

**A Species Action Plan for the
Florida Tree Snail
*Liguus fasciatus***

**Final Draft
November 1, 2013**



Florida Fish and Wildlife Conservation Commission
620 South Meridian Street
Tallahassee, FL 32399-1600
Visit us at MyFWC.com

FLORIDA TREE SNAIL ACTION PLAN TEAM

Team Leader: Lindsay Nester, Division of Habitat and Species Conservation

Team Members: Randy Grau, Division of Habitat and Species Conservation
David Cook, Division of Habitat and Species Conservation

Acknowledgements: Laura Barrett, Division of Habitat and Species Conservation
Claire Sunquist Blunden, Office of Policy and Accountability
Brie Ochoa, Division of Habitat and Species Conservation
Mary Ann Poole, Division of Habitat and Species Conservation
Brian Beneke, Fish and Wildlife Research Institute

Cover photograph courtesy of Randy Grau, FWC

Recommended citation:

Florida Fish and Wildlife Conservation Commission. 2013. A species action plan for the Florida tree snail. Tallahassee, Florida.

EXECUTIVE SUMMARY

The Florida Fish and Wildlife Conservation Commission (FWC) developed this plan in response to the determination that the Florida tree snail (*Liguus fasciatus*) does not meet listing criteria and should no longer be listed as a Species of Special Concern. The goal of this plan is to maintain the population of Florida tree snails in a manner that will not require future listing. Objectives are to maintain or increase the extent of occurrence and area of occupancy of the tree snail and to preserve the diversity of color morphs. There are several high-priority actions for these objectives, including:

- Inventory tropical hardwood hammock and determine presence/absence of Florida tree snail;
- Inventory color morphs;
- Continue non-native plant and animal species removal and removal of introduced species outside of their historic range;
- Map existing color morphs using data obtained from baseline surveys;
- Consider color morphs when reestablishing populations; and
- Maintain current protections that prohibit take and possession without a permit.

Successful management of Florida tree snails through implementation of this plan will require cooperation among local, state, and federal governmental agencies; non-governmental organizations; development and industrial interests; private landowners; academic institutions; and the public. This plan was developed by the FWC in collaboration with identified stakeholders. The first revision is scheduled within 10 years.

This plan details the actions necessary to improve the conservation status of the Florida tree snail (*Liguus fasciatus*). A summary of this plan will be included in the Imperiled Species Management Plan (ISMP), in satisfaction of the management plan requirements in Chapter 68A-27, Florida Administrative Code, Rules Relating to Endangered or Threatened Species. The ISMP will address comprehensive management needs for 60 of Florida's imperiled species and will include an implementation plan; rule recommendations; permitting standards and exempt activities; anticipated economic, ecological, and social impacts; projected costs of implementation and identification of funding sources; and a revision schedule. The imperiled species management planning process relies heavily on stakeholder input and partner support. This level of involvement and support is also critical to the successful implementation of the ISMP. Any significant changes to this management plan will be made with the involvement of our stakeholders.

TABLE OF CONTENTS

FLORIDA TREE SNAIL ACTION PLAN TEAM..... ii

EXECUTIVE SUMMARY iii

LIST OF TABLES v

LIST OF FIGURES vi

GLOSSARY OF TERMS AND ACRONYMS..... vii

INTRODUCTION 1

 Biological Background..... 1

 Conservation History..... 3

 Threats and Recommended Listing Status 4

CONSERVATION GOALS AND OBJECTIVES 6

CONSERVATION ACTIONS 7

 Habitat Conservation and Management 7

 Population Management..... 8

 Monitoring and Research 8

 Rule and Permitting Intent 10

 Law Enforcement 11

 Incentives and Influencing 12

 Education and Outreach 12

 Coordination with Other Entities 13

LITERATURE CITED 18

LIST OF TABLES

Table 1. Conservation Action Table 15

LIST OF FIGURES

Figure 1. Map of general and historic range of the Florida tree snail (*Liguus fasciatus*)..... 2
Figure 2. Cover of “The Liguus Tree Snails of South Florida” by H. T. Close (2000)..... 3

GLOSSARY OF TERMS AND ACRONYMS

Area of Occupancy: The area within its extent of occurrence (see Extent of Occurrence), which is occupied by a taxon, excluding cases of vagrancy. This reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats (as defined by International Union for the Conservation of Nature [IUCN]).

BCNP: Big Cypress National Preserve

BRG: Biological review group, a group of taxa experts convened to assess the biological status of taxa using criteria specified in Rule 68A-27.001, Florida Administrative Code, and following the protocols in the Guidelines for Application of the IUCN Red List Criteria at Regional Levels (Version 3.0) and Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1).

BSR: Biological status review report, the summary of the biological review group's findings. Includes a Florida Fish and Wildlife Conservation Commission (FWC) staff recommendation on whether or not the species status meets the listing criteria in Rule 68A-27-001, Florida Administrative Code. These criteria, based on the IUCN criteria and IUCN guidelines, are used to help decide if a species should be added or removed from the Florida Endangered or Threatened Species List. In addition, FWC staff may provide within the report a biologically justified opinion that differs from the criteria-based finding.

ENP: Everglades National Park

Extent of Occurrence: The geographic area encompassing all observations of individuals of a species, including intervening areas of unoccupied habitat. Synonymous with range. See also Area of Occupancy (as defined by IUCN).

F.A.C.: Florida Administrative Code. The Department of State's Administrative Code, Register and Laws Section is the filing point for rules promulgated by state regulatory agencies. Agency rulemaking is governed by Chapter 120, Florida Statutes, the Administrative Procedures Act. Rules are published in the Florida Administrative Code.

FNAI: Florida Natural Areas Inventory, a non-profit organization administered by Florida State University and dedicated to gathering, interpreting, and disseminating information critical to the conservation of Florida's biological diversity.

FWC: The Florida Fish and Wildlife Conservation Commission, the state agency constitutionally mandated to protect and manage Florida's native fish and wildlife species.

ISMP: Imperiled Species Management Plan

IUCN: International Union for Conservation of Nature, a professional global conservation network.

Less-than-fee acquisition: The acquisition of limited property rights by an outside entity on lands owned by a landowner, usually through a written contract. Less-than-fee acquisitions can occur through direct purchase of specified and agreed-upon rights by the outside entity or through donation of those rights by the landowner. Examples of less-than-fee acquisitions include the purchase/donation of easements, leases, limited use permits, cooperative agreements, etc.

Population: The total number of individuals of the taxon. Population numbers are expressed as numbers of mature individuals only (as defined by the IUCN).

Tropical hardwood hammock: Also called rockland hammock. A highly diverse upland forest rich in rare and endemic plant and animal species. The forest floor is mostly covered with a thin layer of well-drained organic soil and leaf litter. Exposed limestone and solution holes are common. Over 120 species of native trees and shrubs can be found in tropical hardwood hammocks along with a number of rare epiphytes, cacti, and herbaceous plants. Many of the plant species are also native to the Bahamas, the West Indies, and the Yucatan peninsula. Most occur in Florida at the northern limit of their range. Typical canopy trees include gumbo limbo (*Bursera simaruba*), wild tamarind (*Lysiloma latisiliquum*), pigeon plum (*Coccoloba diversifolia*), strangler fig (*Ficus aurea*), Jamaican dogwood (*Piscidia piscipula*), poisonwood (*Metopium toxiferum*), and West Indies mahogany (*Swietenia mahagoni*). In the continental United States, remaining tropical hardwood hammock only occurs in south Florida, where it is restricted to coastal areas of southern Miami-Dade County, the Florida Keys, and a small area of Big Cypress National Preserve in Monroe and Collier counties.

INTRODUCTION

Biological Background

Tree snails of the genus *Liguus* occur in South Florida, Cuba, and Hispaniola (Clench 1965, Jones 1976). Florida tree snails (*Liguus fasciatus*) have historically been found in Collier, Palm Beach, Broward, Miami-Dade, and Monroe counties (Deisler-Seno 1994). Currently the population is restricted to Miami-Dade, Monroe, and Collier counties (Emmel and Cotter 1995; [Figure 1](#)). The Florida tree snail has a conical shell 40 to 70mm (1.6 to 2.7 in) in length. The shell color is extremely variable and can be matte or glossy (Pilsbry 1946). There are 58 named color morphs in Florida (Roth and Bogan 1984, Emmel and Cotter 1995; [Figure 2](#)). Genetics research has found variation in only 1 locus, and only 2 alleles were found for the varying locus. This shows very low genetic variation, and suggests that all color morphs belong to a single species, *Liguus fasciatus* (Hillis 1995). The Florida Fish and Wildlife Conservation Commission's (FWC's) listing of *Liguus fasciatus* considers all color morphs to belong to a single species.

Florida tree snails are hermaphroditic, meaning each individual is both male and female. However, although there is evidence for partial self-fertilization (Hillis et al. 1987, Hillis 1989, Hillis 1995), individuals still must come together to mate. Florida tree snails mate during the rainy season from July through September. Snails follow mucus trails to find mates. Nests are laid in the humus layer at the base of trees 3 to 6 weeks following copulation. The mean clutch size for tree snails is 19 eggs, and hatching is synchronized with a heavy rain in April or May (Voss 1976). They reach sexual maturity in approximately 2.5 years (Emmel and Cotter 1995). During the dry season (November to March) tree snails protect themselves against desiccation by secreting a mucus seal that locks the snail to the tree. This period of inactivity is called aestivation. Tree snails are nocturnal and are most active after rain (Voss 1976). They are thought to feed on confervoid algae (Simpson 1929), fungus (Pilsbry 1946), and lichens (Voss 1976). They inhabit native hammocks and prefer smooth-barked trees. Several tree species are preferred hosts. These species include wild tamarind (*Lysiloma latisiliquum*), poisonwood (*Metopium toxifera*), Jamaica dogwood (*Piscidia piscipula*), strangler fig (*Ficus aurea*), paradise tree (*Simarouba glauca*), sea grape (*Coccoloba uvifera*) (Voss 1976), pigeon plum (*Coccoloba diversifolia*), and gumbo-limbo (*Bursera simaruba*) (Bennetts et al. 2000). Florida tree snails are prey for a carnivorous gastropod, *Euglandina rosea* (Davidson 1965), rats (Pilsbry 1946), raccoons (*Procyon lotor*), and opossums (*Didelphis virginiana*) (Voss 1976).

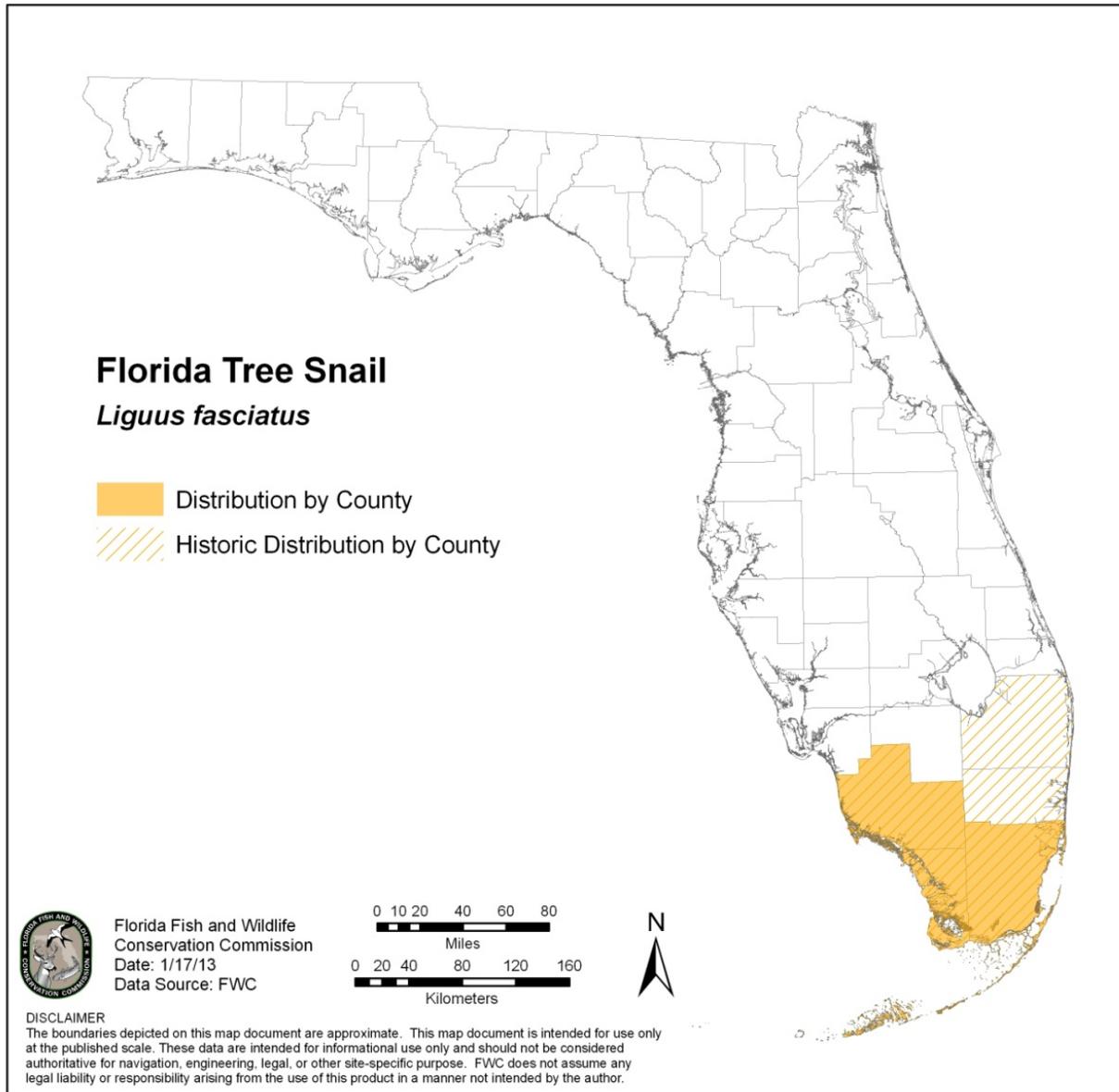


Figure 1. Map of general and historic range of the Florida tree snail (*Liguus fasciatus*).

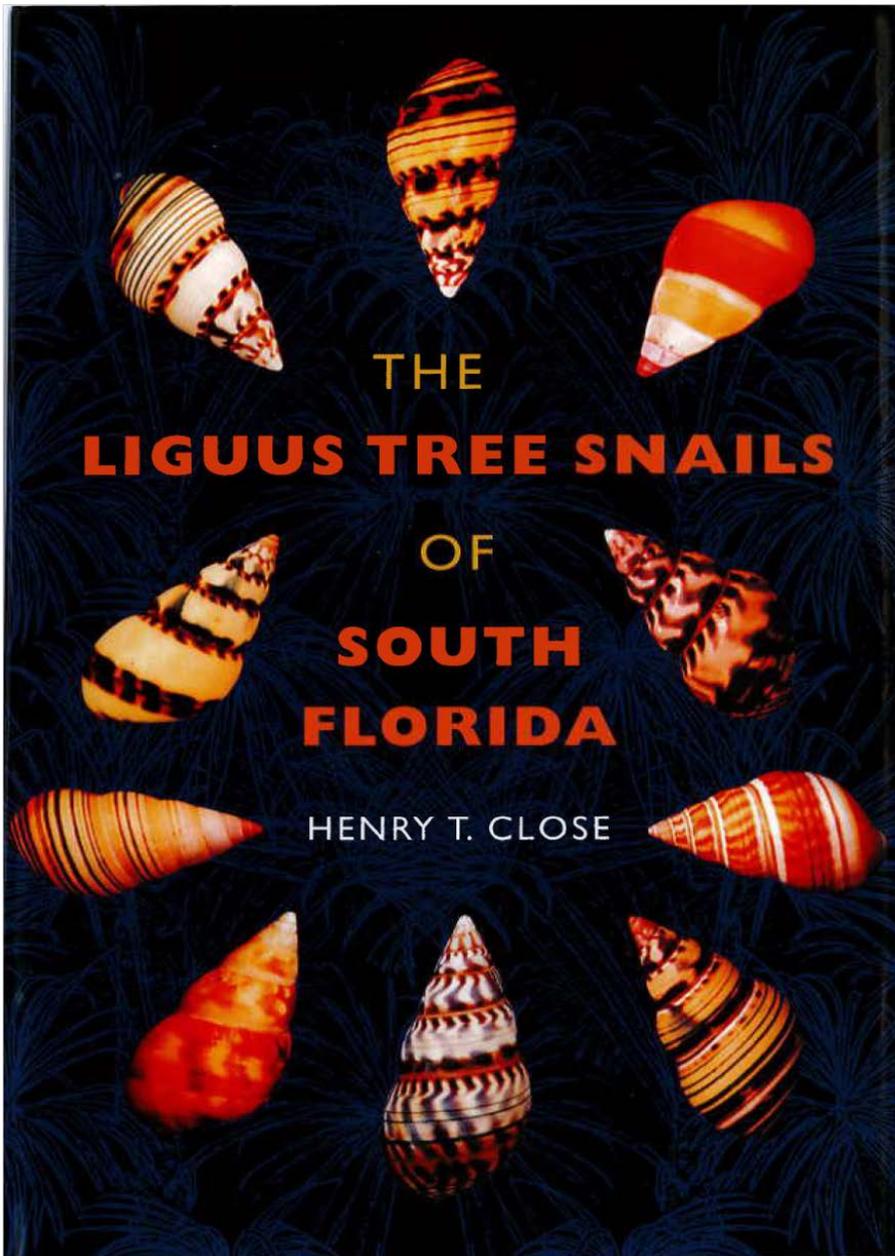


Figure 2. Cover of “The Liguus Tree Snails of South Florida” by H. T. Close (2000), showing examples of color morph variations. Reprinted with permission of the University Press of Florida.

Conservation History

The Florida tree snail was listed as a Species of Special Concern by the state of Florida in 1985. Big Cypress National Preserve (BCNP) has prohibited collection in since 2005. Prior to collection being prohibited, BCNP had a permitting system for collection starting in the mid-1980s. The permit restricted collection to the period of time between 1 October to 31 March (outside the breeding season) and to personal use only. Everglades National Park (ENP) has never allowed collection.

Conservation of the Florida tree snail is complicated by its myriad distinct morphs; ideally, each would be conserved in its natural range. Pilsbry (1946) named 8 subspecies of *L. fasciatus* found in Florida. These have been further divided into subspecies groups, forms, and varieties based on the shell color patterns and differences in shell shape. There are 58 recognized color forms (Jones et al. 1981). Emmel and Cotter (1995) tried to document current (as of 1987) distribution and status of those forms. They also attempted to conjecture their original distribution before habitat loss and the advent, in the 1950s and since, of systematic translocation by snail conservationists of color forms from at-risk hammocks to other, more protected locations (Jones et al. 1981). Similarly, based on historic collection records and more recent surveys, Fadely (2009) compared the distribution of Florida tree snail color forms in the Long Pine Key area of ENP between 1931 and 2006. Fadely (2009) concluded that the tree snail community appeared to be somewhat stable within the study area of 13 hammocks surveyed.

Threats and Recommended Listing Status

The major threat to the Florida tree snail is habitat loss (Emmel and Cotter 1995). Habitat loss of hardwood hammocks in the Upper Keys is estimated to be 31% from 1991 to 2004 (Karim and Main 2009). In addition to habitat loss, disturbance can also threaten tree snails. Disturbance (removal of humus, cutting of trees, or altering of sunlight penetrating hammock, etc.) can result in changes to the microclimate, making that area unsuitable habitat for tree snails (Florida Natural Areas Inventory [FNAI] 2001).

Imported fire ants (*Solenopsis invicta*) are also a great threat to tree snails. Experimentation has shown that, in a semi-natural enclosure, fire ants could kill Florida tree snails in many life stages including during aestivation (Forys et al. 2003). Forys et al. (2003) also found that imported fire ants killed 86% of Florida tree snails in laboratory experiments. Fire ants are suspected to have contributed to the local extinction of another species of tree snail, *Orthalicus reses reses*, from its historic range (Forys et al. 2001).

Non-native species such as black rats (*Rattus rattus*), Norway rats (*Rattus norvegicus*), iguanas, and tegus (*Tupinambis* spp.) could pose a threat to Florida tree snails. These non-native species can have dynamic impacts in a number of ways: by competitive exclusion, niche displacement, or predation (Mooney and Cleland 2001, Keeler et al. 2006). Species introduced outside of their native range could also alter the natural habitat of Florida tree snails. Recently, opossums have been introduced to the Lower Keys, where they did not naturally occur (R. Grau, FWC, personal communication).

Unusually cold temperatures pose a risk to snails and eggs by direct freezing and by killing host trees (Emmel and Cotter 1995). Collection of tree snails posed a threat to the survival of rare color forms prior to a ban on collecting. In the early part of the 1900s collectors amassed collections of snails numbering into the thousands (Emmel and Cotter 1995). If collection is allowed in the future, this threat could resurface.

The Florida Keys' populations of tree snails may be subjected to a different array, or a heightened level, of threats than the peninsular populations. A major decline in the Florida tree snail on Key Largo in the 1970s and 1980s was correlated with the use of Dibrom and Baytex mosquito-control pesticides (Emmel and Cotter 1995). Hurricane storm surge poses another

threat to the Keys' populations (Emmel and Cotter 1995) that would likely not be felt by inland mainland populations. A rise in sea level due to climate change could significantly impact tree snails. In the best-case scenario, a sea level rise of 18 cm (7 inches) by the year 2100 would inundate 34% of Big Pine Key, resulting in the loss of 11% of the island's upland habitat and inundating coastal habitats used by the species. In the worst-case scenario, a sea-level rise of 140 cm (4.6 feet) by the year 2100 would inundate 96% of Big Pine Key (Florida Reef Resilience Program 2010).

FWC directed staff to evaluate all species listed as Threatened or Species of Special Concern as of 8 November 2010 which had not undergone a status review in the past decade. Public information on the status of the Florida tree snail was sought from 17 September 2010 to 1 November 2010. The 3-member Biological Review Group (BRG) met on 9 November 2010. Group members were Lindsay Nester (FWC lead), Steve Sparks (independent consultant), and Deborah Jansen (National Park Service). In accordance with Rule 68A-27.0012, Florida Administrative Code (F.A.C.), the FWC charged the BRG to assess the biological status of the Florida tree snail by using criteria specified in Rule 68A-27.001, F.A.C. This rule includes a requirement for BRGs to follow the Guidelines for Application of the International Union for Conservation of Nature (IUCN) Red List Criteria at Regional Levels (Version 3.0) and Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1). Please visit the [FWC's website](#) to view the listing process rule and the criteria found in the definitions.

In late 2010, FWC staff developed the initial draft of a Biological Status Review (BSR), which included the BRG's findings and a preliminary listing recommendation from staff. The draft was sent out for peer review and the reviewers' input was incorporated to create the final [BSR](#) (FWC 2011). The BRG concluded from the biological assessment that the Florida tree snail does not meet any listing criteria; therefore, FWC staff recommends not listing the Florida tree snail as a Threatened species and removing it from the list of Species of Special Concern. The objectives below deal with maintaining or enhancing the area of occupancy and extent of occurrence in order to preclude future listing.

CONSERVATION GOALS AND OBJECTIVES

Goal

Conservation status of Florida tree snail is maintained or improved so that the species will not again need to be listed on the Florida Threatened Species list.

Objectives

I. Maintain or increase the present extent of occurrence and area of occupancy of the Florida tree snail throughout its range within 10 years of the implementation of this plan.

Rationale

According to the [BSR](#) for the Florida tree snail, the estimated extent of occurrence is 12,869 km² (4,968 mi²) and the area of occupancy is <259 km² (<100 mi²). These area estimates and projected decline in extent of tropical hardwood habitat met part of Criterion B for State listing. Stemming the habitat decline and ensuring that the species continues to exist in >10 threat-defined locations will keep it from fully meeting this listing criterion.

II. Maintain the present diversity of color morphs of the Florida tree snail throughout its range within 10 years of the implementation of this plan.

Rationale

Morphological diversity is not addressed in the [BSR](#) as a listing criterion but the diversity of color patterns is an important intrinsic trait of this species. The variation is represented by dozens of named forms and several proposed subspecies. Any loss of this diversity would be regarded as a significant diminishment to the species and is a threat that should be addressed in the action plan.

CONSERVATION ACTIONS

The following sections describe the conservation actions that will make the greatest contribution toward achieving the conservation objectives. Actions are grouped by category (e.g., Habitat Conservation and Management, Population Management). The Conservation Action Table ([Table 1](#)) provides information on action priority, urgency, potential funding sources, likely effectiveness, identified partners, and leads for implementation.

Habitat Conservation and Management

Maintain or increase Florida tree snail habitat quantity and quality

Action 1 Protect suitable habitat by less-than-fee acquisitions on private land, habitat restoration on private and public lands, and acquisition of as much suitable habitat as possible. Use survey information to prioritize tropical hardwood hammocks for conservation/acquisition and importance to the Florida tree snail.

Coordination with local, state, and federal land managers is needed to develop lists of priority parcels to be directly acquired or protected by less-than-fee acquisitions that protect the highest quality tropical hardwood hammocks. It will be important to work directly with Florida Forever on priority acquisitions in Florida Forever projects that contain populations of Florida tree snails. The needs of the Florida tree snail will be considered when performing restoration; these needs include consideration of preferred native plant species list and maintaining leaf litter. The entire tropical hardwood hammock strata must be restored in order to maintain necessary diversity and microclimate.

Florida also provides tax incentives, including property tax exemptions under s. 196.26, Florida Statutes, for landowners who put a perpetual conservation easement on their land. Additional incentives may include exemption from permits for activities such as invasive non-native vegetation removal, as long as they are not a precursor to development.

Action 2 Develop habitat management recommendations for public land managers and private landowners to follow. Review existing protocol used by utilities for translocating snails out of harm's way.

Action 3 Continue removal of non-native plant and animal species. Remove introduced species from outside of their historic range.

Maintenance of intact tropical hardwood hammock is the most important way to ensure the long-term survival of the Florida tree snail. Habitat management recommendations for this unique Florida habitat should be drafted using input from stakeholders, including landowners, land managers, local government, development interests, conservation organizations, tree snail researchers, and others. This is also discussed in [Coordination with Other Entities](#). Under circumstances to be determined, adherence to habitat management recommendations would allow certain activities involving Florida tree snails to proceed without the requirement for a permit. The habitat management recommendations may address controlling free-roaming domestic and feral animals (chickens, etc.), maintaining understory and microclimate, avoiding

the use of herbicides and pesticides, avoiding disturbance to egg-laying areas, minimizing disturbances during egg laying/hatching season, and removing Florida tree snails from exotic plants before cutting or treating them.

Population Management

It is important to determine what criteria or threshold would trigger need for reintroduction and captive propagation. Prior to the start to any program, color morphs would need to be mapped. Then the color morphs would need to be assessed for priority of reestablishment, and determine criteria for recipient sites.

Action 4 Consider color morphs when reestablishing populations.

Action 5 Map existing color morphs by using data obtained from baseline surveys.

The goal of any captive breeding or reintroduction program would be to bolster the wild population in places where it is diminishing or to reestablish snails in areas where they previously inhabited, while conserving genetic diversity. There has been some success with captive breeding of rare snails. The Federally-Endangered Hawaiian tree snail, *Achatinella fuscobasis*, has been successfully bred and grew rapidly during an 11-year breeding program. Another species of Hawaiian tree snail, *Partulina redfieldi*, also underwent a successful reintroduction program (Kobayashi and Hadfield 1996). Conversely, attempts at captive propagation of the endangered Stock Island tree snail, *Orthalicus reses reses*, which shares habitat and life history attributes with the Florida tree snail, have not been successful (United States Fish and Wildlife Service [USFWS] 1999).

There are currently no plans for a reintroduction program for Florida tree snails, but this idea may be revisited given funding and the demonstrated needs of the species. Prior to any program being considered there are several research needs that need to be addressed. Suitable habitat that is not occupied by tree snails will be documented during population surveys. Special attention would also need to be given to color morphs.

Monitoring and Research

Investigate genetics of color morphs

Action 6 Conduct genetics research to determine whether subspecies designations are warranted and relationships among named color morphs.

Based on previous genetic research, the Florida tree snail was considered to be a single species, *Liguus fasciatus*, with many color morphs (Hillis 1995). One of the peer reviewers from the [BSR](#) and other collectors have commented that they feel that some of these color morphs should be given subspecies status. The Florida Committee on Rare and Endangered Plants and Animals (Deisler-Seno 1994) recognizes 8 subspecies in Florida. Due to this apparent lack of consensus, we recommend that additional genetic work be performed on the color morphs.

Investigate effects of pesticides on tree snails

Action 7 Compile existing literature and determine needed research for effects of pesticides on tree snails.

Less than 1% of pesticides reach their target, leaving the residual poison in the soil, air, and surrounding water (Pimentel 1995). Studies on the effects of mosquito spraying on Florida butterflies have shown that a small amount of pesticide can prove lethal (Eliazar and Emmel 1991, Salvato 2001, Hoang et al. 2011). Pesticide use is among the threats identified for the Stock Island tree snail in the Multi-Species Recovery Plan (USFWS 1999). [The Florida Keys Mosquito Control District](#) conducts both aerial and truck mosquito spraying in the Florida Keys. This spraying has the potential to affect the Keys population of Florida tree snails and needs to be investigated further (Emmel and Cotter 1995).

Investigate effects of non-native species on tree snails

Action 8 Compile existing literature and determine needed research for effects of non-native species on tree snails.

Non-native mammal species such as black and Norway rats, introduced lizard species such as iguanas and tegus, and other exotic species could pose a threat to Florida tree snails by preying directly on snails or upon their eggs deposited in leaf litter on the forest floor. Non-native species can have dynamic impacts in a number of ways: by competitive exclusion, niche displacement, or predation (Mooney and Cleland 2001, Keeler et al. 2006). Species introduced outside of their native range could also alter the natural habitat of Florida tree snails. Recently, opossums have been introduced to the Lower Keys where they did not naturally occur (R. Grau, personal communication). Armadillos (*Dasyurus novemcinctus*), which have expanded their range into south Florida, are a potential threat to adult snails while they are on the ground and to their eggs. Feral hogs (*Sus scrofa*) and free-roaming domestic fowl are also likely predators of tree snails and their eggs. Uncontrolled invasive exotic plant species such as Old World climbing fern (*Lygodium microphyllum*) may impact tree snails by severely damaging the biological integrity of hardwood hammocks. There has been some documentation of fire ants killing tree snails and breaching the seal of the aestivating snails (Smith 1997, Forsys et al. 2003). Predation by fire ants is also a suspected cause of the Stock Island tree snail (*Orthalicus reses reses*) extinction in their native range (Forsys et al. 2001). Additional research is needed to better determine potential impact of invasive species and their control measures on tree snails.

Survey and identify current population and occurrences

Action 9 Develop a standard surveying protocol and train qualified persons to conduct surveys. Train surveyors to identify/recognize named color morphs.

Action 10 Create a database to store all location and color morph information.

Action 11 Inventory tropical hardwood hammocks for presence/absence of Florida tree snail. Determine methods and assess Florida tree snail population sizes (or relative density). Inventory color morphs.

Lignumvitae Key, located in the upper Keys, was surveyed for Florida tree snails in the late 1970s (Tuskes 1981). Jones et al. (1981) summarized the status of color morphs introduced since the 1950s to hammocks in ENP. Emmel and Cotter (1995) summarized the species' status throughout the range as of 1987. The Ten Thousand Islands region of Southwest Florida and the BCNP were intensively surveyed in the mid 1990s (Addison and Auffenberg 1996, Smith 1997). There is a dearth of recent data on the Keys and eastern Everglades populations. A current comprehensive survey is lacking and should be conducted to identify populations, their status, and color morphs. Surveys should be conducted on foot and will require binoculars and a color-morph identification guide. A database will be created with this survey information and will include information on population size, location, and color morph. FNAI is currently tracking only a few color morphs. This database will build on the information FNAI is collecting. This information will be used to map the distribution of color morphs and to inventory tropical hardwood hammock habitat.

Rule and Permitting Intent

Protections

Upon implementation of this plan, the Florida tree snail will be removed from the imperiled species list. Under previous listing as a Species of Special Concern, take and possession were prohibited without a permit from the FWC. These protections are important to prevent unrestricted collection by shell fanciers and loss due to development and other activities. If protections were lifted, these existing threats to the tree snail could lead to its decline and local extirpation. Therefore, although the Florida tree snail does not currently meet the criteria for listing as a state Threatened species and is not to be retained as a Species of Special Concern, it will be essential to maintain the current protections to ensure that it will not need to be added back to the Threatened species list.

Since there is no specific section in the codebook for unlisted mollusks, a new rule related to Florida tree snail conservation may need to be created in the F.A.C. In addition to existing rules that we recommend be maintained, new language would need to be drafted to accommodate the “grandfathering in” of existing collections of Florida tree snail shells. We also recommend that rule language prohibit moving populations and mixing of color morphs.

Prevent incidental take and direct take of Florida tree snail

Action 12 Create a rule preventing collection, moving populations and mixing color morphs, and incidental take from utilities, road maintenance, and development activities.

Although the collection and sale of Florida tree snails has been illegal since 1985, the former snail collectors and shell fanciers maintain collections that need to be addressed. First, in order for these individuals to be compliant with the rule (both existing and proposed) requiring a permit for possession, a provision must be made to such “grandfather-in” collections. Those with

collections, as well as other stakeholders, should be consulted to help FWC draft this permit provision, which would allow the possession of these collections without encouraging the new collection of additional snails from the wild.

In 1993, the Florida Keys Electric Cooperative began relocating tree snails during tree trimming operations along powerline rights-of-way and had moved an estimated 59,000 *Liguus fasciatus* and 1,100 *Orthalicus* sp. as of 2012 (Florida Keys Electric Cooperative 2012). It is important that utilities and other entities that impact Florida tree snails continue to be required to have a permit for incidental take, which includes a protocol for moving snails out of harm's way.

Action 13 Work with stakeholders that have collections to 1) develop a permitting system for grandfathering in existing collections and 2) assess how their collections and records can help guide conservation efforts.

Besides the permit issue, we recognize that the former snail collectors constitute an incomparable knowledgebase on the former, and in some cases, the present distribution of the Florida tree snail and its myriad color morphs. Their collections and collecting records, if carefully curated, can contribute to our understanding of historical distributions and can provide valuable guidance for long-term efforts to reestablish forms in their historic ranges.

Permitting Threshold

Incidental take permits would be issued upon reasonable conclusion that the permitted activity will not be detrimental to the survival potential of the species. Examples would include the permitted moving of tree snails prior to utilities and road maintenance activities (e.g., vegetation clearing, tree trimming, mowing) and activities associated with development, provided that there is an approved plan to mitigate tree snail and tree snail habitat loss.

Scientific collecting permits would be issued upon reasonable conclusion that the permitted activity will not be detrimental to the survival potential of the species. Recipients of such permits might include biologists assisting with survey, monitoring, captive propagation, and reintroduction efforts.

No permit would be required for certain activities if habitat management recommendations are followed. Such habitat management recommendations have not yet been developed, but would probably be targeted to private and public landowners and land managers to allow the conduct of otherwise legal actions, if the result is the conservation of tree snail habitat.

Law Enforcement

Law Enforcement Education

Action 14 Educate new wildlife officers about imperiled species rules and permitting when they graduate from the FWC academy.

Action 15 Provide new and current wildlife officers assigned to the South Florida Region with informative brochures including 1) rule and permit information on Florida tree snails (including

the Stock Island tree snail, the Florida tree snail, and others; and 2) an identification guide for tree snails in Florida.

The FWC's Division of Law Enforcement, in conjunction with federal, state, and local partners, is responsible for enforcing Florida's wildlife and fisheries laws. There have been some arrests in the 1980s and 1990s for Florida tree snails illegally taken (R. Grau, personal communication). Continued effective enforcement of protections for Florida tree snails will require that wildlife officers and other law enforcement officials be trained to distinguish among different species of tree snails present in Florida. The development of an easy-to-use, pictorial guide to tree snails, plus a summary of pertinent rules and protection, will be critical to support law enforcement efforts.

Incentives and Influencing

No actions specific to this section have been identified for the Florida tree snail.

Education and Outreach

There are 2 main groups that will be educated with brochures, the public and relevant utilities and businesses. Both of these groups could have an unintentional negative impact on tree snails.

Action 16 Produce informative brochures about protection and rules applying to Florida tree snails and provide them to relevant utilities and businesses.

Action 17 Make informative brochure for public about snail species identification and rules prohibiting collection to be given out in parks and public lands.

Educational Opportunities with Local Governments, Parks, and Refuges

Action 18 Look for kiosk display opportunities with local governments, parks, and refuges.

Education about the Importance of Tropical Hardwood Hammocks

Action 19 Start an adopt-a-hammock conservation program for school children in south Florida.

Action 20 Compile and evaluate existing material available to schools and see how and where materials on tropical hardwood hammocks and tree snails are in the existing curriculum.

Two brochures are proposed to be made and distributed about Florida tree snails. One will be given out to contractors and utility workers who may come into contact with tree snails. Educating contractors and utility workers will aid in the conservation of this species. This is especially true for tree snails in the Florida Keys where many populations are located along roadsides. This brochure will include information about rules, permitting, and identification of tree snails. The second brochure will be given out to the public with information about identification of tree snails and the restriction placed on collection. The public education brochure will be given to local parks and refuges to distribute. Parks, refuges, and public lands will be explored for additional education opportunities like kiosk displays. Opportunities for an adopt-a-hammock conservation program will be considered with local schools. Many of the

tropical hardwood hammocks in the Florida Keys have been used as dumping grounds and would benefit from some cleaning up. The goal of this conservation program would be to educate local children about the importance of tropical hardwood hammocks and the species that inhabit them.

Coordination with Other Entities

Assistance to Government Agencies, Private Citizens and Other Entities with Permitting and Planning Issues

Action 21 Provide technical assistance (maps of tropical hardwood hammock and Florida tree snail locations) to local government for use in permitting and development planning.

Action 22 Encourage local governments to support existing laws for protection of native tropical hardwood hammock.

Action 23 Encourage public and private landowners to adopt and follow habitat management recommendations to conserve Florida tree snails and their tropical hardwood hammock habitat.

Provide technical assistance and share information (e.g., research, range and distribution, geographic information system [GIS] information, and best development practices for land development) with local planners, biologists, and other staff. See [Action 1](#) and [Action 2](#) for habitat conservation and management recommendations. Provide information to local governments to give to property owners that have Florida tree snails on their property through the county or local-government permitting programs. Information could be distributed with their permit information or materials. Encourage development and enforcement of listed species and habitat protection in comprehensive growth management plans and ordinances. Local government could distribute information to businesses receiving occupational licenses such as contractors, landscapers, golf courses, etc. Monroe County collects mitigation funds when hardwood hammock is cleared for development. FWC could assist Monroe County with directing these funds where appropriate to tree snail habitat restoration and management.

County growth management plans and land development regulations provide an avenue by which FWC can inform and influence land and water uses that are relevant to the conservation of Florida's fish and wildlife. FWC offers conservation planning services to local governments during the development of amendments to growth management plans and associated development proposals.

Chapter 163.3177, Florida Statutes, requires that county comprehensive growth management plans include a conservation element. The conservation element must include the identification of areas within the county that are locations of important wildlife or habitat resources, including State-listed species. This element must contain principles, guidelines, and standards for conservation that restrict activities known to adversely affect the survival of these species. The FWC is identified as a state agency authorized to review county growth management plans and, including any amendments to ensure important state fish, wildlife, and habitat resources are adequately considered. In addition, local government land development regulations require conditions for land and water uses that specify how such uses will be administered to be

consistent with the conservation element of the county growth management plans. Therefore, interagency collaboration on the review and development of the conservation element of these plans is essential for ensuring that they consider wildlife habitat within the county, such as seepage stream and slope habitats.

Table 1. Florida Tree Snail (*Liguus fasciatus*) Conservation Action Table

Note: An explanation of acronyms used is below the table.

Objective(s) Addressed	Team Assigned Priority Level	Action Item Number	Action Items	Conservation Action Category	Ongoing, Expanded or New Effort?	Authority	Man Power	Estimated Cost To Implement	Funding Source(s)	Lead for Implementation: FWC Program(s) and/or Section(s)	External partners	Likely Effectiveness	Feasibility	Urgent?
1	1	1	Protect suitable habitat by less than fee acquisitions on private land, habitat restoration on private and public lands, and acquire as much suitable habitat as possible . Use survey information to rank tropical hardwood hammocks in priority for conservation/acquisition and importance to Florida tree snail.	Habitat Conservation & Mgmt	ONGOING	YES	NO	\$100k+	Trust fund, Legislature, donations, and other	FWC's Habitat and Species Conservation (HSC) Section	State Parks, USFWS, Monroe County, Dade County, National Park Service, and DEP, private land owners, SFWMD	Likely	Yes it can be done, yes it is practical, and relationships exist. If programs like Florida Forever are funded this could facilitate the process.	No, this will not reduce critical threats to the immediate survival.
1	3	2	Develop habitat management recommendations for public land managers and private landowners to follow. Review existing protocol used by utilities for translocating snails out of harm's way.	Incentives & Influencing	NEW	YES	YES	\$0-25k	Existing budget, other	HSC	DEP, State Parks, USFWS, Monroe County, Dade County, National Park Service, and private land owners	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	1	3	Continue removal of non-native plant and animal species. Remove introduced species from outside of their historic range.	Habitat Conservation & Mgmt	EXPANDED	YES	NO	\$100k+	Grants Legislature, Existing budget	HSC	State Parks, USFWS, Monroe County, Dade County, and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
2	1	4	Consider color morphs when reestablishing populations.	Population Mgmt	NEW	YES	NO	TBD	Unknown	HSC	State Parks, USFWS, Monroe County, Dade County, and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
2	1	5	Map existing color morphs using data obtained from baseline surveys.	Monitoring & Research	NEW	YES	NO	TBD	Unknown	HSC	State Parks, USFWS, Monroe County, Dade County, and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
2	3	6	Conduct genetics research to determine whether subspecies designations are warranted and relationships among named color morphs.	Monitoring & Research	NEW	YES	NO	TBD	Unknown	HSC, FWRI	State Parks, USFWS, Monroe County, Dade County, and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	2	7	Compile existing literature and determine needed research for effects of pesticides on tree snails.	Monitoring & Research	NEW	YES	NO	\$0-25k	Grants Legislature, Existing budget	HSC, FWRI	State Parks, USFWS, Monroe County, Dade County, and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	2	8	Compile existing literature and determine needed research for effects of non-native species on tree snails.	Monitoring & Research	NEW	YES	NO	\$0-25k	Grants Legislature, Existing budget	HSC, FWRI	State Parks, USFWS, Monroe County, Dade County, and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	2	9	Develop a standard surveying protocol and train qualified persons to conduct surveys. Train surveyors to identify/recognize named color morphs.	Monitoring & Research	NEW	YES	NO	\$25-50k	Trust fund, Grant, Legislature	HSC	State Parks, USFWS, Monroe County, Dade County, National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	2	10	Create a database to store all location and color morph information.	Monitoring & Research	NEW	YES	NO	\$0-25k	Trust fund, Grant, Legislature	HSC	FNAI, USFWS, National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.

Table 1. Florida Tree Snail (*Liguus fasciatus*) Conservation Action Table

Objective(s) Addressed	Team Assigned Priority Level	Action Item Number	Action Items	Conservation Action Category	Ongoing, Expanded or New Effort?	Authority	Man Power	Estimated Cost To Implement	Funding Source(s)	Lead for Implementation: FWC Program(s) and/or Section(s)	External partners	Likely Effectiveness	Feasibility	Urgent?
1	1	11	Inventory tropical hardwood hammocks for presence/absence of Florida tree snail. Determine methods and assess Florida tree snail population sizes (or relative density). Inventory color morphs.	Monitoring & Research	NEW	YES	NO	\$25-50k	Trust fund, Grant, Legislature	HSC	State Parks, USFWS, Monroe County, Dade County, National Park Service, and private land owners	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	1	12	Create a rule preventing collection, moving populations and mixing color morphs, and incidental take from utilities, road maintenance, and development activities.	Protections & Permitting	ONGOING	YES	YES	\$0-25k	Existing budget	HSC, Law Enforcement	Not applicable	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	3	13	Work with stakeholders that have collections to 1) develop a permitting system for grandfathering in existing collections and 2) assess how their collections and records can help guide conservation efforts.	Protections & Permitting	NEW	YES	NO	\$0-25k	Unknown	HSC	Not applicable	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	2	14	Educate new wildlife officers about imperiled species rules and permitting when they graduate from the FWC academy.	Law Enforcement	NEW	YES	YES	\$0-25k	Existing budget	HSC	State Parks, USFWS, Monroe County, Dade County, and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	3	15	Provide new and current wildlife officers assigned to the South Florida Region with informative brochures including 1) rule and permit information on Florida tree snails (including the Stock Island tree snail, the Florida tree snail, and others; and 2) an identification guide for tree snails in Florida.	Protections & Permitting	NEW	YES	YES	\$0-25k	Existing budget	HSC	Collectors	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	3	16	Produce informative brochures about protection and rules applying to Florida tree snails and provide them to relevant utilities and businesses.	Education & Outreach	NEW	YES	NO	\$0-25k	Unknown	HSC, OCR	State Parks, USFWS, Monroe County, Dade County, and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	3	17	Make informative brochure for public about snail species identification and rules prohibiting collection to be given out in parks and public lands.	Education & Outreach	NEW	YES	NO	\$0-25k	Unknown	HSC, FWC's Community Relations (OCR)	State Parks, USFWS, Monroe County, Dade County, and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	4	18	Look for kiosk display opportunities with local government, parks, and refuges.	Education & Outreach	NEW	YES	NO	TBD	Unknown	HSC, OCR	State Parks, USFWS, Monroe County, Dade County, and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	3	19	Start an adopt-a-hammock conservation program for school children.	Education & Outreach	NEW	YES	NO	\$0-25k	Unknown	HSC, OCR	State Parks, USFWS, Monroe County, Dade County, Local Governments and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	3	20	Compile and evaluate existing material available to schools and see how and where materials on tropical hardwood hammocks and tree snails are in the existing curriculum.	Education & Outreach	NEW	YES	NO	\$0-25k	Unknown	HSC, OCR	State Parks, USFWS, Monroe County, Dade County, Local Governments and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.

Table 1. Florida Tree Snail (*Liguus fasciatus*) Conservation Action Table

Objective(s) Addressed	Team Assigned Priority Level	Action Item Number	Action Items	Conservation Action Category	Ongoing, Expanded or New Effort?	Authority	Man Power	Estimated Cost To Implement	Funding Source(s)	Lead for Implementation: FWC Program(s) and/or Section(s)	External partners	Likely Effectiveness	Feasibility	Urgent?
1	2	21	Provide technical assistance (maps of tropical hardwood hammock and Florida tree snail locations) to local government for use in permitting and development planning.	Coordination with Other Entities	ONGOING	YES	YES	\$0-25k	Existing budget	HSC	State Parks, USFWS, Monroe County, Dade County, Local Governments and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	2	22	Encourage local governments to support existing laws for protection of native tropical hardwood hammock.	Coordination with Other Entities	ONGOING	YES	YES	\$0-25k	Existing budget	HSC	State Parks, USFWS, Monroe County, Dade County, Local Governments and National Park Service	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.
1	2	23	Encourage public and private landowners to adopt and follow habitat management recommendations to conserve Florida tree snails and their tropical hardwood hammock habitat.	Coordination with Other Entities	NEW	YES	YES	\$0-25k	Existing budget	HSC	State Parks, USFWS, Monroe County, Dade County, Local Governments and National Park Service, SFWMD	Likely	Yes it can be done, it's practical, and relationships exist.	No, this will not reduce critical threats to the immediate survival.

Acronyms used in this table:

- DEP: Florida Department of Environmental Protection
- FNAI: Florida Natural Areas Inventory
- FWC: Florida Fish and Wildlife Conservation Commission
- FWRI: Fish and Wildlife Research Institute, the research branch of the Florida Fish and Wildlife Conservation Commission
- HSC: Habitat and Species Conservation, a Division of the Florida Fish and Wildlife Conservation Commission
- OCR: Florida Fish and Wildlife Conservation Commission's Office of Community Relations
- SFWMD: South Florida Water Management District
- TBD: To be determined
- USFWS: United States Fish and Wildlife Service

LITERATURE CITED

- Addison, D. S. and K. Auffenberg. 1996. The distribution of *Liguus fasciatus* and *Orthalicus floridensis* in the coastal hammocks on the southwest coast of Florida. *Malacological Review* 26:79-83.
- Bennetts, R. E., S. A. Sparks, and D. Jansen. 2000. Host-tree selection by Florida tree snails, *Liguus fasciatus* (Muller, 1774), in Big Cypress National Preserve, Florida, USA. *Nautilus* 114:112-116.
- Clench, W. J. 1965. Supplement to the catalogue of the genus *Liguus*. *Occasional Papers on Mollusks* 2(34): 425.
- Close, H. T. 2000. The *Liguus* tree snails of south Florida. University Press of Florida, Gainesville.
- Davidson, T. 1965. Tree snails, gems of the Everglades. *National Geographic Magazine* 127:372-387.
- Deisler-Seno, J. E. 1994. Species of Special Concern: Florida tree snail. Pages 134-140 in M. Deyrup and R. Franz, editors. *Rare and endangered biota of Florida. Volume IV. Invertebrates*. University Press of Florida, Gainesville.
- Emmel, T. C., and A. J. Cotter. 1995. A summary of historical distribution and current status of the Florida tree snail, *Liguus fasciatus*. Florida Game and Fresh Water Fish Commission. Nongame Wildlife Program Project Report, Tallahassee.
- Eliazar, P. J., and T. C. Emmel. 1991. Adverse impacts to non-target insects. Pages 17-19 in T. C. Emmel and J.C. Tucker, editors. *Mosquito control pesticides: ecological impacts and management alternatives*. Conference Proceedings. Scientific Publishers, Gainesville.
- Fadely, J. R. 2009. Population distribution of *Liguus fasciatus solidus* in Long Pine Key of Everglades National Park. M.S. thesis, Florida Atlantic University, Boca Raton.
- Florida Fish and Wildlife Conservation Commission [FWC]. 2011. Florida tree snail biological status review report. Florida Fish and Wildlife Conservation Commission, Tallahassee.
- Florida Keys Electric Cooperative Association, Inc. 2012. C905 electric utility right-of-way maintenance annual report to Florida Fish and Wildlife Conservation Commission.
- Florida Natural Areas Inventory. 2001. Field guide to the rare animals of Florida. Available online: http://www.fnai.org/FieldGuide/pdf/Liguus_fasciatus.pdf. Accessed 4 March 2013.

- Florida Reef Resilience Program. 2010. Initial estimates of the ecological and economic consequences of sea level rise on the Florida Keys through the year 2100. <http://frpp.org/SLR%20documents/FINAL%20-%20Aug%2021%20-WITH%20COVER.pdf>. Accessed 4 March 2013.
- Forys, E. A., C. R. Allen, and D. P. Wojcik . 2003. The potential for negative impacts by red imported fire ants (*Solenopsis invicta*) on listed herpetofauna, mammals, and invertebrates in the Florida Keys. Final Report, Florida Fish and Wildlife Conservation Commission, Tallahassee.
- Forys, E. A., A. Quistorff, C. R. Allen, D. P. Wojcik. 2001. The likely causes of extinction of the tree snail *Orthalicus reses reses* (Say). *Journal of Molluscan Studies* 67:369-376.
- Hillis, D. M. 1989. Genetic consequences of partial self-fertilization on populations of *Liguus fasciatus* (Mollusca: Pulmonata: Bulimulidae). *American Malacological Bulletin* 7(1):7-12.
- Hillis, D. M. 1995. Genetic variation, systematic and reproduction of Florida tree snails (*Liguus fasciatus*). Florida Game and Fresh Water Fish Commission Nongame Wildlife Program Project Report, Tallahassee.
- Hillis, D. M., D. S. Rosenfeld, J. R., and M. Sanchez. 1987. Allozymic variability and heterozygote deficiency within and among morphologically polymorphic populations of *Liguus fasciatus* (Mollusca: Pulmonata: Bulimulidae). *American Malacological Bulletin* 5(2):153-157.
- Hoang, T. C., R. L. Pryor, G. M. Rand, and R. A. Frakes. 2011. Use of butterflies as nontarget insect test species and the acute toxicity and hazard of mosquito control insecticides. *Environmental Toxicology and Chemistry* 30(4):997-1005.
- Jones, A. L. 1976. Description of six new forms of Florida tree snails, *Liguus fasciatus*. *Nautilus* 94:153-159.
- Jones, A. L., E. C. Winte, and O. Bass, Jr. 1981. Status of Florida tree snails (*Liguus fasciatus*), introduced to Everglades National Park. Report T-622, National Park Service, South Florida Research Center, Everglades National Park, Homestead.
- Karim, A., and M. Main. 2009. Habitat fragmentation and conservation strategies for a rare forest habitat in the Florida Keys archipelago. *Urban Ecosystems* 12:359-370.
- Keeler, M. S., F. S. Chew, B. C. Goodale, and J. M. Reed. 2006. Modelling the impacts of two exotic invasive species on a native butterfly: top-down vs. bottom-up effects. *Journal of Animal Ecology* 75:777-788.

- Kobayashi, S. R., and M. G. Hadfield. 1996. An experimental study of growth and reproduction in Hawaiian tree snails *Achatinella mustelina* and *Partulina redfieldii* (Achantinelliane). *Pacific Science* 50:339-59.
- Mooney, H. A., and E. E. Cleland. 2001. The evolutionary impact of invasive species. *Proceedings of the National Academy of Sciences* 98:5446-5451.
- Pilsbry, H. A. 1946. Land Mollusca of North America. Academy of Natural Science of Philadelphia Monograph 2:37-102.
- Pimentel, D. 1995. Amounts of pesticides reaching target pests: environmental impacts and ethics. *Journal of Agricultural and Ethics* 8(1):17-29.
- Roth, B., and A. E. Bogan. 1984. Shell color and banding parameters of the *Liguus fasciatus* phenotype (Mollusca: Pulmonata). *American Malacological Bulletin* 3:1-10.
- Salvato, M. H. 2001. Influence of mosquito control chemicals on butterflies (Nymphalidae, Lycaenidae, Hesperidae) of the lower Florida Keys. *Journal of the Lepidopterists' Society* 55(11):8-14.
- Simpson, C. T. 1929. The Florida tree snails of the genus *Liguus*. *Proceedings U.S. National Museum* 73:1-44.
- Smith, B. 1997. A partial survey of Florida tree snail (*Liguus fasciatus*) distribution in Big Cypress National Preserve. Final Report submitted to the National Park Service at Big Cypress National Preserve, Ochopee, Florida.
- Tuskes, P. M. 1981. Population structure and biology of *Liguus* tree snails on Lignumvitae Key, Florida. *Nautilus* 95:162-169.
- United States Fish and Wildlife Service [USFWS]. 1999. Stock Island tree snail (*Orthalicus reses*). Pages 4-767-4-786 in Multi-species recovery plan for South Florida. United States Fish and Wildlife Service, South Florida Ecological Field Office, Vero Beach.
- Voss, R. S. 1976. Observations on the ecology of the Florida tree snail *Liguus fasciatus* (Muller). *Nautilus* 90:65-69.