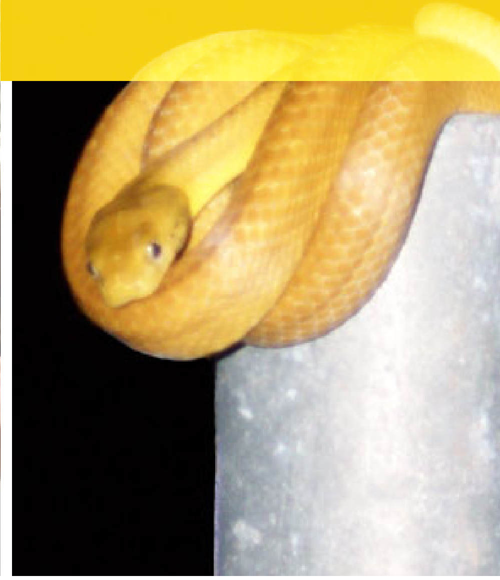




2017-2019

INTERIM

GUAM INVASIVE SPECIES MANAGEMENT PLAN

GUAM INVASIVE SPECIES COUNCIL (GISC)

Guam Invasive Species Council Members

Guam Department of Agriculture (DOAG), *Co-Chair*

Guam Customs & Quarantine (CQA), *Co-Chair*

A.B. Won Pat International Airport Authority (GIAA)

Guam Department of Parks & Recreations (DPR)

Jose D. Leon Guerrero Port Authority of Guam (PAG)

Mayors' Council of Guam (MCOG)

Northern Soil & Water Conservation District (NSWCD)

Southern Soil & Water Conservation District (SSWCD)

University of Guam (UOG)

Non-Voting Members

Bureau of Statistics & Plans (BSP)

Guam Environmental Protection Agency (GEPA)

Guam Homeland Security/Office of Civil Defense (GHS/OCD)

Department of the Navy, Naval Facilities, Marianas (NAVFAC)

U.S. Department of Agriculture (USDA)

Produced under the direction of the Guam Invasive Species Council and the Office of the Governor of Guam.

Sponsored by the Department of the Interior Office of Insular Affairs.

TABLE OF CONTENTS

I.
MISSION STATEMENT

The **Guam Invasive Species Council** protects Guam from alien species that threaten the economy, culture, ecosystem and human health through policy direction, coordination and planning for the prevention, control, monitoring and eradication.

EXECUTIVE SUMMARY

The 2017-2019 Interim Guam Invasive Species Management Plan (GISMP) expresses the overarching goals and priorities of the Guam Invasive Species Council (GISC or Council).

The Guam Invasive Species Act of 2011 (Public Law 31-43) established the Council as Guam's lead entity in coordinating with local, regional, national, and international jurisdictions in the fight against alien invasive species. Although the GISC is in its infancy stages of organization, it draws from the collective knowledge, past research, and progress of its members in establishing the Council's goals and priorities.

Priorities and goals identified in this plan reflect current and near-term resources, member capabilities, and status of certain invasive species. Recommendations contained in the Regional Biosecurity Plan for Micronesia and Hawaii (RBP), the 2016-2018 National Invasive Species Council's Management Plan, the Regional Invasive Species Council (RISC), and various stakeholders were considered in the development of this plan. The Council also considered developments under the purview of the Hawaii Invasive Species Council and its 2015-2020 HISC Strategic Plan.

II.

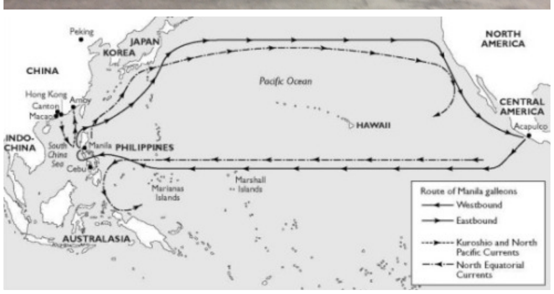
INTRODUCTION

History Of Invasive Species On Guam

Guam's history of introduced species is a mixture of deliberate and accidental introductions. Deliberate introductions may include rice brought in by early Chamorro settlers or domestic farm animals introduced during the Spanish colonial period. Accidental introductions are commonly referred to as invasive species that include rodents, insects, agricultural pests, plants, and disease-causing pathogens.

Prior to Ferdinand Magellan's landing in 1521, the Chamorro people inhabited the Mariana Islands for 4,000 years and likely brought rice with them for cultivation. Their survival rested largely on a subsistence economy where they harvested coconut, root crops, and fish. They continued to practice subsistence farming up until the 1950s. Chamorro people produced primarily for two reasons: survival and the reciprocal practice of exchanging of gifts for goods and services. This system of exchange, or *chenchule'*, is a Chamorro core value still practiced today.

TOP IMAGE COURTESY OF THE GUAM MUSEUM



TOP: Carabao race at the 1934 Guam Fair.
LOWER: Magellan's passage to the Philippines eventually established the Galleon Trade Route, Guam included as a port stop.

Magellan's passage to the Philippines eventually established the Galleon Trade Route. Galleon ships traveled often between Acapulco, Mexico and Manila, Philippines. Guam was signaled as a convenient port stop between the West and the East during the Spanish Colonial Era. Spanish and other European vessels frequently stopped in the Mariana Islands, trading iron and other goods for food and water with the Chamorro people. Through these years, domestic animals such as deer, swine, and cattle, were introduced in these series of trades with the Chamorro people. Some of these species were purposed for sustenance; other animals like the carabao were introduced to the island for farming and transportation. Most of these intentional introductions included species from both the Philippines and Mexico and can still be found today. These feral ungulates like the deer, pig, and carabao roam wild in parts of Guam. The feral swine population continues to grow and because of their burrowing, they have become a significant threat to crops, native trees, the coral reef, and to humans.

Image capture of feral swine impacts to the landscape.

IMAGES COURTESY OF DR. AUBREY MOORE, ENTOMOLOGIST, UNIVERSITY OF GUAM

Introduced species aren't always intentional. Unintended introductions included other animals, pests, plants, and diseases. Possible pathways for entry of invasives included stowaway rodents and pests hidden in cargo container disembarking the ships. They carried in with them disease-causing pathogens like bacteria and fungi that tainted agricultural crops and livestock; subsequently, increasing illness and death among the Chamorro people.

A common known invasive weed is the *Antigonon leptopus*. It is known locally as *kadena*, in Chamorro, and "Chain of Love" in English. The *kadena* is found in Mexico where it also gets its common name, Mexican Creeper. The *kadena* was likely introduced during the Spanish colonial period of Guam. The *kadena* spreads far and wide and completely "climbs" over a host of other trees and plants. This vine can choke smaller plants and trees and prevent photosynthesis by blocking sunlight from reaching those plants.

TOP: "Chain of Love" *Antigonon leptopus* or *kadena* growth in Guam. ***LOWER:*** *Leucaena leucocephala* or *tangantångan* growth in Guam, with seed pods.

PHOTO COURTESY OF THE UNIVERSITY OF GUAM COLLEGE OF NATURAL AND APPLIED SCIENCES, COOPERATIVE EXTENSION PROGRAM

World War II left the island of Guam devastated. The extensive bombing of Guam by American forces to drive out the Japanese soldiers left the island's forested areas almost completely bare and devoid of foliage. Erosion set in and in effort to mitigate it, the Naval government airdropped thousands of *Leucaena leucocephala*, or *tangantångan*, seeds across the island. The *tangantångan*, a type of legume that fixes nitrogen in the soils needed for plant growth through its nitrogen fixing nodes in its root systems, quickly grew atop the war-torn eroded areas. The island saw almost immediate regrowth of vegetation. Today, *tangantångan* provides the local population with various uses such as firewood, timber, shade and compost. While it was well intended, the introduction of the *tangantångan* also came at a cost. Because *tangantångan* grows so quickly and produces an abundance of seed pods, they are literally invasive since they quickly occupy space that would otherwise be taken up by a native plant species. Today, reforestation efforts utilize acacia trees instead of the *tangantångan*; although an alien species, acacia trees prove to be as effective and particularly invasive.

The Guam Customs and Quarantine Agency have identified several deliberate releasing of exotic animals formerly kept as pets in recent years. Some of these intentional releases are committed by pet owners avoiding proper clearances and have even included a pair of pythons. Less exotic animals such as non-native fresh water fish, are found in the island's rivers and streams.

IMAGES COURTESY OF C. ONEDERA

Brown Tree Snake (BTS) on a coconut tree in Chalan Pago, Guam

The most commonly known unintended introduction and perhaps the most impactful is the Brown Tree Snake (BTS). Shortly after World War II, the island was bustling with military activity to rebuild the island's civilian dwellings and businesses, as well as develop and strengthen the United States' military bases. Military cargo ships arrived and departed daily. Among these arrivals included a cargo ship from Manus Island, Papua New Guinea. Aboard this vessel was most likely a single pregnant female brown tree snake. It escaped the vessel and it made its home in the island's jungle. The BTS would thrive on an abundant food source of mostly birds and lizards across the island ultimately causing the extinction and extirpation of many native and endemic species. The loss of pollinating birds and even the fruit bat negatively affects forest regeneration and forest structure on Guam.

The BTS's devastating impact isn't limited to ecological systems but also on the economy. In the mid-1980s, it was discovered that the BTS was largely responsible for the island's frequent power outages as they coiled around power lines. Property damages and repairs are reported to have cost the government millions of dollars. This prompted federal and local government officials to work collaboratively to establish a regulatory framework in which the BTS is managed. This framework includes the Endangered Species Act of 1973, the Memorandum of Agreement on Control of the Brown Tree Snake in 1993, and the Executive Order 13112, Invasive Species in 1999. In 2004, Congress passed the Brown Tree Snake Control and Eradication Act which enabled the formulation of the BTS Technical Work Group (TWG). Since that time, the BTS TWG have made significant progress towards preventing the escape of the BTS from Guam to other locations; reducing their impact on Guam's ecosystems; and develop steps leading to eradication.

Over 50 years after the introduction of the BTS and numerous other damaging species, the government of Guam recognized the dangerous but silent invasion of alien invasive species on the island. In 2005, Governor Felix P. Camacho issued Executive Order 2005-13 relative to the invasive species control and interdiction, which established the Guam Invasive Species Council (GISC), its members and officers, duties and responsibilities, and calling for the draft of an invasive species management plan. While well-intentioned, the efforts to control and prevent invasive species on island did not take traction.

In 2007, Guam faced a new foe in the *Oryctes rhinoceros*, commonly known as the Coconut Rhinoceros Beetle (CRB), when it was first noticed in Tumon Bay. The CRB is a major pest of

IMAGE COURTESY OF ROLAND QUITUGUA, UOG RESEARCH AND COOPERATIVE EXTENSION PROGRAM

Oryctes rhinoceros, commonly known as the Coconut Rhinoceros Beetle (CRB).

the coconut palm, oil palm and other species. Palms are damaged when adult beetles bore into the crowns of palms to feed on sap. Preferred breeding sites are dead, standing coconut stems, and piles of decaying vegetation. Guam, prone to typhoons that leave behind piles of green debris, and the abundance of coconut trees on island make for ideal conditions for the CRB to thrive. The CRB is native to Southeast Asia, primarily in Indonesia and the Philippines. We still do not know how the CRB arrived on Guam but the College of Natural and Applied Sciences at the University of Guam suspects their arrival likely came by way of a shipping container of construction materials and long before they were noticed.

In 2011, reports of *Wasmannia auropunctata*, or the Little Fire Ant (LFA), received highest of concerns since they deliver a very painful sting and can cause an extremely itchy rash. The introduction of the LFA, CRB, BTS and countless other harmful species causing harm to the island's economic and human health, prompted the Guam Legislative to pass Bill 111-31, calling for the formal establishment of the Guam Invasive Species Council, collecting of a biosecurity fee, and the authorization of the Department of Agriculture to establish a Biosecurity Division. The bill was signed into law on May 17, 2011 by Governor Eddie Baza Calvo as the Guam Invasive Species Council Act of 2011. In 2014, the GISC began quarterly meetings to lay the groundwork in carrying out the mandates of the law.

In 2016, the Department of the Interior's (DOI) Assistant Secretary of Insular Areas, Esther Kia'aina, charged the territories with strengthening their defense systems against the threats of alien invasive species. DOI made grants available to the territories for the purposes of drafting their own invasive species management plans and has expressed commitments that future grant-funding will be made available for the sake of fighting against invasive species at all borders. At this time, none of the U.S. territories have issued an invasive species management plan and so far there has never been such a plan adopted by any of the territories. The determination of GISC to submit a plan for Guam demonstrates the diligence of the Council, and the support of Governor Calvo and DOI. Despite the Council's infancy GISC members and stakeholders have been working in the fight against alien invasive species for many years and recognize the opportunities in unifying its efforts.

Scope Of The Invasive Species Problem

Guam's rate of introduced species is alarmingly high. Dr. Aubrey Moore, entomologist with the University of Guam's College of Natural and Applied Sciences recorded sixty known invertebrates since 2000. This is an average of at least three per year. Dr. Moore further reports that before human intervention, species arrived every few thousand years, and today, one new species arrives on Guam every few months. This is 10,000 times the natural rate.

The scope of Guam's invasive species problem rests largely with securing pathways to entry of all plant and animal species into Guam, and human intervention. Guam's borders must be strengthened by improving its capabilities in the prevention of alien invasive species from not only reaching the shores of Guam but entering our neighbors in the region like the Northern Marianas, the rest of Micronesia and Hawaii. As the main gateway between the west and east, GISC intends to rally more federal and local government support to build upon Guam's existing efforts towards biosecurity.

Threats of alien invasive species on Guam are detrimental and a singular pest requires a system of technical approaches from understanding what its predators are, habitats, and other characteristics to identifying the appropriate biocontrols that are effective and do not pose inadvertent harm to the ecosystems they're applied in. Eradication is a term loosely used in conversation and really depends on a range of factors to include how early a new pest is detected, location of detection, and what resources are available for eradication. Because eradication is costly it enforces the immediate need to strengthen prevention measures.

Environmental, Human And Economic Costs To Guam

Environmental And Human Health Costs

Endemic or native species are at risk of extinction because they have not evolved defenses against alien predators, parasites, and diseases. Further, when native plant and animal populations are removed from an ecosystem there are cascading effects as a result. Food webs and habitats are interrupted or destroyed for all species resulting in the overall declining health of the natural environment. Changes in ecosystems and biodiversity translate to increased scarcity of agricultural, herbal, and other natural resources, as well as other unintended consequences affecting human health.

Invasive species are a leading cause of population decline and extinction in animals. BTS have been implicated in the precipitous decline in native forest birds and the modern extinction of at least 10 species on Guam. The loss of pollinating birds and fruit bat prevent forested communities from regeneration. An adverse impact includes the decline in native and endemic species of plants and trees.


PHOTO COURTESY OF UOG EXTENSION BIOSECURITY

Capture of CRB affects on coco palm population and green waste conditions to thrive in.

The CRB is probably the most visually impactful of any arrival of invasive species to the island of Guam to date. Since the time of the CRB's detection in 2007, nearly all of the coconut trees at the Governor Joseph Flores Ypao Beach Park and other public beaches along Tumon Bay have been lost. Only those found on private hotel and resort properties remain standing and the rest of the island's

IMAGES COURTESY OF GUAM DEPARTMENT OF AGRICULTURE

TOP: Guam's native *Cycas micronesica*, or *fadang*, decimated by the Asian Cycad scale. ***LOWER:*** The Cycad scale embeds itself deep within the leaves of the *fadang* to capture the plant's juices.

coconut palm population remain at risk. This devastation negatively impacts the island's population that rely on the tree for its fruit, sap, and leaves.

Guam's native *Cycas micronesica*, or *fadang*, was once in noticeable abundance until 2003 when it was decimated by a new invasive insect pest broadly referred to as the Asian Cycad scale. The Cycad scale embeds itself deep within the leaves and crevices of the *fadang* and latches on to capture the plant's juices. Nearly 90% of the *fadang* has been decimated prompting its protection by law. The *fadang* has served as a cultural resource for the Chamorros for many years and have a significant role to biodiversity in forested areas. The absence of the *fadang* in the forested areas have adverse effects to their communities.

The Greater Banded Hornet (GBH), or *Vespa tropica*, is one of the most recent new detections of invasive wasp in 2016. Two colonies were detected, one in upper Tumon and another in Yoña, after University of Guam entomologists received reports of very painful stings. The GBH is large and aggressive compared to honey bees and other species of wasps. They raid other nests to bring larvae back to feed their own larvae. Though those colonies have been destroyed, the Council continues to monitor for any reports.

IMAGE COURTESY OF C. ONEDERA; INSET IMAGE COURTESY OF THE GUAM FIRE DEPARTMENT

Vespa tropica, or the Greater Banded Hornet (GBH), is one of the most recent new detections of invasive wasp. ***INSET:*** An incident involving the Guam Fire Department demonstrates the harmful stings by the GBH.

The Little Fire Ant (LFA), or *Wasmannia auropunctata*, is listed by the Global Invasive Species Database as one of the top 100 worst invasive species worldwide and is considered the greatest ant threat to the Pacific Region. They deliver a painful sting causing an extremely itchy rash. If left uncontrolled, it leaves the human population vulnerable to stings, poses unintended consequences when it competes for habitats with native species, and is a significant threat to agriculture.

Economic Costs

Monitoring, control, and eradication of invasive species takes expertise, time, and a tremendous amount of resources and money. The Council will develop its own economic assessments on costs related to combating invasive species and explore opportunities for funding.

According to a study conducted in 1999 on Economic Impacts of Invasive Species to Wildlife Services' Cooperators, it is estimated that the cost of BTS-related power outages exceeded

$1 million dollars per year while the cost to treat snake-bites was around $25,000. However, the economic losses still pale in comparison to the loss of native birds and the continued threat to existing species on Guam.

The BTS has long been associated with Guam. Many Guamanians traveling abroad are commonly asked about the abundance of the BTS on island and how Guam's citizens cope. An indirect impact of this stigma is that it deters visitors from choosing Guam as a tourist destination or as a duty station by military personnel. Guam relies on tourism and military spending and the Council is cognizant of the implications in lost revenues for the island. Coconut trees that survive CRB infestation take months to regrow full crowns of healthy leaves. Much of the island's one million tourists are unsatisfied to see bald palm trees on their tropical island vacation.

Guam is enjoying a recent renaissance of cottage-, small-, and commercial-scale plant and poultry farming. This activity positively addresses food security but presents challenges to detect and control/eradicate new invasive species, and highlights capacity and capability gaps of responsible local agencies, to include weak inspection policies, inefficient communication between inspecting agencies, and lack of funding. Researchers and scientists require adequate funding to search and test biocontrols that do not pose adverse impacts to the environment.

Coconut Rhinoceros Beetle (CRB) bore into the crowns of palms to feed on sap.

Thick algal mats, like the one pictured here, can smother corals and have long-lasting impacts on the ecosystem.

The GBH is large and aggressive compared to honey bees and other species of wasps.

IMAGE 1 & 3 COURTESY OF THE UNIVERSITY OF GUAM CNAS, CE PROGRAM; CENTER IMAGE BY BRENT TIBBATTS, GUAM DEPARTMENT OF AGRICULTURE, DIVISION OF AQUATIC AND WILDLIFE RESOURCES.

Summary

Island ecosystems are particularly vulnerable to the destructive power of invasive pests. The unimpeded spread of invasive species is of the greatest threat to Guam's economy, natural environment, and the health and lifestyle of its people. Invasive pests can cause millions of dollars in crop losses, the extinction of native species, the destruction of native forests and habitats, and the spread of diseases. Invasive species are ultimately organisms that causes decreases in ecosystem function. Invasive species also rarely arrive by themselves and common introductions involve human intervention. Overall more support and funding is needed for invasive species work throughout Guam.

The goals and strategies outlined in this plan are intended to move forward on priority issues through the mission and responsibilities of the GISC. They were developed in a series of stakeholder workshops and meetings to get guidance and input on the Council's unique role to progress invasive species work in Guam. The fight to protect Guam's terrestrial, aquatic, and marine ecosystems continues.

Invasive species is everyone's responsibility.

III.

GUAM INVASIVE SPECIES COUNCIL MEMBERSHIP & STRUCTURE

Council Membership

The Council membership is composed of the organizational heads, or their designees, from the following:

- **a) Guam Department of Agriculture (DOAG)**
- **b) Guam Customs and Quarantine Agency (CQA)**
- **c) A.B Won Pat International Airport Authority**
- **d) Jose D. Leon Guerrero Port Authority of Guam (PAG)**
- **e) University of Guam (UOG)**
- **f) Guam Department of Parks and Recreation**
- **g) Mayors' Council of Guam**
- **h) Northern and Southern Soil and Water Conservation Districts.**

Included as non-voting members are representatives from the Bureau of Statistics and Plans (BSP), Homeland Security, and the U.S. Department of Agriculture (USDA).

The Council may invite additional public and private sector members to serve on sub-committees with significant responsibilities concerning invasive species, and may prescribe special procedures for their participation.

The Guam Invasive Species Council Act of 2011 also mandated the Council to review the 2009 Interagency Biosecurity Task Force Work Plan which provides a needed component of a comprehensive biosecurity system that has seamless coverage and enforcement, to achieve a level of protection necessary to maintain or enhance the valuable natural resources of Guam. In 2016, the DOAG and CQA signed the Interagency Biosecurity Work

Plan (IBW), outlining the commitments, duties, roles, and responsibilities between both parties in the interest of collectively combating invasive species. The purpose of the agreement is to establish a heightened agricultural biosecurity effort geared towards enhancing the ability of both CQA and DOAG to provide Guam with a more effective biosecurity protection program; and to improve Guam's protection of dangerous or invasive species and diseases, and to effectively prevent, respond, contain and eradicate agricultural threats, whenever necessary, that may infiltrate the biosecurity net. The IBW reinforces a joint effort by both agencies to cooperatively lead GISC in developing strategies and improving upon existing efforts to the threat of IS. The IBW also establishes a seamless connection between port of entry inspections, exotic pest surveys, and the ability to respond to a disease or pest introduction.

Biosecurity Division And Support Staff

To support GISC policies, the Act also established a Biosecurity Division within the DOAG as the lead local government agency with a purpose to provide for the inspection, quarantine, and eradication of invasive species contained in any freight, including, but not limited to, marine commercial container shipments in efforts to address invasive species coming to, and already present in, Guam.

The law also calls for the establishment of the Guam Invasive Species Inspection Fee to be collected by freight customers and deposited into a separate account. The purpose of the fee was to fund the Biosecurity Division, its support staff, and for the Council to hire a Territorial Invasive Species Coordinator (TISC) who will serve as the Council's Secretary to carry out the communications and coordination as directed by the Council. Implementation of the fee began in July 2015 so vacancies did not open up until the passage of Bill 223-33 by the Guam Legislature (*I Liheslaturan Guåhan*). The bill was signed into law as P.L. 33-130 in March 2016 and appropriated the revenues from the Guam Invasive Species Inspection Fee to fund vacant positions within the Biosecurity Division as well as operational expenses of the program.

In a GISC meeting held in February 2016, following the passage of Bill 223-33, members proposed recruitment for the following:

- **a) Entomologist**
- **b) Botanist**
- **c) Plant pathologist**
- **d) Biosecurity officers**
- **e) Administrative support staff**

The entomologist position was filled shortly thereafter. Active recruitment for the remaining positions is ongoing.

IV.
2017-2019 GOALS & STRATEGIES

The Guam Invasive Species Council Act of 2011 outlines the statutory responsibilities of the Council:

a) **Create a mission statement on invasive species for Guam.****
b) **Develop a Guam Invasive Species Management Plan (GISMP).***
c) **Act as the lead entity for Guam to include local regional, national and international invasive species efforts.***
d) **Provide annual reports on the progress made in achieving the objectives of the GISMP to *I Liheslaturan Guåhan* and *I Maga'låhen Guåhan*.**
e) **Coordinate and promote Guam's position with respect to federal issues concerning invasive species in Guam.***
f) **Identify and record all invasive species present in Guam.* (See Appendix C)**
g) **Identify all needed resources for the purpose of working on invasive species prevention, suppression, and eradication.***
h) **Advise *I Liheslaturan Guåhan* and *I Maga'låhen Guåhan* on budgetary and other issues concerning invasive species.**
i) **Review the structure of fines and penalties to ensure maximum deterrence for invasive species-related crimes.**
j) **Make appropriate recommendations for legislation to improve the management of invasive species programs and policies.**
k) **Update the Interagency Biosecurity Task Force Work Plan.****
l) **Perform all functions necessary to effectuate the mission of the Council.**

** in-progress*
*** final to date*

The goals presented in the next section are identified by the Council as preliminary steps in enhancing and strengthening its capabilities to effectively carry out its mission and responsibilities.

Goal 1

Territorial Invasive Species Coordinator

The GISC will continue to pursue the recruitment of a Territorial Invasive Species Coordinator (TISC) and all necessary personnel to include but not limited to those listed in the Support Staff section of this plan.

The recruitment of a TISC is still in the process of being established as a classified position in the civil service program. The DOAG Biosecurity Division will recruit a Program Coordinator IV in the interim until a TISC has been established and recruited.

Strategies

- Define staffing patterns/ funding capabilities for TISC and personnel.
- Identify potential candidates for recruitment.

Evaluation Measures

- Strong public, regional, and global presence and position of the Council.
- Clear communications and coordination between the Council and branches of government, stakeholders, and community.
- Turnaround time for completion of deliverable actions carried out by the Council.

Goal 2

Prevention

Prevention is the most cost effective strategy for combating invasive species. In 2010, DOAG's Division of Aquatic and Wildlife Resources reported at least 73 non-native organisms found only at the Jose D. Leon Guerrero Port which gave strong implications of pathways via boat traffic. Reprioritizing inspection services for all vessels, goods, and commodities arriving into Guam is critical for the Council to increase prevention measures.

Strategies

- Coordinate with *I Liheslaturan Guåhan* to craft policy and identify funding sources that would establish a fully-contained animal and plant inspection facility at the PAG.
- Ensure comprehensive biosecurity inspections occur prior to arriving in Guam.
- Institute a green waste response plan specifically to reducing micropiles of green debris around the island.

Evaluation Measures

- Regional and global recognition and compliance of Guam's biosecurity controls.
- Rapid response and containment of new detections at ports of entry.
- Decreased rate and volume of pest detections.

Goal 3

Deterrence

Enforcement of regulations will deter violations and further introduction of invasive species via human intervention.

Strategies

- Establish working group to coordinate with *I Liheslaturan Guåhan* in crafting policy that intends to define penalties and fines for those found in violation of contributing to the introduction of invasive species to Guam.

Evaluation Measures

- Rate and volume of detections at known pathways.
- Shift in attitudes regarding public approach to combating invasive species.
- Lean public reporting of suspected violators.

Goal 4

Educational Outreach

Educational outreach programs encourage advocacy in protecting Guam from invasive species. The Council's goal is to engage visitors and the island community to participate as it is an important component to invasive species management on Guam.

Strategies

- Establish working group to build and promote campaigns that increase public awareness and participation in invasive species management.
- Involve the Guam Department of Education and all learning institutions in observing the National Invasive Species Awareness Week. Activities may include school decorating contests, poster/essay contests, and mural contests, geared toward biosecurity and native habitat restoration.
- Coordinate and conduct workshops, conferences, community conversations, and other public forums for sharing of information relative to invasive species on Guam.
- Integrate pest reporting systems between agencies and be made available for public reporting procedures.

Evaluation Measures

- Increased public knowledge of invasive species.
- Changes in rate and volume of reported detections.

Goal 5

Rapid Response Plan

A rapid response plan will detail mobilization and protocol of all stakeholders and agencies responding to new detections of invasive species.

Strategies

- The 2005 Draft Emergency Response Plan will be reviewed and updated for use as the Council's Rapid Response Plan (RRP).

Evaluation Measures

- Clear identification of work flow at the interagency level, leadership roles, and SOP tasks.
- Early detection categorization on newly discovered invasive species.
- Immediate fortifying of pathways of early detections.

V.
OTHER STRATEGIC GOALS

Goal A

Incorporate With RBP

Incorporate Guam priorities and efforts into the Regional Biosecurity Plan.

Goal B

Establish Formal Recognition

Establish formal representation at the federal (NISC, DoD) and regional levels (Regional Invasive Species Council, SPC).

Goal C

Funding Sources

Explore additional local, federal, and grant funding sources for the continued support of existing programs and the development of new programs surrounding the detection, control, monitoring, and eradication/interdiction of invasive species on Guam.

VI.
PRIORITY INVASIVE SPECIES

The Council has identified the following threats as having considerable impact to the island and have deemed it a priority for aggressive and continuous interdiction.

Refer to Appendices on current resource needs.

SPECIES ↓ THREAT or RESOURCE →	Devastates Native Species or Ecosystem?	Economic Threat?	Human Health Threat?	Cultural Threat?	Best/New Science or Technology?
Brown Tree Snake (BTS)	YES	YES	YES	YES	YES
Little Fire Ant (LFA)	UNKNOWN	YES	YES	YES	YES
Coconut Rhinoceros Beetle (CRB)	YES	YES	NO	YES	POSSIBLE
Asian Cycad Scale	YES	YES	NO	YES	YES
Greater Banded Hornet (GBH)	POTENTIAL	YES	YES	YES	YES
Feral Swine	POTENTIAL	YES	YES	YES	NO
Chain of Love or Kadena	YES	POTENTIAL	POSSIBLE	YES	NO

VII.
REFERENCES

Brown Treesnake Technical Working Group. “Brown Treesnake Strategic Plan Final Draft.” n.d.

California Academy of Sciences. *Introduced species and biodiversity*. San Francisco, CA, 27 May 2014. YouTube video: http://bit.ly/2lXml0O

Hawai’i Invasive Species Council. “Hawai’i Invasive Species Council Strategy 2008 - 2013.” Honolulu, HI: Hawai’i Invasive Species Council, June 2008.

Hawaii Invasive Species Council. “HISC Hawaii Invasive Species Council Strategic Plan 2015 - 2020.” *Invasive Species are Everyone’s Kuleana*. Honolulu, HI: Hawaii Invasive Species Council, 2015.

IUCN/SSC Cycad Specialist Group - Subgroup on Invasive Pests. *Report and Recommendations on Cycad Aulascaspis Scale, Aulacaspis yasumatsui Takagi (Hemiptera: Diaspididae)*. Informational. Coral Gables, FL: Cycad Specialist Group (CSG) , 2005.

KUAM News. *Invasive species wreak havoc on Guam’s ecosystem*. Dededo, GU, 19 February 2016. YouTube video: http://bit.ly/2lXanUX

—. *New dangerous wasp species appears on Guam*. Dededo, GU, 4 August 2016. YouTube video: http://bit.ly/2lXmrpg

—. *One of the biggest threats to Guam’s coral reef...feral pigs?* Dededo, GU, 24 February 2016. News article and video: http://bit.ly/2lX7fbS

Lobban, Christopher S., et al. *Tropical Pacific Island Environments*. Honolulu, Hawaii: Bess Press, 2014.

National Invasive Species Council. “NISC National Invasive Species Council Management Plan 2016-2018.” *Protecting What Matters*. Washington D.C.: U.S. Department of Interior, 11 July 2016.

Pimentel, David, et al. “Environmental and Economic Costs Associated with Non-Indigenous Species in the United States.” Ithaca, NY: Cornell University, 22 January 1999. Cornell Chronicle Website.

Rosario, Christopher A. and Sablan, Lee Roy and Miller, Ross H., and Moore, Aubrey. “Greater Banded Hornet Vespa Tropica (Hymenoptera: Vespidae).” *Guam New Invasive Species Alerts, 2016* (2016).

SPC Secretariat of the Pacific Community, SPREP Secretariat of the Pacific Regional Environment Programme. “Guidelines for Invasive Species Management in the Pacific.” *A Pacific strategy for managing pests, weeds, and other invasive species*. Apia, Samoa: Secretariat of the Pacific Regional Environment Programme, 2009.

The Guam Daily Post. *Dog rescue leads to hornet’s nest*. Hagatna, GU, 24 August 2016. YouTube video: http://bit.ly/2lXttdF

University of Guam and the Secretariat of the Pacific Community. “Regional Biosecurity Plan for Micronesia and Hawaii Vol. I, II, III, IV.” Commander, Navy Installations Command (CNIC) and Headquarters, Marine Corps., 2014.

University of Guam College of Natural & Applied Sciences. “2014 Western Pacific Tropical Research Center Impact Report.” Mangilao, Guam: University of Guam, 2014.

—. “2015 Western Pacific Tropical Research Center Impact Report.” Mangilao, Guam: University of Guam, 2015.

—. “Coconut Rhinoceros Beetle Behavior and Biology.” 2014. *University of Guam Cooperative Extension Program*. Booklet.

USDA Fish & Wildlife Service. “The Cost of Invasive Species.” USDA Fish & Wildlife Services, January 2012.

USDA-APHIS. *Battling the Brown Treesnake Aerial Bait Drops on Guam*. Hagatna, GU, 26 August 2016. YouTube video: http://bit.ly/2lXsZEo

VIII.
APPENDICES

A. Definitions

B. Guam Invasive Species Council Act Of 2011

C. Preliminary Listing Of Known Invasive Species On Guam

D. BTS Technical Working Group Draft Strategic Plan

E. LFA Strategy

F. CRB Strategy

G. Greater Banded Hornet

H. Asian Cycad Scale

I. Feral Swine Strategy

APPENDIX A

Definitions

Aquatic ecosystems are ecosystems in a body of water. Two main types of aquatic ecosystems are marine and freshwater ecosystems.

Alien invasive species are plants, animals, pathogens, and other organisms that are non-native to an ecosystem, and which may cause economic and environmental harm or adversely affect human health.

Alien species means, with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem.

Biocontrol is a method of controlling pests such as insects, mites, weeds, and plant diseases using other organisms.

Biodiversity is the variety of life in the world or in a particular habitat or ecosystem.

Biosecurity are the procedures intended to protect humans or animals against disease or harmful biological agents.

Control means, as appropriate, eradicating, suppressing, reducing, or managing invasive species populations, preventing spread of invasive species from areas where they are present, and taking steps such as restoration of native species and habitats to reduce the effects of invasive species and to prevent further invasions.

Detection or Early Detection, is a process of detecting, reporting and verifying the presence of non-native species before a population becomes established or spreads that eradication is no longer feasible.

Ecosystem means the complex of a community of organisms and its environment.

Endemic species are plants and animals that exist only in one geographic region. Islands are likely to have a variety of endemic species because of their separation from larger land masses.

Eradication means the removal or extirpation of invasive species.

Extirpation means the removal, endangerment, or extinction of many of Guam's native birds.

Feral refers to the animals in the wild that are descended from domestic animals.

Infestation is the state of being invaded or overrun by pests or parasites.

Intentional release refers to plants and animals transferred from other regions and are set free in the wild.

Interim Management Plan is an evolving document that discusses the coordinated effort between government officials, organizations, and community stakeholders in the management of Guam's biosecurity and invasive species programs.

Introduction means the intentional or unintentional escape, release, dissemination, or placement of a species into an ecosystem as a result of human activity.

Invasive species means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.

Marine ecosystems refers to salt marshes, intertidal zones, estuaries, lagoons, mangroves, coral reefs, the deep sea, and the sea floor.

Monitoring means continued assessment of existing invasive species and their locations and their impacts on the economy, the environment, and human health.

Native species means, with respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem.

Pathogens means bacterium, fungi, virus, or other microorganism that can cause disease.

Pathways are the means by which invasive species are moved, intentionally or unintentionally, in new areas.

Pests are unwanted plants or animals that are detrimental to human health, agriculture, livestock, and ecosystems.

Pollinating birds refers to the important role of Guam's native birds in the transfer and growth of many native plants.

Prevention means the activities taken to prevent the further introduction of invasive species.

Reforestation means the process of replanting an area with trees.

Regeneration the succession of new plants and animals in an area

Species means a group of organisms all of which have a high degree of physical and genetic similarity, generally interbreed only among themselves, and show persistent differences from members of allied groups of organisms.

Stakeholder means, but is not limited to, Federal, State, Territorial, tribal, and local government agencies, academic institutions, the scientific community, non-governmental entities including environmental, agricultural, and conservation organizations, trade groups, commercial interests, and private landowners.

Subsistence economy is a non-monetary economy which relies on natural resources to provide basic needs through hunting, gathering, and subsistence agriculture.

Terrestrial ecosystems is ecosystem found only on landforms and includes all organisms.

Ungulates refers to a diverse group of primarily large mammals. On Guam, feral ungulates are cattle, carabao, deer, and swine.

APPENDIX B

CHAPTER 70
GUAM INVASIVE SPECIES COUNCIL

SOURCE: Added by P.L. 31-043:2 (Apr. 18, 2011).

2015 NOTE: P.L. 26-076:33 (Mar. 12, 2002) repealed this chapter formerly entitled "Department of Commerce." Section 31(c) of P.L. 26-076 stated:

> (c) Abolition of Department of Commerce. The Guam Eco-nomic Development and Commerce Authority ("Authority") succeeds to, and is vested with, all the powers, duties, responsibilities and jurisdiction of the former Department of Commerce ("DOC").

See 12 GCA Chapter 50 - Guam Economic Development Authority.

§ 70101. Short Title.

This Chapter *shall* be known as the *Guam Invasive Species Council Act of 2011*.

§ 70102. Guam Invasive Species Council, Established.

The Guam Invasive Species Council (GISC) will be established for the special purposes of protecting Guam from alien species that threaten our economy, culture, ecosystem and human health; and providing policy direction, coordination, and planning among government of Guam departments and federal agencies to prevent the introduction of invasive species and the monitoring, control and eradication of invasive species throughout the island of Guam. The Council *shall* convene within thirty (30) days of enactment and *shall* elect its Chairperson and Vice Chairperson.

§ 70103. Duties of Council.

The Council *shall*:

(a) create a mission statement on invasive species for Guam;

(b) develop a Guam Invasive Species Management Plan (GISMP);

(c) act as the lead entity for Guam to include local regional, national and international invasive species efforts;

(d) provide annual reports on the progress made in achieving the objectives of the GISMP to *I Maga'lahen Guåhan* and *I Liheslaturan Guåhan*;

(e) coordinate and promote Guam's position with respect to federal issues concerning invasive species in Guam;

(f) identify and record all invasive species present in Guam;

(g) identify all needed resources for the purpose of working on invasive species prevention, suppression and eradication;

(h) advise *I Maga'lahen Guåhan* and *I Liheslaturan Guåhan* on budgetary and other issues concerning invasive species;

(i) review the structure of fines and penalties to ensure maximum deterrence for invasive species-related crimes;

(j) make appropriate recommendations for legislation to improve the management of invasive species programs and policies;

(k) the Council, in coordination with *I Maga'lahen Guahan*, *shall* review the Interagency Biosecurity Task Force Work Plan adopted in 2009 (*see* Appendix A), and in accordance with the framework and recommendation detailed in the 2009 Plan, the Council *shall* formulate an updated version of such a plan, to include replacing the mentions of the USDA APHIS PPQ, with the "Guam Invasive Species Council" *or* the "Invasive Species Coordinator", as appropriate. Such plan *shall* be submitted to *I Liheslaturan Guahan* in accordance with the Adminstration Adjudication Law process *no later than* ninety (90) calendar days from the date of enactment of this Act, and *shall* be subject to legislative approval; and

(l) perform all functions necessary to effectuate the mission of the Council.

§ 70104. Composition of Council.

(a) The Council *shall* be composed of the organizational heads, or their designees, from the Guam Department of Agriculture (GDOA), the Customs and Quarantine Agency (CQA), the A.B. Won Pat International Airport Authority, Guam; the Jose D. Leon Guerrero Port Authority of Guam; the University of Guam; the Department of Parks and Recreation; the Mayors Council of Guam; and the Northern and Southern Soil and Water Conservation Districts; and to include as non-voting members, representatives from the Bureau of Statistics & Plans, Homeland Security and the U.S. Department of Agriculture.

(b) The Council may invite additional public and private sector members to serve on sub-committees with significant responsibilities concerning invasive species, and may prescribe special procedures for their participation.

§ 70105. Government of Guam Agency Duties.

(a) Each government of Guam agency whose actions may affect the status of invasive species *shall*, to the extent practicable and permitted by law: (1) identify such actions; (2) subject to the availability of appropriations, and within the Administration's budget limits, use relevant programs and authorities to: (A) prevent the introduction of invasive species; (B) detect and respond rapidly to mitigate the population of such species in a cost-effective and environmentally sound manner; (C) monitor invasive species populations accurately and reliably; (D) provide for restoration of native species and habitat conditions in ecosystems that have been affected; (E) conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally sound control of invasive species; and (F) promote public education on invasive species and the means to address them; and (3) *not* authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species in Guam, the United States, or elsewhere, *unless*, pursuant to guidelines that it has prescribed and that have been approved by the Council, the agency has determined and made public its determination that the benefits of such actions clearly outweigh the potential harm caused by invasive species; and that all feasible and prudent measures to minimize risk of harm will be taken in conjunction with the actions.

(b) Government of Guam agencies *shall* pursue the duties set forth in this Section in consultation with the Guam Invasive Species Council, consistent with the Guam Invasive Species Management Plan and in cooperation with stakeholders, as appropriate. The agencies *shall* report on their participation as detailed in § 70107(c) of this Chapter.

§ 70106. Conduct of Meetings.

The Council *shall* meet *no less than* once quarterly to discuss and assess progress, and to recommend changes to the invasive species programs based on the results of current risk assessments, performance standards, and other relevant data. A simple majority of voting members of the Council *shall* constitute a quorum to do business; and any action taken by the Council *shall* be by a simple majority of the voting members. The Open Government Law *shall* apply to meetings of this Council.

§ 70107. Guam Invasive Species Management Plan (GISMP).

(a) The Council *shall* prepare and issue the Guam Invasive Species Management Plan, which *shall* detail and recommend performance-oriented goals and objectives and specific measures of success for government of Guam agency efforts concerning invasive species. The Plan *shall* recommend specific objectives and measures for carrying out each of the government of Guam agency duties established in § 70105 of this Chapter, and *shall* set forth steps to be taken by the Council to carry out duties assigned to it under § 70103. The Plan *shall* be developed through a public process and in consultation with government of Guam agencies and stakeholders, and is subject to Legislative approval.

(b) The Plan *shall* include a review of rapid response protocols, existing and prospective approaches and authorities for preventing the introduction and spread of invasive species in Guam, including those for identifying pathways by which invasive species are introduced and for minimizing the risk of introduction via those pathways, and *shall* identify research needs and recommend measures to minimize the risk that introductions will occur. Such recommended measures *shall* provide for a science-based process to evaluate risks associated with introduction and spread of invasive species and coordinate a systematic risk-based process to interdict, identify, and monitor pathways that may be involved in the introduction of invasive species.

(c) The Council *shall* update the Plan biennially in accordance with the Administrative Adjudication Law and *shall* concurrently evaluate and report on the success in achieving the goals and objectives set forth. The Plan *shall* identify the personnel, other resources, and additional levels of cooperation needed to achieve the Plan's identified goals and objectives, and the Council *shall* provide each edition of the Plan, and each report on it, to the Bureau of Budget and Management Research (BBMR) and *I Liheslatura.* Additionally, progress reports *shall* be submitted annually to the Office of the Governor and *I Liheslatura*. Within eighteen (18) months after measures have been recommended by the Council in any edition of the Plan, each government of Guam agency whose action is required to implement such measures *shall* either take the action recommended or *shall* provide the Council with an explanation as to why the action is *not* feasible. The Council *shall* assess the effectiveness of this Plan *no less than* once every three (3) years after the Plan is issued, and *shall* report to the BBMR and *I Liheslatura* on whether the Plan should be revised.

APPENDIX C

Invasive Species in Guam

SCIENTIFIC NAME	CLASSIFICATION	COMMON NAME
Acanthograeffea denticulata (Redtenbacher)	Phasmatodea: Phasmatidae	denticulate stick insect
Acerimina tiliaceae Mohanasundaram & Arachnida	Actinedida: Eriophyidae	eriophyid mite
Achaea janata (L.)	Lepidoptera: Noctuidae	castor semilooper
Achatina fulica	land invertebrate	giant African snail
Adoretus sinicus Burmeister	Coleptera: Scarabaeidae	Chinese rose beetle
Adoxophyes melia Clarke	Lepidoptera: Tortricidae	melia tortricid
Aedeomyia catasticta Knab	Diptera: Culicidae	mosquito
Aedes albopictus (Skuse)	Diptera: Culicidae	forest day mosquito
Aedes vexans (Meigen)	Diptera: Culicidae	vexans mosquito
Agathodes ostentalis (Geyer)	Lepidoptera: Pyralidae	moth
Agonoxena pyrogramma Meyrick	Lepidopter: Agonoxenidae	coconut flat moth
Agonoxena sp.	Lepidoptera: Agonoxenidae	moth
Agrilus occipitalis (Eschscholtz)	Coleoptera: Buprestidae	citrus bark borer
Agrius convolvuli (L.)	Lepidoptera: Sphingidae	sweet potato hawk moth
Aiolopus thalassinus dubius Willemse	Orthoptera: Acrididae	brown-winged
Alciphron glaucus (F.)	Hemiptera: Pentatomidae	pentatomid bug
Aleurocanthus spiniferus (Quaintance)	Homoptera: Aleyrodidae	orange spiny whitefly
Aleurodicus dispersus Russell	Homoptera: Aleyrodidae	spiraling whitefly
Aleurodothrips fasciapennis (Franklin)	Thysanoptera: Thripidae	thrips
Aleurothrixus floccosus (Maskell)	Homoptera: Aleyrodidae	woolly whitefly
Amblyomma testudinarium Koch	Ixodida: Ixodidae	tick
Anaballus amplicollis (Fairmaire)	Coleoptera: Curculionidae	weevil
Anatrychintis sp.	Lepidoptera: Cosmopterigidae	cosmet moth
Andaspis punicae (Laing)	Homoptera: Diaspididae	scale
Anisodes illepidaria Guenee	Lepidoptera: Geometridae	mango shoot looper
Anomala sulcatula Burmeister	Coleoptera: Scarabaeidae	chafer beetle
Anomis flava (F.)	Lepidoptera: Noctuidae	hibiscus caterpillar
Anopheles aureohirtum	Diptera: Culicidae	mosquito
Anopheles barbirostris Van der Wulp	Diptera: Culicidae	mosquito
Anopheles campestris Reid	Diptera: Culicidae	mosquito
Anopheles indefinitus (Ludlow)	Diptera: Culicidae	mosquito
Anopheles litoralis King	Diptera: Culicidae	mosquito
Anopheles subpictus Grassi	Diptera: Culicidae	mosquito
Anopheles vagus Donitz	Diptera: Culicidae	mosquito
Anoplolepis gracilipes	Hymenoptera: Formicidae	yellow crazy ant
Antigonon leptopus Hooker & Arnott	land plant, Polygonaceae	chain of love
Antonina graminis (Maskell)	Homoptera: Pseudococcidae	rhodesgrass mealybug
Anua coronata (F.)	Lepidoptera: Noctuidae	moth
Anua tongaensis Hampson	Lepidoptera: Noctuidae	moth
Aonidiella comperei Mckenzie	Homoptera: Diaspididae	false yellow scale
Aonidiella inornata Mckenzie	Homoptera: Diaspididae	inornate scale
Aonidiella orientalis (Newstead)	Homoptera: Diaspididae	oriental scale

(Appendix C continued...)

SCIENTIFIC NAME	CLASSIFICATION	COMMON NAME
Aphanisticus cochinchinae	Coleoptera: Buprestidae	sugarcane leafmining buprestid
Aphis craccivora Koch	Homoptera: Aphididae	cowpea aphid
Aphis gossypii Glover	Homoptera: Aphididae	cotton or melon aphid
Aphis nerii Boyer de Fonscolombe	Homoptera: Aphididae	oleander aphid
Aphis rumicis L.	Hemiptera: Aphididae	dock aphid
Aphis spiraecola Patch	Homoptera: Aphididae	spirea aphid
Araneus ventricosus (L. Koch)	Arachnida: Aranaeidae	angulate orbweaving spider
Arenivaga sp.	Blattodea: Polyphagidae	sand cockroach
Armigeres subalbatus (Coquillet)	Diptera: Culicidae	mosquito
Aspidiella sacchari (Cockerell)	Homoptera: Diaspididae	sugarcane scale
Aspidiotus destructor Signoret	Homoptera: Diaspididae	coconut scale
Asterolecanium bambusae (Boisduval)	Homoptera: Asterolecaniidae	bamboo scale
Asterolecanium miliaris (Boisduval)	Homoptera: Asterolecaniidae	bamboo scale
Asterolecanium pseudomiliaris Green	Homoptera: Asterolecaniidae	bamboo scale
Asterolecanium pustulans (Cockerell)	Homoptera: Asterolecaniidae	oleander pit scale
Asterolecanium robustum Green	Homoptera: Asterolecaniidae	bamboo scale
Atractomorpha psittacina Haan	Orthoptera: Pygomorphidae	grasshopper
Aulacaspis yasumatsui Takagi	Hemiptera: Diaspididae	Asian cycad scale
Aulacophora quadrimaculata (F.)	Coleoptera: Chrysomelidae	spotted cucumber beetle
Aulacophora similis (Olivier)	Coleoptera: Chrysomelidae	spotted cucumber beetle
Bactrocera cucurbitae Coquillett	Diptera: Tephritidae	melon fly
Bactrocera ochrosiae Malloch	Diptera: Tephritidae	ochrosia fruit fly
Badamia exclamationis F.	Lepidoptera: Hesperiidae	myrobalan butterfly
Batrachedra sp.	Lepidoptera: Colephoridae	moth
Batrachomorphus atrifrons (Metcalf)	Homoptera: Cicadellidae	leafhopper
Bemisia tabaci (Gennadius)	Homoptera: Aleyrodidae	sweet potato whitefly
Bidens pilosa L.	land plant, Asteraceae	Spanish needles
Boiga irregularis	land reptile	brown tree snake
Bolacidothrips orizae Moulton	Thysanoptera: Thripidae	thrips
Brachymyrmex obscurior Forel	Hymenoptera: Formicidae	rover ant
Brachyplatys insularis Ruckes	Hemiptera: Plataspididae	black island stink bug
Brevipalpus californicus (Banks)	Acari: Tenuipalpidae	flat mite
Brontispa chalybeipennis (Zacher)	Coleoptera: Chrysomelidae	Pohnpei coconut leaf beetle
Brontispa palauensis (Esaki & Chujo)	Coleoptera: Chrysomelidae	Palau coconut leaf beetle
Byrsinus varians Fabricius	Hemiptera: Cydnidae	burrower bug
Calcisuccinea luteola Gould, 1848	Mollusca: Succineidae	Mexico ambersnail
Camponotus chloroticus	Hymenoptera: Formicidae	carpenter ant
Camponotus navigator	Hymenoptera: Formicidae	carpenter ant
Camponotus variegatus	Hymenoptera: Formicidae	Hawaiian carpenter ant
Capelopterum punctatellum Melichar	Homoptera: Issidae	planthopper
Cardiocondyla emeryi Forel	Hymenoptera: Formicidae	ant
Cardiocondyla obscurior Wheeler, W.M.	Hymenoptera: Formicidae	ant
Cardiocondyla tjibodana	Hymenoptera: Formicidae	ant
Cardiocondyla wroughtoni	Hymenoptera: Formicidae	ant
Cerapachys biroi	Hymenoptera: Formicidae	ant
Cerataphis lataniae (Boisduval)	Homoptera: Aphididae	latania aphid

(Appendix C continued...)

SCIENTIFIC NAME	CLASSIFICATION	COMMON NAME
Cerataphis sp.	Hemiptera: Aphididae	palm aphids
Ceresium unicolor (F.)	Coleptera: Cerambycidae	longhorn beetle
Ceroplastes ceriferus Anderson	Homoptera: Coccidae	Mexican wax scale
Ceroplastes floridensis Comstock	Homoptera: Coccidae	Florida was scale
Ceroplastes rubens Maskell	Homoptera: Coccidae	red wax scale
Chaetocnema confinis Crotch	Coleoptera: Chrysomelidae	sweet potato flea beetle
Chanithus gramineus (F.)	Homoptera: Dictyopharidae	grass snout hopper
Chilades pandava Horsfield	Lepidoptera: Lycaenidae	cycad blue butterfly
Chloriona formosella (Matsumura)	Homoptera: Delphacidae	planthopper
Chlorophorus annularis (F.)	Coleoptera: Cerambycidae	bamboo longhorn
Chloropulvinaria psidii Maskell	Homoptera: Coccidae	green shield scale
Chromolaena odorata (L.) R.M. King & H. Robins	land plant, Asteraceae	Siam weed
Chrysobothris costata Kerremans	Coleptera: Buprestidae	wood borer
Chrysodeixis chalcites (Esper)	Lepidoptera: Noctuidae	green garden looper
Chrysomphalus dictyospermi (Morgan)	Homoptera: Diaspididae	dictyospermum scale
Cicadulina bipunctella (Matsumura)	Homoptera: Cicadellidae	leafhopper
Coccidohystrix insolita (Green 1908)	Hemiptera: Pseudococcidae	eggplant mealybug
Coccinia grandis (L.) Voigt	land plant, Cucurbitaceae	ivy gourd
Coccotrypes advena Blandford	Coleoptera: Scolytidae	palm seed borer
Coccus hesperidum L.	Homoptera: Coccidae	brown soft scale
Coccus longulus (Douglas)	Homoptera: Coccidae	long brown scale
Coccus moestus De Lotto	Homoptera: Coccidae	coccid scale
Coccus viridis (Green)	Homoptera: Coccidae	green scale
Colasposoma metallicum Lefevre	Coleoptera: Chrysomelidae	leaf beetle
Conocephalus longipennis (Haan)	Orthoptera: Tettigoniidae	long-horned grasshopper
Cosmopolites sordidus (Germar)	Coleoptera: Curculionidae	banana root borer
Creontiades pallidifer (Walker)	Hemiptera: Miridae	sweet potato yellow bug
Crocidolomia pavenana Zeller.	Lepidoptera: Pyralidae	cabbage cluster caterpillar
Cryptophlebia ombrodelta (Lower)	Lepidoptera: Tortricidae	litchi fruit moth
Cryptophlebia peltastica (Meyrick)	Lepidoptera: Tortricidae	tortricid moth
Cryptorhynchus mangiferae (F.)	Coleoptera: Curculionidae	seed weevil
Culex fuscanus Wied.	Diptera: Culicidae	mosquito
Culex fuscocephalus Theobald	Diptera: Culicidae	mosquito
Culex quinquefasciatus Say	Diptera: Culicidae	southern house mosquito
Culex tritaeniorhynchus Giles	Diptera: Culicidae	mosquito
Culicoides peliliouensis Tokunaga	Diptera: Ceratopogonidae	biting midge
Cunaxa sp.	Acari: Prostigmata: Cunaxidae	mite
Cuscuta sp.	land plant, Convolvulaceae	dodder
Cydalima laticostalis Guenee	Lepidoptera: Crambidae	crambid moth
Cylas formicarius (F.)	Coleoptera: Curculionidae	sweet potato weevil
Cyrtopeltis tenuis (Reuter)	Hemiptera: Miridae	tomato bug
Daphis nerii (L.)	Lepidoptera: Sphingidae	oleander hawk moth
Dasyhelea carolinensis Tokunaga	Diptera: Ceratopogonidae	biting midge
Dasyhelea dupliforceps Tokunaga	Diptera: Ceratopogonidae	biting midge
Dasyses rugosella (Stainton)	Lepidoptera: Tineidae	clothes moth

(Appendix C continued...)

SCIENTIFIC NAME	CLASSIFICATION	COMMON NAME
Diabrotica undecimpuntata (L.)	Coleoptera: Chrysomelidae	spotted cucumber beetle
Dialeurodes citrifolii	Homoptera: Aleyrodidae	whitefly
Dialeurodes kirkaldyi (Kotinsky)	Homoptera: Aleyrodidae	Kirkaldy whitefly
Dialeuropora decempunctata (Quaintance & Baker)	Hemiptera: Aleyrodidae	whitefly
Diaphania hyalinata (L.)	Lepidoptera: Pyralidae	melonworm
Diaphania indica (Saunders)	Lepidoptera: Pyralidae	cucurbit leafroller
Diaphorina citri Kuwayama	Hemiptera: Psyllidae	Asian citrus psyllid
Diaspis bromeliae (Kerner)	Homoptera: Diaspididae	pineapple scale
Dinurothrips hookeri Hood	Thysanoptera: Thripidae	thrips
Diocalandra frumenti (F.)	Coleoptera: Curulionidae	coconut weevil
Dudua aprobola (Meyrick)	Lepidoptera: Tortricidae	tortricid moth
Dymicoccus boninsis (Kuwana)	Homoptera: Pseudococcidae	grey sugarcane mealybug
Dysmicoccus brevipes (Cockerell)	Homoptera: Pseudococcidae	pineapple mealybug
Dysmicoccus neobrevipes Beardsley	Homoptera: Pseudococcidae	grey pineapple mealybug
Dysmicoccus saipanenis (Shiraiwa)	Homoptera: Pseudococcidae	Saipan mealybug
Eichhornia crassipes (Martius) Solms-Laubach	aquatic plant, Pontederiaceae	water hyacinth
Eleutherodactylus planirostris Cope	Anura: Eleutherodactylidae	greenhouse frog
Eotetranychus cendanai Rimando	Acari: Tetranychidae	citrus leaf mite
Culex sitiens Wied.	Diptera: Culicidae	mosquito
Eotetranychus sexmaculatus (Riley)	Acari: Tetranychidae	sixspotted spider mite
Epilachna 26punctata philippensis	Coleoptera: Coccinellidae	Philippine lady beetle
Epilachna cucurbitae Richards	Coleoptera: Coccinellidae	cucurbit lady beetle
Epitrix hirtipennis (Melsheimer)	Coleoptera: Chrysomelidae	tobacco flea beetle
Erechthisa sp.	Lepidoptera: Tineidae	clothes moth
Erionota thrax (L.)	Lepidoptera: Hesperiidae	banana leafroller
Etiella zinckenella (Treischke)	Lepidoptera: Pyralidae	lima-bean pod borer
Euconocephalus nasutus (Thunberg)	Orthoptera: Tettigoniidae	grasshopper
Eudocima fullonia (Clerck)	Lepidoptera: Noctuidae	fruit-piercing moth
Euglandina rosea	land invertebrate	rosy wolf snail
Euploea leucostictos Eschscholtz	Lepidoptera: Nymphalidae	blue-spotted king crow
Eupodes sp.	Acarina: Eupodidae	mite
Euscepes postfasciatus (Fairmaire)	Coleoptera: Curculionidae	West Indian sweet potato weevil
Eusyphax bivittatus (Metcalf)	Homoptera: Derbidae	derbid planthopper
Exitianus capicola (Stal)	Homoptera: Cicadellidae	leafhopper
Exitianuz plebeius (Kirkaldy)	Homoptera: Cicadellidae	leafhopper
Ferrisia virgata (Cockerell	Homoptera: Pseudococcidae	striped mealybug
Fromundus biimpressus (Horvath)	Hemiptera: Cydnidae	burrower bug
Fulvius angustatus Usinger	Hemiptera: Miridae	mirid
Furcaspis oceanica Lindinger	Homoptera: Diaspididae	cocount red scale
Gonocephalum sp.	Coleoptera: Tenebrionidae	darkling beetle
Grammarodes gemetrica (F.)	Lepidoptera: Noctuidae	geometric noctuid
Gryllotalpa sp.	Orthoptera: Gryllotalpidae	mole cricket
Halticus insularis Usinger	Hemiptera: Miridae	island fleahopper
Halticus tibialis Reuter	Hemiptera: Miridae	black garden fleahopper
Helicoverpa armigera (Hubner)	Lepidoptera: Noctuidae	old world bollworm

(Appendix C continued...)

SCIENTIFIC NAME	CLASSIFICATION	COMMON NAME
Heliothrips haemorrhoidalis (Bouche)	Thysanoptera: Thripidae	greenhouse thrips
Hemiberlesia lataniae (Signoret)	Homoptera: Diaspididae	latania scale
Hemiberlesia palmae (Cockerell)	Homoptera: Diaspididae	palm scale
Hippotion celerio (L.)	Lepidoptera: Sphingidae	taro sphinx-moth
Hyalopterus pruni (Geoffroy)	Hemiptera: Aphididae	mealy plum aphid
Hylarana guentheri (Boulenger)	Anura: Ranidae	Gunther's frog
Hylotrupes bajulus (L.)	Coleoptera: Cerambycidae	old house borer
Hypolimnas bolina (L.)	Lepidoptera: Nymphalidae	blue moon butterfly
Hypoponera puntatissima	Hymenoptera: Formicidae	ant
Hypothenemus burmanus	Coleoptera: Scolytidae	borer
Hypothenemus crudiae	Coleoptera: Scolytidae	borer
Hysteroneura setariae (Thomas)	Homoptera: Aphididae	rusty plum aphid
Icerya aegyptiaca (Douglas)	Homoptera: Margarodidae	Egyptian fluted scale
Icerya purchasi Maskell	Homoptera: Margarodidae	cottony cushion scale
Imperata conferta (Presl) Ohwi	land plant, Poaceae	blady grass
Iridomyrmex anceps	Hymenoptera: Formicidae	rainbow ant
Ischnaspis longirostris (Signoret)	Homoptera: Diaspididae	black thread scale
Kallitaxila crini (Matsumura)	Homoptera: Tropiduchidae	green tropiduchid
Karnyothrips melaleuca (Bagnall)	Thysanoptera: Thripidae	thrips
Kilifia acuminata (Signoret)	Homoptera: Coccidae	acuminate scale
Lallemandana phalerata (Stal)	Homoptera: Cercopidae	spittlebug
Lamenia caliginea Stal	Homoptera: Derbidae	derbid planthopper
Lamenia numitor Fennah	Homoptera: Derbidae	derbid planthopper
Lampides boeticus (L.)	Lepidoptera: Lycaenidae	bean butterfly
Lamprosema diemenalis (Guenee)	Lepidoptera: Pyralidae	bean leaf-roller
Lantana camara L.	land plant, Verbenaceae	lantana
Lepidoglyphus destructor (Schrank)	Acari: Astigmata: Glycyphagidae	storage mite
Lepidosaphes beckii (Newman)	Homoptera: Diaspididae	purple scale
Lepidosaphes esakii Takahashi	Homoptera: Diaspididae	armored scale
Lepidosaphes laterochitinosa Green	Homoptera: Diaspididae	armored scale
Lepidosaphes palauensis Beardsley	Homoptera: Diaspididae	Palau scale
Lepidosaphes similis Beardsley	Homoptera: Diaspididae	scale
Lepidosaphes sp.	Homoptera: Diaspididae	scale
Lepidosaphes tokionis (Kuwana)	Homoptera: Diaspididae	croton mussel scale
Leptocentrus taurus (F.)	Homoptera: Membracidae	eggplant horned planthopper
Leptocorixa acuta (Thunberg)	Hemiptera: Alydidae	rice bug
Leptoglossus australis (F.)	Hemiptera: Coreidae	leaf-footed plant bug
Leptynoptera sulfurea Crawford	Homoptera: Psyllidae	kamani psyllid
Leucaena leucocephala (Lam.) de Wit	land plant, Mimosaceae	leucaena
Lipaphis erysimi (Kaltenbach)	Homoptera: Aphididae	turnip aphid
Liriomyza brassicae (Riley)	Diptera: Agromyzidae	cabbage serpentine leafminer
Liriomyza sativae Blanchard	Diptera: Agromyzidae	vegetable leafminer
Litoria fallax Peters	Anura: Hylidae	eastern dwarf tree frog
Locusta migratoria manilensis (Meyen)	Orthoptera: Acrididae	migratory locust
Lophothetes hirsuta Zimmerman	Coleoptera: Curcullionidae	short-nosed weevil
Lophothetes inusitata Zimmerman	Coleoptera: Curcullionidae	short-nosed weevil

(Appendix C continued...)

SCIENTIFIC NAME	CLASSIFICATION	COMMON NAME
Lophothetes sp.	Coleoptera: Curcullionidae	short-nosed weevil
Lophothetes sp.	Coleoptera: Curcullionidae	short-nosed weevil
Lophothetes sp.	Coleoptera: Curcullionidae	short-nosed weevil
Lophothetes vulgaris Zimmerman	Coleoptera: Curcullionidae	short-nosed weevil
Maconellicoccus hirsutus (Green)	Homoptera: Pseudococcidae	Egyptian hibiscus mealybug
Mansonia uniformis (Theobald)	Diptera: Culicidae	mosquito
Marasmia trapezalis (Guenee)	Lepidoptera: Pyralidae	Maize leafroller
Marasmia venilialis (Walker)	Lepidoptera: Pyralidae	grass leaf-folder
Maruca testulalis (Geyer)	Lepidoptera: Pyralidae	bean pod borer
Melanaspis bromeliae (Leonardi)	Homoptera: Diaspididae	brown pineapple scale
Melanitis leda (L.)	Lepidoptera: Satyridae	evening brown butterfly
Merremia peltata L. Merrill	land plant, Convolvulaceae	vine
Mesohomotoma hibisci (Froggatt)	Homoptera: Psyllidae	hibiscus psyllid
Metaleurodes cardini Back	Hemiptera: Aleyrodidae	cardin whitefly
Metapone floricola Jerdon	Hymenoptera: Formicidae	bicolored trailing ant
Metriona circumdata (Herbst)	Coleoptera: Chrysomelidae	green tortoise beetle
Mikania scandens (L.) Willd.	land plant, Asteraceae	mile-a-minute vine
Mimosa (invisa) diplotricha C. Wright ex Sauvalle	land plant, Mimosaceae	creeping sensitive plant
Miscanthus floridulus (Labill.) Warburg	land plant, Poaceae	sword grass
Momordica charantia L.	land plant, Cucurbitaceae	wild bitter melon
Monomorium australicum	Hymenoptera: Formicidae	ant
Monomorium monomorium	Hymenoptera: Formicidae	ant
Monomorium pharaonis	Hymenoptera: Formicidae	pharaoh ant
Myndus bifurcatus Metcalf	Homoptera: Cixiidae	planthopper
Myndus dibaphus Fennah	Homoptera: Cixiidae	planthopper
Myndus irreptor Fennah	Homoptera: Cixiidae	planthopper
Myndus palawanensis Muir	Homoptera: Cixiidae	planthopper
Mythimna loreyi (Duponchel)	Lepidoptera: Noctuidae	rice armyworm
Nasutitermes luzonicus Oshima	Isoptera: Termitidae	Luzon point headed termite
Neomaskellia bergii (Signoret)	Homoptera: Aleyrodidae	sugarcane whitefly
Neotermes connexus Snyder	Isoptera: Kalotermitidae	forest tree termite
Nephotettix apicalis (Motschulsky)	Homoptera: Cicadellidae	green rice leafhopper
Nesophrosyne argentatus (Evans)	Homoptera: Cicadellidae	leafhopper
Nezara viridula (L.)	Hemiptera: Pentatomidae	southern green stink bug
Nipaecoccus nipae (Maskell)	Hemiptera: Pseudococcidae	coconut mealybug
Nymphula fluctuosalis Zeller	Lepidoptera: Pyralidae	rice caseworm
Nysius pulchellus (Stal)	Hemiptera: Lygaeidae	lygeid bug
Odontomachus splendidulus	Hymenoptera: Formicidae	trap-jaw ant
Ophiomyia phaseoli (Tryon)	Diptera: Agromyzidae	bean fly
Orthotylellus pallescens Usinger	Homoptera: Miridae	mirid
Oryctes rhinoceros (L.)	Coleoptera: Scarabaeidae	coconut rhinoceros beetle
Ostrinia furnacalis (Guenee)	Lepidoptera: Pyralidae	Asian corn borer
Oxycarenus bicolor Fieber	Hemiptera: Lygaeidae	stainer bug
Pagria signata (Motschulsky)	Coleoptera: Chrysomelidae	leaf beetle
Panicum maximum Jacquin	land plant, Poaceae	Guinea grass

(Appendix C continued...)

SCIENTIFIC NAME	CLASSIFICATION	COMMON NAME
Papilio polytes L.	Lepidoptera: Papilionidae	black citrus swallowtail
Paracoccus marginatus Williams	Homoptera: Pseudococcidae	papaya mealybug
Parasaissetia nigra (Nietner)	Homoptera: Coccidae	nigra scale
Paratrechina broubonica	Hymenoptera: Formicidae	ant
Paratrechina longicornis	Hymenoptera: Formicidae	longhorn crazy ant
Paratrechina minutula	Hymenoptera: Formicidae	ant
Paratrechina vaga	Hymenoptera: Formicidae	forest parrot ant
Parlatoria cinerea Hadden	Homoptera: Diaspididae	tropical grey chaff scale
Parlatoria proteus (Curtis)	Homoptera: Diaspididae	proteus scale
Passiflora foetida L.	land plant, Passifloraceae	wild passion fruit
Penicillaria jocosatrix Guenee	Lepidoptera: Noctuidae	mango shoot caterpillar
Pennisetum polystachyon (L.) Schultes	land plant, Poaceae	mission grass
Pentalonia caladii Van der Goot	Hemiptera: Aphididae	caladium aphid
Pentalonia nigronervosa Coquerel	Homoptera: Aphididae	banana aphid
Peregrinus maidis (Ashmead)	Homoptera: Delphacidae	corn planthopper
Pericyma cruegeri (Butler)	Lepidoptera: Noctuidae	poinciana looper
Perkinsiella thompsoni Muir	Homoptera: Delphacidae	sugarcane leafhopper
Phaneroptera furcifera Stal	Orthoptera: Tettigoniidae	Philippine katydid
Pheidole fervens	Hymenoptera: Formicidae	big headed ant
Pheidole megacephala	Hymenoptera: Formicidae	bigheaded ant
Pheidole megacephala	Hymenoptera: Formicidae	big headed ant
Pheidole nindi	Hymenoptera: Formicidae	big headed ant
Pheidole oceanica	Hymenoptera: Formicidae	big headed ant
Pheidole recondita	Hymenoptera: Formicidae	big headed ant
Pheidole umbonata	Hymenoptera: Formicidae	big headed ant
Phenacaspis inday (Banks)	Homoptera: Diaspididae	inday scale
Phenacoccus madeirensis Green	Homoptera: Pseudococcidae	mealybug
Phyllocnistis citrella Stainton	Lepidoptera: Phyllocnistidae	citrus leaf miner
Phyllophaga bipunctata (Brenske)	Coleoptera: Scarabaeidae	Mindanao June beetle
Physomerus grossipes (F.)	Hemiptera: Coreidae	large spined-footed bug
Phytorus lineolatus Weise	Coleoptera: Chrysomelidae	phytorus leaf beetle
Piezodorus hybneri (Gmelin)	Hemiptera: Pentatomidae	shield bug
Pinnaspis buxi (Bouche)	Homoptera: Diaspididae	ti scale
Pinnaspis sp.	Homoptera: Diaspididae	white scale
Pinnaspis strachani (Cooley)	Homoptera: Diaspididae	lesser snow scale
Pistia stratiotes L.	aquatic plant, Araceae	water lettuce
Planococcus citri (Risso)	Homoptera: Pseudococcidae	citrus mealybug
Planococcus lilacinus (Cockerell)	Homoptera: Pseudococcidae	lilac mealybug
Planococcus pacificus Cox	Homoptera: Pseudococcidae	mealybug
Plutella xylostella (L.)	Lepidoptera: Plutellidae	diamondback moth
Polypedates megacephalus Hallowell	Anura: Rhacophoridae	spot-legged tree frog
Polyphagotarsonemus latus (Banks)	Acari: Tarsonemidae	broad mite
Polyrhachis dives	Hymenoptera: Formicidae	ant
Polytus mellerborgi (Boheman)	Coleoptera: Curculionidae	banana corm weevil
Pomacea canaliculata	aquatic invertebrate	golden apple snail
Prays endocarpa Meyrick	Lepidoptera: Yponomeutidae	citrus rind borer

(Appendix C continued...)

SCIENTIFIC NAME	CLASSIFICATION	COMMON NAME
Proboscidocoris malayus Reuter	Homoptera: Miridae	mirid bug
Protaetia fusca (Herbst)	Coleoptera: Scarabaeidae	mango flower beetle
Protaetia orientalis (Gory & Percheron	Coleoptera: Scarabaeidae	oriental flower beetle
Protalebrella braziliensis (Baker)	Homoptera: Cicadellidae	leafhopper
Proutista moesta (Westwood)	Homoptera: Derbidae	erect-winged blue planthopper
Pseudaonidia duplex (Cockerell)	Hemiptera: Diaspididae	camphor scale
Pseudaulacaspis cockerelli (Cooley)	Hemiptera: Diaspididae	false oleander scale
Pseudaulacaspis pentagona (Targiona)	Homoptera: Diaspididae	white peach scale
Pseudococcus microadonidum Beardsle	Homoptera: Pseudococcidae	mealybug
Pseudoloxops bifasciatus (Usinger)	Hemiptera: Miridae	mirid bug
Pseudonapomyza spicata (Malloch)	Diptera: Agromyzidae	maize leafminer
Pulvinaria urbicola Cockerell	Hemiptera: Coccidae	soft scale
Rattus norvegicus	mammal	Norway rat
Rattus rattus	mammal	ship rat
Rhabdoscelus obscurus (Boisduval)	Coleoptera: Curculionidae	new guinea sugarcane weevil
Rhinella marina L.	Anura: Bufonidae	cane toad
Rhipicephalus microplus (Canestrini)	Ixodida: Ixodidae	cattle tick
Rhipicephalus sanguineus (Latreille)	Ixodida: Ixodidae	brown dog tick
Rhopalosiphum maidis (Fitch)	Homoptera: Aphididae	corn leaf aphid
Rhopalosiphum rufiabdominale (Sasaki)	Hemiptera: Aphididae	rice root aphid
Rhytidoporus indentatus Uhler	Hemiptera: Cydnidae	burrower bug
Saccharicoccus sacchari (Cockerell)	Homoptera: Pseudococcidae	pink sugarcane mealybug
Saissetia coffeae (Walker)	Homoptera: Coccidae	hemispherical scale
Saissetia miranda (Cockerell & Parrott)	Homoptera: Coccidae	mexican black scale
Saissetia neglecta DeLotto	Homoptera: Coccidae	carribean black scale
Saissetia nigra (Nietner)	Homoptera: Coccidae	nigra scale
Saissetia oleae (Bernard)	Homoptera: Coccidae	black scale
Schedorhinotermes longirostris (Brauer)	Isoptera: Rhinotermitidae	termite
Selenothrips rubrocinctus (Giard)	Thysanoptera: Thripidae	redbanded thrips
Sitophilus oryzae (L.)	Coleoptera: Curculionidae	rice weevil
Sogatella furcifera (Horvath)	Homoptera: Delphacidae	grass planthopper
Solenopsis geminata	Hymenoptera: Formicidae	tropical fire ant
Spathodea campanulata P. de Beauvois	land plant, Bignoniaceae	African tulip tree
Sphenarches caffer Zeller	Lepidoptera: Pterophoridae	plume moth
Spodoptera litura (F.)	Lepidoptera: Noctuidae	rice cutworm
Spodoptera mauritia Guenee	Lepidoptera: Noctuidae	lawn armyworm
Steatococcus samaraius Morrison	Homoptera: Margarodidae	steatococcus scale
Stenocatantops splendens (Thunberg)	Orthoptera: Acrididae	white-banded grasshopper
Sternochetus mangiferae (F.)	Coleoptera: Curculionidae	mango seed weevil
Sundapteryx biguttula (Ishida)	Homoptera: Cicadellidae	indian cotton jassid
Susumia exigua (Butler)	Lepidoptera: Pyralidae	rice leafroller
Swezeyaria viridana Metcalf	Homoptera: Tropiduchidae	planthopper
Swezeyia zephyrus Fennah	Homoptera: Derbidae	derbid hopper
Tapinoma melanocephalum	Hymenoptera: Formicidae	ghost ant/odorous ant
Tapinoma minutum	Hymenoptera: Formicidae	odorous ant
Tarophagus proserpina (Kirkaldy)	Homoptera: Delphacidae	taro leafhopper

(Appendix C continued...)

SCIENTIFIC NAME	CLASSIFICATION	COMMON NAME
Technomyrmex albipes	Hymenoptera: Formicidae	white-footed ant
Technomyrmex kraepelini	Hymenoptera: Formicidae	white-footed ant
Teleogryllus oceanicus (Le Guill.)	Orthoptera: Gryllidae	oceanic field cricket
Tetraleurodes acaciae	Homoptera: Aleyrodidae	whitefly
Tetraleurodes acaciae (Quaintance)	Hemiptera: Aleyrodidae	acacia whitefly
Tetramorium bicarinatum	Hymenoptera: Formicidae	pennant ant
Tetramorium insolens	Hymenoptera: Formicidae	ant
Tetramorium lanuginosum	Hymenoptera: Formicidae	ant
Tetramorium minutum	Hymenoptera: Formicidae	ant
Tetramorium simillimum	Hymenoptera: Formicidae	ant
Tetramorium smithi	Hymenoptera: Formicidae	ant
Tetramorium tonganum	Hymenoptera: Formicidae	ant
Tetraneura akinire Sasaki	Hemiptera: Aphididae	aphid
Tetranychus cinnabarinus (Boisduval)	Acari: Tetranychidae	carmine spider mite
Tetranychus neocaledonicus Andre	Acari: Tetranychidae	vegetable mite
Tetranychus sp.	Acari: Tetranychidae	spider mite
Tetranychus truncatus Ehara	Acari: Tetranychidae	spider mite
Tetranychus tumidus	Acari: Tetranychidae	spider mite
Theretra pinastrina (Martyn)	Lepidoptera: Sphingidae	narrow-winged sphinx moth
Thrips palmi Karny	Thysanoptera: Thripidae	melon thrips
Thrips tabaci Lindeman	Thysanoptera: Thripidae	onion thrips
Tiracola plagiata	Lepidoptera: Noctuidae	cacao armyworm
Toxoptera aurantii (Boyer de Fonscolombe)	Homoptera: Aphididae	black citrus aphid
Toxoptera citricida (Kirkaldy)	Homoptera: Aphididae	brown citrus aphid
Trichomyrmex destructor Jerdon	Hymenoptera: Formicidae	destructive trailing ant/ Singapore ant
Trigonops hirsuta Zimmerman	Coleoptera: Curculionidae	weevil
Trigonops inusitata Zimmerman	Coleoptera: Curculionidae	weevil
Trigonops sp.	Coleoptera: Curculionidae	weevil
Trigonops vulgaris Zimmerman	Coleoptera: Curculionidae	weevil
Trissodoris guamensis Busck	Lepidoptera: Cosmopterigidae	moth
Trochorhopalus strangulatus (Gyllenhal)	Coleoptera: Curculionidae	strangulate weevil
Ugyops annulipes (Stal)	Homoptera: Delphacidae	delphacid planthopper
Valanga excavata Stal	Orthoptera: Acrididae	large short-horn grasshopper
Varroa destructor Anderson & Trueman	Acari: Parasitiformes: Varroidae	varroa mite
Vespa tropica L.	Hymenoptera: Vespidae	greater banded hornet
Wasmannia auropunctata (Roger)	Hymenoptera: Formicidae	little fire ant/electric ant
Xyleborus ferrugineus (F.)	Coleoptera: Curculionidae	black twig borer
Xyleborus morigerus Blandford	Coleoptera: Curculionidae	black twig borer
Xyleborus perforans (Wollaston)	Coleoptera: Curculionidae	coconut shot-hole borer
Xyleborus similis Ferrari	Coleoptera: Curculionidae	shot-hole borer
Xylosandrus compactus (Eichhoff)	Coleoptera: Curculionidae	black twig borer
Xylosandrus crassiusculus	Coleoptera: Curculionidae	borer
Zanchius fragilis Usinger	Hemiptera: Miridae	mirid bug

APPENDIX D ______________________________

BTS Technical Working Group Draft Strategic Plan

See the following 85 page plan.

Brown Treesnake Strategic Plan

Brown Treesnake Technical Working Group

Final Draft

BTS TWG Goals

EXECUTIVE SUMMARY

Shortly after World War II, what was most likely a single pregnant female brown treesnake (BTS) was inadvertently transported from Manus Island, Papua New Guinea to Guam in military cargo. Working collaboratively, managers and scientists have succeeded in preventing the BTS from establishing in areas outside of Guam. On Guam, the snake spread across the island causing widespread impacts at multiple levels. Ecologically, the BTS caused the extinction or extirpation of many native and endemic species of birds and lizards. The loss of these animals has caused, and continues to cause, cascading ecological effects on the island's native plants and animals. For example, the loss of pollinating bird and fruit bat species is negatively affecting forest regeneration and future forest structure on Guam.

The BTS also has socioeconomic and human health effects. Power outages caused by the BTS are common, some lasting up to 12 hours and can number almost 200 per year. The annual cost of these snake-related outages has been estimated at $4.5M. Bites from the venomous BTS are rarely fatal, but typically cause pain and distress, especially to children, sending many to the hospital.

The discovery in the mid-80s that the BTS was responsible for the devastation of Guam's avifauna and frequent power outages prompted management responses from a range of federal, state, and territorial agencies. Several pieces of federal legislation and interagency agreements have been instrumental in providing a regulatory framework in which the BTS is managed. This framework includes the Endangered Species Act of 1973, the Memorandum of Agreement on Control of the Brown Tree Snake in 1993, and the Executive Order 13112, Invasive Species in 1999. The U.S. Congress formally recognized the threat the BTS posed to the country as part of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 and later passed the Brown Tree Snake Control and Eradication Act of 2004. The aforementioned legislation established the Brown Treesnake Technical Working Group (BTS TWG) to ensure that "efforts concerning the brown treesnake are coordinated, effective, complementary, and cost-effective." The BTS TWG has three overarching long-term goals:

1. Preventing the escape of the BTS from Guam to other locations;
2. Suppressing and controlling BTS numbers to reduce their impact on the island of Guam and to restore the island's ecosystem;
3. Eradicating the BTS from Guam.

To achieve the long-term goals outlined above, it is necessary to pursue several objectives that can be achieved on a shorter (5-year) time scale:

- Interdiction
    - Prevent the escape of the BTS from Guam – The BTS TWG has a "zero tolerance" policy for snakes dispersing off and establishing outside of Guam. A 100-percent inspection rate is the objective. Working collaboratively, managers, and scientists have succeeded in preventing the BTS from establishing in areas outside of Guam.
    - Develop and implement a system of quality assessment (QA) for interdiction-related programs – Performance varies considerably across BTS programs, ranging from very

BTS TWG Goals

high operational standards to marginal. A QA system would provide a needed set of standards to evaluate program performance and mechanisms to achieve improvement when a program is performing sub-optimally.

- Suppress BTS populations at a landscape level (a minimum of 2,500 acres) and eradicate at a minimum of a 250 acre scale – To initiate the process of restoring native species on Guam, BTS (and other predators) must be eradicated or severely suppressed at biologically meaningful scales.
- Restore native species on Guam – Returning native species to Guam that have been extirpated by the BTS is a long-standing goal of the BTS TWG. Flightless native species, such as Guam rails or some lizard species, will be the probable first choices for restoration on Guam.
- Ensure BTS activities do not reduce military readiness or impede the commercial transportation sector – Interdiction activities have the potential to impact military readiness or commercial transportation activities; however, it is the goal of the BTS TWG to conduct interdiction efforts as efficiently as possible to minimize the impact of interdiction efforts on military and civilian activities.

Interdiction on Guam, and in the Commonwealth of the Northern Mariana Islands and Hawaii, is the principal means of realizing the primary goal of preventing the spread of the BTS from Guam to other locations. Rapid Response Teams (RRT), administered by U.S. Geological Survey, are deployed as a backup when a BTS is reported outside of Guam. Research on BTS biology and control techniques supports interdiction efforts. Outreach plays a critical role in preventing the dispersal of the BTS from Guam as well, educating the general public and personnel dealing with cargo and conveyances outbound from Guam (i.e., “high-risk cargo”). Achieving the BTS TWG’s second goal of protecting Guam’s human interests and aiding in the restoration of its endangered wildlife is achieved by strategically suppressing local snake populations, in combination with captive rearing and the eventual release of native birds. The third goal of the BTS TWG, eradication of the BTS from Guam is currently beyond reach, but it has the potential to be realized.

For almost 30 years, BTS management, research, and coordination efforts have been tested and refined. Methods to achieve landscape-scale suppression of BTS populations show great promise and interdiction procedures have progressed to the point where United States Department of Agriculture - Animal Plant Health Inspection Service - Wildlife Services inspection rates of cargo and flights departing Guam are almost 100%. It has been two decades since a live BTS has been detected in Hawaii and prior to a capture of a BTS at the sea port on Rota in 2014, it had been five years since one was reported in the CNMI. Despite the major advances in the ability to manage the BTS, there exist a range of needs and issues that must be addressed to achieve programmatic efficacy.

Current snake management strategies have been successful in decreasing, but not eliminating, the probability of snakes becoming established on other islands and positioning managers for restoration of native species. To increase the efficacy of these programs, broaden the scope of control efforts, and develop new tools, additional work is required to understand the effect of control and interdiction strategies on snake populations, snake behavior, and ecosystems. Overall, more research needs to be performed to understand and predict the response of BTS populations to control strategies and tools.

To more effectively and efficiently build on the research successes of the past, the BTS TWG chartered the BTS Research Committee (BTS RC) in 2012. The primary goal of the BTS RC is to develop strategic long-term plans and short-term priorities for advancing research on the BTS, focusing on developing the biological knowledge and technical ability required to meet the management goals of the BTS TWG. Membership on the BTS RC is drawn from the BTS TWG, as well as subject matter experts from academic institutions and the scientific community. Despite the varied missions and priorities of the involved organizations, it rapidly became apparent to all BTS RC members that although BTS research has been remarkably successful, a critical historical weakness remains in place: the lack of predictable base funding for the primary agencies responsible for BTS research. Conducting BTS research and methods development with funds solely from intermittent grants and contracts impacts programs and efficiency in several ways:

1. Staffing continuity – Research and methods development projects based on annual funding often results in a cyclic process of hiring personnel for a single project, investing in training and orienting the employee, then releasing the employee at the end of the contract. This process limits the ability to develop program capacity, is inefficient, and costly. Additionally, intermittent funding for BTS projects implies a degree of uncertainty, which can hinder the ability to leverage resources (e.g., staffing) from cooperating agencies.
2. Sub-contracting costs – Sub-contracting some aspects of projects can be useful; however, the inability to hire permanent or semi-permanent staff often results in an over-reliance on sub-contractors. This has a tendency to increase project costs since each entity charges overhead and has additional start-up costs.
3. Strategically limited projects – Many of the problems inherent to the pursuit of eradication of the BTS from Guam require multi-phase projects that are based on incremental advancements that are directed by results from the preceding stages. Funding cycles and internal administrative policies limit researcher's ability to plan and propose planning and proposing multi-year projects. The uncertainty of receiving funds from year-to-year constraints researchers into conceptualizing and designing projects that can be accomplished in a single funding cycle.

Reaching the current stage of interdiction, research, and restoration has required $100M in total funding since 1987, with support in recent years exceeding $7M annually. Overall, DOI has provided the majority of the funding, contributing $51.5M, and was the primary department supporting the BTS TWG during the first seven years. Sustained support from DoD began in 1994, coinciding with WS's entry into the BTS TWG. Overall, DoD has provided $39.7M in funding. Moving to the next level, where the BTS can be suppressed across hundreds to thousands of acres will require continued support, but more importantly long-term stable funding is essential to conduct consistent research to develop improved BTS control tools, and to understand the response of BTS populations to suppression and the ecological

interaction of the BTS and associated species. Maintaining effective interdiction efforts and funding research at viable levels will require substantial financial support in the near term. However, the alternatives carry much greater costs. A decrease in financial support and concomitant reduction in interdiction would probably result in the BTS invading another area, most likely Saipan or Hawaii. If the BTS was to become established in Hawaii, the impact to its economy is estimated to exceed $1B annually. Simply continuing the status quo will carry costs into perpetuity, with the persistent threat of the BTS dispersing off of Guam. The only viable long-term strategy is to continue to maintain and improve interdiction, while simultaneously supporting research that will enable large-scale suppression of BTS populations, which will ultimately reduce the risk of off-island dispersal and allow for the restoration of Guam's native vertebrate species.

The intent of this Plan is: 1) to provide an overview of the history and achievements of the BTS TWG; 2) to present the current status of BTS-related activities; 3) to provide an overview of the short-term (5-year) BTS management-related research themes and directions; 4) to document areas where improvements in the BTS TWG are needed and achievable; 5) to provide an overview of past BTS funding; and 6) and to detail the current and short-term funding needs under varying funding events.

Note: The Brown Tree Snake Control and Eradication Act of 2004 was titled using "Tree Snake" as two words. This document will follow this convention when referring to the Act itself, documents referencing the Act, and when referring to entities or documents that use “Tree Snake” in the title. However, the more scientifically accepted single word "treesnake" will be used throughout the remainder of this document.

BTS TWG Goals

Title Page photo: Brown Treesnake (S. Siers, USGS)

Table of Contents

LIST OF FIGURES, TABLES & APPENDICES

LIST OF ABBREVIATIONS

AABS – Automated Aerial Broadcast System
AAFB – Andersen Air Force Base
ANSTF - Aquatic Nuisance Species Task Force
APHIS – Animal and Plant Health Inspection Service
BTS – Brown Treesnake
BTS RC – Brown Treesnake Research Committee
BTS TWG – Brown Treesnake Technical Working Group
CBO – Congressional Budget Office
CGAPS – Coordinating Group on Alien Pest Species
CNMI – Commonwealth of the Northern Mariana Islands
CNMI DFW – CNMI Division of Fish and Wildlife
CNMI DLNR – CNMI Department of Land and Natural Resources
CPA – Commonwealth Ports Authority
DNM – Dead Neonate Mouse/Mice
DoD – Department of Defense
DOI – Department of the Interior
DON – Department of the Navy
DOT – Department of Transportation
EDRR – Early Detection and Rapid Response
EPA – Environmental Protection Agency
ESA – Endangered Species Act
FAA – Federal Aviation Administration
FAS – Freely Associated States
GDAWR – Guam Division of Aquatic and Wildlife Resources
GNWR – Guam National Wildlife Refuge
GIAA – Guam International Airport Authority
GovGuam – Government of Guam
GPA – Guam Power Authority
HDLNR – Hawai'i Department of Land and Natural Resources
HDOA PQB – Hawai'i Department of Agriculture Plant Quarantine Branch
HISC – Hawaii Invasive Species Council
HMU – Habitat Management Unit
ISC – Invasive Species Committee
JRM – Joint Regions Marianas
MOA – Memorandum of Agreement
MSA – Munitions Storage Area, Andersen Air Force Base
NABTSCT – North American Brown Tree Snake Control Team
NANPCA – Non-indigenous Aquatic Nuisance Prevention and Control Act

NBG – Naval Base Guam
NISC – National Invasive Species Council
NPS – U.S. National Park Service
NWRC – National Wildlife Research Center
OIA – Office of Insular Affairs
OMB – Office of Management and Budget
PAG – Port Authority of Guam
PIFWO – Pacific Islands Fish and Wildlife Office
QA – Quality Assessment
RISC- Regional Invasive Species Council
RRT – Rapid Response Team
USACE – U.S. Army Corps of Engineers
USDOT – U.S. Department of Transportation
USDA – U.S. Department of Agriculture
USFWS – U.S. Fish and Wildlife Service
USGS – U.S. Geological Survey
WS – Wildlife Services

1.0 INTRODUCTION

1.1 BACKGROUND

As a U.S. territory, the island of Guam is of regional importance to the U.S. It serves as a critical hub for civilian transportation and the Department of Defense (DoD) movement in the Pacific region and is poised to take on an even greater role relative to the aforementioned issues in the near future. Guam's strategic location in the western Pacific has resulted in an increasing volume of military and civilian traffic from Asia and North America intersecting on this 209 square mile island. This convergence of human activities, inadequate quarantine regulations, and an insular system vulnerable to accidental introductions, has created an environment ideally suited for species to invade, establish, and subsequently be introduced into the U.S. or other countries. Over 1,000 species of introduced animals and plants are likely established on Guam, with dozens severely impacting the island's natural systems (Aubrey Moore, University of Guam, pers. comm.). Arguably, the most damaging alien invader to establish on Guam thus far is the brown treesnake (BTS; *Boiga irregularis*).

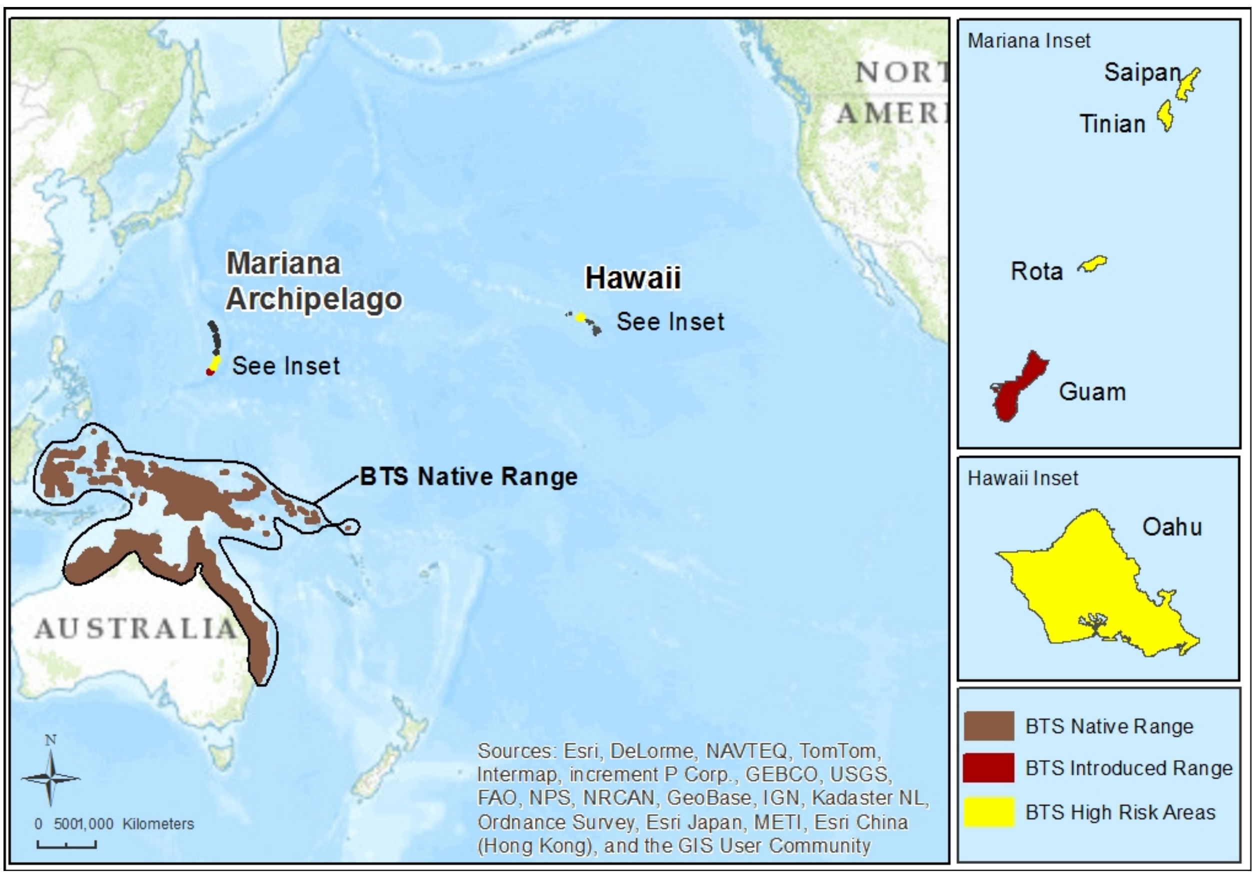


Figure 1. Distribution of brown treesnakes (BTS) in their native and introduced ranges. Areas of the Commonwealth of Northern Mariana Islands and Hawaii are at high risk of having a BTS introduced from Guam.

Shortly after World War II, what was most likely a single pregnant female BTS was inadvertently transported from Manus Island, Papua New Guinea to Guam in military cargo (**Figure 1**; Rawlings 1995, Rodda et al. 1992). Encountering few predators, competitors, or pathogens, and a super-abundance of prey, the BTS spread across the entire island in approximately 20 years. At its peak in the 1980s, the snake population was estimated at two million and in favorable habitats reached densities in excess of 100 snakes / acre (Rodda & Savidge 2007). Elsewhere, densities of large non-aggregated snakes average 5 / ha (Parker & Plummer 1987). Despite having been introduced to a single island, the BTS serves as the textbook example of the ecological havoc arising from invasive species introductions and is among the most damaging invasive species (Lowe et al. 2000). To date, the BTS is not known to have escaped from Guam to successfully invade and establish in another area. But, the above factors that allowed the BTS and other alien species to invade Guam continue to pose a threat for transporting the snake to other vulnerable islands and the U.S.

1.2 BIOLOGY & LIFE HISTORY OF THE BROWN TREESNAKE

The BTS is native to the area encompassing coastal northern and eastern Australia, the Solomon Islands, New Guinea, and Sulawesi (Fritts 1988). These snakes are generally associated with humid, forested habitats and are primarily tree dwelling, but will travel and hunt on the ground (Rodda and Savidge 2007). They have an extraordinarily slender body, giving the appearance of an outsized head. They average four ft. in length, but can grow to over 10 ft. (Rodda et al. 1999b). Though irregular in coloration, the BTS on Guam generally are a brownish olive green, with shadowlike markings (**Figure 2**).

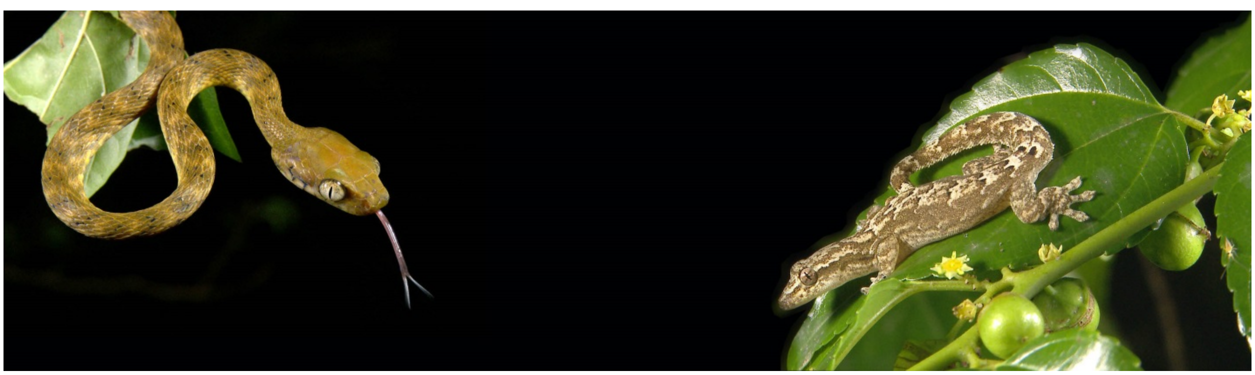


Figure 2. Brown treesnake and mourning gecko (photo B. Lardner, USGS).

They have elliptical eyes, characteristic of their nocturnal behavior. The BTS eats a wide variety of animals, including frogs, lizards, birds, and small mammals (Savidge 1988, Greene 1989, Shine 1991). Younger, smaller snakes (< 2.5 ft.) primarily prey on lizards (e.g., geckos); however, as snakes age and increase in size, prey preference shifts to birds and mammals (Savidge 1988; Lardner et al. 2009). The BTS produces venom that usually causes a mild reaction in humans, but is toxic to lizards and birds (Weinstein et al. 1991, 1993; Mackessy et al. 2006).

1.3 ECOLOGICAL, SOCIOECONOMIC, AND HUMAN HEALTH IMPACTS OF THE BROWN TREESNAKE

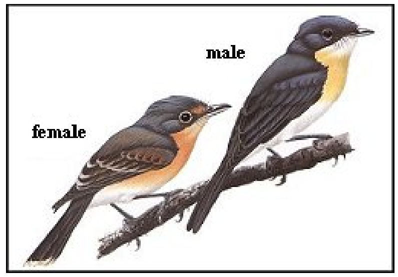
Since their establishment on Guam, the BTS has caused many problems. First and foremost, snakes have had a devastating effect on the island's terrestrial fauna (**Appendix A**). Eleven native birds were extirpated from Guam by the BTS (**Figure 3**), but survive on other islands (Wiles et al. 2003, Wiles 2005). One species, the Guam flycatcher (*Myiagra freycineti*) went extinct in 1984 (Wiles et al. 2003). The endemic Guam rail (*Gallirallus owstoni*) and Micronesian kingfisher (*Todiramphus cinnamominus*; Taylor 2012), went extinct in the wild, but captive populations were established before these birds disappeared from Guam. Translocated populations of rails now occur on the neighboring Cocos Island and Rota, the southernmost island of the Commonwealth of the Northern Mariana Islands (CNMI; DAWR 2001). The BTS has also caused the near extirpation or severe decline of another four species of birds (Wiles et al. 2003). Though less well known and less dramatic than the impact to Guam's birds, the extirpation or decline of several species of native lizards is attributable to the BTS (Rodda and Fritts 1992). Geckos, because of their nocturnal habits, have been affected the most, with one species extirpated and four severely reduced in number (Rodda and Fritts 1992). The BTS is also implicated in the loss or decline of three species of skink, but other introduced species may have played a role. Predation from the BTS is also linked to extinction of one fruit bat and the near extinction of an insectivorous bat, although other factors contributed to the declines (Wiles 1987, 2005). This loss of native vertebrates caused cascading ecological consequences for Guam's forests (Mortensen et al. 2008). The majority of the birds extirpated by the BTS were insectivorous and their absence likely contributed to an explosion of spiders and an altered invertebrate community (Rogers et al. 2012). Some of the lost birds were nectar- and fruit-eaters, as were the fruit bats. The removal of these pollinators and seed dispersers from the ecosystem will likely affect forest regeneration (Cox et al. 1991; Fujita and Tuttle 1991; Corlett 1998).

In addition to the ecological consequences, the BTS has had socioeconomic and human health impacts on Guam. The BTS will routinely climb guy-wires accessing electrical distribution and transmission lines. This can cause ground faults or short circuits resulting in power outages of varying severity and duration, including island-wide blackouts lasting up to 12 hours (Fritts 2002). From 1978 to 1997, more than 1600 snake-related outages occurred, averaging around 85 per year. In 2002, there were almost 200 BTS-caused outages and another 195 from March 2003 to March 2004 (Fritts 2002; Shwiff et al. 2010). A single island-wide outage in 1988 cost more than $3M and annually these power failures, brownouts, and power surges are estimated to cost $4.5M in lost power generating revenue, damaged equipment, and interrupted island functions (e.g., medical services, air transportation, and commerce; Fritts 2002). These figures exclude costs experienced by individuals, such as damaged appliances or the purchase of personal generators (Fritts 2002).

Although not normally life threatening to humans, a BTS bite victims frequently suffer pain, discoloration, and swelling (Fritts et al. 1994). Infants and small children may be slightly more

BTS TWG Goals

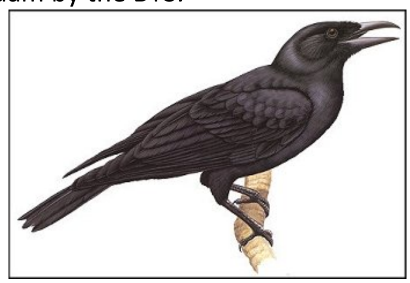
Extinct due to the BTS



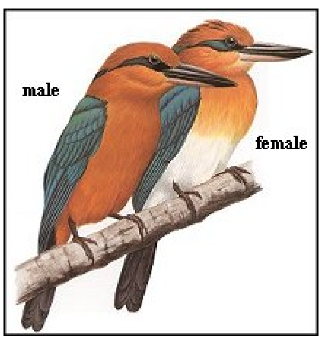
Guam flycatcher – (Pratt et al. 1987).

Some of the birds extirpated from Guam by the BTS.

Mariana fruit-dove – In the CNMI.



Mariana crow – On Rota.



Micronesian kingfisher – In captivity.

Guam rail – In captivity & translocated populations.

Threatened by BTS

Mariana swiftlet – Small populations on Guam.

Figure 3. Examples of birds of Guam that were negatively affected by brown treesnakes.

susceptible to being bitten than other age groups and because of their small body size, they generally experience greater distress from envenomation than larger bite victims (Fritts and McCoid 1999). More recent data (1998-2004) indicate that individuals of all ages are equally likely to be bitten by a BTS (Shwiff 2010).

The presence of the BTS on Guam and the zero tolerance policy of no snakes dispersing off island add a layer of complexity to civilian and military activities that involve the movement of people and cargo off island (**Figure 4**). To prevent the transport of the BTS from Guam, and repeating the devastation elsewhere, it is imperative that all vehicles, equipment, and cargo, as well as personal goods are subject to current BTS inspection and quarantine procedures, which may significantly impact civilian and military operations in cost, time, and mission accomplishment. These efforts require improved coordination between BTS TWG partners (See Section 2.2).

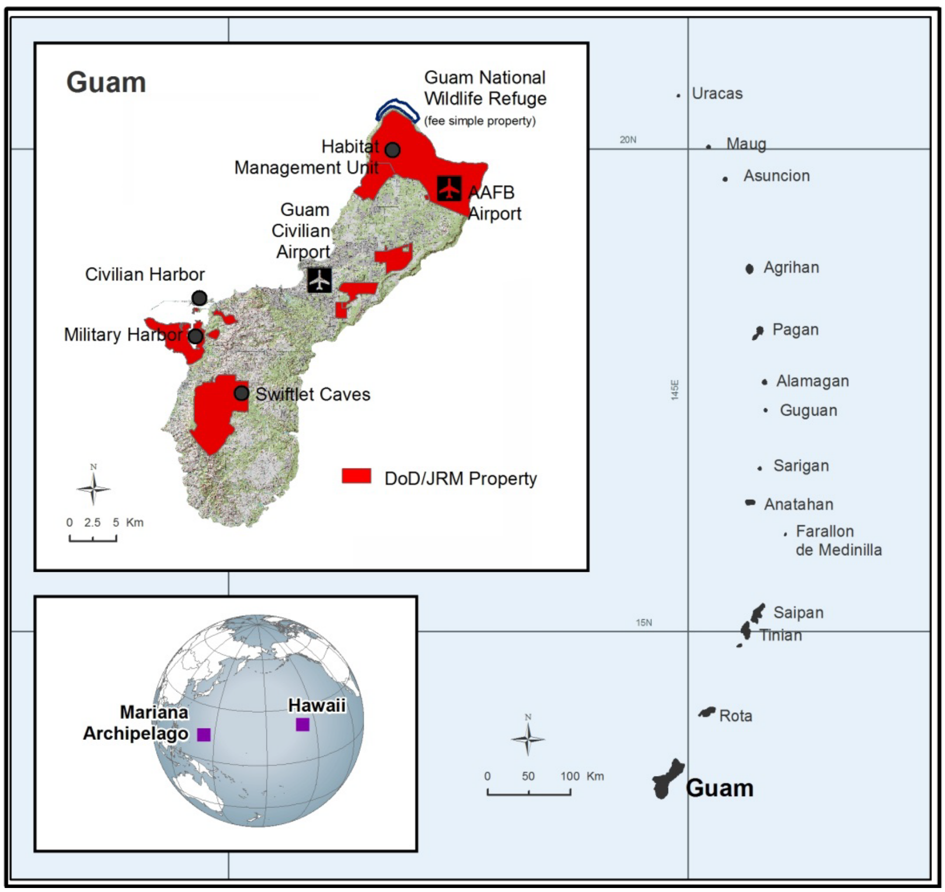


Figure 4. A map of the territory of Guam showing military and civilian air and seaports. Locations of brown treesnake-related management activities are also shown.

1.4 POTENTIAL CONSEQUENCES OF FAILED INTERDICTION

The threat of transporting a BTS to one of the many destinations en route from Guam is a serious concern. As noted above, a single pregnant snake is sufficient to start a population and the BTS is known

to have survived in cargo being shipped from Guam to the continental U.S. for seven months. From Guam, the BTS has been transported alive across the globe to Spain, Alaska, Texas, Oklahoma, and Diego Garcia in the Indian Ocean (Stanford and Rodda 2007). Between 1978 and 2009, approximately 120 snakes have been reported outside of Guam. The majority of those sightings were in the CNMI (93) and on Oahu (10). It should be noted that the credibility of many of these sightings is in doubt. Fortunately, improved interdiction efforts have reduced the risk of snakes hitchhiking to the CNMI and Hawaii from Guam. However, DoD growth in the Marianas (e.g., the proposed relocation of U.S. Marine Corps personnel and assets from Okinawa to Guam) may increase activity at Guam's air and seaports in the near future. Both military and civilian cargo and conveyances are expected to increase in volume and frequency.

From an ecological perspective, the CNMI, Hawaii, and other Pacific islands are extremely vulnerable to invasion by the BTS. The factors that permitted the BTS to invade and overrun Guam exist on the larger islands in the CNMI (**Figure 5**; Perry and Vice 2009). Saipan, for example has diverse and highly abundant prey, such as rodents, lizards, and birds, and a climate similar to Guam. If the BTS became established on Saipan, the island's 11 native forest birds would likely suffer the same fate as those on Guam.

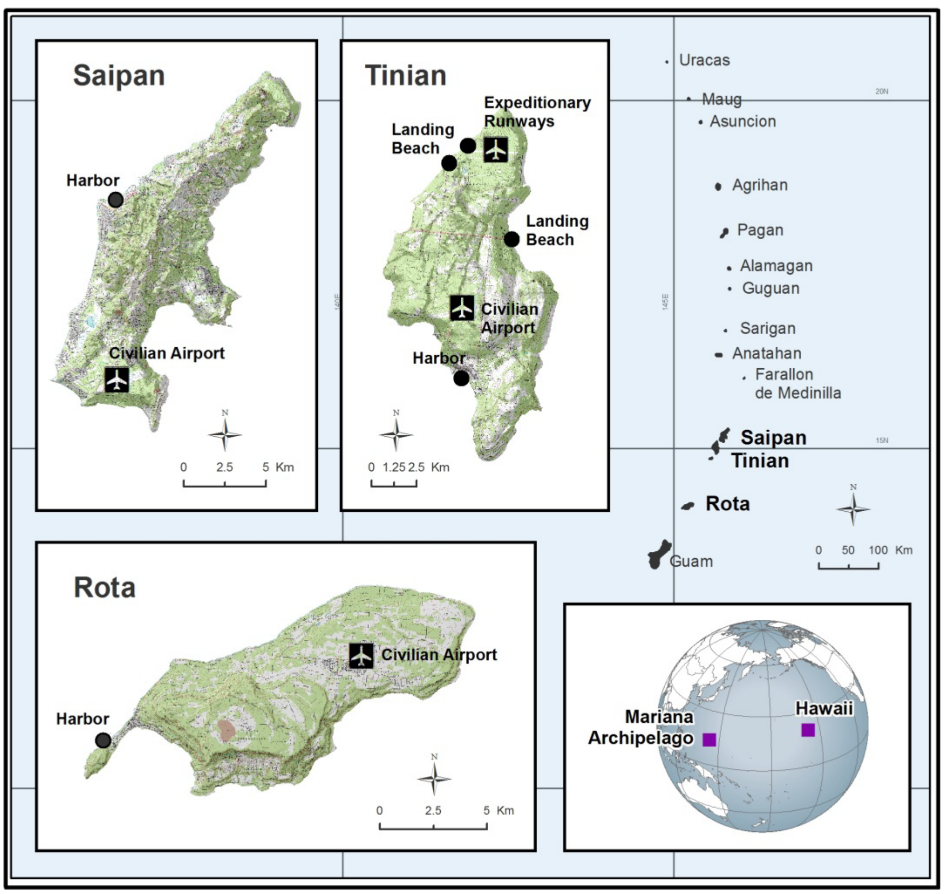


Figure 5. The Commonwealth of the Northern Mariana Islands, with the three main islands and their respective air and seaports (insets).

Hawaii and the Marianas differ in many perspectives, yet the Hawaiian archipelago possesses environmental factors (e.g., abundant native and introduced vertebrate prey and equable climate) similar to the Marianas making it equally susceptible to the impacts from an invasion of the BTS. Oahu is the Hawaiian island most at risk of invasion of the BTS from Guam (**Figure 6**). If established on Oahu, the BTS would endanger many of the archipelago's 65 native species of birds. This would likely trigger monumental conservation efforts and carry with it monetary costs to prevent the extinction of these birds threatened by the BTS. Conservation measures could include the establishment of captive rearing facilities for a wide range of endemic birds and implementation of landscape scale snake suppression. For perspective, captive-rearing of four Hawaiian birds by federal and state agencies averages about $1.1M per year (Jay Nelson, USFWS – PIFWO pers. comm.).

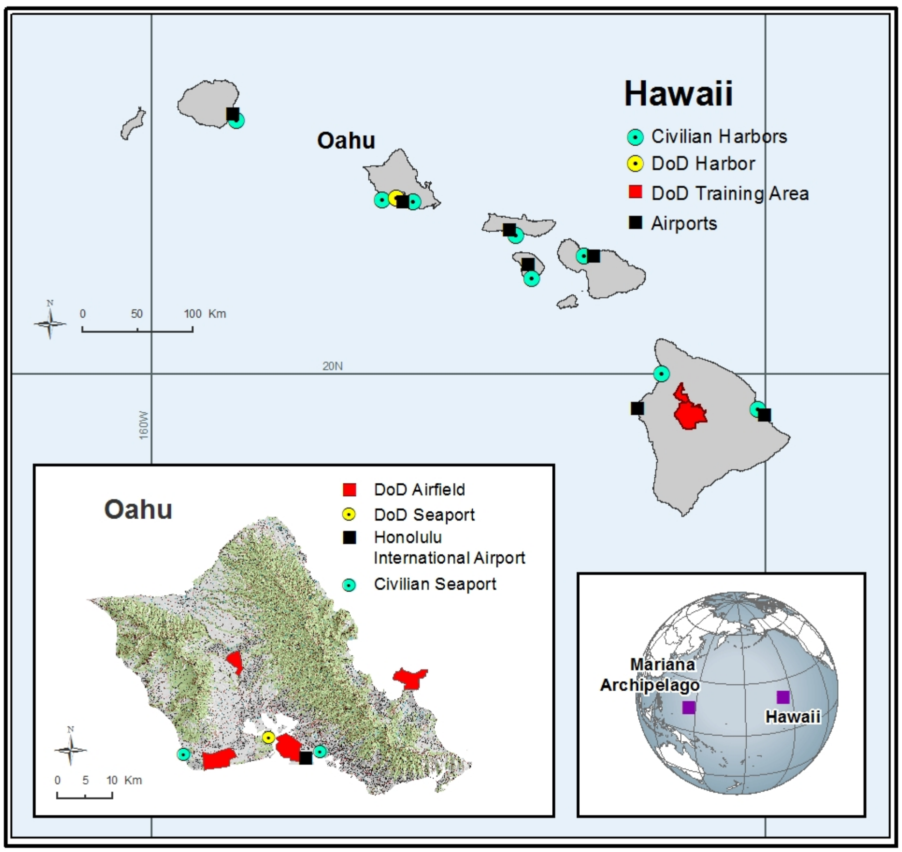


Figure 6. The main Hawaiian Islands showing air and seaports. The majority of the traffic originating in Guam arrives on Oahu (inset).

The presence of the BTS on Oahu would further compound interdiction efforts. Instead of having a single island in the Pacific (Guam), which requires an average of $4.79M annually (2009 – 2012) for BTS interdiction, there would be multiple foci. Moreover, Oahu as the transportation hub in the Pacific would require an order of magnitude greater expenditure of money and effort in an attempt to contain the BTS. If the BTS establish on Oahu, its population is estimated to reach 7.5 million snakes on the island (Burnett et al. 2008). The associated economic losses from power outages and medical costs from snake bites could reach $761M annually (Shwiff et al. 2010). Tourism could be impacted as well. If the BTS invade all of Hawaii, estimated annual costs from lost visitor days, ranged from $138M to almost $1.4B. Focus has been on islands in the Pacific Region, however, it is worth noting that areas of the continental U.S. are also at risk of a BTS invasion. Climate matching models indicate that many areas in the Southern U.S. may be suitable for the BTS (**Figure 7**; Rodda et al. 2007a). South Florida exemplifies this, with almost fifty-three species of alien reptiles (Krysko et al. 2011), which along with Hawaii and the Mariana Archipelago are among the world's leading sites for the number of alien reptile species (Kraus 2009). An amenable climate is one factor facilitating the invasion of alien reptiles, abundant native and non-native prey is another. Burmese pythons (*Python molurus*) provide a cautionary parallel to Guam's situation, having rapidly expanded across the Everglades, they are causing the decline of native species (Reed and Rodda 2009, Krysko et al. 2011, Dorcas et al. 2012).

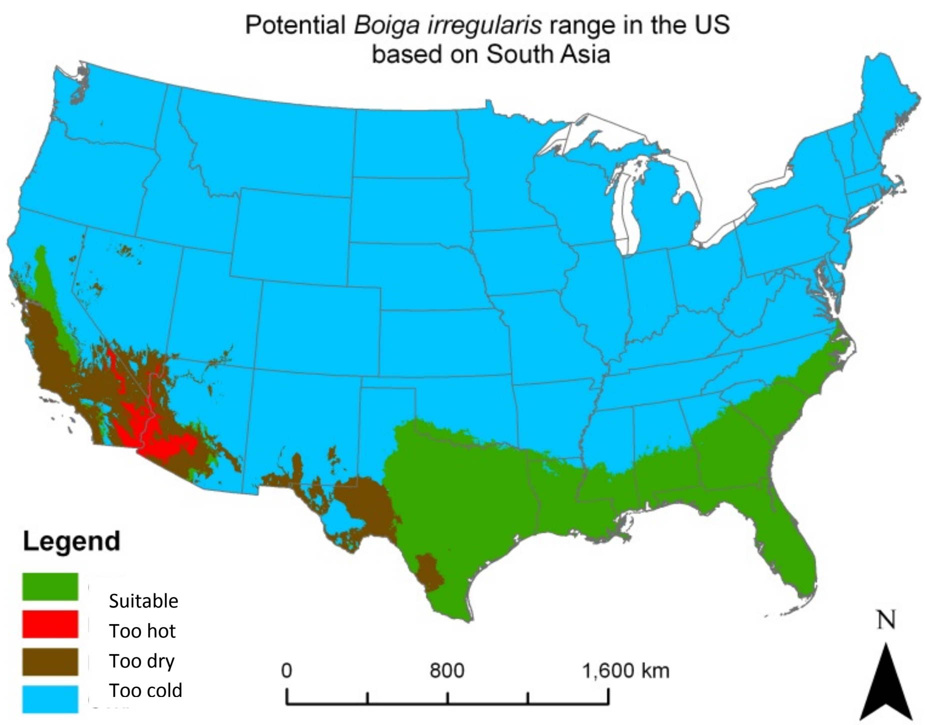


Figure 7. Potential brown treesnake range in the continental U.S. as delimited by climate envelope (from Rodda et al. 2007), based on best available information.

Diligence and determination on the part of BTS TWG partners has been instrumental in preventing the BTS from invading another area. Good fortune has contributed as well: the BTS has failed to establish a population on the occasions when they have escaped Guam. Ultimately, safeguarding the flora and fauna, and the human inhabitants of the CNMI, Hawaii, and elsewhere from the impacts of the BTS will require dedicated long-term funding and regulatory authority mandating inspections of all cargo and conveyances departing Guam to prevent their dispersal off Guam. The alternative is the eventual arrival of a pregnant or inseminated BTS, another Guam, and another ecological disaster.

BTS TWG Goals

2.0 BROWN TREESNAKE TECHNICAL WORKING GROUP

2.1 BACKGROUND

The Brown Treesnake (BTS) Technical Working Group (formerly the Brown Tree Snake Control Committee) was established in 1993 by the Aquatic Nuisance Species Task Force under the authority of section 1209 of the 1990 Nonindigenous Aquatic Nuisance Prevention and Control Act and the 1993 Memorandum of Agreement for Control and Eradication of the Brown Tree Snake (see "Regulatory Timeline" below). As defined in the Brown Tree Snake Control and Eradication Act of 2004, the purpose of BTS Technical Working Group (hereafter BTS TWG) is to ensure that "efforts concerning the brown treesnake are coordinated, effective, complementary, and cost-effective." The BTS TWG is formally comprised of federal, state, and territorial partner agencies, with periodic informal participation by non-governmental organizations. While these entities collaborate to meet the goals of the BTS TWG, it should be recognized that the respective missions of the individual partners are diverse. Below is a list of the partners and a description of their roles in the TWG.

2.2 PARTNERS

U.S. Department of the Interior (DOI)

a) Office of Insular Affairs (OIA) – The OIA implements the Secretary of the Interior's responsibilities for U.S.-affiliated islands (e.g., Guam, CNMI). OIA's primary role in the BTS TWG is to provide technical assistance funds for interdiction, control, research, and restoration efforts with an emphasis on preventing the BTS from being introduced to other areas.
b) U.S. Fish and Wildlife Service - Pacific Islands Fish and Wildlife Office (USFWS) – USFWS provides technical assistance and coordination to the BTS TWG through support from the USFWS Ecological Services and Fisheries Programs. As mandated in the Brown Tree Snake Control and Eradication Act of 2004, it is the responsibility of the USFWS to coordinate effort among BTS TWG partners to ensure the objectives defined in the above Act of 2004 are achieved. The role was originally established in the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. Through the Service's regulatory and endangered species recovery planning roles under the Endangered Species Act, USFWS assists with interdiction and control efforts on Guam and works to prevent the spread of the BTS from Guam.
c) U.S Fish and Wildlife Service - Guam National Wildlife Refuge (GNWR) – Restoration of Guam's avifauna on GNWR lands is a priority. The Refuge has constructed a partial BTS barrier and conducts BTS control on the property. GNWR provides office and lab space for U.S. Geological Survey researchers and sites for field research. The GNWR also conducts education and outreach efforts on the BTS.
d) U.S. Geological Survey (USGS) – The USGS is the research arm of DOI and its role in BTS management includes: 1) quantifying the effects of the BTS on utilities, wildlife, human health and agriculture; 2) devising and evaluating new tools for control; 3) quantifying snake and

snake-prey populations; and 4) managing the BTS Rapid Response Team (RRT), which deploys BTS searchers in response to snake sightings outside of Guam.

e) National Invasive Species Council (NISC) – NISC is an inter-Departmental (federal) council. Its staff participates in BTS efforts, such as preparation of reports to OMB (Office of Management and Budget) and Congress, and the reauthorization of the BTS MOA (Memorandum of Agreement).

f) National Park Service (NPS) - NPS supports training of RRT searchers and surveys, and provides venues for TWG meetings at Guam and Saipan park units.

U.S. Department of Agriculture - Animal Plant Health Inspection Service (USDA - APHIS)

a) Wildlife Services (WS) Operations - WS is responsible for interdiction on Guam. WS works with on-island partners, such as DoD, GovGuam, and private industry to reduce snake-caused damage on the island, and to remove snakes from outbound aircraft and cargo. WS is a federal agency with a legislatively mandated role related to vertebrate pest management. Much of WS efforts nationally are done on a reimbursable basis with support from other federal agencies.

b) WS National Wildlife Research Center (NWRC) – NWRC is the methods development arm of WS. NWRC focuses on the development and refinement of BTS control methods to improve interdiction efforts and reduce the effects of the BTS on Guam. It also evaluates the effects of snakes on natural resources, agriculture, and human health and safety.

U.S. Department of Defense (DoD)

a) Commander Navy Installations Command (CNIC) - CNIC’s primary role is to provide program guidance and funding to support the implementation of the DoD BTS program.

b) Naval Facilities Engineering Command, Headquarters (NAVFAC HQ) - NAVFAC HQ supports implementation of the DoD BTS program. NAVFAC HQ coordinates programs and requirements to support military missions for the Navy in the Pacific.

c) Joint Regions Marianas (JRM) – JRM allocates funding for BTS interdiction and control on Naval Base Guam and Andersen Air Force Base to prevent the spread of the BTS from Guam via military cargo and traffic and for BTS adaptive management and control evaluation projects. JRM provides BTS interdiction oversight during training exercises that involve movements between Guam and the Commonwealth of the Northern Mariana Islands.

    a. Andersen Air Force Base (AAFB) – In support of BTS interdiction and control on Guam, AAFB provides WS logistical assistance (e.g., canine facilities, office & shop facilities, cargo-containment areas) and assists in the dissemination of BTS information to installation personnel. As a conservation measure related to several Endangered Species Act Section 7 Biological Opinions, AAFB funds the inspection and maintenance of the largest BTS exclosure on Guam.

    b. Naval Base Guam (NBG) – In support of BTS interdiction and control on Guam, NBG provides WS logistical assistance (e.g., canine facilities, office & shop facilities, cargo containment areas) and assists in the dissemination of BTS information to installation personnel. NBG promotes endangered species recovery through the funding of BTS control for conservation purposes.

d) Naval Facilities Engineering Command, Pacific (NAVFAC Pacific) – NAVFAC Pacific supports implementation of BTS research projects for DoD customers possessing certain environmental regulatory requirements.
e) Naval Facilities Engineering Command, Marianas (NAVFAC Marianas) – NAVFAC Marianas coordinates BTS control and interdiction requirements for current and future proposed military missions with JRM, WS, and USFWS via specific environmental regulatory processes. It supports implementation of BTS research projects for DoD customers possessing certain regulatory requirements or internal instructions.
f) Armed Forces Pest Management Board (AFPMB) – The AFPMB recommends policy, provides guidance, and coordinates the exchange of information on all matters related to pest management throughout the DoD. Its mission is to ensure that environmentally sound and effective programs are present to prevent pests and disease vectors from adversely affecting DoD operations.

U.S. Department of Transportation (USDOT)

a) Federal Aviation Administration (FAA) – The FAA provides funding to support eligible construction projects on U.S.-affiliated islands and assists in the dissemination of BTS information at workshops in the Pacific region. FAA has a primary role acting as the federal agency that certifies airport safety.

U.S. Territory of Guam

a) Guam Department of Agriculture, Division of Aquatic and Wildlife Resources (GDAWR) – Through annual federal funding GDAWR controls BTS in support of wildlife recovery, conducts BTS and native species awareness campaigns to promote public support for broad-scale use of BTS control tools, and captive breeds endangered species for release in BTS-suppressed areas on Guam.
b) Port Authority of Guam (PAG) – PAG supports the interdiction and control efforts with awareness training for port employees provided by local and federal agencies in the BTS TWG.
c) Guam International Airport Authority (GIAA) – GIAA supports interdiction efforts by allowing inspection at its facilities and has implemented a reporting and awareness program with training provided by both local and federal agencies in the BTS TWG.
d) Guam Power Authority (GPA) – GPA provides funding to WS to conduct BTS control efforts at utility substations to minimize BTS-caused power outages.

Commonwealth of the Northern Mariana Islands (CNMI)

a) Department of Lands and Natural Resources (DLNR), Division of Fish and Wildlife (DFW) – With federal funding from OIA and USFWS, DFW works to prevent the introduction of BTS to the CNMI. Their activities focus on the inspection of high-risk cargo from Guam, addressing reports of snake sightings, and awareness programs.
b) Commonwealth Ports Authority (CPA) – CPA manages and operates air and seaports in the CNMI. It supports the BTS TWG by facilitating inspections at ports and providing logistical support (e.g., seaport: space for containment barrier; airport: canine facilities).

State of Hawaii

a) Hawaii Department of Agriculture (HDOA), Plant Quarantine Branch (PQB) – With federal funding from OIA and USFWS, HDOA works to prevent the introduction of BTS to Hawaii primarily through visual inspection of high-risk cargo from Guam and outreach programs.
b) Hawaii Department of Land and Natural Resources (HDLNR), Division of Forestry and Wildlife (DOFAW) – DOFAW supports BTS TWG efforts by assisting with response to sightings in Hawaii and through awareness programs.
c) Hawaii Invasive Species Council (HISC) – HISC is a cabinet level entity focusing on invasive species / biosecurity issues within the State of Hawaii. One area of focus is gaps in capacity not addressed by state agencies. The HISC supports local capacity (e.g. [Invasive Species Committees] ISCs) and interagency coordination at the state level. Its research grant program has financially supported development of BTS control methods.

Non-governmental partners

a) Coordinating Group on Alien Pest Species (CGAPS) – CGAPS is a voluntary public-private partnership. It facilitates interagency and non-governmental organization communication and cooperation, and operates primarily via public outreach and media assistance.
b) Regional Invasive Species Council (RISC) – RISC is an inter-jurisdictional regional council that has been instrumental in encouraging the Chief Executives of Micronesia to become directly involved in BTS policy issues and funding efforts.
c) Aquatic Nuisance Species Task Force (ANSTF) – ANSTF implements various pieces of invasive species legislation, which facilitate management of the BTS (e.g., the Non-Indigenous Aquatic Nuisance Prevention and Control Act [NANPCA] & the National Invasive Species Act [NISA]; see "Regulatory Timeline" below).
d) North American Brown Tree Snake Control Team (NABTSCT) – NABTSCT is a collaboration of federal and state agencies, and private organizations focused on preventing the BTS from entering the continental U.S. through rapid response capacity building, information sharing, and reporting efforts.

2.3 HISTORY & ACHIEVEMENTS

The discovery in the mid-80s that the BTS was responsible for the devastation of Guam's native birds posed a unique problem. The ecology of invasive species at this time was in its infancy and what was known about controlling and eradicating introduced vertebrates centered on mammals. Although herpetologists had studied snakes for decades, no methods existed for managing snake populations at any meaningful scale. Additionally, there was a lack of basic biological information on the BTS and this type of snake in general. Overcoming these two deficiencies was an initial step in the almost 30 years of BTS management. This large-scale conservation effort has been dedicated to understanding the life history, behavior, and ecology of the BTS, and applying this knowledge to the development of techniques to prevent the off-island transport of the snakes and to protecting the remaining native fauna on Guam. **Table 1** summarizes some of the notable achievements of the BTS TWG. It should be emphasized that accomplishments in the table are assigned to a single lead entity, but most are the result of collaboration between agencies.

Table 1. A compilation of the major programmatic accomplishments of the Brown Treesnake Technical Working Group. Appendix B provides a more comprehensive list of achievements.

Year	WS	NWRC	USGS	DoD[1]/ CNMI DFW[2]/ HDOA[3]/ GDAWR[4]
1985-1990			• BTS need visual cue to enter traps; • BTS found regularly on planes; • BTS caused loss of some lizard species; • BTS pose risk to human infants; • 1st BTS barrier testing	[4] – BTS implicated in bird extinctions; [4] – Preliminary trap development using live bait; [4] – Efforts began to protect birds nesting in trees
1991-1995	• Interdiction began on Guam at NBG & AAFB; Last live BTS on Hawaii reported; • Guam canine inspections began; • BTS control began at commercial packing & shipping companies	• Fumigant development initiated; • Methyl bromide registered as a fumigant for removing snakes from cargo or vehicles	• Standard trap baited w/ live mice developed; • ID origin of Guam BTS; • Create 1st exclosures (2.5 ac.) & BTS eradicated; • Economic impact of BTS establishment on Hawaii estimated	[2] – Interdiction began in the CNMI; [3] – Interdiction began in Hawaii; [4] – Further testing of electric snake barrier on trees successful

Year	WS	NWRC	USGS	DoD[1]/ CNMI DFW[2]/ HDOA[3]/ GDAWR[4]
1996-2000	• Current trap deployed; • Trapping BTS at Mahlac cave to protect swiflet	• Rodent response to BTS control documented on landscape-scale; • DNM bait developed; • Oral toxicant acetaminophen developed; • Bait stations developed as control method	• Permanent & temporary barrier development; • Small BTS not readily trapped; • *Problem Snake Management* volume published; • Determined diseases & parasites ineffective as BTS biocontrol	[2] – Dog inspections began in CNMI; [1,4] – 1st operational BTS barrier constructed at Area 50 on AAFB
2001-2005	• Trapping at Fachi & Maemong caves to protect swiflet; • Institute annual dog team proficiency tests; • Quantified effectiveness trap models	• Acetaminophen registered; • Aerial broadcast of DNM & toxicant tested; Inspector dogs evaluated; Development of BTS repellent & testing of trap spacing; • Repellents patented & licensed;	• Sterilized male BTS used for dog training; • RRT created; Construction of closed population research facility on AAFB	[2] – BTS containment interdiction barrier on Saipan implemented; [2] – CNMI BTS awareness program, "28SNAKE" implemented; [4] – Cocos Island restoration planning began; [4] – BTS survey on Cocos Island
2006-2010	• Oral toxicants integrated interdiction; • 99% inspection rate of military & civilian cargo/flights; • AABS trials conducted on NBG	• Streamer for aerial broadcast developed; BTS population reduced on trial plots with aerial broadcast; • Economic assessment of BTS invasion; • Automated Aerial Broadcast System (AABS) conceptualized;	• Trapping largely ineffective for BTS with a total length of <40 in.; • Small snake trap "resistance" due to dietary preferences; Detector dogs can locate BTS in forested landscapes	[2] – BTS containment interdiction barrier on Tinian implemented; [2] – 90% inspection of cargo & aircraft from Guam; [4] – 16 captive-reared rails released on Cocos Island
2011-2013	• 99.5% inspection rate of military & civilian cargo/flights	• AABS bait package & applicator designed; • AABS initial processing designs completed	• Roads determined to be partially effective barriers to BTS movement	[1] – HMU BTS exclosure at AAFB completed & operational; [4] – Rails reproduce on Cocos Island

See "List of Abbreviations" for definitions.

2. 4 REGULATORY TIMELINE

Meeting the objectives of the BTS TWG has been aided by more than 20 pieces of legislation, regulations, and agreements. Federal, state and territorial agencies are among the entities directly covered by these policy documents. The earliest originate from 1934 and directly or indirectly permit agencies to implement procedures to prevent the spread of invasive species, including the BTS. Below is a synopsis of the major directives important to the BTS TWG. The entire list is provided in **Appendix C**.

- **1973 – Endangered Species Act (ESA)**. Established to protect and recover imperiled species and the ecosystems upon which they depend. Although the ESA has no direct role in the management of the BTS, it is currently the principal regulatory mechanism preventing the introduction of the BTS outside of Guam. Because the BTS is a threat to the recovery of listed species and have the potential to create additional listed species, the ESA can be used as legal mechanism to support BTS-related interdiction or recovery efforts. Each federal agency is to ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed species and federally-funded programs at the state and local level, such as port improvements, require a Section 7 consultation process.

- **1990 – Non-Indigenous Aquatic Nuisance Prevention and Control Act (NANPCA)**. Established a broad new federal program to prevent the introduction of and to control the spread of introduced aquatic nuisance species and the brown treesnake. The Act also established the Aquatic Nuisance Species Task Force (ANSTF).

- **1992 – Amendment to Lacey Act (1900)**. Criminalized the unauthorized importation of species of wild animals, including the BTS, which the Secretary of the Interior prescribes by regulation to be injurious to human beings or to the interests of agriculture, horticulture, forestry, or wildlife, except by permit.

- **1993 – Memorandum of Agreement on Control of the Brown Tree Snake**. Established a working relationship between DOI, DoD, USDA, GovGuam, Hawaii, CNMI, DOT, and NISC. In 1996 CNMI added as a participating agency; renewed 1999 adding DOT; renewed 2011 adding National Invasive Species Council (NISC).

- **1996 – National Invasive Species Act** (NISA amended and reauthorized NANPCA). Created an interagency task force to direct cooperative efforts to control invasive species, including the BTS. NISA required the task force to develop and implement a comprehensive program to control the BTS, producing the 1996 BTS Control Plan.

- **1999 – Executive Order 13112, Invasive Species**. Directed federal agencies to prevent the introduction of invasive species and address their impacts through research, outreach, and restoration. It also directed agencies to not authorize, fund, or carry out actions that are likely to facilitate the introduction or spread of invasive species and established the NISC.

- **2004 – Brown Tree Snake Control and Eradication Act of 2004**. Expressed the sense of Congress that there is a need for better coordinated control, interdiction, research, and eradication of the BTS on the part of the U.S. The Brown Tree Snake Control and Eradication Act of 2004 directed the Secretaries of the Interior and Agriculture to provide funds (subject to availability) to support BTS control, interdiction, research, and eradication efforts carried out by DOI and USDA, other federal agencies, states, territorial governments, local governments, and private sector

entities. The Brown Tree Snake Control and Eradication Act of 2004 established the BTS Technical Working Group (BTS TWG) to ensure that agency efforts concerning the BTS are coordinated, effective, complementary, and cost-effective.

- **2009 – Duncan Hunter National Defense Authorization Act For Fiscal Year 2009 (Public Law 110-417 [Division A], title III, Section 316, October 14, 2008, 122 Statute 4356)**. Required that "The Secretary of Defense shall establish a comprehensive program to control and, to the extent practicable, eradicate the brown tree snake population from military facilities in Guam and to ensure that military activities do not contribute to the spread of brown tree snakes."

<u>2.5 GOALS & OBJECTIVES</u>

Once biologists recognized the devastating effect the BTS was having on Guam's wildlife (Savidge 1987), they began implementing measures to minimize the snake's impacts. These efforts included research to understand BTS biology and the control of snakes in specific areas to minimize the risk of off-island dispersal and to protect species threatened by the BTS. Combined, these efforts have grown to comprise the scope of the multi-entity BTS TWG. The BTS TWG has three overarching goals:

1. Preventing the escape of the BTS from Guam to other locations;
2. Suppressing and controlling BTS numbers to reduce their impact on the island of Guam and to restore the island's ecosystem;
3. Eradicating the BTS from Guam.

To achieve the long-term goals outlined above, it is necessary to pursue several objectives that can be achieved on a shorter (5-year) time scale.

General Objectives -

- <u>Interdiction</u>
  - Prevent the escape of the BTS from Guam – The BTS TWG has a "zero tolerance" policy for snakes dispersing off and establishing outside of Guam. It has been two decades since a live BTS has been detected in Hawaii. Prior to a capture of a BTS at the sea port on Rota in 2014, it had been five years since one was reported in the CNMI. This achievement is due to WS's near 100-percent inspection rate of cargo and flights departing Guam (i.e., "high-risk" cargo). A 100-percent inspection rate is the objective.
  - Develop and implement a system of quality assessment (QA) for interdiction-related programs – Performance varies considerably across BTS programs, ranging from very high operational standards to marginal. To prevent the dispersal and establishment of the BTS outside of Guam it is critical that all programs involved with interdiction are operating at an optimal level that is cost-effective. A QA system would provide a needed set of standards to evaluate program performance and mechanisms to achieve improvement when a program is performing sub-optimally.

BTS TWG Goals

- Suppress BTS populations at a landscape level (a minimum of 2,500 acre) and eradicate at a minimum of a 250 acre scale – To achieve restoration of native species on Guam, the BTS (and other predators) must be eradicated or severely suppressed at biologically meaningful scales. Current efforts using aerial baiting techniques to reduce BTS populations over large areas are showing initial success. Further development and refinement of these control tools, as well as development and assessment of new tools are required to efficaciously suppress or eradicate the BTS at large scales.
- Restore native species on Guam – Returning native species to Guam that have been extirpated by the BTS is a long-standing goal of the BTS TWG. A precursor to achieving native species restoration is developing the capacity to clear large areas of BTS of suitable habitat (see above). The fact that most of the native species under consideration for restoration can fly accentuates the need to create large areas where the BTS is eradicated or suppressed. Flightless native species, such as Guam rails or some lizard species, will be the probable first choices for restoration on Guam.
- Ensure BTS activities do not reduce military readiness or impede the commercial transportation sector – Although it is accepted that BTS inspections are necessary, it is also recognized that interdiction activities may potentially have an effect on military readiness or commercial transportation activities. Therefore, it is the goal of the BTS TWG to conduct interdiction efforts as efficiently as possible to minimize the impact of interdiction efforts on military and civilian activities.

Program-specific Objectives – Below is a list of action items that need to be addressed by the BTS TWG. These items are discussed in more detail throughout this Plan.

- WS
    - Cost projection – A USDA economist is contracted to conduct an analysis estimating costs of conducting interdiction on Guam in the future under various growth scenarios. A final report will be delivered in 2015.
    - BTS off-island pathways – As the human population and development increase on Guam, BTS off-island dispersal vectors have the potential to change. WS leadership is tasked with identifying and ensuring coverage of these new pathways.
    - Technique integration – NWRC and USGS conduct BTS management related research. It is important that techniques and tactics developed by these two agencies are integrated into interdiction and control operations.
- CNMI DFW
    - Programmatic stability – In recent years, the CNMI DFW BTS program has had challenges meeting performance measures. Efforts by the CNMI DLNR, USFWS and OIA have corrected some of the operational and administrative program deficiencies, but more work is required.

- HDOA
    - Canine inspection program – In 2009, budget cuts in Hawaii resulted in the dismantling of the canine inspection team. OIA provided funds in 2010 and 2012 to re-initiate the program; however, HDOA has not met this objective. Reinstating a functioning canine program on Hawaii is a key objective of the BTS TWG.
- NWRC
    - Landscape suppression tools – Recent trials of manually dropping toxic baits from a helicopter have shown the feasibility of this approach. However, manually broadcasting baits is prohibitively expensive. To reduce the cost of application and scale this method up, the automated aerial baiting system (AABS), which is two-thirds through development, must become operational.
- USGS Research
    - Species response to BTS suppression – Aerial baiting with toxicants will substantially decrease the number of snakes over a large area. However, the response of some age classes of snakes is uncertain, as is the rate at which surviving snakes will respond. Additionally, non-target species, such as the prey of the BTS, are expected to respond to the removal of their principal predator. Therefore, it is necessary at an early stage to study the dynamics of target and non-target species to large scale suppression.
- USGS RRT
    - Search result confidence – The task of detecting a BTS reported outside of Guam is inherently difficult (e.g., usually involves a single individual, sightings vary in credibility). Therefore, it is necessary to have a mechanism to estimate the level of confidence in the determination that the BTS is not present.
    - Searcher performance – The ability to detect the BTS in the field varies greatly between searchers, which can affect the confidence level of the determination of BTS presence or absence. Protocols for assessing this variability in searcher ability need to be developed and implemented.
- GDAWR
    - Native bird restoration activities – In areas where the BTS is absent or sufficiently low, restoration activities to restore Guam's native birds are or will be planned and implemented.

The intent of this Plan is: 1) to provide an overview of the history and achievements of the BTS TWG; 2) to present the current status of BTS-related activities; 3) to provide an overview of the short-term (5-year) BTS management-related research themes and directions; 4) to document areas where improvements in the BTS TWG are needed and achievable; 5) to provide an overview of past BTS funding; and 6) and to detail the current and short-term funding needs under varying funding events.

BTS TWG Goals

3.0 TECHNICAL WORKING GROUP STATUS

3.1 CURRENT ACTIVITIES

Interdiction on Guam, and in the CNMI and Hawaii, is the principal means of realizing the primary goal of the BTS TWG, to prevent the dispersal of snakes off Guam. A Rapid Response Team (RRT) is deployed as a backup when a BTS is reported outside of Guam. Interdiction efforts are supported by research conducted on BTS biology and control techniques. Outreach plays a critical role in preventing the dispersal of the BTS from Guam as well, educating the general public and military, government and civilian personnel dealing with cargo and conveyances outbound from Guam. Achieving the BTS TWG's second goal of protecting Guam's human interests and aiding in the restoration of its endangered wildlife is achieved by strategically suppressing the snake population, in combination with captive rearing and release of native birds.

- **Interdiction** – On Guam, control and containment efforts are conducted by WS at military and civilian ports (air and sea), as well as areas where high-risk cargo is packed and consolidated. High-risk cargo as defined by WS is cargo bound for destinations that are deemed high risk – high-risk destinations include all of tropical western pacific, Hawaii, Diego Garcia, Okinawa, and the US mainland. Tools and techniques used to control and contain the BTS on Guam have been developed by NWRC and USGS, and include trapping, toxicant bait stations, nighttime searches, canine inspections, and barriers. Using these tools, WS creates multiple layers of protection. The snake trap is the primary tool used to reduce BTS numbers. A live mouse, which is housed in a separate smaller cage inside the snake trap, is used to attract snakes to the trap. Each mouse is provided with food and moisture. On the outer perimeter of a containment zone, traps are situated along forest edges and fence lines surrounding ports and areas where cargo and vehicles are packed and staged for shipping. In some areas, BTS traps are replaced with BTS bait stations. Stations are baited with a dead neonate mouse (DNM), which has a toxicant (80 mg table of acetaminophen) inserted into the gut. Nighttime fence line searches are also conducted to capture snakes pursuing geckos on the fence. This technique is effective for targeting smaller-sized snakes, which are not as susceptible to capture in traps or toxicant bait take. This strategy provides the initial layer of protection to prevent snakes entering areas with high-risk cargo. Inside the first-line perimeter, outgoing aircraft and high-risk cargo undergo canine inspection. In the CNMI, traps and canine inspections are used by CNMI DFW, similar to methods employed by WS on Guam. Barriers are also used for suspect cargo in-coming from Guam, in which case it is staged inside a secure area until a thorough inspection can be conducted. In Hawaii, HDOA PQB personnel visually inspect high-risk cargo and aircraft arriving from Guam. Maintaining fully functional BTS interdiction programs in high-risk locations such as the CNMI and Hawaii, which have the capacity to conduct secondary canine and visual inspection, and Rapid Response (see below), is essential to preventing the establishment of this pest species outside of Guam.
- **Control** – WS conducts targeted population control of the BTS on Guam around military housing using traps and nighttime searches. This has a twofold benefit. Suppressing snake numbers in and

around housing improves the well-being of residents by reducing snake encounters and minimizing the risk of snakebite. It also lowers the probability of snakes entering cargo when families relocate. Using traps, nighttime searches, and some bait stations, WS also controls the BTS at 19 GPA power substations in an effort to reduce snake-related power outages. Control of the BTS over larger spatial scales is in the initial testing phase and is described in more detail in the "Research Committee Research Strategy" section below. This large-scale control of the BTS is termed "suppression."

- **Rapid Response Team** – The RRT was established in 2002 and is administered by the USGS. The RRT was established to: 1) conduct searcher training courses on Guam, 2) provide experienced searchers for extra-limital (i.e., outside of Guam) searches, 3) assist in communicating new developments in BTS science to recipient islands, and 4) provide guidance and assistance during responses to BTS sightings. Overall the RRT is comprised of 35 to 70 members from U.S. federal, state, and territorial agencies, as well as NGOs and foreign governments dispersed across more than a dozen Pacific islands and the U.S. mainland. The RRT is deployed when a credible snake sighting is reported from a snake-free island. Between 2002 and 2007, the RRT responded to 16 snake reports, the majority of those in the CNMI.
- **Research** – BTS-related core research is conducted primarily by two federal agencies, NWRC and USGS. NWRC concentrates its research on the development of tools for the control and detection of the BTS, such as trap design, toxicant registration, and bait testing. Specific examples of techniques and applications are presented in **Table 1**. USGS focuses its efforts on understanding the biology and ecology of the BTS, including its impact on Guam's ecosystems, which informs all areas of operations, management and methods development. USGS also has important roles in testing and validating control tools and monitoring population status of the BTS. BTS-related research activities are covered in more detail in the "Research Committee Research Strategy" section below.
- **Outreach** – Increasing public awareness on Guam, the CNMI, Hawaii, FAS, and other Pacific islands is vital to the goals of the BTS TWG. On Guam, WS distributes print and electronic media to inform the public of the threats of the BTS and the risks associated with transporting snakes off island. For large military exercises, DoD distributes brochures for incoming personnel and requires they watch an instructional video on the BTS. GDAWR and the GNWR educate the public on the need to preserve Guam's biodiversity and impacts The BTS has caused. GDAWR is currently conducting a BTS awareness campaign, Kontre I Kulepbla (Challenge the Snake), to increase the public's awareness of BTS control tools and preparing Guam for acceptance of large-scale BTS-suppression efforts. On Guam, the RRT also conducts outreach for school groups and public events, and the USGS maintains a website with BTS information. In the CNMI, CNMI DFW has produced radio broadcasts informing the public of the threat from BTS invading their islands, provides a BTS hotline to report snake sightings, and has historically visited schools to conduct BTS education programs. On Hawaii, CGAPS launched the multimedia "Silent Invasion Campaign" on invasive species, including the BTS. In addition, personnel from HDOA PQB, HDLNR, and DOFAW conduct outreach programs on invasive species, including the BTS.

- **Restoration** – Four species of birds have been the center of BTS-related restoration efforts. Two of these, the Guam rail and Guam Micronesian kingfisher are bred in captivity by GDAWR on Guam and in several U.S. mainland zoos for release in snake-free areas. Due to the efforts of GDAWR, rails have been released, and are believed established, on both Rota in the CNMI and on Cocos Island, an 83 acre islet immediately south of Guam. Both of the aforementioned sites are considered snake-free. Historically, GDAWR and partner agencies successfully protected Mariana crow nests in the wild from BTS predation. The Mariana swiftlet population on Guam was also impacted by the BTS. DON biologists oversee conservation efforts to protect the swiftlets that persist in three caves. This includes trapping around the caves by WS to reduce BTS predation on the birds. This project is not directly restoration, but the results will inform future efforts to restore swiftlets to other locations on Guam.

During a 12-month period starting in 2010, the BTS TWG used a structured process for multi-agency prioritization of BTS control efforts (Woods and Morey 2011). This process involved more than 30 participants representing all federal, territorial and state agencies participating in the BTS TWG. One component of this effort was an assessment of the feasibility of avian species restoration on Guam. Two outcomes resulted from this assessment. First, there was an expressed desire to restore species faster than the current rate, but the recognition that the actual number of species restored would likely be much lower (**Figure 8**). Second, shortage of snake-free habitat and funding were identified as factors limiting the restoration of native birds on Guam.

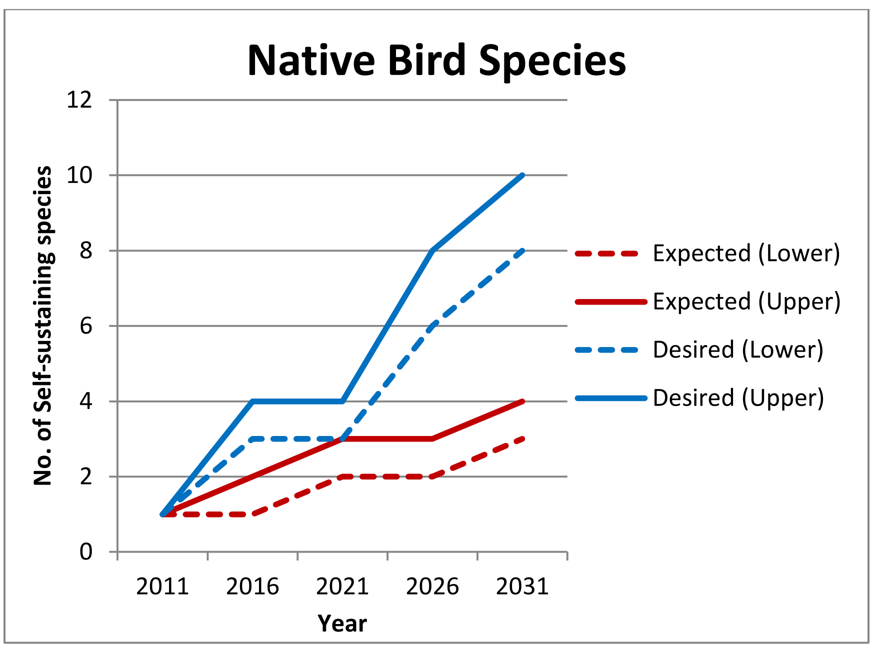


Figure 8. Discrepancy between the “desired” and “expected” number of species restored on Guam given the funds available and the amount of snake-free habitat (adapted from Woods and Morey 2011).

BTS TWG Goals

3.2 TECHNICAL WORKING GROUP ASSESSMENT

The BTS TWG has been labeled a “success story ready to happen” (Colvin et al. 2005). It could more aptly be termed a “success story in progress.” Having prevented the BTS from establishing outside of Guam, the BTS TWG is achieving its primary goal and is working toward minimizing the impacts of the BTS on Guam. Additionally, restoration projects of native species on Guam have demonstrated important achievements, such as the establishment of rails on Cocos Island and preservation of the Mariana swiftlet. Despite these successes, the BTS TWG recognizes there is considerable opportunity for improvement.

During the preparation of this Strategic Plan, the BTS TWG identified a number of problems or issues related to BTS activities. These issues range from inadequate data management that impact efficiency and reporting to the critical loss of an entire interdiction program. Progress in some of these areas is attainable by assessing project activities, increasing project efficiency, and improving BTS TWG coordination and management. Conversely, some advances will require an increase in funding and others a change from the year-to-year funding cycle to one of stable base funding. BTS TWG research needs are not addressed here, but are covered in the following section.

- **Data & Information Issues** – The BTS TWG is large and complex, encompassing a wide range of entities, each with a unique mission and operational hierarchy, which greatly complicates BTS TWG data reporting and analysis. Progress needs to be made by the BTS TWG and its partner agencies to address data management, programmatic performance, and the tracking of funds.
    - Snake sighting database – It is critical to have access to accurate and up-to-date information on BTS sightings outside of Guam to assess the effectiveness of interdiction efforts. Prior the preparation of this Plan, information on sightings of the BTS outside of Guam was in a state of disarray. Documents containing information on extra-limital sights were outdated and contained errors. The electronic database(s) on snake sightings were not readily accessible and contained errors. Recently effort has been put into correcting and verifying the information in the electronic database. Further effort is now required to make this database accessible to persons involved in the BTS TWG.
    - BTS-caused power outages – Power outages caused by the BTS are one of the metrics frequently used to describe the impacts of the BTS on Guam. The economic cost of power outages are also used in studies projecting the potential economic impact on islands, such as Hawaii, if BTS were to establish. However, the last comprehensive examination of BTS-caused outages on Guam was published in 2002 and reports data ending in 1997. To accurately assess the effectiveness of snake control conducted by WS at substations and transmission lines and estimate the potential impact of the BTS on other islands, it is essential to monitor and analyze BTS-caused outages on Guam.
    - Funding and expenditure tracking – Development of this Plan has highlighted the need to improve tracking of funds and maintain a comprehensive funding database for the

entire BTS TWG. Each funding and recipient agency manages its respective budget (or financial input and output) related to BTS TWG activities and expenditures; however, conducting a comprehensive financial analysis of the BTS TWG is problematic due to factors, such as the differing accounting practices of agencies and the tracking of funds on multi-year projects.

- **Programmatic Needs** – Although the BTS TWG has achieved advancements in areas of methods development and inspection rates of outgoing cargo to high risk areas there are many programmatic areas in need of improvement.
    - HDOA canine inspection program – Due to statewide budget constraints HDOA PQB dismantled its canine inspection team in 2009. Despite an infusion of funding in 2010 and 2012 from OIA, HDOA has not reinstated its canine inspection program. It is critical that the canine inspection program be reactivated on Hawaii.
    - CNMI DFW interdiction program performance – In recent years, the CNMI DFW BTS program has had challenges meeting performance measures. Correction of operational and administrative program deficiencies has required significant effort by the CNMI DLNR, USFWS and OIA. Efforts to ensure CNMI DFW BTS program success are on-going, with improvement in certain aspects of program implementation.
    - RRT training & protocols – Since 2002, the RRT Coordinator has trained dozens of personnel from many of the BTS partner entities, which greatly improved searcher capacity on the region's islands. However, the ability of searchers to detect the BTS in field situations diminishes without regular interaction with the snake. Therefore, it is recognized that searchers should undergo refresher training every two years. Many of the RRT members (e.g., 80% of Hawaii's 51 searchers) are overdue for refresher training, which will require substantial funding to complete. In addition to developing and maintaining BTS searcher capacity within the region, it is necessary to develop guidelines and protocols, similar to an incident command system, specific to each jurisdiction, which clearly delegates authorities and responsibilities to the relevant agencies in the event of an extra-limital BTS sighting resulting in a search effort.
    - Disaster planning – Guam is subject to frequent tropical storms. These storms not only impact the island, they can disable the BTS interdiction program, as happened in 2002 when Super Typhoon Pongsona hit Guam. WS has taken some steps to prevent a similar occurrence, including obtaining secure areas for trap storage and developing a "Typhoon/Tropical Storm SOP." Continued focus on disaster planning and programmatic capacity is needed. Similarly, additional infrastructure is needed to ensure that the BTS interdiction program is less vulnerable to storms.
    - The Brown Treesnake Control and Eradication Act of 2004 Reauthorization – The Brown Treesnake Control and Eradication Act of 2004 expired in 2010. It authorized up to \$10.6M in annual appropriations for DOI- and USDA-funded interdiction, control, and research activities. However, limited funding was allocated via the Act. Instead, the BTS

TWG has been primarily supported year-to-year on OIA technical assistance funds and DoD funds associated with regulatory requirements stemming from the ESA. The Brown Treesnake Control and Eradication Act of 2004 provided a clear structure for BTS TWG and defined federal agency roles related to BTS management. It included provisions that could have been used for federal rule-making related to BTS interdiction; however, these were not adequately funded. A reauthorized and strengthened Act could provide stronger federal legal authority for BTS interdiction. Similarly, a re-authorized Act that includes, DOI, DoD, USDA, and DOT could provide the range of federal agencies impacted by the BTS a mechanism to authorize appropriations for BTS control efforts. Lastly, a reauthorized and strengthened Brown Treesnake Control and Eradication Act of 2004 could be a mechanism to provide stability for existing BTS programs.

- Standardize QA (Quality Assessment) BTS operational programs – BTS interdiction is conducted by three distinct programs with different protocols, procedures, and capacities. To provide operational continuity and improve operational efficacy, the three interdiction programs should develop standardized QA protocols. This would include regular assessment of new pathways for extra-limital BTS dispersal on Guam and at recipient sites. Similarly efforts should be made to standardize canine detection program efficacy between WS, Hawaii, and the CNMI DFW.
- Container inspection tracking / certification – Most freight arriving at the Port comes from freight forwarding companies in sealed containers. Prior to delivery to the Port, WS inspects the interior of the containers and their contents on the property of the freight forwarding company. However, there is no certification system in effect that ensures the containers remain closed and BTS free after inspection by WS. The inability to ensure a container remains sealed after inspection creates a breach in the process, which poses a risk that uninspected containers will arrive at the Port. PAG has stated it will work with all cooperating entities involved in the BTS inspection process to ensure this problem is adequately addressed (USFWS; PAG 2013).
- Interdiction program funding – Efforts are needed to ensure programmatic stability for interdiction efforts on Guam, the CNMI, and Hawaii. The WS program highlights this issue. Due to reductions in the federal budget in 2011, the WS program on Guam lost most base programmatic funding from USDA. Currently, the WS interdiction program on Guam is primarily supported via reimbursable funds from DOI and DoD. Ensuring the programmatic stability for WS is critical to preventing the spread of the BTS to new locations. Secure base funding versus year-to-year funding is needed to ensure long-term viability of interdiction on Guam and other islands.

BTS TWG Goals

3.3 RESEARCH COMMITTEE STRATEGY

Federal Agencies Performing BTS Research

Research on the BTS has traditionally been funded by DOI through grants from OIA, but DoD has provided periodic support for research through specific grants and contracts. BTS research is designed to be complementary; NWRC focuses its research on methods development, whereas USGS concentrates on understanding the effects of BTS control and interdiction. This approach has created a more efficient process by clarifying the roles of the research agencies, yet allows for the opportunity to cooperate on projects when necessary.

NWRC – The agency develops and improves methodologies with the objective of improving the overall efficacy of BTS management. NWRC is addressing multiple areas critical to BTS management. First, it is committed to developing tools, such as the automated aerial baiting system (AABS) and artificial baits, which will enhance the ability to conduct large-scale control of the BTS. Second, the agency is working to develop methods to augment the current suite of interdiction tools, such as chemical and thermal irritants to clear cargo of snakes. NWRC also reviews operational methods and tools and conducts program analyses to ensure control and interdiction efforts are as efficacious as possible.

USGS – USGS has a multi-faceted research program designed to inform and enhance BTS operational efforts. The agency's research is focused on understanding the effect of removal techniques on all segments of the BTS population, such as the variation in response to trapping among age or size classes. USGS uses these insights in its research to help refine methods to suppress the BTS at the local and landscape scale. Additionally, USGS pursues research projects aimed at increasing the ability to detect the BTS at low densities and maximize the efficiency of Early Detection & Rapid Response (EDRR).

Both agencies are cooperating in research designed to evaluate ecosystem changes that occur through BTS control methods to understand the impact of large-scale (temporal and spatial) control efforts on the environment.

BTS Research History

High-quality, output-driven research has been a hallmark of BTS control and containment programs since their inception. When the BTS was identified as the cause of bird declines and extinctions on Guam in the mid-1980s, little was known about this species of snake in either its native or invasive range. Meanwhile, the only existing research program on snake control focused on human health risks associated with venomous snakes on small Japanese islands (Rodda et al 1999c). This meant that researchers were starting from scratch with a poorly known target animal and no proven control tools. Initial BTS research efforts thus focused on investigating the basic biology of the snake to discover potential vulnerabilities, while simultaneously developing and testing control tools (especially traps); these two research areas continue to interact strongly, as nearly every new finding on the biology of the BTS helps refine our collective understanding of the efficacy of control tools. Concurrent with the early investigations on the biology of the BTS and control methods, researchers were documenting the high economic costs of the snake on Guam, as well as risks to human health.

The first few years of BTS research effort were spearheaded by staff from GDAWR and USFWS (the research arm of USFWS was later split off to form USGS and NWRC). In the early 1990s, researchers and vertebrate control experts from NWRC and WS joined BTS research and control efforts. An array of scientists has been involved in BTS research over the years, including cooperators from territorial, state, and federal agencies as well as universities and other NGOs. However, it is notable that only a few individuals in federal research agencies have been the primary drivers of BTS research for the last two decades, and that all control tools currently in use are the product of development and testing efforts led by these same federal research agencies.

An important product of early research efforts by NWRC and USGS was the BTS trap. USGS researchers initially developed and tested the concept of a mouse-baited snake trap with one-way entrances, and over the course of testing dozens of trap variables, they succeeded in achieving capture rates that are two orders of magnitude higher than the average for snake traps worldwide (Rodda et al. 1999a). Once trap capture rates had been maximized, NWRC and WS biologists took the existing design and made the traps easier to service and more durable, while conducting field research to ensure that capture rates remained high. These traps remain the most effective snake traps in use anywhere in the world (Rodda et al. 1999a). Overall, the development, testing, and validation of control tools via intensive research programs has directly contributed to the success of interdiction efforts by operational agencies, as these agencies currently use the products of this research.

The need to establish snake-proof barriers became apparent early in efforts to interdict the BTS. To that end, researchers in the 1990s designed and tested barriers capable of excluding the BTS. The foremost challenges to excluding snakes were overcoming their excellent climbing abilities and designing access points that allow human entry and exit, but block the BTS. Because of the work conducted by BTS TWG partnering research agencies, a suite of barrier types have been deployed in Guam and the CNMI, including temporary barriers to reduce snake incursions into military materiel during short-term inter-island exercises, permanent concrete barriers for use around ports, and concrete-base/wire-mesh barriers to enclose conservation areas. These remain the only fully-tested snake barriers in existence anywhere in the world.

After initial development of effective traps and barriers, managers had tools to reduce the risk of the BTS infiltrating Guam's out-going transportation system. However, no tool is 100% effective; therefore researchers developed tools to chemically exclude the BTS via repellents and expelling or killing snakes in cargo via fumigation and thermal treatments. Unfortunately, environmental and cargo-integrity concerns have hampered their use in operations. Research to test the efficacy of canine teams in detecting snakes planted in cargo and other parts of the transportation network increased confidence in ongoing efforts to keep snakes from escaping Guam. Subsequently, validation of canine teams for

finding the BTS in forests offered a new means of detecting and localizing incipient populations on other islands in response to snake sightings. Budgetary constraints have hindered the full implementation of this program.

While the control tools developed by the research program are productive in terms of the number of snakes removed from transportation pathways and high-priority ecological areas, questions remained about the level of population suppression resulting from the application of a given tool and the feasibility of eradication at any scale. Therefore, validation of control tools (visual searching, trapping, toxicant application) at a population level were a major research focus over the last decade, with the goal of understanding which snakes are missed by each tool and how the size and sex of missed snakes might affect population recovery and control opportunities. Such efforts required large investments in fieldwork and development of quantitative tools for analyzing the resulting datasets.

More recently, significant progress has been made towards developing landscape-scale control tools using ground-based and aerial delivery of a snake toxicant. After years of intensive research, in 1999 a highly effective toxicant (acetaminophen) was registered by the EPA (Environmental Protection Agency) for use on the BTS. Over the last five years, the AABS has undergone many steps in a multi-phase development process. Several stages have been completed and the results are promising. Other research avenues have thus far failed to bear fruit in terms of an effective control tool despite considerable energy and funds being expended on them. Small-scale trials of biological control using parasites were attempted with captive snakes, but results were not promising and the method was judged to be of low utility for field application. Similarly, multiple experiments have been conducted to assess pheromonal control of the BTS; results using captive snakes have not been successfully replicated in field trials on Guam. Some of these lines of inquiry, such as toxicant application, deserve additional research effort, while for others the odds are very low that that the technique will yield an effective control tool.

BTS Research & Methods Development – Current & Future Needs

Current snake management strategies have been successful in decreasing, but not eliminating, the probability of snakes becoming established on other islands and positioning managers for restoration of native species. To increase the efficacy of these programs, broaden the scope of control efforts, and develop new tools, additional work is required to understand the effect of control and interdiction strategies on snake populations, snake behavior, and ecosystems. Overall, more research needs to be performed to understand and predict the response of BTS populations to control strategies and tools.

To more effectively and efficiently build on the research successes of the past, the BTS TWG chartered the BTS Research Committee (BTS RC) in 2012. The primary goal of the BTS RC is to develop strategic long-term plans and short-term priorities for advancing research on the BTS, focusing on developing the biological knowledge and technical ability required to meet the management goals of the BTS TWG.

BTS TWG Goals

Membership on the BTS RC is drawn from the BTS TWG, as well as subject matter experts from academic institutions and the scientific community. Despite the varied missions and priorities of the involved organizations, it rapidly became apparent to all BTS RC members that although BTS research has been remarkably successful, a critical historical weakness remains in place: the lack of predictable base funding for agencies responsible for BTS research. Conducting BTS research and methods development with funds solely from intermittent grants, cooperative agreements, or contracts impacts programs and efficiency in several ways:

1. Staffing continuity – Research and methods development projects based on annual funding often results in a cyclic process of hiring personnel for a single project, investing in training and orienting the employee, then releasing the employee at the end of the contract. This process limits the ability to develop program capacity, is inefficient, and costly. Additionally, intermittent funding for BTS projects implies a degree of uncertainty, which can hinder the ability to leverage resources (e.g., staffing) from cooperating agencies.
2. Sub-contracting costs – Sub-contracting some aspects of projects can be useful; however, the inability to hire permanent or semi-permanent staff often results in an over-reliance on sub-contractors. This has a tendency to increase project costs since each entity charges overhead and has additional start-up costs.
3. Strategically limited projects – Many of the problems inherent to the pursuit of eradication of the BTS from Guam require multi-phase projects that are based on incremental advancements that are directed by results from the preceding stages. Annual funding streams limit researchers from planning and proposing multi-year projects. The uncertainty of receiving funds from year-to-year constrains researchers into conceptualizing and designing projects that can be accomplished in a single funding cycle.

To support the BTS TWG Strategic Plan, the BTS RC generated overarching "Research Themes" (**Table 2.**). These themes are broken into: (1) Interdiction, Early Detection & Rapid Response; (2) Landscape-Scale Suppression; and (3) Restoration. Each theme was then populated with what the BTS RC recommended were the highest "Priority Research Areas." The recommended themes and priority research areas were then approved by the entire BTS TWG. More details regarding the priority research areas are provided below.

Effective management and interdiction efforts require a thorough understanding of snake population response to trapping, toxicant application, and other control efforts. Although interdiction and control programs are effective at removing large numbers of individuals, some segments of the population may be less susceptible to removal with the tools in current use. One example is juvenile snakes, which may fail to recognize rodents as suitable prey (Lardner et al. 2009) making them less attracted than adult snakes to control tools using mice as baits (Tyrrell et al. 2009, Lardner et al. 2013).

BTS TWG Goals

Table 2. Brown Treesnake Technical Working Group Research Committee themes and priority research areas. Please note, order does not imply importance.

Interdiction, Early Detection & Rapid Response	**Landscape-scale Suppression**	**Restoration (dependent on suppression R&D)**
Quantify & increase BTS interception rates	Automate toxicant delivery (Automated Aerial Broadcast System; AABS)	Determine level of BTS suppression required for persistence of native species
Develop methods to detect snakes at low-density, including Rapid Response	Study effect of suppression on BTS & non-target species	Determine size of exclosure required for persistence of various native species
Develop methods to detect satiated snakes in new locations	Develop alternative attractant, lures & baits	Predict native ecosystem response to toxicant application
Develop tools for interdiction of BTS not susceptible to mouse-based methods	Develop tools for control of BTS not susceptible to mouse-based methods	Improve barrier cost effectiveness & durability
Develop & test new irritant & repellent methods	Integrate current data operational data sets into research programs	
Assess new barriers (physical, chemical, behavioral) & reduce barrier costs	Control of BTS in urban environments	

This variation in susceptibility of the BTS to mouse baits is one of the underlying problems for population control and interdiction. Researchers have been trying to understand how variation in efficacy of control tools for smaller snakes influences the ability to suppress snakes at the landscape level, intercept snakes moving through areas of interdiction protecting resources (e.g., cargo consolidation areas, ports areas, power lines) or to target and detect incipient snake populations. Understanding the implications of these ‘missed’ individuals for long-term population suppression and eradication prospects is also a key research need. Repeated toxicant applications will be required over time to eliminate snakes as they grow to sizes for which mouse baits are effective. It is critical to determine the frequency and duration of bait application necessary to achieve the desired level of snake suppression and how factors such as sex, size, reproductive status, and foraging history interact.

Snakes arriving on other islands pose additional problems. They are often difficult to locate, therefore a need exists for tools for detecting snakes at very low densities. The utility of canine searches for the BTS in the forest has been validated, but more research effort is needed to make this technique fully operational. Aside from the “needle in the haystack” problem of trying to detect snakes at low densities, food resources are also often abundant and therefore snakes may not be attracted to standard mouse-baited traps. The latter is of particular concern when attempting to detect low-density snakes on recipient islands such as Saipan or Oahu. It is important to determine how to make control techniques effective in food-rich environments on other islands or areas with alternative prey (e.g., introduced frogs). Basic biological concepts need to be investigated to target these individuals to ensure that control efforts are effective.

Recent trials of aerial drops have progressed to the stage that there is promise that this method can control snakes over large areas. However, these trials only demonstrate a proof of concept. Manually broadcasting baits, while feasible, is prohibitively expensive. The AABS would increase the efficiency of broadcasting baits at least 40-fold compared to hand broadcast, greatly decrease helicopter time. To reduce the cost of application and scale this method up, the AABS must become operational. The AABS is more than two thirds through its development and implementation process, but continued funding is needed to proceed with the next stage. Concurrent with the development of the AABS, efforts to develop artificial baits to replace the dead mice that are used with aerial broadcast are being pursued. Currently, live adult mice and dead neonatal mice (DNM) are the only bait effective at attracting the BTS, which presents several problems. Live mice are expensive to purchase and maintain, and DNMs are only effective for a few days before decomposition renders them ineffective. Mice are also difficult to deploy in the field, requiring separate housing for live mice within BTS traps and “streamers” attached to DNM for air-drops. Although bait development has yet to show efficacy in the field after several years of effort, further research is warranted.

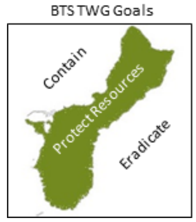
As control strategies shift from site-specific control to large scale suppression, the effect of snake removal on other animals is needed so we can effectively prepare for unintended consequences of snake removal. Once snakes are removed, the densities of rodents and lizards may increase significantly. Evidence for this can be found on nearby snake-free islands, which have rodent densities more than 10 times those on Guam (Wiewel et al. 2009). As noted above, high rodent densities may make control or interdiction tools less effective. Similarly, lizard populations and recently introduced frog populations may increase in size in response to BTS suppression providing more potential prey for the BTS, which could confound control efforts (Christy et al. 2007, Campbell et al. 2012). High rodent densities could not only complicate BTS control, it could also result in economic or ecological damage, with the potential to impact restoration of native birds (Sweetapple and Nugent 2007). Integrating multiple sources of information on the biology of the BTS and its prey and the population-level efficacy of control

tools will allow much more precise predictive models that will allow managers to understand the degree of snake suppression that can be expected as a result of a given control program and how populations of the prey of BTS may respond.

Restoration of native species throughout Guam is contingent upon having effective BTS control techniques and then applying these on a large scale. Most of the current and historic BTS research, from individual tool development to broad-scale suppression strategies, contributes to the eventual restoration of Guam’s native species and its ecosystem as a whole. Up to now, successful releases and protection of native species have been limited in scope due to the endangered status of the species involved in the release projects (i.e., limited amount of crows and permissions for release,). These small-scale field studies have developed release methodologies, and successful strategies for protection of nesting individuals from snake predation (Aguon et al. 1999). With broad-scale BTS control strategies available for testing in suitable release sights, releases of native species and inroads to recovery are possible.

Some aspects of restoration can be advanced through modeling. For instance, research on the spatial dynamics and life history characteristics of Guam rail populations on Rota or Cocos are necessary to conduct minimum viable population analyses, which could then aid in determining the size of snake exclosure necessary for the persistence of a rail population. The enhanced ability to measure/remove snakes at low densities would assist in improving the efficiency of snake control programs. The low-density snake population measurements could feed into models that determine the level of snake control necessary to allow native species to persist in the wild.

The above described priority research areas are vital to improving control and interdiction techniques and advancing the progress towards large-scale control of the BTS on Guam, the latter being a requisite step for restoring native birds on the island. These research areas are also essential for developing and improving the techniques to detect and eradicate new BTS populations should they become established in the CNMI, Hawaii, or elsewhere, as well as to assist in the protection and restoration of resources should the BTS establish elsewhere.



4.0 BROWN TREESNAKE FUNDING

4.1 FUNDING HISTORY

Formal funding for the BTS management efforts began in 1987, with DOI providing $100,000 to the research arm of USFWS (**Figure 9**; $202,000 in 2012 adj. for inflation; USFWS BTS Research later became part of the USGS). Since 1987, annual BTS related-funding has increased substantially, peaking at more than $9.0M in 2010, and then dropping to $7.5M in 2012. Overall, DOI has provided the majority of the funding, contributing $51.5 M, and was the primary Department supporting the BTS TWG during the first seven years. Sustained support from DoD began in 1994, coinciding with WS's entry into the BTS TWG. Overall, DoD has provided $39.7M in funding. Although total DOI and DoD contributions to the BTS TWG are comparable; the funds from each agency generally support different areas. Most DoD funds are directed towards interdiction and control efforts on Guam, with periodic support for research to develop BTS control methods. The latter is from specific multi-year programs (e.g., DoD Legacy and Environmental Security Technology Certification Program). Compared with DoD, DOI funds are more widely dispersed across programs. From 2009 through 2012, DOI provided funding support for interdiction efforts on Hawaii and the CNMI, restoration on Guam, and BTS research. (For specific information on agencies receiving funds, refer to the "BTS TWG Partner and TWG Status" sections for agency roles and activities.). From 1998 to 2010, USDA-APHIS (Animal and Plant Health Inspection Service) provided substantial BTS TWG support, totaling $8.3 M, with WS receiving all of those funds.

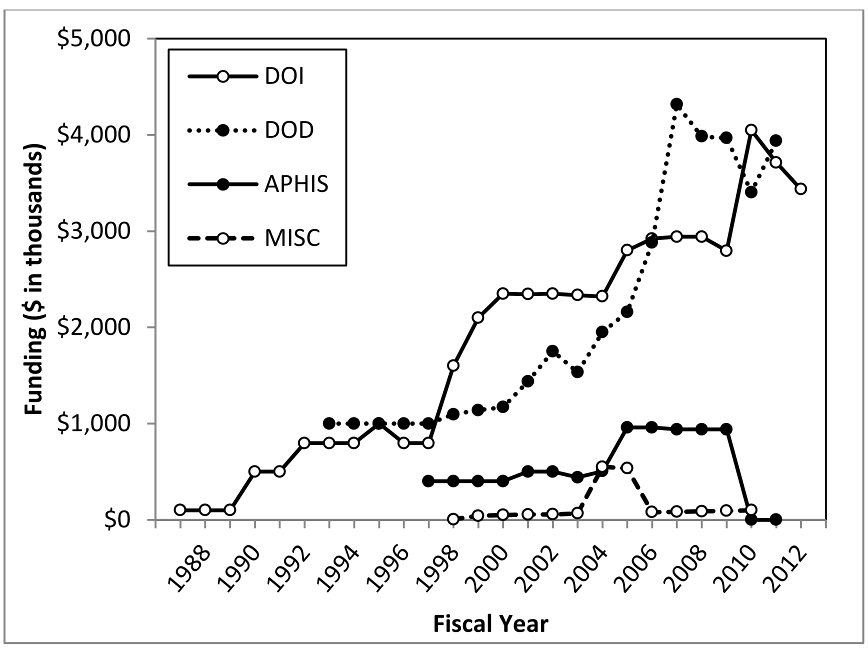


Figure 9. Funding provided by respective agency for brown treesnake management and research since efforts began in 1987. See text for explanation of miscellaneous entities.

BTS TWG Goals

Several other entities have provided funding to the BTS TWG, including HISC, USACE (U.S. Army Corps of Engineers), and GPA, totaling \$1.9M. Between 1987 and 2012, more than \$101.3M has been directed toward BTS-related management, research, and restoration. Not included in this figure is a considerable amount of agency support by DoD, USFWS, USGS, and USDA in the form of salaries, overhead, and cyclical funds. Also not accounted for are funds for a dog kennel constructed on Guam by DoD.

The majority of BTS funding (\$56.5M) has supported interdiction and control on Guam conducted by WS (**Figure 10a**). During the first five years of WS operations, 100% of funds went toward interdiction. Beginning in 1999, WS diversified their BTS role, working on projects related to research, control, and restoration. From 1999 through 2012, on average 84% of funds for WS were directed toward interdiction. During this same period, restoration efforts and BTS control on average received 6% and 7% of WS's funds, respectively. The remainder, 3%, went toward BTS-related research.

In addition to receiving the bulk of the BTS funding, support for WS generally increased over time until 2007 when funding levels began to plateau. The fact that WS funding has exceeded all other recipient agencies combined and has also increased at a greater rate reflects the central role WS plays in preventing the movement of the BTS off Guam. The leveling off of funding to WS in 2007 corresponds to the period where it achieved a 99% inspection rate of cargo departing Guam. This, combined with a reduction in the number of credible snake sightings off Guam in recent years, suggests WS interdiction capacity is approaching the point where it can achieve an almost 100% inspection rate of high-risk cargo at the current volume and funding levels. However, this apparent financial stability of the WS program is not entirely accurate. In 2010, Congress cut funding for a range of WS programs nationally, which resulted in the elimination of long-term USDA base support for the Guam program. Currently, the program is solely supported by reimbursable DoD and DOI funds.

USGS was the earliest recipient of BTS funding and has received \$22.7M. Funding for USGS tended to increase until 2002, after which its support has remained relatively static for more than a decade (**Figure 10a**). Although annual funding levels have been relatively stable, USGS's capacity to conduct BTS research has diminished because of rising salaries and inflation. The increased support for USGS in 2010 was due to a one-time infusion of funding for a DoD project and reprogrammed OIA funds. NWRC has received \$6.7M in support since 1991. Annual support for NWRC can best be described as erratic, with periods of funding increases offset by declines in following years. This is clearly illustrated from 2004 through 2012, when funding regularly decreased and increased five to 15-fold from year to year (**Figure 10a**). The stagnation of USGS support is primarily due to the level of funding available from DOI agencies, which has also been declining. The inadequate and inconsistent funding for NWRC is due to the agency's reliance on soft-money grants for research versus base funding. This has impacted NWRC's capacity to conduct BTS research in recent years. Both BTS core research groups require increased and more stable funding to ensure that critical research themes and objectives are met.

BTS TWG Goals

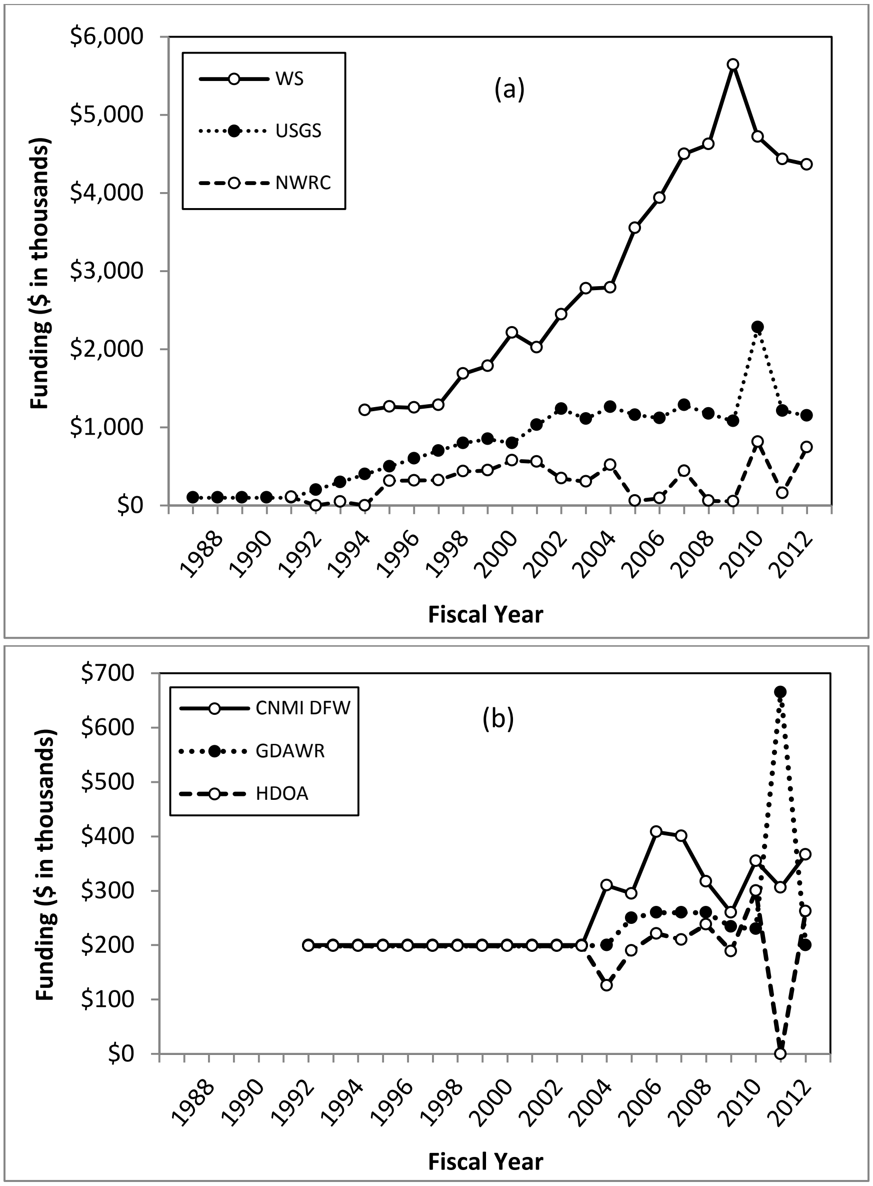


Figure 10. Funding levels for six agencies conducting brown treesnake management. WS, the USGS, and the NWRC received the largest amount of funding (a). The CNMI DFW, GDAWR, and the HDOA received lesser amounts of funding (b). Funding for recipients in "b" from 2007 through 2004 are unavailable, therefore estimates based on previous years funding amounts have been used. WS, CNMI DFW, and HDOA primarily conduct interdiction, USGS research, NWRC methods development, and GDAWR restoration.

CNMI DFW, GDAWR, and HDOA have received $5.4M, $4.9M, $4.1M, respectively (**Figure 10b**; see "BTS TWG Partner" and "BTS Status" sections for agency roles and activities). Smaller amounts of funding totaling less than $300K have been provided to other entities, such as Colorado State University, University of Hawaii, and Bishop Museum.

Examining funding for the most recent years (because details are available for this period) provides perspective on levels of support for specific activities (**Figure 11**). From 2009 to 2012, the federal, territorial, and state partners within the BTS TWG received \$31.5M. Support for interdiction totaled \$18.8M, averaging \$4.8M per year, including RRT. Research and methods development received \$8.4M during that same period, but funding fluctuated greatly. It should be acknowledged that a limited amount of USGS funds support RRT, an interdiction/operational effort.

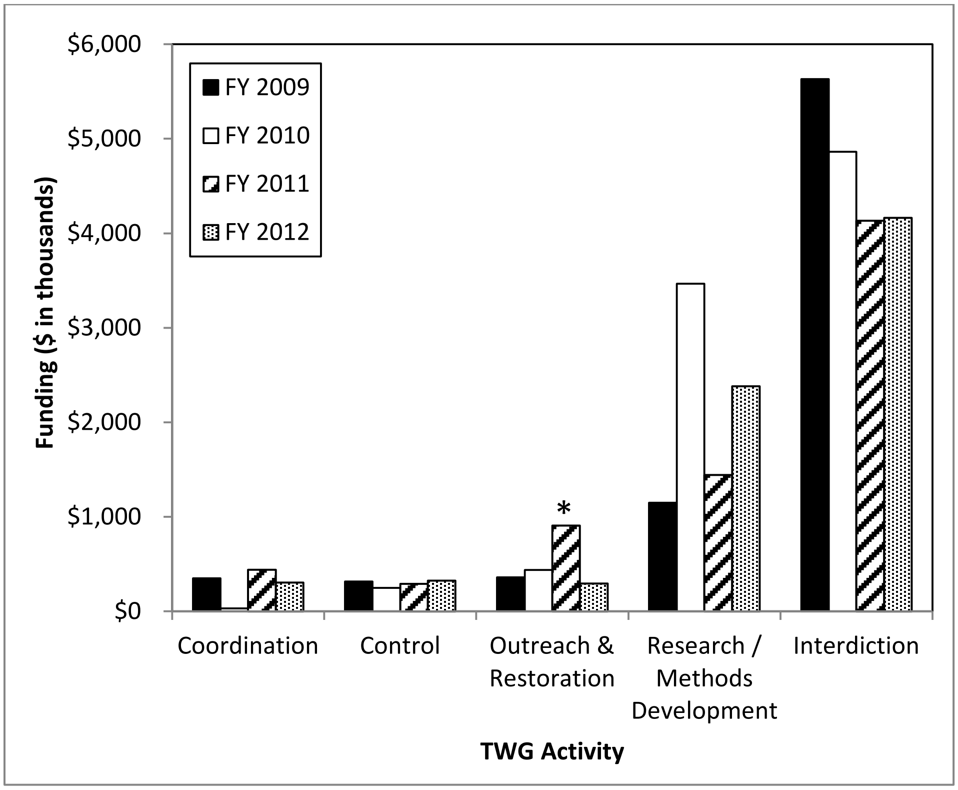


Figure 11. Financial support for specific types of brown treesnake management activities from 2009 through 2012. The doubling of funding for Restoration in 2011 over other years is associated with the funding of a brown treesnake public relations campaign on Guam (*). “Control” as defined in the “Current Activities” section above includes localized suppression of the BTS around housing and electric power facilities.

4.2 FUNDING EVENTS

The funding picture for BTS management will undoubtedly change in the coming years. These changes could include incremental annual increases or decreases in funding, one-time infusions of funds, or major programmatic readjustments requiring substantial long-term augmentation of funding. To anticipate these potential developments, several future funding scenarios or “Events” have been created. Events 1a and 1b examine the impact of sequestration on funding for the BTS TWG, focusing reductions on research and restoration projects. Two additional Events, examine the effect of reductions in DOI funding on recipient activities. Event 2 (no accompanying table) estimates the cost of a landscape-scale BTS control project and in Event 3, an analysis is conducted to examine the cost for WS to conduct interdiction in the CNMI and Hawaii compared to CNMI DFW and HDOA, respectively. Funding projections in these Events are based on 2012 funding levels. During 2012, the total operating funds approached $7.5M (**Table 3**). DoD and DOI provided the majority of the funding, with the Guam Power Authority providing WS $102K for removal of the BTS at power generating stations. Seven agencies received funding in FY12 for BTS interdiction, research, or restoration (**Table 4**).

Events 1a and 1b examine the impacts of the spending cuts (i.e., sequestration) that were called for in the Budget Control Act of 2011. In FY13 under sequestration, non-defense discretionary spending was reduced by approximately 4.7% ($28.7B) from FY12 funding levels (CBO 2013). If sequestration had occurred in FY14, discretionary spending would have decreased by approximately 1.6% ($9.7B) from FY13 levels. Defense discretionary spending decreased 6.5% ($42.7B) in FY13 and subsequently would be expected to decrease another 5.5% ($34.2B) in FY14 (if sequestration had occurred). Under a scenario of annual sequestration from FY14 to FY23, non-defense and defense discretionary spending would be expected to increase 2.3% and 2.1% annually, respectively. This would approximate the Congressional Budget Office's (CBO) projected rate of inflation. Again, this exercise is intended to show the potential long-range impacts of sequestration on BTS control and research as an example.
Event 1a (**Table 3**) presents budget projections on the potential effects of sequestration on funding for the BTS TWG. DoD funding for interdiction and control is differentiated from DOI funding for research and restoration because legal drivers (e.g. Biological Opinions, Installation BTS Instructions, DoD Transportation Regulations) mandate that DoD fund interdiction and control activities. DoD funding for

Table 3. Funding event 1a projections are based on sequestration-level reductions in annual funding to Brown Treesnake Technical Working Group member agencies. See text for percentages used to calculate annual adjustments to fiscal year dollar amounts. Projections are based on 2012 funding levels.

Event 1a							
Agency/ Entity	**FY12***	**FY13****	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**
DoD†	$2,976,421	$2,993,500	$3,056,364	$3,120,547	$3,186,079	$3,252,986	$3,321,299
DoD‡	$960,693	$576,246	$544,552	$555,988	$567,664	$579,585	$591,756
DOI	$3,435,455	$3,229,176	$2,970,842	$3,039,171	$3,109,072	$3,180,581	$3,253,734
GPA	$102,223	$109,827	$117,515	$125,741	$134,543	$143,961	$154,038
Total	$7,474,792	$6,908,749	$6,895,940	$7,052,868	$7,213,641	$7,378,371	$7,547,174

* – FY12 figures are actual expenditures:
** – FY13 figures are estimates based on funding provided by agencies;
† – DoD funding for interdiction & control activities;
‡ – DoD funding for research & restoration activities.

interdiction and control in FY13 remained essentially unchanged from FY12. Factoring in inflationary increases from FY14 through FY18 in a sequestration scenario the funding for interdiction and control would be expected to increase approximately 11% from FY12. DoD funding for research and restoration in FY13 declined approximately 39% from the $945K allocated in FY12. After accounting for an additional reduction in FY14 in a sequestration scenario and marginal inflationary increases (2.1% per annum) from FY15 through FY18, funding for research and restoration will have declined by 37% since FY12. DOI funding declined 6% from FY12 to FY13 and is projected to decline another 8% in FY14 in a sequestration scenario. Inflationary increases from FY14 through FY18 should stabilize DOI funding in Event 1a; however, the agency's BTS funding in FY18 will have decreased 5% from FY12 funding if sequestration projections were to hold. Funding from GPA is not directly affected by sequestration; therefore its funding is not expected to be reduced and since FY00 GPA has increased funding on average 7% per year, which is the value used to calculate annual increases in funding.

Event 1b uses the projected sequestration-related funding reductions discussed above for DOI in Event 1a and extrapolates the effects on recipient agencies (**Table 4**). In this sequestration scenario, FY14

Table 4. Funding event 1b budget projections examine the effect of sequestration on DOI funded Brown Treesnake Technical Working Group agencies conducting research and restoration. Funds for interdiction and control activities are not subject to reduction in support, therefore funding for GDAWR, USFWS, NWRC, and USGS is reduced by 13.5% from FY13 to FY14. Note that NWRC received an additional $380,521 from DOD in FY12. Projections are based on 2012 funding levels.

Event 1b							
Agency (Principal role)	**FY12***	**FY13****	**FY14†**	**FY15**	**FY16**	**FY17**	**FY18**
GDAWR (Restoration)	$200,000	$200,000	$172,980	$176,959	$181,029	$185,192	$189,452
USFWS (Coordination)	$306,399	$327,558	$283,305	$289,821	$296,487	$303,306	$310,282
NWRC (Meth. Develop.)	$365,000	$395,209	$341,816	$349,678	$357,721	$365,948	$374,365
USGS (Research/RRT)	$1,229,618	$1,144,341	$989,741	$1,012,505	$1,035,792	$1,059,615	$1,083,987
HDOA‡ (Interdiction)	$262,420	$262,420	$262,420	$268,456	$274,630	$280,947	$287,408
CNMI DFW (Interdiction)	$366,579	$403,734	$403,734	$413,020	$422,519	$432,237	$442,179
WS (Interdiction/Ctl)	$705,439	$758,334	$758,334	$775,776	$793,619	$811,872	$830,545

* – FY12 figures are actual expenditures:

** – FY13 figures are estimates based on funding provided by agencies;

† – Projected funding (see text);

‡ – Carry-over funds from FY12.

funds for interdiction and control are kept constant from FY13 to FY14. The overall DOI sequestration-related 8% reduction in funds from FY13 to FY14 is spread across fewer programs resulting in a 13.5% cut to GDAWR, USFWS, NWRC, and USGS. Afterwards funding for all programs is increased annually by 2.3%. The effect of sequestration on DOI funded activities is projected to flatten funding for research and restoration, such that FY18 funds approximate FY13 funding levels. It should be noted for some agencies such as NWRC this exercise is unrealistic since their annual funding for BTS-related research is not based on an annual funding and has fluctuated greatly over the preceding 10 years (Figure 9a).

Under Event 1a, the capacity of WS to conduct interdiction and control on Guam should remain unaffected, unless traffic from Guam increases or military training activities increase substantially. In contrast, the reduction in DoD funded research will have widespread ramifications. Recent DoD funding was instrumental in preparation for and implementation of the 2013 aerial toxicant drop on the Habitat Management Unit on Andersen (HMU) and Munitions Storage Area (MSA) on AAFB, each 136 acres. The DoD also provided funding essential to the development of the automated aerial broadcast system (AABS), which is a key component to making aerial toxicant drops cost effective. Reductions in funding could stall the progress made thus far, delaying the use of the HMU for restoration efforts on Guam.

DOI sequestration-related reductions in funding for research described in the Event 1b would fall heavily on USGS and NWRC. A sizeable portion of USGS FY13 research funding is devoted to projects focused on understanding the effects of the aerial toxicant drops on snakes and other species. Thus, Event 1b would further impact species restoration efforts. Event 1b would also seriously impact BTS TWG coordination, which has the potential to diminish interdiction overall, particularly in the CNMI where DOI currently provides significant programmatic oversight in addition to funding.

The previous events examined effect of sequestration-related decreases in funding. Event 2 calculates the cost of conducting a large-scale BTS control project on Guam. Two potential demonstration sites for landscape-scale BTS control and endangered species restoration exist on Guam. The first is the HMU. A second potential site for applying this landscape-level BTS control in the future is the 385-acre GNWR. BTS control could be achieved by using the aforementioned aerial application of acetaminophen-treated baits. Bait delivery would be by hand from helicopter, conducted twice monthly for six months, then once each month for the next 12 months. This project is estimated to cost approximately $1.5M, of which 70% would be helicopter time and 25% bait costs. The estimate for this exercise incorporates only the cost of applying the toxicant baits and does not cover other components of restoration, such as fence completion ($750K) and maintenance ($97K), and BTS population monitoring. This project estimate illustrates that large-scale control of the BTS could be an expensive prospect and that the majority of the expense for such a project would be in helicopter time and bait. As described above, an automated aerial broadcast system (AABS) is in development. When operational, an AABS would increase the efficiency of bait delivery by 40 times, reducing flight time, thus decreasing the overall cost of the method.

Event 3 examines the cost of a two programmatic adjustments. These are the replacement of the HDOA and CNMI DFW BTS interdiction programs with WS. As mentioned in the "Technical Working Group Assessment" section of this document, BTS interdiction efforts in Hawaii have been inadequate since 2009, when the canine inspection program was deactivated. In the event HDOA is unable to reactivate the canine inspection program, WS is prepared to develop an interdiction program for Hawaii. Event 3 compares the annual funding provided by DOI to HDOA to implement a canine inspection program and the cost necessary for WS to undertake the interdiction efforts (**Table 5**). The cost to have WS conduct BTS interdiction in the State of Hawaii would be almost twice that of a fully functioning HDOA program. Several factors contribute to higher cost of WS conducting interdiction compared to HDOA. Because the federalized Hawaii program would be isolated from WS in Guam, it is imperative to have a supervisor in Hawaii. That position accounts for about 20% of the overall cost and overhead contributes another 16%. In addition, federal wages are higher than state wages for a comparable position.

Table 5. Funding event 3 compares cost between HDOA and WS to re-initiate and implement the canine inspection program in Honolulu, Hawaii and CNMI DFW and WS to conduct interdiction efforts in the CNMI. Estimates are adjusted by the CBO average annual inflation rate (2.3%).

Event 3							
Location	**Agency**	**Annual Cost**					**Total Cost**
		FY14	**FY15**	**FY16**	**FY17**	**FY18**	
Hawaii	HDOA	$231,466	$236,790	$242,236	$247,807	$253,507	$1,211,806
	WS	$473,026	$483,906	$495,036	$506,422	$518,069	$2,476,459
CNMI	DFW	$548,451	$561,066	$573,970	$587,172	$600,676	$2,871,335
	WS	$926,475	$947,784	$969,583	$991,883	$1,014,697	$4,850,422

Similarly, CNMI DFW interdiction efforts in the CNMI did not meet programmatic objectives between 2010 and 2011. Beginning in mid-2012, under the guidance of USFWS, CNMI DFW has improved its interdiction capabilities. Despite improvement, the CNMI DFW BTS program continues to face operational deficiencies and administrative challenges. If the CNMI DFW BTS program is unable to meet programmatic goals, one alternative would be to have WS implement an interdiction program in the CNMI. The cost for this would be substantial (**Table 5**). It should be noted that $188,468 of the FY14 CNMI DFW budget funds the USFWS biologist overseeing the program. This funding covers salary, benefits, vehicle and operating expenses. The considerable higher cost of WS assuming interdiction in the CNMI is due primarily to wages of federal versus territorial Employees. A more detailed analysis of both funding estimates is provided in **Appendices D and E**.

Implementing Event 3, in both Hawaii and the CNMI, would come at significantly greater cost to the BTS TWG, requiring an additional $649K per year in support. The extra cost of WS conducting interdiction in both island systems would bring greater programmatic continuity and probably increased expertise. A potential negative, would be local concern related to the federalization of former state / territorial functions.

4.3 FUTURE FUNDING NEEDS

As mentioned earlier in this document, BTS interdiction is currently funded by DOI and DoD. DOI - OIA primarily funds BTS interdiction in support of civilian sector activities on Guam, the CNMI and Hawaii. DoD primarily funds BTS interdiction in support of military sector activities on Guam and the CNMI.

The majority of BTS funding from DOI is provided by OIA through grants from its technical assistance program. OIA has recognized the need to fund BTS research and interdiction and consistently supported BTS efforts since 1990. Several regulatory mechanisms (e.g. Biological Opinions, Installation BTS Instructions, DoD Transportation Regulations) ensure consistent BTS interdiction funding for DoD-related and Port Authority of Guam activities, prompting the creation of regulations and procedures, such as the Defense Transportation Regulation, Part V and Installation BTS Instructions for NBG and AAFB. The role of ESA consultations related to the funding of BTS interdiction is likely to remain a constant as shipping and transport increase from Guam in the future.

The scale and rate of military activities on Guam and in the CNMI are expected to increase, putting additional pressure on BTS programs in each of the respective locations. When military personnel or equipment move from Guam to the CNMI for these training activities BTS inspections are required. The CNMI DFW interdiction program does not have the personnel to maintain regular inspections on Tinian and simultaneously respond to all of the military activities. DoD has funded WS to provide additional interdiction coverage during training exercise on Tinian when the exercise is beyond the capacity of the CNMI DFW interdiction program. To date WS has had sufficient program capacity to manage the level of interdiction efforts related to the expanded training on Guam and Tinian. If in the future military training and associated movement between Guam and the CNMI reaches a point where the current WS staffing cannot maintain acceptable levels of interdiction, then DoD would provide the support necessary to fulfill expanded interdiction requirements to maintain interdiction goals (Stephen Mosher JRM DON, pers. comm.).

The future military relocation on Guam may increase the movement of civilian and military personnel and cargo off-island. BTS interdiction capacity will have to be evaluated and potentially be expanded to account for any increases in off-island traffic resulting from the relocation of military forces to Guam. The future military relocation on Guam may also affect the island's civilian transportation sector. Therefore, the Port Authority of Guam (PAG) has incorporated the future military relocation in its port modernization planning studies (PAG 2008). PAG recognizes the need to mitigate the potential for BTS dispersal off of Guam via outbound marine cargo and is dedicated to work with WS and other GovGuam agencies to alleviate the increased risk of off-island transport of BTS as a result of the modernization project. As part of PAG's Guam Commercial Port Improvement program, funded by DoD and administered under a Memorandum of Understanding between PAG and the USDOT Maritime

Administration (MARAD), MARAD conducted the ESA Section 7 consultation process for Guam Commercial Port Improvement program, during which MARAD prepared a BTS Interdiction Commitment, which states that PAG has committed to developing mechanisms to ensure the funding necessary to achieve the following objectives (USFWS 2010; PAG 2013):

1. Maintain WS inspection levels consistent with current regimes of outgoing cargo containers, and vessels departing from the Port of Guam bound for the U.S. or U.S. territories;
2. Maintain BTS suppression at the Port of Guam at all commercial cargo staging, packing, handling, and trans-shipment facilities located at the Port of Guam handling cargo outbound for the U.S. or U.S territories;
3. Maintain BTS suppression around the perimeter of the Port of Guam property;
4. Maintain current levels of BTS inspection and quarantine for cargo, containers, and vessels departing at the Port of Guam; and
5. Maintain current BTS detection and monitoring at recipient sites at the Port of Guam with established federally-funded interdiction programs (PAG 2013).

There is also a need for continued or potential increase in funding support for the BTS Programs in CNMI and Hawaii based on the likely increase in traffic, both by air and sea, due to the possibility of military relocation to Guam. These jurisdictions are on the receiving end of both modes of transports for passengers and goods. The likely relocation will enhance the threat of BTS dispersion to these jurisdictions.

In addition to the potential need for increased funding due to the future programmatic expansion connected with the growth in the military and civilian sectors on Guam, there is a need to continue funding for research on interdiction, suppression, and eradication. The BTS RC has developed an Action Plan that outlines a series of themes and priority research areas (see **Table 2** "Research Strategy" section and **Appendix F**) that when pursued should yield improved tools to conduct interdiction and rapid response capabilities. On a grander scale these research priority areas provide a pathway to large-scale suppression of the BTS on Guam, which when achieved will not only enhance interdiction efforts, but lead to the ultimate goal of the recovery of the island's native birds.

To make progress with the challenge of suppressing the BTS on a landscape scale, a new funding model for the BTS research is required. Consistency in research can best be achieved by stability in funding, which is why it is important that USGS and NWRC obtain stable baseline funding to maintain the year-to-year capacity of their BTS research programs. NWRC estimates its annual base costs at $709K, which covers salaries and benefits, travel, equipment, and administrative overhead (**Appendix G**). USGS estimates its annual base costs to be between $1.75M and $2.04M, including the RRT Coordinator position (**Appendix H**). The numbers provided above reflect variability in effective indirect rates charged by the Fort Collins Science Center (FORT) on incoming agreements. Indirect costs are reduced for DOI agencies, with the difference being made up by USGS at the bureau level. Furthermore, the facilities indirect charges (for use of FORT facilities) are waived for funds spent on Guam, because the USGS Invasive Reptiles Project pays separately for use of facilities on Guam. Most incoming agreements include some funds to be spent at FORT and some on Guam, and therefore the final indirect rate

BTS TWG Goals

depends on the proportion of the overall funding to be spent at each location, as well as whether funds are coming from DOI or non-DOI sources. It should be emphasized that these estimates only cover base costs and do not include project specific costs, such as those for the development of the AABS.

5.0 CONCLUSIONS & RECOMMENDATIONS

Over the almost 30-year course of BTS management and research, the dedicated efforts of administrators, managers, and biologists have achieved the principal goal of the BTS TWG: preventing the BTS from escaping Guam and repeating the ecological disaster elsewhere. This is attributable to the ingenuity of the researchers studying the BTS and developing tools to capture and kill snakes, as well as the rigorous efforts of biologists, trappers, and dog handlers conducting interdiction on Guam, CNMI, and Hawaii. It is also due to federal, territorial, and state governments recognizing the threat the BTS poses to the interests of the U.S. and providing valuable assistance in the form of legislation and funding. Also, the ability to suppress the BTS over large areas, the precursor to restoration of native species on Guam, has shown promise in recent trials of new methods. With continued funding the AABS should be operational within two to three years. Once this tool is operational, the BTS TWG can begin the steps toward restoring some native species to Guam. The third goal of the BTS TWG, eradication of snakes from Guam, remains outside the time frame of this five-year Plan.

To continue advancing in the coming decade BTS TWG must contend with several issues. The scope and scale of the BTS TWG has grown in response to the magnitude of the problem of managing BTS across the Pacific. With this growth have come issues related to the management of information. These problems are manageable and must be addressed in order to evaluate the efficacy of BTS interdiction efforts. Progress needs to be made by the BTS TWG and its partner agencies to address data management and the tracking of funds. Better organization and oversight will only take the BTS TWG so far. To move beyond perpetual targeted interdiction, toward the goal of large-scale control of the BTS and an eventual repatriation of extirpated species on Guam, stable long-term funding is essential. The funding analysis (**Figure 8**) clearly shows that financial support for the BTS TWG has increased greatly over the past decades. It also illustrates that the majority of the increased support has funded WS and their interdiction and control efforts, which has helped build a program capable of achieving near 100% inspections of out-going cargo from Guam, which is likely attributable, in part, to the decrease in extra-limital sightings of snakes. Funding for research has not kept pace with that of interdiction, and while absolute funding levels are important, stability of support is critical. Pursuing solutions to problems as vexing as those posed by the BTS RC (**Table 2**) will require methodical and incremental research, which is dependent on consistent, dedicated funding over periods of multiple years. Below is a list of recommendations addressing issues related to data management, programmatic needs (see section 3.2 “Technical Working Group Assessment” for more detail), and the manner in which funds are provided for operations and research.

BTS TWG Goals

5. 1 DATA & INFORMATION RECOMMENDATIONS

Snake Sighting Database – The database of extra-limital snake sights has recently undergone a verification check and the credibility of each sighting evaluated. The database should now be linked to a website, which should be managed by the USFWS-PIFWO. This would ensure that the most up-to-date information on snake sightings is available to all BTS TWG partners.

BTS-caused Power Outages – Guam Power Authority (GPA) contracts with WS to reduce BTS numbers around several substations and transmission lines. However, it is unknown whether this effort is causing a reduction in the number of power outages or if BTS-caused outages remain a significant problem on Guam. GPA records should be analyzed by WS (or a contractor) to assess the effect of on BTS control efforts on power outages and to examine the current impact of snakes on power generation on Guam.

Funding & Expenditure Tracking – As part of this Plan, BTS management costs were analyzed. This post-hoc analysis was complicated by the temporal extent of management and the variety of funders and even greater number of recipients. USFWS should maintain a ledger for all recipients of BTS funding and the system should be updated annually.

5.2 PROGRAMMATIC RECOMMENDATIONS

In addition to administrative issues, there are programmatic shortcomings that must be addressed for the BTS TWG to operate more efficiently and to prevent the BTS from establishing outside of Guam. Most of the below programmatic needs are or would be directly dependent on a funding increase to implement.

HDOA Canine Inspection Program – Hawaii has been without a canine inspection program since 2009 leaving it vulnerable to a BTS arriving undetected. This is despite OIA providing funding since 2010. If HDOA is unable to reestablish its program by the end of calendar year 2015, alternative strategies to implement interdiction should be strongly considered, foremost contracting with WS to manage the Hawaii BTS inspection program.

CNMI DFW Interdiction Program Performance – Administrative and operational deficiencies continue to hinder the CNMI DFW Interdiction Program. If CNMI DFW cannot demonstrate the ability to maintain program effectiveness by the end of calendar year 2015, alternative strategies to conduct interdiction should be strongly considered, foremost contracting with WS to implement BTS interdiction in the CNMI.

RRT Training & Protocols – BTS RRT search training has not been conducted since early 2012. Many RRT searchers require refresher courses and new BTS personnel training. RRT training should be provided sufficient support FY2015 to address the need to provide refresher and initial training to personnel.

RRT Protocols – Some RRT protocols and guidelines are incomplete. In 2014, the RRT Coordinator should complete the draft Brown Treesnake Rapid Response Team Searcher Manual. In the Manual, should be guidelines for developing and implementing an incident command system for high-risk areas in the Pacific.

Disaster planning – Tropical storms have hit Guam and diminished the capacity to conduct interdiction. WS has developed standard operating procedures to deal with future storms. Funding is required to implement these procedures and ensure interdiction capacity for future storms.

The Brown Treesnake Control and Eradication Act of 2004 Reauthorization – The Brown Treesnake Control and Eradication Act of 2004 expired in 2010. It provided a clear structure for BTS TWG and defined federal agency roles related to BTS management; however, some provisions were not adequately funded. A reauthorized and strengthened Brown Treesnake Control and Eradication Act of 2004 could provide stronger federal legal authority for BTS interdiction. BTS TWG Partners (federal, state, and territorial) should work together to determine mechanisms to reauthorize the Brown Treesnake Control and Eradication Act of 2004. Two components that should be considered are: which agencies, departments, or bureaus should be added to the Brown Treesnake Control and Eradication Act of 2004, and which mechanisms should be added to it to strengthen BTS quarantine.

Standardize QA (Quality Assessment) BTS Operational Programs – WS, CNMI DFW, and HDOA, in coordination with USFWS, should collaborate to develop protocols to standardize the QA of BTS interdiction programs to ensure outgoing and incoming cargo and vehicles receive the same level inspection.

Container Inspection Tracking / Certification – WS should work with the Port Authority of Guam, the Guam Airport Authority, and freight forwarders to ensure that containers, once inspected, are not re-opened, creating a breach in the inspection process. PAG has stated it will work with all cooperating entities involved in the BTS inspection process to ensure this problem is adequately addressed (USFWS; PAG 2013).

5.3 BASE FUNDING RECOMMENDATIONS

Two of the programmatic needs require an increase in funding and a restructuring in the manner in which funds are provided.

WS Interdiction Program Funding – In 2011, the WS program on Guam lost most base programmatic funding from USDA. Currently, the WS interdiction program on Guam is primarily supported via reimbursable funds from DOI and DoD. Secure base funding versus year-to-year funding is needed to ensure long-term viability of interdiction on Guam.

BTS TWG Goals

USGS & NWRC Research & Methods Development Base Funding – Conducting BTS research and methods development solely on intermittent grants is inefficient and impacts programs. Staffing continuity is reduced, costs are inflated because of the need to use contractors, and it strategically restricts researchers from planning multi-year projects. Stable base funding is needed to overcome these limitations.

6.0 REFERENCES

Aguon CF, Beck RE Jr, Ritter MW (1999) A method for protecting nests of the Mariana Crow from brown treesnake predation. In: Rodda GH, Sawai Y, Chiszar D, Tanaka H (eds) Problem snake management: the habu and brown treesnake. Comstock, Cornell, pp 460-467

Burnett KM, D'Evelyn S, Kaiser BA, Nantamanasikarn P, Roumasset JA (2008) Beyond the lamppost: optimal prevention and control of the brown tree snake in Hawaii. Ecological Economics 67:66–74

Campbell EW III, Yackel-Adams AA, Converse SJ, Fritts TH, Rodda GH (2012) Do predators control prey species abundance? An experimental test with brown treesnakes on Guam. Ecology 93:1194-1203

Christy MT, Savidge JA, Rodda GH (2007) Multiple pathways for invasion of anurans on a Pacific island. Diversity and Distributions 13:598-607

Colvin BA, Fall MW, Fitzgerald LA, Loope, LL (2005) Review of brown treesnake problems and control programs. USDA National Wildlife Research Center-Staff Publications. Paper 631

Congressional Budget Office (2013) The budget and economic outlook: fiscal years 2013 to 2023. February 2013

Corlett, RT (1998) Frugivory and seed dispersal by vertebrates in the Oriental (Indomalayan) region. Biological Reviews 73:413–448

Cox PA, Elmqvist T, Pierson ED, Rainey WE (1991) Flying foxes as strong interactors in South Pacific island ecosystems: a conservation hypothesis. Conservation Biology 5:448–454

Division of Aquatic and Wildlife Resources (2001) Establishment of an experimental population of Guam Rails on Rota or other islands in the Marianas. Guam Department of Agriculture, Job Progress Report, Research Project Segment, Project No. E-2-4

Dorcas ME, Willson JD, Reed RN, Snow RW, Rochford MR, Miller MA, Meshaka WE Jr, Andreadis PT, Mazzotti FJ, Romagosa CM, Hart KM (2012) Severe mammal declines coincide with proliferation of invasive Burmese pythons in Everglades National Park. Proceedings of the National Academy of Sciences of the United States of America 109:2418-2422

Fritts TH (1988) The brown tree snake, *Boiga irregularis*, a threat to Pacific Islands. USFWS Biological Report, 88

Fritts TH, McCoid MJ, Haddock RL (1994) Symptoms and circumstances associated with bites by the brown tree snake (Colubridae: *Boiga irregularis*) on Guam. Journal of Herpetology 28:27–33

Fritts TH, McCoid MJ (1999) The threat to humans from snakebite by snakes of the genus *Boiga* based on data from Guam and other areas In: Rodda, GH, Sawai Y, Chiszar D, Tanaka H (eds) Problem Snake Management: the Habu and the Brown Treesnake Cornell University Press pp 116–127

Fritts TH (2002) Economic costs of electrical system instability and power outages caused by snakes on the island of Guam. International Biodeterioration & Biodegradation 49:93–100

Fujita MS, Tuttle MD (1991) Flying foxes (Chiroptera: Pteropodidae): threatened animals of key ecological and economic importance. Conservation Biology 5:455–463

Greene HW (1989) Ecological, evolutionary, and conservation implications of feeding biology in old world cat snakes, genus *Boiga* (Colubridae). Proceedings of the California Academy of Sciences 46:193-207

Kraus F (2009) Alien Reptiles and Amphibians: A Scientific Compendium and Analysis. Springer Science

Krysko KL, Burgess JP, Rochford MR, Gillette CR, Cueva D, Enge KM, Somma LA, Stabile JL, Smith DC, Wasilewski JA, Kieckhefer GH III, Granatosky MC, Nielson SV (2011) Verified non-indigenous amphibians and reptiles in Florida from 1863 through 2010: Outlining the invasion process and identifying invasion pathways and stages. Zootaxa (Monograph). Magnolia Press: Auckland, New Zealand

Lardner B, Savidge JA, Rodda GH, Reed RN (2009) Prey preferences and prey acceptance in juvenile brown treesnakes (*Boiga irregularis*). Herpetological Conservation and Biology 4:313-323.

Lardner B, Yackel-Adams AA, Savidge JA, Rodda GH, Reed RN, Clark CS (2013) Effectiveness of bait tubes for brown treesnake control on Guam. Wildlife Society Bulletin 37:664-673

Lowe SM, S Browne S, Boudjelas, S, De Poorter, M (2000) 100 of the world's worst invasive alien species: A selection from the global invasive species database. Aliens 1–12

Mackessy SP, Sixberry NM, Heyborne WH, Fritts TH (2006) Venom of the brown treesnake, *Boiga irrregularis*: ontogenetic shifts and taxa-specific toxicity. Toxicon 47:537–548

Mortensen HS, Dupont YL, Olesen JM (2008) A snake in paradise: disturbance of plant reproduction following extirpation of bird flower-visitors on Guam. Biological Conservation 141:2146–2154

Parker WS, Plummer MV (1987) Population ecology. In: Siegel A, Collins JT, Novak SS (eds) Snakes: Ecology and evolutionary biology. Macmillian, New York, pp. 253-301

Perry G, Vice D (2009) Forecasting the risk of brown tree snake dispersal from Guam: a mixed transport-establishment model. Conservation Biology 23:992–1000

Port Authority of Guam (2008) Jose D. Leon Guerrero Commercial Port of Guam: Master plan update 2007 Report

Port Authority of Guam (2013) Port of Authority of Guam port modernization program: Brown treesnake interdiction commitment

Pratt HD, Bruner PL, Berrett DG (1987) A field guide to the birds of Hawaii and the tropical Pacific. Princeton University Press

Rawlings LH (1995) Phylogeography of the brown tree snake, *Boiga irregularis*, particularly relating to populations in Guam. University of Adelaide, BS

Rayner MJ, Hauber ME, Imber MJ, Stamp RK, Clout MN (2007) Spatial heterogeneity of mesopredator release within an oceanic island system. Proceedings of the National Academy of Sciences 104:20862-20865

Reed RN, Rodda GH (2009) Giant constrictors: biological and management profiles and an establishment risk assessment for nine large species of pythons, anacondas, and the boa constrictor: U.S. Geological Survey Open-File Report 2009–1202

Rodda, GH, Fritts, TH (1992) The impact of the introduction of the colubrid snake *Boiga irregularis* on Guam’s lizards. Journal of Herptetology 26:166-174

Rodda GH, Fritts TH, Conry, PJ (1992) Origin and population growth of the brown tree snake, *Boiga irregularis*, on Guam. Pacific Science 46:46-47

Rodda GH, Fritts TH, Clark CS, Gotte SW, Chiszar D (1999a) A state-of-the-art trap for the brown treesnake. In: Rodda GH, Sawai Y, Chiszar D, Tanaka H (eds) Problem snake management: the habu and brown treesnake. Comstock, Cornell, pp 268-305

Rodda GH, Fritts TH, McCoid MJ, Campbell EW III (1999b) An Overview of the Biology of the Brown Treesnake (*Boiga irregularis*), a Costly Introduced Pest on Pacific Islands. USDA National Wildlife Research Center – Staff Publications. Paper 659

Rodda GH, Sawai Y, Chiszar D, Tanaka H (eds) (1999c) Problem snake management: the habu and brown treesnake. Comstock, Cornell

Rodda GH, Reed RN, Jarnevich CS (2007) Climate matching as a tool for predicting potential North American spread of brown treesnakes. Managing Vertebrate Invasive Species. Paper 41

Rodda GH, Savidge JA, Tyrrell CL, Christy MT, Ellingson AR (2007s) Size bias in visual searches and trapping of brown treesnakes on Guam. Journal of Wildlife Management 71:656-661.

Rodda GH, Savidge JA (2007b) Biology and impacts of pacific island invasive species. 2. *Boiga irregularis*, the Brown Tree Snake (Reptilia : Colubridae). Pacific Science 61:307–324

Rogers H, Lambers JHR, Miller R, Tewksbury JJ (2012) 'Natural experiment' demonstrates top-down control of spiders by birds on a landscape level. PLoS ONE 7(9):e43446

Savidge JA (1987) Extinction of an island forest avifauna by an introduced snake. Ecology 68(3):660–668

Savidge JA (1988) Food habits of *Boiga irregularis*, an introduced predator on Guam. Journal of Herpetology 22(3):275–282

Shine R (1991) Strangers in a strange land ecology of the Australian colubrids snakes. Copeia 1991:120-131

Shwiff SA, Gebhardt K, Kirkpatrick KN, Shwiff SS (2010) Potential economic damage from introduction of brown tree snakes, *Boiga irregularis* (Reptilia: Colubridae), to the islands of Hawai'i. Pacific Science 64:1–10

Sweetapple PJ, Nugent G (2011) Ship rat demography and diet following possum control in a mixed podocarp-hardwood forest. New Zealand Journal of Ecology 31:186-201

Stanford JW, Rodda GH (2007) The brown treesnake rapid response team. Managing Vertebrate Invasive Species. Paper 50

Taylor J (2012) Micronesian Kingfisher (*Todiramphus cinnamominus*) is being split: list *T. reichenbachii* as Vulnerable and *T. cinnamominus* as Extinct In The Wild? http://www.birdlife.org/globally-threatened-bird-forums/2012/11/micronesian-kingfisher-todiramphus-cinnamomimus-is-being-split-list-t-reichenbachii-as-vulnerable-and-t-cinnamomimus-as-extinct-in-the-wild/

Tyrrell CL, Christy MT, Rodda GH, Yackel-Adams AA, Ellingson AR, Savidge JA, Dean-Bradley K, Bischof R (2009) Evaluation of trap capture in a geographically closed population of brown treesnakes in Guam. Journal of Applied Ecology 46:128-135

U.S. Fish and Wildlife Service (2010) Biological Opinion for the Joint Guam Program Office relocation of the U.S. Marine Corps from Okinawa to Guam and associated activities on Guam and Tinian. Service Number 2010-F-0122.

Weinstein SA, Chiszar D, Bell RC, Smith LA (1991) Lethal potency and fractionation of Duvernoy's secretion from the brown tree snake, *Boiga irregularis*. Toxicon 29:401–407

Weinstein SA, Stiles BG, McCoid MJ, Smith LA, Kardong KV (1993) Variation of lethal potencies and acetylcholine receptor binding activity of Duvernoy's secretions from the brown tree snake *Boiga irregularis*. Merrem. Journal of Natural Toxins 2:187–198

Wiewel, AS, Yackel-Adams AA, Rodda GH (2009) Distribution, density, and biomass of introduced small mammals in the southern Mariana Islands. Pacific Science 63:205-222

Wiles GJ (1987) The status of fruit bats on Guam. Pacific Science 41:148-157

Wiles GJ (2005) A checklist of the birds and mammals of Micronesia. Micronesia 38:141-189

Wiles GJ, Bart J, Beck RE Jr, Aguon CF (2003) Impacts of the brown tree snake: patterns of decline and species persistence in Guam’s avifauna. Conservation Biology 17:1350–1360

Woods T, Morey S (2011) A Strategic Framework for Allocation Guidance for the Multi-Agency Brown Treesnake Working Group: Brown Treesnake Technical Working Group – Meeting Report, 3 – 5 August 2011

7.0 APPENDICES

Appendix A. Species of native birds, lizards, and bats impacted by the introduction of brown treesnakes to Guam. Information for bird status was derived from Wiles et al. (2003), where it was not defined. For bats, Wiles (1987, 2005) were sources of information.

Common name	Species	Status
Guam flycatcher	*Myiagra freycineti*	Extinct
Micronesian kingfisher	*Todiramphus cinnamominus*	Extirpated/Captive population
Guam rail	*Gallirallus owstoni*	Extirpated/Captive & introduced populations
White-throated ground dove	*Gallicollumba xanthonura*	Extirpated
Mariana fruit-dove	*Ptilinopus roseicapilla*	Extirpated
Rufous fantail	*Rhipidura rufifrons*	Extirpated
Nightingale reed-warbler	*Acrocephalus luscinia*	Extirpated
Micronesian honeyeater	*Myzomela rubrata*	Extirpated
Guam bridled white-eye	*Zosterops conspicillatus*	Extirpated
Mariana crow	*Corvus kubaryi*	Extirpated
White-tailed tropicbird	*Phaethon lepturus*	Extirpated
Brown booby	*Sula leucogaster*	Extirpated
Brown noddy	*Anous stolidus*	Nearly/Temporarily extirpated
White tern	*Gygis alba*	Decline
Mariana swiftlet	*Aerodramus bartschi*	Decline >90%
Micronesian starling	*Aplonis opaca*	Decline >90%
Mariana common moorhen	*Gallinula chloropus guami*	Decline
Micronesian gecko	*Perochirus ateles*	Extirpated
Island gecko	*Gehyra oceanica*	Decline >90%
Mutilating gecko	*Gehyra mutilata*	Decline
Mariana fruit bat	*Pteropus mariannus mariannus*	Decline >90%
Little Mariana fruit bat	*Pteropus tokudae*	Extinct

Appendix B. A compilation of the important programmatic accomplishments of the Brown Treesnake Technical Working Group. It should be noted that the releases of crows and rails and protection measures at crow nest trees did not result in establishing or preserving wild populations on mainland Guam.

Year	WS	NWRC	USGS	DoD[1]/ CNMI DFW[2]/ HDOA[3]/ GDAWR[4]
1985				[4] – BTS implicated in bird extinctions; [4] – preliminary trap development w/ live bait; [4] – diet & population characteristics studied
1986			• BTS easily captured using visual search; • BTS found regularly on planes	
1987			• patterns of BTS activity discerned via timing of power outages	[4] – Efforts began to protect birds nesting in trees; [4] – Preliminary investigative trapping at Mahlac Cave finds BTS consuming swiflets
1989			• BTS need visual cue to enter trap	
1990			• BTS caused loss of some lizard species; • BTS pose risk to human infants; • Rodent response to BTS control documented; Initial BTS barrier testing	[4] – Initiated efforts to introduce rail to Rota; [4] – Create & test electric snake barrier to protect nest trees;
1991		• Fumigant development initiated	• BTS escape traps w/o flaps; • BTS eliminated Guam's poultry industry	[2] – Interdiction began in the CNMI; [4] – Various methods used to protect bird nests
1992			• Standard snake trap baited with live mice developed; • ID Origin of Guam BTS population	[3] – Interdiction began on HI

Year	WS	NWRC	USGS	DoD[1]/ CNMI DFW[2]/ HDOA[3]/ GDAWR[4]
1993	• Interdiction began on Guam at NBG & AAFB		• Huge variability in efficacy of humans searching for BTS; Creation of 1st 2. 5 acre BTS exclosures & BTS eradicated; • Document rodent response to BTS eradication	[4] – Six Rota crows captured & sent to mainland zoos
1994	• Last live BTS on HI reported; • Guam canine inspections began	• Methyl bromide registered as a fumigant for removing snakes from cargo or vehicles	• BTS found to suppress remaining lizard populations	
1995	• BTS control began at commercial packing & shipping companies	• Testing of alternatives to the use of live mice as bait in traps began; Work to develop alternative fumigants began	• "Eradication" methods tested on exclosures; Estimated economic impacts of BTS establishment on HI	[4] – Further testing of electric snake barrier on trees successful
1996		• BTS diet studies continued & incubation documented	• Mark-recapture found superior to other methods for BTS population estimates	[4] – Trapping of sections AAFB MSA to protect native fauna began
1997	• Current trap trap deployed	• Rodent response to BTS control documented on landscape-scale; • DNM bait developed	• Permanent & temporary barrier development	[1] – WS dog kennel constructed on NBG; [2] – Dog inspections began; [1, 4] – 1st operational BTS barrier constructed at Area 50 on AAFB; [4] – Six captive-reared crows released
1998	• BTS control work for GPA began	• Dog & spotlight searches & trap placement evaluated;		[4] – 16 captive-reared rails released in Area 50 on AAFB
1999	• Trapping of sections AAFB MSA to protect native fauna began	• Blind testing improves dog team performance; Oral toxicant acetaminophen developed	• Small BTS not readily trapped; • *Problem Snake Management* volume published	[1,4] – Rails hatched 42 0f 50 eggs in Area 50 on AAFB
2000	• Trapping at Mahlac Cave to protect Mariana swiftlet	• Bait stations developed as control method	• Determined diseases & parasites ineffective as BTS biocontrol	[4] – Seven Rota crows released in MSA
2001		• Acetaminophen registered; • ID artificial attractant odors	• Complete removal methods developed for population estimation; • Sterilized male BTS used for dog training	[4] – Five Rota crows released in MSA, totaling 12; [4] – BTS surveys on Cocos Island

BTS TWG Goals

Year	WS	NWRC	USGS	DoD[1]/ CNMI DFW[2]/ HDOA[3]/ GDAWR[4]
2002	• Oral toxicant field trials; • Trapping at Fachi & Maemong Caves to protect swiflets	• Aerial broadcast of DNM & toxicant tested; Inspector dogs evaluated	• RRT created; • BTS-related power outages cost Guam $4.5M/yr	
2003	• Annual dog team proficiency tests	• Development of BTS repellent & testing of trap spacing	• Reduction of rodents enhances trappability of BTS by up to 65%	[4] – 44 captive-reared rails released in MSA, most killed by feral cats
2004	• Coop. agreement for 30 commercial packing & shipping warehouses	• Repellents patented & licensed; • Non-prey baits developed	• Construction of closed population research facility on AAFB	[4] – Cocos Island restoration planning began
2005	• Quantified effectiveness trap models	• Alternative baits & traps developed	• Additional permanent barrier technology tested, found effective	[2] – BTS containment interdiction barrier on Saipan implemented; CNMI BTS awareness program, “28SNAKE” implemented
2006			• Trapping largely ineffective for BTS with a total length of <40 in.	[4] – 1st parent-reared crow fledged in the wild since early ‘90s
2007	• Oral toxicants integrated interdiction	• Streamer for aerial broadcast developed; BTS population reduced on trial plots with aerial broadcast	• Utility of visual search quantified; • Small snake trap “resistance” due to dietary preferences; • BTS reproductive factors quantified	[2] – BTS containment interdiction barrier on Tinian implemented; [4] – Ko’ko’ for Cocos awareness campaign began
2008	• Rodents eradicated on Cocos to facilitate early detection of BTS & improve habitat for ko’ko’ release (in collaboration w/GDAWR)	• Commercial repellents tested for BTS use	• Bait tubes found to have size selectivity similar to traps; • BTS found to have greatly changed activity behavior over past 20 years	[1] - WS dog kennel expansion on NBG
2009		• ID pheromone components; economic assessment of BTS invasion	• BTS found to be prey-limited; detector dogs can locate BTS in forested landscapes	[2] – 90% inspection of cargo & aircraft from Guam
2010	• Spatial data mgmt.; 99% inspection rate of military & civilian cargo/flights; • AABS trials conducted on NBG	• Automated Aerial Broadcast System conceptualized; • ID potential BTS irritants	• BTS capture probability has 7-day intervals; Gecko-baited traps fail to capture small BTS	[1] – Toxic bait stations used in interdiction at AAFB; [4] – 16 captive-reared rails released on Cocos Island

BTS TWG Goals

Year	WS	NWRC	USGS	DoD[1]/ CNMI DFW[2]/ HDOA[3]/ GDAWR[4]
2011		• Developed products to enhance non-prey baits	• Reaffirmation of snake removal causes rodent irruptions	[1] – HMU BTS exclosure completed at AAFB; [4] – rails reproduce on Cocos Island
2012	• 99.5% inspection rate of military & civilian cargo/flights	• Automated Aerial Broadcast System bait package & applicator designed	• Intermediate-sized BTS more easily detected via visual searching than other size snakes	[2] – Interim Improvement Plan implemented; [4] – 10 rails released on Cocos Island; BTS “Kontre I Kulepbla” awareness campaign
2013		• Automated Aerial Broadcast System initial processing designs completed	• Roads determined to be partially effective barriers to BTS movement	[1] – HMU BTS exclosure operational

See List of Abbreviations for definitions.

Appendix C. Comprehensive list of laws, Executive Orders, directives, regulations and policies related to brown treesnake control.

Federal

- 1934 - Fish and Wildlife Coordination Act (16 U.S.C. §§ 661-667e, as amended 1946, 1958, 1978 and 1995). Authorizes the Secretary of the Interior to provide assistance to, and cooperate with, federal, state, and public or private agencies and organizations in protecting wildlife, and minimizing damages from overabundant species.

- 1947 - Federal Insecticide, Fungicide, and Rodenticide Act. In accordance with this Act (7 U.S.C., Chapter 6, Section 136r-1), the Secretary of Agriculture, in cooperation with the Administer "shall implement research, demonstration, and education programs to support adoption of Integrated Pest Management." Integrated Pest Management (IPM) is defined as "a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks." This Act also mandates that federal agencies use IPM techniques for the undertaking of pest management activities, and that IPM will be promoted through procurement and regulatory policies, and other activities.

- 1969 - National Environmental Policy Act. Through this Act, Congress recognizes the impact of human activities on the environment. This Act states that it is the responsibility of the Federal Government "to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate federal plans, functions, programs, and resources to the end that the Nation may fulfill the responsibilities of each generation as trustee of the environment for succeeding generations."

- 1973 – Endangered Species Act (ESA). Established to protect and recover imperiled species and the ecosystems upon which they depend. Although the ESA has no direct role in the management of BTS, it is currently the principal regulatory mechanism preventing the introduction of BTS outside of Guam. Because BTS are a threat to the recovery of listed species and have the potential to create additional listed species, the ESA can be used to influence entities to fund or adopt BTS-related interdiction or recovery efforts. Each federal agency is to ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed species and federally funded programs at the state and local level, such as port improvements, require a Section 7 consultation process.

- 1977- Executive Order 11987, Exotic Organisms. Directs executive agencies, to the extent permitted by law, to restrict the introduction of exotic species into the natural ecosystems on lands and waters which they own, lease, or hold for purposes of administration; and, shall encourage the States, local governments, and private citizens to prevent the introduction of exotic species into natural ecosystems of the United States.

- 1980 - Fish and Wildlife Conservation Act; (16 USC 2901-2911; 94 Stat. 1322. Public Law 96-366). Authorizes the USFWS to provide financial and technical assistance to the States for the development, revision, and implementation of conservation plans and programs for nongame fish and wildlife.

- 1990 - Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (P.L. 101-646), (reauthorized in 1996 as National Invasive Species Act). Set up interagency task force to direct cooperative efforts to control invasive species, including BTS. Required task force to develop and implement comprehensive program to control BTS, producing the 1996 Brown Tree Snake Control Plan; established the Aquatic Nuisance Species Task Force (ANSTF).

- 1991 - National Defense Authorization Act for fiscal years 1992 and 1993 (Section 348). Directs the Secretary of Defense to take such action as may be necessary to prevent the inadvertent introduction of brown treesnakes from Guam to Hawaii in aircraft and vessels transporting personnel or cargo for the Department of Defense.

- 1992 – Amendment to Lacey Act (18 USC 42). Makes it a crime to import species of wild animals, wild birds, fish (including mollusks and crustacea), amphibians, reptiles, or the offspring or eggs or any of the foregoing which the Secretary of the Interior prescribes by regulation to be injurious to human beings or to the interests of agriculture, horticulture, forestry, or wildlife, except that the Secretary may permit importation for zoological, education, medical, or scientific purposes.

- 1993 – Memorandum of Agreement on Brown Treesnake Control. (1996 CNMI added as a participating agency; renewed 1999 adding DOT; renewed 2011 adding National Invasive Species Council [NISC]). Established a working relationship between DOI, DoD, USDA, GovGuam, Hawaii, CNMI, DOT, and NISC.

- 1996 – National Invasive Species Act (NISA amended and reauthorized NANPCA). Created an interagency task force to direct cooperative efforts to control invasive species, including BTS; required task force to develop and implement a comprehensive program to control BTS, producing the 1996 BTS Control Plan.

- 1998 - Animal Damage Control Act of March 4, 1931; (7 USC 426-426b, 47 Stat. 1468). Amended to direct the Secretary of Agriculture to take actions as necessary to prevent the introduction of brown treesnakes from Guam to other areas of the US, specifically Hawaii. Section 426b authorizes funding.

- 1999 - Executive Order 13112, Invasive Species. Directs federal agencies to prevent the introduction of invasive species, detect and respond rapidly to and control populations of such, monitor invasive species populations, provide for restoration of native species and habitat conditions in ecosystems that have been invaded, conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally sound control of invasive species, and promote public education on invasive species and the means to address them. It also directs agencies to not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species. This Executive Order established the National Invasive Species Council.

- 2003 - Conservation and Rehabilitation Program on Military and Public Lands, as amended from 1960 Act; (Public Law 86-797) (Sikes Act). Directs the Secretary of Defense to carry out a program to provide for the conservation and rehabilitation of natural resources on military installations.

- 2004 - Brown Tree Snake Control and Eradication Act of 2004 (Public Law 108-384, 118 Stat. 2221-2226). Expresses the sense of Congress that there exists a need for improved and better coordinated control, interdiction, research, and eradication of the brown treesnake on the part of the United States and other interested parties. Directs the Secretaries the Interior and Agriculture to provide funds (subject to availability) to support brown treesnake control, interdiction, research, and eradication efforts carried out by the Departments of Interior and Agriculture, other federal agencies, states, territorial governments, local governments, and private sector entities. Appropriations are authorized for such purpose.

  Within two years after the date of the enactment of this Act, but subject to the specified memorandum of agreement with respect to Guam, the Secretaries were directed to establish a system of pre-departure quarantine protocols for cargo and other items being shipped from Guam and any other United States location where the brown treesnake may become established to prevent the introduction or spread of the brown treesnake. Established the Technical Working Group to ensure that federal, state, territorial, and local agency efforts concerning the brown treesnake are coordinated, effective, complementary, and cost-effective.

- 2008 - National Defense Authorization Act for Fiscal Year 2009. Section 316. Directs the Secretary of Defense to establish a comprehensive program to control and, to the extent practicable, eradicate the brown treesnake populations from military facilities in Guam and to ensure that military activities, including the transport of civilian and military personnel and equipment to and from Guam, do not contribute to the spread of brown treesnakes.

<u>Department of Defense Directives</u>

- 1996 – National Defense Authorization Act for Fiscal Year 1997 (Public Law 104-201, Section 2694). Defined Legacy funding criteria to include control of invasive species that may hinder military activities or degrade military training ranges.

- 1996 - DoD Instruction 4715.3 Environmental Planning and Analysis. Instruction 4715.9 states that it is DoD policy to “integrate environmental considerations into DoD plans for defense activities” and that “DoD activity and operational planning should fully consider the environmental consequences of proposed actions in conjunction with national security requirements and other considerations of national policy.”

- 2005 – CONMNAVMARIANAS INSTRUCTION509010.A. This instruction provides guidance and direction to prevent the dispersal of brown tree snakes from Guam to other locales via military sea and air shipments of personnel, equipment, and cargo. Its provisions are applicable to all activities in the COMNAVMARIANAS AOR who directly or indirectly have responsibility for military sea and air shipments. This instruction issues a revised Brown Tree Snake Control and Interdiction plan that is to be followed during the planning and execution of any movement of military sea and air shipments, including personnel. This instruction applies to Guam Installation Commanders, Major Exercise Commanders, Training Unit Commanders, and all military Flight Crews.

- 2006 - 36 WG INSTRUCTION 32-7004. This instruction implements the Brown Tree Snake Control Plan prepared under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, the Brown Tree Snake (BTS) Control and Interdiction Plan (COMNAVMARIANAS INSTRUCTION 5090.10) dated June 2000, and the Brown Tree Snake Control and Eradication Act of 2004 . The purpose of this instruction is to establish procedures and guidelines to prevent the spread of BTS to areas where it is not already established via the AAFB transportation network. It outlines the procedures for cooperative interagency efforts to control and interdict BTS, including DoD coordination, support, and documentation of inspections of outgoing aircraft and cargo by WS personnel.

- 2008 - Report to the Congress, Control of the Brown Treesnake. As a response to the NDAA (FY 2008), a report was submitted to Congress on the control of the brown treesnake. The report provides background on the BTS introduction along with actions taken in response to the BTS introduction. The report states that both Navy and Air Force have committed to 100-percent snake-free cargo and to programming for BTS control and inspection costs in the future. Plans to address the increase of military personnel on Guam are also discussed in the report.

- 2009 – Duncan Hunter National Defense Authorization Act For Fiscal Year 2009 (Public Law 110-417, Section 316, Statute 4356). Required that “The Secretary of Defense shall establish a comprehensive program to control and, to the extent practicable, eradicate the brown tree snake population from military facilities in Guam and to ensure that military activities, … do not contribute to the spread of brown tree snakes.”

- 2009 - Defense Transportation Regulation, Agricultural Cleaning and Inspection Requirements (Part V, Chapter 505). Agricultural Cleaning and Inspection Requirements (Part V, Chapter 505) states that it is the policy of DoD to undertake the necessary actions to prevent transport of non-native species (e.g., BTS) via military-associated cargo and movements.

- 2010-2015 - Biological Opinion for the Mariana Islands Range Complex, Guam and the Commonwealth of the Northern Mariana Islands. The MIRC BO states that the Navy works in cooperation with the USFWS and USDA-APHIS to implement BTS control. This is accomplished through inspection of cargo departing Guam, communication with destinations receiving cargo from Guam, snake-free quarantine areas, support of BTS rapid response, and providing education for DoD personnel.

- 2011 - DoD Instruction 4715.03 Instruction Natural Resources Conservation Program. Per 4715.03 Encl 3, Section 3 Biodiversity, e (Page 21) DoD shall identify, prioritize, monitor, and control invasive and noxious species and feral animals on its installations whenever feasible. Accordingly native species should be used, where feasible, to restore any habitats from which native species are removed or controlled. Per 4715.03 Encl 3, Section 4 Land Management, d: Environmentally and economically beneficial landscaping practices shall be used on all DoD lands consistent with the Presidential Memorandum on "Environmentally and Economically Beneficial Practices on Federal Landscaped Grounds," each installation shall, to the extent practicable, conserve and protect water resources, use locally adapted native plants, avoid using invasive species, and minimize the use of pesticides and supplemental watering.

- 2013 - COMNAVMARIANASINST 3500.4A. Marianas Training Manual. The instruction provides governing procedures for the use of training areas, ranges, and airspace operated under the jurisdiction of the United States Naval Forces, Marianas. Instructions and procedures applicable to Guam, Saipan, Tinian, Rota, and Farallon de Medinilla are made available. Guidance in the instruction identifies specific land use constraints for the protection of environmental resources during military activities within the Mariana Islands Range Complex.

- 2013 - OPNAVINST 5090.1D, Environmental Readiness Program Manual. The Navy is committed to operating in an environmentally responsible manner. National defense and environmental protection are required to be compatible goals. All Navy military and civilian personnel, installation tenants, and contractors working for the Navy shall comply will all applicable Federal, State, and local environmental laws and regulations.

- 2014 - Chief of Naval Operations (OPNAV) Instruction and Manual 5090.1D, Environmental Readiness Program. OPNAV Instruction 5090.1D replaces OPNAV Instruction 1.C dated 2007 and identifies requirements, delineate responsibilities, and issue implementing policy guidance for the management of the environmental, natural, and cultural resources for all Navy ships and shore activities. Specific to invasive species Navy supports prevention and rapid response in order to reduces costs and impacts to the mission, while enhancing native ecosystems. Navy policy requires that invasive species programs.

<u>Government of Guam Laws, Regulations and Policies</u>

- Endangered Species Act of Guam: (5 GCA 63208, Public Law 6-85). Law allows for the adjudication of an endangered species list for Guam.

- Game, Forestry and Conservation; (5 GCA, Chapter 63, Public Law 6-85). Government Code of Guam (Section 47104). Gives the Department of Agriculture the authority to enforce and submit changes for adjudication the laws that govern Game, Forestry, and Conservation.

- USFWS Cooperative Agreement. An agreement that allows Guam to implement endangered species recovery programs

<u>Commonwealth of the Northern Mariana Islands Laws, Regulations and Policies</u>

- Commonwealth Plant and Animal Quarantine Act (2 CMC Section 5301).

- Animal Health Protection and Disease Control Act (2 CMC Sec 5320). Establishes a well – defined system of animal quarantine, inspection procedures, and disease control activities to provide for the sound protection of domestic animals, poultry and birds, as well as pet animals and the public health.

<u>State of Hawaii Laws, Regulations and Policies</u>

- Hawaii Administrative Rules, Title 4 Department Of Agriculture Subtitle 6 Division of Plant Industry: (HRS, Section 150A-6) *States in part*: "(3) Any live snake…..in any stage of development…., except as provided in this chapter and provided that, notwithstanding the list of animals prohibited entry into the State, the department may bring into and maintain in the State four live, sterile brown tree snakes of the male sex for the purpose of research or training of snake detector dogs, and, further, that a government agency may bring into and maintain in the State not more than two live, nonvenomous snakes of the male sex solely for the purpose of exhibition in a government zoo,.….".

- HRS, Section 150A-6.2 Animal import. *States in part:* "(a) The board shall maintain: …. (3) A list of animals that are prohibited entry into the State…..".

(b) HAR, Chapter 4-71, entitled "Non-Domestic Animal Import Rules". HAR, Section 4-71-6 Prohibited introductions. "(a) The introduction into Hawaii of live animals or live non-domestic animals as defined in this chapter at any stage of development is prohibited except for those animals on the lists incorporated in §4-71-6.5 by permit, and except as provided by section

150A-6.2, HRS. (b) The list of animals designated as prohibited entry pursuant to section 150A-6.2, HRS, dated November 28, 2006, and located at the end of this chapter is made a part of this section. No person shall introduce into Hawaii any animal from the list of prohibited animals."

LIST OF PROHIBITED ANIMALS   States in part: "Serpentes (all species in snakes suborder, except for two male nonvenomous snakes for exhibition in a government zoo, and for four sterile male brown tree snakes, Boiga irregularis,for research or training of snake detector dogs by the department)".

Appendix D. Detailed cost comparison between Hawaii Department of Agriculture (HDOA) and Wildlife Services (WS) to re-initiate and implement the canine inspection program in Honolulu. Estimates based on FY2012 funding.

No. Personnel	Position	Agency
1	Trainer	HDOA
3	Canine Handler	HDOA
Total annual cost, based on three years average of funding DOI provided to HDOA.		$231,466
1	Supervisory Wildlife Biologist	WS
1	Trainer	WS
3	Canine Handler	WS
Total annual cost (incl. salaries, benefits, maintenance, office space, supplies). Cost of 3 vehicles is amortized over 6 years.		$473,026

Appendix E. Detailed cost comparison between interdiction efforts conducted by the Commonwealth of the Northern Mariana Islands, Division of Fish and Wildlife (CNMI DFW) and Wildlife Services (WS) in the CNMI. Estimates based on FY2012 funding.

Personnel	Position	Agency – Location
1	Supervisory Wildlife Biologist	USFWS – Saipan
1	Trainer / Canine Handler	CNMI DFW – Saipan
4	Canine Handler (1 position vacant)	CNMI DFW – Saipan
1	Trapper	CNMI DFW – Saipan
2	Canine Handler / Trapper (1 position vacant)	CNMI DFW – Rota
1	Canine Handler	CNMI DFW – Tinian
Total annual cost (incl. salaries, benefits, vehicles, maintenance, office space, supplies)		$548,451
1	Supervisory Wildlife Biologist	WS – Saipan
1	Trainer	WS – Saipan
5	Canine Handler	WS – Saipan
1	Trapper	WS – Saipan
1	Canine Handler	WS – Rota
1	Canine Handler	WS – Tinian
	Total annual cost (incl. salaries, benefits, maintenance, office space, supplies). Cost of 6 vehicles amortized over 6 yr.	$969,644
1	Supervisory Wildlife Biologist	WS – Saipan
1	Trainer	WS – Saipan
5	Canine Handler	WS – Saipan
1	Canine Handler	WS – Rota
1	Canine Handler	WS – Tinian
Total annual cost (incl. salaries, benefits, maintenance, office space, supplies). Cost of 6 vehicles is amortized over 6 years.		$923,390

BTS TWG Goals

Appendix F.

BROWN TREESNAKE RESEARCH COMMITTEE
ACTION PLAN
JANUARY 2015

INTRODUCTION

In 2012, the Brown Treesnake (BTS) Technical Working Group (TWG) chartered the BTS Research Committee (BTS RC). The primary goal of the BTS RC is to develop strategic long-term plans as well as a shorter term (2-3 year) Action Plan for advancing research on the BTS, focusing on developing the biological knowledge and technical ability required to meet the goals of the BTS TWG. Membership on the BTS RC is drawn primarily from the BTS TWG, but includes a subject matter expert from the larger scientific community. Despite the varied missions and priorities of the involved organizations, it rapidly became apparent to all BTS RC members that although BTS research has been remarkably successful, a critical historical weakness remains in place: the lack of predictable base funding for agencies responsible for BTS research.

To secure stable base funding in pursuit of its goals, the BTS RC generated three overarching “Research Themes” to support the larger objectives of the BTS TWG. These themes are: (1) Interdiction, Early Detection & Rapid Response (EDRR); (2) Landscape-Scale Suppression; and (3) Restoration. Each theme was then populated with what the BTS RC recommended were the highest “Priority Research Areas.” The recommended themes and priority research areas were then approved by the entire BTS TWG. Subsequently, for each theme, the BTS RC developed a list of potential research topics to pursue in a 2-3 year timeframe. During this timeframe, the BTS RC will annually review the progress made on topics that have been pursued.

Achieving the research themes stated in the BTS TWG Strategic Plan and this Action Plan is dependent on a suite of components. Research is foremost, which requires consistent reliable funding; however, changes in regulations and policies, more outreach, and improvements in training are important. It is also is essential to clearly define the goal of each theme. The goal of the first research theme, (1) Interdiction, Early Detection & Rapid Response, is two-fold: develop tools that will minimize or eliminate the risk of a BTS being transported off Guam and increase the probability of detecting BTS that do disperse off Guam to other locations. The intent of the (2) Landscape-scale Suppression theme is focused on developing methodologies that will enable managers to reduce BTS numbers on Guam at a spatial scale that will allow for the recovery of the island’s native species. Inherent in this theme is the goal of understanding the effect of population-level suppression methods on BTS and non-target species. The goal of the (3) Restoration theme is to understand the response of native species to landscape-scale suppression of BTS, and to enhance the probability that recovery efforts will be successful.

BTS TWG Goals

BTS RESEARCH HISTORY & CURRENT STATUS

High-quality, output-driven research has been a hallmark of BTS control and containment programs since their inception. This research has traditionally been funded by Department of the Interior through grants from the Office of Insular Affairs and the Department of Defense has provided frequent support for research through specific contracts and funding. The first few years of BTS research effort were spearheaded by staff from the Guam Department of Agriculture - Division of Aquatic and Wildlife Resources and the U.S. Fish and Wildlife Service (USFWS). The research arm of USFWS was later split off to form the U.S. Geologic Survey (USGS) and the National Wildlife Research Center (NWRC). In the early 1990s, researchers and vertebrate control experts from NWRC and Wildlife Services joined BTS research and control efforts. An array of scientists has been involved in BTS research over the years, including cooperators from territorial, state, and federal agencies as well as universities and non-governmental organizations.

Initial BTS research efforts focused on investigating the basic biology of the snake to discover potential vulnerabilities, while simultaneously developing and testing control tools (especially traps). These two research areas continue to interact strongly, as nearly every new finding on the biology of the BTS helps refine our collective understanding of the efficacy of control methodologies. Concurrent with the early investigations on the biology of the BTS and control methods, researchers were documenting the high economic costs of the snake on Guam, as well as risks to human health.

An important product of early research efforts by NWRC and USGS was the current BTS trap. USGS researchers initially developed and tested the concept of a mouse-baited snake trap with one-way entrances. Over the course of testing dozens of trap variables, they succeeded in achieving capture rates that are two orders of magnitude higher than the average for snake traps worldwide (Rodda et al. 1999). Once trap capture rates had been maximized, NWRC and WS biologists took the existing design and made the traps easier to service and more durable. These traps remain the most effective snake traps in use anywhere in the world (Rodda et al. 1999). Overall, the development, testing, and validation of control tools via intensive research programs has directly contributed to the success of interdiction efforts by operational agencies, as these agencies currently use the products of this research.

The need to establish snake-proof barriers became apparent early in efforts to interdict the BTS. To that end, researchers in the 1990s designed and tested barriers capable of excluding the BTS. The foremost challenges to excluding snakes were overcoming their excellent climbing abilities, while designing access points that allow human entry and exit, but block the BTS. Because of the extensive research conducted by BTS TWG partnering research agencies, a suite of barrier types have been deployed in Guam and the CNMI. These include temporary barriers to reduce snake incursions into materiel during short-term inter-island training exercises, permanent concrete barriers for use around ports, and concrete-base/wire-mesh barriers to enclose conservation areas. Despite these being the only fully-tested snake barriers anywhere in the world, further research is warranted to achieve cost savings through greater durability and improved materials.

BTS TWG Goals

After initial development of effective traps and barriers, managers had tools to reduce the risk of the BTS infiltrating Guam's out-going transportation system; however, no tool is 100% effective. Therefore, the need for other methods and tools is required. In response, researchers developed methods to chemically exclude the BTS via repellents and expelling or killing snakes in cargo via fumigation and thermal treatments. Unfortunately, environmental and cargo-integrity concerns have hampered their use in operations. Research was also conducted to test the efficacy of canine teams in detecting snakes planted in cargo and other parts of the transportation network resulting in increased confidence in ongoing efforts to keep snakes from escaping Guam. Subsequently, validation of canine teams for finding the BTS in forests offered a new means of detecting and localizing incipient populations on other islands in response to snake sightings. Unfortunately, budgetary constraints have hindered the full implementation of this program.

While the control tools developed by the research program are productive in terms of the number of snakes removed from transportation pathways and high-priority ecological areas, questions remained about the level of population suppression resulting from the application of a given tool and the feasibility of eradication at any scale. Therefore, validation of control tools (i.e., visual searching, trapping, toxicant application, etc.) at a population level were a major research focus over the last decade, with the goal of understanding which snakes are missed by each tool and how the size and sex of missed snakes might affect population recovery and control opportunities. Such efforts required large investments in fieldwork and development of quantitative tools for analyzing the resulting datasets, and further advancements will require additional funding.

More recently, significant progress has been made towards developing landscape-scale control tools using ground-based and aerial delivery of a snake toxicant. After years of intensive research, in 1999 a highly effective toxicant (acetaminophen) was registered by the Environmental Protection Agency for use on the BTS. Over the last five years, the Automated Aerial Broadcast System (AABS) has undergone many steps in a multi-phase development process. Several stages have been completed and additional research is being conducted in support of this promising technology.

CURRENT & FUTURE RESEARCH NEEDS

The previous decades of research has greatly improved the BTS interdiction tools and EDRR strategies. Research has also provided the AABS, a tool capable of suppressing BTS across large areas in natural habitats, potentially enabling the recovery of native species. However, extensive research still needs to be pursued to achieve the goals of the BTS TWG. In particular, effective management and interdiction efforts continue to require a thorough understanding of difficult biological questions, such as snake population response to trapping, toxicant application, and other control efforts. Although interdiction and control programs are effective at removing large numbers of individuals, some segments of the population may be less susceptible to removal with the tools in current use. One example is juvenile snakes, which may fail to recognize rodents as suitable prey (Lardner et al. 2009) making them less attracted than adult snakes to control tools using mice as baits (Tyrrell et al. 2009, Lardner et al. 2013).

This variation in susceptibility of the BTS to mouse baits is one of the underlying problems for population control and interdiction. Researchers continue to try to understand how variation in efficacy of control tools for smaller snakes influences the ability to suppress snakes at the landscape level, intercept snakes moving through areas of interdiction protecting resources (e.g., cargo consolidation areas, ports areas, power lines) or to target and detect incipient snake populations. Understanding the implications of these 'missed' individuals for long-term population suppression and eradication prospects remain a key research need. Currently, it is understood that repeated toxicant applications will be required over time to eliminate snakes as they grow to sizes for which mouse baits are effective. It is critical to determine the frequency and duration of bait application necessary to achieve the desired level of snake suppression and how factors such as sex, size, reproductive status, and foraging history interact.

Snakes arriving on other islands in the Pacific region pose additional problems. They are often difficult to locate, therefore a need exists for tools for detecting snakes at very low densities. The utility of canine searches for the BTS in the forest has been validated, but more research effort is needed to make this technique fully operational. Aside from the "needle in the haystack" problem of trying to detect snakes at low densities, food resources are also often abundant and therefore snakes may not be attracted to standard mouse-baited traps. The latter is of particular concern when attempting to detect low-density snakes on recipient islands such as Saipan or Oahu. It is important to determine how to make control techniques effective in food-rich environments on other islands or areas with alternative prey (e.g., introduced frogs). Basic biological concepts continue to need to be investigated to target these individuals to ensure that control efforts are effective.

Recent trials of aerial drops have progressed to the stage that there is promise that this method can control snakes over large areas. However, these trials only demonstrate a proof of concept. Manually broadcasting baits, while feasible, is prohibitively expensive. The Automated Aerial Broadcast System (AABS) would increase the efficiency of broadcasting baits at least 40-fold compared to hand broadcast and greatly decrease helicopter time. To reduce the cost of application and scale this method up, the AABS must become operational. The AABS is more than two thirds through its development and implementation process, but continued funding is needed to proceed with the next stage. Concurrent with the development of the AABS, efforts to develop artificial baits to replace the dead mice that are used with aerial broadcast are being pursued. Currently, mice (live adult and dead neonates) are the only bait effective at attracting the BTS, which presents several problems. Live mice are expensive to purchase and maintain, and DNMs are only effective for a few days before decomposition renders them useless. Mice are also difficult to deploy in the field, requiring separate housing for live mice within BTS traps and "streamers" attached to DNM for air-drops. Although bait development has yet to show efficacy in the field after several years of effort, further research is essential.

Once advancement in control strategies allow a shift from site-specific control to large scale suppression, information on the effect of snake removal on other animals is needed so we can effectively prepare for unintended consequences of snake removal. Once snakes are removed, the densities of rodents and lizards may increase significantly. Evidence for this can be found on nearby snake-free islands, which have rodent densities more than 10 times those on Guam (Wiewel et al. 2009). As noted above, high rodent densities may also make control or interdiction tools less effective. Similarly, lizard populations and recently introduced frog populations may increase in size in response to BTS suppression providing more potential prey for the BTS, which could confound control efforts (Christy et al. 2007, Campbell et al. 2012). High rodent densities could not only complicate BTS control, it could also result in unexpected economic or ecological damage, with the potential to impact restoration of native ecosystems and species (Sweetapple and Nugent 2007). Integrating multiple sources of information on the biology of the BTS and its prey and the population-level efficacy of control tools will allow much more precise predictive models that will enable managers to predict the degree of snake suppression that can be expected as a result of a given control program and how populations of the prey of BTS may respond.

Restoration of native species throughout Guam is contingent upon having effective BTS control techniques and then applying these on a large scale. The current and historic BTS research, from individual tool development to broad-scale suppression strategies, contributes to the eventual restoration of Guam's native species and its ecosystem as a whole. Up to now, successful releases and protection of native species have been limited in scope due to several factors, including the inability to suppress snakes across large areas and the endangered status of the species involved in the release projects (i.e., limited amount of crows and permissions for release,). These small-scale field studies have developed successful strategies for protection of nesting individuals from snake predation and release methodologies (Aguon et al. 1999). With broad-scale BTS control strategies available for testing in suitable release sites, releases of native species and inroads to recovery are possible.

Some aspects of restoration can be advanced through modeling. For instance, research on the spatial dynamics and life history characteristics of Guam rail populations on Rota or Cocos are necessary to conduct minimum viable population analyses, which could then aid in determining the size of snake exclosure necessary for the persistence of a rail population. The enhanced ability to measure/remove snakes at low densities would assist in improving the efficiency of snake control programs. The low-density snake population measurements could feed into models that determine the level of snake control necessary to allow native species to persist in the wild.

The above described priority research areas are essential to achieving the zero tolerance policy for BTS establishing outside of Guam. To prevent BTS from being transported off Guam it is vital to improve control and interdiction techniques. It is also necessary to develop and improve the methodologies to detect and eradicate new BTS populations should they be transported to the CNMI, Hawaii, or elsewhere. Finally, research areas in this Action Plan are critical to advancing the progress towards large-scale control of the BTS on Guam, the latter being a requisite step for restoring native ecosystems and species on the island.

BTS TWG Goals

RESEARCH THEMES, PRIORITY AREAS, AND TOPICS

Below are the research themes, priority areas, and specific topics developed by the BTS RC. The themes represent the broad goals of the BTS TWG, which are to prevent BTS from being transported of Guam and establishing in other locations, and to restore native ecosystems and species on Guam. Although, all the themes are important, the order in which they are presented below reflects some ranking. Interdiction and EDRR are the foremost priority of the BTS TWG, while BTS suppression on a land-scape is an essential prerequisite for restoration of native species on Guam. Within a theme, the order of these items does not necessarily indicate the relative importance of a particular theme, area, or topic. Topics are designated under a specific priority area and theme, but there is considerable overlap. Some topics will have utility in multiple priority areas within a theme, other topics cross more than one theme, and some topics are presented more than once. The BTS RC considers that with appropriate funding, substantial progress can be achieved on many of these topics within the 2-3 year timeframe of this Action Plan. Topics labeled “Tech Watch” are exceptions. These topics have the potential to further BTS management efforts and warrant attention; however, some topics are currently prohibitively expensive and others require technological advancements outside of the realm of the BTS RC.

INTERDICTION, EARLY DETECTION & RAPID RESPONSE

Quantify & increase BTS interception rates

- Determine most efficacious combinations of current interdiction techniques.
- Evaluate optimal spacing and density of traps and bait tubes over varying landscapes.
- Determine if moving/shifting of traps affects capture rates.
- Improve canine detection efficacy in field and cargo situations.
- Determine how environmental factors, including temporal degradation, affect the ability of dogs to detect BTS.
- Develop a system that incorporates existing data on interceptions to inform future inspections.

Develop methods to detect snakes at low density, including Rapid Response

- Assess environmental DNA (eDNA) as a potential tool.
- Develop, improve, and evaluate lure systems (e.g., pheromones).
- Assess/evaluate integration of dogs into Rapid Response Team efforts to detect incipient BTS populations.
- Develop/evaluate using remote cameras and artificial intelligence for detecting BTS.
- Compare/determine detection probabilities from open and closed populations.
- Identify the optimal integration of detection tools.
- Improve the level of confidence with current detection systems.
- Understand how BTS behavior at low density affects detection probability.
- Assess attraction radius of various tools to better prescribe control tool density during responses

Develop methods to detect satiated and gravid snakes in all locations

- Determine how satiation affects movement behavior.
- Determine how satiation of snakes affects lure attractiveness.
- Determine how satiated and gravid snakes use micro-habitats and larger landscapes to enable optimal placement of surveillance or control systems.
- Develop/assess methods focused on attracting/finding satiated or gravid females.

Develop tools for interdiction of BTS not susceptible to mouse-based methods

- Evaluate/assess interception-based (e.g., drift fencing) control tools vs. new attractant-based control tools.
- Continue to identify/assess edge effects for enhancing detection.
- Determine if/how man-made structures facilitate or inhibit movement.
- Develop/evaluate toxicants for interdicting snakes (e.g., dermal uptake).

Develop & test irritant & repellent methods

- Screen/evaluate potential compounds for repellency/irritancy for use in and around cargo, aircraft, and vessels.
- Identify systems/processes that predict activity of neurons exposed to compounds at the cellular level and validate those predictions/correlations.
- Continue to evaluate forced as well as passive heat methodologies and expand evaluations under operational conditions.

Assess new barriers (physical, chemical, behavioral) & reduce barrier costs

- Develop/assess improved temporary/mobile barriers.
- Identify/assess new barrier technologies that enhance current ones (e.g., protective coatings applied to barriers).
- Design/evaluate multispecies barriers to include combinations of physical barriers.
- Design/evaluate the use of urban filters (e.g., fencing, grass cutting) that impact/restrict/direct snake movement.
- Maintain a “tech watch” for possible developments in chemical barriers.

<u>LANDSCAPE-SCALE SUPPRESSION</u>

Automate toxicant delivery (Automated Aerial Broadcast System [AABS])

- Evaluate performance/efficacy of AABS on Guam relative to manual drop and other methods currently in use.
- Increase efficiency of AABS (e.g., data to alter registration/usage of toxicant).
- Validate models and develop most effective/efficient methodology.
- Evaluate differences in control methodologies (e.g. AABS vs. ground-based) across habitats.

- Develop/improve snake monitoring methodologies in canopies of varying heights.
- Test various indices of snake abundance to discover which methods yield the most practical and accurate results.

Study effects of suppression on BTS & non-target species

- Determine how non-target species (e.g., rodents) respond to removal or reduction of snake population.
- Continue to assess "rebound" effects of natural prey base as a facilitator for recovery of snake populations after suppression.
- Evaluate how non-target bait-take affects BTS abundance estimates.
- Continue to assess secondary and tertiary effects of snake toxicants on non-target populations.

Develop alternative attractants, lures, & baits

- Develop/evaluate self-sustaining attractants/lures/baits (e.g., bioreactors).
- Develop, improve, and evaluate lure systems (e.g., pheromones).
- Develop/evaluate physics and chemistry for attractants/lure emitters.
- Field test attractants/lures in new emitters.
- Evaluate whether attractants are substrate-bound or volatile, and implications for operational snake control.

Develop tools for control of BTS not susceptible to mouse-based methods

- Continue to develop/evaluate small snake control methodologies.
- Develop/evaluate toxicants to control snakes (e.g., dermal uptake).
- Maintain a "tech watch" for possible developments in biological control (parasites, viruses) tools.
- Maintain a "tech watch" for genetic/molecular-based control methods.
- Maintain "tech watch" for genetic mapping/genomic sequencing.
- Genetically identify if a few reproductives contribute to the population group or if population growth is equally distributed across all reproductives.
- Assess/determine if BTS are adapting/evolving resulting in becoming refractory to control tools.

Integrate current operational data sets into research programs

- Use existing operational information to construct/evaluate models for computer simulations and field validations.
- Develop system(s) to ensure operational data are usable for researchers as a feedback loop to enhance operational successes and identify potential questions for research to answer.
- Evaluate patterns of capture success via GPS mapping of operational efforts (i.e., spatial analyses).
- Synthesis of research and operational failures to inform future BTS efforts.

Control BTS in urban environments

- Develop/evaluate improved ways to deploy/conceal devices for urban use (e.g., smaller devices, camouflage, etc.).
- Develop better methodologies that measure, monitor, and predict the effect of control operations on snake populations in urban environments.
- Determine/assess effects of prey control (e.g., geckos, rodents) on urban snake populations.
- Assess cost/benefit of prey control vs. direct snake control in urban environments.
- Assess basic snake behavior and movement in urban landscapes (e.g. low/high urbanization, etc.).
- Explore/assess the impact of human dimensions and BTS control operations.
- Assess impact of new invaders on BTS control or populations (e.g., Little Fire Ant [LFA]).

<u>RESTORATION</u>

Determine level of BTS suppression or tools to reduce predation for persistence of native species

- Test various indices of snake abundance to discover which methods yield the most practical and accurate results.
- Identify threshold levels/indices for snake suppression that allows successful species reintroduction (e.g., proof of concept studies).
- Develop and validate adaptive management protocols that allow retrospective analyses to inform the ultimate goal of restoration (e.g., biomedical bayesian approach).
- Identify/evaluate species-specific tools (e.g., enhanced nest boxes, BTS exclusion methods) that reduce BTS predation or enhance species restoration.
- Determine size of exclosures/control areas required for persistence of various native species (i.e., proof of concept studies).

Predict native ecosystem response to toxicant application

- Continue/expand current research on effects of toxicants on food web (e.g., fate of poisoned snakes).
- Monitor/evaluate responses of prey and other non-targets to BTS control (e.g., rodents).
- Develop/assess methods to reduce snake toxicant consumption by special status species (e.g., kingfisher, rail).

Improve physical barrier cost effectiveness & durability - Captured in earlier barrier effectiveness topic under Interdiction & Early Detection/Rapid Response theme.

REFERENCES

Aguon CF, Beck RE Jr, Ritter MW (1999) A method for protecting nests of the Mariana Crow from brown treesnake predation. In: Rodda GH, Sawai Y, Chiszar D, Tanaka H (eds) Problem snake management: the habu and brown treesnake. Comstock, Cornell, pp 460-467

Campbell EW III, Yackel-Adams AA, Converse SJ, Fritts TH, Rodda GH (2012) Do predators control prey species abundance? An experimental test with brown treesnakes on Guam. Ecology 93:1194-1203

Christy MT, Savidge JA, Rodda GH (2007) Multiple pathways for invasion of anurans on a Pacific island. Diversity and Distributions 13:598-607

Lardner B, Savidge JA, Rodda GH, Reed RN (2009) Prey preferences and prey acceptance in juvenile brown treesnakes (*Boiga irregularis*). Herpetological Conservation and Biology 4:313-323

Lardner B, Yackel-Adams AA, Savidge JA, Rodda GH, Reed RN, Clark CS (2013) Effectiveness of bait tubes for brown treesnake control on Guam. Wildlife Society Bulletin 37:664-673

Rodda GH, Fritts TH, Clark CS, Gotte SW, Chiszar D (1999) A state-of-the-art trap for the brown treesnake. In: Rodda GH, Sawai Y, Chiszar D, Tanaka H (eds) Problem snake management: the habu and brown treesnake. Comstock, Cornell, pp 268-305

Sweetapple PJ, Nugent G (2007) Ship rat demography and diet following possum control in a mixed podocarp-hardwood forest. New Zealand Journal of Ecology 31:186-201

Tyrrell CL, Christy MT, Rodda GH, Yackel-Adams AA, Ellingson AR, Savidge JA, Dean-Bradley K, Bischof R (2009) Evaluation of trap capture in a geographically closed population of brown treesnakes in Guam. Journal of Applied Ecology 46:128-135

Wiewel, AS, Yackel-Adams AA, Rodda GH (2009) Distribution, density, and biomass of introduced small mammals in the southern Mariana Islands. Pacific Science 63:205-222

Appendix G. Detailed estimate of annual base cost for FY2014 for the National Wildlife Research Center (NWRC) to operate the BTS methods development program. These are base costs and do not currently cover all facility costs or leasing GSA vehicle on Guam. Field and laboratory costs are to maintain research capabilities but not to complete field research. A pooled job cost includes any item of expense that may not be directly identified with a particular project or program and is distributed across all identifiable projects or programs to which it pertains.

Budget item	**Quantity**	**Estimated cost**
Salary & Benefits		
Principle Investigators	2.25 FTE	$307,930
Technicians	1.50 FTE	$118,925
Subtotal		$426,855
Travel		
Field maintenance	3 months	$36,000
BTS meetings	3 trips	$13,500
Subtotal		$49,500
Equipment / Supplies		
Field supplies		$35,000
Laboratory supplies		$10,000
Base vehicle / Facilities		$36,000
Subtotal		$81,000
Grand subtotal		$557,355
APHIS administrative Overhead	16.15%	$90,012
Pooled job cost	11.00%	$61,309
Grand total		$708,677

Appendix H. Detailed estimate of annual base cost for FY2014 for to the U.S. Geological Survey (USGS) to operate the BTS research program. Grand totals will range between the two values presented below depending upon actual funding sources. Budget numbers expected to increase roughly 2% per year to account for inflation etc. Indirect costs (overhead for admin, facilities, etc.) are not included above and are added to direct costs on agreements. Rates vary depending on funding source.

Budget item	**Quantity**	**Estimated cost**
Personnel (salary, benefits & travel)		
Principal Investigators	2 FTE (Research Grade)	$318,000
Science support	3 FTE (Statistician, Research Manager, Project Manager)	$313,000
Field technicians	6 FTE	$407,000
Rapid Response Coordinator	1 FTE	$107,000
University cooperators	0.25 FTE (Principal Investigator), 1 FTE (post-doc), 0.75 FTE (grad student)	$182,000
Subtotal		$1,327,000
Equipment, supplies, vehicles & other expenses		
Consumable supplies		$42,000
Equipment		$18,000
Vehicles, fuel, & maintenance		$40,000
Computers & technician support		$5,000
USGS & journal publishing fees, & printing supplies		$8,000
Guam facilities rental, phones, & utilities		$58,000
Subtotal		$171,000
Grand subtotal		$1,498,000
Overhead (DOI agencies)	17%	$254,660
Overhead (non-DOI agencies)	36%	$539,280
Grand total (DOI overhead)		$1,752,660
Grand total (non-DOI overhead)		$2,037,280

APPENDIX E

Little Fire Ant (2016 - 2021)

Brief History & Introduction

Wasmannia auropunctata, commonly known as the little fire ants (LFA), are native to Central and South America. Documented in the early 1900s, the first known invasions occurred in Africa, Florida, and the Galapagos in 1914, 1924, and 1935, respectively. Little Fire Ants have been increasing and inflicting havoc throughout the Pacific Island region since the early 1970s. Their environmental impact is significant and threatens native and endangered species and ecosystems by outcompeting and replacing high percentages of native insect fauna. Additionally, the presence of Little Fire Ants causes devastating effects on the human population; by making land unfit for agriculture, inflicting painful stings that may lead to more serious infections, and blinding pets. LFA reproduce clonally, which enabled researchers to track their movement and the discovery that their dispersal is linked to major shipping and transit routes. There have been less than five separate introductions into the Pacific Region (HISC; Hawaii Status Summary Feb. 2015)

TOP PHOTO COURTESY OF GRACEN BRILMYER FROM WWW.ANTWEB.ORG; LOWER PHOTO COURTESY OF DEPARTMENT OF AGRICULTURE

TOP: *Wasmannia auropunctata*, commonly known as the little fire ants (LFA). ***LOWER:*** Little Fire Ant nest.

First found on Guam in November 2011, LFA were identified by Dr. Ross Miller's Entomology Laboratory. LFA have been found in numerous villages around the island. Known sites include the northern village of Yigo, near the Guam Animals In Need shelter and several sites alongside the road in the southern village of Umatac (UOG CNAS; LFA: Operation Sting 2015).

LFA is listed by the Global Invasive Species Database as one of the top 100 worst invasive species worldwide and is considered the greatest ant threat to the Pacific Region. They deliver a painful sting causing an extremely itchy rash. Left uncontrolled, it leaves the human population vulnerable to stings, poses devastating consequences to the ecosystem, and is a significant threat to local agriculture.

Control

In September 2014, the USDA Forest Service awarded Dr. Miller and the Western Pacific Tropical Research Center (WPTRC) with a $100,000 grant to treat LFA in Guam and $50,000 for surveillance in CNMI. Dr. Miller teamed up with the Guam Department of Agriculture (DOA) to implement control procedures, while his team continued experimenting with technology adapted in Hawaii for use on Guam. The results showed that the technology worked (UOG CNAS; LFA 2014). The team treated six infested sites around the island and four were successfully rid of LFA.

Methodology

Detailed surveys are performed at each site to determine the magnitude and range of the infestation. The area is then treated with low toxicity granular bait attractive to LFA called Siesta™. A second insecticide that interrupts the growth cycle of the ants, Tango®, is sprayed on tree trunks and leaves. One week later the team conducts a follow-up survey to check the efficacy of the treatment, and then six weeks later both insecticides are reapplied and the site is again surveyed. Each site will receive a total of eight repeat treatments over a period of more than a year (UOG CNAS; LFA: Operation Sting 2015).

LFA Status

At this time, the Department of Agriculture is closely monitoring known infested sites and cautions the public to steer clear of these areas. In the interim, the University of Guam's College of Natural and Applied Sciences (UOG CNAS) continues to conduct research on pest management tools to control the LFA. Additionally, CNAS collaborates with scientists around the world to find biological control methods to control the LFA.

Summary of Resource Needs

The impact of the LFA on the ecosystems of Guam is not yet fully understood, but the work of the WPTRC researchers proves that this invasive species can be controlled (UOG CNAS; LFA: Good News 2016). It is the recommendation of the preparers of the Guam Invasive Species Management Plan to the Guam Invasive Species Council that no disruptions to local funding sources for the LFA programs occur. It is extremely vital that the Council continue to seek grants and other mechanisms to provide the LFA working group with the needed tools and resources to continue control efforts and subsequently the eventual eradication of the LFA from Guam.

References

Hawaii Invasive Species Council; Hawaii Status Summary Report 2015

University of Guam College of Natural and Applied Sciences; Little Fire Ant (periodical); 2014

University of Guam College of Natural and Applied Sciences; LFA: Operation Sting; 2015

University of Guam College of Natural and Applied Sciences; LFA: Good News; 2016

University of Guam College of Natural and Applied Sciences; Little Fire Ant Public Brochure

APPENDIX F

Coconut Rhinoceros Beetle (2016 - 2019)

Brief History & Introduction

Oryctes rhinoceros, commonly known as the coconut rhino beetle (CRB), can be found in the Pacific Oceanic region. The coconut rhino beetle is a threat to coconut palm, oil palm, and other palm species. The palms become damaged and eventually die when the CRB tunnels into the crown to consume the sap. The immature beetles do not cause damage to the palms, however they feed on decaying tree matter that may create a positive feedback cycle that results in a population explosion. First discovered in Guam in 2007, a population explosion occurred in the wake of Typhoon Dolphin. In the 1940s, a similar scenario occurred in Palau killing half of the palm population and the total palm population on some of the islands. Palms are essential to the island as a cash crop and natural resource.

Oryctes rhinoceros, commonly known as the Coconut Rhinoceros Beetle (CRB).

PHOTO COURTESY OF DR. AUBREY MOORE, UNIVERSITY OF GUAM

Control

Following the failed attempt at eradication using a virus that has worked effectively in every other situation, researchers discovered that a new type of CRB was invading Guam. This particular type of CRB is more invasive and is resistant to all viruses that previously worked to eliminate and control. Pheromone traps were used to try to catch the beetle to control the population. This was also proven to be ineffective. Tekken traps, gill fishing net, has been experimented with as an alternative solution to pheromone traps and have been shown to catch 25 times more beetles than the pheromone traps.

Methodology

At this time, the most effective method of reducing the population of this particularly evolved type of CRB and preserving the palm is still undetermined. More research needs to be conducted in order to determine a successful management plan to counteract the destruction that has already been caused by the CRB.

CRB Status

The current status of the CRB has reached a critical point with a prognosis for the future of the palm on the island of Guam being very dismal unless immediate action is taken. The current efforts include a system which encompasses education, monitoring, sanitation, and trapping and is continuously being updated as new information and data is collected and discovered.

Summary of Resource Needs

It is the recommendation of the preparers of the Guam Invasive Species Management Plan to the Guam Invasive Species Council that no disruptions to local funding sources for the CRB programs occur. It is extremely vital that the Council continue to seek grants and other mechanisms to provide the CRB working group with the needed tools and resources to continue control education, monitoring, sanitation, and trapping efforts and subsequently the eventual eradication of the CRB from Guam.

References

Moore, Aubrey. “Update on the Guam Coconut Rhinoceros Beetle Situation for the Guam Invasive Council.” *CNAS Research Extension. University of Guam*, 11 Sept. 2014. Web. 22 Dec. 2016.

University of Guam; College of Natural and Applied Science; Tekken Trap Stopping CRB; 2016

University of Guam. “Guam Coconut Rhinoceros Beetle Worries Scientists.” *Saipan News, Headlines, Events, Ads | Saipan Tribune*. Saipan Tribune, 02 Sept. 2015. Web. 22 Dec. 2016.

APPENDIX G

Greater Banded Hornet (2017 - 2019)

Brief History & Introduction

Vespa tropica, commonly known as the Greater Banded Hornet (GBH), are found in China, Japan, Malaysia, Honk Kong, Singapore, India, and the Philippines where they cause more deaths than snake bites. Christopher Rosario, an assistant researcher at the University of Guam discovered a colony of wasps in Dededo in July 2016, but was only able to obtain one specimen, due to their aggressive nature. Local etymologists identified them as Greater Banded Hornet. GBH feed their larvae with the grubs acquired from attacking the nests of paper wasps. Although they sometimes feed their larva Honeybees, they are almost exclusive in their choice of paper wasp grubs as the sole source of dietary nutrition for their offspring. Their nests are underground or enclosed and rarely visible.

Vespa tropica, commonly known as the Greater Banded Hornet (GBH)

IMAGE COURTESY OF ROLAND QUITUGUA, UOG RESEARCH AND COOPERATIVE EXTENSION PROGRAM

Greater Banded Hornets are large, aggressive, territorial, and able to sting multiple times. Their stings are excruciatingly painful. They pose a special risk to the children, elderly, and those who are allergic to bees and wasps. They also pose a threat to the local ecosystem by the destruction of other wasp and honeybee nests.

Control

CNAS etymologists were called to investigate reports of painful stings in two different areas of the island; Upper Tumon and Yona. Both colonies of wasps responsible for the stings were identified as Greater Banded Hornets. Despite their recent discovery, the reports of two colonies in different locations indicated that GBH might already be established on the island. Both of these colonies were removed. Since then, GBH nests have been located in Mongmong-Toto-Maite, Mangilao, Ordot, Tumon, and Tamuning.

In August, during an attempt to rescue a puppy trapped in a quarry, a Greater Band Hornet nest was discovered as a Guam Firefighter, rappelling down the quarry was attacked and stung multiple times, only escaping possible blindness by covering his head with a cadaver bag. The firefighter, and those responders that assisted him in escaping from the GBH wasp attack were treated at the hospital and released. The efforts to rescue the puppy that day were thwarted by the discovery of GBH nest located deep in the limestone quarry, and one of the largest seen yet.

Destruction of a GBH nest or colony may be dangerous because of their aggressive nature and the proper authorities should be contacted if a nest is identified or a GBH wasp is sighted.

Methodology

Detailed surveys are performed at each site to determine the size and magnitude of the nest. The location of greater banded hornet nests are identified in the evening by tracking the direction they are flying in. Protective gear must be worn to protect the body. Insecticide is applied on the nest to kill the colony. Two days later, the site is inspected, the nest is cleaned and removed, and the area is washed with soap and water to remove scent and prevent the return of more wasps.

Greater Banded Hornet Status

Dr. Aubrey Moore, an extension etymologist created an informative and downloadable trifold on the Greater Banded Hornet in an effort to create public awareness and spread information regarding the discovery of this invasive species on island. CNAS is advising the public to contact the Etymology Lab at the University of Guam, in order to continue local research and tracking of the GBH wasps and to prevent harm or injury caused by stings. In the interim, the University of Guam's College of Natural and Applied Sciences (UOG CNAS) continues to conduct research on pest management tools to control the Greater Banded Hornet. Additionally, CNAS collaborates with scientists around the world to find biological control methods to control the Greater Banded Hornet.

Summary of Resource Needs

It is the recommendation of the preparers of the Guam Invasive Species Management Plan to the Guam Invasive Species Council that no disruptions to local funding sources for the GBH programs occur. Public awareness and education efforts must be continued in order for control to be effective. It is extremely vital that the Council continue to seek grants and other mechanisms to provide the GBH working group with the needed tools and resources to continue control efforts and subsequently the eventual eradication of the GBH from Guam.

References

Guam Daily Post. "Dog rescue leads to hornet nest." Online video clip. YouTube. YouTube, 24 August 2016. Web. 22 December 2016.

Pang, Neil. "Hornets attack firefighters." *Post Guam*. The Guam Daily Post, 26 August 2016. Web. 22 December 2016.

University of Guam College of Natural and Applied Sciences; Greater Banded Hornet; 2016

University of Guam College of Natural and Applied Sciences; Greater Banded Hornet Has Arrived on Guam; 2016

APPENDIX H

Asian Cycad Scale (2017 - 2019)

Brief History & Introduction

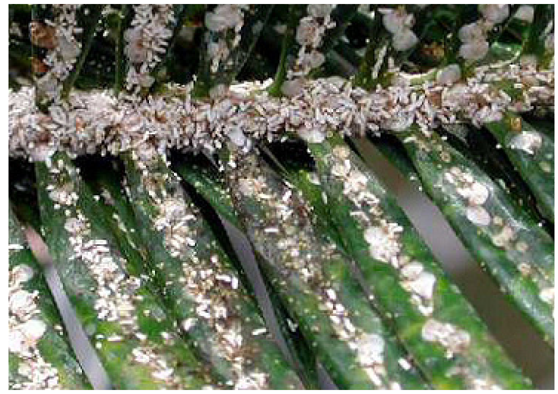


IMAGE COURTESY OF GUAM DEPARTMENT OF AGRICULTURE

Aulacaspis yasumatsui, commonly known as the Asian Cycad Scale

Aulacaspis yasumatsui, commonly known as the Asian Cycad Scale, is native to China and Thailand. It is an armored scale found on cycads in high concentrations. The female armor is about 1.2 mm and may be pear or irregular shaped. The male armor is approximately 0.5 mm and elongate with parallel features. Both male and female are white. It was introduced to the United States via a nursery that was shipped to Florida where it was first reported in 1996 and has since spread to Guam, Puerto Rico, and Hawaii where it threatens the native cycads in the forest.

In 2003, when *Cycas Micronesia* was the most abundant plant on Guam, an invasion of the Asian Cycad Scale occurred. At present, 90% of the *Cycas Micronesia*, to include plants that are over a century old, are dead and the remaining are endangered. Mortality of all infested plants is guaranteed by one year from infestation. ACS is unlike other scales in that they are more resistant to treatment and can affect a plant all the way down to its roots. To further complicate the impact of ACS on the local ecosystem, gaps in the forest that are created by the scale-induced invasion remain sterile, due to what ecologists call the legacy effect. The organic compounds of the dead cycads leave behind a legacy embedded in the soil that obstructs the sprouting and development of other forest plants. The implications of this research are ominous in regards the protection and continuation of *Cycas Micronesia*.

In addition to the destruction of an ancient native plant, and the resulting forest gaps caused by the sterile soil, there are a number of other cascading effects that result from this invasive species on our island. Researchers have discovered that the chemistry of the leaf following destruction by ACS is significantly altered resulting in a faster decomposition rate, which adversely affects all soil-borne decomposing organisms that get their nutrition from the decaying plants. The extent to which the ripple effects of the invasion of this species will reach are still undetermined, but it can be logically assumed that the reach will be far more extensive than originally presumed to be. This species has no known natural predators.

Control

Naval Base environmental staff have responded to the invasion with projects that establish the growth of cycads away from scale infected locations and one that spreads biological control insects to control the population of ACS. Local attempts to control the population of this invasive species include the monitoring of and continued efforts to counteract the impact on the ecosystem through biological and parasitoid bio-control efforts, which have provided limited control.

The inaccessibility of plants deep in the forest makes insecticide application impractical. Therefore the only cost-effective and labor saving method of control is continued biological research and efforts.

Methodology

Detailed surveys are performed at each site to determine the size and scope of the infestation. Infested plants in urban areas are monitored and treated with insecticide and oil until the insects have been removed. Biological efforts include the introduction and dispersal of the biological control insects such as *C. vulva*, which are native to the region and feed on the female scale.

Asian Cycad Scale Status

University of Guam's College of Natural and Applied Sciences (UOG CNAS) continues to collect data to monitor the population and dispersal and conduct research on pest management tools to control the Asian Cycad Scale. Additionally, CNAS collaborates with scientists around the world to find biological control methods to control the ACS.

References

Brook, Anne. "Save Guam's Common Plants." *Navigator Online*. The Pacific Navigator, 9 Nov. 2006. Web. 22 Dec. 2016.

University of Florida. "Cycad Aulacapsis Scale" *University of Florida IFAS Extension*. N.p.: U of Florida, n.d. *University of Florida*. IFAS, Aug. 2006. Web. 22 Dec. 2016

University of Guam; College of Natural and Applied Sciences; Insects Change More Than Plant Host

University of Guam; College of Natural and Applied Sciences; Alien Insect Affects More Than Its Host; 2016

Tatter, Terry, and Arnold Farran. "Control of Asian Cycad Scale on Cycas Revoluta." Diss. U of Massachusetts, n.d. Abstract. *Interagency Forum on Invasive Species*. Web. 22 Dec. 2016.

Womack, Michael. "Asian Cycad Scale: A New Threat to Dado Palms." *Agricultural Life*. Texas Cooperative Extension, 7 Sept. 2004. Web. 22 Dec. 2016.

APPENDIX I

Feral Swine (2017 - 2019)

Brief History & Introduction

Sus Scrofa, otherwise known as the feral swine can be found distributed all around the island. Primary Spanish colonizers brought domestic pigs to Guam between 1672 and 1685. Whether it was purposeful or accidental, domestic pigs established a large feral population by 1772. Today, feral pigs remain distributed island wide and are hunted all year round.

IMAGE COURTESY OF KUAM NEWS, HTTP://BIT.LY/2N6H4ZB

Sus Scrofa, otherwise known as the feral swine.

High concentrations of beasts can cause substantial damage. Wallowing, rooting, and trampling cause the soil to be bare and coarsen, remaining desolate after the annihilation. Pigs also damage agricultural harvests, such as Watermelon and Taro. Damage to agricultural crops has been reported in Inarajan, Malojloj, Dan Dan, Talofofo, Bubulao, Cross Island Road, Barrigada, Dededo and Yigo. Pigs also cause injury in residential areas by rooting in lawns and gardens.

Of the six feral species, pigs have the greatest negative impact on forest resources and should be controlled forcefully to minimize vegetation damage and ecological waste.

Control

Environmental staff from the Naval Military base established projects united in the managing of the uncontrollable swine population. Restricted accesses to military, private, and remote lands make hunting a less effective way to depopulate wild pigs.

Methodology

Programs have been implemented to control the population of this invasive species. Joint Region Marianas launch a program to not only control, but also monitor, the wild pig program. Recreational hunting can lower game population sizes thereby reduce vegetation damage. Pig hunting has been loosened for a three-month period to surge harvest of the invasive species, in an effort to assist controlling the population

Feral Pig Status

The Navy and Air Force control large areas of forestry. Hunting is not permitted on these military locations. Therefore the feral swine population has been growing steadily undetected all this time. The damage is extensive. Native plant consumption, erosion, and watershed degradation are all significant problems associated with the feral pigs.

Summary of Resource Needs

Recreational hunting can be an effective means of controlling the population density of wild pigs, which would reduce the ecological damage they cause to the land.

Reference

Conry PJ. Management of Feral and Exotic Game Species on Guam.