Symbiotic relationships are described as long-term interspecies interactions that are beneficial to one or both of the symbionts, with driving factors including feeding, protection, and reduction of parasite loads (Dickman 1992). Three forms of symbiotic relationship — mutualism (in which the participants depend on the interaction), protocooperation (in which the benefits are facultative), and commensalism (in which one participant benefits and the other is not affected) — are widely reported in the animal kingdom. Interspecies interactions frequently have been observed among birds, mammals, fish, and invertebrates (e.g., Atwell 1966; Preston 1978; Poulin and Grutter 1996; Karplus 2014; Egerton 2015), but those involving amphibians and reptiles are less widely reported, with examples including associations between the Marsh Frog (Pelophylax ridibundus) and the Water Buffalo (Bubalus bubalis) (Zduniak et al. 2017), Nagao’s Pug-snouted Frog (Uperodon nagaoi) and the Ornamental Tarantula (Poecilotheria sp.) (Suranjan Karunarathna and Thasun Amarasinghe 2009), the Common Sandpiper (Actitis hypoleucos) and the Nile Crocodile (Crocodylus niloticus) (Cott 1961), and the Small Ground Finch (Geospiza fuliginosa) and the Galapagos Giant Tortoise (Chelonoidis nigra) (MacFarland and Reeder 1974).

A less-studied form of symbiosis occurs when a single species affects the structure and function of an entire community.
nity through habitat modification that is of benefit to one or more other species (Stachowitcz 2001). Among reptiles, perhaps the most notable example of this is that of the Gopher Tortoise (*Gopherus polyphemus*), whose burrows are utilized by over 360 species of animals, including 13 species of snakes (Jackson and Milstrey 1989).

The Papuan Taipan (*Oxyuranus scutellatus canni*) (Fig. 1) is a large (>2 m total length), highly venomous elapid snake with a distribution encompassing the southern coastal provinces of Papua New Guinea and extending to the southwestern portion of Papua (Indonesian New Guinea). It occupies a wide range of habitats, including lowland savannah and dry woodlands, oil palm plantations, as well as human settlements and even larger towns and cities at elevations of 0–360 m asl (O’Shea 1996; O’Shea, pers. comm.). The Papuan Taipan is an alert and secretive species that routinely demonstrates its retiring nature (Slater 1956). However, its tolerance of disturbed environments increases the likelihood of human-snake conflict, and this species is responsible for the majority of serious snakebite envenomations in Central Province (Lalloo et al. 1995; Williams et al. 2005). Adult taipans have few natural predators in Papua New Guinea, yet remain vulnerable to injury or death through human persecution and from accidental encounters with motor vehicles and machinery (Fig. 2).

Herein, we describe observations of the Papuan Taipan benefiting from modifications to local Kunai Grass (*Imperata cylindrica*) habitat by the Agile Wallaby (*Macropus agilis*), an herbivorous marsupial, within a highly-disturbed anthropogenic environment in southern Central Province, Papua New Guinea.

Our observations were made on the grounds of an industrial site located near Lea Lea Village, Central Province, Papua New Guinea (9°17′34.76″S, 146°59′50.21″E). The site is comprised largely of hardstanding yards, bitumen and gravel roads, and short-mown grassland interspersed within blocks of Kunai grassland, salt marsh, and scattered Pandanus groves. It experiences a high level of human activity from the resident
workforce, restricting much of the local terrestrial fauna to the small, isolated patches of remaining natural habitat. We routinely observed Agile Wallabies taking refuge in the dense growths of Kunai grassland during the day, either individually or in small groups.

Between December 2017 and February 2020, we made 14 observations of *O. s. canni* within a small and isolated block of unmanaged Kunai Grass between 0730 h and 1015 h local time. Kunai Grass is a densely growing perennial that reaches heights of over 2 m, limiting opportunities for basking by reptiles. On 11 occasions, taipans were encountered as they basked in fully enclosed clearings of compacted and short-grazed vegetation (Fig. 3). These clearings were readily identifiable as having been created by Agile Wallabies through the presence of short-grazed and compacted vegetation, scattered droppings, and the presence of individuals or small groups of wallabies (Fig. 4). We observed a further three taipans that were active in the same clearings, possibly disturbed by the observers’ presence.

All taipans moved off rapidly when encountered. Six were captured and transported to the Charles Campbell Toxinology Centre (CCTC) located in Port Moresby for participation in the CCTC antivenom program. Although none of the specimens were accurately measured, they all were considered to be subadults or adults and ranged from an estimated 0.8 m to 1.5 m SVL.

Despite over 80 additional sightings or captures of Papuan Taipans in surrounding habitats during the same period, we observed no basking behavior outside of the Kunai grassland blocks. Furthermore, we encountered 12 taipans that had been killed by machinery or motor vehicles on roads and tracks within the surrounding area.

In a heavily-disturbed anthropogenic environment with limited remaining natural habitats, Kunai grassland blocks provide an ideal habitat for snakes to seek refuge. A close relative of the Papuan Taipan, the Coastal Taipan (*Oxyuranus scutellatus scutellatus*) of northern Queensland, Australia, is well known for utilizing sugarcane fields and windbreaks in a similar manner (Masci and Kendall 1995). The observations reported herein strongly suggest that the presence of Agile Wallaby-modified local grassland habitats enables the Papuan Taipan to exploit sheltered basking sites and avoid exposure in less hospitable areas within a highly-disturbed anthropogenic environment. We observed no interactions between taipans and wallabies. Although wallabies may occasionally be bitten and envenomed by taipans, inevitably resulting in

Fig. 4. Blocks of Kunai grassland (A, B); red arrows mark short-grazed and compacted vegetation (C), and Agile Wallaby (*Macropus agilis*) droppings (D), which are indicative of their presence. Photographs by Tom Charlton.
the death of the wallaby, we found no evidence of this during
the period of our observations and we therefore consider the
wallabies to be largely unaffected by the presence of taipans
within the Kunai grassland.

Observations of symbiotic relationships involving snakes
are rarely reported, possibly due in part to the difficulties of
observing snakes in nature. We suspect that symbiotic rela-
tionships benefitting snakes are more widespread than the lit-
erature would indicate and hope that the observations docu-
mented here will encourage further research into this subject.
Furthermore, because Papuan Taipans are responsible for
a large number of serious snakebites and fatalities in Papua
New Guinea, an improved knowledge of the ecology of this
species remains a valuable part of mitigating the frequency of
venomous snakebites in this region.

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Literature Cited
Atwell, R.I.G. 1966. Oxpeckers, and their association with mammals in Zambia.
Puku 4: 17–48.

Cott, H. 1961. Scientific results of an inquiry into the ecology and economic
status of the Nile crocodile (Crocodilus niloticus) in Uganda and Northern
Rhodesia. Transactions of the Zoological Society London 29: 211–356. https://
doi.org/10.1111/j.1096-3642.1961.tb00220.x.

Dickman, C. 1992. Commensal and mutualistic interaction among terres-
trial vertebrates. Trends in Ecology and Evolution 7: 194–197. https://doi.
org/10.1016/0169-5347(92)90072-J.

Egerton, F.N. 2015. History of ecological sciences, part 52: Symbiosis stud-
ies. Bulletin of the Ecological Society of America 96: 80–139. https://doi.
org/10.1890/0012-9623-96.1.80.

Jackson, D. and E.G. Milstrey. 1989. The fauna of gopher tortoise burrows. Gopher
Tortoise Relocation Symposium Proceedings. The Commission 86:98.

Karpplus, I. 2014) Symbiosis in Fishes: The Biology of Interspecific Partnerships. Wiley-
Blackwell, New Jersey.

Laloo, D.G., A.J. Trevett, A. Korinhona, N. Nwokolo, I.F. Laurensen, M. Paul,
J. Black. S. Naraqi, B. Mavo, and A. Saweri. 1995. Snake bites by the
Papuan taipan (Oxyuranus scutellatus canni): paralysis, hemostatic and elec-
trocardiographic abnormalities, and effects of antivenom. American Journal
of Tropical Medicine and Hygiene 52: 525–531. https://doi.org/10.4269/ajtmh.1995.52.525.

MacFarland, C.G. and W.G. Reeder. 1974. Cleaning symbiosis involving Galápagos
tortoises and two species of Darwin’s finches. Zeitschrift für Tierpsychologie 34:
464–483. https://doi.org/10.1111/j.1439-0310.1974.tb01816.x.

Masci, P. and P. Kendall 1995. The Taipan: The World’s Most Dangerous Snake.
Kangaroo Press, Kenthurst, NSW, Australia.

O’Shea, M. 1996. A Guide to the Snakes of Papua New Guinea. Independent
Publishing Ltd., Port Moresby, Papua New Guinea.

Poulin, R. and A.S. Grutter. 1996. Cleaning symbioses: Proximate and adaptive
explanations. What evolutionary pressures led to the evolution of cleaning
symbioses? Bioscience 46: 512–517. https://doi.org/10.2307/1312929.

Preston, J.L. 1978. Communication systems and social interactions in a goby-shrimp
symbiosis. Animal Behaviour 26: 791–802. https://doi.org/10.1016/0003-
3472(78)90144-6.

Slater, K.R. 1956. On the New Guinea taipan. Memoirs of the National Museum of
Victoria 20: 201–205.

Stachowicz, J.J. 2001. Mutualism, Facilitation, and the Structure of Ecological
Communities: Positive interactions play a critical, but underappre-
ciated, role in ecological communities by reducing physical or biotic stresses
in existing habitats and by creating new habitats on which many spe-
cies depend. BioScience 51: 235–246. https://doi.org/10.1641/0006-
3568(2001)051[0235:MFATSO]2.0.CO;2.

Suranj Karunarathna, D.M.S. and A.A. Thasun Amarasinghe. 2009. Mutualism
in Ramanella nagaoi Manamendra-Arachchi & Pethiyagoda, 2001 (Amphibia:
Microhylidae) and Poecilotheria species (Aracnida: Thelepoidea) from Sri
Lanka. Taprobanica 1: 16–18.

Williams, D., S. Jensen, B. Nimorakiotakis, and K. Winkel (eds.). 2005. Venomous
Bites and Stings in Papua New Guinea. A Guide to Treatment for Health
Workers and Doctors. Australian Venom Research Unit, Parkville, Victoria,
Australia.

Zduniak, P., K. Erciyas-Yavuz, and P. Tryjanowski. 2017. A possible mutualistic inter-
action between vertebrates: frogs use water buffaloes as a foraging place. Acta
Herpetologica 12: 113–11. https://doi.org/10.13128/Acta_Herpetol-20574.