Helminths of 13 species of microhylid frogs (Anura: Microhylidae) from Papua New Guinea

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ABSTRACT

In an attempt to better document the invertebrate biodiversity of the threatened fauna of Papua New Guinea (PNG), 208 microhylid frogs representing 13 species collected in 2009 and 2010 in PNG were examined for endoparasitic helminths. This study found mature individuals of one species of Digenea (Opisthioglyphe cophixali), adults of two species of Cestoda (Nematotaenia hylae, Cylindrotaenia sp.) and cysticerci of an unidentified cestode species; adults of nine species of Nematoda (Aplectana krausi, Bakeria bakeri, Cosmocerca novaeguineae, Cosmocercella phrynomantisi, Falcaustra papuensis, Icosiella papuensis, Ochoterenella papuensis, Parathelandros allisoni, Parathelandros andersoni), and one species of Acanthocephala (cystacanths in the family Centrorhynchidae). There was a high degree of endemism among the helminth species infecting the microhylids, with 83% of the species known only from PNG. Yet the helminth fauna infecting Papuan microhylids are generalists with direct life cycles (no intermediate host) that also infect other anuran species. We thus conclude infection is more dependent upon habitat conditions than diet. Twenty-nine new host records are reported.

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Introduction

The landscape of Papua New Guinea (PNG) is threatened with habitat loss due to logging and resultant forest loss, conversion of land for agriculture, mining, removal of oil and natural gas, and habitat modification and competition from invasive exotic species (Marshall and Beehler 2007a). In view of these threats to the environment, it is crucial to document both invertebrate and vertebrate diversity in Papuan fauna while it is possible. Frogs are particularly sensitive to environmental degradation and many species have suffered serious population declines (Lips and Donnelly 2005). With the above in mind, an examination of frogs for helminths will add to our knowledge of invertebrate biodiversity from a threatened area.

Knowledge of tropical biodiversity is still very imperfect, and this is especially true for the invertebrates, which encompass the vast majority of species diversity. Helminths form a major portion of this diversity, and they can be important in
structuring vertebrate community structure (Poulin 2001), yet knowledge of tropical helminth communities is especially sparse (Choudhury and Dick 2000). Because frogs are particularly sensitive to environmental degradation (Pough et al. 2016), many species have suffered serious population declines (Lannoo 2005). Undoubtedly consequent with those declines but typically unstudied, it may be expected that the helminth faunas of those host frogs have also declined, in some cases perhaps to the point of extinction.

The family Microhylidae occurs on all continents except Antarctica (Vitt and Caldwell 2014), and contains ca. 578 species, of which 287 occur in the Papuan region (= New Guinea, the Bismarck and Admirality archipelagos, and the Solomon Islands) and 192 occur in the country of PNG (Frost 2015). Approximately half of the frogs in New Guinea belong to the Microhylidae (Marshall and Beehler 2007b). In this paper, we present helminthological records for 13 species of microhylid frogs from PNG: *Choerophryne darlingtoni* (Loveridge, 1948); *Choerophryne gudrunae* (Menzies, 1999); *Cophixalus balbus* Günther, 2003; *Cophixalus desticans* Kraus and Allison, 2009; *Cophixalus variabilis* Kraus and Allison, 2006a; *Cophixalus verrucosus* (Boulenger 1898); *Hylompharbus richardsi* Günther, 2001; *Oreophryne biroi* (Méhely, 1897); *Oreophryne geislerorum* (Boettger, 1892); *Oreophryne notata* Zweifel, 2003; *Oreophryne parkeri* Loveridge, 1955; *Sphenophryne cornuta* Peters and Doria, 1878; and *Xenorhina oxycephyala* (Schlegel, 1858). Herein, the initial helminth lists are presented for eight frog species, and the helminth lists for another five species are expanded.

*Choerophryne darlingtoni* is known from the central mountain ranges of PNG, being reported from Southern Highlands, Eastern Highlands, Chimbu and Western Highlands provinces (Menzies 2006; Kraus 2010). *Choerophryne gudrunae* is endemic to the Adelbert Mountains, Madang Province, PNG (Menzies 1999). *Cophixalus balbus* is known from several mountain ranges along the northern coast of New Guinea and from adjacent Yapen Island (Günther 2003; Kraus and Allison 2006b; Kraus unpubl. data). *Cophixalus desticans* is known from Milne Bay and Northern provinces, PNG (Kraus and Allison 2009; Kraus 2013). *Cophixalus variabilis* and *C. verrucosus* are known from Milne Bay, Central and Northern provinces, Papua New Guinea (Kraus and Allison 2006a; Kraus 2010; unpubl. data). *Hylompharbus richardsi* is known only from the vicinity of the type locality on Mount Sisa and the eastern slope of Mount Itukua, Muller Range, Southern Highlands Province, PNG (Günther 2001; Kraus 2010). *Oreophryne biroi* is known from the northern coastal region of New Guinea from the vicinity of Madang, Madang Province, PNG, to the Cyclops Mountains near Jayapura, Papua, Indonesia (Zweifel et al. 2003).

*Oreophryne geislerorum* ranges from the Huon Peninsula, westward to Lae and the Wampit River and from there south through Northern Province, and into the northern end of Milne Bay Province, PNG (Zweifel et al. 2003; Kraus unpubl. data). *Oreophryne notata* occurs in the Central Highlands area of PNG Southern Highlands Province west to near the border with Indonesia (Zweifel 2003). *Oreophryne parkeri* is known from the north-coast area of New Guinea (Zweifel et al. 2003). *Sphenophryne cornuta* is widely distributed in New Guinea from the Vogelkop Peninsula (Papua, Indonesia) to the vicinity of Port Moresby (PNG) and to the Adelbert Mountains, PNG (Menzies 2006) and *Xenorhina oxycephyala* is known from Western Papua (Indonesia) as well as the north-coast ranges of Papua (Indonesia) and PNG (Zweifel 1972). Areas
in PNG where the frogs were collected are indicated in Figure 1. Geographic ranges for the above frog species can be found by searching under the species name at http://www.iucnredlist.org.

**Materials and methods**

Two hundred and eight adult frogs representing 13 species of Microhylidae were collected by hand in PNG (Figure 1) by Fred Kraus during 2009 and 2010 (collection dates for each species are indicated in Appendix 1) and were examined for endoparasites: *Choerophryne darlingtoni* ($n = 5$), *Choerophryne gudrunae* ($n = 19$), *Cophixalus balbus* ($n = 12$), *Cophixalus desticans* ($n = 19$), *Cophixalus variabilis* ($n = 36$), *Cophixalus verrucosus* ($n = 9$), *Hylorhadinus richardsi* ($n = 13$), *Oreophryne biroi* ($n = 5$), *Oreophryne geislerorum* ($n = 29$), *Oreophryne notata* ($n = 35$), *Oreophryne parkeri* ($n = 6$), *Sphenophryne cornuta* ($n = 16$) and *Xenorhina oxycephala* ($n = 4$).

Immediately after capture, frogs were euthanised and fixed in neutral buffered 10% formalin, and were later stored in 70% ethanol in the herpetology collection of the Bishop Museum (BPBM), Honolulu, Hawaii (Appendix 1). Subsequently, the body cavity was opened by a longitudinal abdominal incision, and the gastrointestinal tract was removed by cutting across the esophagus and the rectum and then shipped to Whittier College, Whittier, CA, where a detailed dissection of each digestive organ was carried out using a dissecting microscope. Endoparasites from individual hosts were removed to vials of 70% ethanol, and later placed on a microscope slide in a drop of lactophenol under a coverslip and allowed to clear. Nematodes and acanthocephalans were identified from these temporary preparations. Digeneans and cestodes were washed in water, regressively stained in hematoxylin, and mounted in balsam for identification under a compound microscope. Parasite terminology used herein is in accordance with Bush.
et al. (1997). The number of parasites, prevalence, mean intensity, range of infection and new host records are given in Table 1. Hosts for helminths reported in Paupan frogs are summarised in Table 2. Selected helminth specimens were deposited in the Harold W. Manter Parasitology Laboratory (HWML), University of Nebraska, Lincoln, USA (Appendix 2).

Results

A total of 360 endoparasites was recovered from 88 (42%) of the 208 frogs (Table 1). Of these, 220 (61%) were mature individuals representing one species of Digenea: *Opisthioglyphe cophixali* Moravec and Sey, 1989, (small intestine); two species of Cestoda: *Nematotaenia hylae* Hickman, 1960 (small intestine), and *Cylindrotaenia* sp. (small intestine); and nine species of Nematoda: *Aplectana krausi* Bursey and Goldberg, 2007 (large intestine), *Bakeria bakeri* (Moravec and Sey, 1986) (small intestine), *Cosmocerca novaeguineae* Moravec and Sey, 1990 (small, large intestine), *Cosmocerca phrynomantisi* Moravec, 1990 (large intestine), *Falcaustra papuensis* Bursey, Goldberg and Kraus, 2007 (large intestine), *Icosiella papuensis* Johnston, 1967 (body cavity), *Ochoterenella papuensis* Johnston, 1967 (body cavity), *Parathelandros allisoni* Bursey, Goldberg and Kraus, 2008 (large intestine), and *Parathelandros andersoni* Moravec, 1990 (large intestine). There were 140 larvae (39% of the endoparasites): 134 Cestoda cysticerci in cysts attached to the wall of the intestine and six cystacanths of a species of Acanthocephala assigned to Centrorhynchidae (small, large intestine). Although 14 species of helminths occurred in our sample, no host species harboured more than four helminth species, the mean number of helminth species per host species was 2.5 ± 1.1 standard deviation (SD); range = 1–4, and no individual frog harboured more than two helminth species. The mean number of helminth individuals per individual host was 4.6 ± 8.7 SD; range = 1–58. Twenty-nine new host records are reported.

Comparative endoparasite distributions

The digenean *Opisthioglyphe cophixali* was originally described from two specimens taken from *Cophixalus parkeri* collected at Kotuni, Mt. Otto, PNG by Moravec and Sey (1989). Other reports of *Opisthioglyphe cophixali* are in Table 2. Our records here expand the range of this helminth to several other frog species: *Choerophryne darlingtoni*, *Cophixalus balbus*, *Oreophryne notata* and *Sphenophryne cornuta* (Table 1); all are new host records.

The cestode *Nematotaenia hylae* was originally described from specimens taken from two frog species, the pelodryad *Litoria ewingii* (as *Hyla ewingii*) and the myobatrachid *Crinia signifera* collected in Burnie, Tasmania, by Hickman (1960). Reports of *Nematotaenia hylae* in other anurans are in Table 2. *Nematotaenia hylae* in *Cophixalus variabilis* and *Oreophryne notata* (Table 1) are new host records.

The cestode *Cylindrotaenia* was originally described from specimens taken from two frog species, the pelodryad *Litoria ewingii* (as *Hyla ewingii*) and the myobatrachid *Crinia signifera* collected in Burnie, Tasmania, by Hickman (1960). Reports of *Nematotaenia hylae* in other anurans are in Table 2. *Nematotaenia hylae* in *Cophixalus variabilis* and *Oreophryne notata* (Table 1) are new host records.

Three species of the cestode *Cylindrotaenia* have previously been reported from Oceania, all from lizards, namely *Cylindrotaenia allisonae* from *Gehyra oceanica*, *Hemidactylus frenatus* and *Lepidodactylus lugubris* (Goldberg and Bursey 2002); *Cylindrotaenia decidua* from *Cryptoblepharus poecilopleurus*, *Emoia cyanura*, *Gehyra oceanica* and *Lepidodactylus lugubris* (Goldberg et al. 2000); and *Cylindrotaenia hickmani* from *Emoia jakati*, *Emoia obscura*, *Emoia palldiceps*, and *Emoia popei* (Goldberg et al. 2008).
Table 1. Number (N), prevalence (P as a percentage), mean intensity and one standard deviation and range (MI ± SD [R]) for endoparasites found in 13 species of microhylid frogs from PNG; * = new host record.

| Host                      | Choerophryne darlingi N = 5 | Choerophryne gudrunae N = 19 | Cophixalus balbus N = 12 | Cophixalus desticans N = 19 | Cophixalus variabilis N = 36 |
|--------------------------|-------------------------------|-------------------------------|--------------------------|-------------------------------|-------------------------------|
| Endoparasite             | N | P | MI ± SD (R) | N | P | MI ± SD (R) | N | P | MI ± SD (R) | N | P | MI ± SD (R) |
| Digenea                  |   |   |             |   |   |             |   |   |             |   |   |             |
| Opisthioglyphe cophixali | *2 | 40 | 1           | —— |     |             | —— |     |             | —— |     |             |
| ——                      |   |   |             |   |   |             |   |   |             |   |   |             |
| Cestoda                  |   |   |             |   |   |             |   |   |             |   |   |             |
| Nematotaenia hylae      |   |   |             |   |   |             |   |   |             |   |   |             |
| Cylindrotaenia sp.      |   |   |             |   |   |             |   |   |             |   |   |             |
| Gen. sp. (cysticerci)   |   |   |             |   |   |             |   |   |             |   |   |             |
| Nematoda                |   |   |             |   |   |             |   |   |             |   |   |             |
| Aplectana krausi        |   |   |             |   |   |             |   |   |             |   |   |             |
| Bakeria bakeri          |   |   |             |   |   |             |   |   |             |   |   |             |
| Cosmocerca novaeguineae |   |   |             |   |   |             |   |   |             |   |   |             |
| Cosmocercella phynomantisi |   |   |             |   |   |             |   |   |             |   |   |             |
| Falkustra papuensis     |   |   |             |   |   |             |   |   |             |   |   |             |
| Icosiella papuensis     |   |   |             |   |   |             |   |   |             |   |   |             |
| Ochoterenella papuensis |   |   |             |   |   |             |   |   |             |   |   |             |
| Parathelandraps allisoni |     |     |             |   |   |             |   |   |             |   |   |             |
| Parathelandraps andersoni |   |   |             |   |   |             |   |   |             |   |   |             |
| Acanthocephala          |   |   |             |   |   |             |   |   |             |   |   |             |
| Centrorhynchid cystacanth |     |     |             |   |   |             |   |   |             |   |   |             |

| Host                      | Cophixalus verrucosus N = 9 | Hylophorbus richardsi N = 13 | Oreophryne bira N = 5 | Oreophryne geislerorum N = 29 |
|--------------------------|-------------------------------|-------------------------------|--------------------------|-------------------------------|
| Endoparasite             | N | P | MI ± SD (R) | N | P | MI ± SD (R) | N | P | MI ± SD (R) | N | P | MI ± SD (R) |
| Digenea                  |   |   |             |   |   |             |   |   |             |   |   |             |
| Opisthioglyphe cophixali |   |   |             |   |   |             |   |   |             |   |   |             |
| ——                      |   |   |             |   |   |             |   |   |             |   |   |             |
| Cestoda                  |   |   |             |   |   |             |   |   |             |   |   |             |
| Nematotaenia hylae      |   |   |             |   |   |             |   |   |             |   |   |             |
| Cylindrotaenia sp.      |   |   |             |   |   |             |   |   |             |   |   |             |
| Gen. sp. (cysticerci)   |   |   |             |   |   |             |   |   |             |   |   |             |
| Nematoda                |   |   |             |   |   |             |   |   |             |   |   |             |
| Aplectana krausi        |   |   |             |   |   |             |   |   |             |   |   |             |
| Bakeria bakeri          |   |   |             |   |   |             |   |   |             |   |   |             |
| Cosmocerca novaeguineae |   |   |             |   |   |             |   |   |             |   |   |             |
| Cosmocercella phynomantisi |   |   |             |   |   |             |   |   |             |   |   |             |
| Falkustra papuensis     |   |   |             |   |   |             |   |   |             |   |   |             |
| Icosiella papuensis     |   |   |             |   |   |             |   |   |             |   |   |             |
| Ochoterenella papuensis |   |   |             |   |   |             |   |   |             |   |   |             |
| (Continued)              |   |   |             |   |   |             |   |   |             |   |   |             |
Table 1. (Continued).

| Host                        | Cophixalus verrucosus N = 9 | Hylaphorus richardi N = 13 | Oreophryne biroi N = 5 | Oreophryne geislerorum N = 29 |
|-----------------------------|------------------------------|----------------------------|------------------------|-----------------------------|
| Parathelandros allisoni     | N=9                          | N=13                       | *6 17 6               | N=29 38 2.6 ± 2.3 (1-9)     |
| Parathelandros andersoni    | N=3                          | N=28                       |                        |                             |
| Acanthocephala              | N=3                          | N=17                       |                        |                             |
| Centrorhynchid cystacanths  | N=3                          | N=17                       |                        |                             |

| Endoparasite                | O. noratata N = 35           | O. parkeri N = 6           | Sphenophryne cornuta N = 16 | Xenorhina oxycephala N = 4 |
|----------------------------|------------------------------|----------------------------|----------------------------|----------------------------|
| *Digenea                    | N=4                          | N=1                        | N=10                      | N=5                        |
| Opisthioglyphe cophixali    | 3                            | 6                          | 10                        | 5                          |
| Nematotaenia hylae          | 8                            | 17                         | 25                        | 75                         |
| Cylindrotaenia sp.          | 3                            | 17                         | 25                        | 75                         |
| Gen. sp. (cystaecerci)      | 3                            | 17                         | 25                        | 75                         |
| Nematoda                    | 3                            | 17                         | 25                        | 75                         |
| Aplcetna krausi             | 3                            | 17                         | 25                        | 75                         |
| Bakaria bakeri              | 3                            | 17                         | 25                        | 75                         |
| Cosmocercus novaeguineae     | 3                            | 17                         | 25                        | 75                         |
| Cosmocercula phynomantisi   | 3                            | 17                         | 25                        | 75                         |
| Falcaustra papuensis        | 3                            | 17                         | 25                        | 75                         |
| Icosiella papuensis         | 3                            | 17                         | 25                        | 75                         |
| Ochoterenella papuensis     | 3                            | 17                         | 25                        | 75                         |
| Parathelandros allisoni     | 3                            | 17                         | 25                        | 75                         |
| Parathelandros andersoni    | 3                            | 17                         | 25                        | 75                         |
| Acanthocephala              | 3                            | 17                         | 25                        | 75                         |
| Centrorhynchid cystacanths  | 3                            | 17                         | 25                        | 75                         |
Table 2. Frog host records of helminths reported in this study. References: 1. Hickman (1960); 2. Johnston (1967); 3. Moravec and Sey (1986); 4. Jones (1987); 5. Moravec and Sey (1989); 6. Moravec (1990); 7. Barton (1994); 8. Bursey and Goldberg (2004); 9. Bursey et al. (2006); 10. Bursey and Goldberg (2007); 11. Bursey et al. (2008); 12. Bursey et al. (2009); 13. Goldberg et al. (2009a); 14. Goldberg et al. (2009b); 15. Goldberg et al. (2009c); 16. Goldberg et al. (2013a); 17. Goldberg et al. (2013b); 18. Goldberg et al. (2015); 19. this study.

| Hosts                  | Opisthioglyphe cophxali | Nematotaenia hylae | Cylostomum sp | Cestode cysticerci | Aplectana krausi | Bakera bакерi | Cosmocerca novaeguineae | Cosmocercella phrynomantisi | Falcostraus papuensis | Icosiella papuensis | Ochtoterenella papuensis | Parathlandros alboni | Parathlandros androni | Acanthocephalan cystacanths |
|------------------------|-------------------------|--------------------|---------------|------------------|-----------------|----------------|-------------------------|----------------------------|----------------------|----------------------|--------------------------|------------------------|------------------------|-----------------------------|
| Bufonidae              |                         |                    |               |                  |                 |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Rhinella marina        |                         |                    | 7             |                  |                 |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Ceratobatrachidae      |                         |                    |               |                  |                 |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Cornufer adiastolus    | 14                      | –                  | 14            | 14               | 14              |              |                         |                             |                      |                      |                          |                        |                        |                             |
| Cornufer boulengeri    | 14                      | –                  | 14            | 14               | 14              |              |                         |                             |                      |                      |                          |                        |                        |                             |
| Cornufer browni        | –                       |                    | 14            | 14               | 14              |              |                         |                             |                      |                      |                          |                        |                        |                             |
| Cornufer gilliardi     | 14                      | –                  | 14            | 14               | 14              |              |                         |                             |                      |                      |                          |                        |                        |                             |
| Cornufer neeupus       | 12                      | –                  | 12, 14        | 12, 14           | 12, 14         |              |                         |                             |                      |                      |                          |                        |                        |                             |
| Cornufer papuensis     | –                       |                    | 8             | 14               | 6, 14           |              |                         |                             |                      |                      |                          |                        |                        |                             |
| Cornufer polkwaensis   | –                       |                    |               | 8                | 14              |              |                         |                             |                      |                      |                          |                        |                        |                             |
| Cornufer schmidt       | 14                      | –                  | 14, 14        | 14               |                       |              |                         |                             |                      |                      |                          |                        |                        |                             |
| Limnodynastidae        |                         |                    | 17            |                  |                 |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Lechriodus aganoposii  | –                       |                    | 17            |                  |                 |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Lechriodus melanoopyx  | –                       |                    | 13            |                  |                 |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Platyleptium ornatum   | –                       |                    | 13            |                  |                 |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Miophyliidae           |                         |                    |               |                  |                 |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Austrochaperina basipalmata |                 |                   | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Austrochaperina blumi  | –                       |                    | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Austrochaperina novaebritanniae |              |                   | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Austrochaperina polimeps |                   |                   | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Bargenyx exul          | –                       |                    | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Callulus humicola      | –                       |                    | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Callulus personatus    | –                       |                    | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Callulus robustus      | –                       |                    | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Callulus strictogaster | –                       |                    | 3             |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Callulus wilhelmanus   | –                       |                    | 3             |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Choerophyene darlingoni |                   |                   | 13, 18        |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Choerophyene gudrunae  | –                       |                    | 19            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Choerophyene longirostra|                   |                   | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Choerophyene proboscidia|                   |                   | 13, 18        |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Choerophyene costellifer|                   |                   | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Cophalorus balticus    | 19                      | 13                 | 19, 13, 19    | 19               | 13, 19         |              |                         |                             |                      |                      |                          |                        |                        |                             |
| Cophalorus chesmanae   | 13                      | –                  | 13            |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Cophalorus desticans   | –                       |                    | 19, 19        |                  |                |               |                         |                             |                      |                      |                          |                        |                        |                             |
| Hosts                     | Opisthioglyphe   | Nematotaenia   | Cylindrotaenia | Aplectana | Bakera | Cosmoeca | Cosmocercella | Falcaustra | Icosiella | Ochtoterella | Parathelandros | Parathelandros | Acanthocephalan |
|--------------------------|------------------|----------------|----------------|-----------|--------|----------|---------------|------------|-----------|--------------|----------------|----------------|----------------|
|                          | cophali          | hylae          | sp.            | krausi    | baken  | novaeguineae | phrynomantesi | papuenis   | papuenis   | papuenis     | allioni         | andersoni       | cystercerci     |
| Cophixalus parkeri       | 5                | —               | —              | —         | —      | —         | —             | —          | —         | —             | —               | —               | —               |
| Cophixalus riparius      | —                | —               | —              | —         | —      | —         | —             | —          | —         | —             | —               | —               | —               |
| Cophixalus variabilis    | 19               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 19              | 13              |
| Cophixalus verrucosus    | 13               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 13              | 13              |
| Copiula tiritanii        | 9                | —               | —              | —         | —      | —         | —             | —          | —         | —             | —               | —               | —               |
| Copiula tyleri           | 13               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 13              | 13              |
| Genophryne thomsoni      | 9                | —               | —              | —         | —      | —         | —             | —          | —         | —             | —               | —               | —               |
| Hylaphobus richardi      | 19               | 19             | 19             | 19        | 19     | 19        | 19            | 19         | 19        | 19            | 19              | 19              | 19              |
| Hylaphobus cf. rufescens | 13               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 13              | 13              |
| Liophryne dentata        | 13               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 13              | 13              |
| Liophryne schlaginhaufeni| 13               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 13              | 13              |
| Mantophryne lateralis    | 13               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 13              | 13              |
| Orchophyne brii          | 19               | 19             | 19             | 19        | 19     | 19        | 19            | 19         | 19        | 19            | 19              | 19              | 19              |
| Orchophyne brechynius    | 13               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 13              | 13              |
| Orchophyne gratarum      | 19               | 19             | 19             | 19        | 19     | 19        | 19            | 19         | 19        | 19            | 19              | 19              | 19              |
| Orchophyne mormata       | 13               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 13              | 13              |
| Orchophyne notata        | 13               | 19             | 19             | 19        | 19     | 19        | 19            | 19         | 19        | 19            | 19              | 19              | 19              |
| Orchophyne parkeri       | 13               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 13              | 13              |
| Oxydactyla crassa        | —                | —               | —              | —         | —      | —         | —             | —          | —         | —             | —               | —               | —               |
| Sphenophryne cornuta     | 13               | 13             | 13             | 13        | 13     | 13        | 13            | 13         | 13        | 13            | 13              | 13              | 13              |
| Xenohina parkerorum      | 2, 19            | —               | —              | —         | —      | —         | —             | —          | —         | —             | —               | —               | —               |
| Xenohina oxycephala      | 19               | 19             | 19             | 19        | 19     | 19        | 19            | 19         | 19        | 19            | 19              | 19              | 19              |

(Continued)
| Hosts                      | Opisthioglyphe cophali | Nematotaenia hylae | Cystocesta sp. | Aplectana krausi | Bakeria bakeri | Cosmocerca novaeguineae | Cosmocercella phrynomantisi | Falcaustra papuensis | Icosiella papuensis | Ochtoterella papuensis | Parathelandros allisoni | Parathelandros andersoni | Acanthocephalan cystacanths |
|---------------------------|------------------------|--------------------|----------------|-----------------|----------------|------------------------|--------------------------|---------------------|-------------------|------------------------|------------------------|------------------------|--------------------------|
| Litoria modica            | —                      | —                  | —              | —               | —              | —                      | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Litoria nasuta            | —                      | —                  | —              | —               | —              | —                      | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Litoria pallida           | —                      | 4                  | —              | —               | —              | —                      | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Litoria peronii           | —                      | 4                  | —              | —               | —              | —                      | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Litoria thesaurensis      | —                      | —                  | —              | 15              | —              | —                      | —                        | 15                  | —                 | —                      | 15                     | —                      | —                        |
| Litoria wollastonii       | —                      | —                  | —              | —               | —              | 15                     | 15                       | 15                  | 15                | —                      | 15                     | —                      | —                        |
| Nyctimystes guileisi      | —                      | —                  | —              | 15              | —              | —                      | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Nyctimystes infraneratus  | —                      | —                  | —              | —               | —              | —                      | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Nyctimystes papua         | —                      | —                  | —              | —               | —              | —                      | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Nyctimystes pulcher       | —                      | —                  | —              | —               | —              | —                      | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Nyctimystes semipalmatus  | —                      | —                  | —              | —               | —              | 15                     | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Nyctimystes trachyderma   | —                      | —                  | —              | —               | —              | 15                     | 15                       | —                   | —                 | —                      | —                      | —                      | —                        |
| Ranidae                   |                        |                    |                |                 |                |                        |                          |                     |                   |                         |                        |                        |                          |
| Papuana garritor          | —                      | —                  | —              | —               | —              | 14                     | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Papuana jimbiensis        | —                      | —                  | —              | —               | —              | 14                     | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
| Papuana milneana          | —                      | —                  | —              | 14              | —              | 14                     | —                        | —                   | —                 | —                      | 14                     | —                      | —                        |
| Papuana papua             | —                      | —                  | —              | 14              | —              | 14                     | —                        | —                   | —                 | —                      | —                      | 14                     | —                        |
| Papuana supragrinsa       | —                      | —                  | —              | 14              | 14             | 14                     | —                        | —                   | —                 | —                      | —                      | 14                     | —                        |
| Papuana volkerjane        | —                      | —                  | 17             | —               | —              | 14                     | —                        | —                   | —                 | —                      | —                      | —                      | —                        |
and *Emoia caeruleocauda* (Goldberg et al. 2011). One species, *Cylindrotaenia malayi*, has been reported in Malaysia from the rhacophorid frog *Polypedates leucomystax*, by Yuen and Fernando (1974). Our unidentified species, *Cylindrotaenia* sp. in *Choerophryne gudrunae*, is a new host record (Table 1), and to our knowledge is the first report of *Cylindrotaenia* in a frog from Oceania.

A cysticercus is a cyclophyllidean cestode larval form (metacestode) with a fully developed scolex invaginated into a fluid-filled bladder (Roberts and Janovy 2009). Cysticerceri have been previously reported in other Papuan microhylid frogs, ceratobatrachid frogs and a ranid frog (Table 2). Cysticerci in *Cophixalus balbus*, *Cophixalus desticans*, *Cophixalus variabilis* and *Oreophryne geislerorum* represent new host records.

The nematode *Aplectana krausi* was described from *Cornufer boulengeri* (as *Platymantis boulengeri*) by Bursey and Goldberg (2007). It has been reported from other microhylids, one pelodryad and ceratobatrachids (Table 2). *Sphenophryne cornuta* represents a new host record for *Aplectana krausi*.

The nematode *Bakeria bakeri* was originally described by Moravec and Sey (1986) as *Oswaldocruzia bakeri* from specimens taken from *Callulops stictogaster* (as *Phrynomantis stictogaster*) collected in the Eastern Highlands Province, and *Callulops wilhelmanus* (as *Phrynomantis wilhelmana*) from Chimbu Province, PNG. It was reassigned to *Bakeria* by Ben Slimane et al. (1996) and has been found in Papuan microhylids, one myobatrachid and one ranid (Table 2), as well as in *Cornufer pelewensis* (as *Platymantis pelewensis*) from Belau, Republic of Palau (Bursey and Goldberg 2004). It is also known from the Papuan scincid lizards *Cyrtodactylus louisiadensis*, *Emoia longicauda*, *Eugongylus albofasciolatus*, *Eugongylus rufescens*, *Gehyra oceanica*, *Papuascincus stanleyanus*, *Sphenomorphus aignanus*, *Sphenomorphus forbesi*, *Sphenomorphus fuscolineatus*, *Sphenomorphus jobiensis*, *Sphenomorphus maindroni*, *Sphenomorphus minutus*, *Sphenomorphus nigrilineatus*, *Sphenomorphus simus*, *Sphenomorphus solomonis* (Goldberg et al. 2010) and *Emoia veracunda* (Goldberg et al. forthcoming). *Hylorhina richardsi* represents a new host record for *Bakeria bakeri* (Table 1).

The nematode *Cosmocerca novaeguineae* was described from the ceratobatrachid frog *Cornufer papuensis* (as *Platymantis papuensis*) from West Sepik Province, PNG, by Moravec and Sey (1990). It was also reported from Papuan microhylids, ceratobatrachids, pelodryads and ranids (Table 2). *Choerophryne gudrunae*, *Cophixalus balbus*, *Cophixalus desticans*, *Cophixalus variabilis* and *Cophixalus verrucosus* represent new host records for *Cosmocerca novaeguineae*.

The nematode *Cosmocercella phrynomantisi* was described from the microhylid *Callulops humicola* (as *Phrynomantis humicola*) and reported in *Callulops stictogaster* (as *Phrynomantis stictogaster*) and *Callulops wilhelmanus* (as *Phrynomantis wilhelmana*) from PNG by Moravec (1990). It has also been reported from Papuan microhylids (Table 2). *Xenorhina oxycephala* represents a new host record for *Cosmocercella phrynomantisi*.

The nematode *Falcaustra papuensis* was described from the scincid lizard *Sphenomorphus simus* from PNG by Bursey et al. (2007), and was also reported from the skinks *Emoia atrocostata* (Goldberg et al. 2010) and *Prasinohaema flavipes* (Goldberg et al. forthcoming) from PNG. It was previously found in Papuan ceratobatrachids, pelodryads and microhylids.
(Table 2). *Cophixalus desticans* and *Oreophryne geislerorum* represent new host records for *Falcaustra papuensis*.

The nematode *Icosiella papuensis* was described from *Cornufer papuensis* (as *Platyprantis papuensis*) from East Sepik Province (as Sepic Division), PNG, by Johnston (1967) and has also been reported in a ceratobatrachid, pelodyrads, a microhylid and ranids (Table 2). *Cophixalus verrucosus* and *Oreophryne geislerorum* represent new host records for *Icosiella papuensis*.

The nematode *Ochtoterenella papuensis* was described by Johnston (1967) from the ceratobatrachid *Cornufer papuensis* (as *Platyprantis papuensis*) from East Sepik Province (as Sepic Division), PNG. It has also been reported from microhylids (Table 2). *Oreophryne biroi* and *Oreophryne parikeri* represent new host records for *Ochtoterenella papuensis*.

The nematode *Parathelandros allisoni* was described from the hylid *Nyctimystes trachydermis* from PNG (Bursey et al. 2008). It was also reported from pelodyrads and a microhylid (Table 2). *Oreophryne biroi* represents a new host record for *Parathelandros allisoni*.

The nematode *Parathelandros andersoni* was described by Moravec (1990) from the microhylid *Cophixalus riparius* from Chimbu Province, PNG. It also was found in pelodyrads and microhylids (Table 2). *Choerophryne gudrunae* and *Oreophryne geislerorum* represent new host records for *Parathelandros andersoni*.

Centrorhynchid acanthocephalan cystacanths are larval forms that utilise paratenic (= transport) hosts (never an obligatory host) in which development to the adult does not occur (Kennedy 2006). Cystacanths have been reported in other Papuan frog species, namely ceratobatrachids, pelodyrads, microhylids and a ranid (Table 2). *Cophixalus variabilis* represents a new host record for centrorhynchid cystacanths.

**Conclusions**

There was a high degree of endemism among the adult helminth species infecting our sample of microhylids, with 83% of the species known only from PNG. Of the 12 helminth species represented by mature individuals reported in this study, nine species (75%) were originally described from Papuan anurans, whereas one of the 12 species, *Falcaustra papuensis*, was described from the skink *Sphenomorphus simus* (Bursey et al. 2007) from PNG. Of the nine nematode species capable of reaching maturity in microhylids, *Aplectana krausi*, *Bakeria bakeri*, *Cosmocerca novaeguineae*, *Cosmocercella phrynomantisi*, *Parathelandros allisoni* and *Parathelandros andersoni* are considered monoxenous and infect either orally or by skin penetration (Anderson 2000). Two others (*Icosiella papuensis* and *Ochtoterenella papuensis* Onchocercidae) are transmitted by haematophagous insect vectors (Anderson 2000). *Falcaustra* nematodes are generally considered to require an ingested intermediate host. Among the other kinds of helminths infecting the Papuan microhylids discussed herein, the life cycle of the digenean *Opisthioglyphe cophixali* is not known but its congener *Opisthioglyphe locellus* utilises *Lymnaea* snails as intermediate hosts (Macey and Moore 1958). Both cestodes *Nematotaenia hylae* and *Cylindrotaenia* sp. belong to the Nematotaeniidae (Jones 1987) for which life cycles are not conclusively known. The data presented here suggest that Papuan microhylid frogs are largely infected by helminth generalists that have direct life cycles; thus, infection is more dependent upon habitat conditions than diet.
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Appendix 1. Microhylid frog specimens from Papua New Guinea examined from the herpetology collection of the Bishop Museum (BPBM) Honolulu, HI.

**Choerophryne darlingtoni** (n = 5) BPBM 33,664–33,668 Southern Highlands Province: Muller Range: E slope Mt. Itukua, 2177 m (5°39’37.8”S, 143°37’23.88”E), August 2009.

**Choerophryne gudranae** BPBM 35,559–35,577 Madang Province: Adelbert Mts.: Keki Lodge, 854 m (4°42’17.28”S, 145°24’15.12”E), October 2009.

**Cophixalus balbus** BPBM 35,458–35,459, 35,461–35,462, 35,469 East Sepik Province: Prince Alexander Range: Mindangu Stream, 410 m (3°36’20.16”S, 143°29’31.56”E), September 2009; BPBM 35,460 East Sepik Province: Prince Alexander Range: Imuk, 184 m (3°35’7.08”S, 143°29’34.44”E); BPBM35463–35468 East Sepik Province: Prince Alexander Mts.: Farinara, 360 m (3°36’07.2”S, 143°29’37.32”E), September 2009.

**Cophixalus desticans** BPBM 37,153–37,172 Northern Province: Mt. Victory, Ajoa River, 530 m (9°13’29.28”S, 149°6’22.32”E), September 2010.

**Cophixalus variabilis** BPBM 37,173–37,208 Northern Province: Mt. Victory, along Ajoa River, 530 m (9°13’29.28”S, 149°6’22.32”E), September 2010.

**Cophixalus verrucosus** BPBM 37,209–37,217 Northern Province: Mt. Victory, Ajoa River, 850 m (9°12’0.36”S, 149°5’19.68”E), September 2009.

**Hylophorbus richardi** BPBM 33,749 Southern Highlands Province: Muller Range: E slope Mt. Itukua, 2351 m (5°40’0.485”S, 142°36’58.68”E), March 2009; BPBM 33,751–33,762 Southern Highlands Province: Muller Range: E slope Mt. Itukua, 2177 m (5°40’10.2”S, 142°37’23.88”E), March 2009.

**Oreophryne biroi** BPBM 34,688 East Sepik Province: Prince Alexander Mts.: Mindangu Stream, 410 m (3°36’20.16”S, 143°29’31.56”E), September 2009; BPBM 346,689–34,692 Madang Province: Adelbert Mts.: Keki Lodge, (4°42’17.28”S, 145°24’15.12”E), October 2009.

**Oreophryne geislerorum** BPBM 37,291–37,320 Northern Province: Mt. Victory, along Ajoa River, 530 m (9°13’29.28”S, 149°6’22.32”E), September 2010.

**Oreophryne notata** BPBM 33,672–33,706 Southern Highlands Province: Muller Range: E slope Mt. Itukua, 2177 m (5°40’10.2”S, 142°37’23.88”E), March 2009.

**Oreophryne parkeri** BPBM 34,644 East Sepik Province: Prince Alexander Mts.: Farinara, 357 m (3°36’0.72”S, 143°29’37.32”E), September 2009; BPBM 34,645 East Sepik Province: Prince Alexander Mts.: Mindangu Stream, 410 m, (3°36’20.16”S, 143°29’31.56”E), September 2009; BPBM 34,646–34,649 East Sepik Province: Prince Alexander Mts.: along Joromba River, 410 m (3°34’43.68”S, 143°30’1.08”E), September 2009.

**Sphenophryne cornuta** BPBM 35,520–35,531 East Sepik Province: Prince Alexander Mts.: Mindangu Stream, 410 m (3°36’20.16”S, 143°29’31.56”E), September 2009; BPBM 35,532 East Sepik Province: Prince Alexander Mts.: along Joromba River, 227 m (3°35’28”S, 143°29’42.36”E), September 2009; BPBM 35,533 Madang Province: Adelbert Mts.: Kwerova, 288 m (3°35’5.28”S, 143°29’42.36”E); BPBM 35,534 Madang Province: Adelbert Mts.: Filurkumon 689 m (4°42’40.32”S, 145°24’12.96”E), October 2009; BPBM 35,535 Madang Province: Adelbert Mts.: Keki Lodge, 854 m (4°42’17.28”S, 145°24’15.12”E), October 2009.

**Xenorhina oxycephala** BPBM 34,697 East Sepik Province: Prince Alexander Mts.: along Joromba River, 227 m (334’43.68”S, 143°30’1.08”E); BPBM 34,698 Madang Province: Adelbert Mts.: Samorek, 694 m (4°42’38.16”S, 145°24’5148”E) October 2009; BPBM 34,699–34,700 Madang Province: Adelbert Mts.: Waven, 791 m (4°42’24.84”S, 145°25’7.68”E), October 2009.

Appendix 2. Helminths from Papua New Guinea deposited in the Harold W. Manter Parasitology Laboratory (HWML), University of Nebraska, Lincoln, USA.

From host **Choerophryne darlingtoni**: *Opisthioglyphe cophixali* (HWML 101903).

From host **Choerophryne gudranae**: *Cylindrotaenia* sp. (HWML 101904); *Cosmocerca novaeguineae* (HWML 94166); *Parathelandros andersonii* (HWML 94167).
From host *Cophixalus balbus*: Opisthioglyphe *cophixali* (HWML 94168); Cysticerci (HWML 94169); *Aplectana krausi* (HWML 94170); *Cosmocerca novaeguineae* (HWML 94171).

From host *Cophixalus desticans*: Cysticerci (HWML 94172); *Cosmocerca novaeguineae* (HWML 94173); *Falcaustra papuensis* (HWML 94174).

From host *Cophixalus variabilis*: *Nematotaenia hylae* (HWML 101905); Cysticerci (101906); *Cosmocerca novaeguineae* (HWML 94175).

From host *Cophixalus verrucosus*: *Cosmocerca novaeguineae* (HWML 94176); *Icosiella papuensis* (HWML 94177).

From host *Hylophorus richardi*: Oswaldocruzia *bakeri* (HWML 94161).

From host *Oreophryne boro*: Ochoterenella *papuensis* (HWML 94178); Parathelandros *allisoni* (HWML 94179).

From host *Oreophryne geislerorum*: Cysticerci (HWML 101908); *Falcaustra papuensis* (HWML 94180); *Icosiella papuensis* (HWML 94181); Parathelandros *andersoni* (HWML 94182).

From host *Oreophryne notata*: *Nematotaenia hylae* (HWML 101909).

From host *Oreophryne parkeri*: Ochoterenella *papuensis* (HWML 94183); Parathelandros *andersoni* (HWML 94184).

From host *Sphenophryne cornuta*: Opisthioglyphe *cophixali* (HWML 101910); *Aplectana krausi* (HWML 94185); *Cosmocerca novaeguineae* (HWML 94186).

From host *Xenorhina oxycephala*: Cosmocercella *phrynomantisi* (HWML 94187).