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Food of the blind cave fishes of northwestern Australia

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Abstract – Cape Range peninsula, in the arid northwest of Western Australia, contains the only cavernicolous fishes in Australasia, both of which are considered as vulnerable or endangered. They are associated with a stygofauna considered to be of Tethyan origin. *Ophisternon candidum* (Mees, 1962) (Synbranchiformes: Synbranchidae) and *Milyeringa veritas* Whitley, 1945 (Perciformes: Eleotrididae) occur widely in underground waters and are endemic to the peninsula. The gut contents of existing collections were examined to elucidate their prey. Both species of troglobitic fish are opportunistic in their feeding, able to utilize occasional packets of energy entering the stygal realm.

Ophisternon candidum eats the specialised stygofauna of the region, including *Halosbaena tulki* (Poore and Humphreys, 1992) (Thermosbaenacea) and atyid shrimps (*Stygiocaris* spp.) and also feeds opportunistically on aquatic larvae living in the more open part of the subterranean system. The biogeographic affinities of *O. candidum* is in accord with that of its main prey. The gut contents constitute the only records of *Stygiocaris* and *Halosbaena* from Tantabiddy Well (C–26), the type locality of *O. candidum*. *M. veritas* primarily feeds opportunistically on invertebrates accidentally introduced into the aquatic system (mostly terrestrial isopods and cockroaches) but also feeds on the stygofauna.

INTRODUCTION

The Cape Range peninsula in the arid northwest of Australia is noted for its subterranean animals, both a terrestrial fauna with wet forest affinities (Humphreys 1993a, 1993b, 1993c, 1993d), and an aquatic fauna with Tethyan affinities (Humphreys 1993a, 1993d; Knott 1993). Amongst the latter are two species of blind cave fish, the Blind or Cave Gudgeon, *Milyeringa veritas* Whitley, 1945 (Perciformes: Eleotrididae) and the Blind Cave Eel, *Ophisternon candidum* (Mees, 1962) (Synbranchiformes: Synbranchidae). These two species of fish comprise the entire vertebrate troglobite fauna of Australasia. While other stygobiontic fish have been extensively researched (e.g. Wilkens 1988), nothing is known of the ecology of those inhabiting the Cape Range peninsula.

The Synbranchidae, or swamp eels, are widely distributed in tropical and sub-tropical regions. They exhibit marked habitat plasticity, being predominantly freshwater inhabitants but extending into brackish and estuarine waters; the same species may occupy a range of epigean habitats from streams and lakes to swamps and marshes. Swamp and marsh dwellers often show amphibious or burrowing habits and many are capable of aerial respiration (Rosen and Greenwood 1976).

The genus *Ophisternon* has a disjunct distribution, being found in Australasia, Indo-Malaya, west Africa and some island and mainland areas of the Caribbean. While the diet of *O. candidum* has been unrecorded previously, synbranchids are recognized as nocturnal predators (Moyle and Cech 1982). Cavernicolous species, showing considerable atrophy of the eye tissue, occur on the Yucatan peninsula, Mexico (*O. infernale*) (Rosen and Greenwood 1976) and in Australia (*O. candidum*).

The Eleotrididae are widespread in tropical and subtropical shallow marine to fresh waters mainly in the Indo-Pacific region (Nelson 1984). The monotypic genus *Milyeringa* is endemic to the Cape Range peninsula but the phylogenetic relationships between members of the family Eleotrididae have not been established (see discussion in Knott 1993). *M. veritas* is cavernicolous, eyeless and translucent. This species has been considered to feed opportunistically upon detritus, algae and whatever animals, including insects, accidentally fall into the water (Allen 1989).

Their subterranean habitat restricts observation in life and hence very little is known about the biology of these fishes. Nonetheless, they have respectively been classified as rare and recommended for total protection, and vulnerable (Michaelis 1985); both fish species as well as two of the prey species (*Stygiocaris* spp.) have been listed under Schedule One of the Wildlife Protection Act of Western Australia owing to their small geographic distribution, low populations and vulnerability of their habitat.

To establish basic biological data required for conservation purposes the gut contents of existing collections have been examined to elucidate their prey.

METHODS

The intestines were either dissected out and later examined by flushing the contents, or the flushing was conducted *in situ* on intestines longitudinally incised. The contents were identified to whatever level practicable depending on the state of digestion. As no details are available of the treatment of the specimens prior to preservation, no attempt is made to quantify feeding rates.

With the exception of the holotype the gut contents were examined of all available specimens of *Ophisternon candidum* namely, Paratype P4918 Tantabiddy Well (C–26), Yardie Creek Station, collected A.M. Douglas and G.F. Mees, 17/5/1960; P5813; Tantabiddy Well (C–26), Yardie Creek Station, collected A.M. Douglas, 22/7/1963; P7716; North West Cape area, collected R. Gredling, 1963–4.

The stomach contents of a large series of *Milyeringa veritas* in the collection of the American Museum of Natural History were extracted by MNF and examined in Perth. Material came from: AMNH 45497 (N=30) which included specimens collected by Nelson, Butler and Rosen from the west side of the Cape Range peninsula between Yardie Station and Yardie Creek on the afternoon of 2 April 1969; AMNH 48568 (N=20) which included specimens collected by Nelson, Butler and Rosen from the east side of Cape Range peninsula from Neds Well to Mowbowra Creek on the morning of 5 April 1969.

RESULTS AND DISCUSSION

Ophisternon candidum

Members of the stygofauna were found in the midgut of P5813, namely thermosbaenaceans (*Halosbaena tulki* Poore and Humphreys, 1992) and atyid shrimps (*Stygiocaris* sp.); sand grains to 1.2 mm diameter were also recovered. The hindgut of the same individual yielded only terrestrial taxa or taxa terrestrial as adults namely, slaters (Isopoda: Philosciidae) and dragonfly (Odonata) and dipteran larvae (Table 1). No gut contents were found in P4918 or P7716.

The gut contents and the habitat characteristics of the taxa would suggest that two feeding episodes had occurred in the first (hindgut) of which the eel foraged in an open cave habitat on a non-cave aquatic fauna (Odonata and Diptera larvae) as well as cryptic species accidentally in the water (philosciid isopod). During the subsequent feeding episode the eel foraged solely on the specialised subterranean aquatic (stygo–) fauna comprising sediment foraging species (*Halosbaena* and *Stygiocaris*).

No shrimps were taken from Tantabiddy Well (C–26) in the original collections (Mees 1962) or subsequently (Humphreys and Adams 1991; W.F. Humphreys, unpublished) although both *S. lancifera* and *S. stylifera* occur in an adjacent well (C–25, Kudamurra Well; Mees 1962; W.F. Humphreys and M. Adams, unpublished 1991). *Halosbaena* has not been collected from C–26 (Poore and Humphreys 1992; W.F. Humphreys, unpublished). Hence, these gut contents constitute the only records of *Stygiocaris* and *Halosbaena* from C–26.

The distribution of the genus *Ophisternon* has been described as Gondwanan (Rosen and Greenwood 1976) but a recent interpretation considered both the genus *Ophisternon* and the family Synbranchidae to have a Tethyan distribution (Banarescu 1990: 203). The latter interpretation would accord with the stygofauna of

Table 1 The gut contents of *Ophisternon candidum* in the collections of the Western Australian Museum.

Location	Identification	Reg. No.
Midgut	Thermosbaenacea, *Halosbaena tulki*	BES: 820
Midgut	Atyidae: *Stygiocaris* sp.	BES: 821
Midgut	Atyidae: *Stygiocaris* sp.	BES: 822
Midgut	Thermosbaenacea, *Halosbaena tulki*	BES: 823
Midgut	Thermosbaenacea, *Halosbaena tulki*	BES: 824
Midgut	Thermosbaenacea, *Halosbaena tulki*	BES: 825
Midgut	Sand to 1.2 mm diameter and residue	BES: 826
Hindgut	Isopoda: Philosciidae	BES: 817
Hindgut	Odonata, larva	BES: 818
Hindgut	Unidentified	BES: 819
Hindgut	Diptera, larva	BES: 856

Table 2 The gut contents of *Milyeringa veritas* from the American Museum of Natural History collections. 'Fish N' and 'Prey N' denotes the number of fish containing that prey item.

Side of peninsula AMNH number (N) Contents	West 45497 (N=23) Prey N(%)	 Fish N(%)	East 48568 (N=16) Prey N(%)	 Fish N(%)
No contents	–	8 (31)	–	4 (21)
Cockroaches	1 (5)	1 (4)	9 (53)	7 (37)
Isopods (Armadillidae)	14 (64)	12 (46)	2 (12)	2 (11)
Stygiocaris (shrimps)	1 (5)	1 (4)	1 (6)	1 (5)
Crustacea (probably *Stygiocaris*)	1 (5)	1 (4)	1 (6)	1 (5)
Trichopteran larvae	1 (5)	1 (4)	2 (12)	2 (11)
Ants	4 (18)	1 (4)	0 (0)	0 (0)
Unidentified insect parts	–	1 (4)	0 (0)	0 (0)
Worms?	0 (0)	0 (0)	1 (6)	2 (11)
Total	22	26	16	19

the Cape Range peninsula and that of the prey items (Humphreys 1993a, 1993d; Knott 1993). Indeed, an undescribed species of syncarid crustacean of the genus *Atopobathynella* (H.K. Schminke, pers. comm.) (Parabathynellidae, Bathynellacea) is the only element in the stygofauna of the Cape Range peninsula (and Barrow Island) that is clearly Gondwanan (W.F. Humphreys, unpublished).

Milyeringa veritas

Milyeringa individuals included specialised members of the stygofauna (*Stygiocaris* sp.) in its diet, the aquatic larvae of terrestrial species (caddis larvae), and terrestrial species accidentally in the water (isopods, ants and cockroaches) (Table 2). The identifiable contents were predominantly (79%) terrestrial species that had presumably fallen into the water and, at the most, only 10% were specialised members of the stygofauna.

Milyeringa on the west coast ate predominantly terrestrial isopods (*Buddelundia* sp.), while those on the east coast fed mainly on cockroaches (Table 3); this distribution of prey items differs between coasts (G = 16.868, P<0.001). Despite these differences the source of the food was predominantly from outside the water body, of terrestrial origin (Table 3).

Gudgeons examined for prey were larger (F_s 1,43 = 28.75, P<0.001) on the west coast (38.5±3.99 mm, n=26) than on the east coast (30.6±5.47 mm, n=19), as were those (F_s 1,31 = 17.5, P<0.001) in which prey was found (38.6±4.39 mm and 31.2±5.69 mm respectively).

Table 3 Percentage contribution of prey, by taxa and origin, in the guts of *Milyeringa veritas* on the east and west coasts of the Cape Range peninsula (n=34).

Group	West	East
Insects	12	29
Crustacea	47	12
Aquatic	12	9
Terrestrial	47	32

Prey size was converted to common units (body length, mm) using empirically derived relationships – isopod length (mm) = 2.8 carapace width (mm) – 0.04 (r^2 =0.89, P= 0.017); cockroach length (mm) = 3.9 head capsule width (mm)+1.5. The mean head capsule width of the cockroaches was 1.3±0.16 mm (n=8) giving an estimated overall body length of 5 mm (by regression). The mean carapace width of the isopods was 2.9±1.71 mm (n=6) giving an estimated overall length = 8.1 mm (by regression). Hence, the bigger west coast fish were associated with bigger food items (isopods). However, as terrestrial Crustacea generally have an energy density only about 70% that of terrestrial insects (from Cummins and Wuycheck 1971), then the apparent advantage in food size may not confer an energetic advantage.

Associated fauna in the field

The fish share their habitat with a large number of stygofaunal elements, many of which were not represented in their gut contents (Table 4). The smallest taxa, such as copepods and ostracods, are probably outside the size range of prey items, which for *M. veritas* is known to include the length range of c. 2.8–14 mm, and for *O. candidum* 3 mm (*Halosbaena*) to an estimated 8 mm (Odonata). No fish samples were collected from known remiped habitat, although they do occur sympatrically (W.F. Humphreys, unpublished 1994). The melitid amphipods are sympatric with *M. veritas* (at locations C–24, 25, 105, 274 and 362; W.F. Humphreys, unpublished) and abundant in the stygal habitat but, despite being within the known size range of prey for both species of fish, they are not represented in the gut contents.

Table 4 Stygofauna associated with the two sympatric cave fishes on the Cape Range peninsula. √ = is known from the same sites but not recorded in the guts; + = is known from the same sites and not recorded in the guts; – = is not recorded from the same sites.

	O. candidum	*M. veritas*
Stygiocaris lancifera Holthuis	+[1]	+
S. stylifera Holthuis	+[1]	√
Halosbaena tulki Poore and Humphreys	+	√
Haptolana pholeta Bruce and Humphreys	–	√
Remipedia	–	√
Melitid amphipod gen. et sp. nov.	√	√
Calanoid copepods	√	√
Harpacticoid copepods	√	√
Ostracoda	√	√

[1] The species of *Stygiocaris* in *O. candidum* from C–26 is not known; immediately to the north of C–26 *S. stylifera* and *S. lancifera* are sympatric, while to the south only *S. lancifera* is known.

DISCUSSION

The prey identified is consistent with the behaviour of the fish. *O. candidum* inhabits the surface of, and burrows into, the faecal ooze characteristic of crustacean-rich stygal habitats. All the prey items identified are bottom dwellers or, in the case of the isopod, would sink to the bottom when it fell into the water. In contrast *M. veritas* moves widely through the water column, often hovering in mid– to surface waters where prey with hygrophobic integuments, such as cockroaches, would be encountered when they fell into the water.

The locations sampled for *M. veritas* include flooded sinkholes, small rock pools, shallow open caves in the coastal limestones, old wells (hand-excavated and lined with wood or cement) deep anchialine caves (i.e. inland caves connected at depth to the sea) and deep bores. From these samples the food of *M. veritas* comprised predominantly terrestrial taxa (79%) that have presumably fallen into the water; both the isopods and cockroaches are plentiful in some of the sampling locations as these cryptic taxa shelter there from the hot arid climate. However, there are populations of gudgeon known from caves (e.g. C–215, C–452) where such accidental food is unlikely to occur as the water is reached only at some horizontal distance from the entrance, or from 50 m deep bores. However, both these habitats contain rich stygofauna.

Both species of troglobitic fish are clearly opportunistic in their feeding, able to take accidental inputs of energy. The eel forages on the specialised subterranean inhabitants and the gudgeons must have this ability, although rarely recorded in these samples, because it inhabits some locations, such as C–215 and deep bores, essentially closed to accidentals. The gudgeons are capable of taking large and energy rich prey such as cockroaches, while the eels include prey of minute size (*Halosbaena tulki* is <2 mm in total length; Poore and Humphreys 1992).

There is one area of bias in the data that impinges on the interpretation of these findings. From necessity the fishes were sampled at the few places where the stygal realm opens to the surface – wells and rockholes – and hence where epigean prey species would be present. Throughout the greatest part (>99.99%) of the distribution of this stygal community there are no known openings to the surface. Extensive sampling down boreholes has shown that the stygofauna is present in such areas, with the exception of *O. candidum* which was not sampled there, and that there was a general absence of epigean species in these areas (W.F. Humphreys, unpublished data, 1994). Hence, in general, the fish will be dependent on the stygofauna for food and not, as suggested by the data presented here, on epigean species accidentally in the water.

The stygal community on the Cape Range peninsula is unusual in that there are recorded only eight instances world wide of two species of sympatric cave fish (Thinès and Proudlov 1986), and because of their occurrence with a rich community of crustacea, many belonging to relict groups (Wägele 1992) such as thermosbaenaceans and remipedes (Poore and Humphreys 1992; W.F. Humphreys, unpublished). Given their Tethyan origins (Humphreys 1993a, 1993d; Knott 1993) it is not remarkable that the fish and crustaceans should be part of the same food web and the broad conservation implications are clear – the stygofauna is a functional community, changes to part of which may effect the remainder.

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