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Prepared in cooperation with the U.S. Air Force

Updates for Wake Atoll Biosecurity Management, Biological Control, Survey, and Management, and Integrated Pest Management Plans

Open-File Report 2022–1067

U.S. Department of the Interior
U.S. Geological Survey

Cover: Images showing aerial view of Wake Atoll (Source: Google Earth image taken 2016), ironwood, (Photograph by J.D. Jacobi, U.S. Geological Survey, 2019), yellow crazy ants (Photograph by R. Peck, Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo, 2019), and a common house gecko (Photograph by A.R. Backlin, U.S. Geological Survey, 2019).

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By Stacie A. Hathaway, James D. Jacobi, Robert Peck, and Robert N. Fisher

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Abbreviations

AFI	Air Force Instruction
BOS	Base Operating Support
CDR	Commander
CRB	Coconut rhinoceros beetle (*Oryctes rhinoceros*)
DOD	Department of Defense
DTR	Defense Transportation Regulations
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FR	Federal Register
GISD	Global Invasive Species Database
HMU	Habitat Management Unit
IPM	Integrated Pest Management
INRMP	Integrated Natural Resources Management Plan
IUCN	International Union for Conservation of Nature
NISC	National Invasive Species Council
Ops	Operations
Pan Am	Pan American Airlines
SWAA	Solid Waste Accumulation Area
USAF	U.S. Air Force
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WIA	Wake Island Airfield
YCA	Yellow Crazy Ant

Updates for Wake Atoll Biosecurity Management, Biological Control, Survey, and Management, and Integrated Pest Management Plans

By Stacie A. Hathaway[1], James D. Jacobi[2], Robert Peck[3], and Robert N. Fisher[1]

Introduction

Pests and invasive species have been defined as any organism that can have real or perceived adverse effects on operations, or the well-being of personnel, native plants, animals, their environment and ecosystem processes; attack or damage real property, supplies, equipment, or are otherwise undesirable (paraphrased from many sources including 53 Federal Register [FR] 15975, May 4, 1988, as amended at 78 FR 13507, February 28, 2013). Biosecurity programs and pest management plans can be developed and implemented with the goals of preventing the arrival of or eradication or control of pests and invasive species to reduce the potential for adverse effects. Such plans have been developed for Wake Atoll (U.S. Air Force, unpub. data 2017). Periodic plan reviews are an integral step for evaluating plan efficacy and updating plans with new information for improving plan effectiveness. This report summarizes an evaluation of past, current, and potential biosecurity and pest management for Wake with the intent this information can be used for updating existing plans. This document was prepared in cooperation with the U.S. Air Force (USAF) and surveys were performed for the 611th Civil Engineer Squadron Natural Resources Program ACES PROJECT no. YGFZ17002 under agreement number F2MUAA7116GW01 between the USAF and the U.S. Geological Survey's Western Ecological Research Center (USGS-WERC).

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Purpose

The purpose of this document is to provide the USAF with a review of the current state of biosecurity and pest management for the military base Wake Island Airfield (WIA) on Wake Atoll (hereinafter Wake), including status of native and non-native terrestrial plant, arthropod, and reptile species at Wake. Not all taxa (for example, mollusks, fungi, viruses, and so forth) are addressed in this document. This summary also is intended to be used for identifying where biosecurity and invasive pest management for top invasive/pest plants, arthropods, and terrestrial vertebrates could be strengthened. The U.S. Geological Survey (USGS) served as an external expert to document plant, arthropod, and reptile species on Wake and highlight species that were non-native, acting as an invasive/pest species, or those with the potential to cause harm on the atoll. These species were then evaluated to identify those the Air Force might wish to prioritize for pest management. In addition, measures being taken to prevent further species introductions were evaluated for potential improvements to better Air Force's ability to carry out their responsibilities for the prevention, rapid response, and control of non-native species on Wake, to improve the persistence of native terrestrial flora and fauna (which include federally protected seabirds and shore birds covered under the Migratory Bird Treaty Act of 1916 and potentially any federally endangered green sea turtles and Hawaiian monk seals that might use shorelines) on Wake, and to carry out the installation's mission.

Throughout this report, as various biosecurity concerns are discussed, we repeatedly use several terms to describe circumstances and conditions. For clarity, we define key terms used in this document in the "Glossary" section at the end of the report.

Wake Atoll Brief History

Wake is part of the Gilbert-Marshall Island chain in the Pacific Ocean, about 3,500 kilometers (km; 2,200 miles [mi]) west of the Hawaiian Islands, 2,600 km (1,600 mi) east of Guam, about 3,200 km (2,000 mi) southeast of Japan, and about 570 km (355 mi) north of Bokak Atoll in the Republic of the Marshall Islands (Bryan, 1959; U.S. Air Force, unpub. data, 2017). Wake is one of the most isolated terrestrial islands in the Pacific (fig. 1; U.S. Air Force, unpub. data, 2017). Wake consists of three islets: (1) Peale, (2) Wake, and (3) Wilkes, arranged in a "V"-shaped pattern around a central lagoon (fig. 2; Bryan, 1959). Wake is a low atoll with an average elevation of about 4 meters (m; 12 feet [ft]), maximum elevation of about 6.4 m (21 ft) above sea level and a total land area of about 7 square kilometers (km^2 [2.73 square mi]; U.S. Air Force, unpub. data, 2008). The climate is tropical maritime with little annual temperature variation (U.S. Air Force, unpub. data, 2017). Mean annual temperatures range from 24.4 degrees Celsius (°C; 76 degrees Fahrenheit [°F]) to 28.3 °C (83 °F) with an annual maximum of 35 °C (95 °F) and a minimum of 20 °C (68 °F). Rainfall averages about 890 millimeters (mm; 35 inches [in.]) per year (Weatherbase, 2020). Together, high temperatures and low rainfall generally keep Wake in a state of drought (U.S. Air Force, unpub. data, 2017). Frequent tropical storms and typhoons generating high winds and waves can cause considerable damage to vegetation and infrastructure (U.S. Air Force, unpub. data, 2017). Wake consists of porous coral rubble and limestone with organic matter in vegetated areas (U.S. Air Force, unpub. data, 2017). Despite low endemism and biodiversity in general, Wake and other atolls protect several terrestrial and marine natural resources (Engilis and Naughton, 2004; U.S. Fish and Wildlife Service, 2005).

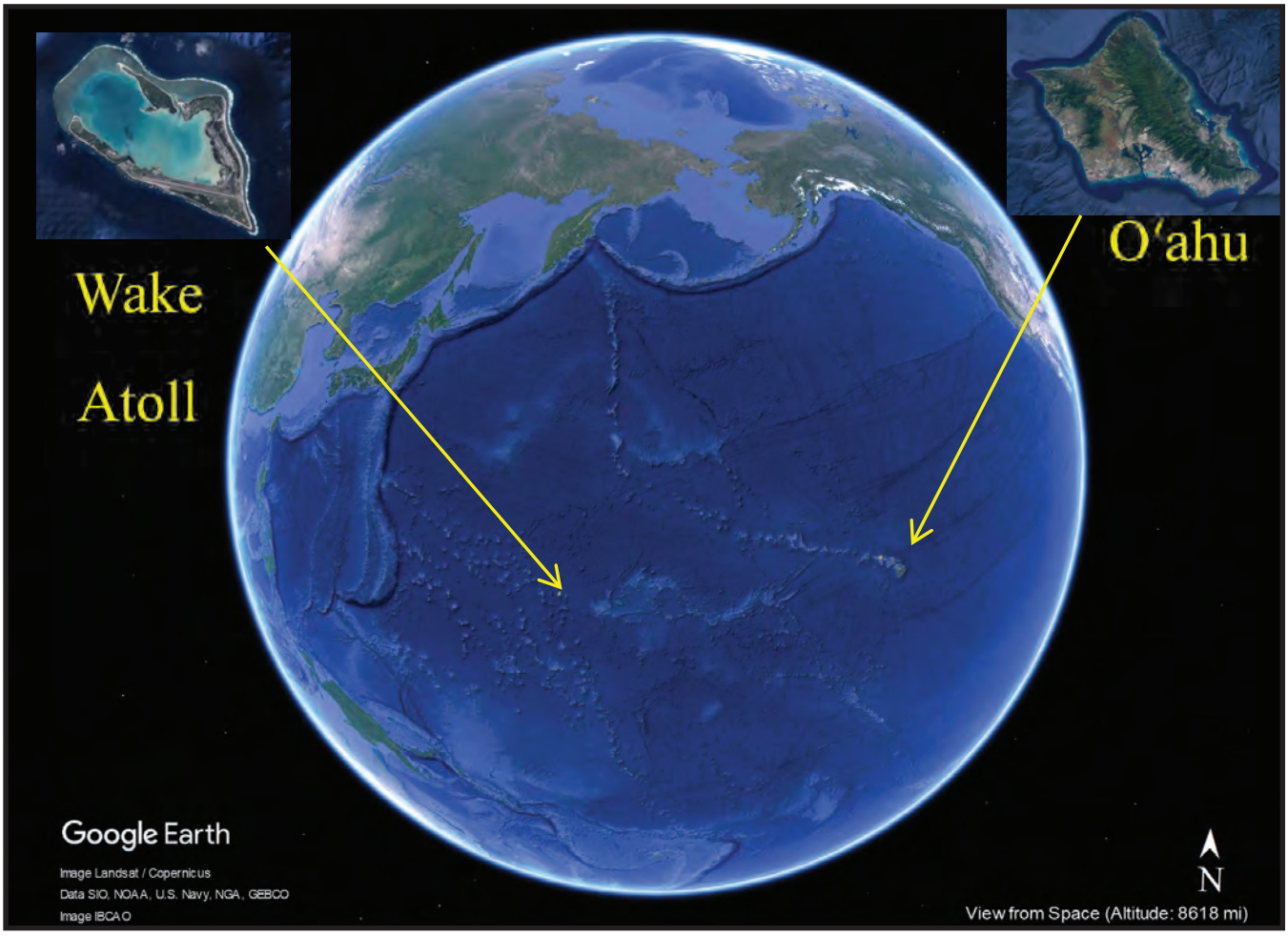


Figure 1. Location of Wake Atoll. (Source: Google Earth image taken 2016).

Figure 2. Wake Atoll with habitat mapping units and selected sites referred to in the report. (Source: Google Earth image taken 2016).

There is no prehistoric evidence that Wake was populated by pre-European Pacific peoples. Heinl (1947) provides an account of the pre-war history of Wake from 1568 to 1941 and additional historical context is contained in the Wake Integrated Cultural Resources Management Plan (Verhaaren and Kullen, unpub. data, 2014) and Wake Integrated Natural Resource Management Plan (hereinafter INRMP; U.S. Air Force, unpub. data, 2017). The brief history that follows is summarized from these documents. Wake was discovered in 1568 by Spanish explorers, though credit is given to British Captain William Wake who rediscovered the island over 200 years later in 1796. Wake was explored by U.S. Navy Commander Charles Wilkes and naturalist Titian Peale in 1841. The United States formally took possession in 1899. There are reports of several shipwrecks and otherwise limited visitations until the Japanese began landing to harvest bird feathers and fish nearby for shark fins, and a group of Japanese castaways were marooned on the atoll. Remaining Japanese camps were abandoned by 1922. Most early zoological and botanical observations are from the Smithsonian's Tanager Expedition which carried out a biological reconnaissance at Wake in 1923. The U.S. Navy was given jurisdiction over Wake in 1934 and gave permission for Pan American Airlines (Pan Am) to begin constructing facilities to support weekly trans-Pacific flights. In 1938, the Navy began plans for an outlying military base; however, construction did not begin until January 1941. Construction was not yet completed when the Japanese invaded and overran the island in December 1941 and occupied Wake for the rest of World War II. During the war, the Japanese continued to build many structures underground or behind embankments to protect them from repeated bombing. The atoll reverted back to U.S. possession in 1945 after Japanese surrender, and the atoll was again placed under jurisdiction of the U.S. Navy, and later, civil administration was given to what is now the Federal Aviation Administration (FAA). Military Air Transport Services and later Military Airlift Command provided service to transient USAF aircraft while at Wake, and Pan Am and other airlines reestablished commercial airline services. During that period, the atoll's population rose to roughly 2,000 people, and an elementary school was constructed. Further botanical and bird surveys were carried out during this period.

In 1972, when long-range jet aircraft reduced the need for Wake as a refueling stop, the FAA transferred jurisdiction to the USAF until 1994. After this, Wake was administered by the U.S. Army for missile defense, then transferred back to the USAF in 2002. On January 6, 2009, by Presidential Proclamation 8336, Wake Atoll was included in the establishment of the Pacific Remote Islands Marine National Monument. The Secretary of the Interior, in consultation with the Secretary of Commerce, have responsibility for management of the monument. On January 16, 2009, through Secretary Order 3284, the Secretary of the Interior delegated management for the monument to the U.S. Fish and Wildlife Service (USFWS). This order (3284) states in accordance with Proclamation 8336 that Wake is under management by the USAF under the 1972 agreement with the Secretary of the Interior (Code of Federal Regulations 32 Part 935) until the agreement is terminated. The USFWS manages the areas surrounding Wake Atoll from the mean low water line out to 50 nautical miles as part of the National Wildlife Refuge System. Emergent lands are managed by the USAF and used for contingency deployments, an emergency landing facility, and fuel storage. With those activities, construction and maintenance at Wake have continued. In addition, there is currently a chartered flight to and from the atoll every other week carrying temporary contractors and supplies. There is also an ocean-going barge that transports large equipment and other supplies, at least once per year.

This history is important for understanding how Wake and its natural resources have been affected over time and illustrates an array of past and current pathways for invasive species. Non-native species have the potential to be invasive, defined by Executive Orders no. 13112 and 13751 as species whose presence has caused harm or may cause harm to environmental or human, animal, or plant health (NISC; National Invasive Species Council, 2008). Invasive species are well known to be important factors in the decline of unique natural communities, species, and ecological processes (Vitousek, 1990; numerous papers in Veitch and Clout, 2002; Engilis and Naughton, 2004). The USAF currently uses Integrated Natural Resource Management Plans (INRMPs) per the Sikes Act to manage and protect natural resources on installations. The INRMP that addresses WIA includes components that address biosecurity and pest management. These are long-term planning documents to guide Department of Defense (DOD) natural resource managers in the management of natural resources to support installation missions while protecting and enhancing resources for multiple use and biological integrity. The initial Wake Atoll INRMP introduced the goal to "bring together and integrate all management activities in a way that sustains, promotes, and restores the health and integrity of ecosystems and that enhances the human environment on Wake Atoll" (Foothill Engineering Consultants, Inc., written commun., 2000). The 2008 INRMP identified the need for an invasive species risk assessment (U.S. Air Force, written commun., 2008).

Invasive/pest species are recognized as one of the greatest threats to ecosystems and economies (Vitousek and others, 1997; Warziniack and others, 2021). Biosecurity is thus a concern at several scales from global to local, and in order to address this, prevention and control policies have been and continue to be improved at several levels of government (Ricciardi and others, 2020; Rawluk and others, 2021). A biosecurity plan is an effective tool for identifying and addressing non-native, potentially invasive species problems and concerns (Matos and others, 2018). In 2012, the USAF with support from private consultants authored the "Wake Island Biosecurity Management Plan" (U.S. Air Force, unpub. data, 2012). This plan was "created to help guide the USAF in carrying out their responsibility for the prevention, rapid response, and control of non-native species on Wake" (U.S. Air Force, unpub. data, 2012). The plan includes references to non-native species laws, policies, and protocols currently in place that directly or indirectly address non-native species on Wake. These include international, national, state (Hawai‘i—though Wake is not officially part of the state, most of the access to Wake comes directly from Hawai‘i), and Air Force Instruction (AFI). The plan recognizes and addresses the importance of minimizing the possibility that new invasive plants and animals are introduced to Wake. Wake has an active port for supply deliveries and an airfield for military operations, thereby connecting it to ports and airfields globally, but in particular with Guam and O‘ahu, Hawai‘i. Movement of people, supplies, equipment, other cargo and the vessels themselves act as potential pathways for species invasions and reinvasions, thus posing biosecurity risk. The aforementioned plan was originally created to reduce risks of rodent incursion and re-defined the container requirements and other elements of USAF shipping to the atoll. The biosecurity plan was updated in 2015 (U.S. Air Force, unpub. data, 2015) and was incorporated into the 2017 INRMP as a component plan. The current (2015) biosecurity plan still retains a rodent focus; however, some components of the intervention measures within it have potential for inhibiting or intercepting invasive species other than rodents.

As defined by order of The Secretary of the Air Force AFI 32-1053, "Integrated Pest Management" (IPM) is a planned program incorporating continuous monitoring, education, record keeping, and communication to prevent pests and disease vectors from causing unacceptable damage to operations, people, property, material, or the environment. Integrated Pest Management includes methods such as habitat modification, biological control, genetic control, cultural methods, mechanical control, physical control, regulatory control, and the judicious use of least-hazardous pesticides" (U.S. Air Force, 2014). The goal of the Integrated Pest Management Program for Wake is to "develop and employ a systematic approach for onshore and offshore biosecurity, inclusive of rapid response" (U.S. Air Force, unpub. data, 2017). The Integrated Pest Management Program for Wake has nested within it an Integrated Pest Management Plan (which is focused on pest management of structures, buildings, and surrounding yards at Wake; Chugach Federal Solutions, Inc., unpub. data, 2013), a Biosecurity Management Plan (as described previously, focuses on invasive species prevention, interception, detection, and rapid response; U.S. Air Force, unpub. data, 2015) and a Biological Control, Survey, and Management Plan (which addresses pest management in the broader context of Wake [beyond structures and surrounding yards]; U.S. Air Force, unpub. data, 2017). Biosecurity plans are thus included in this goal, focusing on preventing invasive species incursions and directing rapid response should they appear. Prevention is by far the most cost-effective management option, followed by early detection of incursion, with potential for successful eradication or control decreasing over time while increasing in cost (fig. 3). Wake presents a unique opportunity for increased potential for successful eradications even as time progresses due to its reduced areal extent; and with its remote location, there can be greater control over reintroduction potential. Integrated pest management includes creating strategies for the most environmentally sound response for eradication or control of invasive or pest species.

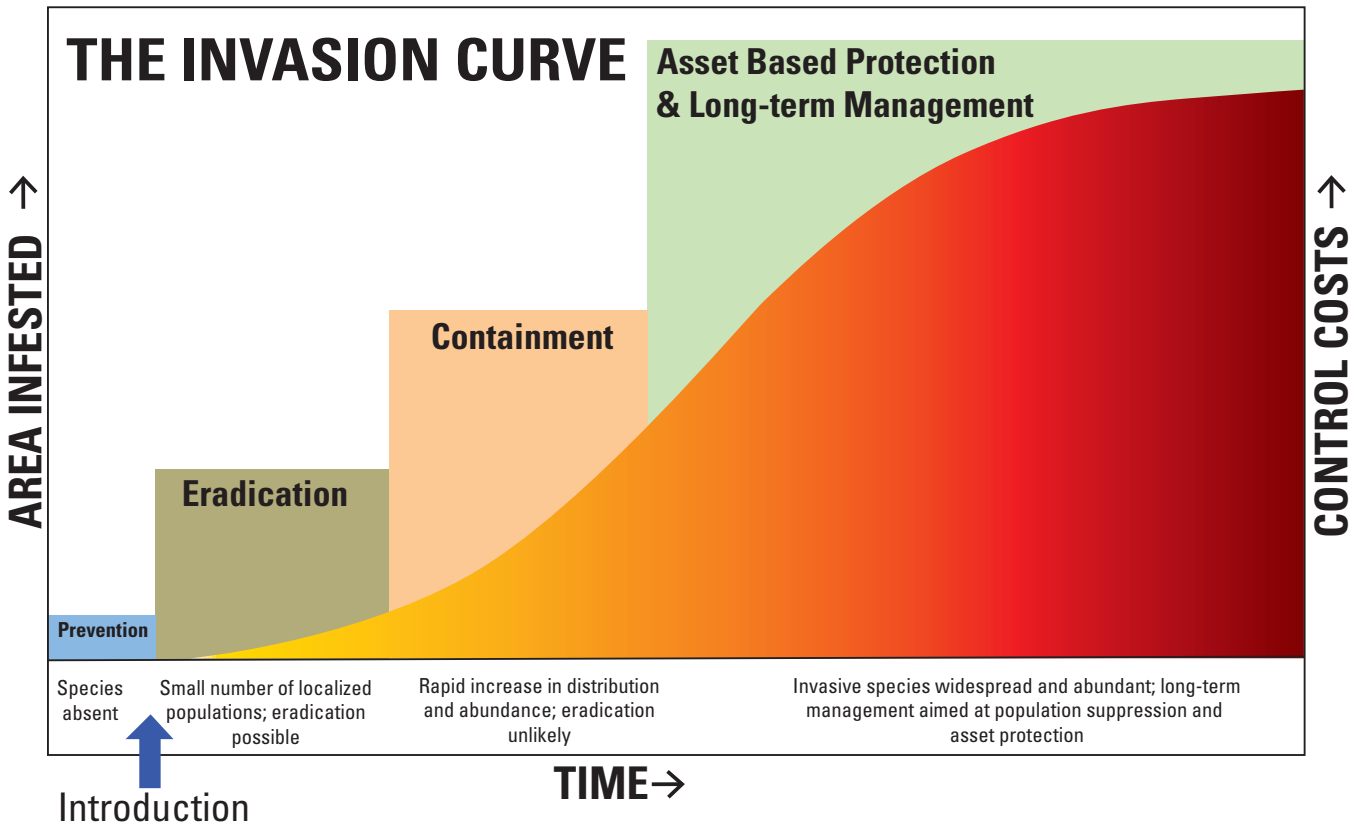


Figure 3. Phases of the Invasion Curve (adapted from Victorian Government [2010]. Invasive Plants and Animals Policy Framework. State of Victoria, Department of Primary Industries). Preventing the introduction of invasive/pest species is the most cost-effective defense against invasion. This is followed by eradication if feasible. Early detection and rapid response actions are generally needed for successful eradication. Eradication success may also be possible after longer periods in small island ecosystems given appropriate tools and methodology, though expenses are still higher as distribution and abundance expand. When eradication is not feasible or tools have not been created, containment and long-term control of an invasive/pest species population may be the only management option. These generally require costly and possibly indefinite financial investment.

The INRMP calls for the Wake integrated pest management program plans to be updated periodically. In 2017, the USAF issued funds to the USGS to support an update to the biosecurity plan and to inform prioritization of terrestrial plant, arthropod, and reptile species for management. The results are presented in this document along with two additional products (described below).

A subset of awarded funds issued was specific to the creation of a current flora and fauna species identification index, from a project entitled "Biodiversity Surveys of Wake Atoll Featuring Field Guides for Plants, Arthropods, and Herpetofauna" (S.A. Hathaway, J.D. Jacobi, A.R. Backlin, C.J. Hitchcock, and R.N. Fisher, U.S. Geological Survey; and R. Peck, Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo, unpub. data, 2022; hereinafter Biodiversity Project), and another subset for performing a concurrent and complementary project focused on the evaluation of Wake's current (2015) vessel and shipping container biosecurity program, entitled "Wake Atoll Vessel Movement Biosecurity Program Efficacy" (S.A. Hathaway, J.C. Molden, C.S. Brehme, and R.N. Fisher; U.S. Geological Survey; R. Peck, Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo; and K.R. Rex, National Oceanic and Atmospheric Administration, unpub. data, 2022; hereinafter Efficacy Project).

The three documents have been drafted as separate pieces in order to provide greater detail on each subject but have strong links to each other. Collectively, they describe an adaptive approach to applying biosecurity which began with creating a plan based on best existing information, followed by USAF plan implementation, then monitoring results (the core of the three documents), and periodically updating the plan as necessary for improving effectiveness. The current (2015) biosecurity protocols used for prevention (contained in the Wake Island Biosecurity Management Plan; U.S. Air Force, unpub. data, 2015; hereinafter Wake Biosecurity Plan) were evaluated for the Efficacy Project and new biodiversity surveys for terrestrial vegetation and arthropods, and the first formal reptile surveys were completed for the Biodiversity Project. Results from field efforts added to existing knowledge and identified potentially new species arrivals to Wake.

The primary goal of the Biodiversity Project was to update and compile established species information for the atoll and create species identification guides for the three taxonomic groups surveyed. Here, we draw on what we learned from our evaluation of the 2015 biosecurity protocols for Wake supply barges during the Efficacy Project and our findings from the Biodiversity Project to indicate where current biosecurity could be improved and identify some of the initial top invasive species at Wake for potential management planning and actions. These could ultimately be considered together in a comprehensive management program. The overall goal is to provide information to the USAF that could strengthen invasive species management at Wake to increase the protection of vulnerable species and habitat, human habitants and visitors, and to reduce the potential for negative effects to the installation's mission.

Methods

Biosecurity

As part of the Efficacy Project, we reviewed the Wake Biosecurity Plan in detail with respect to supply shipment and observed implementation to the extent possible. This included carrying out inspections of the baseline sanitation of empty shipping containers to be used to move cargo to Wake, sanitation of cargo staging areas and evaluating efficacy of biosecurity tools used in cargo staging areas before cargo shipment by barge, placement of biosecurity tools used in containers after loading with cargo, and inspection of barge sanitation, retrieval of biosecurity tools for analysis, and container inspections for evidence of organisms present upon unloading at Wake (S.A. Hathaway and J.C. Molden, U.S. Geological Survey; and K.R. Rex., National Oceanic and Atmospheric Administration, unpub. data, 2018). Throughout the process, we observed the Navy, Base Operating Support (BOS) contractor, and shipping vendor as they implemented prevention protocols specified in the biosecurity plan. We include synthesized results here as relevant to this product. All airflights and all sea-going vessels need to have biosecurity requirements to ensure some level of sanitation before departure for Wake (and also before departing Wake for elsewhere; Executive Order 13112, 1999; Executive Order 13751, 2016; U.S. Department of Defense, 2021). Thus, though not in our scope of work, we also include here any relevant observations of air transport biosecurity. We examined the biosecurity practices in the 2015 Biosecurity Management Plan and how they were executed as well as considered knowledge of pest organisms associated with major points of departure for Wake to ensure field surveys focused not just on native species but also on risk organisms not previously recorded for Wake.

Wake, Wilkes, and Peale Islets have been separated into habitat management units (HMUs) which were delineated to assist in the creation of natural resources management actions and approaches (U.S. Air Force, unpub. data, 2017-INRMP). As part of the overall project, we completed flora and fauna surveys broadly across Wake, including all three islets: (1) Wake, (2) Peale, and (3) Wilkes, as well as in focused areas most likely to be vulnerable to invasive species incursions (for example, the marina and associated area in HMU-11, areas with concentrated populated buildings such as in HMU-58, and cargo container unloading and storage areas in HMU-65; fig. 2). Field surveys were carried out at Wake between May 24 and June 7, 2019. Specific methods used, including visual encounter surveys for all taxa and traps for arthropods and reptiles, are described by S.A. Hathaway, J.D. Jacobi, A.R. Backlin, C.J. Hitchcock, and R.N. Fisher, U.S. Geological Survey; and R. Peck, University of Hawai‘i at Hilo (unpub. data, 2022; chapters 2, 3, and 4 for plants, arthropods, and reptiles respectively). While performing biodiversity field surveys, we sought to confirm historical records compiled from museums, published and unpublished literature, and interviews and prioritize the detection of any new species. We also compared species detected during the Efficacy Project to those detected at Wake compiled during the Biodiversity Project.

Established Pest Concerns

As an initial step to inform creation of long-term management strategies for top invasive or pest species at Wake, we carried out a small-scale, internal preliminary risk analysis using our findings. As defined in the 2016–18 NISC Management Plan, “risk analysis is the set of tools or processes incorporating risk assessment, risk management, and risk communication, which are used to evaluate the potential risks associated with a non-native species or invasion pathway, possible mitigation measures to address the risk, and the information to be shared with decision-makers and other stakeholders” (National Invasive Species Council, 2016).

We based our approach on Booy and others (2017) and J.Q. Richmond, J. Kingston, B.A.I. Ewing, W. Bear, S.A. Hathaway, K.L. Preston, B.E. Kus, and R.N. Fisher, U.S. Geological Survey; C. Lee, C. Swift, and A.J. Schultz, Natural History Museum of Los Angeles County; K. Russel, Riverside-Corona Resource Conservation District; P. Unitt, B.D. Hollingsworth, M. Wall, and S. Tremor, San Diego Natural History Museum; R.E. Espinoza, Department of Biology, California State University Northridge; and K. Palenscar, San Bernardino Valley Municipal Water District (unpub. data, 2019). The protocols consist of a stepwise semi-quantitative procedure and consensus-building among taxonomic experts to identify high ranking species considered to be alien invasives that could be managed effectively. However, because a full risk assessment was beyond the scope of this project, we carried out our evaluation amongst the contributing authors only. Once field surveys were complete, our internal team of experts (reptiles: S.A. Hathaway and R.N. Fisher; plants: J.D. Jacobi; arthropods: R. Peck) carried out a preliminary risk assessment for individual taxa (plants, arthropods, and reptiles) using a consensus method to rank species established at Wake (S.A. Hathaway, J.D. Jacobi, and R.N. Fisher, U.S. Geological Survey; and R. Peck, Hawai‘i Cooperative Studies Unit, University of Hawai‘i at Hilo, unpub. data, 2020) according to their invasive effects (known or potential) and potential feasibility of control or eradication at Wake. We also gave plants identified as weeds a score based on the Hawai‘i-Pacific Weed Risk Assessment (HPWRA) 2019 assessment (Hawai‘i-Pacific Weed Risk Assessment, 2019).

Invasive/pest effects were ranked high, medium, or low based on published risk assessments where available (largely for plants) or effects of similar species. These rank categories were modified based on conditions specific to Wake (for example, the introduced species is unlikely to survive outside cultivation conditions; Wake currently lacks dispersal agents). Management feasibility was also ranked as high, medium, or low considering factors including cost, whether known tools are available and the likelihood of success in achieving eradication or control at Wake. Next, our expert team assembled for discussions and presented our intra-taxonomic rankings with justifications to inform each other of our results and make any potential reassessments based on respective input. After a period of time to individually consider changes to our initial assessments, we convened for additional discussion to consider any changes made to our respective top-ranking species for each taxon. From these, we ranked species at Wake for potential management action (either initiating or building on existing action). We discussed any known management practices in progress at Wake for these species to consider next steps for the highest-ranking species. Strategies for long-term management were considered and included in the reporting for each taxon.

Horizon Species

Horizon species are potentially invasive non-native species. They are most likely to arrive to Wake based on their appearance in transit routes that include Wake, and they are identified by experts as potential risk species. We did not perform an extensive “horizon species” evaluation; however, we considered the most likely potential new arrivals (plants, arthropods, reptiles, and amphibian species) to Wake. This was largely based on the current known pathways (travel) to Wake (for example, supply barge, air traffic) and the most common origination, namely Hawai‘i and Guam. Similar to assessing established species for Wake, we assigned risk and management scores for species detected during the Efficacy Project in our evaluation and consider the overall results here. This is not meant to be a comprehensive list of candidate horizon species.

Results and Discussion

Overview

We summarize the results of our findings on the state of biosecurity for Wake and provide potential improvements for consideration. Next, we summarize the outcomes from evaluating top invasive species currently (2019) present at Wake and those with the greatest potential for arriving. We then present biosecurity concerns and management considerations specific to plant, arthropod, and terrestrial vertebrate taxa and then provide broad considerations for enhancing invasive species management success at Wake. Lastly, we discuss limitations of the current (2019) surveys and future needs.

Biosecurity

There are several guidelines referenced or included in the current (2015) Wake Biosecurity Plan for sea and air transportation regarding invasive species pathways (for example, Defense Transportation Regulations, Foreign Clearance Guide) with recommended or required "quarantine" and pre-screening activities and verbiage suggesting how these be included in barge contract language and pre-screening. We did not review existing contracts but suggest that biosecurity will be most effective if contracts or other documents include clear descriptions of required prevention measures. During the Efficacy Project, we were informed that particular requirements had been clearly stipulated, such as in contracts, and we sometimes observed that they were not followed (for example, Base Operating Support [BOS] was not present during cargo loading into containers, BOS did not load biosecurity tools in containers; S.A. Hathaway and J.C. Molden, U.S. Geological Survey; and K.R. Rex, National Oceanic and Atmospheric Administration, unpub. data, 2018). Clarifying the minimum required biosecurity components in the body of the existing Biosecurity Plan and adding a series of checklists focused on prevention could have the highest beneficial effect on improving biosecurity efficacy. The simple addition of checklists could supplement the current (2015) Biosecurity Plan to guide protocol implementation. This could aid evaluation of protocol compliance and clearly define the steps needed for implementation and recording accountability.

To this end, we created 11 checklists addressing activities related to transportation of supplies and passengers through barge (7) and air transport (3) as well as 1 related to stranded vessels (table 1 and appendix 1). These checklists can be easily modified as needs and protocols shift. Indeed, the checklists represent an integration of previous biosecurity practices for Wake and modifications based on what we observed in our studies. Although the components of the checklists are simple, the checklists can provide insurance that simple steps are not skipped, which could otherwise result in potentially devastating environmental, economic, or mission consequences.

Table 1. Suggested checklists for improving biosecurity efficacy at Wake.

Pathway type	Transportation mode	Biosecurity protocol checklist
Sea	Barge deliveries	Cargo staging areas sanitation inspection checklist
		Container integrity and sanitation checklist
		Cargo loading and biosecurity tool placement checklist
		Barge and tug operators checklist
		Barge and tug docking biosecurity precautions checklist
		Vessel emergency quarantine checklist
		Wake barge arrival container/flat rack/break bulk/cargo integrity and sanitation checklist
	Stranded vessels	Stranded vessel checklist
Air	Air transportation	Aircraft operators checklist
		Aircraft terminal area and baggage/cargo holding facilities "Quarantine area" sanitation inspection checklist
		Passenger checklist

Such checklists would not substitute for detailed biosecurity procedures and protocols but could provide quick guides while carrying out these processes and inspections. Many detailed descriptions of protocols and procedures are available through various sources (for example, the Armed Forces Pest Management Board website, at https://www.acq.osd.mil/eie/afpmb/; United States Transportation Command website, specifically regarding Defense Transportation Regulations [DTR], at https://www.ustranscom.mil/dtr/; Armed Forces Pest Management Board Technical Guide no. 31 [Armed Forces Pest Management Board, 2017]; and Defense Transportation Regulations Part 5 Department of Defense Customs and Border Clearance Policies and Procedures [U.S. Department of Defense, 2021]). These resources contain valuable descriptions and details and are particularly important guides for sanitizing cargo destined for Wake before arrival at cargo staging areas. Our findings regarding container integrity were unexpected and suggest the potential benefit of new protocols and an adaptive management approach for Wake Biosecurity Management, Biological Control, Survey, and Management, and Integrated Pest Management Plan implementation. The example checklists presented here are an integration of protocols the U.S. Air Force already had in place (U.S. Air Force, unpub. data, 2015), with modifications for strengthening effectiveness based on what we observed. In addition, although we did not specifically evaluate how departures are handled for vessels (and their contents), equal care is prudent to prevent human facilitated species movements off of Wake and similar or modified protocols could be required for departures.

The document entitled "Welcome to Wake Island! Home of the United States Air Force Pacific Air Force Pacific Air Forces Regional Support Center" (Chugach Federal Solutions, Inc., unpub. data, [undated]) provides a brief introduction to Wake and includes one line in bold: "Prevent seeds, plants, or animal importation to Wake Island; check your shoes and snorkeling equipment." This document is available to visitors upon arrival at the air terminal at Wake during the welcome orientation. This document could be expanded to include more detailed requirements for anyone arriving at Wake by sea or aircraft (for example, adding clothing, luggage, and so forth to the list of what to check). There would be an additional benefit in taking a few moments to physically check personal effects and provide a disposal receptacle as part of the new-arrivals orientation (or better just before departure for Wake), as well as providing bleach bath location(s) and guidance for disinfecting soft snorkel and dive gear at Wake. Additional educational materials for Wake could be beneficial and posting highly visible materials such as "Wanted" posters with potential horizon species, including those that may not be so obvious, would be helpful too. Photographs and descriptions could heighten awareness, provide search images, and instruct visitors and inhabitants to keep on the lookout and report potential incursions (see data sheet, appendix 2). These suggestions could be an inexpensive addition for early detection of potential invasive and pest species.

Top Invasive Species and Horizon Species

As a first step to rank species for possible management, we assessed each species of terrestrial plant, arthropod, and reptile detected at Wake for its potential to become invasive (or a pest). We also assessed potential invasive effects and management feasibility for the potential invasive species that have been detected at Wake. This assessment consisted of 33 plants, 26 arthropods, and 2 reptiles considered as alien invasive species at Wake (table 2; these and the assessments of species not currently assigned as invasive were compiled by S.A. Hathaway, J.D. Jacobi, and R.N. Fisher, U.S. Geological Survey; and R. Peck, Hawai‘i Cooperative Studies Unit, University of Hawai‘i at Hilo, unpub. data, 2020). Of these species, we identified four plant species and two arthropod species as the invasive species of most concern and on which potential management actions might first focus (fig. 4). Assessments of species not currently considered invasive can be reconsidered in the future if what is known about their potential to become invasive changes. Similarly, we identified non-native species most likely to arrive at Wake and become established and invasive. We identified 28 horizon species (12 plants, 5 arthropods, and 11 amphibians and reptiles; table 3) of most concern based on their invasive characteristics.

Table 2. List of plant, arthropod, and reptile species currently (2019) established at Wake considered to be alien invasive/pest species.

[Relevant published risk assessment scores for these species are included and were considered during a preliminary species risk assessment for identifying potential invasive management actions at Wake. Species detected during 2019 surveys are indicated (X) for each islet (Wilkes N= North S= South, Wake, and Peale). Wake preliminary risk assessment and potential management feasibility scoring was based on an approach developed by Booy and others (2017) and modified by J.Q. Richmond, J. Kingston, B.A.I. Ewing, W. Bear, S.A. Hathaway, K.L. Preston, B.E. Kus, and R.N. Fisher, U.S. Geological Survey; C. Lee, C. Swift, and A.J. Schultz, Natural History Museum of Los Angeles County; K. Russel, Riverside-Corona Resource Conservation District; P. Unitt, B.D. Hollingsworth, M. Wall, and S. Tremor, San Diego Natural History Museum; R.E. Espinoza, Department of Biology, California State University Northridge; and K. Palenscar, San Bernardino Valley Municipal Water District (unpub. data, 2019). This is a step-wise semi-quantitative procedure and consensus-building among taxonomic experts to identify high ranking species that can be managed effectively. A full risk assessment could not be completed; experts consisted of contributing authors only. **Abbreviation**: —, no data]

Scientific name	Common name	Published risk[1]	Risk assessment[2]	Wake risk assessment[3]	Management feasibility[4]	Wilkes N	Wilkes S	Wake	Peale	Not detected 2019
				Plants						
Agave americana	century plant	High risk	HPWRA	M	—	—	—	X	—	—
Agave sisalana	sisal	High risk	HPWRA	H	H	—	—	X	X	—
Sansevieria hyacinthoides	iguana tail, African bowstring hemp	High risk	FISC	M	—	—	—	—	—	X
Cenchrus echinatus	sandbur	High risk	PIER	H	H	—	X	X	X	—
Chloris barbata	swollen fingergrass	High risk	HPWRA	M	—	—	—	X	X	—
Cynodon dactylon	Bermuda grass	High risk	HPWRA	M	—	—	—	X	X	—
Digitaria insularis	sourgrass	High risk	HPWRA	M	—	—	—	—	—	X
Paspalum scrobiculatum	ricegrass, Kodo millet (Syn: *P. orbiculare*)	Noxious	USDA-APHIS	M	—	—	—	X	X	—
Paspalum vaginatum	seashore paspalum, biscuit grass	High risk	HPWRA	H	M	—	—	—	—	X
Bidens alba	beggarticks, Spanish needles	High risk	HPWRA	M	—	—	X	X	—	—
Erigeron bonariensis	hairy horseweed, hairy fleabane	High risk	HPWRA	M	—	—	—	—	—	X
Pluchea carolinensis	sourbush, fleabane	High risk	HPWRA	H	M	—	X	X	X	—
Sonchus oleraceus	common sowthistle	High risk	HPWRA	L	—	—	—	—	—	X
Tridax procumbens	coatbuttons, tridax daisy	High risk	HPWRA	L	—	—	—	X	X	—
Nopalea cochenillifera	cochinilla cactus	High risk	HPWRA	H	H	—	—	X	X	—
Casuarina equisetifolia	ironwood, Australian pine tree	High risk	HPWRA	H	H	X	X	X	X	—
Kalanchoe daigremontiana	devil's backbone, alligator plant	High risk	HPWRA	M	—	—	—	—	—	X
Kalanchoe delagoensis	chandelier plant	High risk	HPWRA	M	—	—	—	X	—	—
Kalanchoe pinnata	air plant, cathedral bells	High risk	HPWRA	H	H	—	—	X	—	—
Euphorbia heterophylla var. *cyathophora*	dwarf poinsettia, wild poinsettia	No assessment	Wake 2019	M	—	—	—	X	X	—
Euphorbia hypericifolia	graceful spurge	High risk	HPWRA	M	—	—	X	X	X	—
Euphorbia prostrata	prostrate purge or prostrate sandmat	High risk	HPWRA	L	—	—	—	X	—	—
Desmanthus pernambucanus	wild tantan, prostrate bundleflower, dwarf koa	No assessment	Wake 2019	M	—	—	—	X	X	—

Table 2. List of plant, arthropod, and reptile species currently (2019) established at Wake considered to be alien invasive/pest species.—Continued

[Relevant published risk assessment scores for these species are included and were considered during a preliminary species risk assessment for identifying potential invasive management actions at Wake. Species detected during 2019 surveys are indicated (X) for each islet (Wilkes N= North S= South, Wake, and Peale). Wake preliminary risk assessment and potential management feasibility scoring was based on an approach developed by Booy and others (2017) and modified by J.Q. Richmond, J. Kingston, B.A.I. Ewing, W. Bear, S.A. Hathaway, K.L. Preston, B.E. Kus, and R.N. Fisher, U.S. Geological Survey; C. Lee, C. Swift, and A.J. Schultz, Natural History Museum of Los Angeles County; K. Russel, Riverside-Corona Resource Conservation District; P. Unitt, B.D. Hollingsworth, M. Wall, and S. Tremor, San Diego Natural History Museum; R.E. Espinoza, Department of Biology, California State University Northridge; and K. Palenscar, San Bernardino Valley Municipal Water District (unpub. data, 2019). This is a step-wise semi-quantitative procedure and consensus-building among taxonomic experts to identify high ranking species that can be managed effectively. A full risk assessment could not be completed; experts consisted of contributing authors only. **Abbreviation**: —, no data]

Scientific name	Common name	Published risk[1]	Risk assessment[2]	Wake risk assessment[3]	Management feasibility[4]	Wilkes N	Wilkes S	Wake	Peale	Not detected 2019
				Plants—Continued						
Leucaena leucocephala	koa haole, tangantangan, lead tree	High risk	HPWRA	H	M	—	—	X	X	—
Passiflora foetida var. *hispida*	passion fruit, scarletfruit passionflower	High risk	HPWRA	H	H	—	X	X	—	—
Phyllanthus amarus	hurricane weed, carry me seed	High risk	HPWRA	L	—	—	X	X	X	—
Coccoloba uvifera	sea grape	High risk	HPWRA	H	H	—	—	X	X	—
Morinda citrifolia	noni, Indian-mulberry	High risk	HPWRA	M	—	—	—	X	—	—
Pilea microphylla	artillery plant	High risk	HPWRA	L	—	—	—	X	—	—
Stachytarpheta jamaicensis	Jamaica vervain, light-blue snakeweed	No assessment	Wake 2019	M	—	—	X	X	X	—
Stachytarpheta urticifolia	blue rat's tail, nettleleaf velvetberry	No assessment	Wake 2019	M	—	—	—	—	—	X
Tribulus terrestris	puncture vine	High risk	HPWRA	L	—	—	—	X	—	—
				Arthropods						
Isometrus maculatus	lesser brown scorpion	No assessment	Wake 2019	M	L	—	—	X	—	—
Scolopendridae sp.	tropical centipede	No assessment	Wake 2019	M	L	—	—	X	—	—
Scolopendra subspinipes	red-headed centipede	No assessment	Wake 2019	M	L	—	—	X	—	—
Coptotermes gestroi	Asian subterranean termite	No assessment	Wake 2019	M	L	—	—	X	X	—
Cylas formicarius	sweet potato weevil	No assessment	Wake 2019	L-M	L	—	—	—	X	—
Dermestes atar	black larder beetle	No assessment	Wake 2019	L-M	L	—	—	X	—	—
Protaetia fusca	mango flower beetle	No assessment	Wake 2019	L-M	L	—	—	X	X	—
Silvanidae sp.	silvan flat bark beetle	No assessment	Wake 2019	L-M	L	—	—	X	—	—
Liriomyza prob. *sativae*	vegetable leaf miner	No assessment	Wake 2019	L-M	L	—	—	X	—	—
Culex quinquefasciatus	southern house mosquito	No assessment	Wake 2019	M	M	—	—	X	—	—
Pulvinaria urbicola	urbicola soft scale	No assessment	Wake 2019	M-H	M	X	—	—	—	—
Anoplolepis gracilipes	yellow crazy ant	No assessment	Wake 2019	H	M	—	X	X	X	—
Monomorium floricola	Monomorium ant	No assessment	Wake 2019	L-M	L	—	—	X	—	—
Monomorium liliuokalanii	Monomorium ant	No assessment	Wake 2019	L-M	L	—	—	X	—	—

Table 2. List of plant, arthropod, and reptile species currently (2019) established at Wake considered to be alien invasive/pest species.—Continued

[Relevant published risk assessment scores for these species are included and were considered during a preliminary species risk assessment for identifying potential invasive management actions at Wake. Species detected during 2019 surveys are indicated (X) for each islet (Wilkes N= North S= South, Wake, and Peale). Wake preliminary risk assessment and potential management feasibility scoring was based on an approach developed by Booy and others (2017) and modified by J.Q. Richmond, J. Kingston, B.A.I. Ewing, W. Bear, S.A. Hathaway, K.L. Preston, B.E. Kus, and R.N. Fisher, U.S. Geological Survey; C. Lee, C. Swift, and A.J. Schultz, Natural History Museum of Los Angeles County; K. Russel, Riverside-Corona Resource Conservation District; P. Unitt, B.D. Hollingsworth, M. Wall, and S. Tremor, San Diego Natural History Museum; R.E. Espinoza, Department of Biology, California State University Northridge; and K. Palenscar, San Bernardino Valley Municipal Water District (unpub. data, 2019). This is a step-wise semi-quantitative procedure and consensus-building among taxonomic experts to identify high ranking species that can be managed effectively. A full risk assessment could not be completed; experts consisted of contributing authors only. **Abbreviation**: —, no data]

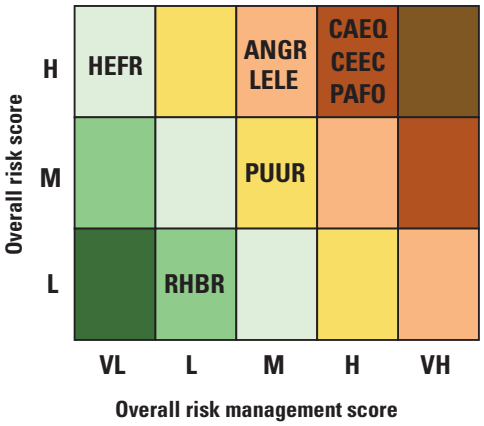
Scientific name	Common name	Published risk[1]	Risk assessment[2]	Wake risk assessment[3]	Management feasibility[4]	Wilkes N	Wilkes S	Wake	Peale	Not detected 2019
Arthropods—Continued										
Nylanderia bourbonica	robust crazy ant	No assessment	Wake 2019	L-M	L	X	—	X	X	—
Paratrechina longicornis	longhorn crazy ant	No assessment	Wake 2019	M	L	X	—	X	—	—
Pheidole megacephala	big-headed ant	No assessment	Wake 2019	M	M	—	—	X	—	—
Pheidole nr. *moerens*	big-headed ant	No assessment	Wake 2019	M	M	—	—	X	—	—
Pheidole sp.	big-headed ant	No assessment	Wake 2019	M	M	—	—	X	X	—
Solenopsis geminata	tropical fire ant	No assessment	Wake 2019	M	M	—	—	X	—	—
Tapinoma melanocephalum	ghost ant	No assessment	Wake 2019	L-M	L	X	X	X	X	—
Tetramorium nr. *simillimum*	Tetramorium ant	No assessment	Wake 2019	L-M	L-M	—	—	X	X	—
Tetramorium sp.	Tetramorium ant	No assessment	Wake 2019	L-M	L-M	—	—	X	—	—
Trichomyrmex destructor	Singapore ant	No assessment	Wake 2019	M	L	X	—	X	X	—
Ropalidia marginata	paper wasp	No assessment	Wake 2019	M	L-M	X	—	X	X	—
Reptiles										
Hemidactylus frenatus	common house gecko	No assessment	Wake 2019	H	VL	X	X	X	X	—
Ramphotyphlops braminus	Brahminy blindsnake	No assessment	Wake 2019	L	L	—	—	—	2017	X

[1]**Published risk-assessment status**: High risk, High risk invasive species; No Assessment, No risk assessment conducted.

[2]**Published risk-assessment reference**: HPWRA (Hawai'i-Pacific Weed Risk Assessment, 2019; www.hpwra.org); FISC database (Florida Invasive Species Council, 2019; https://www.fleppc.org/); PIER, Pacific Island Ecosystems at Risk, U.S. Forest Service (2018; http://www.hear.org/pier/); USDA-APHIS, U.S. Department of Agriculture Animal and Plant Health Inspection Service; Wake 2019, Wake 2019 Survey.

[3]**Wake risk assessment**: H = high, M = medium, L = low.

[4]**Wake management feasibility**: H = high, M = medium, L = low, VL = very low.



Priority	Species	Code	Common names
Highest	*Casuarina equisetifolia*	CAEQ	*ironwood; Australian pine tree*
	Cenchrus echinatus	CEEC	*sandbur*
	Passiflora foetida var. *hispida*	PAFO	*passion fruit, scarletfruit passionflower*
High	*Anoplolepis gracilipes*	ANGR	*yellow crazy ant*
	Leucaena leucocephala	LELE	*koa haole, tangantangan, lead tree*
Moderate	*Pulvinaria urbicola*	PUUR	*urbicola soft scale*
Low	*Hemidactylus frenatus*	HEFR	*common house gecko*
	Ramphotyphlops braminus	PHBR	*Brahminy blindsnake*

Figure 4. Output generated from the Wake 2019 preliminary risk analysis of established invasive species (following from Booy and others, 2017; and J.Q. Richmond, J. Kingston, B.A.I. Ewing, W. Bear, S.A. Hathaway, K.L. Preston, B.E. Kus, and R.N. Fisher, U.S. Geological Survey; C. Lee, C. Swift, and A.J. Schultz, Natural History Museum of Los Angeles County; K. Russel, Riverside-Corona Resource Conservation District; P. Unitt, B.D. Hollingsworth, M. Wall, and S. Tremor, San Diego Natural History Museum; R.E. Espinoza, Department of Biology, California State University Northridge; and K. Palenscar, San Bernardino Valley Municipal Water District, unpub. data, 2019]) for identifying potential species management. The background color of the matrix cells indicates priority (from green = lowest, to dark brown = highest). H = High; M = Medium; L = Low; VH = Very High; VL = Very Low.

Table 3. List of "horizon species," most likely invasive plant, arthropod, and amphibian and reptile species, that could arrive and become established on Wake Atoll based on the authors' understanding of current (2021) vectors, pathways, and invasive or potential invasive species at main departure ports (Hawai'i and Guam) to Wake Atoll.

Family	Scientific name	Common name
	Plants	
Poaceae	*Cenchrus setaceus*	fountaingrass
Poaceae	*Cenchrus ciliaris*	buffelgrass
Poaceae	*Melinis minutiflora*	molasses grass
Poaceae	*Panicum maximum*	guinea grass
Asteraceae	*Pluchea indica*	Indian fleabane
Asteraceae	*Verbesina encelioides*	golden crown-beard
Clusiaceae	*Clusia rosea*	autograph tree
Euphorbiaceae	*Ricinus communis*	castor bean
Fabaceae	*Neonotonia wightii*	glycine
Fabaceae	*Prosopis pallida*	kiawe, mesquite
Fabaceae	*Prosopis juliflora*	mesquite
Verbenaceae	*Lantana camara*	lantana
	Arthropods	
Scarabaeidae	*Oryctes rhinoceros*	coconut rhinoceros beetle
Dermestidae	*Trogoderma granarium*	khapra beetle
Vespidae	*Vespula pensylvanica*	western yellowjacket wasp
Formicidae	*Wasmannia auropunctata*	little fire ant
Culicidae	*Aedes albopictus*	Asian tiger mosquito
	Amphibians and Reptiles	
Bufonidae	*Rhinella marina*	cane toad
Eleutherodactylidae	*Eleutherodactylus coqui*	coqui frog
Scincidae	*Lampropholis delicata*	metallic skink
Scincidae	*Lipinia noctua*	moth skink
Scincidae	*Carlia ailanpalai*	Admiralty brown skink
Gekkonidae	*Nactus pelagicus*	Pacific slender-toed gecko
Gekkonidae	*Gehyra oceanica*	Oceanic gecko
Gekkonidae	*Phelsuma laticauda*	gold-dust day gecko
Dactyloidae	*Anolis carolinensis*	green anole
Dactyloidae	*Anolis sagrei*	brown anole
Colubridae	*Boiga irregularis*	brown tree snake

Invasive Species Management

In any invasive species management program, an emphasis on prevention is the most effective, efficient, and economical strategy (Victorian Government, 2010). Effective prevention relies on minimizing risk of introducing pests at as many points along invasive species pathways as possible (Hulme, 2015). We used the results of our surveys to evaluate the efficacy of the Wake Island Biosecurity Management Plan (U.S. Air Force, unpub. data, 2015) and to suggest supplementary biosecurity practices aimed at preventing unauthorized organism transport to Wake. We incorporated and simplified these effective measures into checklists for ease of use.

We also identified numerous plant, arthropod, and reptile species detected at Wake with potential to be invasive or pests. We identified six species currently (2019) at Wake for which management could be particularly beneficial. Specific results and discussion for each taxonomic group are detailed below.

Biosecurity and Pest Management for Plant Species

Biosecurity Concerns

During the 2019 survey, 51 introduced plant taxa established outside cultivation were found. Out of the 51 plant taxa, 33 are considered invasive, and several (for example, *Casuarina equisetifolia*, *Pluchea carolinensis*, and *Bidens alba*) have become widespread on one or more of the islets in the atoll (U.S. Forest Service, 2018; FISC, [Florida Invasive Species Council, 2019]; Hawai‘i-Pacific Weed Risk Assessment, 2019; International Union for Conservation of Nature, 2019; U.S. Department of Agriculture Natural Resources Conservation Service, 2019; table 2; J.D. Jacobi, unpub. data, 2020). Several invasive species found in the 2019 survey that have become established but are still more locally distributed include *Agave sisalana*, two air plant species (*Kalanchoe delagoensis* and *K. pinnata*), two species of cactus (*Nopalea cochenillifera* and *Opuntia littoralis*), *Passiflora foetida* var. *hispida*, *Abutilon indicum* subsp. *albescens*, and *Coccoloba uvifera* (fig. 5).

Figure 5. *Coccoloba uvifera* (sea grape) trees that are becoming established in several locations on Wake and Peale Islets and have the potential to rapidly spread and dominate the native vegetation if not controlled. Photograph by J. Jacobi, U.S. Geological Survey.

Regularly monitoring for potentially invasive plants could be particularly useful at the Solid Waste Accumulation Area (SWAA; HMU-15) on the south side of Wake Islet. *Solanum torvum*, a tall shrub in the tomato family, appears to be becoming established in this area. These plants likely originated from cultivated plants grown in the residence gardens and then discarded into the SWAA where the seeds were able to grow.

Additionally, some introduced plants grown as ornamentals are considered to be highly or moderately invasive in similar habitats elsewhere and have the potential for becoming naturalized on the atoll. These include *Psidium guajava*, *Phoenix* sp. (date palm), *Coccinia grandis*, *Ficus microcarpa*, *Talipariti tiliaceum* (hau), and *Thespesia populnea* (milo). The current lack of fruit or seed (or both) eating bird species on the atoll has reduced the risk of spread and widespread establishment for these fruit-producing species and other potentially invasive plants currently in cultivation. Several other of the cultivated plants recorded during the 2019 survey, such as *Schefflera actinophylla* and *Nymphaea* sp. (lotus or waterlily), also are considered to be highly invasive elsewhere but naturally grow in much wetter habitats than found outside of cultivation on Wake; therefore, they pose less risk in this environment.

Besides the invasive plant species that are currently found on Wake, there are many other species that could easily become established on the atoll if they are purposely or accidentally introduced in the future. This is a particular concern because cargo and personnel are arriving on Wake through regular aircraft or occasional barge traffic from many locations in the Pacific, including Hawai‘i, Guam, Okinawa, and other military installations in the Pacific. Some examples of highly invasive plant species that could become established on Wake are listed in table 3. These include several grasses, including *Cenchrus setaceus* (fountaingrass; fig. 6), that has become extremely problematic in Hawai‘i and elsewhere in the Pacific; three dry habitat trees: (1) *Prosopis pallida*, (2) *P. juliflora*, and (3) *Clusia rosea* (fig. 7); the herb *Verbesina encelioides*, two shrubs: (1) *Pluchea indica* and (2) *Lantana camara* (fig. 8); an aggressive vine: *Neonotonia wightii* (fig. 9); and a highly invasive large herbaceous plant, *Ricinus communis* (castor bean). *Ricinus* was previously recorded on Wake by Fosberg and Sachet (1969) but has not been found there since then.

Figure 6. *Cenchrus setaceus* has aggressively invaded dry lowland habitats in Hawai‘i, dominating the vegetation and posing a high risk for wildfire. Photograph by J. Jacobi, U.S. Geological Survey.

Figure 7. *Clusia rosea* is a small tree that grows along dry shorelines and lowland habitats in many areas across the Pacific. Photograph by Forest and Kim Starr, Starr Environmental.

Figure 8. *Lantana camara* is a small woody shrub that has been able to dominate lowland dry and mesic habitats in Pacific Island ecosystems such as in Hawai'i. Photograph by J. Jacobi, U.S. Geological Survey.

Figure 9. The aggressive invasive vine, *Neonotonia wightii*, has the ability to smother the vegetation in lowland habitat as seen in many areas in Hawai'i. Photograph by Forest and Kim Starr, Starr Environmental.

Management Considerations for Plant Species

Without active management, many of the invasive plant taxa already established or cultivated on Wake have the potential to spread more widely and have increased effects on the native plant vegetation and possibly, other groups, such as nesting seabirds. For some problematic species, such as *Casuarina equisetifolia*, which is already widespread throughout all the islets in the atoll, management for control and eventually elimination could be a major but beneficial effort. Initially, the most effective short-term approach may be to focus on reducing the abundance and distribution of selected invasive species with the potential shift to eradication based on the availability of funding and capacity.

For several of the recognized highly invasive species that are not currently widespread, such as *Agave americana*, the two airplant species (*Kalanchoe delagoensis* and *K. pinnata*), *Leucaena leucocephala, Passiflora foetida* var. *hispida*, *Abutilon indicum* subsp. *albescens*, the two cactus species, and *Coccoloba uvifera*, quick targeted management actions can result in effective control before they spread beyond their current limited distribution areas. Some of these species, including *Casuarina*, *Agave*, *Leucaena*, *Coccoloba*, and the two cactus species have recently been the focus of control efforts on portions of all three islets in the atoll (J. Gilardi, Island Conservation; and D. Duffy, University of Hawai'i Pacific Cooperative Studies Unit, University of Hawai'i at Mānoa, Hawai'i, unpub. data, 2018). During the 2019 field survey, large areas where *Casuarina* trees were previously controlled were visited; most of the trees were found to be dead, confirming the effectiveness of the treatment. However, a few young seedlings or saplings were seen in some of these areas, reinforcing the need for follow-up control efforts before the new plants reach reproductive maturity. Other invasive plants, like *Cocos nucifera* (coconut), *Pluchea carolinensis*, *Erigeron canadensis*, *Stachytarpheta jamaicensis*, the wild poinsettia (*Euphorbia heterophylla* var. *cyathophora*), and the African spider-flower (*Gynandropsis gynandra*) were found to be either absent or currently have limited distribution on the north section of Wilkes Islet. Controlling these species would be easier to accomplish before they can spread or get fully established there as well as on Peale.

It is a bit of a conundrum that several of the seabirds found on the atoll currently roost, or even nest, in the highly invasive *Casuarina equisetifolia* trees (fig. 10). In creating a strategy to reduce or eventually eliminate this introduced tree from Wake, it would be useful to recognize the importance of tree nesting and roosting sites for the birds. This could be accomplished by combining a control program with a habitat restoration program that focuses on planting native species, such as *Heliotropium foertherianum*, *Cordia subcordata*, and *Pisonia grandis*, to continue to provide trees for the birds to use as the *Casuarina* stands are eliminated. A well-designed restoration strategy with clearly defined vegetation structure and species composition targets can be established to help guide this effort.

Figure 10. Black noddy tern (*Anous minutus*) perching on a branch of a *Casuarina equisetifolia* (ironwood) tree. Photograph by J. Jacobi, U.S. Geological Survey.

From a biosecurity perspective, it is important to minimize the possibility that new species of invasive plants will become established on Wake. With the rare exception of commercial aircraft or mariners in distress, all air and sea traffic arriving and departing Wake is completely under the control of the DOD. That, plus the limited introduction pathways, helps to provide a setting for the implementation of a successful biosecurity strategy to keep new invasive species from getting established on the atoll. Such a strategy has the greatest potential for success if purposeful transport of plants is restricted to a list of species that have low invasion potential or species that will not serve as vectors for species already established on Wake. For example, several plants that are presently in cultivation around the residences (for example, *Psidium guajava*, *Coccinia grandis*, *Solanum torvum*) are currently limited to just where they have been planted. Although these species are considered elsewhere to be highly invasive, they need fruit or seed eating birds to disperse their seeds. Because there are currently no fruit or seed eating bird species on Wake, these invasive species are less likely to spread unless they are actively planted elsewhere on the atoll. However, if fruit or seed (or both) eating birds are brought to the atoll and become established in the wild, plants like *Psidium guava* and *Coccinia grandis* will be able to spread widely and have the potential to greatly alter the native plant communities.

Invasive Species Management Options for Selected Invasive Plants

The following section provides an overview of four introduced plant species. These particular species are considered to be highly invasive on Wake. We also include the current or potential methodologies that may be used for their control.

Casuarina equisetifolia (ironwood)

Casuarina equisetifolia (fig. 11) is considered to be native to coastal regions in Andaman Islands (India) and seacoasts from southern Bangladesh, Myanmar (formerly Burma), Thailand, and Malaysia to subtropical Australia, Melanesia, Micronesia, the Philippines, and parts of Polynesia (Parrotta, 1993). However, where it has been introduced in the Pacific Islands and elsewhere, it is considered to be a highly invasive tree that forms dense stands along dry to moist habitat shorelines (U.S. Forest Service, 2018). *Casuarina* has been considered particularly problematic as it totally dominates many coastal habitats in Hawai‘i, as well as in other lowland sites across the Pacific and has a high weed risk score (Hawai‘i-Pacific Weed Risk Assessment, 2019). Fosberg (1959) mentioned that ironwood was planted on Wake, but he did not indicate its abundance or that it was widely distributed on the atoll at that time. Since then, this species has expanded its distribution to form very dense stands on all three of the islets, as was found during the 2019 survey. Recently, efforts have been focused on reducing the extent of coverage and controlling the spread of this species in selected areas on Wake Islet, particularly around the residence area, and on Wilkes and Peale Islets where they are working to eliminate it entirely (J. Gilardi, Island Conservation; and D. Duffy, University of Hawai‘i Pacific Cooperative Studies Unit, University of Hawai‘i at Mānoa, Hawai‘i, unpub. data, 2018).

Figure 11. Closeup of foliage and cones of *Casuarina equisetifolia*. Photograph by J. Jacobi, U.S. Geological Survey.

Management has been focused on controlling *Casuarina* in many areas in the Pacific, particularly in Hawai‘i. Motooka and others (2003) suggested that this species was sensitive to cut-surface applications of Triclopyr, and Leary and others (2012) recommended using a 4-percent solution of Triclopyr or a 100-percent concentration of Glyphosate to control this species. Current control methods for *Casuarina* on Wake (J. Gilardi, Island Conservation; and D. Duffy, University of Hawai‘i Pacific Cooperative Studies Unit, University of Hawai‘i at Mānoa, Hawai‘i, unpub. data, 2018) are as follows:

1. Seedlings and small saplings are pulled wherever they are found.

2. Saplings less than 3-in. diameter that cannot be pulled out by hand are cut off on the stem at less than 0.25 meters (10 in.) with a small hand saw or battery powered chainsaw and pasted with Garlon (Triclopyr) solution (25-percent Garlon, 75-percent diesel) within 2 minutes of cutting.

3. Trees 8 centimeters (cm; greater than 3 in.) in diameter and larger are treated using the injection technique: the lower branches are cut with loppers, sawed, or broken by hand to allow access to the tree trunk. Dead outer layers of bark are scraped off using the claw of hammer or axe. A series of incisions are then cut at a 45-degree downwards sloping angle, 10–50 cm (4–20 in.) above the soil surface and a Garlon solution (25-percent Garlon, 75-percent diesel) is injected into the incision within 2 minutes of cutting.

Cenchrus echinatus (sandbur)

Cenchrus echinatus (fig. 12) is a small annual grass that is native to the neotropics and widely distributed throughout the Pacific Islands (Wagner and others, 2005–present). It has spiny burr-seeds and grows in dry, lowland sites, particularly along dry coastlines (Motooka and others, 2003; U.S. Forest Service, 2018). The seeds are easily dispersed by small mammals and ground birds, as well as on boots, clothing, and other items transported by humans. This species is already established in several places on at least Wake and Peale Islets, primarily in the strand vegetation along the shore or in other open disturbed sites. This grass is highly invasive and can form dense stands that are difficult to control. Due to the small size of the plant and with foliage that appears similar to other grass species, *Cenchrus* is often overlooked in an area unless the observer encounters the spiny seeds.

Figure 12. The introduced sandbur grass (*Cenchrus echinatus*) is becoming established in many sites on Wake and Peale Islets. Photograph by J. Jacobi, U.S. Geological Survey.

Cenchrus can be controlled using either physical (hand-pulling plants) or chemical methods (IUCN; International Union for Conservation of Nature, 2019). Hand-pulling has been found to be effective if the populations are small, which appears to be the current situation on Wake. However, follow-up monitoring of controlled sites is important since the seeds can remain viable in the ground for several years. Chemicals that have been found effective include glyphosate, chlorazifop, atrazine, and benfluralin (Motooka and others, 2003; U.S. Forest Service, 2018).

Leucaena leucocephala (koa haole, tangantangan)

A tall shrub or small tree, *Leucaena* (fig. 13), can dominate the vegetation in dry lowland sites. It has a high weed risk score, indicating it has high potential to cause substantial ecological or economic harm (Hawai‘i-Pacific Weed Risk Assessment, 2019). *Leucaena* was originally introduced into Hawai‘i and elsewhere in the Pacific as food for cattle because its pods are highly nutritious (Motooka and others, 2003; International Union for Conservation of Nature, 2019). Fosberg and Sachet (1969) mentioned seeing this species at one site on Peale Islet in 1961, as well as near the residence area on Wake Islet. During the 2019 survey, *Leucaena* was found in a few sites on Wake and Peale Islets, as well as three small patches on the south part of Wilkes Islet (J. Gilardi, Island Conservation, oral commun., 2018). However, as seen elsewhere in the Pacific, this species has the potential to spread throughout the atoll and become much more abundant, excluding the native species.

Leucaena has proven to be a difficult weed species to control (Motooka and others, 2003; International Union for Conservation of Nature, 2019). Leary and others (2012) note that a 4-percent foliar spray of triclopyr appeared to be effective on saplings less than 2 m (6 ft) tall. They also recommended using a basal spray or cut stump application of 20-percent triclopyr solution or 20-percent solution of glyphosate.

Figure 13. Flowers, immature seed pods, and foliage of the introduced invasive tree *Leucaena leucocephala* which is becoming established in several locations on Wake and Peale Islets. Photograph by J. Jacobi, U.S. Geological Survey.

The Efficacy Project was focused on animals; however, we opportunistically included plants where possible. Generally, only presence was noted; when possible plant matter or seeds (or both) were collected, though most specimens have not yet been identified to species (S.G. Yelenik, C.M. Yanger, J.D. Jacobi, and S.A. Hathaway, U.S. Geological Survey, unpub. data, 2021). We did, however, note *Leucaena leucocephala* was growing along the dock periphery, and seeds were found in the dock staging area in proximity to break bulk. Given it is a high priority risk species at Wake and removal from the port area would be feasible, removal could be prudent to reduce risk of accidental continued introduction of seeds. Removal could be particularly important if management of this species commences at Wake more generally.

Passiflora foetida var. *hispida* (scarletfruit passionflower)

A vine native to Central and South America, *Passiflora foetida* var. *hispida* (fig. 14) has a high weed risk score (Hawai‘i-Pacific Weed Risk Assessment, 2019). *Passiflora foetida* var. *hispida* has been introduced to many locations throughout the Pacific where it has been consistently considered a highly invasive and problematic species (U.S. Forest Service, 2018). This species invades disturbed sites but can expand into other open habitat areas if not controlled (International Union for Conservation of Nature, 2019).

There is little information on how to control this species. Generally, physical removal of the entire plant, with its roots, has been recommended, with continued monitoring of the site for regrowth (U.S. Forest Service, 2018). Additionally, it appears that glyphosate can be used to control this vine, but there are no details published on a preferred methodology and application rate. The DOD O‘ahu Army Natural Resource Program has had some success controlling similar *Passiflora* species by clipping the vines at the rooting points and applying Garlon 4 Ultra (20-percent dilution in biodiesel; J. Beachy, O‘ahu Army Natural Resource Program, written commun., 2022).

Figure 14. The introduced vine *Passiflora foetida* var. *hispida* is currently found on Wake Islet and the southeastern part of Wilkes Islet just north of the harbor inlet and storage tanks. Photograph by John Gilardi, Island Conservation.

Biosecurity and Pest Management for Arthropod Species

Biosecurity Concerns

Knowledge of biosecurity threats is generally poor for terrestrial arthropods, and there are few broad assessments that can be used to evaluate the current, or potential, assemblage of arthropod fauna on Wake. However, sources such as Nishida and Evenhuis (2000) and the Invasive Species Specialist Group (ISSG) Global Invasive Species Database (GISD; http://www.iucngisd.org/gisd/) provide some guidance for evaluating threats posed by a variety of species. Although both assessments target species of ecological or conservation importance, they also include several taxa that affect human safety or operational effectiveness. Neither assessment claims to be exhaustive. Most other sources available to assess biosecurity threats to Wake primarily focus on the effects of individual species or groups of closely related species, such as ants (for example, Holway and others, 2002; Plentovich and others, 2009).

Our survey identified 14 arthropod species, currently established on the atoll, that pose moderate to high levels of biosecurity concern to Wake. Of those species, the yellow crazy ant (YCA; *Anoplolepis gracilipes*) is of greatest concern due to its strong potential to the reduce nesting success of seabirds (Kropidlowski, 2014; Plentovich and others, 2018). We also included detection of YCAs as part of our reptile surveys because of its known invasion success and adverse ecological effects on Pacific islands (Holway and others, 2002; O'Dowd and others, 2003; Boland and others, 2011; Fisher and Ineich, 2012; Smith and others, 2012; Hoffmann and others, 2014). Yellow crazy ants may have direct effects on reptiles through predation (in other words, ambushing lizards or attacking eggs) or indirect effects through displacement of native arthropods that the reptiles feed on (Holway and others, 2002; Hoffmann and others, 2014). Native species, in general, can be negatively affected by YCAs, and successful ant invasion could potentially lead to great loss of native species in the event of irruptions (as seen on other Pacific islands).

Of moderate concern is the urbicola soft scale (*Pulvinaria urbicola*), a species of Hemiptera that feeds on *Pisonia grandis* trees. Heavy infestation of *Pisonia* by the urbicola soft scale has contributed to stand-level dieback of the trees elsewhere in the Pacific Basin, resulting in the demise of an ecologically important tree (Handler and others, 2007). There are 12 additional arthropod species that are considered moderate biosecurity concerns to Wake, including 6 predatory ants, the Asian subterranean termite (*Coptotermes gestroi*), the southern house mosquito (*Culex quinquefasciatus*), the lesser brown scorpion (*Isometrus maculatus*), the tropical centipede (undetermined Scolopendridae species), the red-headed centipede (*Scolopendra subspinipes*), and the vespid paper wasp (*Ropalidia marginata*). *Scolopendra subspinipes* could be of concern because it is known to be a voracious predator, feeding mostly on insects and vertebrates, including reptiles (snakes, geckos, and possibly skinks; Emery and others, 2021). However, the effects of this centipede on reptiles on Wake are unknown.

The primary biosecurity concern posed by the six ant species is their potential effect on arthropod biodiversity, although big-headed ants and the tropical fire ant may also have a negative effect on seabirds (Plentovich and others, 2009). The Asian subterranean termite is considered a major structural pest (Chouvenc and others, 2016) and appears to be spreading in the Pacific Basin, including Hawai'i. The southern house mosquito is a known vector of several human disease-causing pathogens and is a potential health risk as well as a nuisance to human activities (Juliano and Lounibos, 2005; McClure and others, 2018). Human interactions with the scorpion, centipedes, wasp, and the tropical fire ant (*Solenopsis geminata*) could result in painful bites or stings and may negatively affect operations on the atoll. Because wasps often chase and attack humans en masse for many meters when their nest is disturbed, encounters with this insect can be particularly painful or disruptive or, in the case of a severe allergy, could result in death (Gambino and Loope, 1992).

Species that pose a biosecurity concern to Wake (and elsewhere in the Pacific Basin) that were not found during our survey, or during surveys that preceded our effort, include the coconut rhinoceros beetle (CRB; *Oryctes rhinoceros*), the khapra beetle (*Trogoderma granarium*), the western yellowjacket wasp (*Vespula pensylvanica*), the little fire ant (*Wasmannia auropunctata*), and the Asian tiger mosquito (*Aedes albopictus*; table 3). Each of these species, except for the khapra beetle, is present on one or more of the Hawaiian Islands (Gambino and others, 1990; Vanderwoude and others, 2016; McClure and others, 2018; Russo, 2019). The CRB and little fire ant are subjects of extensive control or eradication efforts in Hawai'i and elsewhere in the Pacific Basin (Vanderwoude and others, 2016; Russo, 2019). In contrast, few tools are available for controlling the western yellowjacket, so this species has received relatively little attention by managers. The Asian tiger mosquito is widespread across much of Hawai'i and generally only controlled at local levels (for example, removing backyard water sources that may harbor larvae).

Comparing the results from the Efficacy Project with those assembled with the Biodiversity Project, we found that 98 of the 133 animal species detected in the cargo staging areas and containers to be used for cargo destined for Wake have not previously been reported from Wake. Following the same assessment procedures for evaluating potential negative effects at Wake as described above with the Biodiversity Surveys, 80 were considered to be of low risk, 2 as low to moderate, 3 as moderate, 7 as high, and the rest unknown. The high risk species include mongoose (*Herpestes javanicus*) which could devastate the seabird population and potentially diurnal lizards (Hays and Conant, 2007), the brown anole (*Anolis sagrei*) which could potentially displace lizard populations, and three fruit and seed eating bird species: (1) the common myna (*Acridotheres tristis*), (2) house sparrow (*Passer domesticus*), and (3) zebra dove (*Geopelia striata*) which could aid in invasive plant dispersal (Simberloff and Von Holle, 1999; Vizentin-Bugoni and others, 2021) with potentially disastrous consequences. We also detected cats which have been eradicated from Wake and house geckos which currently inhabit Wake, both of which are considered high risk to Wake species. We counted 3,924 animals representing at least 65 species (arthropods and house geckos) having made the transit to Wake in containers and break bulk on the barge during the Efficacy Project, of which at least 39 arthropod species have not been previously reported from Wake. These arthropods included the forest parrot ant (*Nylanderia vaga*) and a single dead specimen of the powderpost beetle (*Lyctus* sp.). The ant was assessed to be a low to moderate risk to biodiversity and the beetle a moderate risk due to its potential to damage wood (Snyder, 1938). Both would be difficult to manage (that is, have low management feasibility). Although *Nylanderia* are generally not considered to be significant ecological threats, on Wake, their greatest risk may be associated with their attraction to sugar-rich honeydew that is produced by hemipteran insects (for example, scales, aphids) while they feed on their host plants (Williams and Lucky, 2020). Hemiptera-tending invasive ants have been shown to facilitate population growth of the urbicola scale (*Pulvinaria urbicola*) on *Pisonia grandis* in the Pacific and Indian Basins (Hill and others, 2003; Handler and others, 2007; Gaigher and others, 2011), leading to tree mortality and the need for managing ants (Gaigher and Samways, 2013; Peck and others, 2014). Details on additional species detected during the Efficacy Project compiled by S.A. Hathaway and J.C. Molden, U.S. Geological Survey; and R. Peck, University of Hawai‘i at Hilo (unpub. data, 2020) were assessed to be low risk at this time and so are not addressed here. These results indicate the need for improved prevention measures.

Management Considerations for Arthropod Species

Fortunately, effective management of the YCA and the urbicola soft scale, the arthropod species of greatest invasive species concern to Wake, may be an achievable goal. We found YCAs on Peale, Wake, and Wilkes Islets, but on Wilkes Islet they appear to be restricted to the southern part of the islet and therefore not currently affecting birds nesting on the northern part of the islet (which includes the Bird Sanctuary [HMUs 1–3]), which may currently serve as the only YCA free refuge for native species on Wake. This separation is tenuous, and it is likely due to the narrow channel that separates the two parts of the islet. Establishing biosecurity and monitoring protocols that will prevent establishment of this ant on the northern part of Wilkes Islet may have a substantial, long-term benefit to maintaining healthy and productive seabird colonies. The urbicola soft scale is also a species for which immediate management may result in long-term benefit to the ecology of the atoll. We found the scale at low density at only one location on the northern part of Wilkes Islet. An initial survey of all *Pisonia* on the atoll could identify the distribution of the scale and inform further management decisions. If the population is confined to only one or a few locations, then it may be possible to eradicate this pest from Wake.

Management of the arthropod species identified as posing a moderate biosecurity risk could be more challenging than managing for the YCA and the urbicola soft scale but may be advisable if resources are available. For example, it may be possible to eradicate the southern house mosquito from Wake if attention is paid to standing fresh water, the habitat of the larval stage of the mosquito. Earlier efforts to eradicate three species of mosquito, including *Culex quinquefasciatus*, appear to have been successful (Bryan, 1959). These efforts focused on removing standing water sources and introducing mosquito larvae-eating fish. Larvicides targeting mosquitos are now available and could help with the effort. It also may be possible to eradicate the tropical fire ant from the atoll if its distribution is limited. We found this relatively conspicuous ant at only a few locations, primarily associated with buildings (for example, dorms, airport parking lot). Baits proven effective against tropical fire ants are available and could be used to target this species. Additional surveys to identify the distribution of this ant could inform any eradication efforts.

Invasive Species Management Options for High and Moderate-High Risk Arthropod Species

This section describes possible management options to control or eradicate the YCA and the urbicola soft scale. Control or eradication of YCA is important for the protection of seabird nesting colonies. Control or eradication of urbicola soft scale is important to prevent a potential dieback of the ecologically important *Pisonia grandis* trees.

Management of Yellow Crazy Ants

Yellow crazy ants pose a great threat to the seabirds that nest on the northern part of Wilkes Islet (Plentovich and others, 2009, 2018). The narrow, shallow channel that separates the northern and southern parts of Wilkes Islet appears to act as a tenuous barrier to the movement of YCAs between the land masses. Strict biosecurity protocols that prevent material that may harbor YCAs from being transported across the channel should minimize the risk of the ant's establishment in the bird management area. The invasive species management strategy suggested here could be focused on prevention biosecurity coupled with monitoring. Prevention components could emphasize the careful inspection of all movement onto Wilkes Islet HMUs 1–3. Inspection could include shoes, clothing, personal gear (for example, backpacks, ice chests), and any equipment (mowers) or vehicles used for moving persons and maintenance equipment onto Wilkes. Generally limiting access to HMUs 1–3 also could be beneficial. However, given enough time, the water barrier may be breached naturally by a land-bridge created by a log or other debris that becomes lodged in the channel. Regularly scheduled monitoring of this channel, particularly after storms, may reduce the chance of a land-bridge becoming established.

Extirpating YCAs from the southern part of Wilkes Islet may greatly minimize the chance of the ant becoming established on the northern part of the islet. Yellow crazy ants have been detected at several locations on the southern part of the islet, including in the area near the marina and at the road near the channel bisecting the islet. A systematic survey of the southern part of Wilkes Islet would identify the extent of the infestation on the islet. Eradicating YCAs from the southern part of Wilkes Islet may establish a buffer area that would minimize the chance of the ant moving into the bird management area. If YCAs are eradicated from the southern part of Wilkes Islet, then the total area that buffers the bird management area may be considerably larger than just the islet. The area between the marina and the ironwood stand that ends about mid-way along the runway is dominated by low growing grass and herbs that are likely poor habitat for YCAs. A survey of this area might confirm the absence of these ants in that area.

Yellow Crazy Ant Control Methods

Baits containing insecticides toxic to ants have proven effective for controlling, or eradicating, invasive ant species. Baits generally consist of an insecticide and a carrier attractive to ants into which the insecticide is incorporated. Carbohydrates are highly attractive to YCAs, so sugar-based carriers are often used for this species. The insecticide dinotefuran mixed with sugar water and taken up by polyacrylamide crystals ("hydrogel") has proven effective at killing ants across a 50-hectare (ha; 0.5 km^2) infestation on Johnston Atoll (Peck and others, 2015, 2017), and ultimately led to the eradication of this pest species on the atoll (https://fws.gov/story/2021-11/saving-seabird-paradise-invasive-acid-spraying-ants). To use this method, dry hydrogel beads first soak up the sugar bait (becoming saturated after about 12 hours), and then are spread by hand on the ground in an infested area. Yellow crazy ant workers carry saturated crystals to the nest where the solution is shared with queens and developing brood (fig. 15). Several applications of hydrogel bait may be required before a treated area is free of ants. Several commercially available ant baits have been tested against YCAs, but none have been found capable of eradicating the ant (Kropidlowski, 2014). The granular bait Presto 01 (Bayer Environmental Science) has been effective at controlling YCAs on Christmas Island (Abbott and Green, 2007), but the active ingredient is not registered for controlling ants in the United States. If the area occupied by YCAs on the southern part of Wilkes Islet were clarified, then a treatment strategy could be established.

Figure 15. Yellow crazy ant (*Anoplolepis gracilipes*) carrying a hydrogel crystal containing toxic insecticide to the nest in a tree cavity. Once in the nest, the toxicant will be fed to egg-producing queens and growing larvae. Photograph was taken on Johnston Atoll (Photograph by Robert Peck, Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo).

Management of the Urbicola Soft Scale

The urbicola soft scale (*Pulvinaria urbicola*) was detected at only one location at Wake Atoll, on a group of *Pisonia grandis* on the lagoon-side of the northern edge of Wilkes Islet. Within the stand, which consisted of numerous trees, the scale population appeared to be small as scales were only found on one tree (fig. 16). However, it was difficult to search entire trees, so it is likely that scales could be found elsewhere within the stand. Searching this stand more thoroughly, as well as other stands on the atoll, to identify the distribution of the scale could be an important first step to inform management. If the scale is restricted to only a few branches on one or more trees, then it may be possible to eradicate the scale by clipping and removing the branches hosting the insects. If the scale is more widely distributed on or among trees, then it may be possible to eradicate the scale using an insecticidal root drip, spray, or inoculation of the trees. The systemic insecticide imidacloprid was used to reduce the large population of the urbicola soft scale on *P. grandis* at Rose Atoll, although it did not eradicate the scale from individual trees (Peck and others, 2014). At Rose, several large *P. grandis* were treated with imidacloprid using a system that injected the water-soluble insecticide directly into the tree.

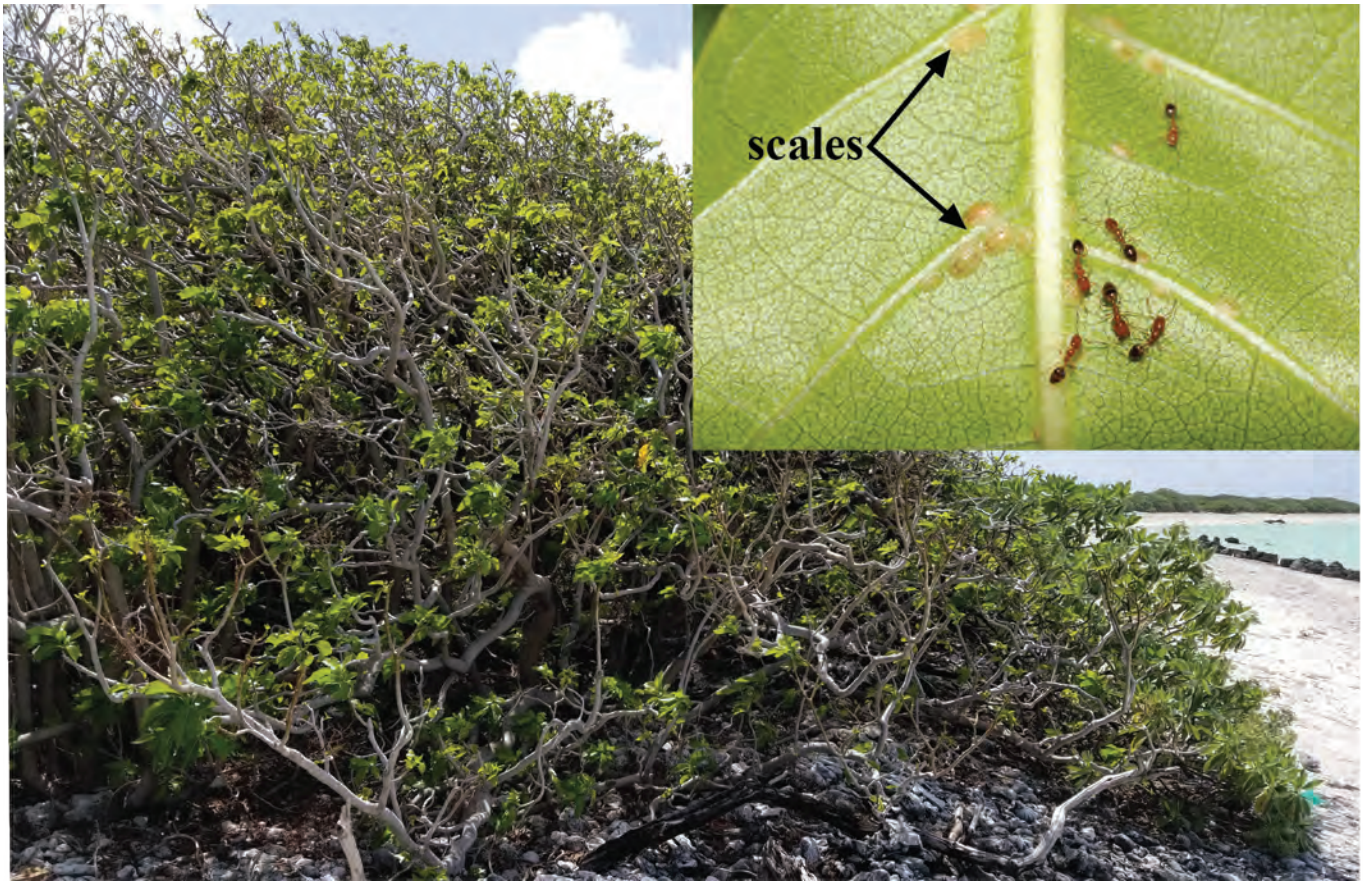


Figure 16. Urbicola soft scales on the underside of *Pisonia grandis* leaves (inset), and the *P. grandis* stand from which the scales were found (Photographs by Robert Peck, Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo). This stand is along the margin of the lagoon on the northern part of Wilkes Islet. The soft scale was detected on a tree about 5 meters toward the interior of the island from the vantage point where the photograph was taken. Note that the ants "tend" the scales, protecting them from natural enemies, and therefore often facilitate their population growth.

Biosecurity and Pest Management for Terrestrial Vertebrate Species

Biosecurity Concerns

Non-native invasive species presumed to have adverse effects on the native reptiles of Wake have included vertebrate and invertebrate taxa. The devastating effects of cats and rats on a wide range of taxa including reptiles cannot be understated; these effects include foraging on the snake-eyed skinks in the central Pacific (Kirkpatrick and Rauzon, 1986). Cats were brought to Wake in the 1960s and by the 1970s, they were considered a noticeable problem (Rauzon and others, 2008). Attempts to control their numbers began in 1996, and an eradication program was implemented in 2003. By 2004, it appeared the population was limited to two feral cats, presumably of the same sex because no additional cats were detected as of 2007 (Rauzon and others, 2008). A rodent eradication was attempted in 2012 and resulted in the successful eradication of one of two species of rodent existing on the atoll, specifically the Asian house rat. Both species were eradicated from Peale, but the Pacific rat (*R. exulans*) remains on Wake and Wilkes (Griffiths and others, 2014). This one species remains, but a future eradication attempt is in the design process (Joel Helm, U.S. Air Force, oral commun., 2020). Successful eradication of the Pacific rat would likely have an overall positive effect on native biodiversity and human inhabitants at Wake.

One invasive reptile species of great concern is the house gecko (*Hemidactylus frenatus*), which was observed widely across the atoll. This gecko competes with or preys upon native reptiles on other western Pacific islands (Bolger and Case, 1992; Case and others, 1994; Petren and Case, 1996; Cole and others, 2005; Cole and Harris, 2011) and is known to invade natural areas (Cole and others, 2005; Smith and others, 2012). The house gecko has been implicated in the decline of the non-native stump-toed gecko (*Gehyra insulensis*) in Guam and Hawai‘i and may have contributed to its apparent extirpation at Wake (Rodda and Fritts, 1992; McKeown, 1996). Therefore, one non-native species (house gecko) may have been at least partially responsible for the extirpation of another non-native species (stump-toed gecko) at Wake. We saw greater numbers of house geckos compared to mourning geckos (*Lepidodactylus lugubris*) on almost every night survey; on some nights, no mourning geckos were found. There is some possibility that this is a native species being negatively affected by the house gecko. We consider mourning geckos native because the presumptive area of origin of this hybrid species that is parthenogenetic (reproduction is asexual) is the southern Marshall Islands at or near Arno Atoll (Radtkey and others, 1995). The mourning gecko has clearly spread with humans more recently, and Ineich (1999) documented high clone turnover in some places due to the movement of people and equipment during World War II. For Wake, the mourning gecko could have arrived on its own, with early Micronesians or with early Europeans or a combination of these. The mourning gecko has probably arrived several times and could have experienced this clonal turnover. Because we cannot resolve this, we conservatively consider mourning geckos to be native. Likewise, it is possible that house geckos may be negatively affecting native Oceania snake-eyed skinks (*Cryptoblepharus poecilopleurus*). However, there are currently no studies completed to date at Wake in direct support of this. There is some evidence from Hawai‘i suggesting that there is a lack of skinks when skink habitat is occupied by the house gecko (R.N. Fisher, U.S. Geological Survey, oral commun., 2021). Cole and others (2005) reported house geckos prey upon small juvenile snake-eyed skinks in Mauritius. Continued monitoring of house geckos at Wake to examine the effects to native reptile species could be highly informative. We suggest that cautionary measures be taken to prevent further introductions, as well as its movement off the atoll.

We carried out searches in leaf litter and woody debris and did not detect the Brahminy blindsnake (*Ramphotyphlops braminus*); however, it was documented just 2 years prior, in 2017 (photograph documented by John Gilardi, Island Conservation). This species is parthenogenetic. This characteristic increases its potential for population expansion, and given its initial sighting in 1998 and the history of plant material being brought to Wake, it is likely that it is established. This small snake is generally unintentionally moved with soil. During site visits in 1952, Fosberg noted plants in pots and boxes of imported soil (Fosberg, 1959), so it is possible the blindsnake could have initially been transported then. This species feeds on tiny insects including larvae, eggs, and pupae of ants and termites (Wallach, 2009) so it may only affect species not thought to be native to Wake (S.A. Hathaway, A.R. Backlin, C.J. Hitchcock, and R.N. Fisher, U.S. Geological Survey; R. Peck, Hawai‘i Cooperative Studies Unit, University of Hawai‘i at Hilo, unpub. data, 2022). The potential for new blindsnake introductions or movement off Wake is reduced if restrictions on importing soil are continued and soil is not moved off Wake. However, other habitat such as stacked wood and debris could also harbor this animal. These types of cargo are still being transported on and off Wake and are biosecurity concerns.

A green anole (*Anolis carolinensis*) was reported as observed in 2008 at Wake (U.S. Air Force, unpub. data, 2017). Unfortunately, there was no location information associated with this record nor was there evidence it was captured or photographed to verify its identification. We did not detect any green anoles during our surveys. Green anoles would likely affect native lizards indirectly through competition for prey, as well as directly preying on juveniles. The green anole is a predator and competitor of the native Ogasawara snake-eyed skink (*Cryptoblepharus nigropunctatus*) and may have greatly decreased its population compared to pre-invasion densities (Suzuki, 1999). This species' similarity to the snake-eyed skink at Wake emphasizes the importance of preventing arrival and establishment of green anoles and other similar invasive species.

We did not detect any reptile species that had not previously been recorded at Wake. The possibility exists that any recent non-native incursions resulting in irruptions were not detected by our short duration surveys. Current biosecurity protocols could be generally effective for terrestrial reptile species. It is unclear whether continued introductions of the species already present have occurred, though this is highly likely for gecko species because they can easily hide in (or on) and attach their eggs to cargo and containers (for example, barges, tugs, and personal gear). This type of transport has been shown for the Society Islands with house geckos (Tonione and others, 2011). The Efficacy Project revealed at least one adult house gecko was transported from Honolulu, Hawai‘i to Wake in a container and was intercepted on a glue board trap (S.A. Hathaway and J.C. Molden, U.S. Geological Survey, unpub. data, 2022). Several specimens of this species, including eggs, were found throughout the cargo staging areas during the Efficacy Project, and this species is also known to be common in Guam (Rodda and others, 1991). More stringent biosecurity protocols could reduce, if not eliminate, this movement.

We identified 11 amphibian and reptile species as horizon species with greatest risk and potential to arrive at Wake (table 3). The brown tree snake (*Boiga irregularis*) is one of the most well-known invasive species, with devastating environmental, human health and economic effects after being accidentally introduced to Guam, for example (Rodda and others, 1992). This species has been of such elevated concern that a letter of verification of U.S. Department of Agriculture (USDA) canine inspection is required for all vessels and aircraft before departure for Wake from Guam. Multiple amphibian and lizard species present on O‘ahu or Guam (or both) have likewise had particularly negative effects on the native fauna there and elsewhere, thus, the importance of preventing their arrival to Wake. Additional information on these species relevant to Wake has been compiled elsewhere (S.A. Hathaway and R.N. Fisher, U.S. Geological Survey, unpub. data, 2022).

Management Considerations for Terrestrial Vertebrate Species

Although eradication of the invasive reptile species currently on Wake (house geckos and Brahminy blindsnakes) would be beneficial, there are currently no known effective tools to do so, and house geckos would likely re-invade. While not a comprehensive list of potential horizon species, additional detail for identifying the reptile and amphibian species listed in table 3 has been compiled for Wake (S.A. Hathaway and R.N. Fisher, U.S. Geological Survey, unpub. data, 2022). Strengthening and enforcing biosecurity protocols could be cost effective and efficient to reduce the potential for additional reptiles (or any organisms), whether new or existing species, to arrive at Wake and move from Wake to other locations.

Additional Considerations for Enhancing Invasive Species Management

The most likely potential pathways for movement on and off the atoll are through barge and tug transport and airplane. Potential pathways include passengers with personal effects, mail, all supplies, and the vessels themselves. These pathways present various opportunities for a variety of viable animal life stages, including eggs, to be inadvertently moved. Continued and enhanced diligence in inspections could reduce the risk of transport. We suggest the management goal be that any non-native organisms (including their seeds or eggs) are intercepted and reported (see appendix 2 for reporting data sheet). The same goes for any individuals of unrecognized animal or plant species found on Wake. Educational materials such as having copies of the species identification guide (S.A. Hathaway, J.D. Jacobi, A.R. Backlin, C.J. Hitchcock, and R.N. Fisher, U.S. Geological Survey; and R. Peck, University of Hawai‘i at Hilo, unpub. data, 2022) on atoll, posted materials depicting the species of most concern, and simple steps for reporting, can further engage onsite staff and visitors to increase their awareness and participation in prevention, early detection, and rapid response.

In our internal preliminary risk assessment, we evaluated plants, arthropods, and reptiles independently, according to taxonomic expertise, and then pooled results to identify potential priority species to consider for allocating resources toward invasive species management planning. Ranking was based on a combination of the species' effects and management feasibility. Of the known plant, arthropod, and reptile species on Wake, we identified six for which management could be particularly beneficial. There has already been considerable progress to control ironwood and creating a restoration framework within which to nest this effort could enhance success of eradication (and further benefit native plant and animal species) by including designed replacement with native plant species to outcompete new or regrowth after removal or treatment. Areas on the atoll have been intensively managed for invasive species control (for example, ironwood control on Peale Islet). Addition of native propagules in areas of invasive removal can facilitate native restoration and enhance invasive species control success by preventing reestablishment of invasive species. The 2017 INRMP lacks a native plant restoration implementation schedule that portrays how outplanting of native plant species will take place in areas where ironwood and other invasive plant species (for example, opuntia and agave) have been treated or removed. This type of update to the existing INRMP could help the installation better ensure areas once dominated by ironwood are not reinhabited by ironwood or other competing invasives.

The absence of YCA, combined with the relative isolation of the Bird Sanctuary at Wilkes, and the potentially limited atoll-wide extent of urbicola scale present opportunities that most islands do not have for managing distribution or eradicating species for substantial ecosystem benefit. Action in these cases would be most effective if taken before the species' distributions expand. There may be similar opportunity for eradicating tropical fire ants as well. The apparent absence of YCA in the Bird Sanctuary lends support to considering YCAs a species for which management could be beneficial, particularly because the area is already being mowed to entice ground nesting birds that would otherwise be more attracted to the runway (U.S. Air Force, unpub. data, 2017). Further, such management could provide refuge for all other native species reported at Wake using the various habitats there.

Limitations of Current (2019) Surveys and Future Needs

Wake is a remote atoll with limited historical flora and fauna collections and descriptions; it has had human visitation and presence and extensive disturbance over time (S.A. Hathaway, J.D. Jacobi, A.R. Backlin, C.J. Hitchcock, and R.N. Fisher, U.S. Geological Survey; and R. Peck, University of Hawai‘i at Hilo, unpub. data, 2022). This creates challenges for determining the native status of species there. Additional surveys are warranted to better map and identify the extent of native, non-native and invasive flora and fauna across the three islets.

Consistent monitoring by onsite staff of areas most likely to be an initial site of incursion for any new plant or animal species, such as cargo staging and loading areas in Hawai‘i and cargo unloading areas at Wake and around heavily used locations on Wake, especially the air terminal, marina, and living quarters, could be highly effective. Further benefits could be achieved from periodic monitoring by experts to detect new incursions of potentially harmful non-native species. A more in-depth risk assessment and horizon scanning with a broader group of taxonomic experts to provide input on potential species of particular concern and to identify invasive species arrivals could provide additional information useful to managers.

Conclusion

Through visitation and various uses, non-native species have been historically intentionally and unintentionally introduced to Wake by humans. Although Wake is remote, there is a moderate tempo of air and sea-based arrivals and departures in support of various DOD operations which include natural resource management. With this continued influx of aircraft, sea vessels, and their contents into and around Wake, there is the potential to import and move non-native and potentially highly invasive species. Non-native and invasive species can negatively affect the native ecosystems in several ways, including through competition, hybridization, habitat modification, predation, and disease transmission. Of the many potential threats to Wake's operations and ecosystems, non-native species are one threat that can be urgent and also preventable. Mandatory biosecurity protocols have been established and implemented (U.S. Air Force, unpub. data, 2015; U.S. Department of Defense, 2021). This project and a complementary project (the Efficacy Project) evaluated the effectiveness of current (2015) biosecurity protocols and their implementation to inform updates aimed at reducing the potential introduction and spread of new species. Potential updates to protocols summarized as biosecurity checklists are presented herein (appendix 1). Control, eradication, and, where necessary, restoration plans associated with incipient and established non-native species could continue to be created and implemented, ideally through an adaptive management framework. Monitoring plans could ensure the efficacy of these actions and reduce potential for negative effects. In addition, continual monitoring would provide important management information to improve protocols and methods to be applied here and in similar environments.

The materials presented here are part of an adaptive management planning process supporting INRMP goals to "develop and employ a systematic approach for onshore and offshore biosecurity," update the Biosecurity Management, Biological Control, Survey, and Management, and Integrated Pest Management Plans, establish a long-term management strategy for top invasive species, and minimize the potential for the inadvertent introduction of alien and invasive species onto Wake with contingency, emergency, and supply operations. Our results focus on ecosystem security, and specifically identify and address issues related to non-native and potentially invasive species. Our suggested updates inform existing and potential supplemental biosecurity practices aimed at preventing unauthorized organism transport to Wake. We incorporated and simplified these effective measures into checklists for ease of use when these practices need to be applied. For invasive species prevention and management to be of greatest value, focusing on pest prevention through biosecurity of pathways of invasion is critical. The overall goal is to inform invasive species management at Wake, the protection of vulnerable species and habitat, human habitants and visitors, and the potential for effects to the installation's mission.

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Glossary

Alien Species Any species, including its seeds, eggs, spores or other biological material capable of propagating that species, that is not native to a respective ecosystem (Executive Order 13112, 1999; Executive Order 13751, 2016).

Biosecurity Practices to prevent or respond to the introduction and proliferation of biological organisms identified as threats or potential threats to plant, animal (including human), ecosystem health, or human made environment or any combination of these.

Break Bulk Goods that must be loaded individually and not in intermodal containers.

Ecosystem Management A holistic approach to maintaining ecological integrity; elements of ecosystem management include sustainability, establishing goals, a sound basis in ecological models and understanding, recognizing the importance of biodiversity and structural complexity and the interconnectedness and dynamic character of ecosystems, preserving key processes that sustain resilience, the consideration of the range of spatial and temporal scales, the role of humans as necessary for achieving sustainable ecosystem management goals, and the importance of adaptability and accountability (Christensen and others, 1996; Lackey, 1998).

Endemic Species A species only known to naturally inhabit a specific location.

Fumigant A chemical compound in a gaseous state as a pesticide or disinfectant.

Fumigation Pest control treatment with a chemical agent (pesticide or disinfectant) that is wholly or primarily in a gaseous state.

Hitchhiker An organism unintentionally moved such as in or on cargo, baggage, vehicles, personal effects, and so forth.

Horizon Species Potentially invasive non-native species most likely to arrive to Wake based on risk of species existing in transit routes that include Wake and are identified by experts as potential risk species.

Integrated Natural Resources Management Plan (INRMP) A plan based on ecosystem management that describes and delineates the interrelationships of the individual natural resource elements in concert with the mission and land use activities affecting the basic land management plans. Defines the natural resources elements and the activities required to implement stated goals and objectives for those resources (U.S. Air Force, 2020).

Integrated Pest Management (IPM) A science-based, sustainable, decision-making process that identifies and reduces risks from pests and pest management-related strategies. Integrated Pest Management coordinates the use of pest biology, environmental information, and available technology to prevent unacceptable levels of pest damage using the most economical means, while minimizing risk to people, property, resources, and the environment. Integrated Pest Management provides an effective strategy for pest management in all arenas from developed agricultural, residential, and public lands to natural and wilderness areas (U.S. Department of Defense, 2019).

Invasive Species An alien animal or plant species whose introduction does, or is likely to cause, economic or environmental harm, or harm to human health (Executive Order 13112, 1999; Executive Order 13751, 2016) usually due to overpopulation and spread in exclusion of or causing alteration to native species or habitat. Similar to "pest," whereas the species might adversely affect or is perceived to adversely affect operations, personnel, native species or their environment and ecosystem processes or may attack or damage property, supplies, equipment, or are otherwise undesirable.

Native species Species presence in a particular ecosystem through natural processes with no human intervention.

Non-native species Species that do not exist naturally in an area but are introduced intentionally or accidentally through human intervention (synonym alien). This might include species that were not historically known to exist on Wake according to records from herbariums, museums, published and unpublished literature, and taking into consideration criteria such as biogeographic barriers and ability to survive without human assistance.

Pest Any organism (native or not) including but not limited to plants or plant parts, arthropods, amphibians, reptiles, mammals, nematodes, fungi, algae, bacteria, viruses, other microorganisms, that adversely affect or are perceived to adversely affect operations, or the well-being of personnel, native plants, animals, their environment, and ecosystem processes; attack or damage real property, supplies, equipment, or are otherwise undesirable (paraphrased from many sources including 53 Federal Register [FR] 15975, May 4, 1988, as amended at 78 FR 13507, February 28, 2013).

Pest Management Prevention and control of disease vectors and pests that may adversely affect other organisms, ecosystem processes, the environment, infrastructure, property, structures, operations in general.

Risk Analysis "The set of tools or processes incorporating risk assessment, risk management, and risk communication, which are used to evaluate the potential risks associated with a non-native species or invasion pathway, possible mitigation measures to address the risk, and the information to be shared with decision-makers and other stakeholders" (National Invasive Species Council, 2016).

Weed A plant (native or non-native) that is not valued in the place where it is growing (USDA-APHIS).

Appendix 1. Examples of Potential Biosecurity Checklists for Wake Atoll

Contact and routing information and direction about contractors' obligations in checklist examples was provided by the USAF and is included at their request. The specific contact information for the USAF 611 CES/CEI Biosecurity Manager is accurate as of publication; it is possible it could change in the future.

Cargo Staging Areas Sanitation Inspection Checklist

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required. All biosecurity activities undertaken by Base Operating Support (BOS) should also be documented in quarterly reports to the USAF 611.

Ensure Wake Island Base Operations (Ops) and 611 CES Environmental has received quarterly report(s) from pest control contracts documenting type of rodent control in place, frequency of baiting, density of traps and trap results (per Defense Transportation Regulations [DTR] Part V) from each facility storing cargo destined for Wake. Cargo Staging areas could include Naval Supply Yard, BOS Contract warehouses, and Air Mobility Command (AMC) Facilities.

Perform visual inspections of storage areas to verify sanitation and preventative tool(s) deployment at final pre-barge storage facility/ies. Complete inspection 3–6 weeks before beginning of stockpiling for barge movements, timing such that it leaves enough lead time for any problem to be resolved before cargo storage or alternate site located. As feasible, inspections should be completed by a team that includes the facilities port management and the 611 biosecurity manager.

Repeat onsite inspections weekly while cargo arrives onsite.

Once cargo begins arriving (including break bulk) ***include cargo in inspections*** paying close attention to any damaged packaging for animals, plants or other sign indicating infestation.

Warehouse(s) Dock Areas and Cargo

Indicate presence/sign and record location:

Animals (presence includes live animals, carcasses or other body parts [such as limbs, wings, fur, feathers, and so forth], or sign of presence [for example, footprints, chew marks, food piles, feces, urine, eggs, nest, web, and so forth])

Rat _____sign/presence type(s) _____location(s)

Cat _____sign/presence type(s) _____location(s)

Mongoose _____sign/presence type(s)_____location(s)

Bird _____sign/presence type(s) _____location(s)

Snake _____sign/presence type(s) _____location(s)

Lizard _____sign/presence type(s) _____location(s)

Frogs/Toad _____sign/presence type(s) _____location(s)

Insect particularly ant _____type/sign/presence type(s) _____location(s)

Other _____sign/presence type(s) _____location(s)

Plant matter particularly seeds _____location(s)

In the event of animal presence coordinate pest control (and notify Wake Island Base Ops and 611 CES Environmental) with Biosecurity Manager on how to proceed, after initial containment attempt if can be completed safely. In the event of plant matter, coordinate cleaning the area.

Resume inspection schedule after pest control or cleaning has been completed.

During Initial Onsite Inspection

Indicate compliance by **initial and date:**

Check Goodnature traps (or similar product) for:

____Appropriate density of traps inside and outside buildings

____Trigger events = Count

____Test Functioning

____Refill bait

Set:

Where Goodnature traps are not used: alternate stations with Stickem Glue Board (or similar product) baited with nontoxic bait or Trapper T-Rex Rat Snap Trap (or similar product) baited with professional rat attractant (use U.S. Environmental Protection Agency [EPA] approved rodenticide [poison] otherwise nontoxic) bait and placed inside appropriate bait station

____Glue board (for example, Trapper Max Free or similar) placed flat alongside each Goodnature trap or bait station

____Wax chew blocks placed alongside each Goodnature trap or bait station

____Ink cards per guidance

____Check camera traps per guidance

Note: Traps should be placed along walls and in corners

NOTE →The Wake Island Commander (CDR) can prohibit the opening of containers or other cargo, if there is no documentation showing that the origin activity has an ongoing pest control program. Contact the 611th CES, Biosecurity Manager, for further information (717-559-0192) or Wake Island Base Operations (808-424-2222).

Submit Cargo Storage Area Sanitation Checklist for archival purposes email:

BASEOPS@WAKEISLAND.NET *and* james.stanford.5.ctr@us.af.mil

Prior to Departure to Wake Container Integrity and Sanitation

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required. All biosecurity activities undertaken by Base Operating Support (BOS) should also be documented in quarterly reports to the USAF 611.

Indicate compliance by **initial and date:**

Upon container/flat rack delivery:

____Check complete initial inspection of container

____Inspect exteriors of every container/flat rack and look for the following and if found reject container or ***contain**** any:

Live animals (be particularly watchful for ants)
Eggs (for example, gecko, spider, roach and so forth)
Seeds/plant matter
Dirt or debris

____Inspect inside every container. Once opened immediately look for the following and if found reject or ***contain**** any:

Live animals (be particularly watchful for ants)
Eggs (for example, gecko, spider, roach and so forth)
Seeds/plant matter
Dirt or debris
Water
Mold

____Inspect interior door gaskets and seals

____Inspect flooring looking for bore holes, missing bolts and other damage that would allow animals or seeds to be easily transported or move into or out of the container

____Go inside container with doors completely closed (make sure you can exit as needed) and look for light indicating holes or gaps from doors not sealing properly (this only works if you are in a well-lit area or have someone outside with a light to shine toward the container).

Request replacement containers for any that fail to meet integrity (outdated Container Safety Convention [CSC] inspection date, seaworthiness, free of damage) and sanitation (clean, free of animal(s) and sign of animals, seeds/plant matter, dirt, debris, water, mold and so forth) requirement

Break Bulk

____Inspect exterior (including undercarriage, wheel wells, engine compartments, cab, trunk or any other parts that can be opened and that could harbor animals, their eggs, seeds and so forth) and ***contain**** any:

Live animals (be particularly watchful for ants)
Eggs (for example, gecko, spider, roach and so forth)
Seeds/plant matter

Dirt or debris
Water
Mold

Submit Container Integrity and Sanitation Checklist for archival purposes email:

BASEOPS@WAKEISLAND.NET ***and*** james.stanford.5.ctr@us.af.mil

Contain means capture and remove (if possible) using disinfecting procedures such as hand capture, vacuuming, fumigation, contact insecticide and so forth.

Cargo Inspection While Loading and Biosecurity Tool Placement

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required. All biosecurity activities undertaken by the Base Operating Support (BOS) should also be documented in quarterly reports to the USAF 611.

Indicate compliance by **initial and date:**

____Before cargo loading into containers, walk through cargo area and look for any pests or plant matter on or near cargo and remove or halt loading until clear and sanitized as appropriate.

____Before loading, inspect to be sure the container staging area is free of animals and plant matter.

____As each container is opened for loading, look for any animals or plant matter in the container and remove or close and isolate for cleaning as appropriate.

____As each cargo item is moved for loading, look for any animals or animal sign, or plant matter on the cargo and halt loading, isolate until clear and sanitized as appropriate before loading.

____During loading operations, **any box, cargo, or container showing signs of infestation (feces, chew marks, footprints, urine scent, hair, eggs, nest, holes in cardboard, food piles) will be pulled out of the shipment and placed in an isolated area and thoroughly inspected and sanitized before being placed back in the shipment.**

Add required biosecurity tools (number of traps were informed by the Efficacy Project container study [S.A. Hathaway, J.C. Molden, C.S. Brehme, and R.N. Fisher, U.S. Geological Survey; R. Peck, Hawai`i Cooperative Studies Unit, University of Hawai`i at Hilo; and K.R. Rex, National Oceanic and Atmospheric Administration, unpub. data, 2022] and can be adjusted according to needs, area being covered, or as additional research suggests):

____Two No Pest Strips (containers without perishables), one at the back and one at the front of each container

____Two Roach baits containing approved insecticide (containers without perishables), one at the back and one at the front of each container

____Two Ant baits containing approved insecticide (containers without perishables), one at the back and one at the front of each container

____Three Stickem or Trapper Max Free (unscented) glue boards (or similar) per container baited with nontoxic bait on the floorboard before sealing container

____One Protective Rodent Bait Station per shipping container—This bait station is intended to house a snap trap, and protect it from accidental trigger

____One Trapper T-Rex Rat Snap Trap (or similar) which will go inside each bait station, baited with nontoxic bait

____Two Wax chew blocks placed at the front of the container

Break Bulk

____Before break bulk loading, walk through the break bulk storage and loading areas and look for and contain* any pests or plants, seeds, or other plant matter

____Before break bulk loading, carefully inspect the break bulk items, looking for and containing* any pests or plant matter, or soil on in or near break bulk. ***This will require examining undercarriage, opening doors to cabs and engine compartments, and inspecting pallets or other storage transport structure being loaded as appropriate***

____Any break bulk or flat rack showing signs of infestation (feces, chew marks, footprints, urine scent, hair, eggs, nest, holes in cardboard, food piles) will be pulled out of the shipment and placed in an isolated area and thoroughly inspected and sanitized before being placed back in the shipment.

Submit Cargo Inspection While Loading and Biosecurity Tool Placement Checklist for archival purposes email:

BASEOPS@WAKEISLAND.NET *and* james.stanford.5.ctr@us.af.mil

Contain means capture and remove (if possible) using disinfecting procedures such as hand capture, vacuuming, fumigation, contact insecticide and so forth.

Barge and Tug Operators Checklist

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required.

Indicate compliance by **initial and date:**

_____Rodent Inspection Certification received and dated and signed within 72 hours departure for Wake and provided to and reviewed by the 611 biosecurity manager (james.stanford.5.ctr@us.af.mil).

_____**For any barge, tug, or cargo (break bulk or containers) that moves through or originates from Guam ports (Navy or commercial):** Brown tree-snake U.S. Department of Agriculture (USDA) canine inspection arranged 14 days before departure for Wake. Letter of verification is to be submitted to the Wake Island Base Operations at

BaseOperations2@wakeisland.net before the vessel or aircraft arrival at Wake and reviewed by the 611 biosecurity manager (james.stanford.5.ctr@us.af.mil).

_____Vessel operators will ensure that during loading operation at the location of origin:

All mooring lines are protected with rat guards, baited snap traps (Trapper T-Rex Snap Traps [or similar]) are deployed at each line exit and tie off point and vent scupper openings are protected by backing them up with heavy gauge screening to prevent rats or other rodents from building nests or accessing vessel. For areas of high rodent activity, baited snap traps will be placed inside a protective box called a “bait station” to avoid accidental triggers. Bait stations for vessels will consist of a protective covering or box for each snap or Stickem or Trapper Max Free (unscented) glue boards (or similar) and each trap will be baited with non-toxic rodent attractant.

_____**NOTE →**In the event that cargo destined for Wake is discovered to be contaminated with an invasive species (that is, seeds or other plant matter, rodents, snakes, insects, or other animal in any life stage including eggs) after departure from point of origin, the captain will isolate the package or container, and refrain from offloading the item on Wake. The captain will immediately contact Wake Base Ops (DSN: 315-424-2222 or Commercial: 808-424-2222) and the 611 biosecurity manager (james.stanford.5.ctr@us.af.mil) to alert them to the presence of an invasive species on the vessel. This notification will activate an equipped Wake Atoll ad hoc on-island response team that will meet the vessel on arrival and ensure to the best of their ability that the suspect incursion is properly addressed and documented.

_____Grant vessel access to a government appointed (611th Civil Engineer Squadron or Detachment 1 Commander) pest control inspector to tug and barge any time vessels are tied up to dock at departure port to and at Wake.

_____Before entering port, equipment, supplies, cargo and waste on ships shall be inspected to avoid the introduction of invasive pests into Hawai`i or Wake Atoll. All vessels shall, before arrival to Hawai`i or Wake, comply with DOD 4500.9-R, Defense Transportation Regulation Part V. Documentation of such inspection shall be provided upon arrival.

_____State of Hawai`i Department of Agriculture, USDA, Customs and Border Patrol (CBP), or Guam Port Authority inspectors shall be given the ability, if requested, to board U.S. Flag vessels to assist with inspection of food stores, cargo, plants, animals, and garbage.

_____The intentional importation of invasive species that might cause damage to or be injurious or detrimental to agriculture, horticulture, forest of the State or to federally protected, endangered, or threatened species of Hawai`i or Wake Atoll, shall be prohibited.

_____If pest sign or an actual specimen (dead or alive) is discovered aboard the barge or tug or external surface of container or cargo, **the vessel operator or contractor awarded barge services shall, at their own cost,** carry out a vessel wide emergency quarantine action to last at least four days. The Barge operator or awarded party shall incur all costs associated with delays or fees associated with late departure due to vessel operator inability to keep invasive species off their vessel. It is advised that vessels carry out invasive species control measures before arriving to the port so that delays and additional charges are not absorbed by the contracted party.

_____Submit a draft quarantine plan to the 611 biosecurity manager at least one week before anticipated departure for review, recommendations and approval.

Vessel Emergency Quarantine Checklist

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required.

Indicate compliance by **initial and date:**

_____Mandatory usage of bait stations armed with state and federally approved pesticide or trap, depending on the target in question. The Government shall direct barge operator as to which pesticide and trap is suitable for deployment based on the target in question.

_____All pesticide applications shall abide by EPA approved label directions.

_____Barge operators shall submit their emergency quarantine plan to the 611 biosecurity manager for review and approval at least one week before anticipated departure.

_____At any time during the quarantine period, the 611 biosecurity manager shall be granted access to the vessel(s) to ensure the plan is indeed being completed as written.

_____611 biosecurity manager approved fumigants shall be used if the target in question cannot be eliminated by the usage of other tools.

_____After the above quarantine actions, all unsealed cargo shall be inspected by 611 biosecurity manager or representative for the 611th Civil Engineer Squadron or Detachment 1 Commander before signing off on success of the emergency quarantine actions and efficacy of the treatment.

Barge and Tug Docking Biosecurity Precautions Checklist

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required. All biosecurity activities undertaken by the Base Operating Support (BOS) should also be documented in quarterly reports to the USAF 611.

Rodent Inspection Certification received and dated and signed within 72 hours departure for Wake

Rodent Inspection Certification Received Date: _____

For any barge, tug, or cargo (break bulk or containers) that moves through or originates from Guam ports (Navy or commercial): Brown tree snake inspection arranged 14 days before departure for Wake and certification of proper inspection received dated and signed within 72 hours departure for Wake. **Coordinate this activity with the 611 biosecurity manager**

Brown Tree snake Inspection Arranged Date: _____

Brown Tree snake Inspection Certification Received Date: _____

Initial and date verifications:

_____ Upon docking barge and tug, appropriately sized rat guards are placed on every line attached to the dock.

_____ Vent and scupper openings are protected by backing them up with heavy gauge screening to prevent rats or other rodents from building nests or accessing vessel.

Initial and date verification that **barge** has set 16 Protective Rodent Bait Stations attached to the deck of the barge using magnetic bait stations or zip ties and indicate other measures as follows:

_____Eight bait stations each containing a set Trapper T-Rex Rat Snap Trap (or similar) baited with nontoxic bait

_____Eight bait stations each containing Stickem Glue Board (or similar) baited with nontoxic bait

_____ Eight wax chew blocks present and free of chew marks

_____ Eight new ant bait stations and roach stations and Stickem or Trapper Max Free (unscented) glue boards (or similar) when docked

_____ barge is free of dirt, debris, and other potential harborage for pests

Initial and date verifications indicating that **tug** has set measures as follows:

_____Eight Stickem or Trapper Max Free (unscented) glue boards (or similar), baited with nontoxic bait

_____ Eight wax chew blocks present and free of chew marks

_____ Eight new ant bait stations and roach stations and Stickem or Trapper Max Free (unscented) glue boards (or similar) when docked

Wake Barge Arrival Container/Flat Rack/Break Bulk/Cargo Integrity and Sanitation

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required. All biosecurity activities undertaken by the Base Operating Support (BOS) should also be documented in quarterly reports to the USAF 611.

Verify action taken **by initial and date** in space provided:

_____Inspect dock area to ensure a minimum of 6–30 bait stations with baited traps (Trapper T-Rex Rat Snap Trap [or similar] baited with nontoxic bait and Stickem Glue Boards [or similar]) have been placed along dock walls and potential movement corridors and along walls inside and outside of all nearby buildings depending on size of cargo area per discussion with biosecurity manager.

_____Inspect dock area to ensure the surrounding area is free of unnecessary piles that would provide refuge to any animal that may be inadvertently transported on barge/tug.

Upon Barge Arrival to Wake and Prior to Offloading Containers/Flat Racks from Barge

_____Inspect exterior of all **Container/Flat rack** and **Break Bulk** (to the extent possible include ***undercarriage, opening doors to cabs and engine compartments, and inspecting pallets or other storage transport structure being loaded as appropriate***) looking for and containing any

Live Animals-all but in particular: mammals, reptiles, and ants
Eggs
Seeds

If found, leave on barge until containment is successful. Report any incidents to the base command and 611 biosecurity manager.

Cargo Inspection While Unloading

Once containers are opened for unloading immediately check:

_____wax chew blocks for chew marks and traps for readily visible mammal sign and if found immediately close container and follow guidelines below.

_____look for and if found close container or ***contain****
Live Animals-all but in particular: mammals, reptiles, and ants
Eggs
Seeds

_____During unloading operations **any box, cargo, or container showing signs of infestation (feces, chew marks, footprints**, **urine scent, hair, eggs, nest, holes in cardboard, food piles) will be put back in the container and closed up to be thoroughly inspected prior unloading.**

Contain means capture and remove (if possible) using disinfecting procedures such as hand capture, vacuuming, fumigation, contact insecticide etc.

Submit Container/Flat rack/Break Bulk/Cargo Sanitation Checklist for archival purposes email:

BASEOPS@WAKEISLAND.NET ***and*** james.stanford.5.ctr@us.af.mil

NOTE → When glue boards are collected, they should be immediately incinerated if they have not been requested for further analysis. Wax tags can be reused. They would need to be remolded first if damaged in any way.

Stranded Vessel Checklist

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required. All biosecurity activities undertaken by the Base Operating Support (BOS) should also be documented in quarterly reports to the USAF 611.

In the event that a yacht or sailors in distress request mooring within 200 meters or access to the installation.

Verify action taken by **initial and date** in space provided:

_____Inspect dock area to ensure a minimum of eight bait stations with baited traps (Trapper T-Rex Rat Snap Trap [or similar] baited with nontoxic bait and Stickem or Trapper Max Free [unscented] glue boards [or similar]) have been placed along dock walls and potential movement corridors and along walls inside and outside of all nearby buildings.

_____Inspect dock area to ensure the surrounding area is free of unnecessary piles that would provide refuge to any animal that may be inadvertently transported on the vessel.

_____Rat deflectors of appropriate size for each line are present and can be attached to all lines from vessel to dock.

_____Deploy interception tools on vessel: bait stations with baited traps (Trapper T-Rex Rat Snap Trap [or similar] baited with nontoxic bait and Stickem or Trapper Max Free [unscented] glue boards [or similar]), chew blocks, ant bait stations, and so forth, as needed per biosecurity manager guidance.

Aircraft Operators Checklist

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required.

NOTE → In the event that cargo destined for Wake is discovered to be contaminated with an invasive species (that is, rodents, snakes, insects, seeds, and so forth) after departure from point of origin, the pilot will isolate the package or container, and refrain from offloading the item on Wake. The pilot will immediately contact Wake Base Ops (DSN: 315-424-2222 or Commercial: 808-424-2222) and the 611 biosecurity manager (james.stanford.5.ctr@us.af.mil) and alert them to the presence of an invasive species on the aircraft. This notification will activate an equipped Wake Atoll ad hoc on island response team, which will deploy to meet the aircraft on arrival and as feasible ensure that any pests are contained and managed appropriately.

During loading operations at origin, any box, cargo, or container showing signs of infestation (feces, chew marks, footprints, urine scent, hair, eggs, nest, holes in cardboard, food piles, and so forth) will be pulled out of the shipment and placed in an isolated area and thoroughly inspected and sanitized before being placed back in the shipment. If the item cannot be sanitized it will not be transported to the destination.

For any aircraft or cargo that moves through or originates from Guam ports (Navy or commercial): Ensure that brown tree snake USDA Wildlife Services canine inspection is arranged 14 days before departure for Wake and completed before departure. Letter of verification is to be submitted to the Wake Island Base Operations at BaseOperations2@wakeisland.net and 611 biosecurity manager (james.stanford.5.ctr@us.af.mil) before the vessel or aircraft arrival at Wake. This action should be arranged with the 611 biosecurity manager.

Aircraft Terminal Area and Baggage/Cargo Holding Facilities "Quarantine Area" Sanitation Inspection Checklist

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required. All biosecurity activities undertaken by the Base Operating Support (BOS) should also be documented in quarterly reports to the USAF 611.

Ensure Wake Island Base Ops and 611 CES Environmental has received quarterly report(s) from pest control contracts documenting type of rodent control in place, frequency of baiting, density of traps and trapping results (per DTR Part V) from each facility storing cargo destined for Wake.

Perform quarterly onsite walk through visual inspections of storage areas to verify sanitation and preventative tool(s) deployment at final pre-barge storage facility. Complete inspection 3–6 weeks before planned cargo (including break bulk) storage, timing such that it leaves enough lead time for any problem to be resolved before cargo storage or alternate site located.

Initial and date verification for all facilities:

_____Quarter 1

_____Quarter 2

_____Quarter 3

_____Quarter 4

Repeat onsite inspections before flights ***include cargo in inspections*** paying close attention to any damaged packaging for animals, plants or other sign indicating infestation

Terminal Area, Baggage Holding Facilities and Cargo

Indicate presence/sign and record location:

Animals (presence includes live animals, carcasses or other body parts [such as limbs, wings, fur, feathers, and so forth], or sign of presence [for example, footprints, chew marks, food piles, feces, urine, eggs, nest, web, and so forth])

Rat _____sign/presence type(s) _____location(s)

Cat _____sign/presence type(s) _____location(s)

Mongoose _____sign/presence type(s)_____location(s)

Bird _____sign/presence type(s) _____location(s)

Snake _____sign/presence type(s) _____location(s)

Lizard _____sign/presence type(s) _____location(s)

Frogs/Toad _____sign/presence type(s) _____location(s)

Insect particularly ant _____type/sign/presence type(s) _____location(s)

Other _____sign/presence type(s) _____location(s)

Plant matter particularly seeds _____location(s)

In the event of animal presence, coordinate pest control (and notify Wake Island Base Ops and 611 CES Environmental). In the event of plant matter, coordinate cleaning the area.

Repeat inspection after pest control or cleaning has been completed.

During Initial Onsite Inspection

Indicate compliance by **initial and date:**

Check rodent traps for:

____Appropriate density of traps inside and outside buildings per biosecurity manager guidance

____Trigger events = record count if using Goodnature traps

____Test Functioning if using Goodnature traps

____Refill bait

Where Goodnature traps are not used: alternate stations with Stickem Glue Board (or similar) baited with nontoxic bait or Trapper T-Rex Rat Snap Trap (or similar) baited with professional rat attractant (use EPA approved rodenticide [poison] if area has a certified pesticide applicator on staff or contracted, otherwise use nontoxic) and placed inside appropriate bait station

____Place glue board (for example, Stickem or Trapper Max Free [unscented] glue boards [or similar]) alongside each Goodnature trap or bait station

____Place indicators (in other words, wax chew blocks, ink cards) placed alongside each Goodnature trap or bait station

____Check camera traps

Note: Traps should be placed along walls and in corners

NOTE →The Wake Island CDR can prohibit the opening of containers or other cargo, if there is no documentation showing that the origin activity has an ongoing pest control program. Contact the 611th CES, Natural Resources Manager, for further information (907-552-0788) or Wake Island Base Operations (808-424-2222).

Submit Aircraft Terminal Area and Baggage/Cargo Holding Facilities "Quarantine Area" Sanitation Inspection Checklist for archival purposes email:

BASEOPS@WAKEISLAND.NET *and* james.stanford.5.ctr@us.af.mil

Passenger Checklist

DOD Foreign Clearance Guide Available at https://www.fcg.pentagon.mil/index.html?aspxerrorpath=/U. From the left column select Pacific, South Asia, then Wake Island.

Checklist activity should be coordinated with the USAF 611 CES/CEI Biosecurity Manager, James Stanford: james.stanford.5.ctr@us.af.mil; 717-559-0192. This checklist should be completed expeditiously and submitted to the Biosecurity Manager to document actions taken within a timeframe that allows for follow-up if required. All biosecurity activities undertaken by the Base Operating Support (BOS) should also be documented in quarterly reports to the USAF 611.

Name_____ Indicate compliance by **initial and date:**

I will not knowingly transport nor will send by mail

____any invasive species: An alien animal or plant species whose introduction does, or is likely to cause, economic or environmental harm, or harm to human health (Executive Order 13112, 1999) usually due to overpopulation and spread of itself in exclusion of or causing alteration to native species or habitat (for example, cane toad, tiger mosquito, castor bean).

____any seeds or food products that contain seeds (including dry fruits). This includes seeds for gardens.

____any animal products unless dried and in sealed packages

I have inspected all personal gear paying special attention to pockets, Velcro, shoelaces, or other components hidden from view (for example, pockets, jacket linings, and so forth) to be sure it is free of:

Live animals (be particularly watchful for ants)
Eggs (for example, gecko, spider, roach and so forth)
Seeds/plant matter
Dirt or debris

Initial that each has been thoroughly inspected:

____Baggage
____Footwear (boots, sneakers, slippers, and so forth)
____Socks
____Jackets/Raingear
____Other clothing
____Equipment for work or Recreation (computers, phones, bicycles, cooking supplies, and so forth)
____Other personal items
____Dive/Snorkel gear
____Food items

Ideally any food items brought have been previously dried, cooked or frozen to reduce viable insects or their eggs

____I have inspected all dive/snorkel or other gear entering the water have been cleaned of debris, algae, and soaked for a minimum of 10 minutes in a 10-percent bleach solution or similarly effective treatment (as documented by the biosecurity manager).

Signature_____ Date_____

Submit completed Passenger Checklist for archival purposes email:

BASEOPS@WAKEISLAND.NET *and* james.stanford.5.ctr@us.af.mil

Appendix 2. Example Species Observation Data Sheet

Species Observation Data Sheet

Please return this form, any photographs and collected material to:

(Name/Contact Information) _____ _____

Contact the 611th CES, Biosecurity Manager, for further information (717-559-0192) or Wake Island Base Operations (808-424-2222)

BASEOPS@WAKEISLAND.NET *and* james.stanford.5.ctr@us.af.mil

Date of Observation:

Observer Name:

Contact Information:

email

phone number(s)

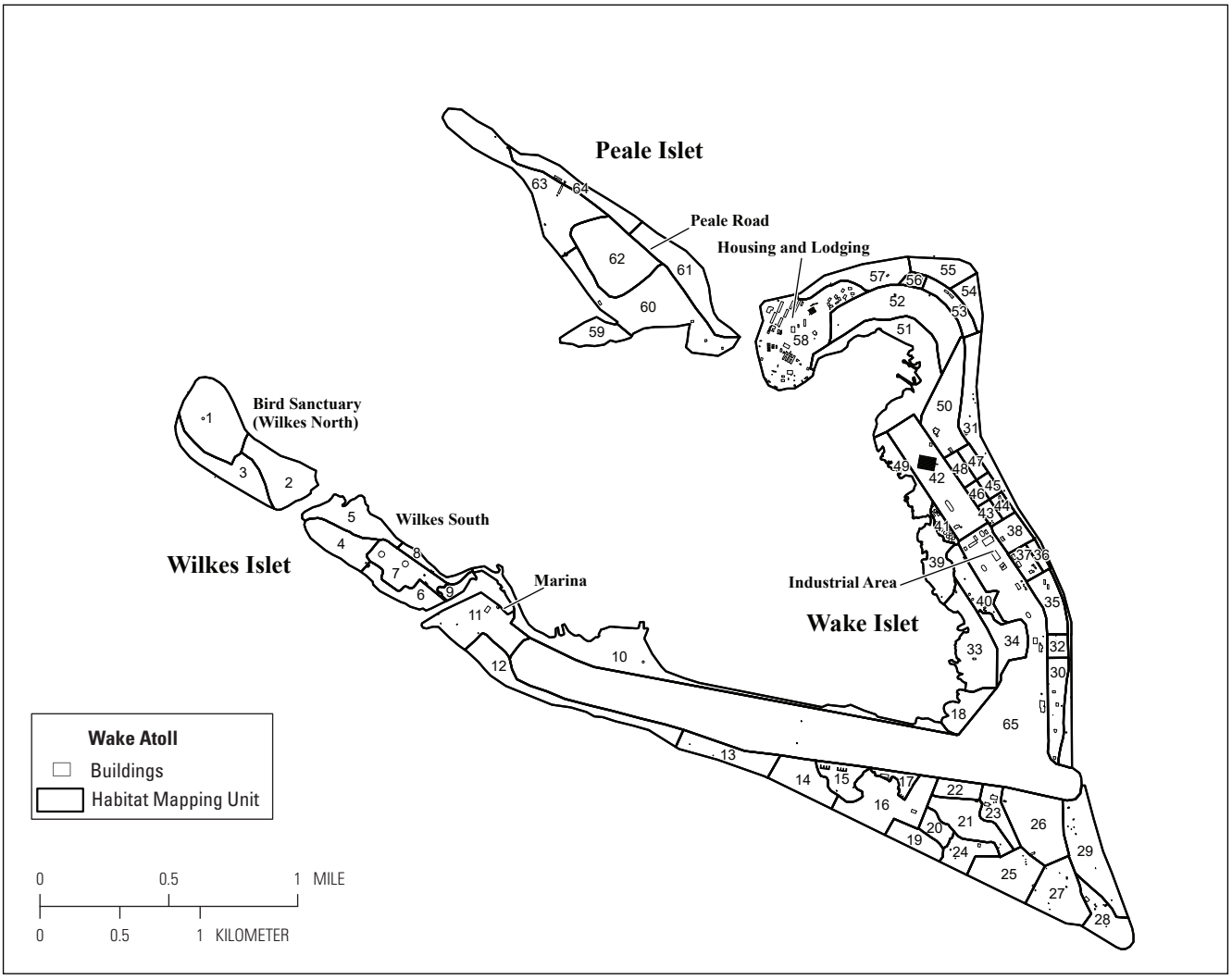
Species Observed (if identified):

Please circle one: Was it alive, dead, unknown

Was it collected?

Photographed?

Where was it seen? Please describe as many details as possible (for example, in woodpile at Building X), and please indicate where as specifically as possible on the illustration on back of this page.


Peale Islet
Peale Road
Housing and Lodging
Bird Sanctuary
(Wilkes North)
Wilkes South
Wilkes Islet
Marina
Industrial Area
Wake Islet
Wake Atoll
Buildings
Habitat Mapping Unit
0 0.5 1 MILE
0 0.5 1 KILOMETER

For more information concerning the research in this report, contact the

Director, Western Ecological Research Center
U.S. Geological Survey
3020 State University Drive East
Sacramento, California 95819
https://www.usgs.gov/centers/werc

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