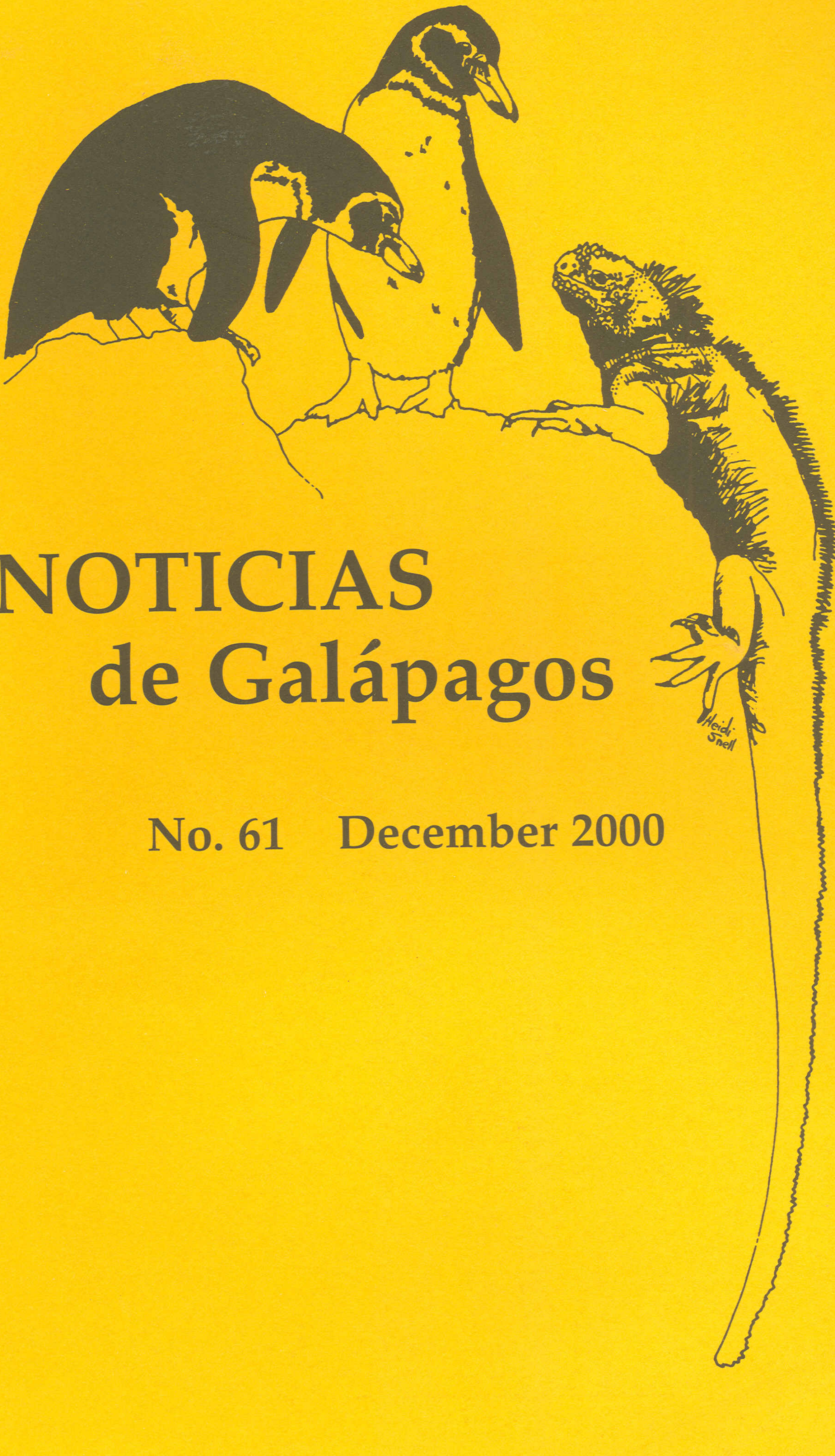

NOTICIAS de Galápagos

No. 61 December 2000

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NOTICIAS DE GALÁPAGOS

A publication about Science and Conservation in the Galápagos Islands, the Galápagos National Park Service, and the Charles Darwin Foundation

No. 61 December 2000

Contents

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WHISH: MORE THAN A TOOL-USING FINCH

Godfrey Merlen and Gayle Davis-Merlen

Whish grew from a bedraggled chick to a full fledged bird through a fortuitous year which abounded in a steady supply of protein-rich caterpillars and succulent fruits. His bold, curious nature led him to investigate every new object, including all the buttons and controls of a video camera.

Dr. Habel, of New York, visited Galápagos in 1868 (Salvin 1876). Without either a grant or private yacht, the determined collector reached the Islands from Guayaquil aboard a leaky sailing vessel which was engaged in the "orchilla" trade (orchilla, a small, tree-borne lichen, *Roccella babingtonii*, being the source of commercial dyes).

Perhaps Habel is best remembered for the pretty white-flowered vine *Ipomoea habeliana* that decorates the cliff-tops in the arid zone. In fact his journey was more remarkable for the large collection of bird skins (460), which he managed to carry to England. There he placed them in the hands of the English ornithologists, Osbert Salvin and Phillip Sclater (Sharpe 1906), who described seven new species (Sclater and Salvin 1870). Among them are two skins of pale-colored finches with long, strong beaks gathered on the island of Indefatigable (Santa Cruz) (Salvin 1876). Perhaps they were collected at Puerto Garrapatero, which Habel mentions (Salvin 1876), a few miles from present-day Puerto Ayora. They were the first finches to receive the specific name *pallida,* now known as the woodpecker finch (Sclater and Salvin 1870), and were labeled as co-types.

Pallida remains a good species name to this day, but the taxonomy at higher levels has been confused, demonstrating the complex morphological relationship among Darwin's finches. When first described, the species was placed in the genus *Cactornis,* along with the cactus finches, *C. scandens* (Sclater and Salvin 1870). (*Cactornis* was originally a sub-genus used by J. Gould to describe cactus finches collected by Charles Darwin.) This was followed by *Camarhynchus* in 1897 (Ridgway) and *Geospiza* in 1899 (Rothchild & Hartert). Thirty-two years later, Swarth retrieved an earlier name, *Cactospiza* (Swarth 1931). He dropped the cactus finches, whose beaks were considered only fortuitously similar to *pallida,* but included *heliobates,* the mangrove finches, the rarest and perhaps least-studied of all the finch species. Fifty years after Ridgway, David Lack rekindled *Camarynchus pallidus* (Lack 1947) (*pallida* changes to *pallidus* through the rules of nomenclature and Latin grammar).

Today Dr. Peter Grant, world-renowned expert on Darwin's finches, prefers to differentiate the genera and uses the older name of *Cactospiza pallida.* However, although woodpecker finches are now separated from cactus finches morphologically and genetically, both species occur in the arid zone, where cactus spines form a definitive part of the woodpecker finch's remarkable feeding adaptation — the use of tools. A finch with a culture.

Habel never noted this unique feeding behavior and it remained unrecorded until Edward Gifford, Assistant Curator of Ornithology at the California Academy of Sciences and a member of the Academy's Galápagos expedition of 1905-06, wrote in his field notes that several people, including himself, had observed these finches using twigs as probes into recesses in branches (Gifford 1919).

From that time on, these small, buffy-breasted birds, with their distinctive pale eye stripes, have fascinated visitors to the Galápagos Islands, whether tourist, voyager, or scientist. Many leave disappointed, for not only are the birds most common in the humid zone, where they spend much of their time in the tree canopy and are difficult to observe or even find in the spangled light among the leaves, but tools are an adjunct to their feeding habits and not necessarily a constant feature of their feeding behavior. Often the most that can be noticed is the buzz of their wings and the rapid staccato notes of their calls.

"Woodpecker" or "carpenter" are both good words to describe *pallida's* foraging behavior, as these mainly insectivorous birds spend much time chipping and wrenching at the bark and old wood on dead branches, with their relatively powerful pick-like bills, in an endeavor to uncover grubs and beetles. As they work, torn off splints of wood may make ideal digging tools, allowing the birds to reach into crevices unavailable to the beak. But a bird using a tool? An evolutionary surprise from a remote archipelago, formed in a unique habitat? There can be few things more astonishing than to see a finch working away on a dead branch, as other Darwin's finches do, when suddenly it seizes a piece of its wood-working as a longitudinal extension of the bill and inserts it with precision into some inaccessible recess or uses it as a pry-bar. Even more astonishing is to see that, by careful manipulation of the tool, a choice grub is brought to the surface and consumed, with the tool often being abandoned to the leaf litter below.

Various objects are used as tools depending on where the birds are found, for they live over a wide altitudinal range on all the principal islands. Cactus spines are commonly used in the arid zone, but often small twigs, about 2-5 cm long, are broken off and cropped for this specific purpose. In the higher, wetter regions, leaf petioles, such as from the shrub *Miconia robinsoniana*, and the rachis of ferns are also trimmed down for use. Although most tools are abandoned after successful or unsuccessful probing, on some occasions these active birds will guard a tool under a foot while continuing to dig with the pick-axe-like beak. Thus, bill and tool are used, turn and turn about. On other occasions, a tool may actually be carried from one foraging site to another as the bird moves through the trees.

The use of tools as crevice probes is found in one other group of birds, the Corvidae (Magpies, crows, and jays) (Heinrich 1989) but the common, daily habit seen in the woodpecker finch seems to be unique. As far as we are aware, there are only two records of even other Darwin's finch species attempting to manipulate objects in their bills. George Millikan and Robert Bowman (1967) observed a captive large-billed cactus finch, *Geospiza conirostris*, which managed to manipulate a tool with some facility, but never seemed to associate the use of a tool with food. They believed that it had picked up the habit from living in close proximity to caged woodpecker finches which were using tools. If this is so, it shows a remarkable mental and physical ability for the possibility of adaptation, perhaps the secret of success of all Darwin's finch species. In 1963, Margaret Hundley observed a warbler finch, *Certhidea olivacea*, at Conway Bay, on the north side of Santa Cruz Island, use a leaf petiole or flower stem as a probe. This appeared to be unsuccessful since it bent and was soon abandoned.

However, 130 years after the first woodpecker finches were collected and 91 years after tool use was first described, the origins of this remarkable habit remain obscure. As far as we are aware, no tool-using finch has been bred in captivity, although a number of other Darwin's finch species have been.

In 1939, the California Academy of Sciences became the caretaker of 30 finches (Orr 1945). Among the species were large, medium, and small ground finches, as well as cactus finches. These were originally collected on the Galápagos by David Lack and were on their way to England. On arriving to Panama, Lack was confronted with the imminent outbreak of the Second World War and, at the same time, the deteriorating condition of the finches, one of which died.

The precious cargo was thus diverted to California, where they were received by Mr. Kinsey, who nursed them back to health. Later, they were transferred to the California Academy of Sciences and were studied by Robert Orr (1945). He was skeptical of the study to begin with, but quickly found that they behaved similarly to wild birds and soon they even began to breed. They were fed a bird seed mixture, a substitute nectar food, plus berries and greens. The nectar food was made from honey, Mellin's baby food, evaporated milk, and water. The finches relished cotoneaster and pyrocanthus berries, but accepted sowthistles, dandelion flowers, and lettuce. Cuttle bone was left in the cages (Orr 1945).

Robert Bowman, from San Francisco State University, also held a number of Darwin's finches in captivity in the late 1950s and the early 1960s. He concentrated on the tree finches, large, medium, and small, as well as the vegetarian, the woodpecker, and the large-billed cactus finches. He also obtained some examples of the 14th Darwin's finch species, *Pinaroloxias inornata*, from Cocos Island. There were six woodpecker finches, five males and a female (Millikan and Bowman 1967). Bowman states in a communication to Hernan Vargas (1998), ornithologist at the Charles Darwin Research Station, that the woodpecker finches did not breed in captivity.

Millikan and Bowman's "Observations on Galápagos tool-using finches in captivity" (1967) is a fascinating account of the behavior of these unique birds. However, on page 31, they remark on the "abnormal" behavior of one of the finches and open the difficult subject of whether tool-using is innate or learned.

They state:

"Of the six birds, one, a male (58-132537), cocked its head and held food under its feet like the other birds, but we never saw it probe with a twig, even during two periods of intensive observation carried out within an interval of about one year. On looking back into its history we discovered that this individual, captured when young, had, unlike the other five, been housed by itself for the three months before it was caged with the tool-using *pallida*. We are unable to conclude that association with experienced birds is necessary for the development of tool-using behavior, since this bird may have suffered another deficiency of experience or inheritance which impaired its performance. If association is important, however, it is apparently maximally effective during a 'sensitive' period when the bird is young, since later exposure to experienced birds did not cause the bird to start using a tool."

A number of tool-using finches have been maintained in captivity, over relatively short periods of time, at the Charles Darwin Research Station. These have been used by scientists and film-makers to record their remarkable habits — a very difficult proposition in the wild. The birds settle down very quickly, become tame, and perform well in captivity. What was curious was that, in 1985, a group of woodpecker finches refused to use tools at all and were released. A second group that was obtained used tools and were easily filmed. Did this mean that the first group of birds were somehow "put-off" the tool-using habit? Or did it mean that there exist birds that use tools and those that don't? That might indicate that there cannot be some general genetic background to woodpecker finches that ensures that they will use tools instinctively, but that they learn it from watching other birds, probably their parents. On the other hand there may be areas on the island where food is obtained efficiently without the use of a tool and, therefore, although the ability to manipulate objects is innate, it is never developed.

Perhaps tool-using was developed under very specific habitat conditions where it was useful, and still is, but when the species moved into other habitats it became less advantageous to spend the extra time gathering and using tools. How many things are we capable of but never develop? We may be able to run backwards, but it serves us little and we don't do it!

Thus, until 1997, it seems that no woodpecker finch had ever been raised in captivity and, moreover, definitely none had been raised in the absence of its parents. This brings us to the subject of Whish.

By chance a small, bedraggled, lame, yet mentally strong finch came into our hands on April 9, 1997. Godfrey finally released this charming creature back to his home country among the upland *Scalesia* forest on June 6 of the same year, when the finch was nearly 100 days old. He went back to the wild with a remarkable confidence, but perhaps he did not survive, for, even though equipped with natural instincts of fright and flight, without those days of youth when he would have followed his knowledgeable parents, his caged life may have led him quickly into harm's way.

But that is another story. What is recalled here are the events that occurred during the short stay that Whish, for so he was named, spent with us. We do not know his sex, but the neuter gender can hardly be applicable. Thus, for us, Whish became male. We cannot say that these historical notes reveal answers to deep biological questions, but perhaps there is information that might be useful for a future finch caretaker. We were, however, through this bird, made acutely aware of the power that the unique Galápagos environment has had over its native inhabitants and that we were extraordinarily privileged to have been able to nurture one of its unique products.

Whish was born in the first days of March. According to data from various sources, the incubation period for several ground finches is about 12 days and the fledging period in the nest is 13-15 days (Orr 1945, Grant and Grant 1980, Schluter 1984). The young birds then spend a further 28 days or so (Schluter 1984) following their parents (mostly their father), being fed, and learning about their environment. The whole process from egg-laying to independence is thus about 54 days, the period from birth to independence being 42 days or 6 weeks. These times are probably true of tree finches as well and therefore, if Whish was born on the 1st of March, he should have been fending for himself by the end of the second week of April. But he lost his parents.

Born into a domed nest of mosses and grasses tucked into the swaying branches of a giant endemic composite tree, *Scalesia pedunculata*, he lived out the first days of his life with at least one sibling. The nest was observed by Sabine Tebbich and Birgit Fessl, who were studying wild woodpecker finches. They noticed that no parents had visited the young for several days. The nest was examined on April 7 and found to contain two tiny birds. Their eyes were already open, which would probably give them an age of four days or so (Peter Grant, pers comm). They were in poor condition and suffering attacks from the larvae of a fly. The fly has been identified as belonging to the genus *Philornis* (Muscidae) by Dr. Eric Fisher and team of the California Department of Food and Agriculture at Sacramento. This genus is apparently new to Galápagos but elsewhere they are described as a "neotropical subcutaneous haematophage on nestling birds" (W. Harmon, pers. comm.).

The two scientists took the doomed, starving, and pathetic birds to the Charles Darwin Research Station, where the devouring maggots were removed. One of the finches died shortly thereafter, but the other, although partially crippled in the left leg by the parasite attack, survived his first few weeks under the care of

Sabine and Birgit, a dedicated task, for it is known that insectivorous birds are difficult to raise.

He became exceptionally tame, hopping from person to person with total innocence. At the time we inherited him, on April 9, he should have been on the verge of independence, but this was obviously not the case and he still needed help. His food at that time was a commercially prepared bird food containing dead insects. To this was added raw carrot and scrambled egg. If he had been released then, the state of his plumage, his poor flight capability, coupled with his physical disability, would have led him to an early grave. Since Sabine and Birgit were leaving the islands at the end of their study and as there seemed to be no other offers of a home, we became the new foster parents.

Whish was placed in an old aviary that had been built for woodpecker finches 15 years previously. Even some native plants were growing inside it, which provided something of a natural atmosphere to the place. The aviary was 4m by 4m by 2m high. A constant supply of old branches gave him interest and material upon which to hone his skills and beak.

It is, we have to say, difficult to imagine the work of a parent finch unless one undertakes the work oneself. It was decided from the beginning to try to feed him with fresh food. In this we were lucky, for the spring of 1997 was a wet one, which meant that insect life, though often cryptic, was abundant. It also meant that berries were plentiful. It is fair to say that an average of 3 hours per day, wet or fine, were spent in examining rolled-up salt bush leaves (*Cryptocarpus pyriformis*) for caterpillars, trying to catch jumping hemipterans and grasshoppers, outwitting small spiders, and gathering berries. To this must be added cooking scrambled egg and setting out a night light to trap moths. Mainly the work was concentrated into three periods: from 6-7:00 am; 12-1:00 pm and after 5:00 pm. On this diet he grew strong.

Several people helped in the labor. However, there can be no doubt that through the dedication of Gayle, this small bag of feathers became the remarkable finch that he did. Heidi Snell, well versed in Galápagos ways, helped enormously. So too did Anne Schultz, who came to the Station from New Mexico as a volunteer in the library. Anne's first few nights in Galápagos found her sleeping in the lower of two bunks. The upper was occupied by a cattle egret that had been found half-drowned in the bay. Next, she found that one of her library duties was to fill jars with leaves containing caterpillars during many of her spare hours.

Gathering food was one thing, but feeding him was another. As soon as someone approached or entered the cage, Whish would call and fly over, impatiently hopping from one outstretched finger to another in his anticipation. Once the lid was off the caterpillar jar, he would reach down inside to grasp at the leaves. Rather than give him caterpillars directly, we offered him the leaves and he had to explore them himself. He was not a careful eater and tended to fling his food about. Sometimes he would take the food on to one's shoulder or head and dismember it there. In the process, he flung pieces left and right, leaving oozing green remnants of caterpillars and grasshoppers everywhere. Two aspects of Whish's behavior were especially noteworthy in his first days. One was the habit of taking food onto Gayle's shoulder and "bunting" it into her hair. This habit appeared to mimic an action used by finches when building the domes of their nests. The second was shoving food down in the gap between a sock and the top of a boot. Sometimes he left the pieces there, but mostly he returned to remove them in a short while.

He was very much a meat and veg man. The orange berries of *Tournefortia psilostachya*, which were placed around the aviary each day, were his favorite fruit and he would alternate eating these with insects or larvae. Godfrey has observed the alternating of feeding in this manner in adult tree finches which live around the endemic *Miconia robinsoniana* woodlands at 600 meters elevation. There the finches will alternate between searching for invertebrates among the mosses on the shrubby branches and feeding on the sweet, black berries of *Miconia* in the canopy a few feet above. Whish's berries had to be changed every day, for any that were even a day old were ignored.

Although he was extremely active most of the day, a good meal would nearly always send him to sleep! This was especially so in the first couple of weeks. These periods of rest were short, no more than 15 minutes or so. He was also provided with a permanent supply of fresh water in which he could bathe. This he took to instinctively and caused him to heavily preen himself afterward.

In mid-April, Peter Grant came to visit him and thought that Whish was about three weeks behind in general plumage condition. His ragged appearance may have been due to some extent to his inability to scratch himself. He could not stand on his bad leg and thus could not scratch with the good one. He could stand on the good one, but could not scratch with the bad one! However, he made good progress and his leg began to strengthen. By April 21 he was able to scratch with his good leg. Even though he still suffered somewhat from the disability of his leg, he spent much time working at small holes with his beak. Some of them seemed to fascinate him and became favorite places.

Then, a few days later, at about 54 days old, a remarkable process began to develop. To begin with there was little to notice. Yet within a short time there was no doubt that he was spending more time "playing" with the stems of flowers, such as *Alternanthera echinocephala*, small twigs, and other objects within the aviary. These he would twiddle in his beak in what seemed to be a random pattern, often holding them at right angles to the longitudinal axis of the bill. After a short time he would discard them and move on to another point of interest.

By May 1 there was no question. He was showing considerable interest in "handling" objects and began rolling them around in his beak and aligning them to a greater and greater extent with the longitudinal axis of the bill. At the same time, his poor leg was becoming stronger by the day, so that by May 10 he was able to fly to the screen-covered walls and hang there on the vertical plane with both legs supporting him. It was at this time that he began to hold objects under his feet, which is a common attribute of many of Darwin's finches, including the ground finches, who often use the beak to grasp seed heads of grasses, which are then transferred to the feet for holding while the bird feeds. Perhaps Whish would have done this earlier if he had not been lame or had had parents to follow.

His interest in all things was extreme. The video camera was an example. It was frequently difficult to film him, for he would often fly over to the camera and examine every item with great curiosity. First the viewfinder lens would be inspected while he clutched the rubber eye cup. Then he would work his way along the top, enquiring into every control and connector. Considerable time was spent in trying to pry out the various buttons, which he tried to tweak out with a twist of the head as if he were removing berries from a twig. At other times he would attempt to remove them by using the upper mandible as a pick. His gape was close to 90°. This action he would also use with some of his favorite holes in branches which were too small for both mandibles to enter. Later, he would be able to insert a tool with precision into these same holes.

His beak was also used as a pry and a wedge. When handed salt bush leaves, *Cryptocarpus pyriformis*, which were often closed by caterpillars with silken threads, he would insert his bill between the leaf edges and open the mandibles to pry them apart. This seemed to allow his line of sight to pass within the leaf. If there appeared to be food inside, then he would set about the leaf, even tearing holes in it. The caterpillars he would normally catch, even if they descended on silk strands, for he kept a sharp eye on them. Spiders sometimes escaped him, as did grasshoppers, but he was extremely quick with his beak and, if necessary, leaped after them. Yet he did not eat everything, and seemed to avoid certain species of spiders and large ants.

Prying was also noted by Robert Orr in a captive cactus finch that he inherited from David Lack (Orr 1945). This bird tried to open Orr's closed fingers. It seemed to Whish that any potential crack was worth trying to open. Even a person's face was not sacrosanct. He would fly to the face and clutch hold on the nose arch. He would then hang upside down and peer into the nostrils. If the face possessed a beard he would sometimes land on the hair, as if on a mossy trunk. From this vantage point, he thrust his bill between the lips and forced them apart. If the mouth opened, he then examined the teeth with the tip of the beak or at times he seemed to want to drink the saliva on the gums.

This experience taught us that he was not only curious and capable of reaching difficult places with ease but also that his grasp was powerful. If the lips did not open right away, he tweaked and twisted the skin as if it were a piece of rotten wood, easily drawing blood. From time to time he encountered small wounds on sandaled feet. These he attacked with his needle-like bill, even eating small pieces of skin or scab or sipping at the fluids.

During late April and the early days of May (thus when he was about 60 days old), his ragged, juvenile contour feathers molted rapidly and soon he was resplendent in a smooth, buffy-breasted, brown-backed plumage that appeared very similar to that of an adult, including the pale eye stripes. The tail was always somewhat deranged, for he used it as a support against the screen, as a woodpecker might, and the rough wiry texture damaged the feathers. The beak, which always had a dark tip on both mandibles, changed slowly from a pinkish hue to that of horn, losing the swollen basal edges of a chick.

The only call that we heard was apparently used when he was in an impatient mood or wished to indicate where he was, as for instance when he knew someone was approaching the aviary with food, especially in the morning after a long night. Once, when he was sitting on Gayle's finger eating berries, she forgot to turn the fresh ones toward him, as was customary. This provoked him to call. He only had to call once, and the twig was turned so that the berries were available to him. This call we have heard from other finches, including woodpecker finches. It seems to indicate a bird's presence, "I'm here."

During the month of May, he became highly adept at handling tools. To begin with, his accuracy with them was not good and he often missed the place he was aiming for. With practice, however, he became highly proficient, aligning the tool with the beak. His relationship to tools was variable. Sometimes while working on old branches — which we collected for him — he would use elongated fragments that came off the wood (usually a couple of centimeters long) to help in the excavation, often using several, one after another, interspersed with rapid and active digging with the bill. At other times he would drop down to the floor of the aviary, pick up a twig — he even once used the rear leg of a green grasshopper — and fly up to a branch to start probing.

On these occasions, he might use a series of tools, one after another, without using his bill directly. It was not uncommon for him to lose his probes in deep holes or when they became jammed under bark when he had been using twigs as pry bars under the loose, springy edge. The time spent with tools varied from a few seconds to several minutes. We also collected branches with holes bored in them, about 10mm diameter and 20mm deep, which had been made by carpenter bees (*Xylocopa darwinii*). This demonstrated another feature of his feeding habits —"peering".

While Whish was busy excavating wood, which was done with considerable energy — many times he sat on one's finger and the rapid, strong, contractions of the tendons in the feet was very noticeable — he would pause every so often to search with his eyes, or was he listening? On the logs with bee holes this was especially so. Whether he was using a tool or not, he would, on encountering a hole, lower his head to within a centimeter of the recess, cock his head sideways, and peer intently into the dark interior. If he had a tool with him, it was usually held in his beak while peering, but sometimes he placed it under his foot.

Although carpenter bee larvae were readily eaten, it would seem curious if this was a major part of woodpecker finch diet. Usually the bees make a vertical hole into an old, but not rotten, branch and then bore a considerable distance along the grain of the wood before depositing their eggs and sweet-smelling pollen balls that will feed the larva. The distance bored may be at least 20cm and therefore in general totally out of reach to the woodpecker finches, who are not able to tear hard wood apart.

Whish's sight seemed to be important at other times, too. On many occasions, we would use our own fingers and nails to pry up bark and old pieces of wood. Whish would follow this action with great interest, lowering his head to peer under the slowly separating pieces. At the first sight of a spider's silken nest, a grub, a beetle, or insect eggs, his impatience would cause him to rush forward to help in the excavation.

Whish blossomed into a tool-user with remarkable facility. From no tool use to accurate tool placement was a period of about two weeks. It would seem at the very least that there is a strong instinctive drive to pick up and handle all sorts of objects. That, coupled with an insatiable curiosity about holes and the capability of perfecting the technique through copy and practice, may be the ingredients for a tool-using finch. His tools varied and included a feather, a grasshopper leg, twigs, slivers of wood, pieces of shell, and fragments of old water-worn glass that were amongst the debris on the floor of the aviary.

The tool-using habit was apparently not, at least in the case of Whish, initiated by the association of a reward with the time spent using a tool, for we are not aware that any human, let alone his own parents (since he was taken from the nest before fledging), actually demonstrated to him that the use of a tool produced food. When he came to us, he should have been an independent feeder, since he was five weeks old, and therefore one assumes that, under normal circumstances in the wild, he already would have been able to handle tools if this was a vital factor for survival, whether instinctive or learned. However, he did not show an interest in tools until he was nearly eight weeks old.

Perhaps his poor condition due to the initial debilitating attack by fly larvae delayed his development. Later, the constant supply of rich food may have reduced the necessity for active tool use. Furthermore, the encouragement of the parents may be needed to foster an innate ability. Perhaps, also, it is a habit that develops quickly under the guidance of tool-using parents when they are supplementing food to the fledgling. Whish's early casual handling of tools, with no food resulting from their use, would have left him a very hungry bird without additional nourishment.

It is difficult to know the effect of self-teaching. As he worked at a trunk, he would often use slivers of wood to advance the project. From the cracks and crevices, he did obtain various grubs, spiders, spider nests, and small ants, but these might have been obtained as easily by the beak alone. And this was often the case. Therefore, it is not clear how he would definitely know that the slivers of wood were important. Perhaps the success in feeding using a combination of beak and "extended beak" is sufficient reinforcement for the habit to become entrenched. There are, perhaps, two elements involved. The instinctive ability to handle, with precision, many objects that are basically longer than wide and thus similar to the bill in shape, and the learning from parents who are efficient in profiting from this "game". One wonders for how long human beings handled round objects in many ways before the wheel was invented!

Once Whish had displayed a real penchant for tool use, which seemed to have a strong instinctive source, we deliberately encouraged him by offering him tools, for, in order to return him to the wild, it was important that he perfected as many skills as possible.

Towards the end of May, his bad leg was as good as the other. He could hang upside-down from the roof of the aviary and had gained powerful wing muscles that allowed him to navigate amongst the branches with ease. He appeared to have his favorite perches for preening and sleeping. Although very tame, Whish became flighty and seemed agitated if people were in the aviary toward night time (5:30 pm), when he wished to remain quiet in his roosting spot. This seemed to be a good sign, for it perhaps meant that he was responding to an instinctive behavior that warned him that the night was a time, not just for sleep, but for wariness, for avian predators, such as barn owls (*Tyto alba*) and short eared owls (*Asio flammeus*) are a threat in the wild.

Peter Grant points out that the barn owl has become a specialist on mice, *Mus domesticus*, an introduced species. In the past they no doubt fed on the rice rats (*Nesoryzimus*) which are now apparently extinct on Santa Cruz. However, in caves where barn owls live, or have lived, the bones of ten species of finches have been found and appear to have been a part of their diet (Steadman 1981).

During the period Whish spent with us, there were some torrential rains and a box was installed for his protection. This he shunned totally, as if caves contained danger. He preferred to perch on a branch under a waterproof section of the roof.

Any new object was treated with great curiosity. Buttons were tweaked off. Pens and pencils nibbled at. Pockets were investigated. Hair was yanked through the small ventilation holes in a slouch hat. Toes were pried apart with the beak and long tools. Tools were inserted between socks and boots where in previous days he had inserted food (since removed!). Ears were inspected and ear-rings pulled. Drinking straws seemed like enormous tools. His presence captivated every person who encountered him.

Then it was time for us to release him. This was no easy matter, yet was always the plan. The introduction of avian pox to the Galápagos Islands, perhaps through domestic chickens, takes an annual toll of Darwin's finches and is particularly rife around the village of Puerto Ayora. It was always a fear that he would contract this potentially mortal disease. The introduced rats of Europe scuttled across the roof of the aviary and also threatened him. Moreover it was necessary to release him near his old home, for perhaps, even on the one island of Santa Cruz, there may exist genetically differentiated populations of woodpecker finches. And after all, he was a wild-bred bird.

We were fortunate that the rainy season had continued, so that the abundance of food had been maintained. This would not last indefinitely and it would become increasingly difficult to locate a suitable diet as the season changed. Thus on June 6, he was taken, along with a number of his known branches and other objects of the aviary, to the green-canopied *Scalesia* forest at 600m elevation. Godfrey built a semblance of Whish's cage so that, should the young bird need a familiar spot, he might have a place to return to. Godfrey also resolved to spend several days there himself, should Whish be too dependent on foster parents to survive alone. There was no need to worry. Whish spent five hours with Godfrey in that old world that is true Galápagos, the world that created the environment in which the unique woodpecker finch survives and today is changing through the invasion of introduced plants. Around us were the mossy trunks of his native home, the dainty warbler finches darting through sunlight and shade in their quest for insects, and, yes, one could hear the begging cry of a young short-eared owl.

On release, Whish stood for a while with cocked head examining the green umbrella of leaves above. Then he moved onto the nearby trees, returned to drink a little water, sat on Godfrey's shoulder, flew to his beard, pried open the lips, and returned to the tree. He seemed to be completely at home, yet for the moment, still contained within the confines of the aviary. He caught several arthropods, a spider, and, prying open the rolled up leaves of the endemic coffee (*Psychotria rufipes*), found a number of insect larvae.

Thus Whish passed the hours, moving amongst the trees, meeting other finches, then returning. In the late afternoon, he began moving off confidently through the forest, finally breaking the physical and mental bounds of confinement that governed his whole life of a period just shy of 100 days. Godfrey followed for an hour, but now Whish was following a life that had no relation to ours and Godfrey finally lost him. Whish's fate was locked into a new set of rules, but at least he was home.

If you should travel to this beautiful forest and see a small finch bearing two rings on his right leg, a black above an orange, then you will know his story.

DIET

Perhaps other insects than those indicated below were consumed, as a variety of creatures wandered in and out of the aviary. We feel, however, that the mainstay of his young life were Tournefortia berries and green caterpillars. This omnivorous diet may change with age. David Lack (1945) stated that woodpecker finches were "almost exclusively insectivorous". Bowman (1961) found that woodpecker finch stomachs contained insects, principally beetles (Coleoptera), larvae of moths (Lepidoptera), larvae of flies (Diptera), and ants (Formicidae). However, he also observed that they ate the ripe fruits of the palo santo trees (Bursera graveolens) and Maytenus octogona in the arid zone and, in the Scalesia forest, where Whish was born, the fruits of Psychotria rufipes, the native coffee plant, and the pollen sacs of the vine Echinopippon.

Peter Grant informs us that he has seen these finches eating Scutia berries at Playa Tortuga Negra. We cannot state that the diet shown below is typical for young woodpecker finches in the wild, which must depend on the particular parents, as well as on altitude and location. We were guided by his taste rather than our knowledge. What is certain is that he grew well, cured his bad leg, and changed his plumage, whilst maintaining an extremely active life.

Vegetation:

Alternanthera echinocephala (Amaranthaceae). Seeds.
Cyperus sp. (Cyperaceae). Seeds.
Solanum nodiflorum (Solanaceae). Berries. There were several plants growing wild in the cage.
Tournefortia psilostachya (Boraginaceae). Berries, both yellow and red, but the red were favorites.
Cordia lutea (Boraginaceae). Flowers.
Cordia leucophlyctis (Boraginaceae). Berries. Not very popular.
Pear.
Apple.

The following were tried but discarded:
Physalis sp. (Solanaceae). Berries.
Lycopersicon cheesmani (Solanaceae). Fruit (tomato).

Meats:
Grasshoppers (Orthoptera). Green, > 2cm in length.
Crickets (Grillidae). Brown, about 2cm in length.
Hemipterans (Heteroptera). Green *Acrosterna viridans.*
Brown (Rhopalidae).
Spiders (Arachnida)
Small, brown, rolled in *Cryptocarpus pyriformis* (salt bush) leaves.
Spider nests (white, woven), found in old wood, were opened and the contents eaten.
Spider web. Noted on three occasions.
Carpenter bee *Xylocopa darwinii.* Larvae.
Large grubs under *Scalesia* trees in soil. Unidentified.
Grubs in dead wood. Unidentified.
Moth larvae (caterpillars). (Lepidoptera):
Green Disoliosipacta stellata. Inside salt bush *(Cryptocarpus pyriformis)* leaves, partially or completely closed by silk strands.
Small, grey (Pyralidae). Inside rolled leaves (like a cigarette) of *Psychotria rufipes* (Rubiaceae).
Red.
Milky white with brown spots.
Geometridae. Inch worms.
Moths (Lepidoptera). Various species, including hawk moths.
Coleoptera. Various species.
Springers.
Small ants. Especially from silken nests.
Scrambled egg. This was replaced by smashed boiled eggs. He ate both.

Offered but not eaten:
Large ants, *Camponotus macilentus.*
Spider. Silver argiope, *Argiope argentata.*
Cockroaches. Coleoptera.

Tools:
Pieces of wood. Splinters from his own workings.
Old pieces of worn glass.
Large green grasshopper hind leg.
Pieces of shell.
Feather.
Twigs.
Inflorescent stems.

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The history of Whish would not have existed except for circumstance and luck. He was not part of a plan but the result of fortuitous events. We thank Sabine Tebbich and Birgit Fessl for his rescue and early care. A number of people helped later in caring for him but we thank Heidi Snell and Anne Schultz in particular for the endless hours spent in the rain and sun seeking his sustenance. We also thank Eliecer Cruz, Director of the Galápagos National Park, for his kind permission to allow us to raise this wild-born bird to a condition where he might survive in the wild. Dr. Peter Grant and Dr. Martin Wikelski were kind enough to read and comment on the manuscript.

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ALIEN ARTHROPOD SPECIES DETERRED FROM ESTABLISHING IN THE GALÁPAGOS, BUT HOW MANY ARE ENTERING UNDETECTED?

Charlotte E. Causton, Carlos E. Zapata and Lázaro Roque-Albelo

INTRODUCTION

The greatest threat to the biodiversity of the Galápagos Islands is the introduction of alien organisms. The growth of tourism and associated migration of people to the islands in the last 20 years has brought about a dramatic rise in the number of accidental and intentional introductions. To date, 24 species of vertebrates, more than 500 plant species, and at least 300 invertebrate species have been introduced into the Archipelago (Snell *et al.* 1996; Mauchamp 1997; Peck *et al.* 1998, Tye in prep.). Many of these species feed on the native and endemic flora and fauna and, in some cases, may displace them. As a result of this, some Galápagos organisms that were common 20 years ago are now rare.

New species are arriving on a daily basis. To reduce the rate of new arrivals, it is imperative that measures are taken to prevent species from reaching the Archipelago, based upon the quarantine regulations established under the International Plant Protection Convention. In response to this, a task force, composed of representatives from the Galápagos National Park Service (GNPS), the Charles Darwin Research Station (CDRS), the National Institute of Galápagos (INGALA), and the Provincial Agricultural Office (DPA) (an annex of the Ministry of Agriculture) was formed in 1997 to find mechanisms to implement a much needed quarantine and inspection system for the Archipelago. The "Sistema de Inspección y Cuarentena para las Islas Galápagos" (SICGAL), proposed by Whelan (1995), recommends regulatory control and inspection points for mainland Ecuador and the Galápagos Islands. A monitoring system to detect the arrival of new organisms is proposed, as well as an environmental education program to increase the awareness of the general public and others of the impact of introduced species. This proposal also includes complementary tactics for reducing the number of introductions, such as increasing local farm production and building a waste disposal system.

Since the SICGAL proposal was written, a series of actions have been taken with the aim of reducing the number of introductions to the islands. The enactment in 1998 of the Law of the Special Regimen for the Conservation and Sustainable Development of the Province of the Galápagos and the general regulation for this law (January 2000) have given the islands some legislative support to implement a quarantine and inspection system.

Meanwhile, special regulations will be promulgated within the next six months to define the procedural framework of SICGAL, the implementation of fees for service, and the identification of offences and penalties for non-compliance. These regulations are particularly important, as the success of the system ultimately depends on the step-by-step inspection and monitoring procedures that will be identified by the law. On the other hand, the use of user fees in addition to revenue from 5% of the tourist entrance fees to the Galápagos National Park should ensure the sustainability of the system.

On May 31, 1999, a pilot quarantine control and inspection program, funded by USAID, was initiated in the Galápagos Islands. In the first year of this program, six Galápagos residents were accredited as inspectors and were responsible for checking incoming hand luggage and cargo in Baltra, Santa Cruz, San Cristóbal, and Isabela. Personnel numbers have increased to 38 inspectors in the second year, and inspection and control points are currently being set up in Guayaquil and Quito.

Complementary to this, a list of permitted and prohibited products, devised by stakeholders in a participatory process and approved by the Ecuadorian Service for Animal Health (SESA) and the PNG, has been published. Intensive education campaigns have produced TV and radio spots, leaflets, and posters with the aim of raising public awareness of the impact of introductions and the benefit of the new quarantine restrictions. Meanwhile, registers and forms for collecting all data relevant to the inspection process have been designed.

ALIEN SPECIES DETECTED BY SICGAL INSPECTORS

During the first seven-month period to December 1999, 33 arthropod species were detected during the inspection of personal baggage and commercial consignments of imported goods (Table 1). In addition to this, 90 plant and animal products (including a Cyperaceae sedge with roots, a rabbit, and a fighting cock!) were confiscated. Although inspection activities at this time were being carried out at a quarter of the capacity identified as necessary to implement the program in its entirety (only hand luggage and a limited amount of cargo were being inspected), the number of insects detected is an indication that additional species are being introduced through other unmonitored pathways.

Port of entry	Pathway	Order	Species	Common name
B	Flowers	Homoptera	unidentified	scale insect
B	?	Lepidoptera	unidentified	moth larva
B	Fruits	Diptera	*Drosophila* sp.	pomace fly
B	Vegetables	Coleoptera	unidentified	ladybird
B	Mango	Diptera	*Anastrepha fraterculus*	fruit fly
B	Fruits	Hymenoptera	*Tapinoma* sp.	ghost ant
B	Corn	Lepidoptera	*Helicoverpa zea*	corn ear worm
B	Vegetables	Hemiptera	unidentified	
I	Beans	Diptera	unidentified	
I	?		unidentified	
I	Dried Beans		unidentified	weevil
SC	Vegetables	Lepidoptera	unidentified	moth
SC	?	Hymenoptera	unidentified	ants
SC	Fruits	Diptera	unidentified	flies
SC	?	Lepidoptera	unidentified	moth
SC	Seeds		unidentified	
SC	Fruits	Acari	*Tetranychus urticae*	two spotted mite
SC	On cargo boat	Lepidoptera	*Thyrinteina arnobia*	geometrid moth
SC	Fruits		unidentified	
SC	Fruits		unidentified	
SC	Vegetables		unidentified	
SC	Cabbage		unidentified	
SC	Fruits	Lepidoptera	unidentified	moth
SC	Vegetables		unidentified	
SC	?		unidentified	
SC	Vegetables		unidentified	
SC	Melon	Orthoptera	unidentified	
SX	Vegetables	Diptera	unidentified	flies (several species)
SX	?	Coleoptera	unidentified	beetle larva
SX	On cargo boat	Lepidoptera	*Thyrinteina arnobia*	geometrid moth
SX	?	Diptera	unidentified	flies
SX	Vegetables		unidentified	
SX	Flowers	Lepidoptera	unidentified	moth larva
SX	Vegetables	Lepidoptera	*Spodoptera* sp	
SX	Corn		unidentified	

Table 1. Arthropods detected by SICGAL inspectors from June-December 1999 (Ports of entry: B = Baltra, I = Isabela, SC = San Cristóbal, SX = Santa Cruz)

Even more alarming is that some of these species are recognized pests on the mainland and in other parts of the world. Several species that have arrived in the last seven months are of particular concern. In September 1999, eggs and adults of a geometrid moth, *Thyrinteina arnobia* Stoll, were found on two different cargo boats delivering goods to San Cristóbal and Santa Cruz. This species was responsible for defoliating hectares of mangrove forests, primarily red mangrove (*Rhizophora mangle* L.), from August-September in the Guayas region of Ecuador ("El Universo," 11 August 1999).

The establishment of *T. arnobia* in the Galápagos is particularly worrying given that four species of mangrove trees are native to the Archipelago, including the red mangrove. Following its identification, inspectors were alerted to the importance of detecting further incursions of this species and periodic targeted monitoring has been carried out in the mangrove trees near the port of entry. Like many species of insect, *T. arnobia* flies towards lights and was probably attracted to the lights of the cargo boats in the port of Guayaquil. Movement of insects by boats was reported in the 1970s (Silberglied 1978), but with the increase in boat traffic (cargo ships and tourist vessels) this mode of transport has contributed to the introduction of insects to the Galápagos from the mainland and is responsible for the spread of species between the islands of the Archipelago.

The pathway with the highest number of introductions in the first seven months of the program was the importation of fruit and vegetable products (Table 1). Due to staff shortages, inspectors concentrate on checking fresh produce and this might explain why few insects were intercepted on other pathways. However, the increasing consumer demands of the Galápagos residents requires that a high number of perishable goods are imported every month, increasing the risk that arthropods associated with crops are imported (Zapata *et al.* in press). Some of the species that we were able to identify are known to be aggressive agricultural pests in other parts of the world.

Prior to approval of the permitted product list, corncobs were regularly imported with their outer leaves, providing a refuge for several unidentified Lepidoptera and Diptera, in addition to *Helicoverpa zea* (Boddie). Commonly known as the corn earworm or tomato fruit worm, this is a pest of corn, but has a greater impact on tomato crops. This is the first time that it has been reported in the Galápagos. *Helicoverpa zea* is polyphagous and could feed on native species. The greatest threat, however, is to agricultural crops. Tomatoes and corn form part of the basic diet of the Galápagos residents. Incentives and training are currently being offered to farmers to increase local agricultural production, with the aim of reducing imports from the continent and the risk of new incursions. The introduction of pests like *H. zea* could affect yield considerably.

Fruits are also important hosts of arthropods, including some of the most aggressive pests known in the world, such as scale insects (Homoptera) and fruit flies (Diptera: Tephritidae). On checking a shipment of mango fruits in October 1999, SICGAL inspectors found the majority infested with up to ten larvae of a fruit fly. This detection caused huge concern, as the introduction of fruit flies into the Galápagos could affect both local agricultural production and native plants. Many species are polyphagous, with some known to be pests on up to 200 species of plants (White and Elson-Harris 1992). Fortunately, the fly was identified as *Anastrepha fraterculus*, the only species of fruit fly already present in the Galápagos. It was believed to have been originally brought in on guava (Foote 1982, Harper *et al.* 1989).

NEXT STEPS

Many of the specimens collected by inspectors in the first year of the program could not be identified rapidly, since specialists were required to identify them. Others were submitted to the entomologists in poor condition. Quick identifications are needed to determine whether a species intercepted by inspectors is a newly arrived species that requires immediate action to be taken to prevent its establishment, or is one that is already present in the Galápagos. For this, a series of steps needs to be taken. Firstly, we need to expand the recently created CDRS reference collection to ensure that all species found in Galápagos are represented in the collection. Technical staff also need to be on hand for diagnostic services and, lastly, a network with international specialists should be set up for remote interception diagnostics.

Knowing what species are entering Galápagos will also enable us to find out which groups are introduced on a regular basis and which pathways require stricter controls. It will not give us an indication of the number of species that are entering undetected. To be able to determine how many species are able to evade the barriers at the ports of exit and entry to the Galápagos, a system will be set up in the Archipelago to monitor the arrival of new species. Contingency plans will be available in the event that a species that has been classified as a potential threat to the Galápagos manages to reach the Archipelago. With these measures and the stricter controls that will be provided by the inspectors and the regulations, the number of incursions should be reduced considerably.

CONCLUSIONS

Due to its isolation (1000 km from the closest land mass) and its recent colonization, the Galápagos Archipelago is fortunate to still have 96% of its original flora and fauna (Gibbs *et al.* 1999). Unfortunately, this biodiversity is now under threat from insects and other arthropods that are being detected in the increasing volume of imported fresh fruit and vegetables. Preventing new species entering Galápagos through the operation of the SICGAL inspection service is a small investment compared with the costs incurred by their effects on Galápagos biodiversity, agriculture, and human health, in addition to those involved in running control and eradication programs.

Achieving these goals requires a two-stage approach. An initial injection of funds is needed to train inspectors, run education programs, prepare procedures manuals, and construct inspection facilities and diagnostic laboratories. Once the system is set up, income generated from user fees and the tourist park entrance fees should cover maintenance costs, salaries, training, and communication campaigns. Multilateral and bilateral donor agencies such as the Global Environment Facility, Ted Turner's United Nations Foundation, UNESCO, and the Spanish International Cooperation Agency have recognized the threat of alien species and have begun to participate actively in the implementation of SICGAL. If all goes to plan, the quarantine and inspection system should be complete within the next four years and the influx of introduced species effectively controlled and monitored.

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NEW RECORDS OF MYRIAPODA (CENTIPEDES AND MILLIPEDES) FROM THE GALÁPAGOS ISLANDS

Stewart B. Peck and W.A. Shear

Earlier, we presented data and keys for the identification of Galápagos millipedes and centipedes (Shear and Peck 1987, 1992). The first author had the opportunity for an additional three months of field work in the Galápagos in 1996. Two previously unreported species of millipedes were found, as well as new island records. No new species of centipedes were found, but additional island records were found.

This raises the Galápagos totals to 12 centipede species (7 introduced, 5 endemic) and 10 millipede species (9 introduced, 1 endemic). We take this opportunity to present detailed data on the new species and island records, a revised key for the identification of Galápagos millipedes, and a summary of old and new records of millipedes and centipedes (Table 1).

The new millipede species records are *Nanostreptus geayi* (Brölemann) and *Cyrtodesmus* sp. The genus *Nanostreptus* (Family Spirostreptidae) contains six species, distributed through Brazil, Peru, and Venezuela (Hoffman 1979). *Nanostreptus geayi* has been widely introduced in the West Indies and Central America and has undoubtedly reached the Galápagos through human agency. *Cyrtodesmus* (Family Cyrtodesmidae) includes 25 described species (and many additional undescribed ones), ranging from Costa Rica to Peru (Hoffman 1979). Because a number of the described species are known only from females, or remain unillustrated in the literature, a revision of the genus would be required to establish the identity of the species collected in the Galápagos. The gonopods of the males do not match those of any of the species for which we were able to find illustrations. The metazonites of many of the species of *Cyrtodesmus* are set with long, specialized setae which gather a coat of soil and litter. The specimens from the Galápagos were entirely clean, despite the presence of such setae.

Our 1996 pitfall trapping on Santa Cruz found that the introduced millipede *Asiomorpha coarctata* has become extremely abundant in pasture lands in the agricultural zone and that the species has moved up into the *Miconia* zone, where it is also abundant. Farmers now commonly find this species in decaying vegetation and around the bases of banana plants. We think the species feeds as a general detritivore on decaying plant material, and we are not aware that it causes any economic or ecological harm. A comparative ecological study on the impact of introduced millipedes seems a good research topic.

The label data on the new species and island records are given below. Additional data from other collections are available from SBP. The specimens have been placed in the collection of the American Museum of Natural History. Additional identified voucher material is in the collection of the Charles Darwin Research Station (CDRS).

NEW ISLAND AND SPECIES RECORDS

CHILOPODA

Henicopidae

Lamyctes coeculus (Brölemann). New island record. San Cristóbal. 1 km W El Junco, Miconia and tree-fern litter, 540 m, 17.III.96, S.B. Peck, 10 (specimens).

Scolopendridae

Scolopendra galapagoensis Brölemann. New island record. Darwin. South side talus slopes, under Croton shrubs, 20 m, 11.V.96, S.B. Peck, 2.

Schendylidae

Pectiniunguis albemarlensis Chamberlin. New island record. San Cristóbal. 3 km SE Wreck Bay, littoral zone, soil washing under Croton shrubs, 16.III.96, S.B. Peck, 2.

Pectiniungius krausi Shear and Peck. New island record. Fernandina. Cape Hammond, littoral zone, in cracks in sea cliff, 24.V.96, S.B. Peck, 1.

DIPLOPODA

Lophoproctidae

Lophoturus drifti (Condé and Terver). New island record. Santa Cruz. Cueva Iguana at CDRS, in litter at side of cave pool, 1 m, 4.V.96, S.B. Peck, 1.

Rhinocricidae

Nanostreptus geayi (Brölemann). New Archipelago record. Isabela. Santo Tomas, humid forest, 300 m, 4-15.III.89, Peck and Sinclair, 1 in pitfall trap. Santo Tomas, humid forest, 200 m, I.89, G. Reck, 10. Santo Tomas, on fungus on wood in Rose Apple grove, 300 m, S.B. Peck, 3. Santa Cruz. Puerto Ayora, CDRS, arid zone, 5 m, 13.III.91, S. Abedrabbo, 1. 4 km E Santa Rosa, in pitfall traps in roadside in agriculture zone, 350 m, 10.IV-4.V.96, S.B. Peck, 3.

Cyrtodesmidae

Cyrtodesmus sp. New Archipelago record. Santa Cruz. 4 km E Santa Rosa, in pitfall traps in roadside in agriculture zone, 350 m, 10.IV-4.V.96, S.B. Peck, 3.

Haplodesmidae

Prosopodesmus jacobsoni Silvestri. New island record. San Cristóbal. 3 km SE Wreck Bay, littoral zone, from soilwash of litter under *Croton*, 16.III.96, S.B. Peck, 2.

Continued on page 16

Table 1. Status and distribution by main islands (excluding satellite islands) of Galápagos Myriapoda. Island abbreviations are: D, Darwin; E, Española; Fe, Fernandina; Fl, Floreana; G, Genovesa; I, Isabela; M, Marchena; Pa, Pinta; Pn, Pinzon; SCl, San Cristóbal; SCz, Santa Cruz; So, Santiago; Sr. Seymour; SFe, Santa Fe; W, Wolf. x indicates previous records; * indicates new species or island records; ? indicates species possibly now extinct.

		ISLAND RECORDS														
	Status	**D**	**E**	**Fe**	**Fl**	**G**	**I**	**M**	**Pa**	**Pn**	**SCl**	**SCz**	**SFe**	**So**	**Sr**	**W**
Class Symphyla																
Family Scutigerellidae																
Hanseniella caldaria (Hansen)	probably introduced										x	x				
Class Chilopoda																
Order Lithobiomorpha																
Family Henicopidae																
Lamyctes coeculus (Brölemann)	introduced										*	x				
L. fulvicornis Meinert	introduced						x		x		x	x				
Order Scolopendromorpha																
Family Scolopendrididae																
Cormocephalus andinus Kraepelin	introduced probably extinct			?								?				
Scolopendra galapagoensis Brölemann	probably endemic	*	x	x	x	x	x	x	x		x	x	x			x
Family Cryptopidae																
Cryptops beebei Chamberlin	possibly endemic					x	x		x	x	x	x				
Newportia monticola Pocock	probably introduced						x				x	x				
Order Geophilomorpha																
Family Oryidae																
Orphnaeus brevilabiatus (Newport)	introduced		x		x		x		x	x		x		x		
Family Chilenophilidae																
Pachymerium pereirai Shear and Peck	probably native				x		x				x	x				
Family Schendylidae																
Pectiniunguis albemarlensis Chamberlin	possibly endemic	x	x			x	x		x		*	x		x		
P. krausi Shear and Peck	possibly endemic			*		x	x					x				
Nannopodellus purpurescens Chamberlin	introduced probably extinct													?		
Nesondyla nealota Chamberlin	possibly endemic		x				x					x				
Class Diplopoda																
Order Polyzenida																
Family Lophoproctidae																
Lophoturus drifti (Condè and Terver)	probably introduced										x	*				
Order Polyzoniida																
Family Siphonotidae																
Rhinotus purpureus (Pocock)	introduced											x				
Order Spirobolida																
Family Rhinocricidae																
Nanostreptus geayi (Brölemann)	introduced						*					*				
Order Polydesmida																
Family Cyrtodesmidae																
Cyrtodesmus sp.	introduced											*				
Family Furhmannodesmidae																
Agenodesmus nullus Shear and Peck	introduced											x				
Hexadesmus latridens Loomis	introduced											x				
Family Haplodesmidae																
Cylindrodesmus hirsutus Pocock	introduced											x				
Prosopodesmus jacobsoni Silvestri	introduced						x				*	x				
Family Paradoxosomatidae																
Asiomorpha coarctata (Saussure)	introduced											x				
Family Pyrgodesmidae																
Nesodesmus insulanus Chamberlin	endemic				*		x				x	x				

El Junco, *Miconia* litter near road, 560 m, 15.III.96, S.B. Peck, 20. El Junco summit, 640 m, in guava-fern litter of humid forest, 14.III.96, S.B. Peck, 10. El Junco summit, 640 m, in horse dung and grass litter, 14.III.96, S.B. Peck, 10. 1 km W El Junco, 540 m, *Miconia* tree-fern litter, 17.III.96, S.B. Peck, 20.

Pyrgodesmidae

Nesodesmus insulanus Chamberlin. New island record. Floreana. Cerro Pajas crater bottom, pitfall traps in *Scalesia* forest, 325 m, 18-22.IV.96, S.B. Peck, 1.

REVISED KEY TO GALÁPAGOS MILLIPEDES

For the convenience of future researchers, we present the following key, by which the known species of the Galápagos Islands may be separated.

1a. Body covered with tufts of serrate setae; 11 segments .... *Lophoturus drifti* (Condé and Terver)

1b. Body without dorsal setae, or if present, the setae are not in tufts; 18-50 body segments 2

2a. Adults with 35 or more body segments; color often purplish 3

2b. Adults with 18-20 body segments, less than 10 times as long as wide, not marked with purple 4

3a. Adults small, body to 7 mm long; generally marked with purple, without dorsal midline stripe .... *Rhinotus purpureus* (Pocock)

3b. Adults large, body 20-30 mm long; generally brown-purple color, with dorsal midline yellowish stripe .. .. *Nanostreptus geayi* (Brölemann)

4a. Able to roll into a thick disk, with notably enlarged side lobes (paranota) of second body segment covering the space in the centre of the disk .... *Cyrtodesmus* sp.

4b. Not rolling into a thick disk and without notably enlarged side lobes on second body segment 5

5a. Adults less than 4 mm long, unpigmented, males with 18 segments, females with 18 or 20 6

5b. Adults more than 4 mm long, often with pigment, with 19 or 20 segments 7

6a. Adults about 2.5 mm long, setae of dorsum club-shaped .... *Agenodesmus nullus* Shear and Peck

6b. Adults about 3.5 mm long; setae of dorsum sharply pointed .... *Hexadesmus lateridens* Loomis

7a. Body roughly cylindrical, densely pilose; color creamy white ...... *Cylindrodesmus hirsutus* Pocock

7b. Body flattened, not densely pilose 8

8a. Dorsum mostly smooth, shiny, black with yellow paranota (side-lobes); adult length greater than 15 mm .... *Asiomorpha coarctata* (Saussure)

8b. Dorsum with series of tubercles, often with adhering soil, ozopores (openings of repugnatorial glands) on elevated porosteles (tubercles) 9

9a. Ozopores in a continuous series from segment 7 posterior; color usually cream white; 5-6 mm long .... *Prosopodesmus jacobsoni* Silvestri

9b. Ozopores in a continuous series from segment 15 posterior; color usually gray or black; 9-11 mm long .... *Nesodesmus insulanus* Chamberlin

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THE ANTS OF MARCHENA ISLAND, TWELVE YEARS AFTER THE INTRODUCTION OF THE LITTLE FIRE ANT *WASMANNIA AUROPUNCTATA*

Lázaro Roque-Albelo, Charlotte E. Causton and Alejandro Mieles

INTRODUCTION

Marchena is a small and isolated island to the north of the Archipelago. The island is largely covered by pyroclastic cones and fresh lava fields. The vegetated area is small (32.8 km^2), compared with the size of the island (130 km^2). The vegetation is formed by a dry forest dominated by *Bursera graveolens* (HBK) Trian. & Planch., *Croton scouleri* Hook.f., *Waltheria ovata* Cav., *Lantana peduncularis* Anderss., *Opuntia helleri* K. Scum., and *Castela galapageia* Hook.f. (Hamman 1981). Published information refers to only one species of ant being found on Marchena, *Camponotus macilentus bidloensis* (Wheeler 1919). Lubin (1984) reports three species from this island, but does not mention which species.

In 1988, the little fire ant, *Wasmannia auropunctata* (Roger), was first reported on Marchena by Baert (1988). In a short visit to this island, Baert found "some Wasmannia ants" in a campsite in Playa Negra (Fig.1). This is probably the most aggressive species of invertebrate that has been introduced in the Galápagos Islands. Where *W. auropunctata* is found, few native ants and other invertebrates exist (Lubin 1984). There is also evidence that they have an impact on the nesting activities of reptiles and nesting birds (Roque and Causton 1999).

Four years after the visit of Baert's team, Sandra Abedrabbo, a Charles Darwin Research Station (CDRS) entomologist, detected the occurrence of *W. auropuncta-ta* in two fishing camps, in Playa Negra, Marchena, but she did not determine the area infested.

In 1993, the Galápagos National Park Service (GNPS) and CDRS began an ant control project in the island, adopting the methodology used in a control project for the same ant species in Santa Fé Island (Abedrabbo 1994). In 1993, the area of infestation of little fire ant was investigated. Bait stations were set up using transects with a grid design to estimate the area of infestation and AMDRO applied to control the ants. The area was determined as 5.2 ha. The GNPS carried out a second control trip in 1994 and the ant infestation was apparently reduced to 3.5 ha (Zuniga 1994). Unfortunately, the control program stopped for two years and only in 1996 was it possible to continue it. A GNPS team in 1996 apparently detected a reduction of the area of infestation to between 1 and 1.5 ha (Garcia 1996).

In August 1998 (during the El Niño event) and May 2000, we visited the island to determine the status of the *W. auropunctata* population and to initiate activities to eradicate this species. This paper provides information about its distribution. We also discuss a plan to control this species in Playa Negra, Marchena, and report new island records for the ant fauna of the Galápagos Islands.

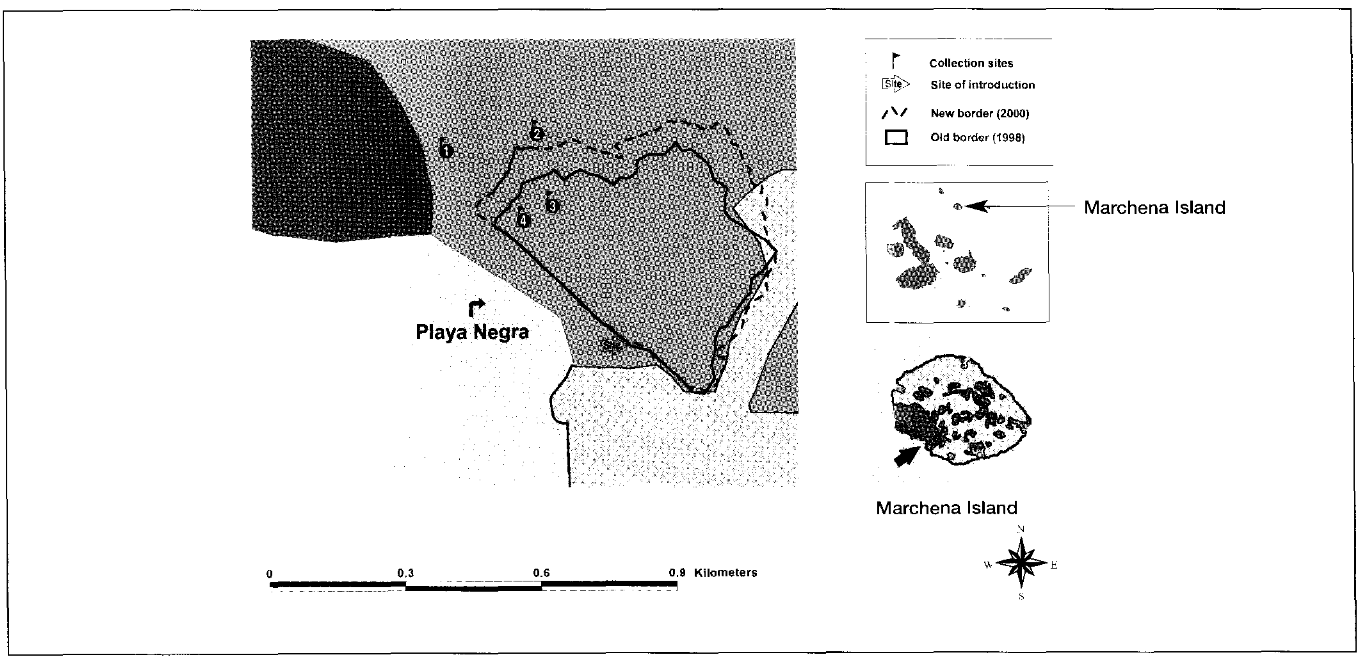

Figure 1 Playa Negra, Marchena Island

Ant Species	Status	1919	1988	1993	1994	1996	1998	2000
Camponotus macilentus bidloensis	E	X	X				X	X
Camponotus planus	E						X	X
Paratrechina fulva	N		X				X	X
Tapinoma melanocephalum	I			X			X	X
Dorymyrmex piramicus albemarlensis	E			X		X		
Hypoponera beebe	E						X	X
Cardiocondyla emery	I						X	X
Cardiocondyla nuda	I						X	X
Monomorium floricola	I			X			X	
Solenopsis globularia pacifica	I			X				
Tetramorium simillimum	I			X				
Wasmannia auropunctata	I		X	X	X	X	X	X

Table 1. Ant species found on Marchena during seven expeditions. Status in the Archipelago: E = endemic; I = introduced; N = native.

Ant Species	Number collected			
	Uninfested	Infested		
	T1	T2	T3	T4
Camponotus planus	1	0	0	0
Paratrechina fulva	3	16	0	1
Tapinoma melanocephalum	8	4	0	0
Hypoponera sp	0	1	0	0
Cardiocondyla nuda	3	6	0	0
Cardiocondyla emery	92	46	8	6
Wasmannia auropunctata	0	0	2124	1390

Table 2. Ant abundance from pitfall traps placed in uninfested and infested areas.

METHODS

Fieldwork was carried out in August 1988 and May 2000 by CDRS and GNPS personnel at the south side of Marchena (Playa Negra) (Fig. 1). Bait stations were used in order to determine the area infested by *W. auropunctata*. Hot dogs (frankfurters) marked with red flags were placed every 5 m along a 50 m transect from the last infestation point recorded on the previous visit. The baits were checked after 30 minutes and additional baits placed if little fire ants were recorded from the last bait station along the transect. A Geographical Position System (Garmin 12 CX) was used to calculate the infested area with a GIS Arcview program.

The ant fauna was collected using a variety of methods. We collected ants with bait traps (honey, tuna fish, and frankfurters). These traps were checked after one hour because aggressive species monopolized the baits. Pitfall trapping, leaf litter sifting, and hand collecting methods were also used. Samples of the ants collected were preserved in 70% ethanol and transported to the CDRS for identification. This material was deposited in the CDRS entomological collection.

In May 2000, pitfall traps were used to obtain quantitative information about the ant community. Four transects were established, two in the *W. auropunctata* infested area and two outside this area (Fig. 1). Ten traps per transect were placed along a line of 10 m. They consisted of 500-ml plastic cups containing detergent, formalin, salt, and water (two-thirds of the volume) as a preservative. Traps were placed in the ground for two days. Ant identification followed that of Bolton (1994, 1995), Wheeler (1919), and Wilson and Taylor (1967). Two indices were chosen to measure species diversity, namely the Margalef index (M.I.), which highlights richness in term of the number of species, and the Shannon and Weaver index (H'), which emphasizes species dominance.

RESULTS AND DISCUSSION

Ant diversity

Among the species we collected in 1998 and 2000 were five new records for Marchena: *Camponotus planus* Smith, *Cardiocondyla emery* Forel, *Cardiocondyla nuda* (Mayr), *Paratrechina fulva* (Mayr), and *Hypoponera beebe*

(Wheeler). These are in addition to five species recorded for the first time on Marchena in 1988 and 1993 by L. Baert and S. Abedrabbo (unpublished and reported for the first time in this paper): *Tapinoma melanocephalum* (Fabricius), *Monomorium floricola* (Jerdon), *Dorymyrmex piramicus albemarlensis* (Wheeler), *Tetramorium simillimun* (Smith), and *Solenopsis globularia pacifica* Wheeler.

We found that many more species of ants exist on the island than has previously been published. A total of 12 species have been recorded from Marchena (Table 1) out of the 55 ant taxa recorded from the Galápagos Islands (Wheeler 1919, 1924, 1933, Clark *et al.* 1982, Lubin 1984, Pezatti *et al.* 1998). The ant fauna of the island is characterized by a high number of tramp species. Among the 12 species encountered on Marchena, five are introduced. Only four, *C. m. bidloensis, C. planus, D. p. albemarlensis,* and *H. beebe* are endemic to the Galápagos. The remaining native species could have been introduced to Marchena in recent years from the inhabited islands or may have been missed previously.

When comparing the collections made in early surveys with our recent collections, we noted a marked increase of the species richness in the island. Two factors could be responsible for this increase: a) the early surveys were incomplete or lacked locality data, or b) ants have continued to migrate to the islands by natural means or have been introduced by humans. Although it is difficult to answer this basic question, anecdotal evidence can be discussed.

We suspect that some species were simply overlooked by early collectors who visited the island *(e.g., C. planus and H. beebe).* Unfortunately, we do not have published records that mention how much time or effort was invested in the early ant collections. Some records also appear to be incorrect. For example, Wheeler (1919) described *C. m. bidloensis* from material collected by the "*Albatross* Expedition of 1899"; however, Slevin (1931) and Linsley and Usinger (1966) do not report the visit of the steamer *Albatross* to Marchena in its two Galápagos expeditions (1888 and 1891). The material studied by Wheeler was probably collected during the Hopkins-Stanford Expedition in 1888 and 1889. However, it does appear that their effort was restricted to a few hours, since Marchena is not considered a special place for collecting wildlife specimens. If this is true, species which are localized would have escaped early collectors. For example, during our collection, pitfall traps captured most of the species present at a site, but hand-collecting and leaf-sifting techniques using a Berlesse funnel collected more rare or localized species *(e.g. H. beebe).*

Peck *et al.* (1998) documented the known introduced insects in the Galápagos Islands, including ants. He found a strong correlation between the species numbers of introduced insects and the number of human inhabitants per island.

Marchena was never inhabited, and has only been visited by fishermen, scientists, Park guards, and some tourists, with most visits being concentrated in Playa Negra. Tramp ants have a high capacity for reaching isolated habitats because of their small size and the strong relation with transport by humans. This permits them to travel long distances and establish themselves in remote islands. We propose that *T. melanocephalum, T. simillinum, S. globularia, M. floricola, P. fulva,* and *W. auropunctata* probably arrived in Marchena in camping provisions and equipment.

Species diversity in the presence and absence of *W. auropunctata*

In May 2000, pitfall trapping was the only method used to determine the species density of ants, because our aim was to identify ground species that can be influenced by *W. auropunctata.* There was a striking contrast between ant communities in habitats where *W. auropunctata* was present and absent (Table 2, Fig. 1). *Wasmannia auropunctata* was collected in all traps in the infested area. Meanwhile, a low number of other ant species, *P. fulva* (1) and *C. emery* (14), were collected in the infested area. This co-occurrence was also reported by Clark *et al.* (1982) in certain areas of Santa Cruz Island where *W. auropunctata* was dominant during the wet season. In contrast, six species were collected from the uninfected area, including the two species found in the habitats occupied by *W. auropunctata.* These species were *C. planus, T. melanocephalum, H. beebe, and C. nuda.* Although *C. emery* was dominant in the uninfected habitat, it was not numerically as dominant as *W. auropunctata.*

The exposure time of pitfall traps (two days) apparently affected the collections. In some traps only a few ants were collected, with some species represented by a single specimen. However, on this trip it was not possible to leave the traps out for longer. In the future, pitfall traps will be placed in the field for one week.

The results of the tests using the Margalef Diversity Index and the Shannon Weaver Index confirm that there was a greater species richness and equitability in areas where *W. auropunctata* was absent. The values from the Margalef Diversity Index were 0.60 and 0.95 in the little fire ant-occupied area, while in the uninfected area they were 1.97 and 2.15. A similar pattern was observed with the Shannon Weaver Index (0.01 in the infested area and 0.25 and 0.45 in the uninfected area). The total number of ants increased by about twenty times in the infested area due to the high density of *W. auropunctata* individuals. On the other hand, representatives of other ant species dropped by 90% and species richness declined by 50%, from 6 to 3 (Table 2). Similar impacts were reported by Porter and Savignaro (1990) for *Solenopsis invicta* Buren in Texas.

Distribution of *W. auropunctata* on Marchena

During the El Niño event of 1998, 17 ha of the vegetation surrounding Playa Negra was occupied by dense mats of *W. auropunctata*. Two years later the infested area had increased by 41% to 24 ha. The area of distribution shows a marked increase from estimates made on trips prior to 1998. Although high precipitation rates during El Niño may account for a rise in ant numbers (high rainfall leads to vegetation growth and increased prey numbers), it is unlikely that it is responsible for such dramatic population growth (1.5 to 17 ha in one year). This may be due to the techniques that were used on earlier trips. What is evident, however, is that the distribution of *W. auropunctata* in Marchena is expanding. This ant typically infests vegetated areas. In Marchena, vegetation covers 25% of the total area of the island. If this ant continues to spread at this rate, it could have a high impact on the native invertebrate species, especially those that are localized in distribution.

Can we control *W. auropunctata*?

Two factors should contribute towards the success of this project: (a) the area occupied by *W. auropunctata* is still relatively small and manageable, and (b) new colonies are formed by colony budding, thus generally restricting the dispersal capacity of this species to areas immediately adjacent to existing colonies. During the monitoring trip in May 2000, a project design to eradicate *W. auropunctata* from Marchena Island was elaborated. Over the next four years, AMDRO®, the ant bait identified as most effective for *W. auropunctata* in the Galápagos Islands (Williams and Whelan 1994), will be hand-spread over the infested area. Bait applications will be carried out according to the results of a monitoring program that will run parallel to the eradication efforts. This program will be initiated in September 2000. It is expected that the project will run for four years.

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VARIATION IN THE GALÁPAGOS SHRUB SNAPDRAGON: IS THERE ANOTHER SUBSPECIES OF *GALVEZIA LEUCANTHA*?

Conley K. McMullen and Wayne J. Elisens

Galvezia leucantha Wiggins (Galápagos shrub snapdragon) is an attractive, though rarely seen, Galápagos endemic plant. This species, a member of the Scrophulariaceae, may be described as follows: Perennial shrub, much-branched, to 1.5 m tall. Leaves simple, opposite, elliptic-lanceolate to ovate-lanceolate. Flowers borne singly in leaf axils; corolla tubular, bilabiate, upper lip 2-lobed, lower lip 3-lobed, inner and outer surfaces somewhat hairy and glandular; stamens 5 (4 functional). Fruit a many-seeded capsule. *Galvezia fruticosa* Gmelin., which inhabits the arid coastal regions of mainland Ecuador and Peru, appears to be most similar morphologically and most closely related (Elisens 1989).

Based on surface covering and flower color, Wiggins (1968) segregated *G. leucantha* into two subspecies. *Galvezia leucantha* subsp. leucantha was described as possessing smooth or sparsely hairy young twigs, leaves, flower stalks, and calyces; and waxy white corollas. This description was based on specimens from Isabela (Tagus Cove). Wiggins and Porter (1971) later included specimens from Santiago in this subspecies. *Galvezia leucantha* subsp. *pubescens* Wiggins was said to differ in that the above-mentioned parts were densely glandular-hairy and the inside of the corolla was occasionally reddish or pink. It was described from specimens collected on Rábida.

In 1986, W.J. Elisens began morphological and genetic variation studies on *G. leucantha* populations on Isabela, Rábida, and Santiago. In addition, herbarium specimens from Fernandina and Isabela were studied. Results indicated that there was little morphological and genetic variation within populations of this species (Elisens 1989). However, morphological differentiation between populations was apparent. Characters that apparently varied between populations included the pubescence of young stems, leaves, flower stalks, and calyces; corolla color; flower stalk length; and corolla tube length.

Continued on next page

Elisens (1989) suggested that these characters were under genetic control and were not an example of environmental variation, and that three subspecies should be recognized:

Galvezia leucantha subsp. *leucantha*, which inhabits Fernandina and Isabela, was described as smooth or sparsely hairy, with completely white corollas, flower stalks 13-24 mm long, and corolla tubes 5.5-6.5 mm long.

Galvezia leucantha subsp. *pubescens*, which inhabits Rábida, was described as hairy and densely glandular, with corollas typically completely white, but rarely tinged with violet (2 of 36 individuals observed), flower stalks 10-12.5 mm long, and corolla tubes 5.0-5.5 mm long.

The third subspecies, which was recently named *G. leucantha* subsp. *porphyrantha* Tye & H. Jäger, inhabits Santiago (Tye and Jäger 2000). Elisens (1989) described this plant as being smooth or sparsely hairy, with corollas white tinged with violet, flower stalks 12.5-14 mm long, and corolla tubes 5.5-6.5 mm long. Tye and Jäger (2000) examined more material and described the exterior of the corolla as magenta with the tips of the upper lobes white, while the interior is pink and white striped. They also showed that the supposed size differences in the flower parts from different islands were mostly not substantiated by larger collections.

On 18 October 1983, while visiting Rábida, C.K. McMullen photographed an individual of *G. leucantha*. This photograph may be seen on page 167 of McMullen (1999) and in black and white on the first page of this paper. The specimen was located on the north side of the island, in the vicinity of the reddish brown cliffs near the tourist trail. Two morphological characters are obvious from the photograph. First, the young twigs, leaves, flower stalks, and calyces are densely glandular-hairy, as in subsp. *pubescens*. Second, the outside of the corolla is completely reddish purple, while the inside ranges from pink to white. This plant is apparently different from the subspecies described previously, although Wiggins and Porter (1971) mention it. It has been observed only on Rábida.

The collections and field notes of Elisens from Rábida, made in 1986, indicated that individuals at the same coastal cliff site near the north landing were glandular pubescent and white-flowered, except for two plants (of 33 observed) that had corollas tinged red to violet. After four additional days searching on Rábida, accompanied by Carlos Cerón of the Universidad Central del Ecuador, Elisens found only three plants at two higher elevation sites (100 m and 400 m). These were glandular pubescent and white-flowered.

Based on the observations of McMullen and on variation patterns in plant pubescence and floral coloration, at least four morphological variants of *G. leucantha* are present in the archipelago:

1) plants smooth or sparsely hairy with corollas white (Fernandina and Isabela), subsp. *leucantha*;
2) plants densely glandular-hairy with corollas typically white (Rábida), subsp. *pubescens*;
3) plants smooth or sparsely hairy with corollas white and magenta to violet on the outside and pink and white striped on the inside (Santiago), subsp. *porphyrantha*; and
4) plants densely glandular-hairy with corollas reddish purple on the outside and pink to white on the inside (Rábida), undescribed.

Because no specimens of the plant observed by McMullen were collected in 1983 and none have been seen in herbarium material, it is not appropriate at this time to propose a new subspecies or variety for the Galápagos shrub snapdragon. However, we would encourage those visiting Rábida and other islands to look diligently for this plant and to report any unusual sightings to the head of the Department of Plant and Invertebrate Sciences at the Charles Darwin Research Station.

Numerous questions remain unanswered about *G. leucantha* and its pattern of morphological variation. Are reddish purple-flowered forms present on Isabela and Fernandina? Is the variation observed among Rábida plants a result of hybridization with individuals introduced or dispersed from Santiago? These and other questions can only be answered with careful field observations and additional experimental studies.

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IS THE ENDEMIC GALÁPAGOS TIGER BEETLE THREATENED WITH EXTINCTION?

Fabio Cassola, Lázaro Roque-Albelo, and Konjev Desender

The Galápagos Islands have long been known to be the home of just one tiger beetle species, the endemic *Cicindela galapagoensis* (Coleoptera, Cicindelidae), first mentioned by Walther Horn in 1915. It was formally described in 1920 based on specimens collected in 1906 by F.X. Williams at Banks Bay, Isabela Island (Horn 1926, 1936, 1938: pl. 84, fig. 9). In 1938 Mutchler described *Cicindela vonhageni* based on a small sample collected by H. von Hagen at Tortuga Bay, Santa Cruz Island (Van Dyke 1953). Furthermore, a *galapagoensis* subspecies, *discolorata,* was described by Mandl (1967a) from a single male specimen collected in 1963 at Genovesa Island (Linsley 1977). Reichardt (1976) synonymized both forms under *galapagoensis* on the basis of two larger samples collected in 1964-65 by N. and J. Leleup on Santa Cruz and Floreana islands. He showed *discolorata* to completely overlap with *vonhageni,* and *vonhageni* to actually be a *galapagoensis* form with fully testaceous elytra, falling within the range of *galapagoensis.*

To date, the Galápagos tiger beetle has been collected from the following islands: Isabela (Banks Bay [type locality]: Horn 1920, Desender *et al.* 1989, 1990, 1992a fig. 2; Playa Tortuga Negra: Desender *et al.* 1992a fig. 2); Fernandina (Cape Hammond: Desender *et al.* 1990, 1992a fig. 2; Punta Espinosa); Santa Cruz (Tortuga Bay [type locality of *C. vonhageni*]: Mutchler 1938, Reichardt 1976, Desender *et al.* 1989; Academy Bay and Darwin Station: Reichardt 1976, Desender *et al.* 1989, 1990; North Coast, Playa Bachas: Desender *et al.* 1990 fig. 1, 1992a fig. 2, 1998 (unpublished data)); San Cristóbal (Sappho Cove, 1996: Desender, Baert, and Verdyck, unpublished); Genovesa (Darwin Bay (Mandl 1967a, Desender *et al.* 1990, 1992a fig. 2)); Marchena (Playa Negra: Desender *et al.* 1990 fig. 1, 1992a fig. 2; 2000, unpublished data); and Floreana (Black Beach: Reichardt 1976, Desender *et al.* 1989, 1992a fig. 2; Punta Cormoran: Desender *et al.* 1989, 1992a fig. 2).

Until now, all records refer to night collecting at light-traps. Indeed, *C. galapagoensis,* unlike most tiger beetles, has never been observed active during the day, not even at sites where it has on numerous occasions been collected at night, such as salt tidal marshes and mud flats near lagoons. This could be a special adaptation of the Galápagos species, in relation to extreme conditions during daytime and/or the reduced daytime activity of potential prey.

The taxonomic classification of this group is still not clear. The old-fashioned, nearly cosmopolitan, biogeographically meaningless, giant genus *Cicindela* Linné, 1758 [type-species: *C. campestris* Linné, 1758, from the Palaearctic region] was long ago split into many distinct genera by Rivalier (1954). This author ascribed most Mexican and Central American species to his genus *Cicindelidia.* Reichardt (1976) demonstrated that *galapagoensis* is related to *Cicindelidia* because of the typical ear-like conformation of the inner sac of the male genitalia. However, Wiesner (1992) instead arranged both *galapagoensis* and *vonhageni* as two distinct species, in the genus *Habroscelimorpha* Doktouroff, 1883 [type-species: *H. dorsalis* (Dejean, 1826), from coastal eastern United States], between the Central American species *H. schwarzi* (W. Horn, 1923) and *H. boops* (Dejean, 1831). This association was recently maintained by Pearson *et al.* (1999).

An attempt to collect further fresh *galapagoensis* specimens at Tortuga Bay on 18 April 2000 (F. Cassola and L. Roque-Albelo) unfortunately failed. However, we examined a male *galapagoensis* specimen from Genovesa, collected in March 1988, and this species proved to belong to the genus *Cicindelidia,* despite some unusual characteristics such as the large protruding eyes, the poorly microserrated elytra, and the relatively long legs. The same conclusion was reached after examination of specimens from Floreana and Santa Cruz (K. Desender). More detailed studies are at the moment also performed on Galápagos cicindelid populations, including biometrics, karyotyping, and genetic investigations (K. Desender and co-workers). The results of these ongoing studies may have taxonomic implications, but will certainly be important for conservation purposes.

Desender *et al.* (1992 a, b) reported the recent arrival to Santa Cruz Island of another tiger beetle species, *Cicindelidia trifasciata* (Fabricius, 1781). This is a common, widespread, mainly coastal American species with several subspecies described in the known large distribution range. *Cicindelidia trifasciata* was first collected in Galápagos in 1983, following an extreme El Niño event, and apparently rapidly reached higher numbers than the co-occurring endemic *C. galapagoensis.* At the Tortuga Bay lagoon, light trapping sessions in 1986 and 1991 showed *galapagoensis* to have progressively been reduced to almost insignificant proportions in a very short time span, relative to the ever expanding trifasciata population (Desender *et al.* 1992b).

In 1996 and 1998, the Belgian team observed, respectively, three and four *galapagoensis* and 28 and 30 *trifasciata* in the same area. Two recent daytime visits to the same site (16 and 18 April 2000, F. Cassola and L. Roque) failed to yield any *galapagoensis* at all; however, *trifasciata* occurred in the area by the hundreds (maybe even

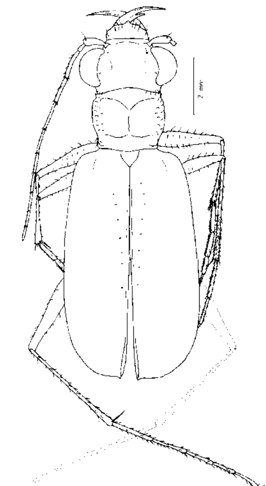

Fig. 1. *Cicindelidia galapagoensis* (W. Horn, 1915), male specimen from Genovesa Island (m. *vonhageni* Mutchler, 1938).

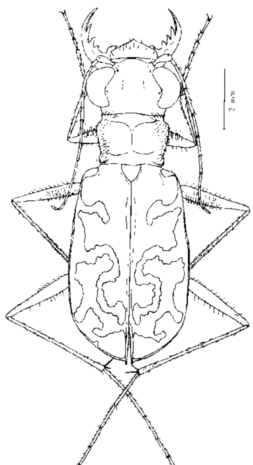

Fig. 2. *Cicindelidia trifasciata* (Fabricius) ssp. *latioresignata* (Mandl, 1967), female specimen from Tortuga Bay, Santa Cruz Island.

thousands). Meanwhile, on 5 April 2000 a night light-trapping session (K. Desender and co-workers) yielded five *galapagoensis* specimens amongst an overwhelmingly large *trifasciata* population (780 individuals counted at traps and partly sampled).

It is evident that *C. trifasciata* has become firmly established on Santa Cruz (Tortuga Bay, surroundings of CDRS, and Playa Bachas: Desender *et al.* 1992b). This species could well be threatening the endemic *C. galapagoensis* with extinction. Probably the two are in some way competitors for prey or range, and, as is often the case, the newcomer, despite its smaller size, could be out-competing the endemic species. In addition, there may be another problem related to the high proportion of *trifasciata* beetles: an observation of a heterospecific pair in copulation (Tortuga Bay, 1991: K. Desender and co-workers) suggests that *galapagoensis* might also be facing confusion or competition in mate choice. To date, *C. galapagoensis* has shown itself to be unable to shift to a different ecological niche, such as the sandy beach of Tortuga Bay, close to the tidal pond where it was once abundant. This habitat type does not support tiger beetles and obviously represents an empty niche.

Desender *et al.* (1992b) concluded that *C. trifasciata* most probably had been introduced accidently to Galápagos. Arrival by natural means through dispersal by flight or rafting on vegetation is less probable, but not completely excluded. The species appeared first on Santa Cruz, the central island most involved in human transport for tourism and local inhabitants. After some 20 years since its arrival in Galápagos, *C. trifasciata* seems still restricted to Santa Cruz in its occurrence.

Peck and Kukalova-Peck (1990) estimated that in order to explain the recent number of beetle species in Galápagos, one succesful natural colonization event had to take place each 10,000 years during the past 3 million years (or, for ground and tiger beetles, one event in about 100,000 years). The numerous recent observations of other species new to Galápagos, therefore, most probably are of human-mediated introductions.

C. trifasciata is known to be highly vagile. It is readily attracted to lights, actively flying to them at night. For instance, it has been collected on oil platforms up to 160km offshore (Graves 1981, 1982). *C. trifasciata* was also able to reach the Revillagigedo Islands in the Pacific Ocean west of Mexico (Cazier 1954), and could have arrived in Galápagos by the same mechanism. It is easy to suppose that individuals attracted to ships' lights in harbors at night could well have made the whole 3-7 days cruise to the Galápagos Islands as well. Given its habits, this species is likely to use this means of dispersal and transport again in the future, to colonize new habitats in the archipelago, thus threatening and displacing other *galapagoensis* populations.

This supposition seems to be strengthened by the fact that the *C. trifasciata* population which has established itself at Tortuga Bay does not appear to belong to the Central American subspecies (*ascendens* LeConte, 1851), but rather to ssp. *latioresignata* (Mandl, 1967), described from northern Peru (Mandl 1967b, 1975) and known to occur commonly in the Guayaquil area as well, thus suggesting an Ecuadorian coastal origin. Because Galápagos material of *trifasciata* has been collected and fixed for genetic studies (Desender and co-workers), it might be possible in the future to trace even more exactly the origin of these beetles on the mainland.

The present situation poses a difficult conservation dilemma. If *C. trifasciata* has colonized the Galápagos naturally, a campaign of eradication would be precluded by the rules of the Galápagos National Park Service

(GNPS). This would hold true even if *C. trifasciata* eliminates *C. galapagoensis*. If, on the other hand, *C. trifasciata* has been introduced by humans, its attempted eradication would be both legal and desirable.

Unfortunately, we cannot yet prove either scenario, although circumstantial evidence points to the latter possibility. It is therefore necessary for entomologists to study this problem in further detail in order to be able to advise the GNPS if and how to control *C. trifasciata*. It seems most probable that steps should be taken to protect the endemic *C. galapagoensis* from extinction.

One such urgent measure is related to another problem facing *C. galapagoensis*. During recent visits (K. Desender and co-workers) to Genovesa, we unfortunately failed to observe any beetles. Apparently the inland part of the small beach at Darwin Bay is now part of the tourist trail. A highly isolated population of *C. galapagoensis* occurred on this site until at least 1988, when the tourist trail did not cross the area. The site is now trampled daily by many visitors. *Cicindelid* larvae live in burrows in humid bare sand or mud and easily suffer from excessive trampling, eventually leading to population extinction.

It is not known whether the species might still be surviving on Genovesa, possibly along one of the few other beaches. A first and urgent measure to protect the Galápagos tiger beetle would be to institute the complete protection of population sites from trampling by tourists, in conjunction with monitoring their present distribution.

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