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

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Running head: Canopy bridge use by slow lorises

Abstract:

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

Keywords: conservation evidence, forest fragmentation, *Nycticebus javanicus,* wildlife crossings

Research highlights:

- We integrated artificial canopy bridges into the home range of Javan slow lorises allowing them to save energy and access new areas.
- Bridges made of waterpipes supplied irrigation to farmers' crops providing additional 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).

In the case of arboreal primate species, such studies have lagged behind, but are now necessary as primary forests disappear at an alarming rate (Estrada et al., 2017). The conversion of forests to agriculture affects the availability of feeding resources and sleeping trees for primates (Das, Biswas, Bhattacherjee, and Rao, 2009a; Arroyo-Rodríguez and Mandujano, 2009). Arboreal primates may need to perform terrestrial behaviors to cross disconnected areas within their home ranges (Lokschin et al.,2007; Das et al., 2009a; Mas et al., 2011; Donaldson and Cunneyworth, 2015). The lack of connectivity imposes costs such as high mortality due to predators or road collisions (Mass et al., 2011), dietary changes (Onderdonk and Chapman, 2000; Das et al., 2009a), home range modifications (Onderdonk and Chapman, 2000; Bicca-Marques, 2003) and increased physiological stress and parasite loads (Chapman et al., 2006). Artificial canopy bridges can be used to replace the lack of connectivity between fragments occupied by primates (Valladares-Padua et al., 1995; Teixeria et al., 2013; Lindshield, 2016; Table 1). Designed from different materials (rope, ladder, rubber, pole, bamboo), they can represent efficient structures for dispersal, travelling or foraging movements (Das et al., 2009a).

The island of Java, Indonesia, is highly populated and largely deforested, with less than 10% of the original forest left (Whitten, Soeriaatmadja, and Afiff, 1996; Margono, Potapov, Turubanova, Stolle, and Hansen, 2014). Contrary to other areas of Indonesia, deforestation occurred mainly before the year 2000 and current deforestation rates are low (Margono et al., 2014; Brun et al., 2015). In the 90s, it was reported that about 17% of the agricultural land on Java consisted of fragmented forests surrounded by agroforest environments (Whitten et al., 1996). Forest has been replaced by a mosaic of cities, villages, and agricultural forest plantations (Nijman, 2013). In this study, we examined the impact of the implementation of artificial canopy bridges on the habitat use of Javan slow loris (*Nycticebus javanicus*) in an agroforestry environment. The Javan slow loris is listed as Critically Endangered due to habitat loss and persecution for the illegal wildlife trade (Nekaris, 2016). Slow lorises are fully arboreally adapted and cannot leap and require canopy connectivity for movement (Nekaris, 2014). Some loris species, however, have been observed to use terrestrial movements in disconnected habitats, but only rarely and with caution (Das, Biswas, Das, Ray, Sangma, and Bhattacharjee, 2009b; Nekaris, Spaan, Nijman, 2019). Reinhardt, Wirdateti, and Nekaris (2016) showed that the lack of connectivity of feeding trees was related to a decrease in activity by Javan slow lorises. The ability of slow loris populations to persist in intensively human-modified and fragmented landscapes thus depends on the restoration of canopy connectivity. We expect that, after the erection of canopy bridges, Javan slow lorises will 1) use bridges as artificial canopy; 2) expand their home ranges to include previously disconnected areas; 3) reduce terrestrial movements; 4) reduce exploring and travelling time or increase the number of feeding trees visited.

Methods

Field site

We conducted the study in an agroforest environment in Cipaganti, Cisurupan, Garut District, West Java (7°16’44.30”S, 107°46‘7.80”E). Cipaganti is located at 1345 m a.s.l. on Mount Puntang, which is a part of the Java-Bali Montane Rain Forests ecoregion. This area is characterized by a mosaic of gardens, where local farmers practice an annual rotating crop system (Nekaris et al., 2017). This traditional system consists of a variety of crop formations, with tall trees planted along farm property boundaries, or interspersed between crop types (Reinhardt et al., 2016).

Slow loris behavioral observations and home ranges

We examined the behavior of Javan slow lorises in relation to erection of artificial canopy bridges, as part of an ongoing long-term community conservation project on the species started in 2012. For this study, we focused our data collection and analysis on seven adult collared individuals (four females and three males) four of which were part of mated pairs. Slow lorises were caught safely by hand and were equipped with 19 g VHF radio collars (PIP3, Biotrack, Wareham, United Kingdom). With the assistance of local trackers, we located collared individuals using an antenna (Lintec flexible, Biotrack, Wareham, United Kingdom) and a receiver (Sika receiver, Biotrack, Wareham, United Kingdom). We observed focal individuals at night throughout their entire active period (1700 h – 0500 h), using head torches (HL17 super spot, Clulite, Petersfield, United Kingdom) fitted with red filters. We collected behavioral data following the instantaneous focal sampling method (Altmann, 1974) and location data using a handheld GPS unit (GPS62s, Garmin International, Olathe, USA), both at the same five-minute intervals. Via instantaneous focal sampling, we collected data on number of trees used, and proportion of data points spent travelling and exploring (c.f. Rode-Margono, Nijman, Wirdateti, and Nekaris, 2014). We collected data on terrestriality (i.e. distance and duration of time spent on the ground) via the all occurrences method (Altmann, 1974).

Artificial connectivity and use monitoring

In order to improve connectivity in the study site, we implemented one bridge in June 2016 and six bridges between June and July 2017. They were built to connect disconnected trees that were separated by agricultural fields. We built two different types of artificial wildlife crossings: “loris bridge” and “waterline”. We made four loris bridges by using rubber wrapped around a 1.5 cm width wire and three waterline bridges from rigid 3 cm diameter water pipe tied to a wire (Figure 1). A wire was used as a support to ensure stability and to minimize breaks during storms. We considered two important criteria when erecting waterlines to favor farmers as well: access to source water and positive slope to allow the flow of water. We installed bridges at a mean height of 4.2 m ± SD 1.4 (range: 2-8 m) attached to trees with a mean height of 9.1 m ± SD 2.9 (range: 4-15 m). The mean rubber bridge length was 37.75 m ± SD 14.05 (range: 29-56 m), while the mean waterline length was 75 m ± SD 32.2 (range: 26-82 m). To monitor efficiently the use of bridges by slow lorises, we set up motion triggered infrared cameras (Bushnell HD model 119836) at extremities of all bridges the day they were implemented. We set up cameras to take three photos per capture with a delay of 3 seconds. We considered the events in which the same animal crossed the bridges and not the number of pictures since the animals were easily recognizable. Camera traps also recorded videos associated with each crossing, which we used to analyze the prevalence of three behaviors (travelling, alert, social; c.f. Rode-Margono et al. 2014). We examined camera trap photos and videos from June 2016 to April 2018. Camera traps collected data for a maximum of 266 days (mean=195 ± SD 85 days), yielding a total trapping effort of 741 days on waterlines and 820 days on rubber bridges.

Data analysis

Considering behavioral observations on the seven focal animals, we compared the data collected three months before and three months after the installation of bridges. We excluded the first month after the installation of bridges since we considered it as habituation period. We collected a total of 179.67 h and 162.09 h of observations before and after the implementation of bridges respectively. We computed the ranging patterns (in hectares) of the seven individuals via Fixed Kernel (FK) method with smoothing selected by least-squares cross-validation (LSCVh) (Seaman et al., 1999) using the software Ranges 9. We considered home ranges at 95% FK (Seaman et al., 1999). We exported the shapefiles to ArcGIS 10.4 software for graphical visualization. To test for statistical differences between the behaviors before and after the installation of bridges, we used the Wilcoxon test for paired samples. We considered home ranges, distance walked and time spent on the ground, number of feeding trees used per hour, and proportion of data points spent travelling and exploring as dependent variables. We performed the tests via SPSS v25 considering $P < 0.05$ as level of significance.

All research was approved by the Animal Care Subcommittee of Oxford Brookes University and followed the American Society of Primatologists (ASP) Principles for Ethical Treatment of Non-human Primates. All research adhered to the legal and ethical guidelines of the Indonesian Institute of Sciences, Department of Wildlife and Department of Forestry.

RESULTS

Camera traps collected a total of 817 events of slow lorises using bridges (463 events on waterlines and 354 events on rubber bridges). From camera trap footage, we found that slow lorises used both waterlines and rubber bridges on average 12.9 ± SD 9.7 days after we installed them (waterlines: mean=10.3 ± SD 9.7 days; rubber bridges: mean=14.4 ± SD 10.4 days; Figure 2). Slow lorises continued to use the bridges for the whole duration of the study. They used waterlines for travelling in 77.3 % of the observations, being alert 17.7% of observations, the lorises engaged in social activities for 5.0%, with up to three slow lorises crossing at once. Slow lorises used loris bridges mainly for travelling (97.2% of observations) and only in 2.8 % of events they were alert.

From behavioral observations, we found that two males (AL and TO) and three females (OE, TE, and XE) expanded their home ranges after the installation of bridges (Table 2, Figure 3). The home range size before and after the installation of bridges was not statistically different, although there is a trend towards larger home ranges after the installation of bridges (before: median=2.57 ha, quartiles=2.37-2.84 ha; after: median=4.11 ha, quartiles=3.46-4.30 ha; $W=1.859$, $p=0.063$).

After the installation of bridges, slow lorises diminished the distance spent on the ground (before: median=1.15 m/h, quartiles=0.40-1.70 m/h; after: median=0.10 m/h, quartiles=0.04-0.48 m/h; $W=-2.197$, $p=0.028$). The actual time spent on the ground was not statistically different, although there is a trend towards less time spent on the ground after the installation of bridges (before: median=5.98 s/h, quartiles=3.37-16.77 s/h; after: median=0.43 s/h, quartiles=0.03-5.20 m/h; W=-1.859, p=0.063). The number of feeding trees used per hour did not change after the installation of bridges (before: median=0.35 trees/h, quartiles=0.24-0.42 trees/h; after: median=0.30 trees/h, quartiles=0.18-0.53 trees/h; W=0.507, p=0.612). The proportion of data points spent travelling and exploring, however, significantly decreased after the installation of bridges (before: median=36.65 % of the observations, quartiles=34.93-42.32 %; after: median=24.64 % of the observations, quartiles=20.87-34.71 %; W=-2.366, p=0.018) (Table 2).

DISCUSSION

We built artificial canopy bridges in a fragmented agroforest environment in West Java, Indonesia to evaluate the effect that wildlife bridges had on a Javan slow loris population in terms of crossing gaps. We found that slow lorises used all of the rubber bridges and waterlines we erected to cross gaps over areas with limited to no arboreal connectivity. After implementation of the bridges, slow lorises started to use bridges for complete crossings after an average of 12.9 days. This time period is similar to that recorded for western ringtail possums (*Pseudocheirus occidentalis*) in Australia and Hoolock gibbons (*Hoolock hooklock*) in India (Yokochi and Bencini, 2015; Das et al., 2009a)**.** After the habituation period, slow lorises used the bridges for the remaining study period (Little Fireface Project, unpublished data). Locomotion across bridges was swift and efficient. Slow lorises could move on the top or underneath the bridges, and in this manner, could cross with social group members or other species (c.f. Das et al., 2009a; Teixeira, Printes, Fagundes, Alonso, and Kindel, 2013). Bridge use has been safe, with no animals falling from or gaining an injury from bridge use or suffering predation whilst on a bridge. Here we discuss bridge use in the context of slow loris behavior and conservation.

Various studies have demonstrated that mammals, including primates, are able to adapt to fragmented habitats (Luckett, Danforth, Linsenbardt, and Pruetz,2004). For tree dwelling species, bridges as artificial wildlife crossings are a good temporary solution to improve connectivity in fragmented habitats (Das et al., 2009a). All slow lorises included in this study made use of both types of bridges. Testing styles of bridge is important, as in an initial pilot study, we unsuccessfully trialed a ladder type bridge that had been successfully employed for black and white colobus monkeys (*Colobus angolensis palliatus*) (Donaldson and

Cunneyworth, 2015). By employing two additional styles of bridge, not only were we successful, but slow lorises used both types, as also seen in six different lemur species in eastern Madagascar (Mass et al., 2011). Rubber and waterline bridges may also have been more successful for slow lorises because of their propensity to grasp small substrates around which they can clasp their hands (Rode-Margono et al., 2014). Despite the potentially loris-specific size of the bridges, all seven bridges we built were used by other animal species, including Javan palm civets (*Paradoxurus musanga javanicus*), black-striped squirrels (*Callosciurus nigrovittatus)*, Horsfield's treeshrews (*Tupaia javanica*), as well as by owls and other bird species. Civets, however, only used the waterline structures, and were not observed using the rubber structures. These observations concur with Goosem, Weston, and Bhushnell (2005), who demonstrated that canopy bridges are not species-selective but can provide benefits for non-focal species.

Canopy bridges allowed slow lorises to include areas in their home ranges that were previously disconnected. In particular, they used bridges to connect either to patches that previously only could be accessed via the ground or were able to add new areas to their home range (c.f. Gregory, Carrasco-Rueda, Alonso, Kolowski, and Deichmann, 2017). In all cases, focal slow lorises used both sides of the bridges, although we have observed animals in our population using bridges in only one direction during dispersal events. Other taxa, including Hoolock gibbons in India and black and white colobus monkeys in Kenya, also used both sides of the bridges (Das et al., 2009a; Donaldson and Cunneyworth, 2015). Rainforest ringtail possums, however, only occasionally used the habitat on the opposite side of the bridge, with numerous ‘half crossings’ observed (Wilson, Marsh, and Winter 2007). Although home range sizes were not significantly larger, in a highly fragmented landscape, the importance of access to additional resources cannot be underestimated.

Increasing home range size and having better access across the landscape also may be reflected in reducing exploring or travelling time or increasing the number of feeding trees visited (Gregory et al., 2017). Indeed, slow lorises spent a lower proportion of data points travelling in search of food resources after the implementation of the bridges, although they still visited the same number of feeding trees per hour. The presence of the bridges may significantly increase the survival of the individuals. Slow lorises, in fact, spent a lower proportion of data points travelling through their home range to search for resources, which may allow them to save energy (i.e. time minimizer strategy; Hixon 1982, Campera et al., 2014). The viability of a species depends not only on its population size but also on its habitat structure and on the movement of individuals between habitat patches (Valladares-Padua et al., 1995). The canopy bridges that we constructed in this study connected trees in loris home ranges and therefore created access to new habitable areas and feeding resources. They reduced isolation between individuals and encouraged dispersal. Das et al. (2009a) also found that Hoolock gibbons had access to previously disconnected areas as well as new food resources after the installation of bridges.

Only a handful of studies concerning primate use of canopy bridges have been reported (e.g. Mass et al., 2011; Teixeira et al., 2013; but see Donaldson and Cunnyworth, 2015; Table 1). We found that not only did slow lorises use bridges almost nightly, but that they also engaged in fewer terrestrial behaviors after the implementation of the bridges. Habitat fragmentation may increase arboreal primate mortality (Das et al., 2009a). With a lack of connectivity, primates have no choice but to walk on the ground, increasing the risk of predation (Silva and Bicca-Marques, 2013), as well as the risk of disease and parasites (Chapman et al., 2006). Farmers in our study area use dogs to guard their land and to hunt. Dogs are left at night in the field and may be aggressive. Since 2012, despite a lack of other predation events, at least four slow lorises have been injured or killed by dogs in Cipaganti. Dogs are frequent in the fields and are probably the second greatest threat to slow lorises in the area after hunting by humans. Thus, an increase in arboreal connectivity may reduce the risk of injury or death to these Critically Endangered primates.

Clearly an increase in arboreal pathways is a desired impact of long-term conservation projects. To achieve this goal, habitat restoration schemes such as forest corridors are ultimately the most desirable (Harris, 1984). Corridors can be implemented in degraded habitats to restore connectivity between natural forest areas (Ganzhorn, 1987). Nevertheless, forest corridors are not always easy to implement, as they may cross privately owned human properties, whose landlords may not always be willing to collaborate (Valladares-Padua et al., 1995; Alexander, 2000; Gibson, Lehoucq, and Williams, 2002; Wyman and Stein 2010). A solution to this conflict may be the planting of tree corridors, with trees that have value to local communities or land-owners whether they be native species or not. Primates can benefit from these corridors by using them for travelling and resting and may exploit non-native tree 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 support of the local community, and we encourage others to include as much involvement as possible with local people when developing similar projects.

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Conflicts of Interest:

Authors have no conflicts of interest to report.

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

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

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

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

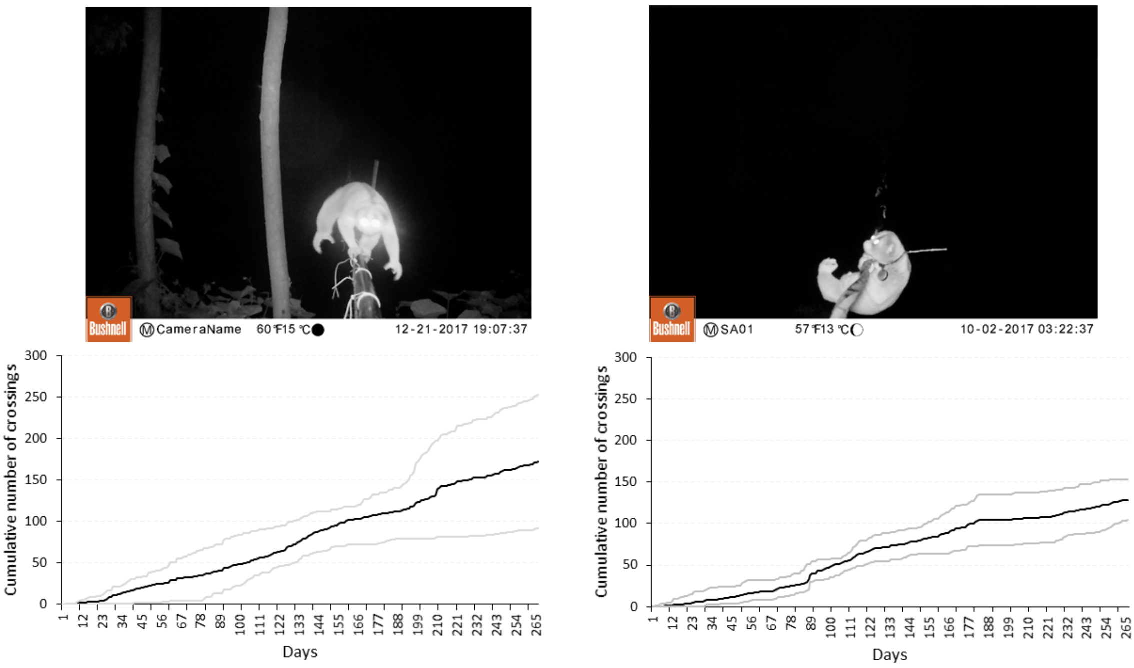
		Pre-bridge implementation						Post-bridge implementation					
Bridge structure	ID	Observation time (h)	Home range size (ha)	Terrestrial distance (m/h)	Terrestrial time (s/h)	Feeding trees (N/h)	% explore + travel	Observation time (h)	Home range size (ha)	Terrestrial distance (m/h)	Terrestrial time (s/h)	Feeding trees (N/h)	% explore + travel
Waterline	AL	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	TE	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	XE	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	OE	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	TO	18.17	2.52	0.55	15.41	0.44	35.32	11.50	3.86	0.09	0.43	0.43	24.64

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.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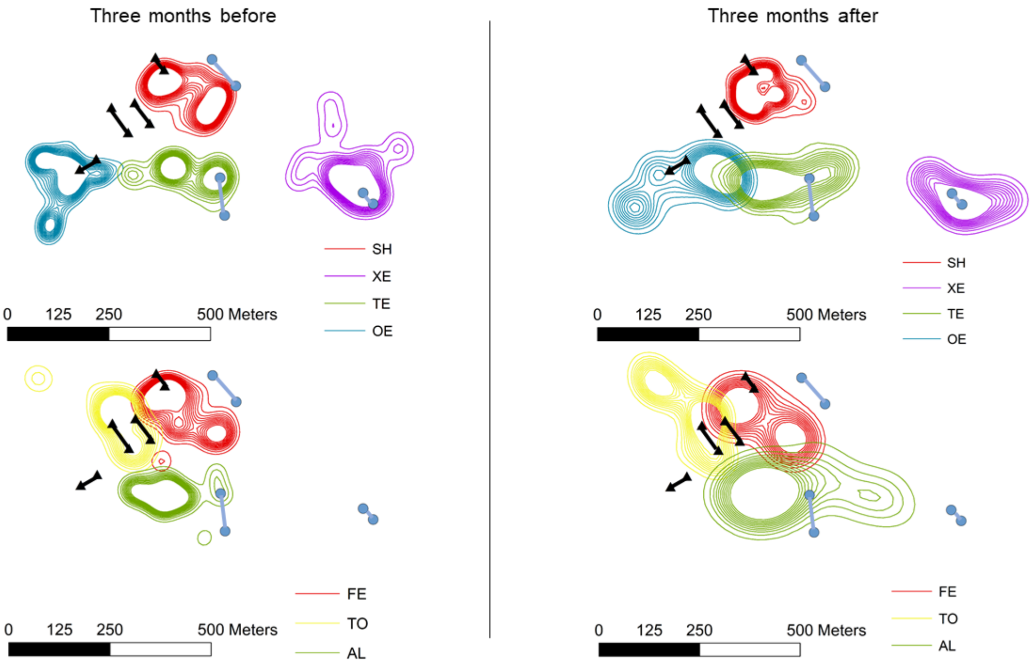
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