

**1 Demography of the understory herb *Heliconia acuminata* (Heliconiaceae) in an
2 experimentally fragmented tropical landscape**

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19 Open Research: The complete data set described here is available as Supporting Information
20 at: [ESA *url to be added*] and at the Dryad Digital Repository:
21 <https://doi.org/10.5061/dryad.stqjq2c8d>. The version of the code used to review, correct,
22 and prepare this archive (v1.0.0) is available at Zenodo:
23 <https://doi.org/10.5281/zenodo.8284379>. The code used to prepare this manuscript,
24 including statistical summaries reported in the text, tables, and figures, has also been
25 archived at Zenodo [*url to be added*]. Post-publication updates to code and data sets, along
26 with other project-related information, can be found at Github:
27 <https://github.com/BrunaLab/HeliconiaSurveys>.

METADATA

29 **I. CLASS I. Data Set Descriptors**

30 **A. Data set identity:** Demographic data from populations of the understory herb
31 *Heliconia acuminata* (Heliconiaceae) in an experimentally fragmented tropical landscape
32 (1998-2009).

33 **B. Data set identification code:**

- 34 1. Data set File 1: HDP_plots.csv
35 2. Data set File 2: HDP_survey.csv

36 **C. Data set description:**

37 1. **Originators:** Emilio M. Bruna, Department of Wildlife Ecology and Conservation,
38 University of Florida, PO Box 110430, Gainesville, FL 32611-0430, USA and Center for
39 Latin American Studies, University of Florida, PO Box 115530, Gainesville, FL 32611,
40 USA.

41 2. **Abstract:** Habitat fragmentation remains a major focus of research by ecologists
42 decades after being put forward as a threat to the integrity of ecosystems. While
43 studies have documented myriad biotic changes in fragmented landscapes, including
44 the local extinction of species from fragments, the demographic mechanisms underlying
45 these extinctions are rarely known. However, many of them – especially in lowland
46 tropical forests – are thought to be driven by one of two mechanisms: (1) reduced
47 recruitment in fragments resulting from changes in the diversity or abundance of
48 pollinators and seed dispersers or (2) increased rates of individual mortality in
49 fragments due to dramatically altered abiotic conditions, especially near fragment
50 edges. Unfortunately, there have been few tests of these potential mechanisms due to
51 the paucity of long-term and comprehensive demographic data collected in both forest

fragments and continuous forest sites. Here we report 11 years (1998-2009) of demographic data from populations of the Amazonian understory herb *Heliconia acuminata* (LC Rich.) found at Brazil's Biological Dynamics of Forest Fragments Project (BDFFP). The resulting data set comprises >66000 plant×year records of 8586 plants, including 3464 seedlings that became established after the initial census. Seven populations were in experimentally isolated fragments (one in each of four 1-ha fragments and one in each of three 10-ha fragments), with the remaining six populations in continuous forest. Each population was in a 50 × 100m permanent plot, with the distance between plots ranging from 500 m-60 km. The plants in each plot were censused annually, at which time we recorded, identified, marked, and measured new seedlings, identified any previously marked plants that died, and recorded the size of surviving individuals. Each plot was also surveyed 4-5 times during the flowering season to identify reproductive plants and record the number of inflorescences each produced. These data have been used to investigate topics ranging from the way fragmentation-related reductions in germination influence population dynamics to statistical methods for analyzing reproductive rates. This breadth of prior use reflects the value of these data to future researchers. In addition to analyses of plant responses to habitat fragmentation, these data can be used to address fundamental questions in plant demography, the evolutionary ecology of tropical plants, and for developing and testing demographic models and tools. Though we welcome opportunities to collaborate with interested users, there are no restrictions on the use this data set. However, we do request that those using the data for teaching or research inform us of how they are doing so and cite this paper and the data archive when appropriate. Any publication using the data must also include a BDFFP Technical Series Number in the Acknowledgments. Authors can request this series number upon the acceptance of their article by contacting the BDFFP's Scientific Coordinator or E. M. Bruna.

D. Key words: Amazon, Brazil, deforestation, demography, edge effects, forest

79 fragments, habitat fragmentation, integral projection models, matrix models, population
80 dynamics, vital rates.

81 **CLASS II. RESEARCH ORIGIN DESCRIPTORS**

82 **A. Overall project description:**

83 1. **Identity:** The *Heliconia* Demography Project

84 2. **Originators:** Emilio M. Bruna, W. John Kress, and María Uriarte

85 3. **Period of study:** 1998-2009

86 4. **Objectives:** Habitat fragmentation remains a major focus of research by ecologists
87 (Didham et al. 2012, Haddad et al. 2015, Brudvig et al. 2017, Resasco et al. 2017,
88 Fletcher et al. 2018) decades after it was first put forward as a threat to the integrity
89 of ecosystems (Harris 1984, Wilcove et al. 1986). Studies have documented myriad
90 biotic changes in fragmented landscapes, including the local extinction of species from
91 fragments (Harrison and Bruna 1999, Laurance et al. 2011). The demographic
92 mechanisms underlying these extinctions are rarely known (Bruna et al. 2009).
93 However, many of them – especially in lowland tropical forests – are thought to be
94 driven by one of two mechanisms: (1) reduced recruitment in fragments resulting from
95 changes in the diversity or abundance of specialized pollinators and seed dispersers
96 (Murcia 1996, Silva and Tabarelli 2000), or (2) increased rates of individual mortality
97 in fragments (Laurance et al. 1998, Zartman et al. 2015) due to dramatically altered
98 abiotic conditions, especially near fragment edges (reviewed in Broadbent et al. 2008).
99 Unfortunately, tests of these potential mechanisms remain limited due to the paucity of
100 long-term demographic data collected in both forest fragments and continuous forest
sites (Bruna et al. 2009).

102 Most studies investigating the effects of forest fragmentation on tropical plants

103 focus on trees (Cordeiro et al. 2009, Jurinitz et al. 2013, Zambrano and
104 Salguero-Gómez 2014), in part because they are major reservoirs of carbon (Slik
105 et al. 2010, Lasky et al. 2014). However, herbaceous species can comprise up to
106 30% of the plant species in lowland tropical forests (Gentry and Emmons 1987,
107 Ribeiro et al. 2010, Iannone and Vargas 2022, Spicer et al. 2022), where they are
108 habitat and food for myriad animal taxa as well as economically and culturally
109 important non-timber forest products (Nakazono et al. 2004, Athayde et al.
110 2006). Despite their biocultural importance, however, the way in which habitat
111 fragmentation and other global change phenomena influences the population
112 dynamics of tropical understory plants remains conspicuously understudied
113 (Bruna et al. 2009).

114 The *Heliconia* Demography Project (HDP) was established to address the lack of
115 data on the demography of understory plants in fragmented tropical landscapes.
116 The core of the HDP is annual censuses of thirteen populations of *Heliconia*
117 *acuminata* located in either continuous forest or experimentally isolated forest
118 fragments at Brazil's Biological Dynamics of Forest Fragments Project
119 (Laurance et al. 2011) The primary purpose behind their initial collection was to
120 parameterize size-structured demographic models (Caswell 2000, Ellner and Rees
121 2006) with which to (1) compare the demography and population dynamics of *H.*
122 *acuminata* populations in fragments and continuous forest, and (2) test the
123 hypothesis that reductions in seedling establishment in forest fragments would
124 lead to population declines. Simulations suggested extreme reductions in
125 recruitment were necessary for population declines (Bruna 2003), and empirical
126 estimates of seedling establishment in fragments were frequently below these
127 thresholds (Bruna 2002). Other studies demonstrated that the growth rates of
128 plants in fragments, where abiotic conditions are often(Broadbent et al. 2008)
129 severely altered, are much lower than in continuous forest (Bruna et al. 2002).

130 Chronically reduced growth (Gagnon et al. 2011), especially of large plants, is a
131 primary contributor to lower population growth rates in forest fragments (Bruna
132 and Oli 2005). More recent projects using the data set described have has, for
133 example, assessed the effects of local environmental conditions, disperser diversity,
134 and disperser behavior on safe-site vs. seed-limitation (Uriarte et al. 2010, 2011),
135 quantified population genetic structure (Côrtes et al. 2013), and compared
136 statistical methods for modeling reproductive rates (Brooks et al. 2019).

137 **5. Abstract:** Habitat fragmentation remains a major focus of research by ecologists
138 decades after being put forward as a threat to the integrity of ecosystems. While
139 studies have documented myriad biotic changes in fragmented landscapes, including
140 the local extinction of species from fragments, the demographic mechanisms underlying
141 these extinctions are rarely known. However, many of them – especially in lowland
142 tropical forests – are thought to be driven by one of two mechanisms: (1) reduced
143 recruitment in fragments resulting from changes in the diversity or abundance of
144 pollinators and seed dispersers or (2) increased rates of individual mortality in
145 fragments due to dramatically altered abiotic conditions, especially near fragment
146 edges. Unfortunately, there have been few tests of these potential mechanisms due to
147 the paucity of long-term and comprehensive demographic data collected in both forest
148 fragments and continuous forest sites. Here we report 11 years (1998-2009) of
149 demographic data from populations of the Amazonian understory herb *Heliconia*
150 *acuminata* (LC Rich.) found at Brazil's Biological Dynamics of Forest Fragments
151 Project (BDFFP). The resulting data set comprises >66000 plant×year records of 8586
152 plants, including 3464 seedlings that became established after the initial census. Seven
153 populations were in experimentally isolated fragments (one in each of four 1-ha
154 fragments and one in each of three 10-ha fragments), with the remaining six
155 populations in continuous forest. Each population was in a 50 × 100m permanent plot,
156 with the distance between plots ranging from 500 m-60 km. The plants in each plot

were censused annually, at which time we recorded, identified, marked, and measured new seedlings, identified any previously marked plants that died, and recorded the size of surviving individuals. Each plot was also surveyed 4-5 times during the flowering season to identify reproductive plants and record the number of inflorescences each produced. These data have been used to investigate topics ranging from the way fragmentation-related reductions in germination influence population dynamics to statistical methods for analyzing reproductive rates. This breadth of prior use reflects the value of these data to future researchers. In addition to analyses of plant responses to habitat fragmentation, these data can be used to address fundamental questions in plant demography, the evolutionary ecology of tropical plants, and for developing and testing demographic models and tools. Though we welcome opportunities to collaborate with interested users, there are no restrictions on the use this data set. However, we do request that those using the data for teaching or research inform us of how they are doing so and cite this paper and the data archive when appropriate. Any publication using the data must also include a BDFFP Technical Series Number in the Acknowledgments. Authors can request this number upon the acceptance of their article by contacting the BDFFP's Scientific Coordinator or E. M. Bruna.

6. Sources of funding: The initial establishment of plots and the 1998-2002 surveys were supported by grants and fellowships to E. M. Bruna from the Smithsonian Institution (Graduate Student Research Award), the University of California, Davis (Center for Population Biology Graduate Research Grant, M. E. Mathias Graduate Research Grant), the Biological Dynamics of Forest Fragments Project (Graduate Student Logistics Grant), the National Science Foundation (OISE Dissertation Improvement Grant 9806351, Minority Predoctoral Research Fellowship 0109226) and the Ford Foundation (Dissertation Year Fellowship). The 2001-2005 surveys were supported a grant from the National Science Foundation to E. M. Bruna (0309819). The 2006-2009 surveys were supported by grants from the National Science Foundation

184 to E. M. Bruna (0614149) and María Uriarte (0614339). Subsequent analyses and the
185 preparation of these data for archiving were supported by a grant from the National
186 Science Foundation (1948607).

187 **B. Subproject description**

188 **1. Site description**

189 a. **Site type:** Lowland tropical forest

190 b. **Geography:** The data were collected at the Biological Dynamics of Forest
191 Fragments Project (BDFFP, 2°30'S, 60°W), a 1000-km mosaic of lowland
192 forest, forest fragments, secondary forests, and pastures located
193 approximately 70 km north of Manaus, Amazonas, Brazil (Fig. 1).

194 c. **Habitat:** The BDFFP is dominated by tropical evergreen lowland forest
195 (i.e., ‘tropical moist forest’, *sensu* Holdridge (1967). The forest canopy at
196 the sites is ~35–40 m tall, with emergent trees of up to ~45 m
197 (Rankin-de-Mérona et al. 1992). The tree community at the BDFFP is
198 highly diverse: ~1300 species total (Laurance 2001), with as many as 280
199 tree species ha⁻¹ (Oliveira and Mori 1999). The understory is dominated by
200 stemless palms (Scariot 1999). All HDP plots are located in *terra-firme* (i.e.,
201 non-flooded) forest and none are bisected by streams.

202 d. **Geology:** Soils in the sites are nutrient-poor xanthic ferralsols, known as
203 yellow latosols in the Brazilian soil classification system. Despite their high
204 clay content they have poor water-retention capacity (Fearnside and
205 Leal-Filho 2001). The often rugged topography at the BDFFP ranges in
206 elevation from 50-150 m elevation (Gascon and Bierregaard 2001).

207 e. **Watersheds:** The BDFFP landscape includes catchments of the Urubu,

208 Cuieiras, and Preto da Eva rivers (Nessimian et al. 2008).

209 f. **Site history:** A complete history of the BDFFP can be found in Gascon
210 and Bierregaard (2001) and Bierregaard et al. (2002). Briefly, the BDFFP
211 reserves were established on three cattle ranches. Fragments were isolated
212 between 1980-1984 by felling the trees surrounding the patch of forest to be
213 isolated (Lovejoy et al. 1986). Fragment reserves were fenced to prevent the
214 incursion of cattle from the surrounding pastures, and the vegetation in a
215 100 m strip around each fragment is mechanically cleared every 5-6 years to
216 ensure fragments remain isolated (Gascon and Bierregaard 2001). The
217 structure and species composition of the secondary growth that surrounds a
218 fragment, which is strongly dependent on whether fire was used to clear
219 land prior to planting pasture grasses (Mesquita et al. 2001), can have large
220 effects on the species composition, ecological processes, and abiotic
221 conditions in fragments (reviewed in Laurance et al. 2002, 2011). The
222 BDFFP is currently administered collaboratively by the Smithsonian
223 Tropical Research Institute and Brazil's Instituto Nacional de Pesquisas da
224 Amazônia (INPA).

225 g. **Climate:** Mean annual temperature at the site is 26°C (range 19-39°C).
226 Annual rainfall ranges from 1900-2300 mm (Scott et al. 2022), with a
227 pronounced dry season from June-December in which there is <100 mm
228 rain per month.

229 2. Sampling Design

230 a. **Design characteristics:** Annual demographic surveys of *Heliconia*
231 *acuminata* populations were carried out in 13 permanent plots distributed
232 across the BDFFP landscape (Bruna and Kress 2002). Six plots are located

233 in continuous forest, four in 1-ha fragments, and three in 10-ha fragments
234 (one plot per fragment; Fig. 1).

235 *Heliconia acuminata* (Heliconiaceae) is a perennial, self-incompatible
236 monocot native to Amazonia (Kress 1990) and widely distributed
237 throughout the Amazon basin (Kress 1990). Although many species of
238 *Heliconia* grow in large aggregations on roadsides, gaps, and in other
239 disturbed habitats, others, including *H. acuminata*, grow primarily in
240 the shaded forest understory (Kress 1983). *Heliconia acuminata* is the
241 most abundant understory herb throughout most of the BDFFP
242 (Ribeiro et al. 2010); the other two *Heliconia* species found in the
243 BDFFP reserves are either very rare (*H. latispatha*) or restricted to
244 saturated soils adjacent to streams (*H. tarumaensis*).

245 Each *Heliconia acuminata* has a basal rhizome from which erect
246 vegetative shoots with broad leaves emerge. Plants grow very slowly –
247 an analysis based on the 1998–2006 survey data found that the average
248 change in shoot number was < 10% per year (averaged across all
249 plants), with negative growth rates (i.e., plants lost shoots) in three of
250 the years (Gagnon et al. 2011). The slow growth rate of *H. acuminata*
251 observed in demographic plots is similar to that observed in
252 experimental transplants (Bruna and Ribeiro 2005a). Stem loss is not
253 the result of herbivory. The primary foliar herbivores of *Heliconia*
254 species are Hispine beetles, whose larvae and adults perforate or scrape
255 the surface of unrolled immature leaves or feed on inflorescences
256 (Strong 1977). The beetle species associated with *H. acuminata* is
257 *Cephaloleia nigriceps* Baly (Staines and Garcia-Robledo 2014); it does
258 little damage to most leaves but can cause extensive damage to bracts,

259 flowers, and developing ovaries.

260 *Heliconia acuminata* flowers during the rainy season, and the likelihood
261 an individual will flower is strongly size size-dependent (Bruna 2002,
262 Bruna and Kress 2002 fig. 2). Reproductive plants produce one or
263 more flowering shoots, each of which terminates in single inflorescence
264 comprising red bracts (i.e., modified leaves) subtending white flowers.
265 Reproductive plants can produce multiple flowering shoots, but 74% of
266 the reproductive plants recorded in our demographic suveys produced
267 a single inflorescence (range = 1-7). Flowers remain open for a single
268 day, after which the style and perianth abscise and fall from the plant.
269 In 1998 we documented the phenology of N = 112 flowering plants
270 found along the trails of BDFFP Reserve #1501 (Bruna 2021) and
271 found that they produced an average of 20.62 ± 8.61 SD flowers each
272 (range: 0-48). Flowers remain open for a single day, after which the
273 style and perianth abscise and fall from the plant. Pollen transfer
274 experiments indicate self-compatibility is extremely low (E. M. Bruna
275 and M. R. Darrigo, *unpubl. data*).

276 *Heliconia* in the Americas are hummingbird-pollinated. In our field
277 sites *H. acuminata* is pollinated by the ‘traplining’ hummingbirds
278 *Phaeothornis superciliosus* and *P. bourcieri* (Stouffer and Bierregaard
279 1995, 1996), whose visitation rates to flowers are extremely low (<1
280 visit hour⁻¹, Bruna et al. 2004). This, coupled with damage by *C.*
281 *nigriceps* to the developing ovaries, results in low rates of fruit
282 production (Bruna and Kress 2002). A successfully pollinated flower
283 produces a fleshy blue fruit with up to 3 seeds (average = 1.90 ± 0.81
284 SD, N = 873 fruits, Bruna 2014).

285 *Heliconia* fruits are consumed by frugivorous birds, which then disperse
286 the seeds. In our study sites the primary dispersers of *Heliconia*
287 *acuminata* seeds are several species of manakin (*Pipra erythrocephala*,
288 *P. pipra*, *Lepidothrix serena*, *Schiffornis turdinus*, *Corapipo gutturalis*)
289 and the White-necked Thrush (*Turdus albicollis*) (Uriarte et al. 2011).
290 Seeds germinate 6–7 months after they are dispersed, which coincides
291 with the onset of the rainy season (Bruna 1999, 2002). Rates of seed
292 germination and seedling establishment in field experiments were
293 generally low, but they were significantly higher in continuous forest
294 than forest fragments (Bruna 1999, 2002). Experiments also indicate
295 that post-dispersal seed predation is negligible. While some seeds did
296 germinate >1 year after experimental dispersal, this was generally rare
297 – especially in fragments. These results are consistent with others
298 suggesting long-lived seed banks are rare in lowland tropical forests
299 (Vázquez-Yanes and Orozco-Segovia 1993), as well as observations that
300 understory *Heliconia* species recruit primarily via seeds and not clonal
301 spread (Stiles 1975).

302 *Heliconia acuminata* individuals are easily collected in the field and can
303 be grown in pots or transplanted directly into the ground (Bruna et al.
304 2002, Bruna and Ribeiro 2005a). Plants can be readily propagated for
305 use in transplant experiments (e.g., Bruna and Andrade 2011) by
306 segmenting the rhizome (Berry and Kress 1991). Seeds collected from
307 ripe fruits and treated using protocols described in Bruna (2002) can
308 be stored for weeks for use in experiments (e.g., Bruna 2002, Bruna
309 and Ribeiro 2005b) and they have high germination rates in field shade
310 houses. Finally, plants from the demographic surveys were used to
311 develop a library of microsatellite markers (Côrtes et al. 2009).

312 b. **Permanent Plots:** Each demographic plot is 50×100 m and is subdivided
313 into 50 contiguous subplots of 10×10 m to facilitate the surveys. Plots in
314 1-ha fragments were established in a randomly selected half of the fragment
315 (Fig. 3), plots in 10-ha fragments are located in the center of the fragment
316 (Fig. 4), and plots in continuous forest are located 500-4000 m from any
317 borders with cattle pastures or secondary forest (Fig. 5). The plots furthest
318 apart are from each other are separated by ~70 km.

319 In January 1997 we established four demographic plots in fragments
320 (FF-3, FF-4, FF-6, FF-7) and one in a continuous forest (CF 3) to
321 refine census protocols and sample plants for genetic analyses. The
322 remaining three plots in forest fragments and two additional plots in
323 Contiuous Forest (CF-1, CF-2) were established in January and
324 February 1998, at which time a complete census was conducted in the
325 ten plots established to date. To find and mark the plants, a team of
326 2-3 people walked slowly through each subplot to locate any *Heliconia*
327 *acuminata*, which they then marked with a wooden stake to which was
328 attached an individually numbered aluminum tag. They also recorded
329 (1) how many vegetative shoots the plant had, and (2) its height,
330 measured as the distance from the ground to the top of the tallest leaf
331 (rounded to the nearest cm). Both of these size metrics are
332 significantly correlated with the total leaf-area of a plant (shoots-leaf
333 area: $\rho = 0.59$, $p < 0.0001$; height-leaf area: $\rho = 0.49$, $p < 0.0001$).
334 Finally, in November 1998 we established the final three plots in
335 Continuouus Forest (CF-4, CF-5, CF-6) and censused them as above.

336 c. **Frequency of Data Collection:** Demographic surveys were conducted
337 annually. Seedling establishment coincides with the onset of the rainy

338 season, which is typically in late November or early December. We therefore
339 began to census plots in late January and typically completed the survey by
340 mid-February. The exception was the three Continuous Forest plots
341 established in November 1998 – after being censused in November 1999,
342 they were censused in January from 2001 forward.

343 Regular visits were made to all 13 plots throughout the rainy season to
344 identify any reproductive individuals and record the number of
345 flowering shoots (i.e., inflorescences) that they produced.

346 3. Research Methods

347 a. **Demographic Surveys:** During each census team members recorded
348 which plants died, the size (i.e., height and number of shoots) of all
349 surviving plants, and the size of all new seedlings, which were also marked
350 with a numbered tag. Survey team members also noted any new canopy
351 gaps created by fallen trees or limbs, estimated the proportion of any subplot
352 that was affected by a treefall, and recorded if plants were under treefalls or
353 damaged by fallen branches or palm fronds. These treefall records
354 (`treefall_impacts.csv` and `subplot_treefalls.csv`) are in the
355 `data/survey_clean` subfolder of the HDP Repository
356 (<https://github.com/BrunaLab/HeliconiaSurveys>).

357 b. **Taxonomy and systematics:** *Heliconia* is the only genus in the family
358 Heliconiaceae. This family is distinguished from the others in the order
359 Zingiberales by having inverted flowers, a single staminode, and drupaceous
360 fruits (Kress 1990). It is estimated that there are 200-250 species of
361 *Heliconia*, almost all of which are native to the Neotropics. *Heliconia*
362 *acuminata* L. C. (Rich.) (Richard 1831) is one of the approximately 20

363 *Heliconia* species found in the Brazilian Amazon (Kress 1990). We
364 deposited voucher specimens of *H. acuminata* collected in areas adjacent to
365 demographic plots at the herbaria of the Instituto Nacional de Pesquisas da
366 Amazônia (Accession Numbers INPA 189569-189573) and the University of
367 California, Davis (Accession Numbers DAV 69391-69396).

368 **4. Project personnel:** In addition to the Project Originators, other key personnel
369 include the Project Managers that were responsible for coordinating the annual
370 censuses and other field activities, BDFFP Technicians (“*Mateiros*”) that assisted with
371 data collection and provided logistical support in the field, and undergraduate and
372 postgraduate field assistants hired to assist with the surveys.

373 a. **Project Managers:** Maria Rosa Darrigo (2002-2003), Cris Follman
374 Jurinitz (2003), Simone Benedet (2004), Maria Beatriz Nogueira (2005),
375 Paulo Rubim (2006-2012)

376 b. **BDFFP Technicians:** Osmaildo Ferreira da Silva, Francisco Marques,
377 Alaercio Marajó dos Reis, João de Deus Fragata, Romeu Cardoso.

378 c. **Undergraduate & Postgraduate Field Assistants:** Olavo Nardy
379 (2000), Obed Garcia (2001), Sylvia Heredia (2001-2002), Maria Beatriz
380 Nogueira (2002), Cris Follman Jurinitz (2003), David M. Lapola (2003),
381 Denise Cruz (2003), Cristina Escate (2004), Bruno Turbiani (2005),
382 Elisabete Marques da Costa (2006), Wesley Dátillo da Cruz (2007),
383 Jefferson José Valsko da Silva (2007), Tony Vizcarra Bentos (2007).

384 **CLASS III. DATA SET STATUS AND ACCESSIBILITY**

385 **A. Status**

386 **1. Latest updates:**

- 387 a. File 1 (`HDP_plots.csv`): 2023-08-25
388 b. File 2 (`HDP_survey.csv`): 2023-08-25

389 **2. Latest archive date:** 25 August 2023

390 **3. Metadata status:** Complete (last update: 2023-08-25)

391 **4. Data verification:** An extensive review of the data was conducted in preparation for
392 archiving. We began by generating a list of potential anomalies that could indicate
393 errors (e.g. extremely large changes in size from one year to the next, plants marked as
394 dead that had subsequent measurements), and then wrote code to search for these
395 anomalies using the R statistical programming language (R Core Development Team
396 2014). We also used the `pointblank` library (Iannone and Vargas 2022) to identify
397 cases in the data set for review and validation. All records flagged were evaluated by E.
398 M. Bruna by checking the values in the electronic records against the original data
399 sheets. Corrections to the data set were made using R scripts; the code documenting
400 and implementing these changes is archived at Zenodo (Bruna and Scott 2023).
401 Questions regarding the data set or code should be posted as `Issues` on the HDP
402 Repository (<https://github.com/BrunaLab/HeliconiaSurveys/issues>) or referred to E.
403 M. Bruna, who will investigate and update the database or code as needed. Summaries
404 of any post-publication updates will be posted to the `NEWS.md` file of the HDP Github
405 Repository (<https://github.com/BrunaLab/HeliconiaSurveys>), with revised data sets
406 assigned new version numbers based on the ‘Frictionless Data’ guidelines
407 (<https://frictionlessdata.io/specs/patterns/>). This will allow users to reference the
408 version of the data used in their analyses to ensure their reproducibility (reviewed in
409 Yenni et al. 2019).

410 **B. Accessibility**

411 **1. Storage location and medium:** The data described here are available as Supporting

412 Information at [ESA url to be added] and have been archived at the Dryad Digital
413 Repository (Bruna et al. 2023). The version of the code used to review, correct, and
414 prepare this archive is available at Zenodo (Bruna and Scott 2023). The code used to
415 prepare this manuscript, including statistical summaries reported in the text, tables,
416 and figures, has also been archived at Zenodo [url to be added]. Post-publication
417 updates to code and the data sets, along with other project-related information, can be
418 found in the HDP Github Repository
419 (<https://github.com/BrunaLab/HeliconiaSurveys>).

420 **2. Contact person:** Emilio M. Bruna, Department of Wildlife Ecology and
421 Conservation, Box 110430, Gainesville, FL 32611 USA. Phone: (352) 846-0634. Email:
422 embruna@ufl.edu

423 **3. Copyright restrictions:** None

424 **4. Proprietary restrictions:** None.

425 a. **Conditions of Reuse:** Though we welcome opportunities to collaborate
426 with interested users, there are no restrictions on the use this data set.
427 However, any publication using data collected at the BDFFP – including
428 this data set – must include a BDFFP Technical Series Number in the
429 Acknowledgments. Authors can request this series number upon the
430 acceptance of their article by contacting the BDFFP’s Scientific
431 Coordinator (pdbff@inpa.gov.br) or E. M. Bruna (embruna@ufl.edu).

432 b. **Citation:** Authors of any publications or products using these data should
433 cite both this data paper and the Dryad data archive (Bruna et al. 2023).
434 We also request that they provide E. M. Bruna a copy of their article upon
435 acceptance, which allows us to track the data set’s usage, inform users of
436 any corrections or updates, report articles using the data to the funding

437 agencies that provided support, and document the different ways in which
438 the scientific community uses the data.

439 c. **Disclaimers:** While the data are provided in good faith and are accurate
440 to the best of our knowledge, they are provided “as is”. We do not assume
441 any legal liability or responsibility for their accuracy, completeness, or
442 utility. The responsibility for use and analysis of these data lies completely
443 with the user.

444 5. **Costs of acquiring data:** None.

445 **CLASS IV. DATA STRUCTURAL DESCRIPTORS**

446 A. **Data set File 1:** Descriptors of demographic plots

447 1. **Identity:** HDP_plots.csv

448 2. **Size:** 14 rows (including header), 407 bytes

449 3. **Format and storage mode:** ASCII text, comma delimited. No compression scheme
450 used.

451 4. **Header information:** The first row of the file contains the variable names.

452 5. **Alphanumeric attributes:** Mixed

453 6. **Special Characters:** Missing values are represented with NA.

454 7. **Authentication Procedures:** checksum (MD5 of the file downloaded to computer
455 from the online repository: 7c39b8905ecef0a99c18ceb615ba6ca8.

456 8. **Start & End Columns:** Start: plot_id, End: yr_isolated

457 9. **Variable Information:** Each row is one plot, with the columns providing

458 plot-specific values for each variable (Table 1).

459 **B. Data set File 2:** *Heliconia* Demographic Data

460 1. **Identity:** HDP_survey.csv

461 2. **Size:** 66397 rows (including header), 3.56 MB

462 3. **Format and storage mode:** ASCII text, comma delimited. No compression scheme
463 used.

464 4. **Header information:** The first row of the file contains the variable names.

465 5. **Alphanumeric attributes:** Mixed.

466 6. **Special Characters:** Missing values are represented with NA.

467 7. **Authentication Procedures:** checksum (MD5 of the file downloaded to computer
468 from the online repository: 885481e42a39cdc90201b7c77983c464.

469 8. **Start & End Columns:** Start: plot_id, End: tag_number

470 9. **Data anomalies:** Plants that could not be found during a survey were recorded as
471 ‘missing’ but maintained on the survey list to be searched for in subsequent years. The
472 same is true of plants under branches or the crowns of fallen trees, which might not be
473 found for several years when the crown’s leaves dried and fell or the area under the
474 crown could be safely searched. The codes used to denote such cases are defined in
475 Table 2.

476 The stakes and numbered tags used to mark plants were sometimes displaced,
477 broken, or buried under leaf litter as a result of tree falls or other disturbances. If
478 a plant’s tag couldn’t be found after an extensive search, it would be marked
479 with a new tag. In some cases, it was straightforward to determine such a plant’s

original number when entering the survey data (e.g., when all plants in a low-density subplot were found except one, which in the prior year was similar in size as the plant found without a tag). In those cases, the plant's prior measurements were transferred to the new number and we logged the details of the change in tag number; the `tag_changes.csv` file is available in the `data/survey_clean` subfolder of the HDP Repository (<https://github.com/BrunaLab/HeliconiaSurveys>). In other cases, it was impossible to definitively determine a plant's original number (e.g., when two similarly sized plants in a subplots were both missing their tags). In these cases, the original number was maintained in the database with the plant's status noted as 'missing' in subsequent surveys. The record for the new number indicates the plant with which it is associated is an established plant that was found without a tag (see Section IV, Table 2) and not a new seedling.

There were also cases in which established plants were found without tags in subplots where all previously tagged plants had already been located and measured, indicating previous survey teams had failed to find and mark them. These plants were marked, measured, and added to the database with a code indicating they were a established (i.e., post-seedling) but previously unmarked plant (See Table 2). Of the $N = 1562$ plants in the data set, 18.2% were found without tags after the plot had been established. Almost half of these (45%) were in the three plots where *H. acuminata* density was highest (CF-1, FF-7, CF-3).

Due to logistical or financial constraints, no surveys were conducted in plot CF-6 in 2003; in plots CF-4, CF-5, and CF-6 in 2000; or plots FF-5, FF-6, and FF-7 in 2008-2009.

- 504 10. **Variable information:** Each row in the data set is a demographic plot, with columns
505 of data describing that plot (Table 2). Blanks do not denote missing information, but

506 rather nothing relevant to report.

507 **CLASS V. SUPPLEMENTAL DESCRIPTORS**

508 **A. Data acquisition:**

509 **1. Data forms:** Examples of the forms used to collect survey data can be found at
510 `survey_records.md` in the `docs/survey_records/survey_sheets` subfolder of the
511 HDP Github Repository (<https://github.com/BrunaLab/HeliconiaSurveys>).

512 **2. Location of original data forms, electronic files, and archived copies:** Original
513 data sheets are stored at the University of Florida. Scanned copies of the data sheets
514 (in .pdf format) and the electronic copies of the data (in .csv format) are stored on a
515 desktop computer at the University of Florida that is backed up daily to two portable
516 hard drives and two cloud storage services. The integrity of digital files is verified
517 semi-annually.

518 **3. Data entry verification procedures:** Surveys were typically conducted in field trips
519 of 7-14 days with a 2-4 day interval in Manaus. During each interval we made backup
520 paper copies of the data sheets which we stored in the BDFFP office, and the PI or
521 Project Manager entered the data into plot-specific spreadsheets. These spreadsheets
522 had been prepared in advance; they were based on the previous census and the printed
523 versions were used to record data in the field. This helped reduce data entry errors by
524 allowing the person entering the data to verify a plant's tag number on both the paper
525 data sheet and the electronic spreadsheet prior. Questions regarding the interpretation
526 of field observations or values recorded were clarified immediately with the person
527 recording the data. We identified potential errors or outliers with histograms of plant
528 height and shoot number as well plots of individual plant height vs. shoot number.

529 **B. Quality assurance/quality control procedures:** Once the data for a plot had been

530 entered and verified, they were added to previous years' surveys by using tag ID and subplot
531 as the join keys. The measurements of plant height and stem number were then compared
532 with those from the previous year to identify potential errors in either plant measurement or
533 entry (e.g., a plant with 1 shoot in year t and 11 shoots in year t+1 is likely an error in data
534 entry). Discrepancies were investigated by referring to the original data sheets and, on
535 occasion, returning to the field to remeasure plants.

536 **C. Related materials:** Each demographic plots' location, orientation, and subdivision into
537 subplots can be seen in Fig. 1. Links to photographs, the output of data validation
538 algorithms, summaries of other data sets collected by HDP researchers, and other related
539 materials can be found on the `README.md` file of the HDP Github Repository.

540 **D. Computer programs and data-processing algorithms:** The version of the R code
541 used to prepare this data archive can be found at Zenodo (Bruna and Scott 2023).
542 Post-publication updates to the code and data will be available on the `NEWS.md` file of the
543 HDP Repository (<https://github.com/BrunaLab/HeliconiaSurveys>) until updated version of
544 the archives are uploaded to Zenodo and Dryad.

545 **F. Publications using the demographic data set:** The following publications include
546 analyses of the demographic data set. Links to an updated publication list and downloadable
547 *BibTeX* file can be found on the `README.md` file of the HDP Github repository
548 (<https://github.com/BrunaLab/HeliconiaSurveys>)

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606 fragmented ecosystems. *Ecological Modelling* 457: 109681.
- 607 **G. Related publications and data sets:** The information in the following data archives
608 and publications can be used in concert with the census data to conduct demographic
609 modeling or carry out other analyses. The HDP Github Repository's `README.md` file
610 provides links to an updated list and downloadable BibTeX file of these publications and
611 data sets (<https://github.com/BrunaLab/HeliconiaSurveys>).
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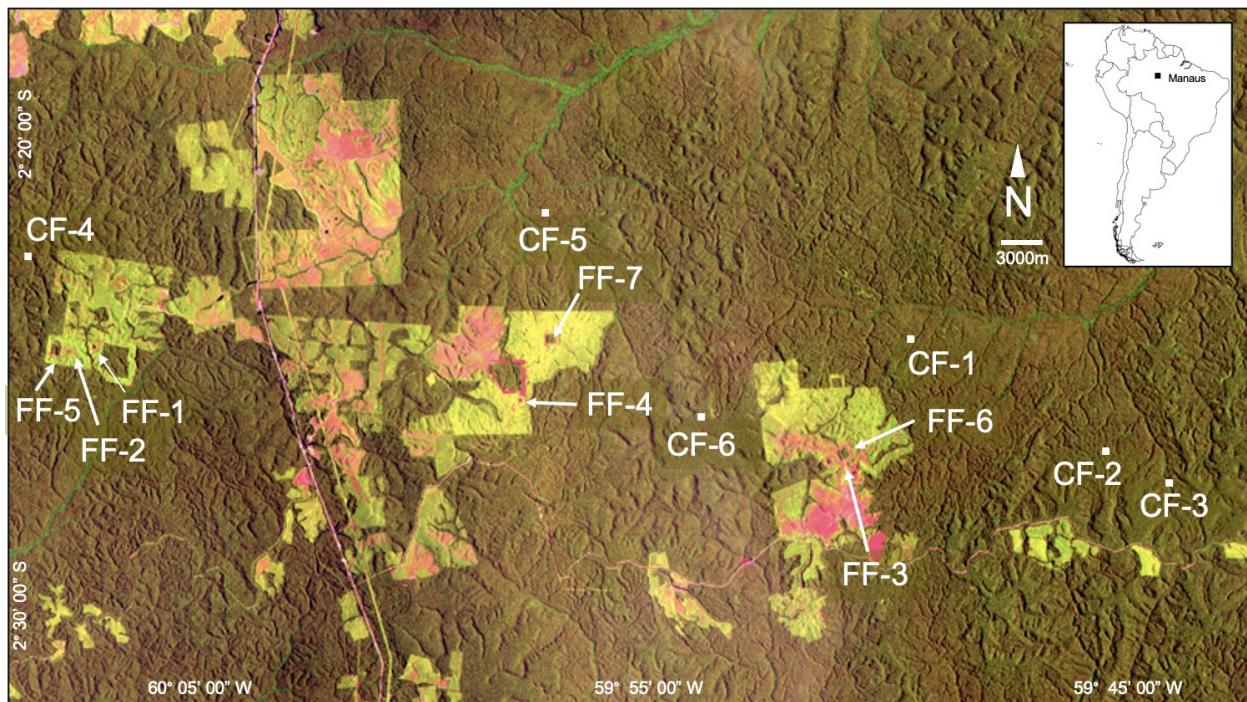


Figure 1. Satellite image of the Biological Dynamics of Forest Fragments Project (ca. 1995) showing the location of the *Heliconia* Demographic Plots. Plots are located in Continuous Forest (CF1-CF6) or Forest Fragments (FF1-FF7), both of which are dark green. Light green areas are regenerating forest, while red indicates pasture. The BDFFP is located 70 km north of Manaus, Brazil (inset map). For additional details on each plot see Table 1.

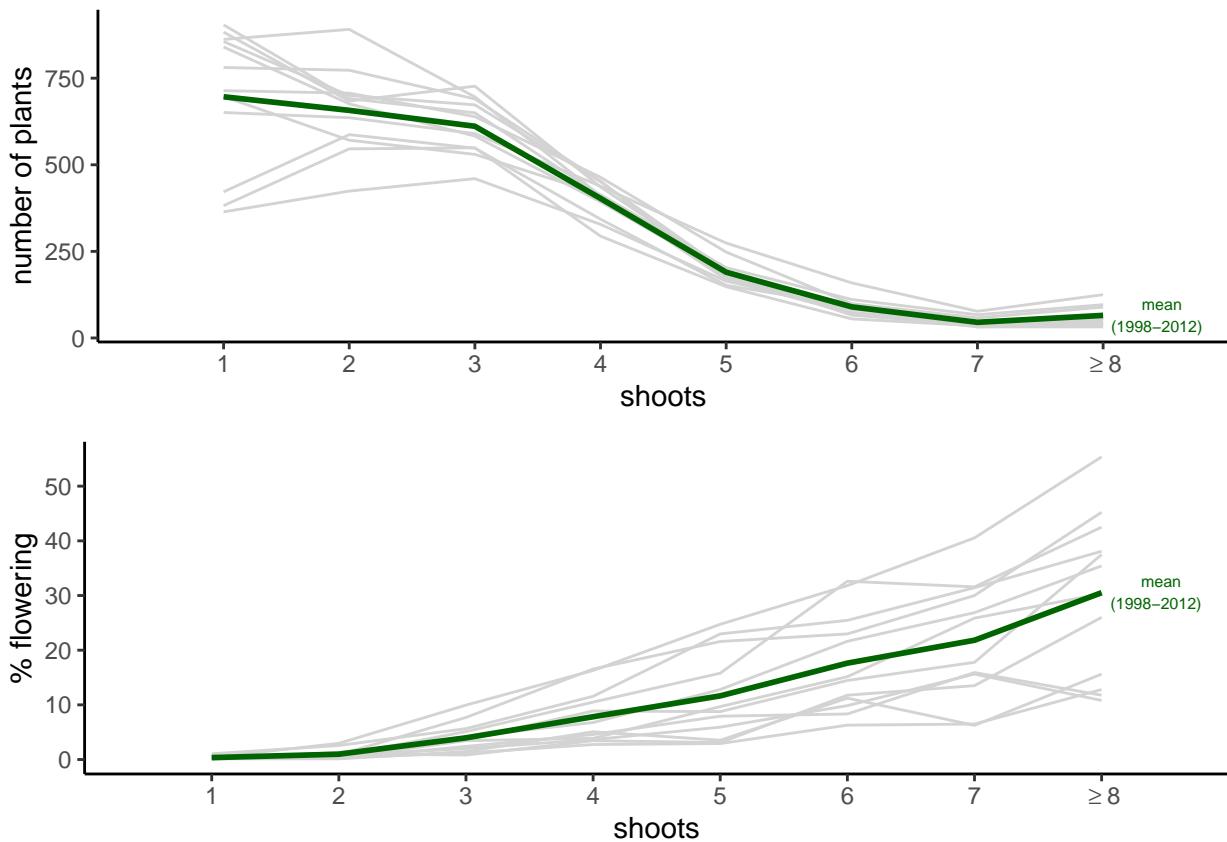
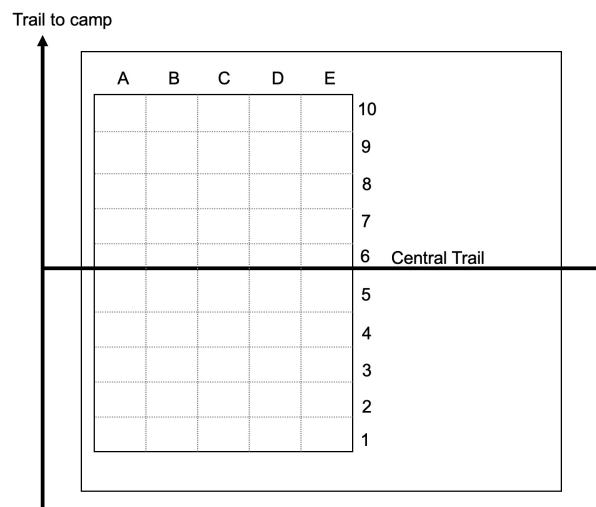
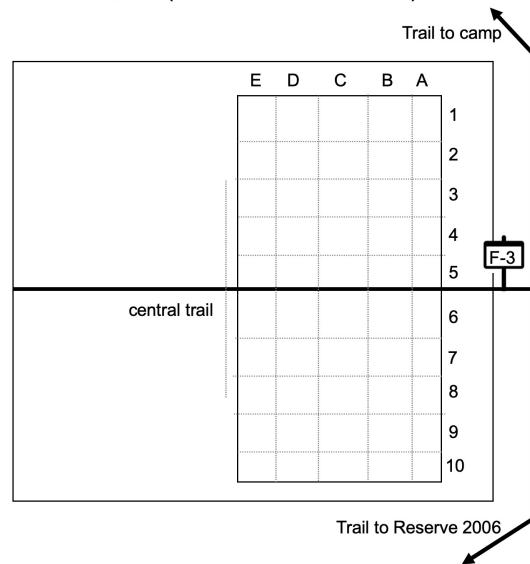


Figure 2. The abundance and reproduction of *Heliconia acuminata* in Continuous Forest. In each of survey year (gray lines) the data from the six demographic plots in Continuous Forest were pooled to give (A) the total number of post-seedling *H. acuminata* in size classes based on shoot number, and (B) the percentage of plants in each size class that produced at least 1 inflorescence. The green line is the average of the annual values for each size category.

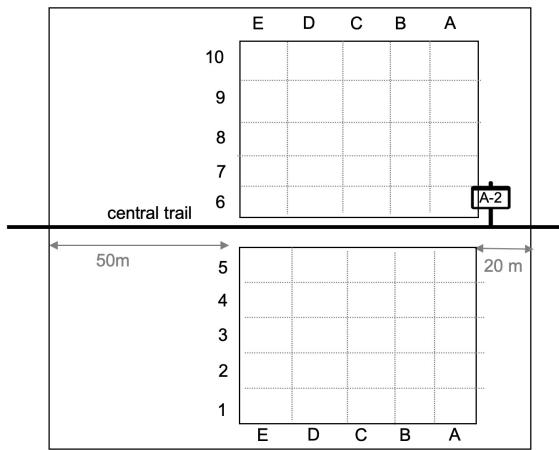
FF-1 (Dimona, Reserve 2107)



FF-2 (Dimona, Reserve 2108)



FF-3 (Esteio, Reserve 1104)



FF-4 (Porto Alegre, Reserve 1301)

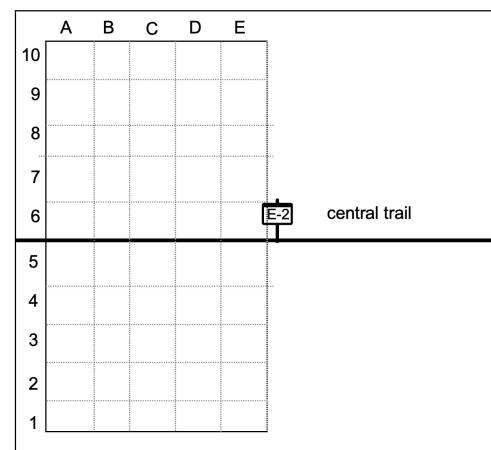
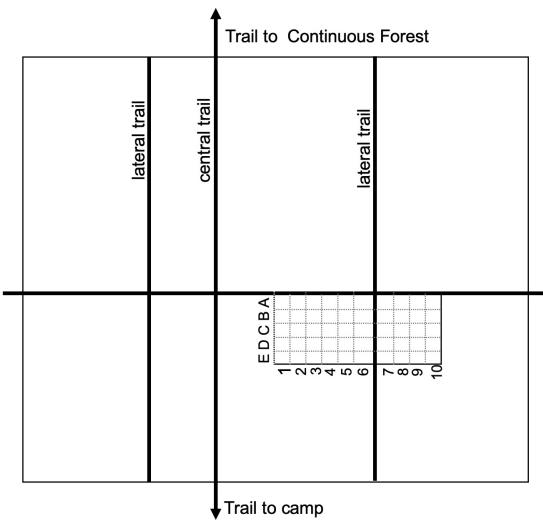
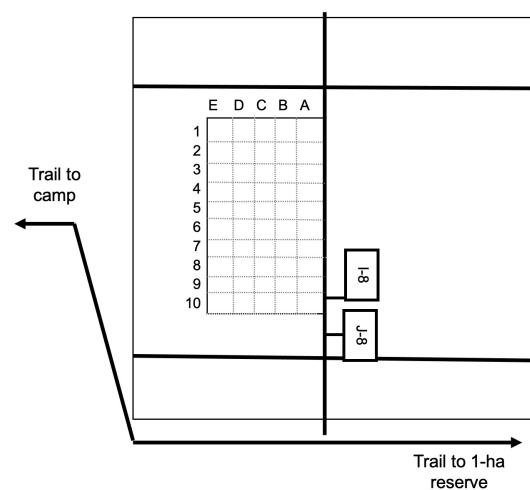


Figure 3. Schematic of the *Heliconia* Demographic Plots in the BDFFP 1-hectare forest fragment reserves (note: not to scale). The rectangles filled with a letter-number combination (i.e., F-3, A-2, E-2) are coordinate stakes marking the permanent plots of the BDFFP Phytodemographic Project (Rankin-de-Mérona et al. 1992).

FF-5 (Dimona, Reserve 2206)



FF-6 (Esteio, Reserve 1202)



FF-7 (Porto Alegre, Reserve 3209)

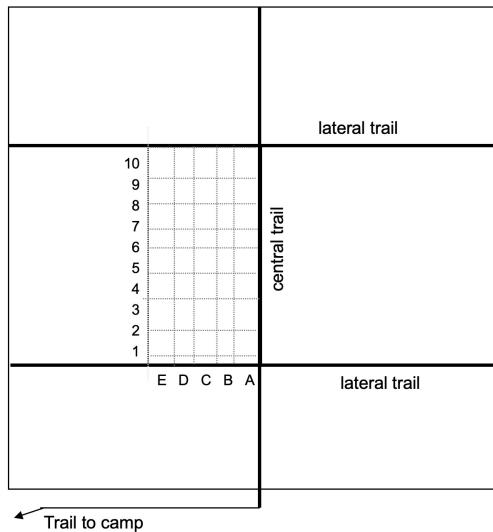
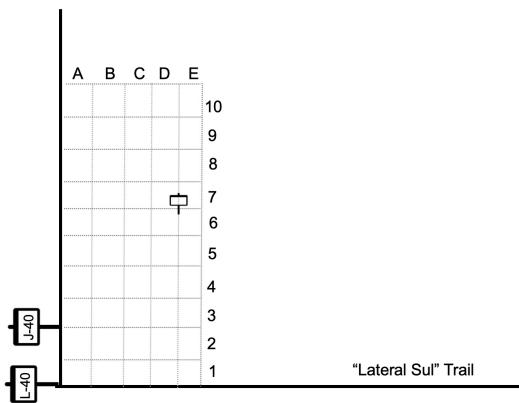
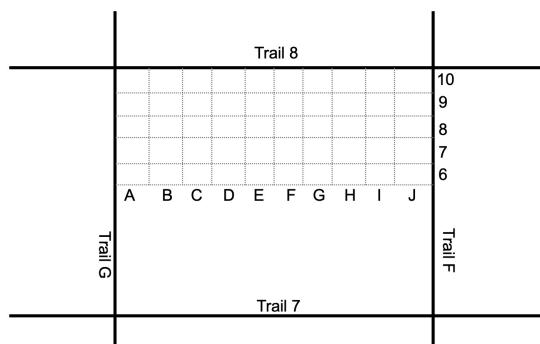


Figure 4. Schematic of the *Heliconia* Demographic Plots in the BDFFP 10-ha forest fragment reserves (note: not to scale). The rectangles filled with a letter-number combination (i.e., I-8, J-8) are coordinate stakes marking the permanent plots of the BDFFP Phytodemographic Project (Rankin-de-Mérona et al. 1992).

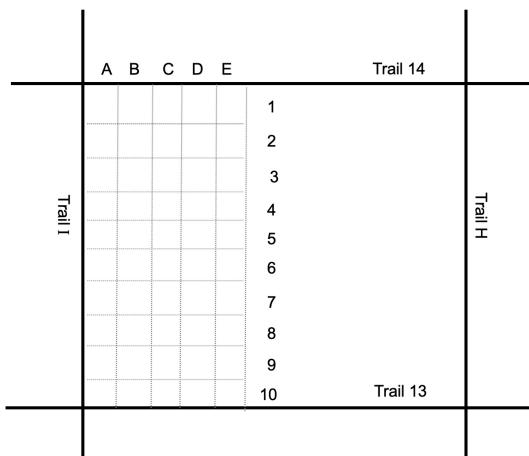
CF-1 (Esteio, Reserve 1301)



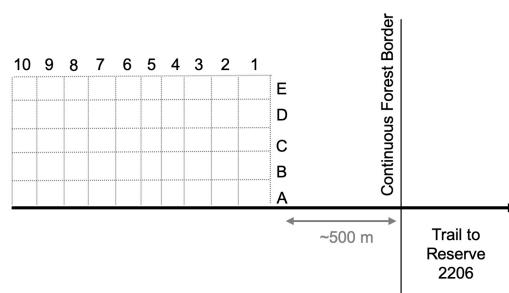
CF-2 (Esteio, Reserve 1501)



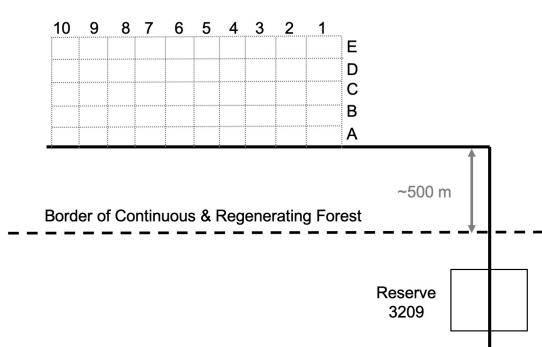
CF-3 (Esteio, Reserve 1501)



CF-4 (Dimona, Outside demarcated reserves)



CF-5 (Porto Alegre, Outside demarcated reserves)



CF-6 (Porto Alegre, Reserve 3402)

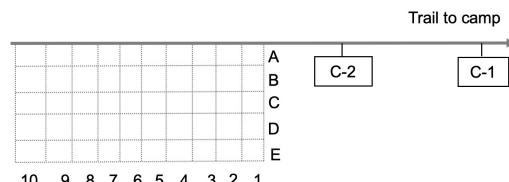


Figure 5. *Heliconia* Demographic Plots in Continuous Forest (note: not to scale). Rectangles with a letter-number combination (i.e., L-40, J-40, C-1, C-2) are coordinate stakes marking permanent plots of the BDFFP Phytodemographic Project (Rankin-de-Mérona et al. 1992).

Table 1. Variable Information for “Data set File 1: *Descriptors of demographic plots*”.

Variable	Definition	Codes	Storage
plot_id	Code used to identify a plot	FF1-FF7: plots in fragments CF1-CF6: plots in continuous forest	string
habitat	Habitat in which a plot is located	one: 1-ha fragment ten: 10-ha fragment forest: continuous forest	string
ranch	Ranch in which a plot is located	porto alegre, esteio, dimona	string
bdffp_no	BDFFPs Reserve ID Number ¹	1104, 1202, 1301, 1501, 2107, 2108, 2206, 3209, 3402, NA	string
yr_isolated	For fragments, the year initially isolated	1980, 1983, 1984	integer

¹See Gascon and Bierregaard (2001) for details of the reserve numbering scheme. ‘NA’ indicates the plot is not inside a formally demarcated BDFFP reserve.

Table 2. Variable Information for “Data set File 2: *Heliconia Demographic Data*”.

Variable	Definition	Codes or Range of Values	Storage
plot_id	Plot in which plant is located	FF1-FF7, CF1-CF6	string
subplot	Subplot in which plant is located	A1-E10 except in CF3, where F6-J10 ¹	string
plant_id	Unique ID no. assigned to plant	range = 1-8660 (units: number, precision: 1)	integer
tag_number	Number on tag attached to plant	range = 1-3751 (units: number, precision: 1)	integer
year	Calendar year of survey	range = 1998-2009 (units: year, precision: 1)	integer
shts	No. of shoots when surveyed	range = 0-24 (units: shoots, precision: 1) NA: data missing	integer
ht	Plant height when surveyed	range = 0-226 (units: cm, precision: 1) NA: data missing	integer
infl	No. of inflorescences (if flowering)	range = 1-7 (units: shoots, precision: 1) NA: data missing	integer
recorded_sdlg	New seedling	TRUE, FALSE	logical
adult_no_tag	Established (i.e., post-seedling) individual without tag	TRUE, FALSE	logical
treefall_status	Plant found under fallen tree crown, branches, or leaf litter at time of survey	branch: under fallen tree limbs tree: under tree crown or fallen trees litter: under accumulated leaf-litter NA: not relevant or no observation recorded	string
census_status	Plant status in a census	measured: alive, measured dead: died prior to census missing: not found during census	string

¹ For the arrangement of the subplots see Figures 3-5