconia, and ungulates include decreased groundwater recharge, increased surface water runoff, and increased sedimentation in streams (Cronk & Fuller, 2013). Increased sedimentation and runoff negatively impacts downstream ecosystems. Additionally the runoff leads to lower visibility in adjacent near shore coastal areas, directly impacting tourism, recreation activities, and aesthetics.

In Hawai'i's farmlands, invasive species impact the production of food, decreasing food security and food self-sufficiency. For example, fruit flies lay eggs in fresh fruit and vegetables, which eventually hatch into larvae causing extensive plant damage (State of Hawai'i Department of Agriculture, 2012).

In near shore coastal areas, productive fisheries are reliant on healthy coral and healthy native sea grass. Invasive algae destroy these critical habitats, therefore reducing the production of fisheries and causing significant loss to biodiversity (Molnar, Gamboa, Revenga, & Spalding, 2008). Additionally, some invasive algae such as *Hypnea musciforms* form massive blooms on reef flats; these blooms lead to reduced occupancy rates in hotels, and reduced property values (Friedlander et al., 2008).

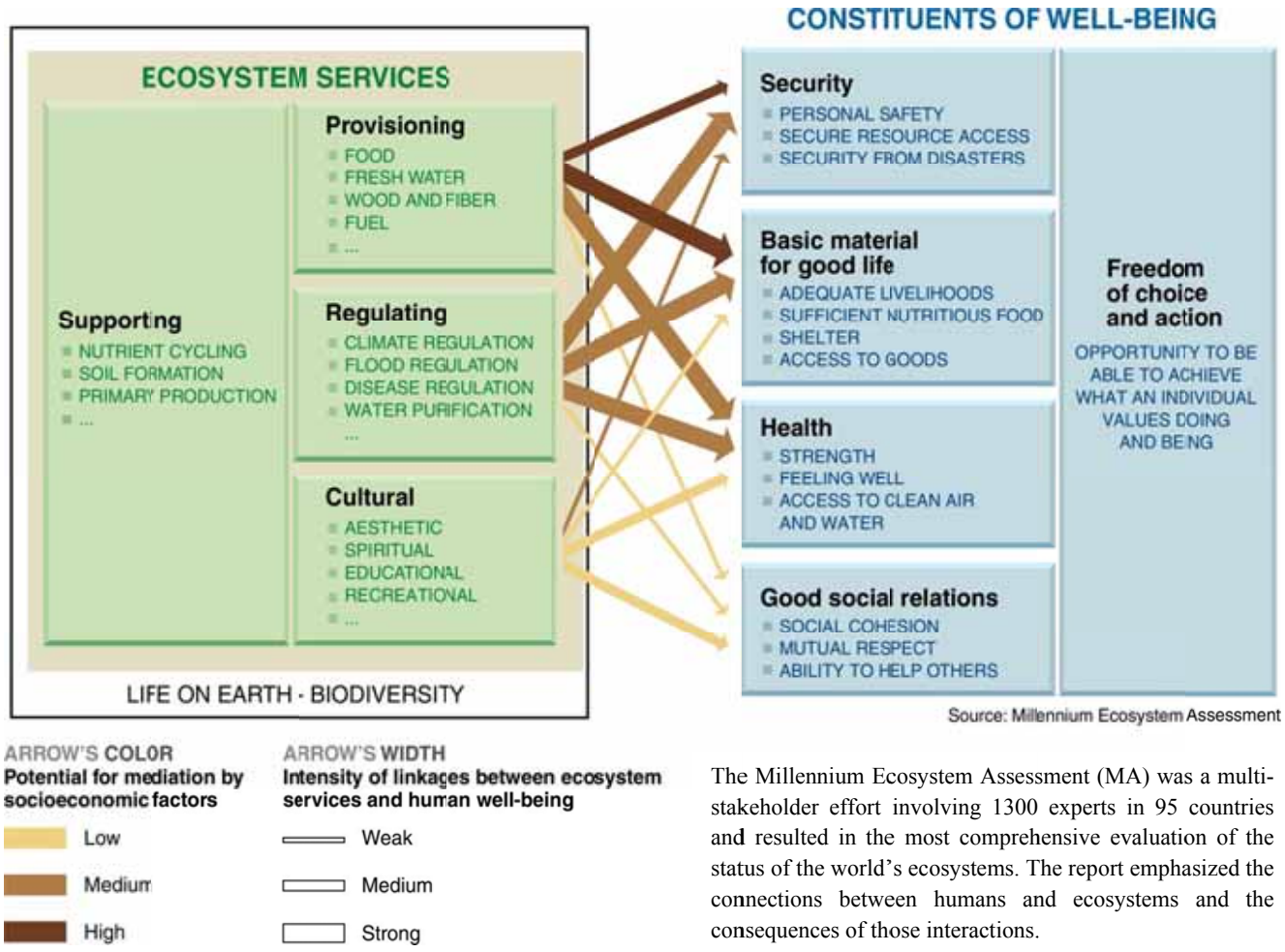
In wetlands, non-native species threaten to outcompete those natives that provide critical habitat and nursery grounds for endangered waterbirds, marine organisms, and plant pollinators, among others (supporting services).

The regulating services normally provided by healthy wetlands, such as fresh water regulation, flood control, water purification, ground water recharge, are compromised in the presence of invasive species.

Invasive species found across all land types have potential to negatively impact human health, as they can carry and transmit bacteria and viruses, such as leptospirosis, that can lead to serious illness. Additionally, environments dominated by non-native species tend to provide habitat for other species that carry disease, or threaten human health.

Ancient and modern Hawaiians celebrate native plants, coral reefs, animals, and fish that thrive in the forests, farmlands, wetlands, and near shore coastal areas. The traditional subsistence lifestyle Hawaiians once lived was dependent on the services provided by native ecosystems. There is an inherent loss to culture when native ecosystems are destroyed. For Hawaiians, a natural resource is a cultural resource. Destroying natural resources is destroying cultural resources (Hawai'i Association of Watershed Partnerships, 2014). Tourism and recreational resources are also threatened by invasive species because they threaten safety and the beauty and uniqueness for which Hawai'i is known.

Figure 1. Ecosystem Service



The Millennium Ecosystem Assessment (MA) was a multi-stakeholder effort involving 1300 experts in 95 countries and resulted in the most comprehensive evaluation of the status of the world's ecosystems. The report emphasized the connections between humans and ecosystems and the consequences of those interactions.

This figure illustrates how our well-being is intimately connected to ecosystems. Each arrow represents a flow of goods and/or services from ecosystems to humans. The arrow's width represents the strength or intensity of the connection between that service and our well-being. The arrow's color depicts the likelihood that social or economic factors can support that connection. For example, a thick and dark arrow between provisioning services and basics needs for a good life could illustrate the critical delivery of food or clean water and the high potential for economic and social factors to ensure that the link is maintained. Notice also how each type of ecosystem services is tied to multiple factors of well-being.

Methods

The GPI application for Hawai‘i (GPI “Island Style”) includes environmental indicators for four different types of land and marine areas: forests; farmland; wetlands; and near shore coastal areas. While wetlands, forests, and farmlands are part of the original GPI framework, near shore coastal areas was added by GPI Island Style as a locally relevant indicator. For each environmental indicator, GPI tracks biophysical changes, such as a loss in forested area, and then attaches a dollar value to each unit of change. The dollar amount associated with each type of area captures the area’s contribution to social wellbeing by valuing the flow of ecosystem services (provisioning, regulating, and/or cultural). In this way, GPI is useful to track the trends in land use and associated costs or benefits. The value assigned to each type of land is derived from past studies, most of which were done outside of Hawai‘i, so represents a gross approximation of the area’s value,

In this report, we maintain that it is important to highlight changes in not only quantity (i.e., area of forest), but also how quality (i.e., forest health) impacts the ecosystem services provided.

In this report, we maintain that it is important to highlight changes in not only quantity (i.e., area of forest), but also how quality (i.e., forest health) impacts the ecosystem services provided, by further examining the relationships in the following formula:

Impact of invasive species on area of a land type → change in ecosystem function → change in ecosystem service → change in value

For the purpose of this report, within each of the four ecosystem types we identify one invasive species and discuss the associated ecosystem services that are impacted by that species (Table 2); for example, Miconia in forested areas and potential impacts on erosion and/or water supply.

We recognize that choosing only one species is a simplification of the many interrelationships that exist within complex systems, but is intended as illustrative examples for this discussion. We based our choices on results of literature reviews and a series of interviews with experts from invasive species committees, state agencies, academia and others. The criteria to rank invasive species per land type included economic, environmental, human health, and social/cultural impacts, as well as risk and extent of spread.

Table 2. Ecosystems Services Impacted by Invasive Species on Ecosystem Types

Ecosystem Service	Forest	Farmlands	Wetlands	Coastal Systems
Invasive Species	*Miconia*	Little Fire Ant	California Grass	Prickly seaweed
Provisioning	Groundwater recharge	Agricultural crops	Food	Fisheries
Regulating	Erosion prevention	Pollination	Runoff prevention; water filtration	Carbon Sequestration
Cultural	Recreation	Human health; recreation	Recreation; aesthetics	Tourism
Supporting	Genetic diversity	Habitats	Habitat	Habitats

Results

Forests

Before introductions and changes were made to Hawai‘i’s forests due to human settlement and even more recent urban development, the forests covered upwards of 95% of the land (Bennett & Friday, 2010). These forests provided critical ecosystem services to Hawaiians, including clean water, sites for recreation, habitat for native species, and opportunities for cultural practices. Current forests span only 36% of land area (Gon et al., 2006), but recent trends indicate a slight increase in forested area. Previous GPI studies showed that forested land has expanded over the time frame of 2001-2005, representing a gain of ecosystem services worth US $11 million (State of Hawai‘i Environmental Council, 2014). This value is based on economic valuation studies from other regions of the US that found an acre of forest provides ecosystem services worth US $1,690 per acre.

However, because the values assigned to forests in the past GPI studies were derived from economic valuations done outside of the state, these values may not accurately represent the true value of the forests in Hawai‘i. Furthermore, the current method assigns the same value to any given acre of forest, regardless of its “quality”; i.e., the ecological functioning that results in ecosystem services. While overall forest area increased, the quality of the new or existing forests may have changed in the same period. For instance, new forests may be plantations, and in native forests, non-native species may be undermining aquifer recharge. Fourteen percent of forest area is dominated by non-native invasive species. (Gon et al., 2006)

Based on the interviews we conducted with experts in forestry and invasive species, we chose *Miconia calvescens* (Common Names: Miconia, Purple Plague, and Purple Velvet Leaf) as a representative invasive species in forest ecosystems in Hawai‘i. Miconia is on the Hawai‘i State Noxious Weed List, as well as being recognized as one of Hawai‘i’s most invasive horticultural plants (Hawai‘i Invasive Species Council, n.d.).

Figure 2. *Miconia calvescens* (habit)

Starr, F. & K. (2003). Location: Hilo, Hawai‘i. Retrieved from http://commons.wikimedia.org/wiki/File:Starr_031118-0108_Miconia_calvescens.jpg

Miconia is a large tree growing up to 50 feet tall with purple colorization on the bottom of its leaf, and is commonly known in Hawai‘i as the “Purple Plague.” It has large oval-shaped leaves and a shallow root system (Figure 2). These trees are best suited to areas at elevation up to 1600 feet and more than 70 inches of annual rainfall (Baruch, Pattison, & Goldstein, 2000). In Hawai‘i’s ideal conditions, a single plant can result in a population extending to almost 100 hectares in the matter of only five to 10 years (Kaiser, 2006).

Miconia was originally introduced in 1961 to Oahu at the Wahiawa Botanical Gardens, and similarly in the 1970s to Maui at a botanical garden in the Hana area. Originating from Central and South America, the tree was brought to the islands as an ornamental plant. The trees were planted in backyards on most of the islands and as a result have become widespread (Kaiser, 2006).

The extent of spread on Hawai‘i Island (mostly on the windward side) and Maui (well established on the eastern side) has made it exceedingly unlikely for complete eradication. In East Maui alone, there is an estimated 15,000 hectares of potential Miconia invasion (Hawai‘i Invasive Species Council, n.d.).

Preventing further spread on these islands has become the main goal of non-governmental organizations, invasive species committees, and local government. Miconia is also present, but to a lesser extent, on O‘ahu and Kaua‘i; only approximately 700 hectares on O‘ahu, mostly in the Ko‘olau Mountains (Burnett, Kaiser, & Roumasset, 2007), and only one known population on Kaua‘i (Hawai‘i Invasive Species Council, n.d.). The ability to control, manage, and possibly eradicate Miconia is greater on these islands given the limited establishment.

Once Miconia is established in a forested area, it outcompetes and eventually displaces the native plants within. Such changes occur due to a few key reasons, and are particularly relevant after a disturbance such as deforestation or fire (Baruch et al., 2000). Due to their height and large oval-shaped leaves, the trees easily block the sun from reaching the native undergrowth (Kaiser, 2006). Essentially, future growth of all other (including native) plants stops and the diversity of plants decrease as Miconia’s presence as a monotypic stand increases. Furthermore, native species are unable to keep up with the reproductive rate of Miconia; this invasive species can produce upwards of 3 million seeds in one fruiting event and will do this about two to three times per year (Kaiser, 2006). Furthermore, Miconia can grow to an adult tree in just four years.

While experts agree that Miconia will negatively impact social and economic functions, the primary concern is the impact to ecological functions. Experts are highly concerned about the risk of spread as well as the potentially large spatial extent, as Miconia is evident on four of the Main Hawaiian Islands. Furthermore, in a similar situation, Tahiti is inundated with Miconia making up over 65% of the total land cover on the main island. This was after only a single plant was introduced in 1937 (Burnett et al., 2007).

Many ecosystem services are provided from healthy, diverse forest systems and are likewise compromised when the quality of the forest is degraded by invasive species. Possibly the most concerning change in ecosystem function relates to the forests’ hydrological processes. In Hawai‘i, the forest is critical to maintaining freshwater supplies as island residents rely heavily on the ecosystem service associated with groundwater recharge. The moisture captured when clouds are intercepted by trees in higher altitude forests contributes to a 30% increase in rainfall (State of Hawai‘i Department of Land and Natural Resources, 2011). Miconia promotes decreased soil permeability, increased soil erosion, and transpiration (Giambelluca, Sutherland, Nanko, Mudd, & Ziegler, 2009). Miconia is known to increase runoff therefore disrupting the groundwater recharge (Kaiser, 2006). These changes directly impact the watershed quantity and quality, i.e. the large leaves are collecting most of the rainfall and therefore the watershed is bypassed. Noticeably fewer canopy gaps occur where Miconia is present. The “umbrella” effect of the leaves combined with damage from the larger drops of water that do permeate the cover, prevent ground cover vegetation from growing, which in turn contributes to increased soil erosion and loss in biodiversity of the forest (Giambelluca et al., 2009).

In terms of control measures for Miconia, population reduction has been the best management practice so far on the impacted islands, with the exception of Kaua‘i where costs are greatest and population has yet to reach an established state (Burnett et al., 2007). Eradication is also a current control effort when not cost prohibitive (i.e., aerial spraying), nevertheless preventative policies could be more cost effective in the long run. Invasive species policies that prevent Miconia from entering the state could help stop the early establishment of the species. Enacting optimal polices for Miconia could have an estimated present value benefit of $6.5 million on O‘ahu and $34.5 million on Maui (Burnett et al., 2007).

A cost-benefit analysis conducted in Hawai‘i estimated that if left untreated, the ecological damages from Miconia invasion could reach a total of US $627 million over the next 40 years (Burnett et al. 2007). Estimates of potential expected losses from Miconia’s impact on groundwater recharge alone and just for O‘ahu are upwards of US $137 million dollars per year (Kaiser and Roumasset 2002; Kaiser, 2006).

Farmlands

Agriculture is the third largest economic sector in the state. While the number of farms within the State has increased since 2002, the total area of farmland and the average farm size have both decreased (Economic Research Service, 2014). Agriculture is critical to local food security, given estimates that 85% to 90% of food is imported to Hawai‘i (Leung & Loke, 2008). Furthermore, the issue is not just about the quantity of acres of farmland, but also the quality (i.e., productivity) of that farmland.

In Hawai‘i, the issues of invasive species and food self-sufficiency are uniquely intertwined. The state’s dependency on imported food simultaneously increases its vulnerability to unwanted pests, particularly in the case of imported fresh produce (Leung & Loke, 2008). Furthermore, the spread of invasive species could lead to additional stress or damage to existing agricultural crops, further detracting from efforts to become more food self-sufficient. One example is the varroa mite, a parasite that attacks honey bees, that was detected on O‘ahu in 2007 and Hawai‘i Island in 2008. The mites threaten commercial beekeeping, an estimated $4 million industry, and could significantly impact the pollination of fruit trees and vegetable crops (Ramadan et al., 2008; Office of Planning, 2012). Increasing local agricultural production could help Hawai‘i to decrease not only the dependency on outside food, but also the risk of introducing harmful species, and at the same time reduce the associated costs for pest prevention and management.

Based on interviews with experts in invasive species, we chose the *Wasmannia auropunctata* (Common Name: Little Fire Ant or “LFA”) as a representative invasive species in agricultural ecosystems (farmland) in Hawai‘i (Figure 3). The Little Fire Ant is native to South America where its distribution is constrained by other ant species (Motoki, et al., 2013). However, Hawai‘i is one of the few locations worldwide where ants are naturally absent, giving LFA the advantage to survive and thrive. The LFA is in found in several states within the US, most notably Florida and Hawai‘i.

LFA are tiny, measuring 1/16 inch long. They are pale orange and characteristically move very slowly (Pest Control Branch, 2007). *W. auropunctata* is a shade-loving species that nests in trees and other vegetation as

Figure 3. ***Wasmannia auropunctata***

Photo by April Nobile; from www.antweb.org.

well as on the ground (Pacific Ant Project, 2011). *W. auropunctata* has many traits, shared with other highly successful and destructive invasive ant species, that make these ants more likely to invade new areas and more likely to succeed after they arrive. These traits include: polygyny (more than one queen per colony); polydomy (multiple nests per colony) and unicoloniality or large continuous populations (Krushelnycky, Loope, & Reimer, 2005; Motoki, 2013). Like many sugar-loving ants, *W. auropunctata* will tend hemipterans such as mealybugs and soft scales for their honeydew which causes plant stress and can lead to increased prevalence of these pests on fruit (Souza, Follett, & Price, 2008).

In Hawai‘i, LFA had been previously intercepted, but not established, as early as 1930. LFA currently exist on the islands of Hawai‘i, Kaua‘i, Maui, and O‘ahu. The first established population of LFA was found in the state in March 1999 in the Puna District on the island of Hawai‘i (Starr, Starr, & Loope, 2007). LFA are now widely distributed on Hawai‘i Island (Division of Forestry and Wildlife, 2013) and the ant population is too widespread for eradication efforts (Department of Agriculture, 2014).

More recently, in December 2013, LFA were detected on O‘ahu, and by summer 2014 infestations were identified in nurseries in Waimanalo as well as a residential neighborhood in Mililani. The largest infestation yet, over 20 acres, was uncovered along the Hana Highway on Maui in October 2014. HDOA is currently trying to determine how the ants arrived and what to do in response. It appears that LFA, known as “hitch hiker” ants, were inadvertently transported from the Big Island to the other locations on hapu‘u (Hawaiian fern) logs or in the soil of potted plants. Given the high concern for the potential damages from LFA, HDOA enacted inter-island quarantine regulations that prevent the shipment of infested plants (Souza, Follett, & Price, 2008).

LFA impact the agricultural sector by infesting fields, damaging crops, and stinging farm workers. (HISC, n.d.). The most consistent and detrimental agricultural impact of these ants is indirect. LFA feed on the plant sap that is secreted by other pests like aphids, scales, mealybugs, and white flies. This mutualistic relationship leads to great increases in the abundance of these pest insects, harming agricultural output (HISC, n.d.; Krushelnycky, Loope, & Reimer, 2005). If left untreated, LFA could potentially reduce agricultural yields up to 50% and damages to the agricultural sector would be about 20-30% of sales, roughly $33 million to $50 million per year (Motoki, et al., 2013). LFA also harm livestock (e.g. cattle, hogs, poultry) by repeatedly stinging animals, causing pain and discomfort and resulting in slower growth, lower weight, and/or decreased output (Motoki, et al., 2013). The impact of LFA on the agricultural sector is particularly relevant to the island of Hawai‘i, since the island generates one-third of all agricultural sales in the state (Motoki et al., 2013), yet has the highest number of occurrences of LFA.

Outside the agricultural sector, LFA can infest houses and sting residents and pets, leading to painful welts lasting for days or weeks (HISC, n.d.). Other potential future impacts of LFA include loss of pollination services, negative impacts on recreation, and decreased genetic diversity within LFA infested ecosystems (Motoki et al., 2013).

Based on results of a 35-year model to track the impacts on agriculture, human health, and other factors from LFA on the Big Island, Motoki et al. (2013) estimated that increased management could lead to US $5 billion in cost savings and a significant reduction in the number of stings (about 2 billion fewer) over the 35-year period.

Wetlands

Wetland ecosystems worldwide provide valuable services to humans, including food, flood control, sediment retention, habitat for biodiversity, and recreational sites, and as such are some of the most valuable ecosystems on a per hectare basis (Costanza et al., 2014). In Hawai‘i, this vital role is no less critical to society, yet data suggest our wetland areas are slowly contracting. Wetlands in Hawai‘i account for less than 3 percent of total land area (USGS, 1997).

Previous GPI studies estimated a cumulative net economic loss of over US $305 thousand due to loss of wetland area between 2002-2005 (State of Hawai‘i Environmental Council, 2014). This is based on a per-hectare value derived from a study on the continental US. This uniform value does not consider the difference between coastal and inland wetlands, the heavy reliance of islands on wetland ecosystem services, the cultural importance of wetlands, or the unique nature of Hawai‘i’s wetlands.

Hawai‘i’s geography and hydrological conditions result in wetlands that are different than those in other regions of the United States (USGS, 1997). Wetlands are defined as “areas inundated or saturated by ground or surface water at a frequency and duration sufficient to support, and that under normal conditions, do support a prevalence of vegetation typically adapted for life in saturated soil conditions” (US Army Corp of Engineers, 1987).

In Hawai‘i this includes wetlands along riverbanks, marshes and bogs, swamps and mudflats at river mouths, and marine wetlands, such as intertidal zones. These areas are often critical habitat for native and threatened species, and are thus protected by state and federal agencies.

Based on interviews, five out of five experts indicated *Uchochloa mutica* as one of the top three most problematic invaders. *Uchochloa mutica* also known as California Grass or "para grass," is native to Africa. California Grass is a large coarse perennial grass forming dense patches up to 2.5 m tall. It is often found in pastures and on marshy ground, and can be used for fodder (Stemmerman, 1981) (Figure 4).

California Grass is currently naturalized throughout Hawai'i and the Pacific region. First collected on Oahu in 1924, it is common in wetlands, along streams, ditches, and wet disturbed sites from sea level to 1,100 meter elevation (Erickson, 2006). Experts are uncertain whether it was introduced intentionally or not. If intentionally introduced, it was likely for pasturelands, cattle grazing, or fodder. Once established, California grass is likely to spread in extent and easily invades elsewhere through seed dispersal by wind or birds.

Current management for this noxious weed is on a case-by-case basis; it may be tolerated or controlled on site. No regulations currently exist and management is expensive. Weed whacking and digging out by hand require a work crew, while other control methods include cutting down and applying herbicide or plastic, burning, or flooding. All management requires a long-term maintenance regime to control re-propagation.

Multiple impacts on wetlands' ecosystem functions result from the invasion of California grass. These noxious weeds block waterways. California grass in wetlands grows in dense tufts that support breeding habitat for mosquitos, which can spread human disease, and are too dense for fish and wildlife to forage. Wetlands can become unidentifiable as wetlands, both visually and operatively. This is because California grass grows a dense mat system that other plants and trees can grow upon. Many of these are themselves problematic invaders. Moreover, the California grass inhibits natural regeneration and facilitates complete alteration of native habitat, preventing native plant recruitment and overall site biodiversity.

Multiple ecosystem services provided by wetlands can be negatively impacted by non-native species invasion. Nutrient cycling and water purification can be interrupted by invasion, which may disturb habitat for native insects and wildlife. Recreational activities such as bird watching can be hindered due to very dense growth California grass monoculture, which can diminish views and preclude seabird stopovers and inhabitation by water birds. A decrease in bird and insects could impact nearby pollination.

Figure 4. *Uchochloa mutica*

The non-native plant *U. mutica*. Photo courtesy UF/IFAS Center for Aquatic and Invasive Plants. Photographer Vic Ramey. Accessed on Dec. 19, 2014 at: http://www.sms.si.edu/irlspec/Urochloa_mutica.htm

Sites of cultural and spiritual relevance can be greatly degraded by invasion of the non-native grass, which may outcompete traditionally important species. Kawai Nui Wetland on Windward O'ahu is an important example of this, as it is the largest wetland on the islands and of great spiritual importance. Unfortunately, nearly 90% of the wetland is degraded by this plant. Grass invasion can also inhibit or prevent kalo cultivation and represents a loss in local food provisioning. Other social losses include aesthetic, cultural, recreation, tourism, education, and spiritual inspiration.

Coastal systems

Coral reefs are the most valuable ecosystem on a per-area basis, yet their global area is shrinking (Costanza et al., 2014). Due to their relative value, the Hawai'i GPI study concentrates on coral reefs, although other coastal systems, including estuaries, seagrass beds, and shelves, provide important services.

The structure of Hawai‘i’s coral reefs are influenced by the archipelago’s exposure to ocean swell and winds (Friedlander 2008). The relative isolation of Hawai‘i’s reefs resulted in high endemism and thus unique ecosystems of high conservation value (idem). Reefs also provide significant ecosystem services, including food, sites for cultural practices, and opportunities for recreation. The economic value of Hawai‘i’s reefs was estimated at $360 million annually (Cesar and van Beukering 2004), yet reefs and their associated services are threatened by multiple global and local stressors. Stressors include coral bleaching due to rising sea surface temperatures, coral disease, intense storms, coastal development and runoff, pollution, tourism impacts, fishing, and invasive species.

In Hawai‘i, the estimated number of marine species that are non-indigenous and crytogenic (of unknown origin) was recently revised to 421, compared with 343 estimated in 2009 (Gorgulia, 2013). More than 60% of the marine alien species were introduced to the waters of Hawai‘i by biofouling (hull fouling); i.e., organisms attached to the surfaces of the hulls of vessels.

While the majority of invasions are due to biofouling, about six percent of the introductions are attributed to ballast water emptied from ships arriving from elsewhere (Gouglia, 2013).

Acanthophora spicifera (with common name of “prickly seaweed”) was most likely introduced to Hawai‘i in 1952, attached to the bottom of a barge making its way from Guam to Pearl Harbor, O‘ahu (Godwin, S., et al., 2005; Smith et al., 2002). Currently, *A. spicifera* is considered the most pervasive alien algal species in Hawai‘i (LaPointe, et al., 2010). The species can now be found on all main Hawaiian islands (although less abundant on the island of Hawai‘i), and is considered the most abundant red algae occurring in reef flats with uniform distribution around all coastlines (Godwin, S., et al., 2005; Smith et al., 2002). From its point of introduction, it has spread in all directions to inhabit intertidal regions, reef flats, and tide pools (Smith et al., 2002; Wang et al., 2012).

The reproductive nature of *A. spicifera* is both asexual and sexual, contributing to its broad distribution, as it can reproduce through both fragmentation and the release of sexual propagules (Smith et al., 2002; O’Doherty et al., 2007). It generally takes less than two days for a fragment of *A. spicifera* to attach itself to new substrate or the hull of a ship due to its hook-like branches that can easily snag rock, coral, or other algal species (Godwin et al., (2005). Additionally, its sexual propagules are capable of travelling long distances, aided by the tides and currents, allowing it to reproduce far away from its impact zone (Smith et al., 2002; O’Doherty et al., 2007). Its original method of arrival as hull fouling is duplicated in harbors and hulls of ships on at least four of the five main islands, facilitating its spread to new habitats (Smith, et al., 2002).

A. spicifera produces large amounts of biomass that reduces biodiversity and alters the structure of reef ecosystems (Smith et al., 2002; O’Doherty et al., 2007). These near-shore coastal regions function to provide biological support to the wide array of native species, protection to coastal regions and ecosystems, carbon storage, aesthetic value (recreation, tourism, etc.), and extractive uses (food, aquariums, pharmaceuticals, etc.) (Cesar et al., 2004).

The pervasiveness of *A. spicifera* threatens supporting services (Gorgula, 2014), specifically by competing and thriving in comparison to other native red algae such as *Laurencia nidifica* (Wang et al., 2012). The overabundance of the alien algae diminishes the biological diversity upon which sustainable ecosystem services are highly dependent (Palumbi et al., 2009). Moreover, the alien algae presence reduces the native algae available to herbivores, forcing them to consume non-native algae, of which the impact is unknown (O’Doherty et al., 2007).

A. spicifera’s effect on provisioning services (i.e., extractive uses), is limiting the available native marine food sources. This has cultural impacts as well, by altering the convenience of resources for subsistence fishing practices (Gorgula, 2014).

While over 20 species of alien algae have been introduced to the Hawaiian Islands since the 1950s, only about five species (including *A. spicifera*) are established and cause extensive algal blooms, altering coastal ecosystems (LaPointe et al., 2010). Yet data on the ecological and economic impacts of alien seaweed bioinvasions are unclear or non-existent.

However, large impacts have been documented for some species. In an economic evaluation of the second most prevalent alien seaweed, *Hypnea musciformis*, (Cesar, et al., 2002) measured the economic losses to the State of Hawai‘i in excess of $20 million, Losses included: reduced occupancy rates in hotels and condominiums; reduced property value; and direct costs of removing rotting seaweed from beaches (Cesar et al., 2002).

The spread of *A. spicifera* is likely irreversible given its current extent, but control measures can be deployed to prevent further expansion (O'Doherty et al., 2007). The first often cited control measure is effective policy for managing the spread of invasive algae via hull fouling, supplementary to the existing laws managing ships' ballast water (DLNR, 2007). One method may require the use of anti-fouling and highly ablative surface paints, making it difficult for algae to latch on. Another useful control measure is the introduction of native herbivores (e.g., turtles) that feed on the algae. However, little is known about how the consumption of invasive algae affects these native herbivores; this is particularly relevant now that A. spicifera accounts for roughly 20% of their diet (O'Doherty et al., 2007).

Another possible control measure addresses the positive correlation between storm-water run-off and invasive algae growth. As it moves across land toward the ocean, storm water run-off accumulates anthropogenic nutrients (phosphates and nitrates) and deposits the nutrients into coastal areas. *A. spicifera* grows rapidly in the nutrient rich conditions, consequently hindering the growth of native red algae and threatening ecosystem services. As long as storm water run-off contains anthropogenic nutrients, *A. spicifera* will have a competitive advantage in run-off zones. Improving filtration and storm water infrastructure could slow *A. spicifera* and other invasive algae growth, allowing native algae the opportunity to thrive (LaPointe et al., (2010).

Currently the only state measures regard ballast water intake and outtake (O'Doherty et al. (2007); DLNR (2007). Similarly, *A. spicifera* is not on the HDOA importation list, so is disqualified from entering Hawai‘i (Schluker, 2003). Nevertheless, this has done very little to slow the growth of *A. spicifera*, let alone reverse the impacts on ecosystem functions and native biological richness.

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Conclusion and Next Steps

This report builds upon the GPI framework that was introduced in earlier annual reports for the State of Hawai‘i Environmental Council. It highlights how the GPI platform can be used to better recognize the costs and benefits associated with invasive species and their management. Through a review of existing literature and semi-structured interviews with a range of experts, we assembled case studies on an invasive species in each of four different ecosystems types: forests, farmland, wetlands, and coastal systems. We discuss the close connection between economics and invasive species and then tie in the concept of ecosystem services, providing a starting point for discussion for policy makers, managers, and others.

To ensure that GPI meets the needs of managers and policy makers who seek better estimates of the economic impacts of change, we need to better understand how ecosystem quality relates to the sustained flow of services and benefits coming from those ecosystems. With regard to invasive species, this requires uncovering the linkages between invasive species and ecological function, particularly those functions critical for ecosystem service delivery.

An ecosystem services approach to invasive species, featured under the GPI umbrella, offers an opportunity to expand ongoing invasive species work beyond its classic focus on ecological function, to factor in human dimensions represented by the costs of lost ecosystem services. Invasive species harm humans directly and indirectly, and a nature-human coupled approach may offer new insights into policy prioritization.

This holistic approach would necessitate collaboration across a broader audience of ecologists, economists, policy makers, the public, and other stakeholders. It blends the discoveries of ecological processes with the evaluation of ecosystem services, to then translate into policy and management recommendations.

Most ecosystem services are considered “non-market” in that they are not bought or sold but rather provided by nature free of charge. If we manage the ecosystems wisely, the flow of free yet valuable services can be sustained. Granted, we recognized the complexity and uncertainty related to ecosystems. Yet by placing an approximate value on these services, the aim is to illustrate their relative economic importance, better assess tradeoffs among policy options (including short- versus long-term actions) and hopefully catalyze stewardship. In contrast, when a monetary unit is not assigned, the importance of these non-market environmental goods and services is routinely undervalued or even overlooked, but decisions are made regardless.

Valuing ecosystem services is a relatively new field. Our call to explicitly include quality at a small scale would require advances in the ecological-economic modeling of those systems. Many of the impacts of invasive species on ecosystem services will be difficult to convert into monetary costs and benefits simply because we do not know either how they impact ecological function, or how changes in ecological function alter flows of ecosystem services. Nevertheless, these critical knowledge gaps are worthy of attention, because broader discussions of the economics of invasive species can lead to better informed decisions about action, both now and in the future.

ACRONYMS AND ABBREVIATIONS

CGAPS	Coordinating Group on Alien Pest Species
DLNR	Hawai‘i State Department of Land and Natural Resources
DoS	US Department of State
EC	Environmental Council
GDP	Gross Domestic Product
GPI	Genuine Progress Indicator
HDOA	Hawai‘i Department of Agriculture
HDOH	Hawai‘i State Department of Health
HGG	Hawai‘i Green Growth
HISC	Hawai‘i Invasive Species Council
IUCN	International Union for Conservation of Nature
LFA	Little Fire Ant
MA	Millennium Assessment
NGO	Non-governmental Organization
NTBG	National Tropical Botanical Garden
OEQC	Office of Environmental Quality Control
TWI	Trade Wind Inversion
UH	University of Hawai‘i
WCC	World Conservation Congress

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