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Rediscovery of the rare Star Mountains Worm-eating Snake, *Toxicocalamus ernstmayri* O'Shea et al., 2015 (Serpentes: Elapidae: Hydrophiinae) with the description of its coloration in life

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***Abstract.*—A series of photographs of the recently described Star Mountains Worm-eating Snake, *Toxicocalamus ernstmayri* O'Shea et al., 2015, taken at the Ok Tedi Mine in the Star Mountains, North Fly District, Western Province, Papua New Guinea, represents only the second record of this poorly-known species. *Toxicocalamus ernstmayri* was hitherto only known from its holotype, collected in December 1969 at the village of Wangbin approximately 13.2 km ESE of the photo locality. The Ok Tedi snake was observed and photographed during the day in October 2015 as it moved across a section of active mine workings, before retreating into dense montane rainforest. This series of photographs constitutes the first sighting of this snake in 45 years and the first sighting of a living animal, providing evidence of the species' continued existence in an area of considerable environmental and demographic changes brought about by human development. These images also provide evidence of its startling coloration in life.**

Keywords. Elapidae, *Toxicocalamus ernstmayri*, snake, Star Mountains, Western Province, Papua New Guinea

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The genus *Toxicocalamus* Boulenger, 1896 currently comprises fifteen taxa (fourteen species and one subspecies) of diurnal, semi-fossorial to terrestrial, secretive, vermivorous elapid snakes that are endemic to the island of New Guinea and nearby islands. Several species are poorly represented in museum collections, and the most recently described species, *Toxicocalamus ernstmayri* O'Shea et al., 2015, is one of four species known only from their holotypes, the others being *T. grandis* (Boulenger, 1914), *T. mintoni* Kraus, 2009, *T. pachysomus* Kraus, 2009, and *T. cratermontanus* Kraus 2017. The holotype of *T. ernstmayri* (Museum of Comparative Zoology, Harvard University, accession number R-145946) is also the largest specimen so far recorded for the genus, with a snout-vent length (SVL) of 1,100 mm, and a total length of 1,200 mm (O'Shea et al. 2015).

The holotype of *Toxicocalamus ernstmayri*, an adult female, was collected by one of us (FP) at Wangbin Village in the Star Mountains (5°14'26.72"S, 141°15'31.92"E, elev. 1,468 m), North Fly District, Western Province, Papua New Guinea, on 23 December 1969. The snake had been killed by a villager and handed to FP, a *kiap*[1] patrolling the area. It was originally accessioned into the museum collection as *Micropechis ikaheka* Lesson, 1830, due to its superficial resemblance to that taxon.

We here report on the second individual of *T. ernstmayri*, the first seen and photographed in life. The snake was sighted by one of us (BP) at 0750 hrs on 9 October

[1]*Kiap* is a pidgin word derived from the German word *Kapitän*, which was applied to Australian pre-independence government patrol officers. Fred Parker served as a kiap from 1960–73, being based in Western Province from 1968–73.

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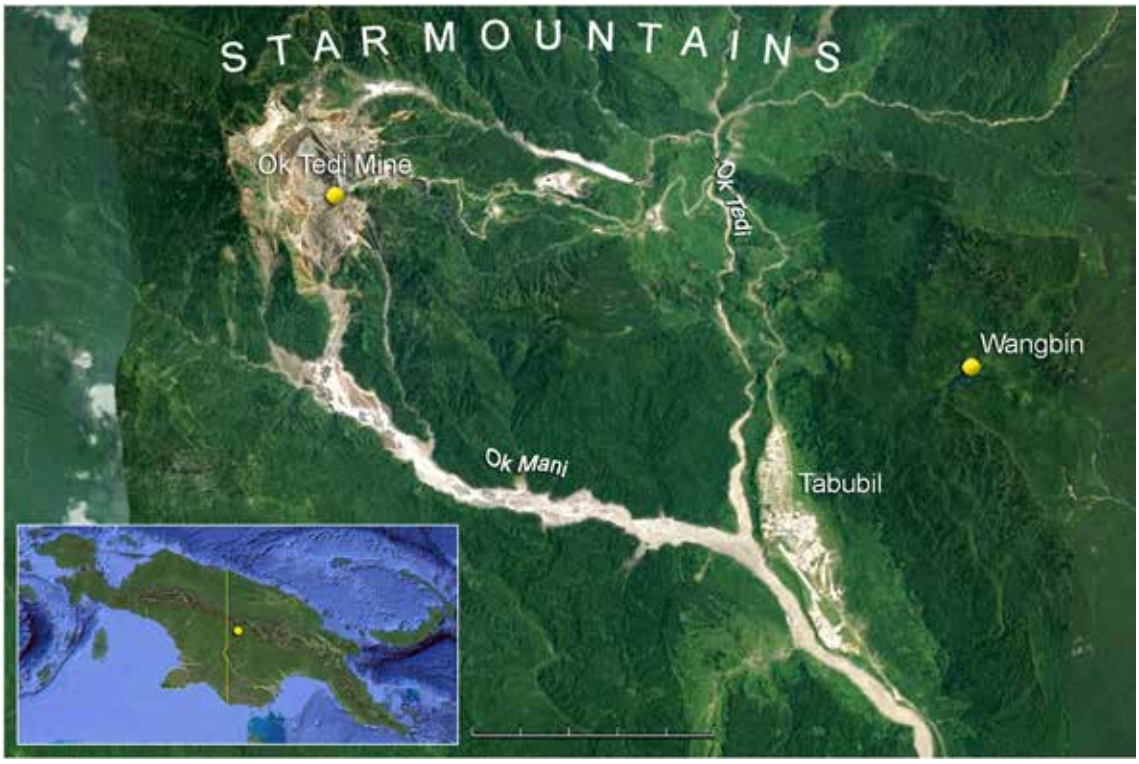

Fig. 1. Satellite map (derived from Google Earth) of the southern Star Mountains, North Fly District, Western Province, Papua New Guinea, with yellow dots on the larger map indicating two localities (Wangbin and Ok Tedi Mine), approximately 13 km apart, where *Toxicocalamus ernstmayri* has been recorded. The main town is Tabubil at the confluence of the Ok Tedi and Ok Mani, which flow into the Fly River. Scale = 5 km. The inset map illustrates the location of the larger map in relationship to the rest of New Guinea.

2015, as it crawled across an area of active mine workings along the west wall at the Ok Tedi Mine (5°12'53.77"S, 141°08'38.57"E, elev. 1,670 m) approximately 13.2 km WNW of Wangbin, in the North Fly District where the holotype was collected (Fig. 1). It was observed for approximately 20 min and photographed several times.

The snake was not captured and measured, but as it can be seen completely spanning a 747 mm tire track (Fig. 2A) its total length is certainly > 750 mm (estimated as ca. 850 mm). It was observed and photographed as it crossed open ground (Fig. 2B), rubble piles (Fig. 2C), and passed underneath a stationary digger (Fig. 2D), until it disappeared into the vegetation on the steep slope at the top left of Fig. 3.

The snake can be identified as a member of the genus *Toxicocalamus* by the presence of six supralabials and the lack of the temporolabial scale (Fig. 4B'). The only other terrestrial Papuan elapid genus to lack a temporolabial scale is *Pseudonaja*. An anterior body dorsal scale count of eight, from the vertebral scale row to the lowest dorsal scale row, can also be discerned from the images (Fig. 4C', D'), indicating an anterior dorsal scale count of 15. There does not appear to be any head scute fusion although this is harder to discern with certainty from the images. The patterning of this snake in life can be seen clearly: it has a yellow body with large grey basal spots on each dorsal scale, and a grey cap to the head. This description agrees very closely with that given by Parker (1982: 55) for the aberrant *Micropechis ikaheka*, which would become the holotype of *Toxicocalamus ernstmayri*:

> *"One snake taken at Wangbin (1500 m above sea level) in the Star Mountains differed so much in colouring from those at Kiunga and Ningerum that it may well represent another species. It was brought in already dead by a Wangbin villager. People there agreed with him that it was extremely rare in the area. The head was black, the lips bright yellow. The body scales were a deep yellow, each having a grey anterior tip. The amount of pigmentation on each scale decreased from the vertebral row towards the outermost laterals, and increased evenly along the body, with the tail darkest. There were no indications of any bars on the body. The ventral surfaces were uniform yellow."*

The characters observed in the photographs of the newly observed individual are clearly diagnostic of *T. ernstmayri* and allow us to make an unequivocal species determination. The only other genus with which this snake can be confused is *Micropechis*, which exhibits a temporolabial scale (Fig. 5). Although entirely yellow specimens of *M. ikaheka* are known, they are confined to the Vogelkop Peninsula, West Papua Province, western New Guinea; all specimens of *M. ikaheka* known from PNG are strongly banded on the posterior

Fig. 2. The first live individual of *Toxicocalamus ernstmayri*, observed and photographed in broad daylight at the Ok Tedi Mine, North Fly District, Western Province, Papua New Guinea. **(A)** The individual's serendipitous crossing of a 747 mm wide tire track allowed an approximation of its total length as near 850 mm. **(B)** The snake moves in a straight line across open ground. **(C)** Slower movement across a rubble pile allowed a more detailed examination of head and body scales (see Fig. 4). **(D)** The individual moving under the tracks of a stationary digger. *Photos by Blaise Paivu.*

body. At an SVL > 750 mm total length this individual of *T. ernstmayri* would appear to be a subadult, as it is considerably shorter than the holotype (SVL 1,200 mm). The encounter with an unusual, "golden" snake at the Ok Tedi Mine was sufficiently noteworthy, even in Papua New Guinea where snake encounters are commonplace, that it was presented in the mine's own magazine (*Ok Tedi Weng* magazine, Issue 1, 2017, p. 6).

Topography

The source of the Ok Tedi[2] lies at approximately 2,900 m elevation in the central Star Mountains (Hyndman and Menzies 1990), just north of the provincial border between Western and Sandaun (formerly West Sepik) Provinces of PNG, and approximately 28 km east of the international border with Papua Province, Indonesian New Guinea. From its source the Upper Ok Tedi flows rapidly south through extremely rugged mountainous terrain to meet the Ok Mani, flowing in from the southern slopes of Mount Fubilan, at an elevation of 400 m, just to the west of Tabubil. The distance travelled from the source of the Ok Tedi to the Ok Mani confluence is only ca. 28.5 river kilometers (23 km in a direct line), but the river has already lost 2,500 m in elevation. The distance from Tabubil to the confluence of the Ok Tedi with the Fly River at d'Albertis Junction[3] is a further 170 river kilometers (100 km in a direct line) with a further drop in elevation to 70 m, from where the Fly meanders first southwest, then southeast to the Gulf of Papua. The town of Kiunga on the Fly River, (upstream by 45 river kilometers, 20 km in a direct line) east of d'Albertis Junction, lies at an elevation of only 20 m, yet it is approximately 375 km from the Fly delta, while the actual distance is closer to 800 river kilometers due to its meandering course across the low-lying flood plains (Halse et al. 1996).

The Ok Tedi Mine is located on the slopes of Mount Fubilan (2,084 m), "a copper mountain with a gold cap" (Knox 2013), at an elevation of approximately 1,700 m. It is approximately 12 km northwest of the nearest popu-

[2]*Ok* = river, in the local Wopkaimin language (Keig 2001), the river is therefore known as the Ok Tedi, not the Ok Tedi River. In 1876 the Italian naturalist-explorer Luigi Maria d'Albertis (1841–1901) was the first foreigner to discover and navigate the lower reaches of the Ok Tedi, which he named the Alice River (d'Albertis 1879, 1880), in honor of an acquaintance, Miss Alice Hargrave.

[3]D'Albertis originally called the confluence of the Alice River (Ok Tedi) with the Fly "Snake Junction" because he captured a python there (d'Albertis 1880) but today it is named in his honor.

Fig. 3. View of an actively worked area of the Ok Tedi Mine. The observed individual of *Toxicocalamus ernstmayri* eventually disappeared into the vegetation on the slope in the top left of the photograph. *Photo by Blaise Paivu.*

lation center, the town of Tabubil which was established to support the mine, yet the mine lies over 1.2 km higher. Tabubil, located at only 457 m elevation, is approximately 450 km from the coast. The steepness of the southern Star Mountains, rising by 1,200 m in elevation over only 12 km in horizontal distance, contrasts with the almost imperceptible south-north increase in elevation (< 500 m over 450 km) of the Trans-Fly Region as a whole.

At 1,700 m elevation, the Ok Tedi Mine is approximately 230 m higher than Wangbin Village (1,468 m elevation), the type locality of *T. ernstmayri*, suggesting that this snake is probably confined to mid-montane elevations in the Star Mountains. It is unlikely that it occurs as low as Tabubil (elevation < 500 m), given the complete lack of any specimens from there despite the large-scale development and burgeoning human population (see below). Even within its known range, this relatively large, diurnally-active snake would seem to be rare, as this region has been fairly thoroughly investigated by biologists, including by one of us (SJR), yet no specimens have been collected or reported.

The Vegetation and Climate

Ok Tedi Mine's elevation is close to the boundary between Lower Montane Rainforest (1,000–1,800 m elevation), and Low-altitude Midmontane Rainforest (1,800–2,200 m elevation), Zones 2 and 3 respectively of Hyndman and Menzies (1990). Lower Montane Rainforest comprises mixed evergreen forest with a 20–30 m tall canopy, dominated by emergent white oak (*Castanopsis acuminatissima*) at tree height of up to 40 m, whereas Low-altitude Midmontane Rainforest is dominated by moss-covered Myrtle (*Syzygium*) and Screw Palm (*Pandanus*) with a 25–30 m canopy height.

Rainfall is high in the Upper Ok Tedi-Mount Fubilan region, with as much as 10,000 mm being recorded annually at the mine (Hearn 1995), with little seasonal variation, the lowest rainfall averaging 433 mm in November, and the highest averaging 576 mm in June (Merkel 2017). The area lies in a belt known as the "midaltitude fringe high rainfall zone" (Hyndman and Menzies 1990), which experiences continual heavy rain, defined as over 50 mm per week (Brookfield and Hart 1971), although the previous figures amount to 100–140 mm of rainfall per week. Sometimes rainfall is excessive, and on at least four days a year there will be over 100 mm of rainfall over a 24-hour period, and once every 1–3 years rainfall will exceed 150 mm in a single day (McAlpine et al. 1983). The Upper Ok Tedi-Mount Fubilan region is one of the wettest places, not only on the island of New Guinea but in the world[4].

The almost constant rainfall, and accompanying heavy cloud cover, results in lowered ambient temperatures. Temperatures recorded at several sites, at different elevations from Tabubil to Mount Fubilan, are lower than those expected for central New Guinea (Hyndman and Menzies 1990). Maximum daily temperatures range from 23.0–24.7 °C, while minimums at night range from 13.8–14.6 °C (Merkel 2017). The nights above 2,200 m are even colder with lows of 6.4 °C being recorded at Finimterr (2,300 m) (Hyndman and Menzies 1990), which means temperatures fall by 1 °C with every 200 m increase in elevation. This combination of relatively cold nighttime temperatures, almost continual rain, and dense cloud cover could in part account for the diurnal activity cycle of a relatively large snake species such as *T. ernstmayri*.

Human Development

Until the late 1960s Tabubil did not exist as a settlement. Shortly after the holotype of *T. ernstmayri* was collected by FP (late 1969) a small mining camp was established besides an airstrip (O'Shea et al. 2015: Fig. 9H) by the Kennecott Copper Corporation, who were engaged in the exploratory drilling on Mount Fubilan. Wangbin was a small neighboring hamlet on the edge of Lake Wangbin (O'Shea et al. 2015: Figs. 9A–C). During 1976–1980 the Anglo-Australian mining company BHP Billiton negotiated with the Government of Papua New Guinea to establish the mining town of Tabubil and they subsequently established Ok Tedi Mining Limited to operate the gold and copper mine.

The population of the Star Mountains Tabubil "census division" increased by 201%, from 556 to 1,676, in the decade 1980–1990 (Keig 2001), directly as a result of the establishment of the Ok Tedi Mine and the development of Tabubil. Over the same period Keig (2001) reported that the population of Western Province increased from 64,623 to 74,834, which amounts to only a 15.8% popu-

[4]The annual rainfall at the Ok Tedi Mine is close to that received by the wettest places on Earth, listed as Mawsynram, Meghalaya (11,873 mm) and Cherrapunji, Meghalaya (11,430 mm), both in northeastern India (Anonymous 2017).

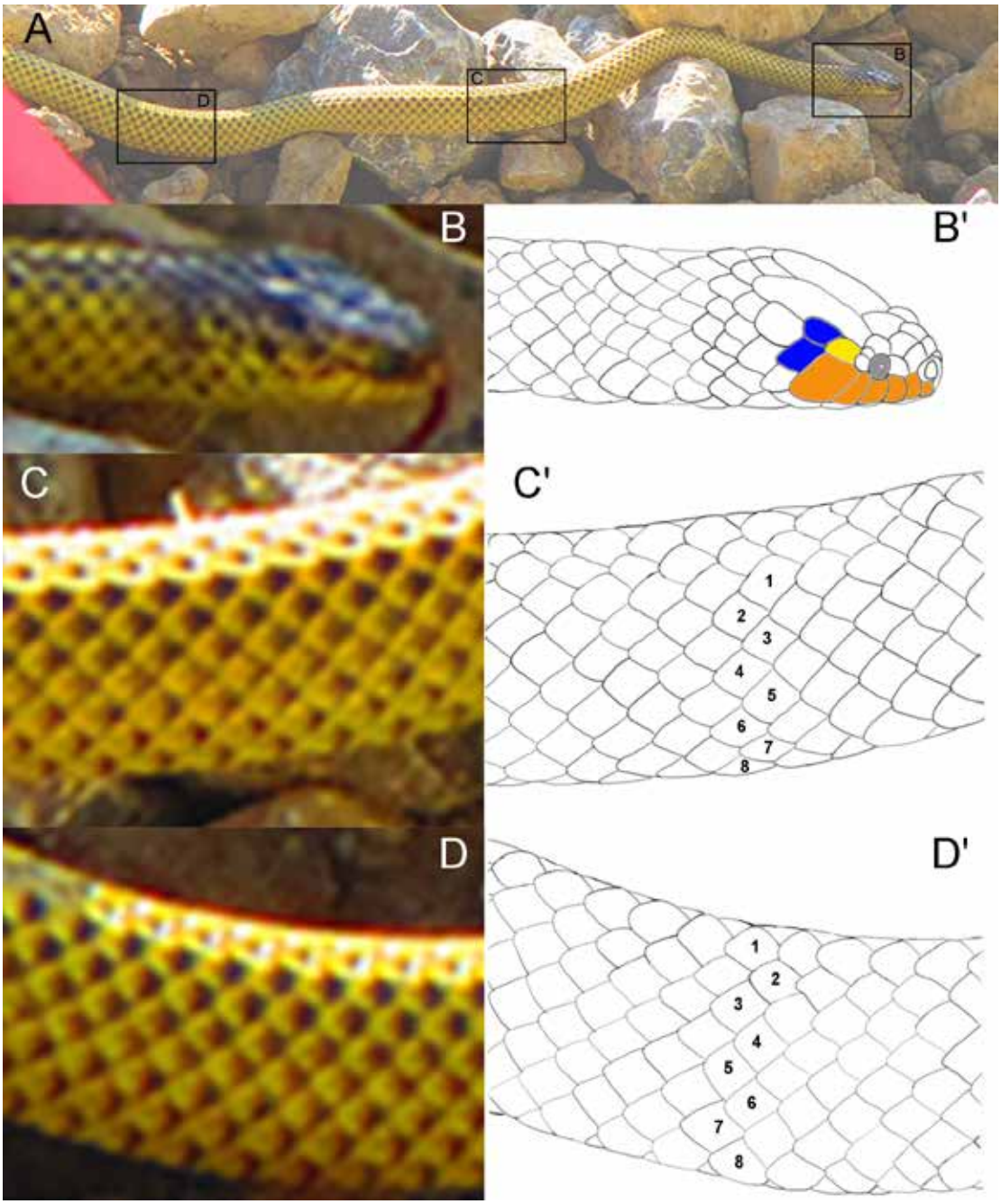

Fig. 4. Confirming the individual's identification as *Toxicocalamus ernstmayri*. **(A)** Close-up of the snake shown in Fig. 2C with insets B, C, and D indicated. **(B, B')** Head and neck in extreme close-up. Color coding of head scalation includes six supralabials (orange), one anterior temporal (yellow), and two posterior temporals (blue), but no temporolabial (see Fig. 5). The head scutes appear to comply with the colubrid-elapid nine dorsal scute arrangement (i.e., two internasals, two prefrontals, one frontal, two supraoculars, and two parietals; therefore lacking any head scute fusion, although this is difficult to discern from the magnified image with accuracy. **(C, C')** Based on the visible dorsal scales, the dorsal scale count on the anterior body is 15. The count is achieved by locating the vertebral scale row and counting down to the lowest dorsal scale row (eight scales), doubling the count, and subtracting one scale to account for the single vertebral scale row. **(D, D')** The dorsal scale count at midbody, performed as described for the previous panel, is also 15.

lation increase overall. Western Province is vast, covering 96,218 km^2 (37,150 sq mi; Blake 1972), and it is PNG's largest province (by land area), and while a report by the IUCN (1995) gave the population of the province as 110,000, with a very low overall population density of 1.14/km^2, the same report provided a population of 12,000 for Tabubil. This indicates a 716% increase in population size during the years 1990–1995, making Tabubil the largest urban population in the province, exceeding even the 8,490 population of Daru, the provincial capital in the south of the province. The 2011 census (National Statistical Office of Papua New Guinea 2014)

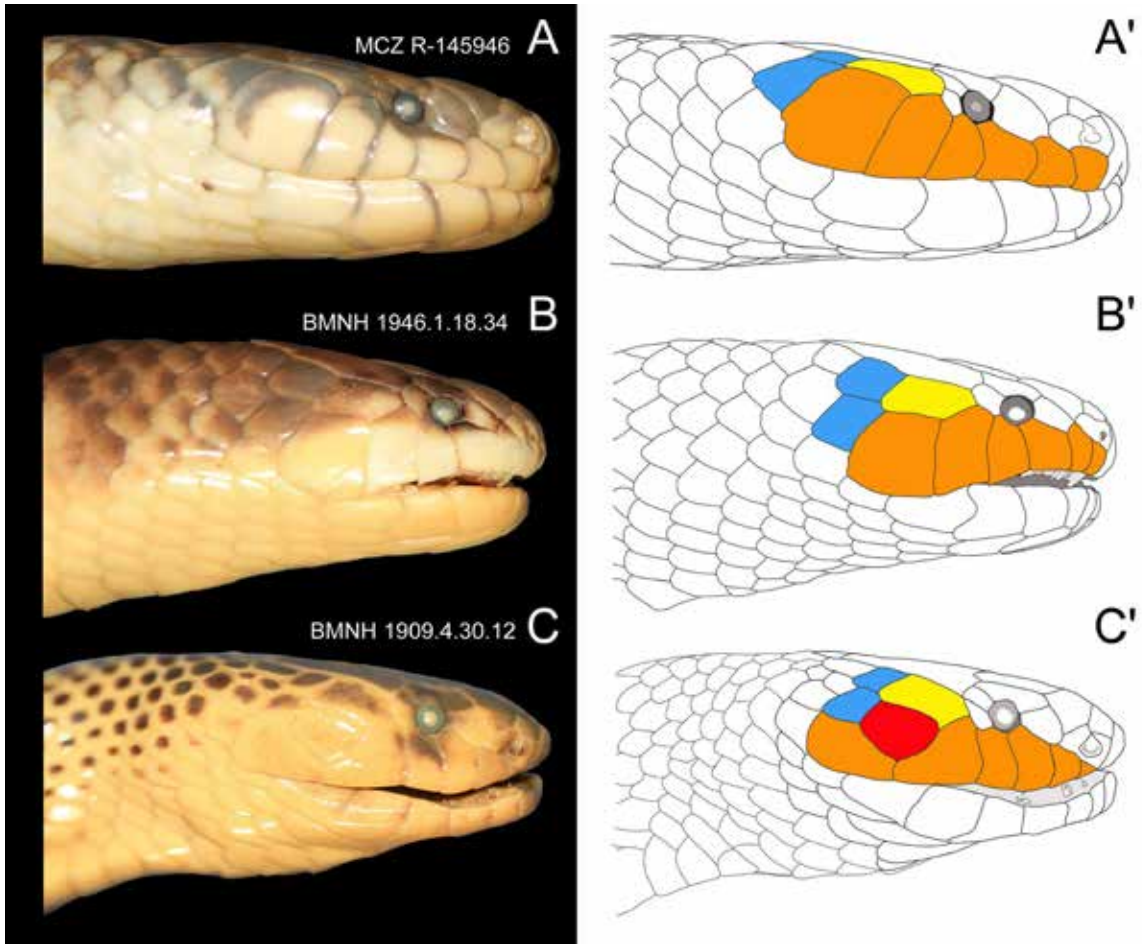

Fig. 5. Distinguishing *Toxicocalamus* from *Micropechis*. **(A, A')** Holotype of *T. ernstmayri* (MCZ R-145946) from Wangbin, Western Province, PNG. **(B, B')** Holotype of *T. grandis* (BMNH 1946.1.18.34) from Setakwa River, Papua Province, Indonesian New Guinea. **(C, C')** Yellow phase of *Micropechis ikaheka* (BMNH 1909.4.30.12) from the FakFak Peninsula, West Papua Province, Indonesian New Guinea. Color-coding of head scalation includes six supralabials (orange), a single anterior temporal (yellow), two posterior temporals (blue), and a temporolabial (red). The individual we report here clearly has the same head scute arrangement as *T. ernstmayri*.

provided a provincial population of 201,351 with 10,270 for Tabubil, 631 for Wangbin, and 15,142 for Daru, suggesting a reversal in the relative populations sizes of Tabubil and Daru. Regardless of this apparent decline the population size and development of the Tabubil area during the last 4.5 decades has been substantial. The demographics of the Tabubil population are eclectic with company employees from around the world. However, the population of the Ok Tedi Mine remains relatively small, with employees concentrated within the actual mine compound. The surrounding midmontane rainforest remains thinly populated and under-explored.

Conservation

The incursion of roads into remote rainforest areas could lead to the persecution and disappearance of vulnerable and misunderstood species like snakes. *Toxicocalamus ernstmayri* has always been an infrequently encountered species, as exemplified by Parker's (1982) comment above: "*People there agreed with him that it was extremely rare in the area.*" That it is also a diurnal species, of moderately large size, and seemingly relatively slow moving, would suggest that this species could be more vulnerable to persecution than some other taxa. It is therefore especially heartening that this snake was at no time hindered or molested as it crossed the mine workings, and that it was thought interesting and newsworthy enough to be photographed, the images then being circulated to specialists for an identification, and then finally the sighting was featured as a full-page article in the company's seven-page in-house publication, which finishes with this plea to its readers:

> *"So should you be fortunate enough to see one of these snakes in the wild, please observe it from a distance and let it go on its way. They are very rare and recorded sightings are even rarer. Like all the wild life in our foot print we should appreciate its diversity, this snake and perhaps there are other animals out there are unique to this part of PNG and the world and should be appreciated and not killed."*

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Mark O'Shea is a British herpetologist with a specialist interest in the snakes of New Guinea. He wrote *A Guide to the Snakes of Papua New Guinea* (1996) and is currently working on the second edition, expanded to encompass the entire New Guinea region, and he is also the author of four other books. Since 1986 he has made ten expeditions to New Guinea to conduct herpetological fieldwork, capture medically important elapids for snakebite research, or made films for Animal Planet or the BBC. He has worked in PNG for a variety of organizations from Operation Raleigh to Oxford University's Department of Clinical Medicine, Liverpool School of Tropical Medicine, and the Australian Venom Research Unit, University of Melbourne. O'Shea has considerable field experience in other countries in Asia, Africa, and South America, and has been engaged in fieldwork projects since the 1980s. He presented four seasons of the herpetological television series *O'Shea's Big Adventure*, for Animal Planet and Discovery Channel, and has made films with other companies and broadcasters. Mark was awarded the Millennium Award for Services to Zoology by the British Chapter of the Explorers' Club in 2000, and in 2001 was awarded an honorary Doctor of Sciences degree by his alma mater, the University of Wolverhampton, for services to herpetology. He is now Professor of Herpetology at the University of Wolverhampton and teaches the "Animal Behaviour and Wildlife Conservation and Evolution" and "Origins of Life" courses at the University. He also holds the post as Consultant Curator of Reptiles at West Midland Safari Park, in the United Kingdom. O'Shea and Kaiser (below) are the leaders of the first comprehensive survey of the herpetofauna of Timor-Leste, Asia's newest country. With ten phases of the project completed since 2009, the team has recorded upwards of 70 species, with more than twenty of these new to science. O'Shea, Kaiser, and Fred Parker (also below) are the describers of *Toxicocalamus ernstmayri*, the subject species of this paper.

Brian Herlihy is a New Zealander, and a Senior Safety Advisor for Ok Tedi Mines Limited (OTML). He holds an MBA in Technology Management from Deakin University/APESMA (Association of Professional Engineers, Scientists and Managers, Australia). He has worked for OTML since 2016.

Blaise Paivu is a Papua New Guinean citizen, and a Senior Mining Engineer for Ok Tedi Mines Limited (OTML). He has been employed by OTML from 1995 to 2010, and from 2013 until the present. He holds a Bachelor in Mining Engineering from University of Technology, Lae, Papua New Guinea.

Fred Parker was born in India and migrated to Australia in 1949. While working at the Healesville Sanctuary in the late 1950s he met the herpetologist Charles Tanner and became interested in herpetology. From 1960 until 1973 he worked as a *kiap* on Bougainville, in the Central Highlands, and Western District, Papua New Guinea. Derived from the German word *kapitän*, it is the *tok pisin* name for a Government Patrol Officer, usually an Australian, in Pre-Independence Papua New Guinea. During this time Parker collected many herpetological specimens for Ernest Williams, at the Museum of Comparative Zoology (MCZ), Harvard, and Richard Zweifel, at the American Museum of Natural History (AMNH), New York. He also collected a large number of death adders for venom research and antivenom production by Tanner at the Commonwealth Serum Laboratories (CSL), Melbourne, Australia. From 1973 he worked for the Wildlife Division in Port Moresby, on projects as diverse as crocodiles and butterflies, and rose to the position of Head of the Division, before returning to Australia in 1979. He has authored and coauthored numerous papers on the herpetofauna of PNG, including the original description of *Toxicocalamus ernstmayri.* Two frogs (*Cornufer parkeri* and *Xenorhina parkerorum*), one turtle (*Chelodina parkeri*), a skink (*Tribolonotus parkeri*), and three snakes (*Bothrochilus fredparkeri*, *Gerrhopilus fredparkeri*, and *Tropidonophis parkeri*) are named in his honor.

Stephen J. Richards is an Honorary Research Associate at the South Australian Museum in Adelaide, Australia with a special interest in the herpetofauna of New Guinea. Since 1991 he has made approximately 50 expeditions to New Guinea to conduct herpetological fieldwork, and he has co-authored more than 130 publications about frogs and reptiles of that region, including the formal descriptions of nearly 100 new species discovered during these expeditions. He has published three field guides to frogs of local regions in New Guinea and the Solomon Islands. Stephen is the Regional Chair for Melanesia of the IUCN's Amphibian Specialist Group and a member of the Papua New Guinea Government's Biodiversity Expert Group. Richards has two frogs (*Hylophorbus richardsi* and *Litoria richardsi*) and a skink (*Cryptoblepharus richardsi*) named in his honor.

Hinrich Kaiser is a German-American herpetologist and educator with a research focus on biodiversity and conservation of tropical environments. A passion for scuba diving with experiences in the arctic and the tropics led Hinrich to study marine biology at McGill University and the University of Victoria in Canada. After an inspiring semester learning about amphibians and reptiles in David Green's herpetology class in the Redpath Museum, Kaiser found his true calling and earned his Ph.D. at McGill with a dissertation on the systematics and biogeography of Lesser Antillean frogs. After a Boehringer Ingelheim postdoctoral fellowship at the University of Würzburg, Germany, he spent five years as Professor of Biology at La Sierra University, Riverside, California, USA, before accepting his current position in the Department of Biology at Victor Valley College in Victorville, California, USA. Kaiser holds an appointment as Research Associate with the United States National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA. He currently serves as an Editor-in-Chief of *Herpetology Notes*, but his interests in international affairs and music also led him to memberships on the International Advisory Board of the Foundation for Post-Conflict Development, New York, and on the Advisory Council of the Baltimore Symphony Youth Orchestras. Kaiser serves as a member of the Executive Committee of the World Congress of Herpetology. His most recent publications have focused on the herpetofauna of Timor-Leste and nearby areas of Wallacea, as well as on the defense of herpetological taxonomy against taxonomic vandalism. He was also a coauthor on the original description of *Toxicocalamus ernstmayri*. His educational specialty is to expose community college students to biological, cultural, and historical experiences overseas, including canopy walks in Brunei, cooking classes in Bali, tracking Komodo dragons on Rinca Island, homestays in Cuba, and surveying Pacific atolls.