1 **Artificial canopy bridges improve connectivity in fragmented landscapes:**
2 **the case of Javan slow lorises in an agroforest environment**
3

4 Authors: Hélène Birot[1], Marco Campera[1,2], Muhammad Ali Imron[3], K.A.I. Nekaris[1,2*]

5

6 Affiliations: 1. Little Fireface Project, Cipaganti, West Java, Indonesia

7 2. Nocturnal Primate Research Group, Oxford Brookes University, Oxford, United Kingdom

8 3. Department of Forest Resources Conservation, Universitas Gadjah Mada, Yogyakarta, Indonesia

9 *Corresponding author: anekaris@brookes.ac.uk

10

11 **ORCID ID:**

12 Birot: 0000-0002-5857-001X

13 Campera: 0000-0003-2643-8329

14 Imron: orcid.org/0000-0003-2371-7795

15 Nekaris: orcid.org/0000-0001-5523-7353
16

17 Running head: Canopy bridge use by slow lorises

18
19 **Abstract:**
20
21 Canopy bridges are increasingly used to reduce fragmentation in tropical habitats yet
22 monitoring of their impact on the behavior of primates remains limited. The Javan slow loris
23 (*Nycticebus javanicus*) is endemic to Java, Indonesia, where the species most often occurs in
24 human-dominated, highly patchy landscapes. Slow lorises cannot leap, are highly arboreally
25 adapted, and are vulnerable on the ground. To increase arboreal connectivity, as part of a
26 long-term conservation project in Cipaganti, West Java, we built and monitored seven slow
27 lorises bridges of two types – waterline or rubber – and monitored their use by seven adult
28 individuals from 2016-2017. Motion triggered camera traps collected data for $195 \pm$ SD 85
29 days on each bridge. We collected 341.76 hours (179.67 h before and 162.09 h after the
30 installation of bridges) of behavioral and home range data via instantaneous sampling every
31 5-min, and terrestrial behavior (distance and duration of time spent on the ground) via all
32 occurrences sampling. We found that slow lorises used bridges on average $12.9 \pm$ SD 9.7
33 days after their instalment mainly for travelling. Slow lorises showed a trend towards an
34 increase in their home range size (2.57 ha before, 4.11 ha after; p=0.063) and reduced ground
35 use (5.98 s/h before, 0.43 s/h; p=0.063) after implementation of bridges. Although the
36 number of feeding trees did not change, new feeding trees were included in the home range,
37 and the proportion of data points spent travelling and exploring significantly decreased
38 (p=0.018). Waterline bridges serve a purpose to irrigate the crops of local farmers who thus
39 help to maintain the bridges, and also ascribe value to the presence of slow lorises. Other
40 endemic mammal species also used the bridges. We advocate the use and monitoring of
41 artificial canopy bridges as an important supplement for habitat connectivity in conservation
42 interventions.
43
44 **Keywords:** conservation evidence, forest fragmentation, *Nycticebus javanicus,* wildlife
45 crossings
46

47

48 **Research highlights:**

49 • We integrated artificial canopy bridges into the home range of Javan slow lorises
50   allowing them to save energy and access new areas.
51 • Bridges made of waterpipes supplied irrigation to farmers' crops providing additional
52   benefits for local communities.

Introduction

Exponential human population growth rate and the ever-growing demands for ecosystem services are having a dramatic impact on wildlife (Power, 2010). The expansion of agriculture and urbanization are the major causes of deforestation, resulting in the reduction and fragmentation of once continuous habitats (Hilty, Lidicker, and Merenlender, 2006; Lokschin, Printes, and Cabral, 2007; Arroyo-Rodríguez and Mandujano, 2009; Vickers et al., 2015). The lack of connectivity affects movements between animal populations (Valladares-Padua, Cullen, and Padua, 1995; Yokochi, Chambers, and Bencini, 2015). Consequences can impact extinction risks due to demographic bottlenecks, geographic barriers and low genetic diversity (Dixo, Metzger, Morgante, and Zamudio, 2009; Taylor and Goldingay, 2010; Yokochi, Kennington, and Bencini, 2016).

The preservation of high-quality forest habitats is vital for the conservation of global biodiversity; nevertheless, they cannot be all strictly protected (Mortelliti, Amori, and Boitani, 2010). Understanding wildlife's ability to survive and even thrive in fragmented environments is becoming more and more important (Estrada et al., 2017). Conservation approaches have been investigated to overcome fragmentation, and the creation of wildlife corridors has been strongly discussed in the last decades (Gilbert-Norton, Wilson, Stevens, and Beard, 2010; Hodgson, Hodgson, Moilanen, Wintle, and Thomas, 2011; Naidoo et al., 2018). Wildlife corridors are essential in population management strategies by ensuring connection between fragmented habitats isolated by deforestation and other human activities (Arroyo-Rodríguez and Mandujano, 2009). Human-implemented wildlife crossings are a popular type of corridor used to help achieve canopy connectivity, but their impact is not always assessed (van der Grift and van der Ree,2015; Yokochi and Bencini, 2015). Researchers who have assessed wildlife crossings have shown that a variety of them, including artificial and natural canopy bridges, road underpasses and green bridges are a successful means of passage for different mammalian taxa, for example, dormice (*Glis glis*) (Georgii et al., 2011), western ring-tailed possums (*Pseudocheirus occidentalis*) (Yokochi and Bencini, 2015), squirrel gliders (*Petaurus norfolcensis*) (Taylor, Walker, Goldingay, Ball, and van der Ree, 2011), grizzly (*Ursus arctos*) and black bears (*U. americanus*) (Sawaya, Kalinowski, and Clevenger, 2014).

86   In the case of arboreal primate species, such studies have lagged behind, but are now

87   necessary as primary forests disappear at an alarming rate (Estrada et al., 2017). The

88   conversion of forests to agriculture affects the availability of feeding resources and sleeping

89   trees for primates (Das, Biswas, Bhattacherjee, and Rao, 2009a; Arroyo-Rodríguez and

90   Mandujano, 2009). Arboreal primates may need to perform terrestrial behaviors to cross

91   disconnected areas within their home ranges (Lokschin et al.,2007; Das et al., 2009a; Mas et

92   al., 2011; Donaldson and Cunneyworth, 2015). The lack of connectivity imposes costs such

93   as high mortality due to predators or road collisions (Mass et al., 2011), dietary changes

94   (Onderdonk and Chapman, 2000; Das et al., 2009a), home range modifications (Onderdonk

95   and Chapman, 2000; Bicca-Marques, 2003) and increased physiological stress and parasite

96   loads (Chapman et al., 2006). Artificial canopy bridges can be used to replace the lack of

97   connectivity between fragments occupied by primates (Valladares-Padua et al., 1995;

98   Teixeria et al., 2013; Lindshield, 2016; Table 1). Designed from different materials (rope,

99   ladder, rubber, pole, bamboo), they can represent efficient structures for dispersal, travelling

100   or foraging movements (Das et al., 2009a).

101

102   The island of Java, Indonesia, is highly populated and largely deforested, with less than 10%

103   of the original forest left (Whitten, Soeriaatmadja, and Afiff, 1996; Margono, Potapov,

104   Turubanova, Stolle, and Hansen, 2014). Contrary to other areas of Indonesia, deforestation

105   occurred mainly before the year 2000 and current deforestation rates are low (Margono et al.,

106   2014; Brun et al., 2015). In the 90s, it was reported that about 17% of the agricultural land on

107   Java consisted of fragmented forests surrounded by agroforest environments (Whitten et al.,

108   1996). Forest has been replaced by a mosaic of cities, villages, and agricultural forest

109   plantations (Nijman, 2013). In this study, we examined the impact of the implementation of

110   artificial canopy bridges on the habitat use of Javan slow loris (*Nycticebus javanicus*) in an

111   agroforestry environment. The Javan slow loris is listed as Critically Endangered due to

112   habitat loss and persecution for the illegal wildlife trade (Nekaris, 2016). Slow lorises are

113   fully arboreally adapted and cannot leap and require canopy connectivity for movement

114   (Nekaris, 2014). Some loris species, however, have been observed to use terrestrial

115   movements in disconnected habitats, but only rarely and with caution (Das, Biswas, Das,

116   Ray, Sangma, and Bhattacharjee, 2009b; Nekaris, Spaan, Nijman, 2019). Reinhardt,

117   Wirdateti, and Nekaris (2016) showed that the lack of connectivity of feeding trees was

118   related to a decrease in activity by Javan slow lorises. The ability of slow loris populations to

119   persist in intensively human-modified and fragmented landscapes thus depends on the

120 restoration of canopy connectivity. We expect that, after the erection of canopy bridges,

121 Javan slow lorises will 1) use bridges as artificial canopy; 2) expand their home ranges to

122 include previously disconnected areas; 3) reduce terrestrial movements; 4) reduce exploring

123 and travelling time or increase the number of feeding trees visited.

124

125 **Methods**

126

127 *Field site*

128 We conducted the study in an agroforest environment in Cipaganti, Cisurupan, Garut District,

129 West Java (7°16'44.30"S, 107°46'7.80"E). Cipaganti is located at 1345 m a.s.l. on Mount

130 Puntang, which is a part of the Java-Bali Montane Rain Forests ecoregion. This area is

131 characterized by a mosaic of gardens, where local farmers practice an annual rotating crop

132 system (Nekaris et al., 2017). This traditional system consists of a variety of crop formations,

133 with tall trees planted along farm property boundaries, or interspersed between crop types

134 (Reinhardt et al., 2016).

135

136 *Slow loris behavioral observations and home ranges*

137 We examined the behavior of Javan slow lorises in relation to erection of artificial canopy

138 bridges, as part of an ongoing long-term community conservation project on the species

139 started in 2012. For this study, we focused our data collection and analysis on seven adult

140 collared individuals (four females and three males) four of which were part of mated pairs.

141 Slow lorises were caught safely by hand and were equipped with 19 g VHF radio collars

142 (PIP3, Biotrack, Wareham, United Kingdom). With the assistance of local trackers, we

143 located collared individuals using an antenna (Lintec flexible, Biotrack, Wareham, United

144 Kingdom) and a receiver (Sika receiver, Biotrack, Wareham, United Kingdom). We observed

145 focal individuals at night throughout their entire active period (1700 h – 0500 h), using head

146 torches (HL17 super spot, Clulite, Petersfield, United Kingdom) fitted with red filters. We

147 collected behavioral data following the instantaneous focal sampling method (Altmann,

148 1974) and location data using a handheld GPS unit (GPS62s, Garmin International, Olathe,

149 USA), both at the same five-minute intervals. Via instantaneous focal sampling, we collected

150 data on number of trees used, and proportion of data points spent travelling and exploring

151 (c.f. Rode-Margono, Nijman, Wirdateti, and Nekaris, 2014). We collected data on

152 terrestriality (i.e. distance and duration of time spent on the ground) via the all occurrences
153 method (Altmann, 1974).
154
155 *Artificial connectivity and use monitoring*
156 In order to improve connectivity in the study site, we implemented one bridge in June 2016
157 and six bridges between June and July 2017. They were built to connect disconnected trees
158 that were separated by agricultural fields. We built two different types of artificial wildlife
159 crossings: "loris bridge" and "waterline". We made four loris bridges by using rubber
160 wrapped around a 1.5 cm width wire and three waterline bridges from rigid 3 cm diameter
161 water pipe tied to a wire (Figure 1). A wire was used as a support to ensure stability and to
162 minimize breaks during storms. We considered two important criteria when erecting
163 waterlines to favor farmers as well: access to source water and positive slope to allow the
164 flow of water. We installed bridges at a mean height of 4.2 m ± SD 1.4 (range: 2-8 m)
165 attached to trees with a mean height of 9.1 m ± SD 2.9 (range: 4-15 m). The mean rubber
166 bridge length was 37.75 m ± SD 14.05 (range: 29-56 m), while the mean waterline length
167 was 75 m ± SD 32.2 (range: 26-82 m). To monitor efficiently the use of bridges by slow
168 lorises, we set up motion triggered infrared cameras (Bushnell HD model 119836) at
169 extremities of all bridges the day they were implemented. We set up cameras to take three
170 photos per capture with a delay of 3 seconds. We considered the events in which the same
171 animal crossed the bridges and not the number of pictures since the animals were easily
172 recognizable. Camera traps also recorded videos associated with each crossing, which we
173 used to analyze the prevalence of three behaviors (travelling, alert, social; c.f. Rode-Margono
174 et al. 2014). We examined camera trap photos and videos from June 2016 to April 2018.
175 Camera traps collected data for a maximum of 266 days (mean=195 ± SD 85 days), yielding
176 a total trapping effort of 741 days on waterlines and 820 days on rubber bridges.
177
178 *Data analysis*
179 Considering behavioral observations on the seven focal animals, we compared the data
180 collected three months before and three months after the installation of bridges. We excluded
181 the first month after the installation of bridges since we considered it as habituation period.
182 We collected a total of 179.67 h and 162.09 h of observations before and after the
183 implementation of bridges respectively. We computed the ranging patterns (in hectares) of
184 the seven individuals via Fixed Kernel (FK) method with smoothing selected by least-squares

185   cross-validation (LSCVh) (Seaman et al., 1999) using the software Ranges 9. We considered

186   home ranges at 95% FK (Seaman et al., 1999). We exported the shapefiles to ArcGIS 10.4

187   software for graphical visualization. To test for statistical differences between the behaviors

188   before and after the installation of bridges, we used the Wilcoxon test for paired samples. We

189   considered home ranges, distance walked and time spent on the ground, number of feeding

190   trees used per hour, and proportion of data points spent travelling and exploring as dependent

191   variables. We performed the tests via SPSS v25 considering $P < 0.05$ as level of significance.

192

193   All research was approved by the Animal Care Subcommittee of Oxford Brookes University

194   and followed the American Society of Primatologists (ASP) Principles for Ethical Treatment

195   of Non-human Primates. All research adhered to the legal and ethical guidelines of the

196   Indonesian Institute of Sciences, Department of Wildlife and Department of Forestry.

197

198   **RESULTS**

199   Camera traps collected a total of 817 events of slow lorises using bridges (463 events on

200   waterlines and 354 events on rubber bridges). From camera trap footage, we found that slow

201   lorises used both waterlines and rubber bridges on average $12.9 \pm$ SD 9.7 days after we

202   installed them (waterlines: mean=$10.3 \pm$ SD 9.7 days; rubber bridges: mean=$14.4 \pm$ SD 10.4

203   days; Figure 2). Slow lorises continued to use the bridges for the whole duration of the study.

204   They used waterlines for travelling in 77.3 % of the observations, being alert 17.7% of

205   observations, the lorises engaged in social activities for 5.0%, with up to three slow lorises

206   crossing at once. Slow lorises used loris bridges mainly for travelling (97.2% of observations)

207   and only in 2.8 % of events they were alert.

208

209   From behavioral observations, we found that two males (AL and TO) and three females (OE,

210   TE, and XE) expanded their home ranges after the installation of bridges (Table 2, Figure 3).

211   The home range size before and after the installation of bridges was not statistically different,

212   although there is a trend towards larger home ranges after the installation of bridges (before:

213   median=2.57 ha, quartiles=2.37-2.84 ha; after: median=4.11 ha, quartiles=3.46-4.30 ha;

214   W=1.859, p=0.063).

215

216   After the installation of bridges, slow lorises diminished the distance spent on the ground

217   (before: median=1.15 m/h, quartiles=0.40-1.70 m/h; after: median=0.10 m/h, quartiles=0.04-

218   0.48 m/h; W=-2.197, p=0.028). The actual time spent on the ground was not statistically

219   different, although there is a trend towards less time spent on the ground after the installation

220   of bridges (before: median=5.98 s/h, quartiles=3.37-16.77 s/h; after: median=0.43 s/h,

221   quartiles=0.03-5.20 m/h; W=-1.859, p=0.063). The number of feeding trees used per hour did

222   not change after the installation of bridges (before: median=0.35 trees/h, quartiles=0.24-0.42

223   trees/h; after: median=0.30 trees/h, quartiles=0.18-0.53 trees/h; W=0.507, p=0.612). The

224   proportion of data points spent travelling and exploring, however, significantly decreased

225   after the installation of bridges (before: median=36.65 % of the observations,

226   quartiles=34.93-42.32 %; after: median=24.64 % of the observations, quartiles=20.87-34.71

227   %; W=-2.366, p=0.018) (Table 2).

228

229   **DISCUSSION**

230   We built artificial canopy bridges in a fragmented agroforest environment in West Java,

231   Indonesia to evaluate the effect that wildlife bridges had on a Javan slow loris population in

232   terms of crossing gaps. We found that slow lorises used all of the rubber bridges and

233   waterlines we erected to cross gaps over areas with limited to no arboreal connectivity. After

234   implementation of the bridges, slow lorises started to use bridges for complete crossings after

235   an average of 12.9 days. This time period is similar to that recorded for western ringtail

236   possums (*Pseudocheirus occidentalis*) in Australia and Hoolock gibbons (*Hoolock hooklock*)

237   in India (Yokochi and Bencini, 2015; Das et al., 2009a). After the habituation period, slow

238   lorises used the bridges for the remaining study period (Little Fireface Project, unpublished

239   data). Locomotion across bridges was swift and efficient. Slow lorises could move on the top

240   or underneath the bridges, and in this manner, could cross with social group members or

241   other species (c.f. Das et al., 2009a; Teixeira, Printes, Fagundes, Alonso, and Kindel, 2013).

242   Bridge use has been safe, with no animals falling from or gaining an injury from bridge use

243   or suffering predation whilst on a bridge. Here we discuss bridge use in the context of slow

244   loris behavior and conservation.

245

246   Various studies have demonstrated that mammals, including primates, are able to adapt to

247   fragmented habitats (Luckett, Danforth, Linsenbardt, and Pruetz,2004). For tree dwelling

248   species, bridges as artificial wildlife crossings are a good temporary solution to improve

249   connectivity in fragmented habitats (Das et al., 2009a). All slow lorises included in this study

250   made use of both types of bridges. Testing styles of bridge is important, as in an initial pilot

251   study, we unsuccessfully trialed a ladder type bridge that had been successfully employed for

252   black and white colobus monkeys (*Colobus angolensis palliatus*) (Donaldson and

253   Cunneyworth, 2015). By employing two additional styles of bridge, not only were we

254   successful, but slow lorises used both types, as also seen in six different lemur species in

255   eastern Madagascar (Mass et al., 2011). Rubber and waterline bridges may also have been

256   more successful for slow lorises because of their propensity to grasp small substrates around

257   which they can clasp their hands (Rode-Margono et al., 2014). Despite the potentially loris-

258   specific size of the bridges, all seven bridges we built were used by other animal species,

259   including Javan palm civets (*Paradoxurus musanga javanicus*), black-striped squirrels

260   (*Callosciurus nigrovittatus)*, Horsfield's treeshrews (*Tupaia javanica*), as well as by owls and

261   other bird species. Civets, however, only used the waterline structures, and were not

262   observed using the rubber structures. These observations concur with Goosem, Weston, and

263   Bhushnell (2005), who demonstrated that canopy bridges are not species-selective but can

264   provide benefits for non-focal species.

265

266   Canopy bridges allowed slow lorises to include areas in their home ranges that were

267   previously disconnected. In particular, they used bridges to connect either to patches that

268   previously only could be accessed via the ground or were able to add new areas to their home

269   range (c.f. Gregory, Carrasco-Rueda, Alonso, Kolowski, and Deichmann, 2017). In all cases,

270   focal slow lorises used both sides of the bridges, although we have observed animals in our

271   population using bridges in only one direction during dispersal events. Other taxa, including

272   Hoolock gibbons in India and black and white colobus monkeys in Kenya, also used both

273   sides of the bridges (Das et al., 2009a; Donaldson and Cunneyworth, 2015). Rainforest

274   ringtail possums, however, only occasionally used the habitat on the opposite side of the

275   bridge, with numerous 'half crossings' observed (Wilson, Marsh, and Winter 2007).

276   Although home range sizes were not significantly larger, in a highly fragmented landscape,

277   the importance of access to additional resources cannot be underestimated.

278

279   Increasing home range size and having better access across the landscape also may be

280   reflected in reducing exploring or travelling time or increasing the number of feeding trees

281   visited (Gregory et al., 2017). Indeed, slow lorises spent a lower proportion of data points

282   travelling in search of food resources after the implementation of the bridges, although they

283   still visited the same number of feeding trees per hour. The presence of the bridges may

284   significantly increase the survival of the individuals. Slow lorises, in fact, spent a lower

285   proportion of data points travelling through their home range to search for resources, which

286   may allow them to save energy (i.e. time minimizer strategy; Hixon 1982, Campera et al.,

287   2014). The viability of a species depends not only on its population size but also on its habitat

288   structure and on the movement of individuals between habitat patches (Valladares-Padua et

289   al., 1995). The canopy bridges that we constructed in this study connected trees in loris home

290   ranges and therefore created access to new habitable areas and feeding resources. They

291   reduced isolation between individuals and encouraged dispersal. Das et al. (2009a) also found

292   that Hoolock gibbons had access to previously disconnected areas as well as new food

293   resources after the installation of bridges.

294

295   Only a handful of studies concerning primate use of canopy bridges have been reported (e.g.

296   Mass et al., 2011; Teixeira et al., 2013; but see Donaldson and Cunnyworth, 2015; Table 1).

297   We found that not only did slow lorises use bridges almost nightly, but that they also engaged

298   in fewer terrestrial behaviors after the implementation of the bridges. Habitat fragmentation

299   may increase arboreal primate mortality (Das et al., 2009a). With a lack of connectivity,

300   primates have no choice but to walk on the ground, increasing the risk of predation (Silva and

301   Bicca-Marques, 2013), as well as the risk of disease and parasites (Chapman et al., 2006).

302   Farmers in our study area use dogs to guard their land and to hunt. Dogs are left at night in

303   the field and may be aggressive. Since 2012, despite a lack of other predation events, at least

304   four slow lorises have been injured or killed by dogs in Cipaganti. Dogs are frequent in the

305   fields and are probably the second greatest threat to slow lorises in the area after hunting by

306   humans. Thus, an increase in arboreal connectivity may reduce the risk of injury or death to

307   these Critically Endangered primates.

308   Clearly an increase in arboreal pathways is a desired impact of long-term conservation

309   projects. To achieve this goal, habitat restoration schemes such as forest corridors are

310   ultimately the most desirable (Harris, 1984). Corridors can be implemented in degraded

311   habitats to restore connectivity between natural forest areas (Ganzhorn, 1987). Nevertheless,

312   forest corridors are not always easy to implement, as they may cross privately owned human

313   properties, whose landlords may not always be willing to collaborate (Valladares-Padua et

314   al., 1995; Alexander, 2000; Gibson, Lehoucq, and Williams, 2002; Wyman and Stein 2010).

315   A solution to this conflict may be the planting of tree corridors, with trees that have value to

316   local communities or land-owners whether they be native species or not. Primates can benefit

317   from these corridors by using them for travelling and resting and may exploit non-native tree

318   species as new food sources (Ganzhorn, 1985, 1987; Luckett, 2004). Javan slow lorises often

consume the nectar of *Calliandra callothrysus*, and gum of *Acacia decurrens*, two invasive

species planted by farmers for nitrogen fixation of the soil (Rode-Margono et al., 2014). In

the midst of controversy over rewilding highly degraded areas with native or non-native

species, artificial canopy bridges remain a temporary solution until implications of choice of

species used in habitat restoration are decided (Hansen, 2010).

The conservation value of the type of wildlife crossings used in our heavily fragmented study

site cannot be overlooked, and lessons learned in this study can be applied to other arboreal

primates living in fragmented landscapes. Firstly, canopy bridges may increase slow loris

population persistence in the study area by providing safer routes for animals and more

opportunities for animal dispersal and gene exchange (Yokochi et al., 2016). Secondly,

wildlife crossing structures need not be only built for wildlife but may serve other functions

such as water drainage or access to ecosystem services by humans (van der Ree et al., 2017).

The waterline bridges implemented in our study play an important role in community

involvement in their long-term maintenance, since they are used by farmers for crop

irrigation. We conducted several outreach events with local farmers before the

implementation of bridges, including one-on-one interviews, focus groups and workshops

(Nekaris, 2016). The aim of these events was not only to obtain the permission of farmers to

implement bridges on their properties, but also to identify the needs of farmers who did not

yet possess water irrigation. The local perception regarding the importance of primates to

forest ecology is often missing in conservation interventions (Parathian and Maldonado,

2010; Stafford, Alarcon-Valenzuela, Patiño, Preziosi, and Sellers, 2016; Lindshield, Bogart,

Gueye, Ndiaye, and Pruetz, 2019). Before our project started, the community felt that it was

acceptable to catch and sell slow lorises or to ignore these activities by outsiders, even though

this trade is illegal (Nijman and Nekaris, 2014). As part of the bridge implementation, we

conducted education sessions and held bi-annual community outreach events to inform the

local community about the ecological value of slow lorises as pollinators and insect pest

consumers (Nekaris, 2016; Nekaris, McCabe, Spaan, Imron, and Nijman, 2018). The

implementation of waterline bridges as a water source for farmers only increased the local

value of slow lorises. As of October 2019, all bridges implemented in our study are still

standing and used by slow lorises. We attribute this success to the intense monitoring of our

study animals alongside regular community outreach and involvement. The days are past

when outsiders can enter a new area and engage in conservation interventions without the

352 support of the local community, and we encourage others to include as much involvement as

353 possible with local people when developing similar projects.

354

355 **Acknowledgements**

370

371 **Conflicts of Interest:**

372 Authors have no conflicts of interest to report.

373

374 **Reference list**

375 Acrenaz, M. (2010). Orang-utan bridges in lower Kalimantan (Unpublished report, Arcus).
376
377 Alexander, S. (2000). Resident attitudes towards conservation and black howler monkeys in
378   Belize: the Community Baboon Sanctuary. *Environmental Conservation*, 27(4), 341–350.
379   DOI: 10.1017/S0376892900000394

380

381 Altmann, J. (1974). Observational study of behaviour: sampling methods. *Behaviour*, 49(3/4),
382   227–267. DOI: 10.1163/156853974X00534

383

384 Arroyo-Rodriguez, V., & Dias, P. A. D. (2009). Effects of habitat fragmentation and
385   disturbance on howler monkeys: a review. *American Journal of Primatology* ,72(1), 1–16.
386   DOI: 10.1002/ajp.20753

387

388 Arroyo-Rodriguez, V., & Mandujano, S. (2009). Conceptualization and measurement of
389   habitat fragmentation from the primates' perspective. *International Journal of*
390   *Primatology*, 30, 497–514. DOI: 10.1007/s10764-009-9355-0

391

392 Bicca-Marques, J. C. (2003). How do howler monkeys cope with habitat fragmentation? In L.
393   K. Marsh (Ed.), *Primates in Fragments: Ecology and Conservation* (pp. 283–303). New
394   York, USA: Kluwer Academics/Plenum Press. DOI: 10.1007/978-1-4757-3770-7_18

395

396 Bissonette, J. A., & Cramer, P. C. (2008). Evaluation of the use and effectiveness of wildlife
397   crossings. National Cooperative Highway Research Program. Report 615. Washington,
398   DC: Transportation Research Board

399

400 Brun, C., Cook, A. R., Lee, J. S. H., Wich, S. A., Koh, L. P., & Carrasco, L. R. (2015).
401   Analysis of deforestation and protected area effectiveness in Indonesia: a comparison of
402   Bayesian spatial models. *Global Environmental Change*, 31, 285–295. DOI:
403   10.1016/j.gloenvcha.2015.02.004

404

405 Campera, M., Serra, V., Balestri, M., Barresi, M., Ravaolahy, M., Randriatafika, F., &
406   Donati, G. (2014). Effects of habitat quality and seasonality on ranging patterns of
407   collared brown lemur (*Eulemur collaris*) in littoral forest fragments. *International Journal*
408   *of Primatology*, 35, 957–975. DOI: 10.1007/s10764-014-9780-6

409

410 Chapman, C. A., Wasserman, M. D., Gillespie, T. R., Speirs, M. L., Lawes, M. J., Saj, T. L.,
411   & Ziegler, T. E. (2006). Do food availability, parasitism, and stress have synergistic
412   effects on red colobus populations living in forest fragments? *American Journal of*
413   *Physical Anthropology*, 131(4), 525–534. DOI: 10.1002/ajpa.20477

414

415 Das, J., Biswas, J., Bhattacherjee, P.C., & Rao, S. S. (2009a). Canopy bridges: an effective
416   conservation tactic for supporting gibbon populations in forest fragments. In S. Lappan &
417   D. J. Whittaker (Eds.) *The Gibbons. Developments in Primatology: Progress and*
418   *Prospects* (pp. 467–475). New York, NY: Springer.

419

420 Das, N., J. Biswas, J., Das, Ray, P. C., Sangma, A., & Bhattacharjee, P.C. (2009b). Status of
421   Bengal slow loris *Nycticebus bengalensis* (Primates: Lorisidae) in Gibbon Wildlife
422   Sanctuary, Assam, India. *Journal of Threatened Taxa,* 1(11), 558–561. DOI:
423   10.11609/JoTT.o2219.558-61

424

425 Dixo, M., Metzger, J. P., Morgante, J. S., & Zamudio, K. R. (2009). Habitat fragmentation
426   reduces genetic diversity and connectivity among toad populations in the Brazilian
427   Atlantic Coastal Forest. *Biological Conservation*, 142, 1560–1569. DOI:
428   10.1016/j.biocon.2008.11.016

429

430   Donaldson, A., & Cunneyworth, P. (2015). Case study: canopy bridges for primate
431   conservation. In R. van der Ree, D. J. Smith, & C. Grilo (Eds.), *Handbook of Road*
432   *Ecology* (pp. 341–343). West Sussex, UK: Wiley

434   Estrada, A., Garber, P.A., Rylands, A.B., Roos, C., Fernandez-Duque, E., Di Fiore, A., … Li,
435   B. (2017). Impending extinction crisis of the world's primates: why primates matter.
436   *Science Advances*, *3*(1), 1–16. DOI: 10.1126/sciadv.1600946

438   Ganzhorn, J. U. (1985). Utilization of eucalyptus and pine plantations by brown lemurs in the
439   eastern rainforest of Madagascar. *Primate Conservation*, 6, 34–35.

441   Ganzhorn, J. U. (1987). A possible role of plantations for primate conservation in
442   Madagascar. *American Journal of Primatology*, 12(2), 205–215. DOI:
443   10.1002/ajp.1350120208

445   Georgii, B., Keller, V., Pfister, H.P., Reck, H., Peters-Ostenberg, E., Henneberg, M., …
446   Bach, L. (2011). Use of wildlife passages by invertebrates and vertebrate species. *Wildlife*
447   *Passages in Germany*, 2011, 1–27.

449   Gibson, C. C., Lehoucq, F. E., & Williams, J. T. (2002). Does privatization protect natural
450   resources? Property rights and forests in Guatemala. *Social Science Quarterly*, 83(1), 206–
451   225. www.jstor.org/stable/42956282

453   Gilbert-Norton, L., Wilson, R., Stevens, J. R., & Beard, K. H. (2010). A meta-analytic review
454   of corridor effectiveness. *Conservation Biology*, 24(3), 660–668. DOI: 10.1111/j.1523-
455   1739.2010.01450

457   Goosem, M., Weston, N., & Bhushnell, S. (2005). Effectiveness of rope bridge arboreal
458   overpasses and faunal underpasses in providing connectivity for rainforest fauna. In C. L.
459   Irwin, D. Nelson & K. P. McDermott (Eds.), *Proceedings of the 2005 International*
460   *Conference on Ecology and Transportation* (pp. 304–316). North Carolina State
461   University, NC: Center for Transportation and the Environment.

463   Gregory, T., Carrasco-Rueda, F., Alonso, A., Kolowski, J., & Deichmann, J. L. (2017).
464   Natural canopy bridges effectively mitigate tropical forest fragmentation for arboreal
465   mammals. *Scientific Reports*, 7(1), 3892. DOI: 10.1038/s41598-017-04112-x

467   Haddad, N. M., Bowne, D. R., Cunningham, A., Danielson, B. J., Levey, D. J., Sargent, S., &
468   Spira, T. (2003). Corridor use by diverse taxa. *Ecology*, 84(3), 609–615. DOI:
469   10.1890/0012-9658(2003)084[0609:CUBDT]2.0.CO;2

471   Hansen, D. M. (2010). On the use of taxon substitutes in rewilding projects on islands. In
472   Pérez-Mellado, V., & Ramon, C. (Eds.) *Islands and Evolution* (pp. 111–146). Menorca,
473   Spain: Institut Menorquí d'Estudis.

475   Harris, L. (1984). *The Fragmented Forest*. Chicago, IL: University of Chicago Press.
476

477 Hilty., J. A., Lidicker Jr, W. Z., & Merenlender, A. D. (2006). *Corridor Ecology: the Science*
478   *and Practice of Linking Landscapes for Biodiversity Conservation*. Washington, DC:
479   Island Press.
480
481 Hixon, M. A. (1982). Energy maximizers and time minimizers: theory and reality. *The*
482   *American Naturalist*, 119(4), 596–599. DOI: 10.1086/283937
483
484 Hodgson, J. A., Moilanen, A., Wintle, B. A., & Thomas, C. D. (2011). Habitat area, quality
485   and connectivity: striking the balance for efficient conservation. *Journal of Applied*
486   *Ecology*, 48(1), 148-152. DOI: 10.1111/j.1365-2664.2010.01919
487
488 Langur Project Penang (LPP) (2018). Road ecology and canopy bridges for arboreal wildlife
489   to cope with habitat fragmentation in Penang (Unpublished report, The Rufford
490   Foundation).
491
492 Lindshield, S. M. (2016). Protecting nonhuman primates in peri-urban environments: a case
493   study of neotropical monkeys, corridor ecology, and coastal economy in the Caribe Sur of
494   Costa Rica. In M. T. Waller (Ed.), *Ethnoprimatology: Primate Conservation in the 21st*
495   *Century. Progress and Prospects* (pp. 351–369). Cham, Switzerland: Springer.
496
497 Lindshield, S., Bogart, S. L., Gueye, M., Ndiaye, P. I., & Pruetz, J. D. (2019). Informing
498   protection efforts for Critically Endangered chimpanzees (*Pan troglodytes verus*) and
499   sympatric mammals amidst rapid growth of extractive industries in Senegal. *Folia*
500   *Primatologica*, 90(2), 124–136. DOI:10.1159/000496145
501
502 Lokschin, L. X., Printes, R. C., & Cabral, J. N. H. (2007). Power lines and howler monkey
503   conservation in Porto Alegre, Rio Grande do Sul, Brazil. *Neotropical Primates*, 14(2),
504   76–80. DOI: 10.1896/044.014.0206
505
506 Lombardi, L. (2017, April 13). Connectivity and coexistence key to orangutan survival on
507   croplands. Mongabay Series: Great Apes
508
509 Luckett, J., Danforth, E., Linsenbardt, K., & Pruetz, J. (2004). Planted trees as corridors for
510   primates at El Zota Biological Field Station, Costa Rica. *Neotropical Primates*, 12(3),
511   143–146. DOI: 10.1896/1413-4705.12.3.143
512
513 Malo, J. E., Hervás, I., Herranz, J., Mata, C., & Suárez, F. (2006). How many days to monitor
514   a wildlife passage? Species detection patterns and the estimation of the vertebrate fauna
515   using crossing structures at a motorway. In C. L. Irwin, P. Garrett, & K. P. McDermott
516   (Eds.) *Proceedings of the 2005 International Conference on Ecology and Transportation*
517   (pp. 406–413). Raleigh, NC: North Carolina State University.
518
519 Margono, B. A., Potapov, P. V., Turubanova, S., Stolle, F., & Hansen, M. C. (2014). Primary
520   forest cover loss in Indonesia over 2000–2012. *Nature Climate Change*, 4, 730–735. DOI:
521   10.1038/NCLIMATE2277
522
523 Martín, M. P. (2012). Evaluacíon del uso de puentes para monos según la percepción de la
524   comunidad de Manuel Antonio, Quepos, Costa Rica (Unpublished report, Kids Saving the
525   Rainforest).

15

526

527 Mass, V., Rakotomanga, B., Rakotondratsimba, G., Razafindramisa, S., Andrianaivomahefa,
528   P., Dickinson, S., … Cooke, A. (2011). Lemur bridges provide crossing structures over
529   roads within a forested mining concession near Moramanga, Toamasina Province,
530   Madagascar. *Conservation Evidence*, 8, 11–18.
531

532 Mortelliti, A., Amori, G., & Boitani, L. (2010). The role of habitat quality in fragmented
533   landscapes: a conceptual overview and prospectus for future research. *Oecologia*, 163(2),
534   535–547. DOI: 10.1007/s00442-010-1623-3
535

536 Naidoo, R., Kilian, J. W., Du Preez, P., Beytell, P., Aschenborn, O., Taylor, R. D., & Stuart-
537   Hill, G. (2018). Evaluating the effectiveness of local-and regional-scale wildlife corridors
538   using quantitative metrics of functional connectivity. *Biological Conservation*, 217, 96–
539   103. DOI: 10.1016/j.biocon.2017.10.037
540

541 Nekaris, K. A. I. (2014). Extreme primates: ecology and evolution of Asian lorises.
542   *Evolutionary Anthropology*, 23(5), 177–187. DOI: 10.1002/evan.21425
543

544 Nekaris, K. A. I. (2016). The Little Fireface Project: community conservation of Asia's slow
545   lorises via ecology, education, and empowerment. In M. Waller (Ed.) *Ethnoprimatology.*
546   *Primate Conservation in the 21st Century. Progress and Prospects* (pp. 259–272). Cham,
547   Switzerland: Springer.
548

549 Nekaris, K. A. I., McCabe, S., Spaan, D., Ali, M. I., & Nijman, V. (2018). A novel
550   application of cultural consensus models to evaluate conservation education programs.
551   *Conservation Biology*, 32(2), 466-476. DOI: 10.1111/cobi.13023
552

553 Nekaris, K. A. I., Poindexter, S., Reinhardt, K. D., Sigaud, M., Cabana, F., Wirdateti, W., &
554   Nijman, V. (2017). Coexistence between Javan slow lorises (*Nycticebus javanicus*) and
555   humans in a dynamic agroforestry landscape in West Java, Indonesia. *International*
556   *Journal of Primatology*, 38(2), 303–320. DOI: 10.1007/s10764-017-9960-2
557

558 Nekaris, K.A.I., Spaan, D., Nijman, V. (2019). Non-leaping lorises – implications for flooded
559   habitats. In K. Nowak & A. Barnett (Eds.), *Primates in Flooded Habitats: Ecology and*
560   *Conservation* (pp. 279–283). Cambridge, UK: Cambridge University Press.
561

562 Nijman, V. (2013). One hundred years of solitude: effects of long-term forest fragmentation
563   on the primate community of Java, Indonesia. In L. K. Marsh & C. A. Chapman (Eds.),
564   *Primates in Fragments: Complexity and Resilience. Developments in Primatology:*
565   *Progress and Prospects.* (pp. 33–45). New York, NY: Springer science+Business Media.
566

567 Nijman, V., & Nekaris, K. A. I. (2014). Traditions, taboos and trade in slow lorises in
568   Sundanese communities in southern Java, Indonesia. *Endangered Species Research*, 25(1),
569   79–88. DOI: 10.3354/esr00610
570

571 Onderdonk, D. A., & Chapman, C. A. (2000). Coping with forest fragmentation: the primates
572   of Kibale National Park, Uganda. *International Journal of Primatology*, 21(4), 587–611.
573   DOI: 10.1023/ A:1005509119693
574

575 Paige, C. (2015). Putting the crosshairs on deadly crossings. *Bugle*, 32, 70–81.

576
577 Parathian, H. E., & Maldonado, A. M. (2010). Human–nonhuman primate interactions
578   amongst Tikuna people: perceptions and local initiatives for resource management in
579   Amacayacu in the Colombian Amazon. *American Journal of Primatology*, 72(10), 855–
580   865. DOI: 10.1002/ajp.20816
581
582 Power, A. G. (2010). Ecosystem services and agriculture: tradeoffs and synergies.
583   *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1554), 2959–
584   2971. DOI: 10.1098/rstb.2010.0143
585
586 Reinhardt, K. D., Wirdateti, W., & Nekaris, K. A. I. (2016). Climate-mediated activity of the
587   Javan slow loris, *Nycticebus javanicus*. *AIMS Environmental Science*, 3(2), 249–260.
588
589 Rode-Margono, E. J., Nijman, V., Wirdateti, W., & Nekaris, K. A. I. (2014). Ethology of the
590   Critically Endangered Javan slow loris *Nycticebus javanicus* E. Geoffroy Saint-Hilaire in
591   West Java. *Asian Primates*, 4(2), 27–41.
592
593 Saralamba, C., & Menpreeda, W. (2018). Increasing connectivity through artificial canopy
594   bridge for the gibbons: a case study on the activity budget. The 87th Annual Meeting of
595   the American Association of Physical Anthropologists, Austin (Texas), April 12, 2018.
596
597 Sawaya, M. A., Kalinowski, S. T., & Clevenger, A. P. (2014). Genetic connectivity for two
598   bear species at wildlife crossing structures in Banff National Park. *Proceedings of the
599   Royal Society B: Biological Sciences*, 281(1780), 1–11. DOI: 10.1098/rspb.2013.1705
600
601 Seaman, D. E., Millspaugh, J. J., Kernohan, B. J., Brundige, G. C., Raedeke, K. J., & Gitzen,
602   R. A. (1999). Effects of sample size on kernel home range estimates. *Journal of Wildlife
603   Management*, 63(2), 739–747. DOI: 10.2307/3802664
604
605 Silva, F. E., & Bicca-Marques, J. C. (2013). Do patch size and interpatch distance influence
606   the distribution of brown howler monkeys (*Alouatta uariba clamitans*) in a fragmented
607   landscape in south Brazil? In L. K. Marsh & C. A. Chapman (Eds.), *Primates in
608   Fragments: Complexity and Resilience* (pp. 137–145). New York, NY: Springer.
609
610 Stafford, C. A., Alarcon-Valenzuela, J., Patiño, J., Preziosi, R. F., & Sellers, W. I. (2016).
611   Know your monkey: identifying primate conservation challenges in an indigenous Kichwa
612   community using an ethnoprimatological approach. *Folia Primatologica*, 87(1), 31–47.
613   DOI: 10.1159/000444414
614
615 Taylor, B. D., & Goldingay, R. L. (2010). Roads and wildlife: impacts, mitigation and
616   implications for wildlife management in Australia. *Wildlife Research*, 37(4), 320–331.
617   DOI: 10.1071/WR09171
618
619 Taylor, A. C., Walker, F. M., Goldingay, R. L., Ball, T., & Van Der Ree, R. (2011). Degree
620   of landscape fragmentation influences genetic isolation among populations of a gliding
621   mammal. *PLoS One*, 6(10), 1–11. DOI: 10.1371/journal.pone.0026651
622

623 Teixeira, F. Z., Printes, R. C., Fagundes, J. C. G., Alonso, A. C., & Kindel, A. (2013).
624   Canopy bridges as road overpasses for wildlife in urban fragmented landscapes. *Biota*
625   *Neotropical*, *13*(1), 117–123. DOI: 10.1590/S1676-06032013000100013
626
627 Tischendorf, L., & Fahrig, L. (2000). On the usage and measurement of landscape
628   connectivity. *Oikos* 90(1),7–19. DOI: 10.1034/j.1600-0706.2000.900102
629
630 Valladares-Padua, C., Cullen, L., & Padua, S. (1995). A pole bridge to avoid primate road
631   kills. *Neotropical Primates*, 3, 13–15.
632
633 Van der Grift, E. A., & van der Ree, R. (2015). Guidelines for evaluating use of wildlife
634   crossing structures. In R. van der Ree, D. J. Smith, & C. Grilo (Eds.), *Handbook of Road*
635   *Ecology* (pp. 119–128). West Sussex, UK: Wiley.
636
637 Van der Ree, R., Gulle, N., Holland, K., Grift, E. A. V. D., Mata, C., & Suarez, F. (2007).
638   Overcoming the barrier effect of roads – how effective are mitigation strategies? UC
639   Davis: Road Ecology Center. Retrieved from https://escholarship.org/uc/item/66j8095x
640
641 Vickers, T. W., Sanchez, J. N., 1, Johnson, C. K., Morrison, S.A., Botta, R., Smith, T.,
642   Cohen, B. S., Huber, P. R., Ernest, H. B., & Boyce, W. B. (2015). Survival and mortality
643   of pumas (*Puma concolor)* in a fragmented urbanizing landscape. *PLoS One*, 10(7). DOI:
644   10.1371/journal.pone.0131490
645
646 Whitten, A. J., Soeriaatmadja, R. E., & Afiff, S. A. (1996). *The Ecology of Java and Bali. the*
647   *Ecology of Indonesia (Vol. II)*. New York, NY: Tuttle Publishing.
648
649 Wyman, M., & Stein, T. (2010). Examining the linkages between community benefits, place-
650   based meanings, and conservation program involvement: a study within the Community
651   Baboon Sanctuary, Belize. *Society & Natural Resources*, 23(6), 542–556. DOI:
652   10.1080/08941920902878267
653
654 Yokochi, K., & Bencini, R. (2015). A remarkably quick habituation and high use of a rope
655   bridge by an endangered marsupial, the western ringtail possum. *Nature Conservation*, 11,
656   79–94. DOI: 10.3897/natureconservation.11.4385
657
658 Yokochi, K., Chambers, B. K., & Bencini, R. (2015). An artificial waterway and road restrict
659   movements and alter home ranges of endangered arboreal marsupial. *Journal of*
660   *Mammalogy*, 96(2), 1284–1294. DOI: 10.1093/jmammal/gyv137
661
662 Yokochi, K., Kennington, W. J. & Bencini, R. (2016). An endangered arboreal specialist, the
663   western ringtail possum (*Pseudocheirus occidentalis*), shows a greater genetic divergence
664   across a narrow artificial waterway than a major road. *PLos One*, 11(1), e0146167. DOI:
665   10.1371/journal.pone.0146167
666
667 Wilson, R. F., Marsh, H., & Winter, J. (2007). Importance of canopy connectivity for home
668   range and movements of the rainforest arboreal ringtail possum (*Hemibelideus*
669   *lemuroides*). *Wildlife Research*, 34(3), 177–184. DOI: 10.1071/wr06

670 Table 1. Summary of research publications documenting wildlife crossings for primates and their ecological benefits.
671 NA: information not available SYS: systematic quantitative study, UNS: qualitative unsystematic study
672

Type	Material	Number	Length (m)	Study country	Study period	Habituation period	Collection method	Primate Species	Ecological benefits	Reference
Ladder	rope, rubber	2	NA	Brazil	3 years	NA	UNS	*Alouatta guariba clamitans*	Minimize mortality	Lokschin et al., 2007
	rope, rubber	6	NA	Brazil	15 months	NA	SYS	*A. g. clamitan*	Minimize mortality; increase resource access	Teixeria et al., 2013
	PVC, rubber, wire cable	28	NA	Kenya	"Several months"	NA	SYS	*Cercopithecus albogularis; Colobus angolensis; Chlorocebus pygerythrus*	Minimize mortality	Donaldson and Cunneyworth, 2015
	PVC, rubber, wire cable	7	10-30	Costa Rica	2 non-consecutive years	NA	SYS	*A. palliata*	Minimize mortality; reduce isolation	Lindshield, 2016
	wood	1	NA	Brazil	3 years	NA	UNS	*Leontopithecus chrysopygus; Cebus apella*	Minimize mortality; reduce isolation	Valladares-Padua et al., 1995
	bamboo	9	7–25	India	2 months	15 days	SYS	*Hoolock hoolock*	Minimize terrestrial locomotion; increase resource access	Das et al., 2009
Linear	wire cable, wood	3	8-15	Madagascar	18 months	NA	SYS	*Avahi laniger; Cheirogaleus major; Eulemur fulvus; E. rubriventer Propithecus diadema; Hapalemur griseus*	Minimize mortality	Mass et al., 2011
	wood	4	22-25							
	rope	NA	NA	Costa Rica	NA	NA	NA	*Saimiri oerstedii; Cebus imitator*	Minimize mortality	Martin, 2012 Unpublished
	rope	7	10-30	Costa Rica	7 years	NA	SYS	*Alouatta palliata*	Minimize mortality; reduce isolation	Lindshield, 2016

19

pipeline	13	415	Peru	1 year	NA	SYS	*Aotus nigriceps; Sapajus apella; Cebus albifrons; Pithecia irrorata; Saguinus imperator; Callicebus brunneus; Saguinus fuscicollis*	Reduce fragmentation	Gregory et al., 2017
rope	NA	NA	Thailand	5 months	NA	UNS	*Hylobates lar*	Reduce fragmentation	Saralamba and Menpreeda, 2018
fire hose	NA	5m	Malaysia	NA	NA	NA	*Trachypithecus obscurus*	Minimize collision	Langur Project Penang (LPP), Unpublished
fire hose, ropes, chain links	6	NA	Malaysia	NA	4 years	UNS	*Pongo pygmaeus*	Reduce isolation; favor dispersal	Ancrenaz 2010; Lombardi, 2017

673

674

675

676 **Table 2:** Home range size, terrestriality (distance and time), number of feeding trees used, and percentage of sample points spent exploring and travelling by
677 the seven focal Javan slow lorises in Cipaganti, West Java, before and after the implementation of bridges.

678

Bridge structure	ID	Pre-bridge implementation						Post-bridge implementation					
		Observation time (h)	Home range size (ha)	Terrestrial distance (m/h)	Terrestrial time (s/h)	Feeding trees (N/h)	% explore + travel	Observation time (h)	Home range size (ha)	Terrestrial distance (m/h)	Terrestrial time (s/h)	Feeding trees (N/h)	% explore + travel
Waterline	ALE	34.75	2.00	3.60	18.3	0.23	34.53	27.17	6.77	0.67	1.62	0.22	23.31
Waterline	TEE	31.83	2.22	1.82	0.82	0.25	36.65	26.42	4.36	0.00	0.00	0.30	25.24
Waterline	XEE	20.25	3.33	0.25	5.93	0.35	38.27	27.58	3.05	0.00	0.00	0.15	18.43
Rubber	FE	22.25	2.93	1.57	20.22	0.09	20.97	18.17	4.11	0.77	11.56	0.06	11.93
Rubber	OEE	30.67	2.57	0.03	0.16	0.42	57.88	30.75	4.23	0.10	0.07	1.33	44.17
Rubber	SH	21.75	2.74	1.15	5.98	0.41	46.36	20.50	2.11	0.59	8.78	0.63	44.31
Rubber	TOO	18.17	2.52	0.55	15.41	0.44	35.32	11.50	3.86	0.09	0.43	0.43	24.64

679

Figure Headings:

Figure 1: Photos of the two types of bridges used in the study of Javan slow lorises in Cipaganti, West Java: waterline made with water pipe (left) and of the 'loris bridge' made with rubber material (right).

Figure 2: Mean (in black) and range (in gray) cumulative number of crossings on waterlines (left) and rubber bridges (right) by Javan slow loris in Cipaganti, West Java, based on camera trap data.
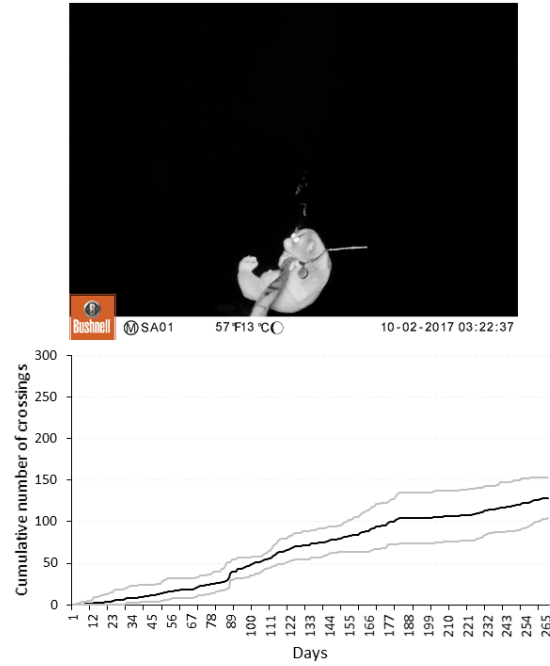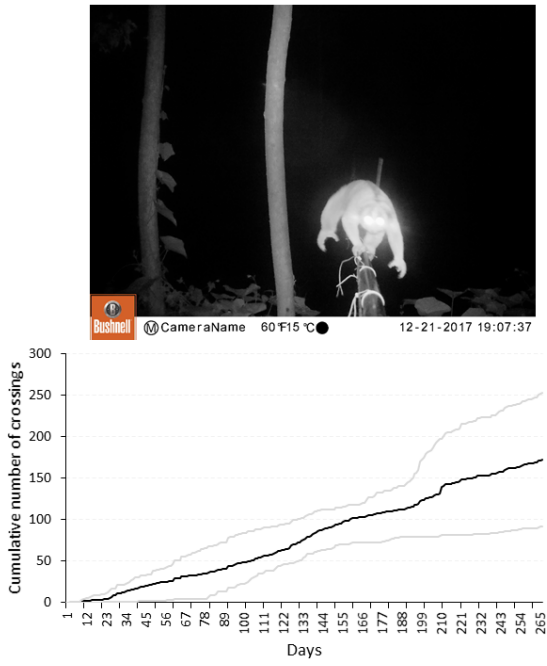

Figure 3: Home ranges of female (above) and male (below) Javan slow lorises before and after the installation of bridges in Cipaganti, West Java. Rubber bridges are in black, waterlines are in blue.
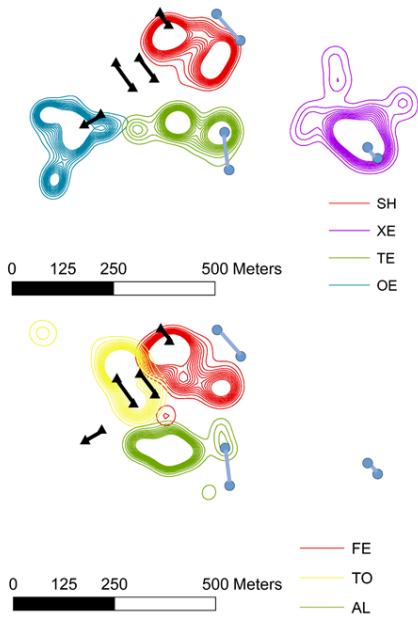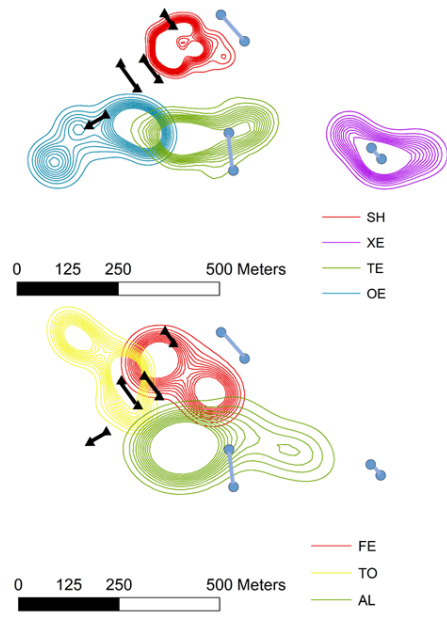
692

693

Three months before

Three months after

694
695

24