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The Schaus Swallowtail Habitat Enhancement Project: An Applied Service-Learning Project Continuum from Biscayne National Park to Miami–Dade County Public Schools

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Abstract - Urbanization in Miami–Dade County has modified large tracts of suitable habitats into smaller patches and increased distance between habitats. As a result, the endangered *Heraclides aristodemus ponceanus* (Schaus Swallowtail), which historically inhabited subtropical dry forests in south Florida and the Florida Keys, is now restricted to several islands in the Florida Keys and its numbers are precipitously declining. Here we report on a project that combined a remote in situ restoration project with a community-outreach component that brought the restoration effort to local urban elementary schools. The Schaus Swallowtail Habitat Enhancement Project in Biscayne National Park utilized volunteers to remove exotic plants and plant over 3000 *Amryis elemifera* (Sea Torchwood) and *Zanthoxylum fagara* (Wild Lime), which are host plants for the Schaus Swallowtail. After planting and initial establishment, we monitored growth and survival of host plants. We developed the Schaus and Coastal Hardwood Hammock curriculum unit in partnership with teachers and university faculty, and implemented it at 8 locations including 5 public schools in an ex situ outreach and education program. Lesson plans aimed to: (1) inform students about the Schaus Swallowtail, (2) increase the number and size of native-plant butterfly gardens at schools and homes, and (3) thwart "extinction of experience" in nature for school children. Teachers implement applied activities modeled on the habitat enhancement project in Biscayne National Park in the classroom and on school grounds, and used them to illustrate the butterfly life cycle, species' niche requirements, biodiversity, and restoration and conservation of south Florida habitats. Ongoing engagement with school gardens through maintenance and project-based assignments can help students achieve academically and become responsible environmental stewards.

Introduction

Charismatic, "flagship" species such as butterflies have been used to raise awareness and promote conservation and biodiversity of organisms, ecosystems, and resources in the US and other countries (Leader-Williams and Dublin 2000, Walpole and Leader-Williams 2002). South Florida hosts over 100 species of butterflies; temperate and tropical species coexist in various habitats, ranging from residential neighborhoods to subtropical dry forests (Minno and Emmel 1993). Urbanization in south Florida has reduced large tracts of viable habitats into

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smaller patches (Alonso and Heinen 2011). Habitat loss is a major factor that has contributed to the decline of insect species globally (Bender et al. 1998, Ricketts 2001, Ricketts et al. 2008, Taki and Kevan 2007). Anthropogenic development has modified the natural environment through habitat simplification, expanded matrix (unsuitable surrounding habitat), and increased distance between viable habitats (Rosa et al. 2004). As a result, many insect species, often habitat specialists, have declined to very low numbers.

Many butterfly species have experienced significant population reductions (Calhoun et al. 2002, Loftus and Kushlan 1984, USFWS 2008), including *Heraclides aristodemus ponceanus* (Schaus Swallowtail), a species symbolic of the plight of many insect species in south Florida. Historically, the Schaus Swallowtail inhabited subtropical dry forests in both peninsular south Florida and the Florida Keys, but it is now restricted to several islands in the Florida Keys (Fig. 1). The Schaus Swallowtail, endemic to south Florida and the Bahamas, was among the first insects given federal protection; listed as threatened in 1976, it was reclassified as endangered in 1984 (Smith et al. 1994; USFWS 2008, 2015).

Many butterflies, including federally and state-listed species, inhabit subtropical dry forests (known as hardwood hammocks in Florida; Snyder et al. 1990). Hardwood hammocks in the northern Florida Keys are vital to the Schaus Swallowtail because the preferred host plant, *Amyris elemifera* (Torchwood), exists primarily in this particular habitat (Minno and Emmel 1993, Rutkowski 1971). Torchwoods are

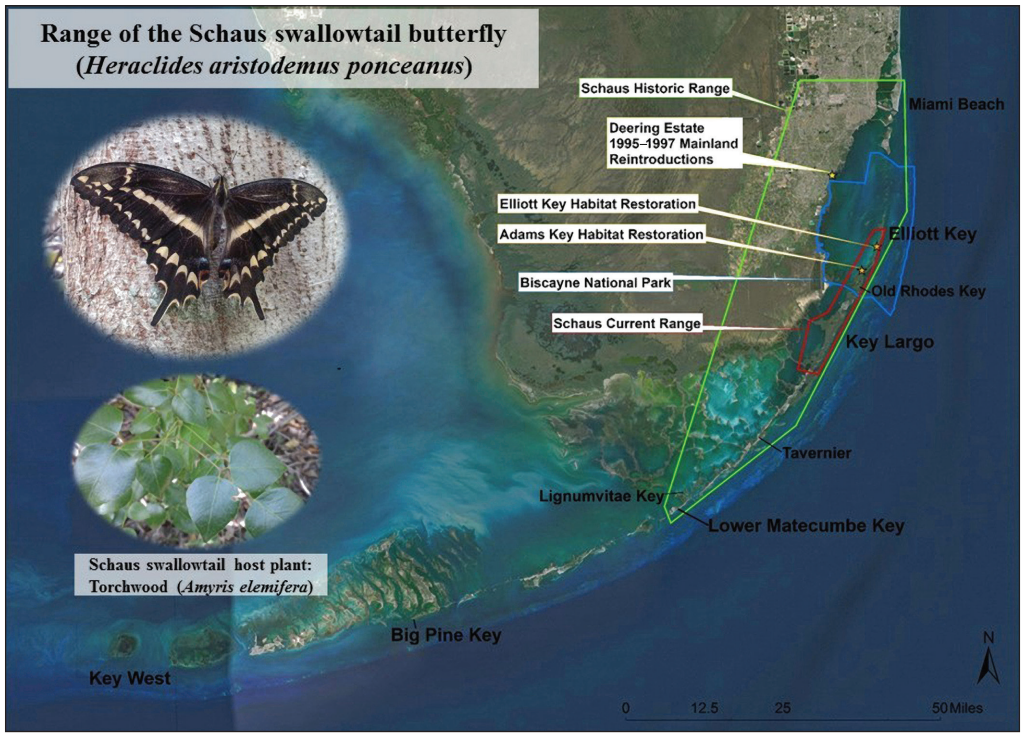

Figure 1. Current range of the Schaus Swallowtail Butterfly in south Florida. Map generated by Helena Giannini.

subcanopy trees that thrive in gaps in the interior and along the edges of hardwood hammocks (Jameson 2002, Ray et al. 1998, Ross et al. 2001). Hardwood hammocks in the Florida Keys experienced timber harvests from the 1700s until the 20th century, followed by agricultural cultivation (early 1900s), and a transition to human habitation and tourism uses (Snyder et al. 1990, Strong and Bancroft 1994). Development and tourism have had direct and indirect deleterious effects on local flora and fauna. Direct effects include loss of land area, habitat degradation, and pollution; indirect effects include the spread of invasive species and the impacts of mosquito abatement treatments (Hoekstra et al. 2005, Janzen 1988, Roe et al. 1997). As a result, some native species in the Florida Keys are now imperiled or extinct.

The Schaus Swallowtail Habitat Enhancement Project in Biscayne National Park (BNP) is an ongoing project on Elliott and Adams Keys—2 islands protected within the boundaries of BNP—since 2011. National parks can provide refugia for imperiled insects to thrive and flourish; the protection of natural habitats and restoration of degraded areas are 2 of many solutions available to protect Earth's biodiversity (Hoekstra et al. 2005, Oliver et al. 2010). Hardwood hammocks are protected in BNP from both development and mosquito abatement. Biscayne National Park is home to imperiled species extirpated from the Floridian mainland, and continues to protect the Schaus Swallowtail from deleterious, anthropogenic impacts. The project was designed by National Park Service (NPS) staff to enhance the habitat of the endangered butterfly. They planned to restore degraded habitat overgrown with invasive plant species within the butterfly's prime territory by planting and nurturing large numbers of host plants, mainly Torchwood (Whelan 2011). The distribution of larval host plants is clustered (Jameson 2002, Whelan 2011); therefore, another goal of the project was to more widely distribute larval host plants across the landscape to help increase overall butterfly population stability, by mitigating against negative stochastic episodes that might impact the current limited population of larval host plants (Whelan 2011).

We also sought to raise public awareness of the importance of these natural areas in the conservation of threatened and imperiled species, and instill stewardship in project volunteers. Information explaining the human and natural history of south Florida, especially with regard to hardwood hammocks and the Schaus Swallowtail, are readily available at the BNP nature center, and are also featured on the interpretive trail at Elliott Key. The decrease in visitors to this and other parks is symptomatic of the disconnection between humans and nature which has increased over time in south Florida (Pergams and Zaradic 2008, Zaradic and Pergams 2007). Despite an increase in "baby boomer" visitors, overall visitation to national parks has steadily declined over the years. The low attendance rates among young people foreshadow an uncertain future for the conservation and preservation of natural resources (NPS 2015; Pergams and Zaradic 2006, 2008; Stevens et al. 2014). People who are introduced to natural areas as children are more likely to value them as adults (Bögeholz 2006, Duda et al. 1998, Hungerford and Volk 1990, Louv 2008, Pergams and Zaradic 2008, Wells and Lekies 2006). When children have repeated exposure to nature, they often grow up to be adults that advocate for the protection

of natural areas and biodiversity conservation (Chawla 1998, Hungerford and Volk 1990, Matthews and Riley 1995, Wells and Lekies 2006).

The Schaus Swallowtail Habitat Enhancement Project in BNP has involved volunteers since 2011 to help restore patches of land by removing widespread exotic, invasive vegetation and replanting native butterfly-attracting plants (Whelan and Atkinson 2015). A similar model can be applied in local communities (Mathew and Anto 2007); schools, community centers, businesses, and residences can enhance habitat by constructing butterfly gardens with a focus on native plants (Vickery 1995). These places provide opportunities to expose legions of young people to the national parks through in situ field trips to natural areas and ex situ activities in the classroom or schoolyard, with activities ranging from exploratory observations to service-learning projects.

Based on the Schaus Swallowtail Habitat Enhancement Project in BNP, J. Clayborn designed the Schaus and Coastal Hardwood Hammock curriculum unit (containing multiple lesson plans) to connect students in Miami–Dade County to their local environment in south Florida. Participating professors and veteran teachers from Air Base K–8 Center, Coral Terrace Elementary, Florida International University, and Gateway Environmental K–8 Learning Center provided comments to improve the initial draft. The curriculum uses the charismatic Schaus Swallowtail as a flagship species to demonstrate habitat restoration, a process which can also be applied locally at schools and homes to collectively benefit other butterfly and invertebrate species. Many students were unaware that south Florida's remnant ecosystems were historically expansive and exist now only as fragments outside of BNP, Big Cypress National Preserve, and Everglades National Park (Myers and Ewel 1990). This disconnect in understanding of the significance of native ecosystems can be detrimental to many organisms if anthropogenic constructs replace natural ecosystems.

As part of the newly developed curriculum, schoolyard gardens were created in most of the schools involved; most students active in this ex situ outreach and educational program did not participate in the Schaus Swallowtail Habitat Enhancement Project in BNP. Enhancing areas such as schools and community centers by planting native plants, removing invasive plants, and minimizing pesticide application can provide suitable habitats that protect butterflies (including imperiled taxa) and other species (especially arthropods) from urbanization (Ricketts 2001). Host plants are critical for all butterflies to maintain their populations (Dennis et al. 2004, Minno and Emmel 1993, Vickery 1995); adult butterflies are less abundant in areas lacking such plants (Mathew and Anto 2007). Outreach programs that integrate habitat restoration projects with habitat rehabilitation projects in backyards, parks, and schoolyards can simultaneously help thwart extinction of species of imperiled butterflies in south Florida and "extinction of experience" in nature for children in urban areas (Louv 2008, Miller 2005, Pyle 1978).

The project at BNP and those carried out in other communities had the following objectives:

Schaus Swallowtail Habitat Enhancement Project

- Establish supplemental plantings of host species Torchwood and *Zanthoxylum fagara* (Wild Lime) in various locations at BNP.
- Restore critical hardwood hammock habitat by removing invasive plant species and planting native species.
- Provide volunteer-based in situ outreach and education programs to increase public awareness of Schaus Swallowtail habitat and instill stewardship values.

Schaus and Coastal Hardwood Hammock curriculum unit

- Replicate the Schaus Swallowtail Habitat Enhancement Project in the Schaus and Coastal Hardwood Hammock curriculum unit created for urban schools and communities in south Florida.
- Construct native plant butterfly gardens with high plant diversity, and observe and identify different butterfly species; in some cases, track the movement of butterflies from school grounds to adjacent communities.
- Implement an ex situ education and outreach program to promote the use of native plants and awareness of the negative implications of pesticide application for butterflies.

Note that complete lists of all species mentioned in this paper including the authorities and common names are provided in Appendices 1 and 2.

Field-site Description

Originally established as Biscayne National Monument in 1968, BNP became a national park in 1980. There is limited terrestrial area in BNP; 95% of the park is comprised of marine environments. The terrestrial area consists of a narrow strip of land on the mainland and 42 islands, the majority of which are dominated by mangrove forest (2400 ha).

Hardwood hammocks are dense, evergreen, subtropical dry forests dominated by broad-leaved trees that occur primarily in the southern portion of Florida (Ross et al. 1992, Snyder et al. 1990). Hardwood hammocks of the northern and middle Keys have marine-based limestone outcroppings (Key Largo limestone), which are partially covered with a shallow layer of endogenous soil (Armentano et al. 2002, Horvitz and Koop 2001). Coastal hardwood hammocks in BNP cover about 723 ha (23%) of the terrestrial lands (Whelan et al. 2013). The largest island, Elliott Key, is roughly 7 miles long and nearly a mile wide; the hardwood hammock covers 68% of its area and 43% of Adams Key (Whelan et al. 2013). Many of these keys are currently impacted by exotic, invasive plant and animal species (FISP 2017, Invasive.org 2017). Approximately 500,000 people visit BNP each year (NPS 2015).

For this study, we established 2 site locations in BNP: Adams Key (AK) and Elliott Key (EK) (Fig. 2). Other parts of this research were conducted at Florida International University's (FIU) nature preserve, greenhouse, and the Ziff Education Building; the Miami-Dade College Hialeah Campus (MDC); and the Open House Ministries Community Center (OHM). We also had sites at 5 public schools: Air

Base K–8 Center (AB), Coral Terrace Elementary (CTE), Gateway Environmental K–8 Learning Center (GEL), North Hialeah Elementary School (NHE), and Whispering Pines Elementary School (WPE) (Fig. 2).

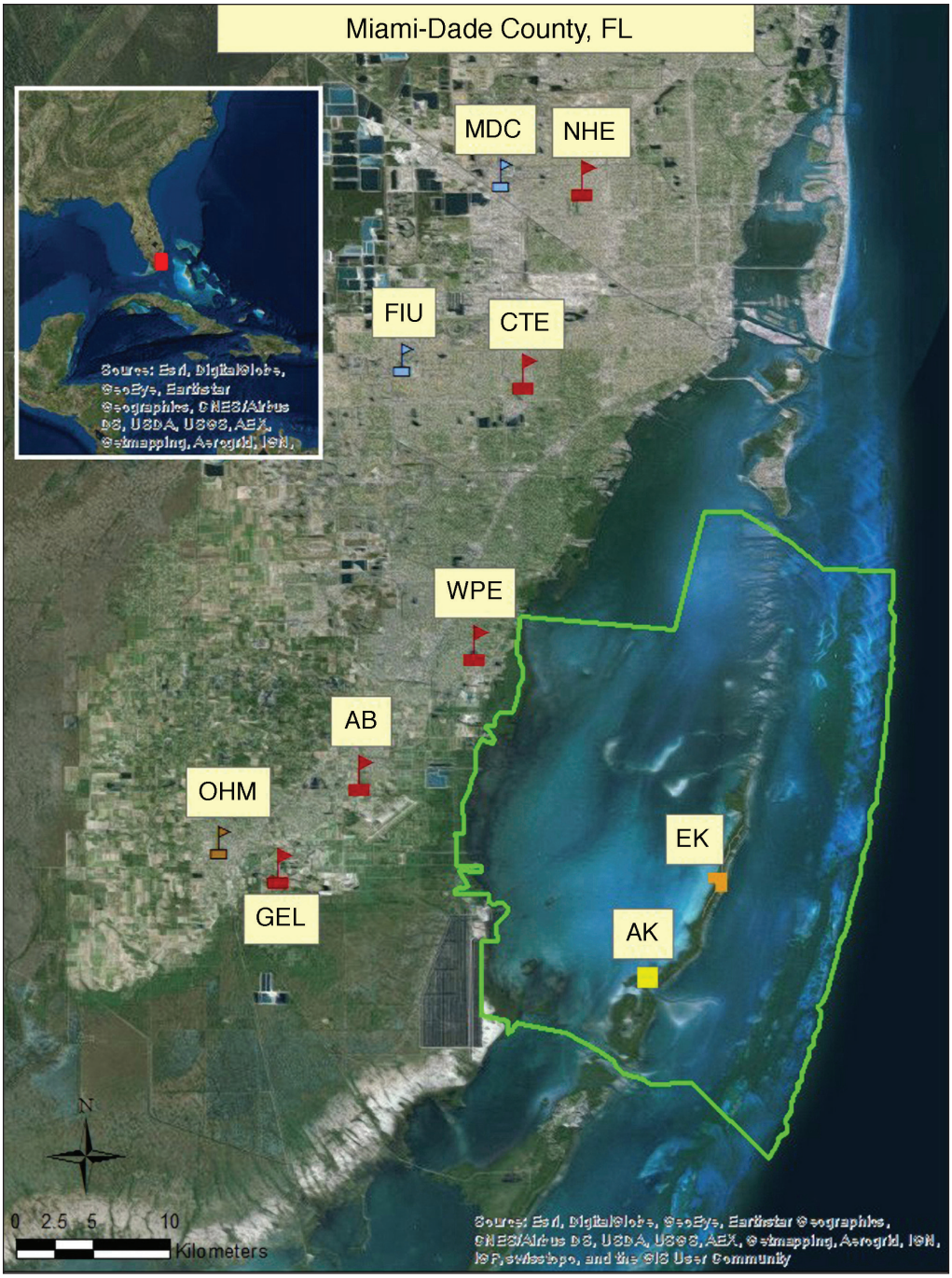

Figure 2. Study-site locations in Miami–Dade County (Biscayne National Park is outlined on the bottom right in the map). See text for site abbreviations.

Methods

Establishment of Torchwood corridors in Biscayne National Park, Elliott Key, and Adams Key

The enhancement project involved planting Torchwood in restoration areas, and along a 8.05-km (5-mile) north–south trail down the middle of Elliott Key to provide a corridor of host plants (2 ha [4.94 ac]) between known Schaus Swallowtail locations and restoration areas. The 2 restoration areas were initially dominated by 2 invasive plant species, *Colubrina asiatica* (Latherleaf) and *Neyraudia reynaudiana* (Burma Reed), that had become established after disturbances at the sites. Enhancement project collaborators removed invasive plants and replaced them with native vegetation at 2 sites: 1 on Elliott Key (0.58 ha [1.43 ac]) and 1 on Adams Key (0.27[0.66 ac]). The establishment of native plants can prevent, or substantially reduce, the reestablishment of invasive species (Berger 1993, Egan and Howell 2001). Numerous Torchwood and Wild Lime seedlings (host plants for Schaus Swallowtail), as well as other species of typical hardwoods, were planted to allow development of upper-canopy vegetation in the restoration area.

Establishment of supplemental host plants

National Park Service (NPS) staff, John Pennekamp State Park staff (Key Largo, FL), volunteers, and a commercial nursery operator collected Torchwood and Wild Lime fruits from native populations. The fruits were transported to a native plant nursery in Homestead, FL, in 2011–2013, where the globose Torchwood berries were processed by removing the fleshy outer coat, scarifying the seed, and planting them in germination trays. Project personnel removed Wild Lime seeds from the follicles, and placed single seeds directly into germination trays, and grew the resulting seedlings in a greenhouse for a year before transporting them to Elliott and Adams Keys for planting.

J. Clayborn gave volunteers a brief lecture about insect conservation and the plight of the Schaus Swallowtail before they began fieldwork. Volunteers and other project personnel proceeded to the field for hands-on service-learning work in the restoration areas. Their tasks included digging, planting, watering, and tracking host-plant growth and survival at both Elliott and Adams Keys. Upon completion of the fieldwork in the restoration sites, volunteers surveyed the planted Torchwood and Wild Lime for eggs and caterpillars by scanning newly emerged leaves.

We conducted volunteer fieldwork days with a number of groups, including the Sierra Club of Miami, FIU biology students, FIU Insect Conservation Club, University of Miami (UM) Ecosystem Science and Policy undergraduates, UM Alternative Fall Break Group, Miami Dade College Environmental Science class, and Doral High School 11th and 12th graders. Before volunteers left the field site, we gave them t-shirts with a graphic that read Schaus Swallowtail Habitat Helper to reward their hard work and to raise public awareness of the project and mission.

Ex situ outreach and educational program

Five public schools, 1 university, 1 community college, and 1 community center participated in the Schaus and Coastal Hardwood Hammock curriculum unit. The curriculum unit followed the Learning Cycle Teaching Approach to actively engage students, in which we created lessons for the student investigations modeled on the "5 Es" (engage, explore, explain, extend, evaluate; Bybee 2002, Settlage and Southerland 2012). The lesson design highlighted several important aspects of teaching toward the Next Generation Science Standards (Achieve, Inc. 2013, Bybee 2014): (a) establishing meaningful context, (b) engaging in scientific inquiry, (c) collaborating to share/refine understanding, (d) utilizing learning tools, and (e) creating class/individual artifacts. Each participating school followed the same curriculum protocol for 3 months.

Lesson 1. The plight of the butterfly (historical lessons about Biscayne National Park). Students formed small groups and constructed a model of an island, considered ways to attract and maintain a population of Schaus Swallowtails, and proposed possible solutions to ameliorate extinction after 3 kinds of disturbances (anthropogenic habitat development, application of mosquito insecticides, and tropical storms).

Lesson 2: Pin the Schaus Swallowtail in the right habitat. After an interactive lecture presentation on imperiled butterflies of south Florida (including basic butterfly information, native plant gardening, and insect conservation), students participated in an activity titled "Place the Schaus Swallowtail in its habitat (current range)." A randomly selected student was blindfolded and given a butterfly magnet. The remaining students brainstormed a plan to navigate the blindfolded student with the butterfly to the appropriate location on a large poster map displaying the historic and current range of the Schaus Swallowtail (Fig. 1). Students were only allowed to communicate nonverbally, by using musical instruments (harmonica, flute, kazoo, and tambourine), until the blindfolded person placed the butterfly on the map.

Lesson 3: Habitat rehabilitation on school grounds. Students performed a butterfly survey on their school grounds using south Florida butterfly identification guides. The guides also served as a reference to let students see what host plants were appropriate for recruitment of new species and to encourage increases in local butterfly populations. Most of the species students planted in the butterfly gardens naturally occur in hardwood hammocks and pine rockland ecosystems—globally imperiled ecosystems found in south Florida (Alonso and Heinen 2011, Janzen 1988, Ross et al. 2009, Snyder et al. 1990). Several months after garden completion, students conducted another butterfly survey to compare and contrast species recruitment and abundance with their initial observations.

Lesson 4: Hardwood hammock restoration and butterfly monitoring project. FIU education students restored parts of the FIU Nature Preserve by planting native hardwood hammock and pine rockland plants, and, with training, participated in an on-campus butterfly monitoring project (including tagging, release, and retrieval; MonarchWatch 2014). These students (different groups each semester) learned how to estimate population size using mark–recapture techniques. They tagged

Heliconius charithonia (Zebra Longwing), a common and slow-flying species of butterfly found in hardwood hammocks, in the FIU Nature Preserve for 3 semesters (Fall 2014, Spring 2015, and Summer 2015) to track butterfly movement on campus, monitor their population, and learn new skills useful for careers in education and science. Students captured Zebra Longwings with butterfly nets and placed a non-toxic label (with a specific code) on the hindwing of the butterfly. Tagged butterflies were released back into the preserve; 2 weeks later, students again caught Zebra Longwings to see how many were recaptured (Fig. 3).

Results

Schaus Swallowtail habitat enhancement project

This project utilized over 150 volunteers from the general public; the volunteers spent 2670 field hours (valued at ~$60,000, in 2015 dollars). Overall, participants planted more than 3200 plants at Elliott and Adams Keys. The main species used in restoration was Torchwood (Table 1), which participants planted in the hardwood hammock near trails at Elliott Key, connecting wild Torchwood patches to the main restoration site.

On 16 May 2015, a Schaus Swallowtail egg was documented on 1 of the planted Torchwoods in the main restoration site at Elliott Key (Fig. 4). Students documented recruitment (larvae and eggs) of 2 species closely related to the Schaus Swallowtail, *Heraclides cresphontes* (Giant Swallowtail) and *Heraclides andraemon* (Bahamian Swallowtail).

Figure 3. Tagged Zebra Longwing ready for release at the Florida International University nature preserve.

Ex situ outreach and educational program (schools and community center)
Overall, we distributed 34 plant species (31 native) to the schools and community center (Table 2). Most of the plants were used to rehabilitate the school grounds; however, students at Miami–Dade County Hialeah Campus were encouraged to plant seedlings at home and establish their own butterfly garden. Twenty-one of the plant species used were butterfly host plants (Table 3); the other 13 plant species were nectar-producing and structural plants for insects and other garden inhabitants.

When the results of the pre- and post-surveys conducted by students at 5 of the 7 survey locations were compared, we found that butterflies increased in abundance (Table 4). Students had learned a considerable amount about butterflies and they conducted the post-survey without assistance from their instructors; the instructors were present only to validate the post-survey results.

Table 1. Number of plants including Torchwood, Wild Lime, and nectar plants planted at Elliott and Adams Keys. Numbers are shown per restoration area. Column on right shows total number of plants planted per restoration area.

Island	Restoration area	Torchwood	Wild Lime	Nectar plants	Total plants to date
Elliott Key	Elliott Main	598	116	60	774
	Elliott Breezeway	433	102	2	537
	Elliott Spite Highway North	824	-	-	824
	Elliott East	58	-	-	58
	Elliott West	151	-	-	151
Adams Key	Adams Main	414	104	15	533
	Adams Breezeway	275	64	17	356
Total		2753	386	94	3233

Figure 4. (A, left). Schaus Swallowtail egg on Torchwood in the main restoration site at Elliott Key in Biscayne National Park; (B, right). Giant Swallowtail caterpillar on Wild Lime in the main restoration site at Adams Key.

Participants tagged a total of 63 butterflies. Of these, 1 female Zebra Longwing tagged on 21 October 2014 in the FIU Nature Preserve was recaptured by a student 425 m away, near the center of campus on 16 November 2014. Four Zebra Longwings tagged on 4 June 2015 were recovered (3 males, 1 female) 2 weeks later (18 June 2015) near the same location in the FIU Nature Preserve.

Discussion

BNP is a sanctuary for the Schaus Swallowtail and other imperiled organisms that depend on healthy hardwood hammocks. Because BNP maintains the largest

Table 2. Plants planted in the butterfly gardens and FIU Nature Preserve. Note: MDC students were given plants to take home. Asterisks (*) denote exotic plants. See text for site abbreviations.

	Site								
Plant species	MDC	FIU	OHM	AB	CTE	GEL	NHE	WPE	Total
Alvaradoa amorphoides	6	5	3	0	4	5	0	0	23
Amyris elemifera	0	4	1	0	2	0	0	0	7
Angadenia berteroi	14	7	6	3	8	6	0	4	48
*Aristolochia gigantea**	0	0	0	0	2	0	2	2	6
*Asclepias curassavica**	0	0	3	0	4	15	4	1	27
Asclepias incarnata	10	0	0	0	0	0	0	2	12
Asclepias tuberosa	12	10	0	0	1	3	0	0	26
Bourreria succulenta	4	0	0	1	0	0	2	0	7
Byrsonima lucida	6	5	3	3	3	0	0	3	23
Cardiospermum corindum	2	0	0	0	0	0	0	0	2
Chamaecrista fasciculata	0	0	0	0	8	0	0	12	20
Citharexylum spinosum	0	0	0	0	0	4	0	0	4
Coccothrinax argentata	0	0	0	0	2	0	0	0	2
Colubrina elliptica	0	0	0	0	0	0	3	3	6
Cordia sebestena	3	0	0	0	3	0	4	0	10
Croton linearis	0	4	3	0	2	9	0	4	22
Cynophalla flexuosa	2	6	0	3	5	4	0	1	21
Ficus aurea	0	0	0	0	2	1	0	0	3
Flaveria linearis	0	2	0	2	8	4	0	6	22
Guaiacum sanctum	5	0	0	2	3	4	0	3	17
Guapira discolor	8	2	0	0	2	0	0	0	12
Jacquinia keyensis	0	0	0	16	0	0	0	0	16
Lantana involucrata	10	8	0	4	4	0	0	6	32
Passiflora suberosa	14	3	3	10	20	8	5	20	83
Physalis walteri	3	6	0	2	6	5	0	4	26
Pithecellobium unguis-cati	4	1	1	1	3	2	0	0	12
Plumbago zeylanica	1	0	0	0	3	1	2	0	7
Psychotria nervosa	4	3	0	0	4	0	0	0	11
*Ruta graveolens**	0	0	0	0	3	3	2	0	8
Senna mexicana	3	8	4	5	2	4	10	4	40
Solidago sempervirens	9	0	0	0	0	0	0	4	13
Varronia globosa	2	0	0	0	0	2	0	0	4
Zamia integrifolia	0	0	10	6	4	28	4	6	58
Zanthoxylum fagara	10	4	0	3	3	2	2	2	26
Total	132	78	37	61	111	110	40	87	656

Table 3. Host plants planted in the gardens and Lepidoptera (butterflies, moths, and skippers) attracted to them. Asterisks denote exotic plants.

Host plants	Butterfly, moth, and skipper species that depend on each host plant
Alvaradoa amorphoides (Mexican Alvaradoa)	*Pyrisitia dina* (Dina Yellow)
Amyris elemifera (Sea Torchwood)	*Heraclides aristodemus ponceanus* (Schaus Swallowtail), *Heraclides andraemon* (Bahamian Swallowtail), *Heraclides cresphontes* (Giant Swallowtail)
Angadenia berteroi (Pineland Golden Trumpet)	*Syntomeida epilais* (Polka-Dot Wasp Moth)
*Aristolochia gigantea** (Brazilian Dutchman's Pipe)	*Battus polydamas* (Polydamas Swallowtail)
Asclepias species*(Milkweed)	*Danaus plexippus* (Monarch), *Danaus gilippus* (Queen), *Danaus eresimus* (Soldier)
Byrsonima lucida (Locustberry)	*Ephyriades brunnea* (Florida Duskywing)
Capparis flexuosa (Limber Caper)	*Glutophrissa drusilla neumoegenii* (Florida White), *Ascia monuste* (Great Southern White)
Cardiospermum corindum (Balloonvine)	*Chlorostrymon simaethis* (Silver-Banded Hairstreak)
Chamaecrista fasciculata (Partridge Pea)	*Hemiargus ceraunus* (Ceraunus Blue), *Phoebis sennae* (Cloudless Sulphur), *Eurema nicippe* (Sleepy Orange), *Pyrisitia lisa* (Little Yellow)
Citharexylum spinosum (Fiddlewood)	*Epicorsia oedipodalis* (Fiddlewood Leafroller)
Coccothrinax argentata (Silver Palm)	*Asbolis capucinus* (Monk Skipper)
Croton linearis (Pineland Croton)	*Anaea troglodyta floridalis* (Florida Leafwing), *Strymon acis bartrami* (Bartram's Scrub-Hairstreak)
Ficus aurea (Strangler Fig)	*Marpesia petreus* (Ruddy Daggerwing)
Guaiacum sanctum (Lignum-Vitae)	*Kricogonia lyside* (Lyside Sulphur)
Passiflora suberosa (Corkystem Passionflower)	*Heliconius charithonia* (Zebra Longwing), *Dryas iulia* (Julia), *Agraulis vanillae* (Gulf Fritillary)
Pithecellobium unguis-cati (Catclaw Blackbead)	*Leptotes cassius* (Cassius Blue), *Phoebis agarithe* (Large Orange Sulphur)
Plumbago zeylanica (Doctorbush)	*Leptotes cassius* (Cassius Blue)
*Ruta graveolens** (Rue)	*Heraclides cresphontes* (Giant Swallowtail), *Papilio polyxenes* (Black Swallowtail)
Senna mexicana (Chapman's Senna)	*Phoebis philea* (Orange-Barred Sulphur), *Phoebis sennae* (Cloudless Sulphur)
Zamia integrifolia (Coontie)	*Eumaeus atala* (Atala)
Zanthoxylum fagara (Wild Lime)	*Heraclides aristodemus ponceanus* (Schaus Swallowtail), *Heraclides andraemon* (Bahamian Swallowtail), *Heraclides cresphontes* (Giant Swallowtail)

Schaus Swallowtail population in the Florida Keys, it is imperative to maintain the park's ecological integrity (Saunders and Hobbs 1989, USFWS 2008). As human populations continue to increase, land is continually developed, and there is pressure on the tracts surrounding protected areas. In addition, people are increasingly engulfed in cocoons provided by their enhanced mobile technology, and many have become disconnected from nature. A negative feedback pattern has been generated by these phenomena, where species may persist in protected parks but still face the threat of habitat loss and degradation near park boundaries (Pergams and Zaradic 2006, Wiersma et al. 2004).

This intensive, multi-year, service-learning project raised awareness about a federally endangered butterfly, and demonstrated memorable hands-on approaches to proactive solutions. Habitat restoration efforts led to visitation of sites and oviposition on planted Torchwood by Schaus Swallowtails (Fig. 4), as well as oviposition

Table 4. Before garden construction, butterfly-species counts (pre-survey) were conducted (numbers indicated in parenthesis) at each site. Several months later, a post-survey was conducted in the same area at each site. Asterisks (*) denote an increase in butterflies from the pre-survey. Note: Students at MDCHC did not construct a butterfly garden.

	Site							
Butterfly species	MDCHC	OHMCC	AB K-8	CTE	GEL K-8	NHE	WPE	Total
Agraulis vanillae	(0)0	(0)1	(5)0	(0)2	(1)5	(0)3	(2)3	(8)14*
Anartia jatrophae	(3)4	(5)2	(4)0	(6)3	(5)5	(2)2	(4)3	(29)19
Asbolis capucinus	(0)0	(0)0	(0)4	(0)0	(3)2	(0)1	(0)1	(3)8*
Ascia monuste	(0)0	(0)1	(0)0	(0)0	(0)0	(0)3	(0)1	(0)5*
Battus polydamas	(0)0	(0)0	(0)0	(0)1	(0)0	(0)0	(1)3	(1)4*
Danaus gilippus	(0)0	(0)0	(0)0	(0)0	(2)2	(0)0	(2)1	(4)3
Danaus plexippus	(0)0	(0)3	(3)0	(5)2	(3)12	(1)5	(4)5	(16)27*
Dryas iulia	(0)0	(0)2	(1)0	(0)0	(0)1	(0)0	(1)3	(4)6*
Electrostrymon angelia	(0)0	(1)1	(0)0	(0)0	(0)1	(0)0	(0)0	(1)2*
Eumaeus atala	(0)0	(0)0	(2)3	(0)0	(0)0	(0)0	(0)0	(2)3*
Eurema daira	(0)2	(5)3	(0)2	(8)3	(0)0	(4)2	(0)0	17(12)
Heliconius charithonia	(0)0	(0)0	(4)6	(0)0	(0)1	(0)0	(3)5	(7)12*
Hemiargus ceraunus	(0)0	(0)0	(1)1	(0)2	(5)2	(0)0	(2)1	(8)6
Hylephila phyleus	(0)0	(0)1	(0)3	(0)0	(0)0	(0)0	(0)0	(0)4*
Junonia coenia	(0)0	(0)1	(1)1	(0)0	(2)1	(0)0	(2)1	(5)4
Leptotes cassius	(3)1	(0)2	(1)0	(3)3	(6)8	(1)3	(0)2	(14)19*
Marpesia petreus	(0)0	(0)0	(0)1	(0)0	(0)0	(0)0	(1)1	(1)2*
Nathalis iole	(0)0	(3)1	(2)0	(1)4	(0)3	(0)1	(0)0	(6)9*
Papilio cresphontes	(0)0	(0)0	(1)0	(0)1	(0)0	(1)1	(0)0	(2)2
Papilio polyxenes	(0)0	(0)0	(0)0	(0)0	(0)1	(0)0	(0)0	(0)1*
Phoebis agarithe	(2)1	(4)2	(3)2	(0)0	(10)9	(1)0	(0)0	(20)14
Phoebis philea	(0)0	(0)0	(0)1	(0)1	(2)1	(0)0	(0)0	(2)3*
Phoebis sennae	(0)0	(0)0	(0)0	(0)2	(0)1	(0)1	(0)0	(0)4*
Phyciodes phaon	(0)0	(1)1	(1)0	(0)0	(1)1	(0)0	(2)1	(5)3
Polites vibex	(0)0	(0)0	(0)1	(0)0	(0)0	(1)0	(0)1	(1)2*
Pyrgus oileus	(0)0	(1)1	(0)0	(0)0	(0)0	(0)0	(1)1	(2)2
Urbanus proteus	(0)0	(1)0	(0)0	(0)0	(0)0	(0)1	(0)1	(1)2*
Total	(8)8	(21)22*	(29)25	(23)24*	(40)56*	(11)23*	(27)34*	(159)192*

by the rare Bahamian Swallowtail Butterfly. Project volunteers saw many other species at the restoration sites, including native bees, flies, resident and neotropical migrant birds, and giant land and hermit crabs, exposing them to BNP's terrestrial biodiversity. Every participating volunteer at BNP, the schools, and community center became aware of the Schaus Swallowtail's conservation status, as well as other butterflies and their native host plants.

The schools that integrated the Schaus and Coastal Hardwood Hammock curriculum unit into their lesson plans engaged students in the garden and used field guides to identify and count various butterfly species. Students of all ages were able to conduct the butterfly count without the aid of teachers and other experts, and were able to identify more species during the post-survey, a prime example of "scaffolding." Scaffolding refers to students accomplishing something they, under other circumstances, would be unable to achieve, with only minimal support from a teacher (Settlage and Southerland 2012). This teacher support is temporary, and can be withdrawn as students acquire confidence, skills, and knowledge. At participating schools, students absorbed the information and used it in a multitude of ways, taking ownership and sharing with others, and working as scientists themselves.

The gardens still flourish, and both new and veteran students continue to add native plants each year while maintaining their gardens through weeding, watering, and edging. Each garden serves to enhance academic achievement, social capital, and environmental quality through active learning, applied and practical science, and self-governing responsibilities (student-driven ownership; Blair 2009, Sobel 2005). Students who value habitat preservation for wildlife in their school garden become protective of the plants they nurtured after placing them to the ground. Teachers use the garden not only for science, but also for activities in other subject areas such as mathematics, writing, and art.

Schools can raise awareness and motivate large numbers of people to think globally by acting locally. School grounds can be more ecologically valuable than the traditional grass monoculture bordered with several exotic plant species. By establishing butterfly gardens during the project, these areas became complex, multi-layered, verdant landscapes harboring diverse insect species. Teachers can use the school's surroundings as a framework upon which students can build their own learning while also increasing the biodiversity of organisms (Lieberman and Hoody 1998, Skelly and Bradley 2000). Projects involving schoolyard habitats can also encourage further activities by families and lifelong compassion for the environment, as well as provide guidelines for our behavior towards other people in the outdoors and our behavior towards nature (Matthews and Riley 1995, Waliczek and Zajicek 1999). By greening their school grounds and neighborhoods, teachers, students, and families can help butterflies and other insect species overcome habitat loss in areas that still harbor imperiled species.

South Florida and the Keys provide extreme examples of human habitation and development at the expense of native wildlife (Alonso and Heinen 2011, Bancroft et al. 1995, Karim and Main 2009). Education can bring about change through an increased understanding of the importance of maintaining wildlife habitat, and a

sense of empowerment that individuals can do something, even on a small scale, to help promote species diversity (Miller 2005). Butterflies can be used as flagship species to educate and raise public awareness of many important environmental issues because they are charismatic and provide attractive models for conservation (Guiney and Oberhauser 2009, Leader-Williams and Dublin 2000, Walpole and Leader-Williams 2002). The establishment of butterfly gardens, such as those created for the Schaus and Coastal Hardwood Hammock curriculum unit, can provide habitat for other vulnerable species and generate an "umbrella" that can protect multiple species against negative human impacts (Guiney and Oberhauser 2009, Malone et al. 2015, Mathew and Anto 2007, Vickery 1995).

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Appendix 1. Latin names, taxonomic authority, and common names of butterfly, moth, and skipper species mentioned in this paper.

Scientific name	Common name
Abaeis nicippe (Cramer)	Sleepy Orange
Agraulis vanillae nigrior Michener	Gulf Fritillary
Anaea troglodyta floridalis F. Johnson & W.P. Comstock	Florida Leafwing
Anartia jatrophae guantanamo Munroe	White Peacock
Asbolis capucinus (Lucas)	Monk Skipper
Ascia monuste (L.)	Great Southern White
Battus polydamas lucayus (Rothschild and Jordan)	Polydama Swallowtail
Chlorostrymon simaethis (Drury)	Silver-banded Hairstreak
Danaus eresimus tethys W. Forbes	Soldier
Danaus gilippus berenice (Cramer)	Queen
Danaus plexippus (L.)	Monarch
Dryas iulia largo Clench	Julia
Electrostrymon angelia (Hewitson)	Fulvous Hairstreak
Ephyriades brunnea floridensis E. Bell & W. Comstock	Florida Duskywing
Epicorsia oedipodalis (Guenée)	Fiddlewood Leafroller
Eumaeus atala Poey	Atala
Eurema daira (Godart)	Barred Yellow
Glutophrissa drusilla neumoegenii (Skinner)	Florida White
Heliconius charithonia tuckeri W. Comstock & F. Brown	Zebra Longwing
Hemiargus ceraunus antibubastus Hübner	Ceraunus Blue
Hylephila phyleus (Drury)	Fiery Skipper
Junonia coenia Hübner	Common Buckeye
Kricogonia lyside (Godart)	Lyside Sulphur
Leptotes cassius theonus (Lucas)	Cassius Blue
Marpesia petreus (Cramer)	Ruddy Daggerwing
Nathalis iole Boisduval	Dainty Sulphur
Papilio (*Heraclides*) *andraemon* (Hübner)	Bahamian Swallowtail
Papilio (*Heraclides*) *aristodemus ponceanus* (Schaus)	Schaus Swallowtail
Papilio (*Heraclides*) *cresphontes* Cramer	Giant Swallowtail
Papilio polyxenes asterius (Stoll)	Black Swallowtail
Phoebis agarithe maxima (Neumoegen)	Large Orange Sulphur
Phoebis philea (L.)	Orange-barred Sulphur
Phoebis sennae (L.)	Cloudless Sulphur
Phyciodes phaon (W.H. Edwards)	Phaon Crescent
Polites vibex (Geyer)	Whirlabout
Pyrgus oileus (Linnaeus)	Tropical Checkered-Skipper
Pyrisitia dina helios (D. Bates)	Dina Yellow
Pyrisitia lisa (Boisduval & Le Conte)	Little Yellow
Syntomeida epilais (Walker)	Polka-Dot Wasp Moth
Strymon acis bartrami (W. Comstock and Huntington)	Bartram's Scrub-Hairstreak
Urbanus proteus (L.)	Long-tailed Skipper

Appendix 2. Latin names, taxonomic authority, and common names of plants mentioned in this paper.

Scientific name	Common name
Alvaradoa amorphoides Liebm.	Mexican Alvaradoa
Amyris elemifera L.	Sea Torchwood
Angadenia berteroi (A.DC.) Miers	Pineland Golden Trumpet
Aristolochia gigantea Mart. & Zucc.	Brazilian Dutchman's Pipe
Asclepias curassavica L.	Tropical Milkweed
Asclepias incarnata L.	Swamp Milkweed
Asclepias tuberosa L.	Butterfly Milkweed
Bourreria succulenta Jacq.	Bahama Strongbark
Byrsonima lucida (Mill.) DC.	Locustberry
Cardiospermum corindum L.	Balloonvine, Heartseed
Chamaecrista fasciculata (Michx.) Greene	Partridge Pea
Citharexylum spinosum L.	Florida Fiddlewood
Coccothrinax argentata (Jacq.)L.H. Bailey	Florida Silver Palm
Colubrina asiatica (L.)Brongn.	Asian Nakedwood, Latherleaf
Colubrina elliptica (Sw.)Brizicky & W.L.Stern	Soldierwood
Cordia sebestena L.	Largeleaf Geigertree
Croton linearis Jacquin	Pineland Croton
Cynophalla flexuosa (L.) J. Presl	Bayleaf Capertree, Limber Caper
Ficus aurea Nuttall	Strangler Fig
Flaveria linearis Lag.	Narrowleaf Yellowtops
Guaiacum sanctum L.	Holywood Lignumvitae
Guapira discolor (Spreng.) Little	Beeftree, Blolly
Jacquinia keyensis Mez	Joewood
Lantana involucrata L.	Buttonsage
Neyraudia reynaudiana (Kunth) Keng ex Hitchc.	Burmareed, Silkreed
Passiflora suberosa L.	Corkystem Passionflower
Physalis walteri Nutt.	Walter's Groundcherry
Pithecellobium unguis-cati (L.) Benth.	Catclaw Blackbead
Plumbago zeylanica L.	Doctorbush
Psychotria nervosa Swartz	Wild Coffee
Ruta graveolens L.	Rue
Senna mexicana var. *chapmanni* (Isely) H.S. Irwin & Barneby	Chapman's Wild Sensitive Plant
Solidago sempervirens L.	Seaside Goldenrod
Varronia globosa Jacq.	Butterflybush, Curacao Bush
Zamia integrifolia L.	Coontie
Zanthoxylum fagara (L.) Sarg.	Lime Pricklyash, Wild Lime