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THE ECOLOGY OF THE WATER SNAKES OF BAN THA HIN, SONGKHLA PROVINCE, THAILAND

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ABSTRACT

The ecology of the rainbow water snake, *Enhydris enhydris,* was studied near the village of Ban Tha Hin on the east shore of Lake Songkhla, in 1996 and 1997. Temperature, humidity, and light were monitored. Snakes were trapped, injected with PIT tags, and released. A total of 235 individuals were marked and the population was estimated to range from 406 to 567. Snakes were also collected by hand in conjunction with a unique local fishing technique. Radiotelemetry observations on eleven snakes demonstrated that they prefer the mud-root tangle along the edges of the ditches and klongs. Body temperatures ranged from 29.2 to 32.1°C, with no differences between the sexes. Radio transmitters were also implanted in small numbers of *Enhydris plumbea, Homalopsis buccata, Xenochrophis piscator,* and *Cylindrophis ruffus.* Observations were made on litter size, diet, and predation. An appendix lists all snake species encountered in the area.

INTRODUCTION

Lake Songkhla, a 98,000-hectare wetland complex in southern Thailand, is composed of three shallow basins. The lake has formed over the past 150 years as a series of barrier islands gradually enclosed the basins. The islands, which now form the Sathing-Phra Peninsula, almost completely isolate Lake Songkhla from the Gulf of Thailand; there is only one opening to the sea located at the south end of the lake near the city of Songkhla.

As a result of the changes in water levels and water chemistry that accompanied the formation of the lake, Lake Songkhla has an unusual mixture of freshwater and marine flora and fauna. When ANNANDALE (1916) reported on its fauna the lake was no more

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than 4.9 m deep. Gradually the lake has continued to accumulate silt and today the three basins have a mean depth of 1.2 m and a maximum depth of 2.4 m (LEELAWATHANAGOON *ET AL.*, 1997).

The wetlands of Lake Songkhla are one of Thailand's unique and important natural resources and the lake is of regional significance as a stopover for many species of migratory birds. A recent study of the fishes of Lake Songkhla (LHEKNIM, 1998) demonstrates that the basins of this lake and the nearby freshwater Thale Noi serve as a reservoir of marine and freshwater species diversity. Thus, it is not surprising that this vast wetland complex provides an ideal location to study aquatic snakes.

Lake Songkhla is home to perhaps the most diverse assemblage of aquatic snakes in the world. One true sea snake (*Hydrophis brookii*, Hydrophiidae), one aquatic file snake (*Acrochordus granulatus*, Acrochordidae), one pipe snake (*Cylindrophis ruffus*, Uropeltidae) and at least four species of Asian water snakes (Homalopsinae, Colubridae) live in the lake or along its wet edges. Our focus has been on the small- to medium-sized species of Asian water snakes that are rarely more than one meter in total length. These snakes are characterized by small dorsally oriented eyes, crescent-shaped valvular nostrils, enlarged rear fangs and mild venom.

The 32 species of Homalopsinae are grouped into 10 genera and found westward to Pakistan's Indus Valley eastward to China and southward to New Guinea and Australia. The homalopsine snake *Cerberus rynchops* may be the most abundant snake on the planet. For example, as many as three dog faced water snakes occupies every meter of shoreline at the mouth of the Muar River in Malaysia (JAYNE *ET AL*, 1988) and it appears to occur in similar densities throughout much of its range from India to northern Australia.

Half of the 32 species of homalopsine snakes inhabit the waters of Indochina and 8 of these species are restricted to this region. Thailand has a particularly high diversity, with 12 species in its wetlands. This peak diversity suggests that this region is the likely center of distribution and probable site of origin and evolutionary radiation for this group of water snakes.

While the anatomy, taxonomy and overall geographic distribution of the Asian water snakes has been studied at some length (e.g., SMITH, 1943; GYI, 1970; MURPHY & VORIS, 1994a) their natural history remains largely anecdotal (MURPHY & VORIS, 1994b). Until recently the specifics of habitat use, thermal biology, food and feeding behavior, reproductive cycles, and population biology were virtually unknown. The ecology of Asian water snakes is of particular interest because members of the subfamily are at different stages of transition between terrestrial and aquatic life zones. For example, the plumbeous water snake (*Enhydris plumbea*) is one of the more terrestrial of the group and although it is usually found in paddy fields, buffalo wallows, marshes, ditches, and small streams, it sometimes can be found on dry land several meters from standing water (KARNS *ET AL.*, 1996 and VORIS & KARNS, 1996). On the other hand, the keel-bellied water snake (Bitia hydroides) may be the most aquatic as it rarely, if ever, leaves shallow or intertidal marine habitats (JAYNE, *ET AL.*, 1995).

METHODS

Study Site

The study site (Figure 1) is located about 0.2 km west of Ban Tha Hin, at the Ban Tha Hin Royal Forestry Substation (7°23'N, 100°26'E), Thale Sap Non-hunting area, on the southeast side of Lake Songkhla's Thale Sap. The study site is approximately 20 ha. The major habitat at the study site is extensive wet meadow dominated by a single species of grass, *Paspalum distichum* L. (Gramineae), a salt-tolerant, cosmopolitan species. At Ban Tha Hin *P. distichum* attains a height of from 0.5 to 0.75 m and is emergent in areas that are continually inundated with water at lake level (Figure 2). Less common plants that occur at Ban Tha Hin include *Scirpus litoralis* Schrad. (Cyperaceae), *Najas marina* L., and *Najas minor* All. (Najadaceae).

A narrow raised road runs west from Ban Tha Hin to the lake (Figure 1). The road is closed to all vehicle traffic and is bordered by water-filled ditches on both sides that are 1.7 to 2.0 m deep, 1.5 to 4.0 m wide, and extend to the lake. These ditches resulted from dredging during road construction and are deep enough to be free of emergent vegetation .

The northern edge of the study site is bordered by a canal (Klong Tha Hin) that runs west from the town to the lake (Figure 1). The klong is approximately 25 to 40 m across and attains a depth of about 0.7 m. Scattered mangroves (*Sonneratia caseolaris* L. Engl., Sonneratiaceae) occur along the edge of the klong and at the eastern perimeter of the study site. A smaller klong bisects the wet meadow south of the road and it intersects Klong Tha Hin at the west end of our study site (Figure 1). This minor klong is from 10 to 15 m wide, and approximately 0.7 m deep. Several small canals (< 3 m width) branch off of the minor klong and connect to the main ditches that parallel the road. A third canal, Klong Huairut, about 0.7 km south of the main study site was used for observations of the puff-faced water snake (*Homalopsis buccata*). This canal 25 to 30 m wide, is heavily used by fisherman and it is bordered by Sonneratia caseloaris trees.

A unique anthropogenic feature of the canals are teardrop-shaped fish bays dug into the bank of the canal (Figure 1). Many of these occur within and adjacent to the study site. The fish bays have a mean depth of 1.4 ± 0.3 m, a mean length of 9 ± 0.9 m, and a mean maximum width of 1.8 ± 0.7 m. The fish bays are maintained by fisherman who place tree branches in them, and cover them with palm branches to provide shade. Both fish and snakes move in and out of the fish bays. After several weeks fisherman seal off the narrow openings of bays with boards and mud, pump out the water, and collect the fish by hand.

Mapping

A grid system composed of staked positions at 10 m intervals was constructed during the 1996 field season. The grid covered about 10,000 m^2 of the study area and was used to map this portion of the study site. Topographic and anthropogenic features (i.e. fish bays, canals, ditches, buildings) were mapped and distances were calculated by triangulation and direct measurement (Figure 1).

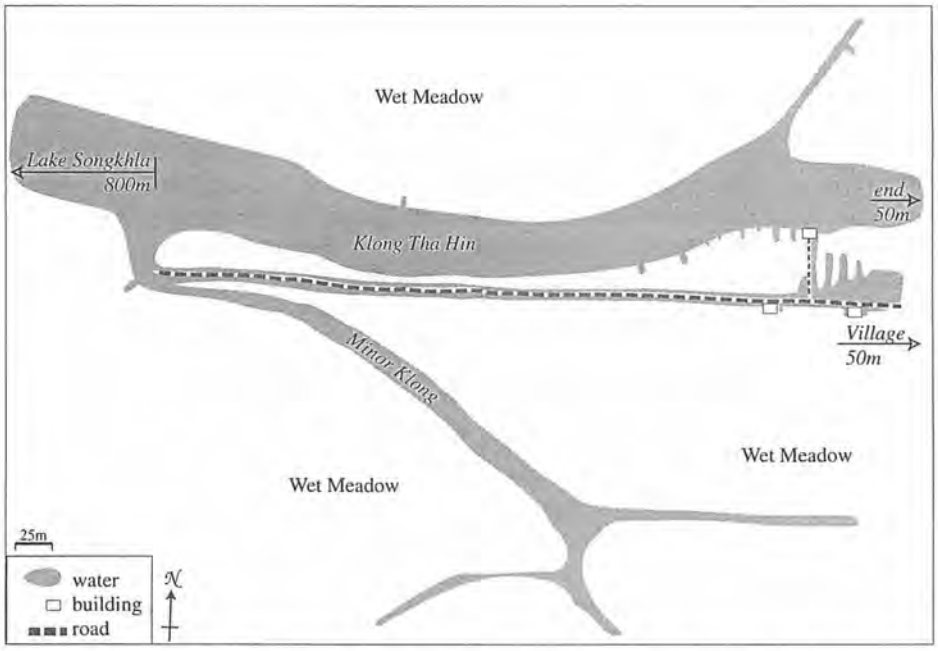

Figure 1. A map of the study site at Ban Tha Hin. The wet meadow is dominated by seashore paspalum (*Paspalum distichum*). The Royal Forestry Department manages the Ban Tha Hin area. A narrow road with ditches on both sides runs west from the village (dashed line). Two buildings on the site (rectangles on southern edge of road) serve as offices for forestry personnel.

Figure 2. The wet meadow at the Ban Tha Hin study site is dominated by the grass *Paspalum distichum.* A fisherman is shown with his boat and fish traps in Klong Tha Hin.

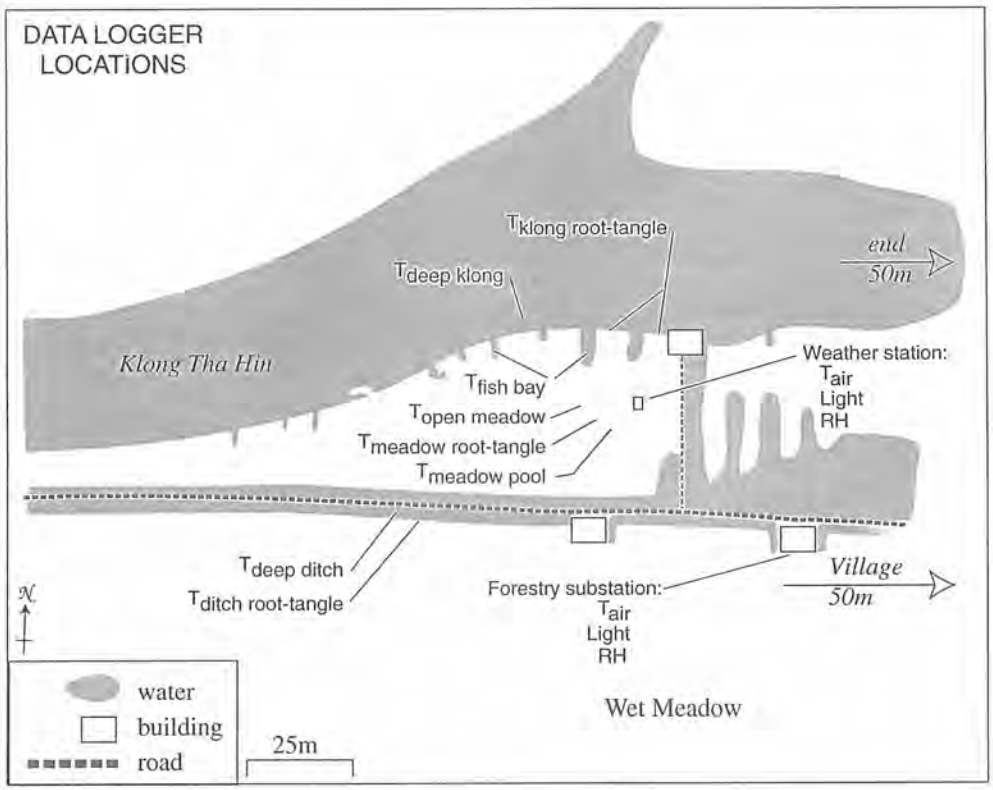

Figure 3. A map of the Ban Tha Hin study site showing the locations of the weather stations and most of the thermal data loggers.

Environmental Monitoring

In order to describe the environmental conditions available to the snakes at Ban Tha Hin we deployed 15 data loggers (Onset Computer, Procasset, Massachusetts). Three data loggers attached to a small weather station (1 m high) in the meadow (Figure 3) were used to measure shaded air temperature (T_{air}), light intensity (lumens), and relative humidity (RH). A similar weather station was located near a window in the forestry substation house. We deployed nine temperature data loggers in microhabitats available to the snakes. The data loggers were placed inside copper snake models (copper tubes 2 cm in diameter, 25 cm long; painted olive green to match the reflectivity of the snakes; and sealed at both ends with stoppers) (PETERSON *ET AL.*, 1993). The temperature data loggers (T_e models) recorded temperature data every 3 to 5 minutes from 18 July to 1 August. A rain gauge adjacent to the small weather station was checked daily.

The data loggers (T_e models) were placed in a broad range of microhabitats in order to monitor the temperature range at Ban Tha Hin. We paid special attention to those microhabitats frequented by snakes. Figure 3 shows eight of eleven logger locations.

Table 1. Day any night statistics for centigrade temperatures for 11 locations and relative humidity for two locations at Ban Tha Hin as recorded by portable data loggers between July 17 and August 1, 1996. The number of readings is provided under the measurements column and the time between each measurement is provided in the interval column. Day readings were those taken between 0600 and 1800 hours while night readings were those taken between from 1800 and 0600 hours. See the text for more details on the position of the data loggers in the various microhabitats.

Location	Measure-ments	Interval (min.)	Day Measurements				Night Measurements			
			Mean	Std.	Min.	Max.	Mean	Std.	Min.	Max.
Meadow weather station	2182	5	32.44	3.64	23.03	38.14	26.53	1.30	24.06	32.39
Forestry substation	674	16	30.48	2.72	25.21	36.00	27.89	1.60	25.21	36.79
A-5 Fish bay on klong	2017	5	30.96	1.96	26.81	36.18	28.65	0.82	26.81	31.19
C-5 Fish bay on klong	3154	3	31.19	2.08	25.36	38.58	28.75	1.58	25.36	32.68
Deep in Klong Tha Hin	2017	5	31.60	2.66	24.98	36.52	28.94	1.54	25.15	33.05
Klong root tangle	2176	5	30.90	2.08	27.55	35.82	29.95	1.13	27.55	33.49
Deep in south ditch	2026	5	30.44	0.62	28.98	31.95	30.60	0.52	29.34	31.58
Ditch root tangle	2179	5	31.16	1.48	27.89	34.23	30.69	1.00	28.25	33.46
Open exposed edge of ditch	2178	5	40.39	9.52	23.59	61.87	25.96	1.45	23.59	33.08
Open pool in meadow	2181	5	32.88	4.14	24.82	38.09	27.92	1.83	24.82	33.9
Open root tangle in meadow	2180	5	32.05	4.11	24.39	38.16	27.20	1.77	24.22	31.24
RH meadow weather station	675	16	68.85	15.58	41.40	100.00	88.94	8.87	53.60	100.00
RH forestry substation	674	16	69.08	13.36	41.20	94.40	80.37	7.94	46.00	92.7

Along the edge of Klong Tha Hin we placed temperature loggers in the root-tangle of two fish bays ($T_{A\text{-}5\ fish\ bay}$ and $T_{C\text{-}5\ fish\ bay}$) at a depth 15cm (Table 1). In addition, one logger was placed on the mud bottom of Klong Tha Hin at a depth 70 cm ($T_{klong\ 70\ cm}$) and another was placed in the root-tangle of the south bank of the klong at a depth 15 cm ($T_{klong\ root\text{-}tangle}$).

In the south ditch one logger was placed on the mud bottom at a depth of 110 cm ($T_{ditch\ 110\ cm}$) while another was placed 15 cm below the water surface in the root-tangle along the edge of the ditch ($T_{ditch\ root\text{-}tangle}$). A third logger was placed on the surface of exposed mud on the south shore of Klong Tha Hin ($T_{exposed\ mud}$). In the meadow, one logger was placed just 2 cm below the surface of the water in an open pool ($T_{meadow\ pool}$), and another was placed in the root-tangle 15 cm below the surface of the meadow pool ($T_{meadow\ root\text{-}tangle}$).

Water temperatures at different depths were measured in several aquatic habitats using thermal probes (Table 2). Water temperatures in meadow pools were taken at the surface, at the bottom of the pool, and at 5, 10, 15, and 20 cm below the bottom of the pool in the soft mud. Water temperatures were taken at the surface, 0.5, 0.8, and 1.0 m below the

Table 2. Mean and standard deviation of water temperature (C) at different depths in several habitats at the Ban Tha Hin study site.

Habitat	Depth (m)	Temperature (C)		Mean Difference
		0700 hrs.	1600 hrs.	
Klong	Surface	27.6+0.0	32.9+0.1	5.3
	0.50 m	27.6+0.1	33.1+0.1	5.5
	0.80 m	27.5+0.0	33.1-0.1	5.6
	1.00 m	29.4+0.3	31.0+0.3	1.6
Fish bay	Surface	28.3+0.4	31.6+0.5	3.3
	0.50 m	28.2+0.5	31.4+0.3	3.2
	0.80 m	28.1+0.3	30.9+0.5	2.8
	1.00 m	29.5+0.1	29.7+0.1	0.2
Meadow	Surface	25.1+0.2	33.5+1.0	8.4
	0.02 m	25.1+0.3	33.0+1.7	7.9
	0.07 m	25.9+0.5	32.2+0.9	6.2
	0.12 m	28.2+0.4	29.9+1.1	1.1
	0.17 m	28.0+0.3	30.2+1.2	2.2
	0.22 m	27.0+0.4	31.1+1.0	4.1
Ditch	Surface	30.0+0.1	31.9+0.1	1.9
	0.25 m	30.1+0.1	32.0+0.1	2.0
	0.50 m	30.1+0.1	32.0+0.2	1.9
	0.80 m	30.1+0.1	31.6+0.1	1.5
	1.00 m	30.0+0.1	31.4+0.3	1.4

water's surface in the klong, in fish bays, and in the ditches. The temperatures were taken in the morning (approximately 0700 h) and the afternoon (approximately 1600 h).

The salinity and pH of the water was measured using Hach Colorimetric Test Kit and litmus paper respectively. The measurements were taken in the south ditch, fish bays, the klong, and meadow pools. The pH of all of sites was circumneutral (6.6–6.9±0.1) based upon three tests taken at each location. The salinity of the meadow pools (6.5±0.3 ppt) was approximately twice that of the water in the south ditch, the klong, and the fish bays (3.3–3.5±0.4 ppt).

Trapping

The study site was visited from 17 June to 12 August 1996, and from 21 June to 8 July 1997. Funnel traps were constructed from aluminum window screen and plastic screen. The traps had a funnel diameter of 25 cm and a length of about 60 cm. The funnel openings into the traps were about 4 cm in diameter and a 15 cm long, floppy nozzle of plastic screen was secured to the funnel opening inside the trap. In 1996 we deployed 18 traps in ditches and canals for 12 days, 36 traps along the lake shore for 12 days, and 25 traps in meadow pools for 10 days. Traps were baited with small pieces of fresh fish. Each day all the traps were checked and each snake was weighed to the nearest 0.1 g, snout to vent length (SVL) measured to the nearest mm, and subcaudal scales counted to determine sex. Snakes were then released in the vicinity of where they were trapped.

In 1997, 51 traps were deployed along the south edge of Klong Tha Hin and in ditches (Figure 4) for 13 days. An additional 16 traps were deployed among these traps for the last four trap-days. For purposes of analysis we calculated the number of trap-days as the cumulative total number of days of trapping. The trap rate was calculated as the total number of snakes trapped divided by the respective number of trap-days. We divided the study site into four trapping regions: the klong, east ditch, west ditch, and south ditch (Figure 4).

Each snake caught in 1997 was placed in a plastic bag with its trap number, and weighed to the nearest 0.1 g. Snout-vent and tail length measured to the nearest mm, and subcaudal scales were counted to determine sex. Prior to release at the site of capture a passive integrated transponder (PIT) tag was injected subcutaneously.

Radiotelemetry

In the two years of the study, temperature-sensitive radio transmitters (Holohil Systems, Corp, Ontario, Canada; Model BD–2; size 4x8x15 mm, 1.8 g; Model SI–2T, 5x10x20 mm; 9.1 g battery, battery life four weeks at 30°C; range <200 m) were implanted intraperitoneally into 11 *Enhydris enhydris* (2 males and 5 females in 1996 and 4 males in 1997), 2 female *E. plumbea* in 1996, and 1 female *Homalopsis buccata* in 1996. Transmitters were also implanted in 1 red-tailed pipe snake (*Cylindrophis ruffus*, Uropeltidae) and 1 common keelback (*Xenochrophis piscator*, Colubridae: Natricinae) in 1997. The surgical procedures of KINGSBURY (1994) and REINHARDT & CUNDALL (1982) were followed. Transmitters were calibrated in water baths before and after use and performed within 0.5°C. Body masses for the *E. enhydris* ranged from 57.0 to 125.0 g, for *E.*

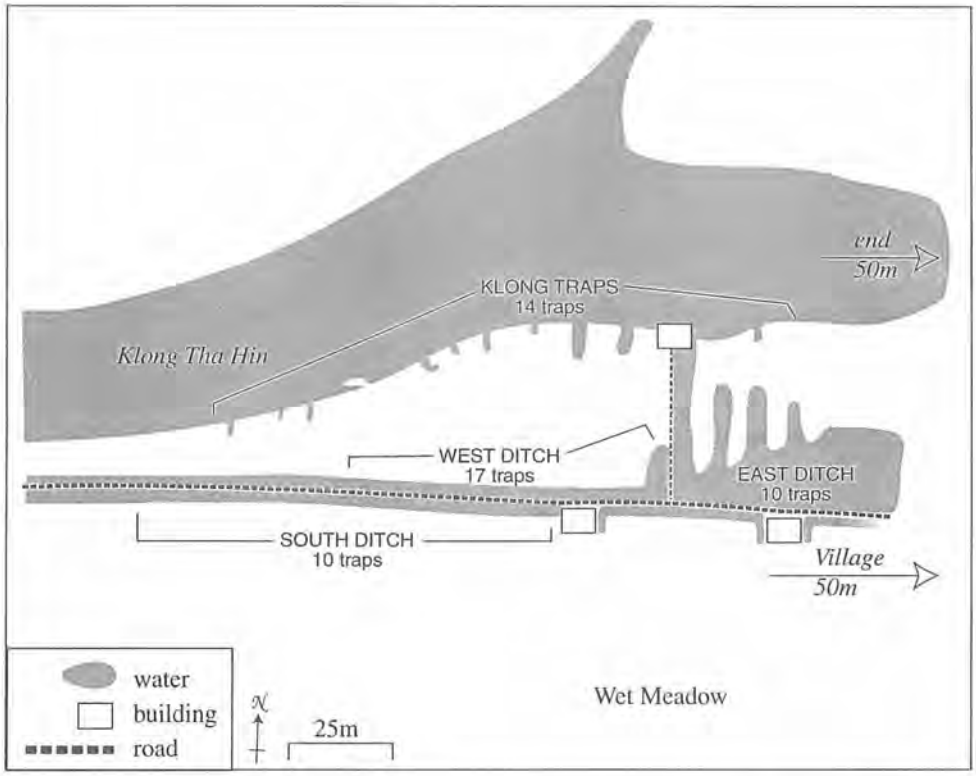

Figure 4. A map of the Ban Tha Hin study site showing the locations and numbers of traps in four areas: klong, east ditch, west ditch and south ditch. Note the fish bays located along the south shore of the klong.

plumbea masses were 71 and 146 g, and for the *H. buccata* the mass was 265 g. Transmitters did not exceed 3.5 % of the snakes body mass in any case. Further details may be found in KARNS, *ET AL.* (in preparation).

RESULTS AND DISCUSSION

Local Climate

The wet meadow at Ban Tha Hin is the dominant habitat and it exhibits large daily fluctuations in light intensity, air temperature (Figure 5) and relative humidity (Figure 6). Data logger measurements from the meadow weather station over a 3-day period in July show hot dry days alternating with warm humid nights. Air temperatures gradually decreased through the night to reach lows in the early morning while relative humidity increased through the night to often reach 100% before sunrise (Figure 6). Air temperatures increased

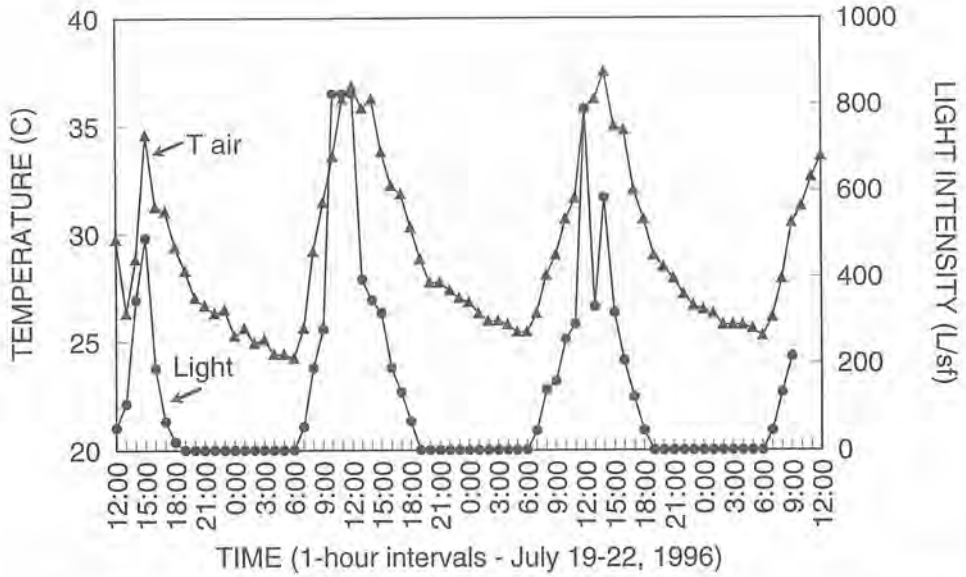

Figure 5. The relationship between air temperature and light over a three day period (July 19 to 22, 1996) at the weather station located in the meadow between Klong Tha Hin and the road (see figure 3). Note that the air temperature ($T_{meadow\ air}$) usually lags behind the meadow light intensity as measured in lumens per square foot.

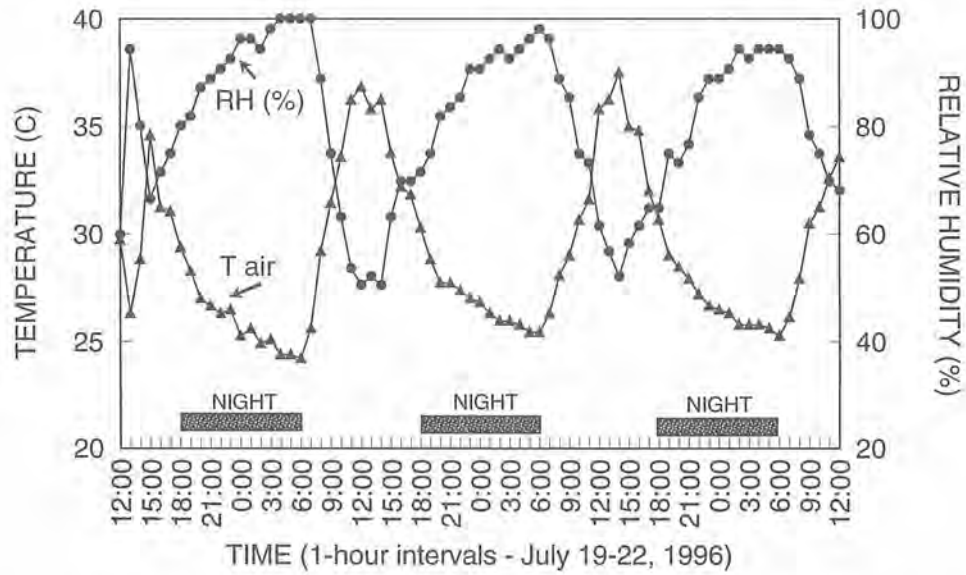

Figure 6. The relationship between the air temperature and relative humidity over a 3-day period at Ban Tha Hin. As air temperatures rose after sunrise, the relative humidity declined; as the temperatures dropped following sunset the humidity rose.

through the morning to reach highs between 1200 and 1500 hrs while relative humidity reached lows near 50% during this same period.

Table 1 gives the means, standard deviations and ranges of temperatures recorded by data loggers over 14 days at the meadow weather station, at the forestry substation weather station, and in nine microhabitats available to snakes. Air temperatures at the meadow weather station ranged from 23.0 to 38.1°C during the day with a narrower range of 24.1 to 32.4°C during the night. The most extreme temperatures were found on the exposed mud bank where the temperature reached a high of 61.9°C during the day and a low of 23.6°C at night. The exposed mud bank also exhibited the highest mean day-time temperature (40.4°C) and the lowest mean night-time temperature (26.0°C) of any of the microhabitats monitored. The mean day-time and night-time temperatures of the fish bays, the klong and the ditch are remarkably similar at 30 to 32°C during the day and 28 to 31°C during the night. The mean temperatures in the meadow were about 1°C warmer during the day and about 1°C cooler at night than the mean temperatures in the fish bays, the klong and the ditch.

None of the primary aquatic habitats showed substantial vertical temperature stratification (Table 2). Water temperature differences between early morning and early evening were greatest in the shallow meadow pools.

Habitat Utilization

Traps placed in pools within the wet meadow produced a few snakes. The great majority of *E. enhydris* (n=229) came from traps set along the edges of the klong, the fish bays and the ditches. Radiotelemetric tracking of 11 *E. enhydris* (5 females, 6 males) revealed that although this snake will occasionally venture into pools and small narrow ditches of the wet meadow, the bulk of its activity appears to be restricted to the root-tangle habitat at the aquatic-edges of the klong, the fish bays and the ditches dissecting the wet meadow. This water snake spends most of its life within a 1 m wide band along the margins of open water. This finding is consistent with the view of CAMPDEN-MAIN (1970:75) who wrote that it is "...entirely aquatic..." (see also MURTHY, 1987:11 and WALL, 1912:1019).

E. plumbea and *Homalopsis buccata* were trapped in small numbers during both years but they too appear to use the root-tangle at the edges of the klongs and ditches. *Cylindrophis ruffus* also was similar to *E. enhydris* in its use of the aquatic-edge microhabitat. However, radiotelemetry data suggests that this species may be more sedentary, staying within a few square meters over an 8–day observation period. Radiotelemetry and direct observations demonstrated that the common keel back snake readily moves overland through open meadow, as well as in and out of meadow pools and ditches at the study site.

Snake Body Temperatures

Diurnal snake body temperature (T_b) data from 11 *E. enhydris* (6 males and 5 females) were obtained using radiotelemetry in 1996 and 1997 (KARNS *ET AL.*, in preparation). No differences were found between the body temperatures of male and female snakes (males $\bar{x}$ = 30.2°C, females $\bar{x}$ = 30.5°C). Snake body temperatures proved to be relatively stable

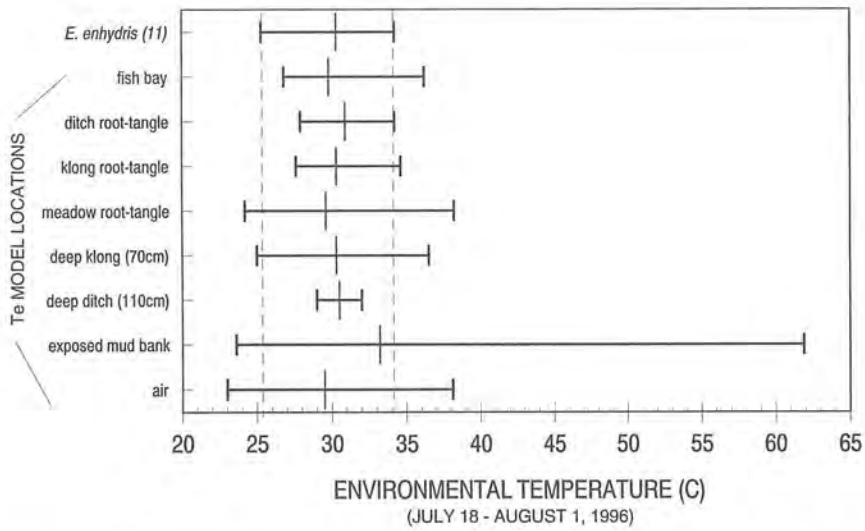

Figure 7. The mean and range of environmental temperatures in 7 microhabitats at Ban Tha Hin, as compared to the mean body temperature of 11 *Enhydris enhydris* (5 females and 6 males) . Note the similarities between the snake's mean body temperature and the mean temperatures in the aquatic microhabitats.

and ranged from 29.2 to 32.1°C ($\bar{x}$ = 30.4°C, sd = 0.86, n = 110). Figure 7 shows the mean and range of body temperatures of the 11 rainbow water snakes relative to the mean and range of temperatures in the various microhabitats. Note that the average snake body temperature is similar to the average temperatures observed in the klong, the klong root-tangle, the ditch and the ditch root-tangle. Figure 8 shows diurnal and nocturnal body temperatures for 5 telemetered *E. enhydris* followed closely for 3 days and nights in 1996. The snake body temperatures fall within the minimum and maximums of the temperature loggers most of the time and show little variation from 30°C. Thus, the rainbow water snake appears to be a thermoconformer.

Data for two other species of homalopsine water snake found in the wet meadow were obtained using radiotelemetry (Figure 9). Two female *E. plumbea* had body temperatures that ranged from 28.6 to 30.1°C ($\bar{x}$ = 29.4, sd = 1.1, n = 28) and one female *H. buccata* exhibited body temperatures ranging from 28 to 32°C ($\bar{x}$ = 30.1°C, sd = 1.2, n = 10). Two other semiaquatic snakes were monitored in the wet meadow during the day in 1997. One male *C. ruffus* had body temperatures ranging from 29.5 to 31.1°C ($\bar{x}$ = 30.1°C, sd = 0.5, n = 8) and one male *X. piscator* had a range in body temperature from 26 to 28.5°C ($\bar{x}$ = 27.5, sd = 1.0, n = 8).

The data summarized in figure 9 suggest that the three species of homalopsine water snakes and *C. ruffus* are all thermoconformers, showing body temperatures of 29.3 to 30.3°C, similar to their immediate surroundings. However, the diurnal, actively foraging *X. piscator* showed a lower mean body temperature (27.5°C). This is unexpectedly low, considering we observed it foraging for frogs in the midday heat. It seems probable that it is able to achieve these relatively low body temperatures by evaporative cooling as it

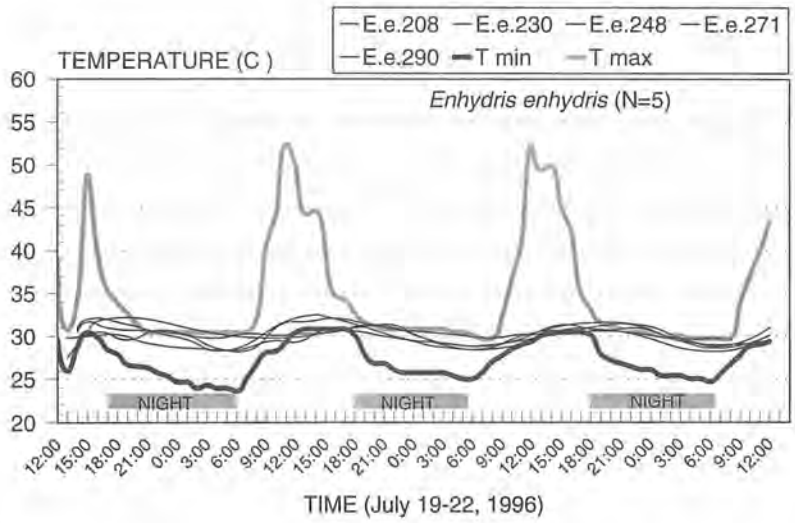

Figure 8. The thermal range at Ban Tha Hin. Maximum temperatures are shown by the thick grey line, minimum temperatures by the thick black line. The 5 thin, black lines are the body temperatures of 5 individual *Enhydris enhydris*, which maintain a narrow thermal preference by thermally conforming to the wet mud root-tangle microhabitat.

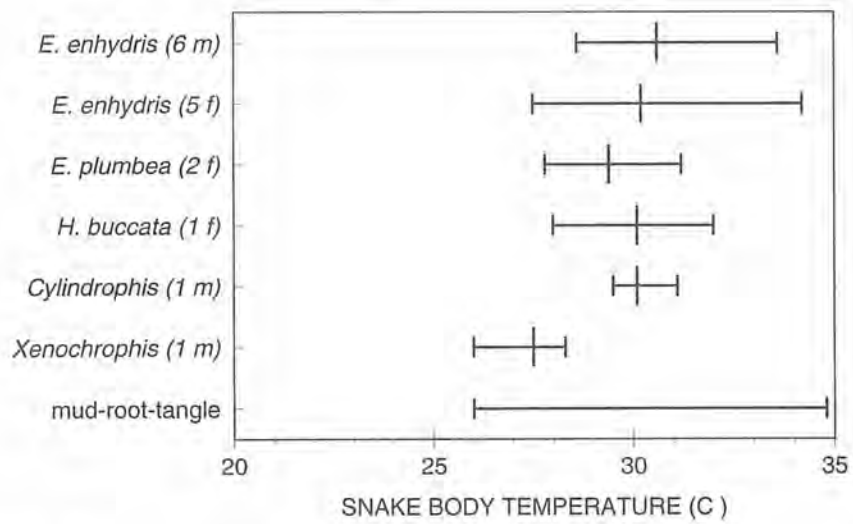

Figure 9. The mean and range in body temperature for 5 species of snakes found at Ban Tha Hin. The number of individuals and their sex (m = male, f = female) is given in parentheses. Note the 3 homalopsines (*Enhydris enhydris*, *E. plumbea*, and *H. buccata*) and *Cylindrophis ruffus* have similar mean temperatures of about 30°C. *Xenochrophis piscator* had the lowest mean body temperature. Although active during the heat of midday, it maintains a lower body temperature by evaporative cooling.

moves in and out of meadow pools during the midday conditions of high temperatures and relatively low humidity.

Population Size and Density

There was little visual evidence for the presence of snakes at the study site. The turbid water and dense vegetation combined with the cryptic coloration and behavior of this snake render it all but invisible. Snakes were occasionally seen at night, and one of us saw a snake quickly surface and then dive at midday. These few sightings over hundreds of hours of field work were quite misleading as to the actual number of snakes present at the study site.

E. enhydris was the most abundant snake in the funnel traps, with a total of 235 snakes receiving PIT tags. A total of 380 *E. enhydris* were captured and recaptures numbered 144. The details of the *E. enhydris* population size estimates will be published elsewhere, but preliminary results suggest that between 406 and 567 *E. enhydris* were present at the study site. The density of snakes along the edges of the ditches and klong was approximately 1 snake per 2 meters of shore line.

Size Distribution

Neonates of *E. enhydris* have a mean SVL of 155 mm (143 to 162 mm, n=15) based upon our measurements of specimens born to two females obtained in the Bangkok market. This is almost twice the size of the young reported by BATCHELOR (1958:109), who stated neonates were about 3 inches. The smallest snake we found at the study site had a SVL of 300 mm, and all others (n = 251) fell into the 350 to 549 mm SVL classes. The absence of young snakes in our traps may be because the young snakes may use different microhabitats and they may forage differently.

Neonates of *E. plumbea* are poorly known. The smallest museum specimen we measured was 135 mm in SVL. In Borneo a freshly caught female with a pre-partruition mass of 39.5 g gave birth to five young that had an average SVL of 127.2 mm (range 126 to 130 mm). The five young had a combined mass of 10.5 g (VORIS & KARNS, 1996). Four *E. plumbea* collected at Ban Tha Hin in 1996 ranged in size from 370 to 530 mm SVL. Five collected in traps in 1997 were from 364–563 mm SVL.

Eighteen near full term embryos from a female *H. bucatta* collected at the study site were 115 to 216 mm SVL (mean, 202 mm). Nine adult *H. bucatta* collected in 1996 and 2 in 1997 ranged in SVL from 422 to 810 mm.

LIM & LEE (1989) state that hatchlings of *X. piscator* are about 110 mm. Two specimens collected in 1996, and 3 in 1997, ranged in SVL from 306 to 577 mm. The snake measuring 306 mm in SVL was likely a subadult while the others were adults. LIM & LEE (1989) reported the young of *C. ruffus* with SVL of 205 mm at hatching. Two specimens collected in traps at Ban Tha Hin in 1996 had SV lengths of 282 and 460 mm.

Sex Ratios

Our data on the sex ratio of *E. enhydris* at Ban Tha Hin are highly variable. For

example, of 66 *E. enhydris* trapped in the south ditch in 1997, 54 were males and 12 were females (sex ratio 4.5 males per female). On the opposite side of the road in the west ditch, 39 males and 16 females were tapped (ratio 2.4:1). The total ratio of *E. enhydris* in 1997 was 3.1:1. We suspect that this skewed sex ratio may be due to behavioral differences between males and females. For example, many females are gravid in June-July when the field work was carried out, and hence they may not have sought the food offered as bait. This hypothesis is supported by the fact that gravid snakes of several taxa will frequently refuse food in captivity, and females found with embryos in advanced stages of development rarely contain food (see SHINE, 1988, for a review). Of six *E. enhydris* that were hand caught in drained fish bays in 1997 two were males and four were females, which further supports the idea of an even sex ratio.

Reproduction

What little is known about the reproductive behavior of *E. enhydris* is anecdotal. WALL (1912:1019) wrote "...Evans came across a pair 'incopula' at Hmawbi (Lower Burma) on 16th October 1899..." Other authors (ACHARJI & MUKHERJEE, 1966:79; KOPSTEIN, 1930:307; POPE, 1935:135; TAYLOR, 1965:914) have reported parturition in all months between March and August. Gravid female snakes obtained in a Bangkok market in June and July gave birth in both of those months. COX (1991) summarized the literature on clutch size and reported litters of 6 to 18 young.

While handling snakes for data collection we frequently had male snakes vibrating their body in our hands and assumed this behavior to be a response to female phermones left on our skin from previously handled females.

In 1996 and 1997, 34 female *E. enhydris* from Ban Tha Hin were examined for reproductive status. Seventeen of 22 (57%) contained eggs or embryos (mean number = 7.9, range = 5 to 16) in the 1996 sample, and 5 of 12 (42%) contained eggs or embryos (mean number = 6.4, range = 4 to 7) from the 1997 sample. The number of eggs and embryos was positively correlated with female body size. The smallest gravid female was 38.5 cm SVL, the largest was 52.9 cm SVL.

ST. GIRONS (1972) and BERRY & LIM (1967) considered *H. buccata* to breed year round, although the later authors believed breeding peaked between October and March. Litter sizes reported in the literature ranged from 4 to 21 young (BERGMAN, 1951; SMITH, 1943). BERGMAN (1951) reported on 11 litters that ranged in size from 4 to 17 young with a mean of 10. An 81 cm female *H. buccata* from Ban Tha Hin in 1996 contained a litter of 18 young. We collected no data on reproduction from *E. plumbea, C. ruffus*, or *X. piscator* at the study site.

Diet

E. enhydris appears to feed exclusively on fish at Ban Tha Hin. Animals taken from traps had frequently eaten the bait (pieces of dead fish). The draining of fish bays provided an opportunity to watch snakes capturing and trying to eat stranded fish and in these instances snakes frequently took fish larger than they could swallow. In one instance a snake seized a stranded three-spot gourami, *Trichogaster trichopterus* (Belontiidae), by the

head, picked the fish up in its jaws, and with the first third of its body off the mud substrate moved about 1.5 m, probably in search of a secure location to swallow the fish. *T. trichopterus* were taken from the stomachs of five specimens from the fish bays, and a sixth specimen contained unidentified fish remains. Three species of fish *Channa striatus* (Channidae), *Trichopsis vittatus* (Belontiidae), and *Trichogaster trichopterus*) frequently entered the traps and may have attracted snakes. Others (ACHARJI & MUKHERJEE, 1966:79; CAMPDEN-MAIN, 1970:75; SMITH, 1914:100; SMITH, 1943:384; TAYLOR & ELBEL, 1958:1159; TAYLOR, 1965:914) have also considered *E. enhydris* to be piscivorous.

We collected no data on the food habits of *E. plumbea* at Ban Tha Hin, but other populations feed on frogs, tadpoles, and fish. VORIS & KARNS (1996) showed that a population of this species in Borneo has a preference for larval amphibians.

Of the five specimens of *H. buccata* from Ban Tha Hin that we examined, one contained one fish, *Anabas testudineus* (Anabantidae). The literature on this species suggests that it feeds on amphibians, their larvae, and fish (FRITH, 1977 and SMITH, 1943)

C. ruffus feeds on other snakes (TWEEDIE, 1983) and eels (COX, *ET AL.*, 1998) and our observations suggest that it feeds on *E. enhydris* at Ban Tha Hin. *X. piscator* feeds on frogs and we observed this species foraging actively on *Rana erythrea* at the study site.

Predators

The secretive nature of snakes makes direct observations of predation difficult. Nevertheless, we observed many potential snake predators at Ban Tha Hin. Local fishermen caught a small-clawed otter, *Aonyx cinerea* (Mustelidae) on the study site and these small carnivores are likely to prey upon any appropriate sized vertebrate they encounter. Herons, *Casmarodius albus, Egretta garzetta* (Ardeidae) and *Bubulcus ibis* (Threskiornithidae) were seen wading at the margins of the klong and roadside ditches daily, and are likely predators on snakes. Additionally, the eagle, *Haliaeetus leucogaster* (Accipitridae) was observed near the site, and is known to feed on aquatic snakes.

Other snake species feed on homalopsines, at this site. In 1996 a trapped pipe snake (*C. ruffus*) regurgitated two *E. enhydris*. We did not observe *Xenopeltis unicolor* (Xenopeltidae) at the study site, but a road-killed specimen was found nearby. When we presented a captive *X. unicolor* with a neonate *E. enhydris*, it ate it. Two *Bungarus fasciatus* (Elapidae) were taken from traps at Ban Tha Hin, and MAO (1970) reported this snake to feed on *E. plumbea*. The cobra, *Naja kaouthia* (Elapidae) was observed near Ban Tha Hin. This snake is well known for its snake-eating habits and it most likely feeds on homalopsines at this site (WALL, 1913).

Large fish at Ban Tha Hin may also pose a threat to small snakes at Ban Tha Hin. Five species of catfish, *Arius caelatus, A. maculatus* (Ariidae), *Clarias macrocephalus, C. nieuhofii* (Clariidae), *Ompok bimaculatus* (Siluridae); and two species of snakeheads *Channa lucius, C. striatus* (Channidae) are all likely predators of juvenile aquatic snakes.

Summary

Within the wetlands at Ban Tha Hin, the rainbow water snake, *E. enhydris*, occurs in high densities in the mud root-tangle along the edges of the klongs and ditches. Several

other snake species use this microhabitat but do not attain high population densities. The body temperature of *E. enhydris* remains close to 30°C and conforms closely to the temperature of its preferred microhabitat, the mud root-tangle. This is in contrast to *Xenochrophis piscator* which uses multiple microhabitats and cools its body during the day by evaporation. *E. enhydris* forages for fish both at night and during the day in meadow pools and along the edges of ditches and klongs that dissect the wet meadow. This is in contrast to snakes such as *Cylindrophis ruffus*, which are extremely sedentary and others like *X. piscator* that forage between terrestrial and aquatic microhabitats. Male *E. enhydris* entered our funnel traps 3 times more often than females, but the sex ratio of snakes hand-collected from fish bays was nearly 1 to 1. Information from the literature on reproduction, diet and predators of *E. enhydris* is presented to complete an overview of the ecology of the rainbow water snake.

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Appendix 1. A preliminary checklist of the snakes from Ban Tha Hin and surrounding areas, Songkhla Province, Thailand. While we moved to and from the study site we salvaged road killed snakes (DOR), and made notes on other snakes observed in nearby habitats. One of the most productive habitats was the dry paddy and sugar palms that bordered the 5 km road connecting Route 408 to Ban Tha Hin.

Acrochordus granulatus (in lake, collected with seine); *Chrysopelea ornata* (n=1 DOR); *Cylindrophis ruffus* (n=3 in traps); *Dendrelaphis caudolineatus* (n=3 DOR); *Elaphe radiata* (n=2 DOR); *Enhydris enhydris* (n=5 DOR, most abundant snake in aquatic traps); *Enhydris plumbea* (n=9, in traps); *Homalopsis buccata* (n=3 in traps); *Ptyas korros* (n=1 DOR); *Xenochrophis piscator* (n=7 DOR, and in traps); *Xenopeltis unicolor* (n=2 DOR); *Bungarus fasciatus* (n=3 in trap, and in gill nets in ditch); *Hydrophis brookii* (n=6 in lake, collected with seine); *Naja kaouthia* (n=4 DOR).