

**Assessing the importance of artificial canopy bridge design for
Costa Rican monkeys in an experimental setting**

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Supplementary material

Table S1. Summary of artificial canopy bridge studies for nonhuman primates including the study site, species, bridge model description and major findings as provided by authors.

Study site	Primate species	Bridge model	Major findings	Authors
Borajan, India	Hoolock gibbons (<i>Hoolock hoolock</i>)	Single bamboo poles	Three types of single bamboo pole bridges were tested and two of those worked best to allow gibbons to brachiate between forest patches.	Das <i>et al.</i> , 2009
Refugio Nacional Mixto de Vida Silvestre Gandoca-Manzanillo, Costa Rica	Mantled howler monkey (<i>Alouatta palliata</i>), White-faced capuchin monkey (<i>Cebus imitator</i>), black-handed spider monkey (<i>Ateles geoffroyi</i>)	PVC horizontal step ladder, single linear bridge made of two synthetic ropes twisted together	No primates were recorded using the artificial crossing structures. Fewer instances of animals using ladder bridges made of PVC, as opposed to single rope bridges, which may suggest bridge design and materials to influence bridge use by primates.	Lindshield, 2016
Ruta 257, Costa Rica	White-faced capuchin monkey (<i>Cebus imitator</i>), howler monkey (<i>Alouatta palliata</i>), spider monkey (<i>Ateles geoffroyi</i>)	Tunnel-like bridge made with ropes and mesh-like material	Of the three species present, capuchins were the only ones recorded to use the crossing structure.	Panthera, 2019 ^a
Manuel Antonio, Quepos, Costa Rica	Squirrel monkey (<i>Saimiri oesterdii</i>), white-face capuchin monkey (<i>Cebus imitator</i>), mantled howler monkey (<i>Alouatta palliata</i>)	Single linear rope	Three species of monkeys are reportedly using the crossing structures, but in variable frequency.	Pfa Martin, 2012
Ruta 4, Costa Rica	Mantled howler monkey (<i>Alouatta palliata</i>), white-faced capuchin monkey (<i>Cebus imitator</i>), spider monkey (<i>Ateles geoffroyi</i>)	Tunnel-like bridge made with ropes and mesh-like material	Howler monkeys and capuchins used the aerial bridges more than other arboreal species. Spider monkeys were not recorded using the bridges.	Araya-Jiménez, 2019 ^b
Lami district, Porto Alegre, Brazil	Brown howler monkey (<i>Alouatta guariba clamitans</i>)	Rope and rubber horizontal ladder	Parallel vertical ropes were not effective and was changed for a horizontal ladder bridge model. This model is helping reduce primate electrocution accidents. Monkeys use the bridges seasonally and more often in areas of increased surrounding vegetation, as opposed to more urban.	Lokschin <i>et al.</i> , 2007; Teixeira, 2013
Diani Beach Road, Kenya	Angolan black and white colobus monkey (<i>Colobus angolensis palliatus</i>), Sykes monkey (<i>Cercopithecus mitis</i>), vervet monkey (<i>Chlorocebus pygerythrus</i>)	Horizontal ladder made with rubber, PVC, and wire cable	Horizontal ladder bridges were successfully used by three primate species. However, the rate of use by each species was highly variable.	Donaldson and Cunneyworth, 2015 ^c
Kinabatangan, Malaysian Borneo	Orang-utan (<i>Pongo pygmaeus</i>)	Double ropes, double chain links, two to three fire hoses intertwined together	Orang-utans documented using single rope bridges suggesting effective reconnection of sub-populations isolated by water bodies.	Arenaz, 2010 ^d

Toamasina Province, Madagascar	Eastern woolly lemur (<i>Avahi laniger</i>), hairy-eared dwarf lemur (<i>Allocebus trichotis</i>), greater dwarf lemur (<i>Cheirogaleus major</i>), aye-aye (<i>Daubentonia madagascariensis</i>), weasel sportive lemur (<i>Lepilemur mustelinus</i>), Goodman's mouse lemur (<i>Microcebus lehilahytsara</i>), grey bamboo lemur (<i>Hapalemur griseus</i>), indri (<i>Indri indri</i>), diademed sifaka (<i>Propithecus diadema</i>), black-and-white ruffed lemur (<i>Varacia variegata</i>), brown lemur (<i>Eulemur fulvus</i>), red-bellied lemur (<i>Eulemur rubriventer</i>), greater bamboo lemur (<i>Prolemur simus</i>)	Suspension bridge made of cables, tensors, carabineers, and wood, and a wooden pole bridge	Two types of bridge were used by six species of lemur. The suspension bridge was used more frequently than the pole bridge.	Mass <i>et al.</i> , 2011
Cipaganti, Cisarupan, Garut District, West Java, Indonesia	Javan slow loris (<i>Nycticebus javanicus</i>)	Linear bridge made of rubber wrapped around a 1.5cm width wire, and a linear waterline bridge from rigid 3 cm diameter water pipe tied to a wire	Unsuccessful trial of ladder bridges. Slow lorises used both linear bridge models, but waterlines more frequently.	Birot <i>et al.</i> , 2019
Penang, Malaysia	Dusky langur (<i>Trachypithecus obscurus</i>), long-tailed macaque (<i>Macaca fascicularis</i>)	A single twisted upcycled firehose	Dusky langurs did not use the bridge during the study period, but long-tailed macaques used it to cross the road. Using firehoses is a cost-efficient and strong material	Leen and Rupert, 2019 ^e
Fazenda Rio Claro, Sao Paulo, Brazil	Black lion tamarin (<i>Leontopithecus chrysopygus</i>), capuchin (<i>Cebus apella</i>)	Round wooden pole	Both species of monkeys frequently use the pole bridge to cross the road.	Valladares-Padua <i>et al.</i> , 1995 ^f
Rancho San Román UMA, Laguna de Términos Protected Area, Mexico	Black howler monkey (<i>Alouatta pigra</i>)	Horizontal ladder bridge made with silk rope, wooden rods, and wires.	Howlers used the bridge in a daily basis to travel between forest patches.	Hernández Perez, 2015
Limpopo Province, South Africa	Samango monkey (<i>Cercopithecus albogularis</i>), chacma baboon (<i>Papio ursinus</i>), brown greater galago (<i>Otolemur crassicaudatu</i>), lesser galago (<i>Galago moholi</i>)	Bamboo pole bridge, horizontal ladder bridge made of nylon rope and wood cross-pieces	Pole bridge was preferred over the ladder bridge.	Linden <i>et al.</i> , 2020

Note: We conducted a literature search through the Web of Science database using a combination of keywords and phrases including ‘artificial canopy bridge*,’ ‘monkey*,’ ‘primate*’ and included in this table a summary of studies on artificial canopy bridges for nonhuman primates aiming to represent a wide geographic area, multiple arboreal primate species, and diverse bridge models. We also included grey literature shared through Research Gate and email exchanges with colleagues (i.e., Araya-Jiménez, 2019; Leen and Rupert, 2019).

^a Panthera (2019). Monitoreo del jaguar, otros felinos silvestres y sus especies presa en el cantón central de Limón, Costa Rica. Informe final para CCT-APM Terminals. Costa Rica.

^b Araya-Jiménez Y (2019). Efectividad de estructuras para el paso de fauna silvestre en la Ruta Nacional No 4, Bajos de Chilamate-Vuelta Kooper, Costa Rica. Universidad Latina de Costa Rica. DOI: [10.1017/CBO9781107415324.004](https://doi.org/10.1017/CBO9781107415324.004).

^c Donaldson A, Cunneyworth P (2015). Case study: Canopy bridges for primate conservation. In *Handbook of Road Ecology* (van der Ree R, Smith DJ, Grilo C, eds.), pp. 341–343. Chichester, John Wiley & Sons. DOI: [10.1002/9781118568170.ch41](https://doi.org/10.1002/9781118568170.ch41).

^d Ancrenaz M (2010). Orang-utan bridges in Lower Kinabatangan: Field surveys between Abai and Batu Puteh. Final report for Arcus Foundation. Kota Kinabalu, Malaysia.

^e Leen YJ, Ruppert N (2019). Bridging the Gap-Malaysia’s first urban canopy bridge to help arboreal animals to cross roads safely. DOI: [10.13140/RG.2.2.27430.27209](https://doi.org/10.13140/RG.2.2.27430.27209).

^f Valladares-Padua C, Cullen Jr. L, Padua S (1995). A pole bridge to avoid primate road kills. *Neotropical Primates* 3(1): 13–15.

Table S2. Performance indices of each bridge model and their rank.

Bridge model	Proportion of incomplete crossings (P_1)	Proportion of crossings with missteps (P_2)	Proportion of crossings in fear or anxiety (P_3)	Performance index	Rank
SRB	0.50	0.38	0.50	1.63	1
DRB	0.36	0.27	0.09	2.27	2
LB	0.52	0.09	0.09	2.30	3
RMB	0.21	0.08	0.00	2.71	5
BB	0.31	0.00	0.04	2.65	4