Invisible but Identifiable: p-Chips as a Reliable Marking Method for Amazonian Bats

Running title: p-Chip marking in free-ranging Amazonian bats

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Abstract

Marking techniques are essential for studying bat ecology and informing conservation efforts, yet many existing methods present challenges related to size, tag detectability, and long-term retention. p-Chips, ultra-miniaturized transponders detectable via red laser light, offer a promising alternative to traditional banding or passive integrated transponder (PIT) tags. While their use has been successfully demonstrated in captive bats, their effectiveness in free-ranging populations remains largely untested. Across three years of bat research in the Peruvian Amazon, we tagged with p-Chips individuals across 31 species. We documented 88 recaptures, with all p-Chips remaining functional over both short term (≤ 40 days) and long term (> one year) periods. Notably, no adverse effects such as scarring or tissue damage were observed. Red LED illumination facilitated rapid tag visual detection, reducing handling time. These findings support the use of p-Chips as a viable, detectable, minimally invasive, and cost-effective alternative to PIT tags, particularly for small-bodied species. We recommend further research to optimize p-Chip technology for broader application in wildlife tracking and conservation.

Keywords: Chiroptera, forearm, life tag, mark-recapture, technology, wild bats

Introduction

Individual identification of bats is critical for applied conservation research programs on population dynamics, aging, health and mortality (e.g., van Harten et al., 2022; Humphrey and Oli, 2015; Jin et al., 2012; O'Shea et al., 2010; O'Shea et al., 2004; Cheng and Lee, 2002). Researchers have employed a variety of methods to individually mark bats for long-term monitoring (Kunz and Weise, 2009). Nevertheless, choosing the most effective marking technique remains a challenge, as available techniques vary in terms of cost, durability, practicality, and their impacts on animal health and behavior (Loeb et al., 2025; Reynolds et al., 2025; Lobato-Bailón et al., 2023; Markotter et al. 2023, Mellado et al., 2022; Kunz and Weise, 2009). Effectiveness may also be species-dependent, necessitating the use of multiple complementary approaches (Kunz and Weise, 2009; Bonaccorso et al., 1976).

Historically, forearm bands have been widely used due to their relatively low cost and ease of application (Kunz and Weise, 2009). However, concerns over lethal and sublethal injuries, and potential interference with foraging activities in a range of species (Lobato-Bailón et al., 2023) have prompted researchers to explore alternatives (Markotter et al., 2023; Kirkpatrick et al., 2019; Kunz and Weise, 2009; Sherwin et al., 2002; Barnard, 1989).

Passive integrated transponder (PIT) tags, a type of radio-frequency identification (RFID) marker, have been frequently employed to permanently mark bats over the last few decades (Fontaine et al., 2024; Escobar et al., 2022; Locatelli et al., 2019; Britzke et al., 2014; Rigby et al., 2012; Ellison et al., 2007; Neubaum et al., 2005; Kerth and Reckardt, 2003; Schooley et al., 1993; Barnard, 1989). These subcutaneous tags encode a unique identification number that is readable by RFID readers, which can even be adapted to automatically detect bats at roost entrances (Rivera-Villanueva et al., 2024; Adams and Ammerman, 2015; Britzke et al., 2014). Although they are widely used and evidence suggests that PIT tags do not negatively affect bats' body mass, body condition, or reproductive success (Waag et al., 2025; van Harten et al., 2019; Locatelli et al., 2019; Rigby et al., 2012; Neubaum et al., 2005), they have some limitations. Their application typically requires a large needle (12-gauge), which may be invasive for smaller species (Seheult et al., 2024). Tags are not externally visible; therefore, the use of a hand-held ID reader is required; nevertheless, they can migrate or even be occasionally expelled from the body, in which case this may lead to detection difficulties or data loss (van Harten et al., 2021; Rigby et al., 2012; Kunz and Weise, 2009; Barnard, 1989). Finally, they are cost-prohibitive at large scales (USD 5–10; Seheult et al., 2024), but these prices vary depending on the vendor and the quantity. Generally, PIT tags are preferable to forearm bands due to their higher retention rates (van Harten et al., 2021; Ellison et al., 2007); however, the

concerns over cost, detectability, potential safety issues for very small bats (forearm length < 30 mm), and tag loss in some studies (e.g., Rigby et al., 2012) warrant investigation into alternative technologies.

p-Chips (p-Chip Corp., Chicago, Illinois) are ultra-miniaturized semiconductor transponders (500 × 500 µm) that emit a unique ID when activated by a red laser light (PharmaSeq 2012). Although they were designed for a wide range of applications, including labeling, tracking, and authenticating items, their primary initial use was the permanent identification of laboratory mice (Gruda et al., 2010; PharmaSeq, 2012). Since the laser tip must be in close proximity to the tag for successful scanning (< 1 cm), the tag is injected subcutaneously in an area with thin, translucent, and almost hairless skin via a narrow, 21-gauge needle, making them a promising alternative for marking even the smallest bat species in a less invasive way (Ngamprasertwong et al., 2022; Gruda et al., 2010). P-Chips (1-2 USD per unit) can also be five to ten-fold less expensive than PIT tags (Seheult et al., 2024). P-Chips (p-Chip Corp.) were available either in preloaded or loose formats; in the latter case, they can be manually loaded into injectors, which can be sterilized between uses or discarded. Currently, PharmaSeq is no longer engaged in commercial sales of p-Chips or preloaded injectors. Researchers interested in using p-Chips may contact p-Chip Corp. directly to purchase them (p-Chip Corp. personal communication) and adapt other needles for injection (see Methods).

p-Chips have been successfully used for marking and identification in animals of various sizes, including fish (Spooner and Spurgeon, 2024; Moore and Brewer, 2021; Faggion et al. 2020), rodents (Clein et al., 2024; Warren et al., 2021; San Diego Zoo Wildlife Alliance, 2016), crayfish (Huber et al., 2023), salamanders (Moore et al., 2024), bees (Hamilton et al., 2019; Tenczar et al., 2014), ants (Robinson et al., 2014, Robinson et al., 2009), and even ectoparasites (Folk et al., 2024). Although most evidence comes from captive conditions, p-Chips have been shown to be effective identification markers for wild fish (Spooner and Spurgeon, 2024; Moore, 2020), demonstrating no significant adverse effects and a tag retention rate of up to 94% after more than a year, even in underwater conditions. Therefore, p-Chips are a suitable and considerably smaller alternative to PIT tags. Although p-Chips still require the recapture of marked individuals, unlike some PIT tags that are large enough to be detected by passive detector arrays, their reduced size represents a promising avenue for innovation for small-sized species for which traditional marking techniques are impractical or invasive.

Seheult et al., (2024) tested p-Chips in 30 captive *Eptesicus fuscus* (forearm length: 40–48 mm), inserting them in the skin of the wings and tibia. They found that the tags remained functional for over a year (464 days after tagging) while requiring minimal handling due to rapid scanning by the

scanner. However, they also noted that visibility decreased over time, which may complicate recapture efforts. This issue could pose a significant challenge in free-ranging bats, where uncertainty about previous tagging might lead to excessive handling in an effort to locate a potentially nonexistent tag.

Given these challenges, it was recommended to test them in more species and non-captive conditions. In this study, we share results from using p-Chips in free-ranging Amazonian bats, assessing their application, detectability, and retention across species.

Methodology

This study was conducted at the Estación Biológica Los Amigos (EBLA), located in the southeastern Peruvian Amazon, at the confluence of the Los Amigos and Madre de Dios Rivers (12°30'–12°36'S, 70°02'–70°09'W). The region primarily consists of high and low terra firme forests, flooded palm forests, and meandering river floodplain forests (MINAM, 2015). According to *Servicio Nacional de Meteorología e Hidrología del Perú* (SENAMHI), in Puerto Maldonado (~ 50 km away and the nearest site), temperature ranges from 16.6°C to 32.2°C and monthly precipitation varies from 58 to 299 mm. At this site, an annual mark-recapture program for medium and large mammals has been ongoing since 2018, under which we were able to try this method for the individual identification of bats. Although sampling of bats has taken place since 2018, marking efforts began only at the end of our 2023 field season (end of July–beginning of August).

From 2023 to 2025, we captured bats using 6 × 3 m and 12 × 3 m mist nets at accessible sites along the trail system at the field station (Watsa et al., 2023; Figure 1). Bats were identified taxonomically using the dichotomous keys from López-Baucells et al. (2016) and Díaz et al. (2021); and aged based on epiphyseal ossification (Brunet-Rossinni and Wilkinson, 2009). To individually mark bats, p-Chips (USD 0.67 each in 2023; PharmaSeq) were subcutaneously implanted into the right mid-forearm region of each animal, primarily using preloaded 21-gauge needles (Figure 2, Video S1). To replicate the pre-loaded injectors developed by p-Chip Corp. (p-Chip Corp. personal communication), in 2025 we manually flattened 40 conventional 21-gauge needles using a press, then loaded them with loose p-Chips under sterile, controlled conditions. These needles were used to insert the p-Chips in bats and performed comparably to the preloaded needles. The forearm was selected as the implantation site to accommodate the wide range of body sizes included in this study, particularly smaller-bodied species, in which implantation in the metacarpals may be anatomically unfeasible or difficult due to needle gauge relative to bone width. We ensured that each p-Chip was inserted into a disinfected injection site being careful that the chip remains right-side-up to maintain detectability.

Individual tag numbers were checked using the handheld reader (model WA-6000) connected to a Windows 10 laptop or tablet via USB connection. We purchased our reader from PharmaSeq for USD 3,000 in 2023, whereas Seheult et al., (2024) reported a cost of USD 2,000. During preliminary tests, we identified instances where some p-Chips were unreadable or preloaded in a flipped orientation. For this reason, we checked them before injection by slightly exposing the p-Chip with the plunger of the needle to verify its readability and orientation before implanting it. Additionally, the ongoing bat research program involved taking fur for toxicology analyses and a wing punch for DNA barcoding, both serving as short-term external marks that helped confirm recaptures when p-Chip detectability was initially uncertain. Once red LED-assisted visualization reliably revealed tag presence under the skin, these auxiliary short-term marks were no longer needed for this purpose. No standardized timing protocol was applied.

We defined eight sampling sites where we have conducted bat sampling since we began marking bats with p-Chips. In 2024, we ran out of p-Chips for sites 1, 5 and 7; however, we report our full sampling schedule (Supplementary Table S2) because recaptures were recorded at sites 1 and 7. Mist-net locations were georeferenced to measure distances between recapture events. We assessed tag functionality within and across years by recording the distance and time between encounters of recaptured individuals.

Mist-netting effort was not standardized across sites or nights. Nets were installed in single-high configurations, but the number of nets deployed per night varied with logistical and environmental constraints and with the objectives prioritized by the ongoing research program since 2018. As a result, our mark–recapture assessment was opportunistic, and we therefore do not quantify recapture rates or success. Our observations of recapture events are reported to document p-Chip visual detection, reading and retention under typical field conditions.

This study was conducted under the permission RDG-000116-2021-DGGSPFFS (*Servicio Nacional Forestal y de Fauna Silvestre*; SERFOR), following the guidelines of the American Society of Mammalogists (Sikes et al., 2016) and with IACUC approval from Washington University in St. Louis and the San Diego Zoo Wildlife Alliance. For the full handling protocol, please see Watsa et al. (2023).

Results

Bats were sampled and tagged from 2023 to 2025 (details in Supplementary Table S2). In 2023, p-Chips were implanted in 24 bats across eight species; in 2024, in 97 bats across 19 species; and in 2025, in 179 bats across 27 species (Table 1). In total, we implanted tags in 31 species across three

families (Phyllostomidae, Emballonuridae, and Vespertilionidae), spanning a wide range of body sizes from small bats (forearm length < 36 mm) to very large bats (forearm length > 75 mm). The smallest tagged individual had a forearm length of 29.7 mm (*Mesophylla macconnelli*), whereas the largest was a *Vampyrum spectrum* with a forearm length of 108.1 mm. p-Chip visual detection and reading was successful across this size range, however, standardized metrics were not collected (e.g., detection/reading time), precluding formal comparisons of efficiency among size classes.

Over the entire study period, we recaptured 57 individual bats (12 species) across 88 recapture events, given that some individuals were recaptured more than once (Table 2; Supplementary Table S2). The smallest recaptured individual had a forearm length of 31 mm (*Hsunycteris thomasi*), and the largest had a forearm length of 87.5 mm (*Phyllostomus hastatus*). All recaptured individuals that were expected to carry a functional p-Chip, based on complementary marks (shaved hair or wing biopsy), retained the tag, which remained fully functional.

In all recaptured individuals, the injection site was undetectable, with no visible scarring, inflammation, or other apparent adverse effects, including in individuals recaptured more than one year after tagging. During the first sampling sessions, we sometimes had difficulty visually locating the p-Chip immediately after injection and during some recapture events. Visual detectability of the p-Chip varied among species. In bats with dark or thick skin (e.g., *Phyllostomus* spp. and *Vampyrum spectrum*), the tag was not externally visible under ambient light and could be confused with natural pigmentation patterns, skin markings, or minor wounds. We later found that placing a red LED backlight beneath the wing caused the p-Chip to appear clearly as a black, opaque square, even in dark-skinned species (Figure 2; Video S2). This technique consistently enabled rapid visual detection and reading of the tag across all species, regardless of size or skin characteristics. Scanning time was reduced to a few seconds per individual (< 15 s; outer limit to reading a tag based on rough field estimates), and tags were typically read on the first attempt with the handheld reader. After implementing this technique, and as the handling team gained experience, all implanted p-Chips were successfully detected and scanned.

Notably, 11 individuals across six species were recaptured after more than 170 days from the marking date, including a notable recapture event of a female *Carollia brevicauda* captured more than two years after the marking date (859 days) (Table 2). The rest of individuals were recaptured within short periods (0–40 days) after the marking date (Table 2; Supplementary Table S2). Four individuals (3 species) were recaptured at distances over 1 km from previous capture locations, while others were always recaptured between 0 and 500 m from previous capture locations (Table 2; Supplementary Table S2).

Discussion

Previously, Seheult et al. (2024) tested p-Chips in captive *E. fuscus*, while Ngamprasertwong et al. (2022) used them to study roost fidelity in *Craseonycteris thonglongyai*, the smallest bat in the world. Our results provide the first evidence of their performance in free-ranging bats within a highly diverse Amazonian high-terrace forest. p-Chips were inserted and successfully read in the forearm of 31 bat species. The short-term functionality of the tags (up to 40 days) was confirmed in 41 individuals across nine species, while long-term functionality (more than 170 days) was confirmed in 16 individuals from six species (Table 1; Supplementary Table S2).

We demonstrate that inserting p-Chips in the forearm is feasible and effective. Although forearm implantation may reduce visual detectability in large, dark-skinned species, the use of red LED backlighting overcomes previously reported limitations in visual tag localization and enables reliable tag detection across all species. This approach expands the applicability of p-Chips across morphologically diverse bat taxa. After implementing pre-injection verification, we did not observe any flipped p-Chips in preloaded syringes, except possibly during the initial sessions before verification was applied. However, we do not rule out the possibility that tags may flip over time, as noted by Seheult et al. (2024). Although we did not quantitatively assess p-Chip performance across species, our observations suggest that, when the methods described here are followed, p-Chip functionality is broadly consistent across species within the range of forearm sizes evaluated. As with any marking technique, practice is required to achieve consistent successful application. Although the fine-gauge needle used for p-Chip marking allows all species to be tagged with minimal difficulty, handling and tagging very small species may be slightly more challenging. Nevertheless, we expect that training in this technique would be straightforward for new users when following our protocol.

Importantly, we did not detect any visible tissue damage or other adverse effects at the implantation site in any recaptured individuals, including those recaptured more than one year after tagging. Although our sampling design does not allow precise quantitative estimates of tag retention or loss in free-ranging bats, these observations suggest that the implantation protocol used here (Watsa et al., 2023) is unlikely to cause detectable morbidity or acute adverse effects associated with p-Chip application. Observations from Seheult et al. (2024) in captive bats further support that mortality or other adverse effects due to p-Chip insertion are highly improbable. Future work could assess tag loss rates in wild bats. Although tag loss appears low in captive bats, estimating loss in free-ranging individuals is challenging; targeted sampling at roosts with high site fidelity may be well suited for this purpose. In addition, consistent with that captive-bat study, we recommend that future evaluations

also include other marking methods (e.g., bands, PIT tags) to allow quantitative comparisons of efficiency.

Although the number of recaptured bats may appear low, recapture rates in the Amazon are commonly low (e.g., Tavares et al., 2017; Ramos et al., 2010; Sampaio et al., 2003), including at EBLA (Bravo et al., 2008). Comprehensive sampling in the Amazon is logistically challenging because much of the habitat within a given site is inaccessible. Even in areas with established trails, such as at EBLA, it is difficult to sample large areas simultaneously. Recapturing free-ranging bats is further complicated by the potential for long-distance movements; for example, *Artibeus lituratus* can travel up to 113 km (Arnone et al., 2016), and movement data for most species are scarce. Given these constraints, our recapture records across time and space support the effectiveness of p-Chips as a marking method. Several individuals were recaptured more than one year after marking (including one after two years), sometimes at the same site, whereas a few were recaptured at more distant sites within relatively short time intervals. Recaptures at the same site after more than a year may indicate roost or foraging-area fidelity, although our sampling design does not allow stronger inference. Together, these results highlight the potential value of p-Chips for large-scale mark-recapture programs across Amazonian bat communities, an approach that has likely been uncommon due to cost and feasibility constraints for some species. Future work could implement a systematic, long-term sampling design that periodically surveys specific areas. Priority sites could include spatially clustered, high-resource locations that attract bats from long distances (e.g., mammal clay licks) and major roost sites.

Standardized protocols are essential to advance research using this technique. In particular, consistent placement of p-Chips is critical to ensure reliable localization during recapture events, especially given the absence of visible external marks after healing. This standardization is also crucial for eventually applying p-Chips across broader geographic contexts and among multiple research teams. Our study contributes information on the long-term retention of p-Chips in free-ranging bats, the importance of proper insertion techniques, and the benefits of pre-injection confirmation and red light scanning to improve readability. These results suggest that p-Chips are an effective and minimally invasive method for longitudinal research on wild bats, offering a viable alternative to PIT tags, particularly for smaller species.

Acknowledgments

This work was funded by Field Projects International (FPI) and the San Diego Zoo Wildlife Alliance (SDZWA). The inspiration to work with p-Chips originated from the Pacific Pocket Mouse Program at the SDZWA, where their application demonstrated promising potential for small vertebrate

tracking. We extend our gratitude to the numerous volunteers and staff who contribute to FPI's annual research program; their dedication and effort were instrumental in making this study possible. We also acknowledge *Conservación Amazónica* - ACCA for maintaining the Los Amigos Biological Station, where fieldwork for this research was conducted.

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Table 1. Number of individuals per species tagged with p-Chips during the 2023 and 2024 sampling efforts at the Estación Biológica Los Amigos (Peru). Size categories were arbitrarily defined based on the average forearm length (FA) of the captured individuals in this study.

Size category	Species	2023	2024	2025
Small	*Carollia benkeithi*	3	8	12
(FA: < 36 mm; n = 69)	*Glossophaga soricina*			5
	Hsunycteris thomasi			1
	Mesophylla macconnelli		1	3
	Micronycteris microtis			1
	Micronycteris minuta		1	3
	Myotis nigricans			1
	Myotis riparius		3	8
	Rhinophylla pumilio	1	2	15
	Thyroptera tricolor			1
Medium	*Carollia brevicauda*	5	23	27
(FA: 36 – 55 mm; n = 127)	*Carollia perspicillata*	2	17	34
	Chiroderma trinitatum			1
	Dermanura anderseni		1	
	Dermanura gnoma		1	2
	Gardnerycteris crenulata		1	5
	Micronycteris hirsuta		1	
	Saccopteryx bilineata		1	
	Sturnira tildae			2
	Trinycteris nicefori			4
Large	*Artibeus lituratus*	1		2
(FA: 55 – 75 mm; n = 83)	*Artibeus obscurus*	4	12	5
	Artibeus planirostris	2		11
	Desmodus rotundus			1
	Lophostoma silvicola		8	8
	Phyllostomus elongatus		5	14
	Platyrrhinus infuscus			1
	Tonatia maresi		3	3
	Trachops cirrhosus		1	2
Very large	*Phyllostomus hastatus*	6	7	7
(FA: > 75 mm; n = 21)	*Vampyrum spectrum*		1	

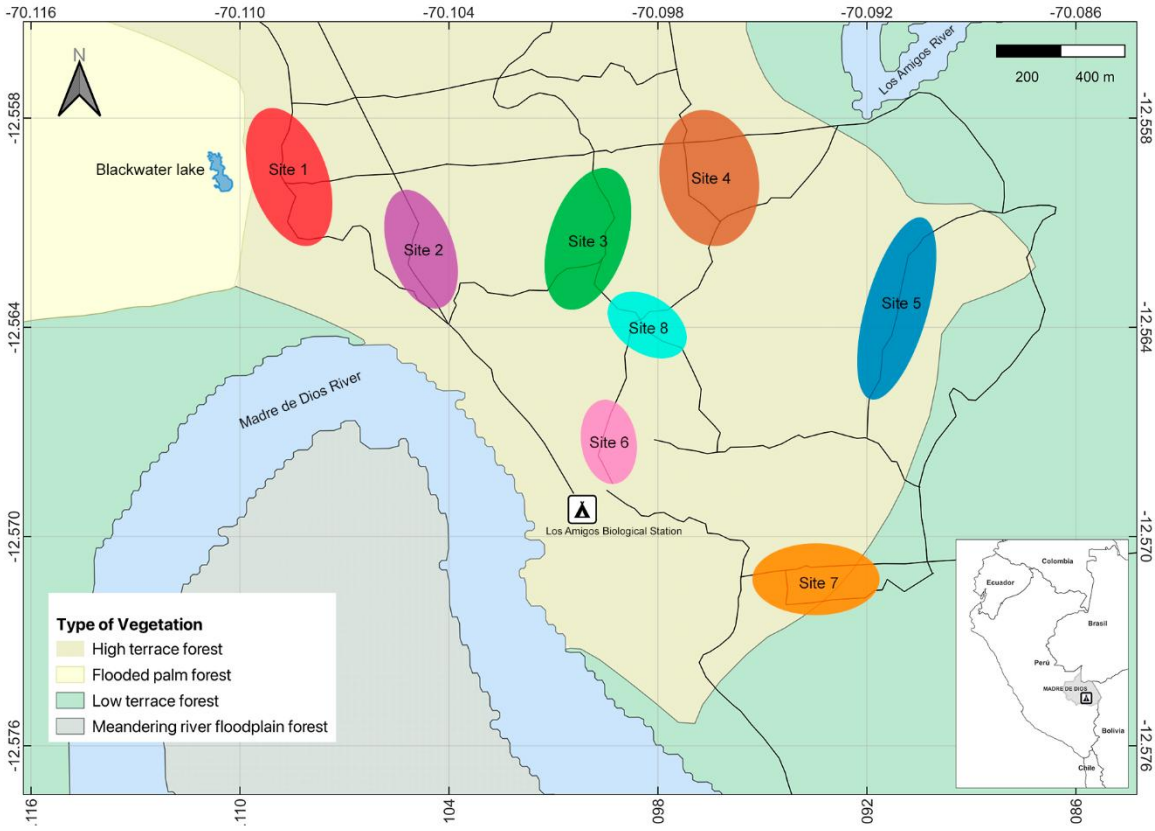
Table 2. Bats marked with p-Chips and recaptured at Estación Biológica Los Amigos, Peru. Only the individuals with the longest intervals and greatest distances between initial capture/marking and subsequent recapture(s) locations are shown. Each row corresponds to a unique individual. Full detailed results are available in Supplementary Table S2. For each individual, the table lists the marking date, the number of recapture events, the maximum number of days from marking to the last recapture, and the maximum distance recorded among recapture events. "Recapture site" indicates the site of the farthest recapture. Abbreviations: a, adult; j, juvenile; p, pregnant. *Captured as juvenile and recaptured as adult; †captured as adult non-pregnant and recaptured pregnant; ‡captured and recaptured as pregnant.

Bat individual	Date marking	Max. days to recapture	Max. distance traveled	Recapture times	Marking site	Recapture site
Carollia brevicauda ♀j,a*	21/07/2023	344	1014	1	3	1
Artibeus obscurus ♂a	21/07/2023	334	234	1	3	3
Carollia benkeithi ♀a	26/07/2023	334	22	1	2	2
Carollia brevicauda ♀a	03/08/2023	859	192	1	2	2
Phyllostomus elongatus ♂a	11/06/2024	32	194	1	4	4
Carollia brevicauda ♂a	13/06/2024	30	319	1	4	4
Tonatia maresi ♂a	14/06/2024	366	471	1	4	8
Carollia brevicauda ♀a,p†	17/06/2024	345	90	3	4	4
Carollia brevicauda ♀a	18/06/2024	345	131	1	4	4
Artibeus obscurus ♂a	20/06/2024	17	1138	1	3	7
Carollia brevicauda ♂a	20/06/2024	355	160	2	3	3
Carollia brevicauda ♀a	20/06/2024	17	1190	2	3	7
Carollia brevicauda ♀a	20/06/2024	360	217	3	3	8
Lophostoma silvicola ♂a	20/06/2024	374	303	1	3	8
Lophostoma silvicola ♀a	24/06/2024	350	286	2	3	3
Carollia benkeithi ♀a	25/06/2024	343	74	3	2	2
Carollia benkeithi ♂a	25/06/2024	343	160	3	2	2
Carollia perspicillata ♀a	25/06/2024	3	435	1	2	1
Carollia brevicauda ♂a	08/07/2024	542	468	2	6	8
Carollia perspicillata ♀a,p	29/05/2025	17	458	1	4	8
Carollia perspicillata ♂a	30/05/2025	18	443	2	4	8
Carollia perspicillata ♂a	30/05/2025	33	468	1	4	3
Carollia perspicillata ♀a	30/05/2025	20	497	2	4	8
Carollia brevicauda ♂a	04/06/2025	28	365	1	2	3
Carollia brevicauda ♀a,p‡	10/06/2025	176	421	8	3	8
Carollia brevicauda ♂a	11/06/2025	27	327	2	3	8
Carollia benkeithi ♀a	13/06/2025	25	360	4	3	8
Phyllostomus elongatus ♀a	16/06/2025	32	1102	1	8	1
Phyllostomus elongatus ♀a	19/06/2025	171	287	1	8	3

Figure 1. Bat capture sites at the Estación Biológica Los Amigos (Peru). The vegetation types follow MINAM (2015). Details on the days evaluated at each site are in the Supplementary Table S2.

Figure 2. Visualization of p-Chips implanted in the middle of the forearm of free-ranging bats at the Estación Biológica Los Amigos (Peru). Each column corresponds to a different individual, with the top and bottom images showing the same individual under natural light and red LED backlighting, respectively. Arrows indicate the location of the p-Chip when visually detectable. Scale bars = 5 mm. *Carollia brevicauda* (A, B); *Carollia benkeithi* (C, D); *Lophostoma silvicola* (E, F); *Artibeus obscurus* (G, H); *Phyllostomus hastatus* (I, J). Video demonstration of p-Chip visualization and reading is available in Video S1.

434 **Figure 1**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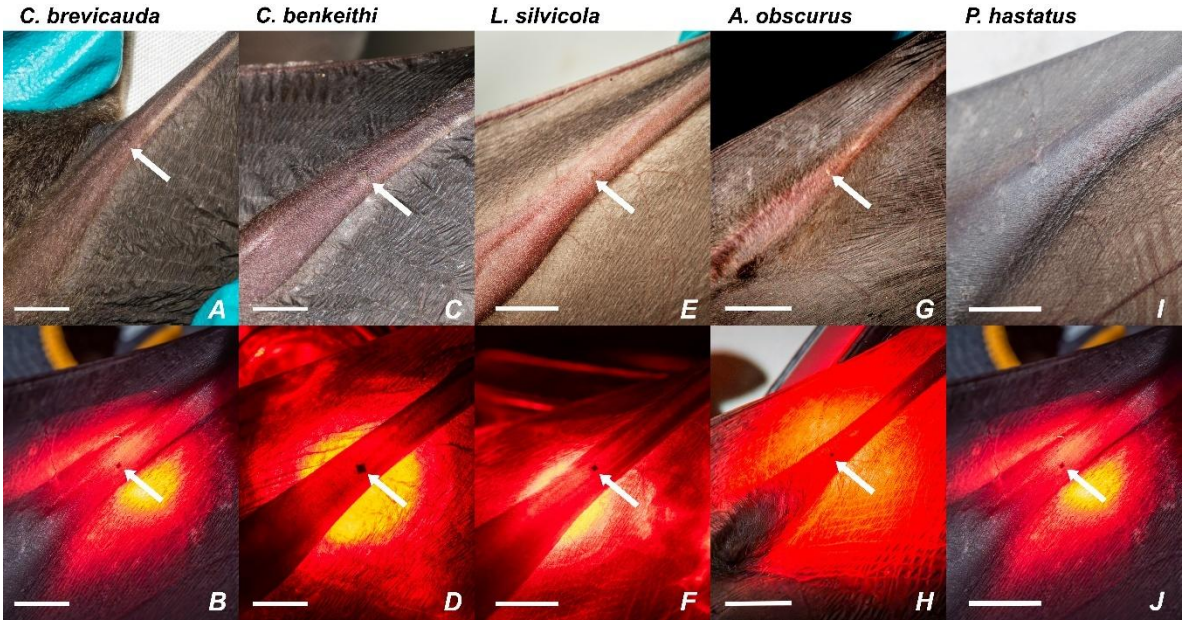
-70.110
-70.104
-70.098
-70.092
-70.086
-12.558
-12.564
-12.570
-12.576
N
200
400 m
Los Amigos River
Blackwater lake
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Site 7
Site 8
Madre de Dios River
Los Amigos Biological Station
Type of Vegetation
High terrace forest
Flooded palm forest
Low terrace forest
Meandering river floodplain forest
Colombia
Ecuador
Brasil
Perú
MADRE DE DIOS
Bolivia
Chile

435 **Figure 2**

436



Video S1. Demonstration of p-chip placement and reading in a free-ranging Phyllostomus elongatus at the Estación Biológica Los Amigos (Peru). Video was too heavy to upload in the platform. The image uploaded are just previews of the video. During the review process, it will be available at this link: https://drive.google.com/file/d/1pIHgsqXfBpOb7tb8dfRu0pJMNg88YSR5/view?usp=sharing

Table S2 (excel file). Details of bats marked with p-Chips and recaptured at Estación Biológica Los Amigos, Peru, including the complete sampling schedule since p-Chip tagging began. Each row corresponds to a unique individual. No active marking was conducted at sites 1, 5, and 7. The first row in the timeline indicates the year (23, 2023; 24, 2024; 25, 2025), while the second row represents the site (Figure 1 of the main manuscript). For each individual, the table lists the marking date, the number of recapture events, the maximum number of days from marking to the last recapture, and the maximum distance recorded among recapture events. Cells labeled "C" indicate the initial capture/marking date, and "R" indicates a recapture event on that date. In some instances, individuals were recaptured twice on the same day, indicated by "2." Abbreviations: a, adult; j, juvenile; l, lactating; p, pregnant. *Captured as juvenile and recaptured as adult; †captured as an adult non-pregnant individual and recaptured pregnant; ‡captured as pregnant and recaptured pregnant. During the review process, the excel file will be available at this link: https://docs.google.com/spreadsheets/d/1SRwH_ru278LL04s85BLTbRgazSPglDxd/edit?usp=sharing&ouid=101859936044648558134&rtpof=true&sd=true