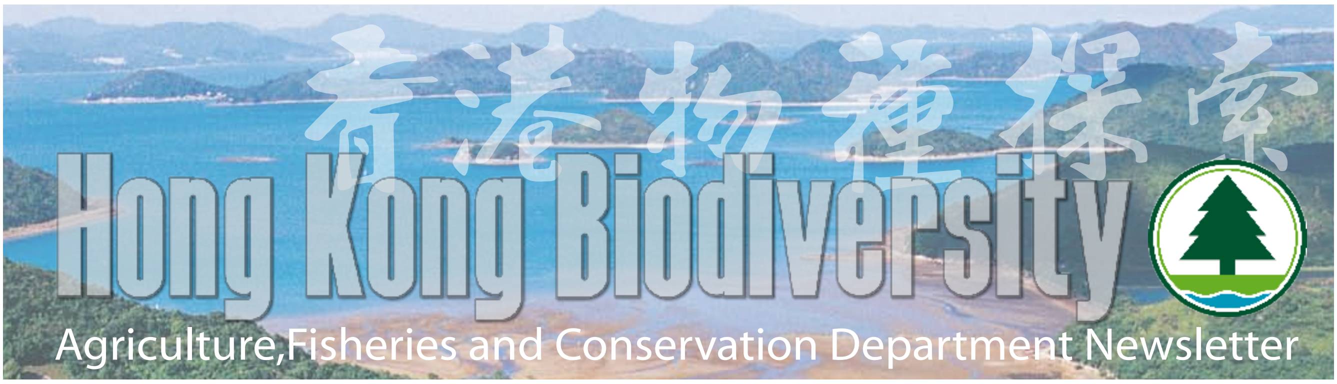

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Feature Article

The Skinks of Hong Kong

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漁農自然護理署兩棲及爬行動物工作小組自2002年開始的基線調查結果顯示，本港石龍子科的蜥蜴共有11種。石龍子廣泛分布於本港各區，全都可見於郊野公園及特別地區等保護區內，當中包括稀有的藍尾石龍子和越南五線石龍子，以及不常見的光蜥和四綫石龍子。本文介紹本港11種石龍子的特徵、生態、分布及其保育狀況。

Introduction

Skinks belong to the family Scincidae, which is the most diverse group of lizards, with about 1,200 species worldwide. Most are medium-sized lizards, with a maximum body length (snout to vent) of about 12 cm. They are characterised by a small head without a pronounced neck, elongated cylindrical body, smooth shiny scales, long tapering tail and relatively small legs. Some species even have no legs at all. As a result, they move more like snakes than do other lizards.

Skinks are generally alert and active during the daytime, but tend to be secretive, spending much time foraging under leaf litter. Most are carnivorous, feeding mainly on insects, with some also preying on other small invertebrates and even other lizards and small mice. They can break their tails easily when confronted, but the tails will regenerate.

Skinks are oviparous (egg-laying) or ovoviviparous (eggs hatch inside the female's body before birth). During the breeding season, some species exhibit orange or red body markings to indicate sexual maturity.

Different skink species exhibit various colours and patterns. Due to their relatively small size, appealing appearances and easy maintenance in captivity, skinks have become favourite pets for many people. Although skinks are found in a variety of habitats worldwide, some species are endangered and especially prone to the impact of wildlife trade.

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In Hong Kong 11 skink species have been recorded to date. Some are forest dwellers, such as the Chinese Forest Skink (*Ateuchosaurus chinensis*), Slender Forest Skink (*Scincella modesta*), Indian Forest Skink (*Sphenomorphus indicus*) and Brown Forest Skink (*Sphenomorphus incognitus*); some are found in lowland areas such as Chinese Skink (*Eumeces chinensis chinensis*), Reeves' Smooth Skink (*Scincella reevesii*) and Vietnamese Five-lined Skink (*Plestiodon tamdaoensis*), while others are usually found in the uplands, such as Five-striped Blue-tailed Skink (*Eumeces elegans*). The Chinese Waterside Skink (*Tropidophorus sinicus*) is the only skink in Hong Kong that is found living in or around streams.

Classification

Reptilia (爬行綱) – Lacertiformes (蜥蜴目) – Scincidae (石龍子)

Species of Skinks Found in Hong Kong

Chinese Forest Skink *(Ateuchosaurus chinensis)* (Figs. 1 and 2)

The genus name *Ateuchosaurus* (from the Greek "*Ateuch*", meaning legless; "*sauru*" referring to lizard) originates from this genus having very short legs. Thus, Chinese Forest Skink is also commonly known as Chinese Short-legged Skink. This species was named "*chinensis*" after it was first discovered in China. Chinese Forest Skink is medium-sized, reaching up to 17 cm in total length: snout-vent length of 7.5 cm at most, and tail length about 1.3 times the snout-vent length.

Its head is slightly set-off from the neck; the snout is short and obtuse. The dorsal head, body and base of tail of adults are brownish, each scale having a darker central spot (Fig. 1); whereas juveniles are overall less brownish (Fig. 2). The flanks are creamy or yellowish white and spotted with black and white, with the black spots in front of the white ones. The dark marbling extends onto the anterior two thirds of the tail. The sides of the neck are dark brown or black, with white spots. The chin and throat are speckled with black spots, while the adult male is characterised by its pinkish orange throat and underside between the forelegs (Fig. 1).

Fig 1. Chinese Forest Skink: adult male showing the orange throat.

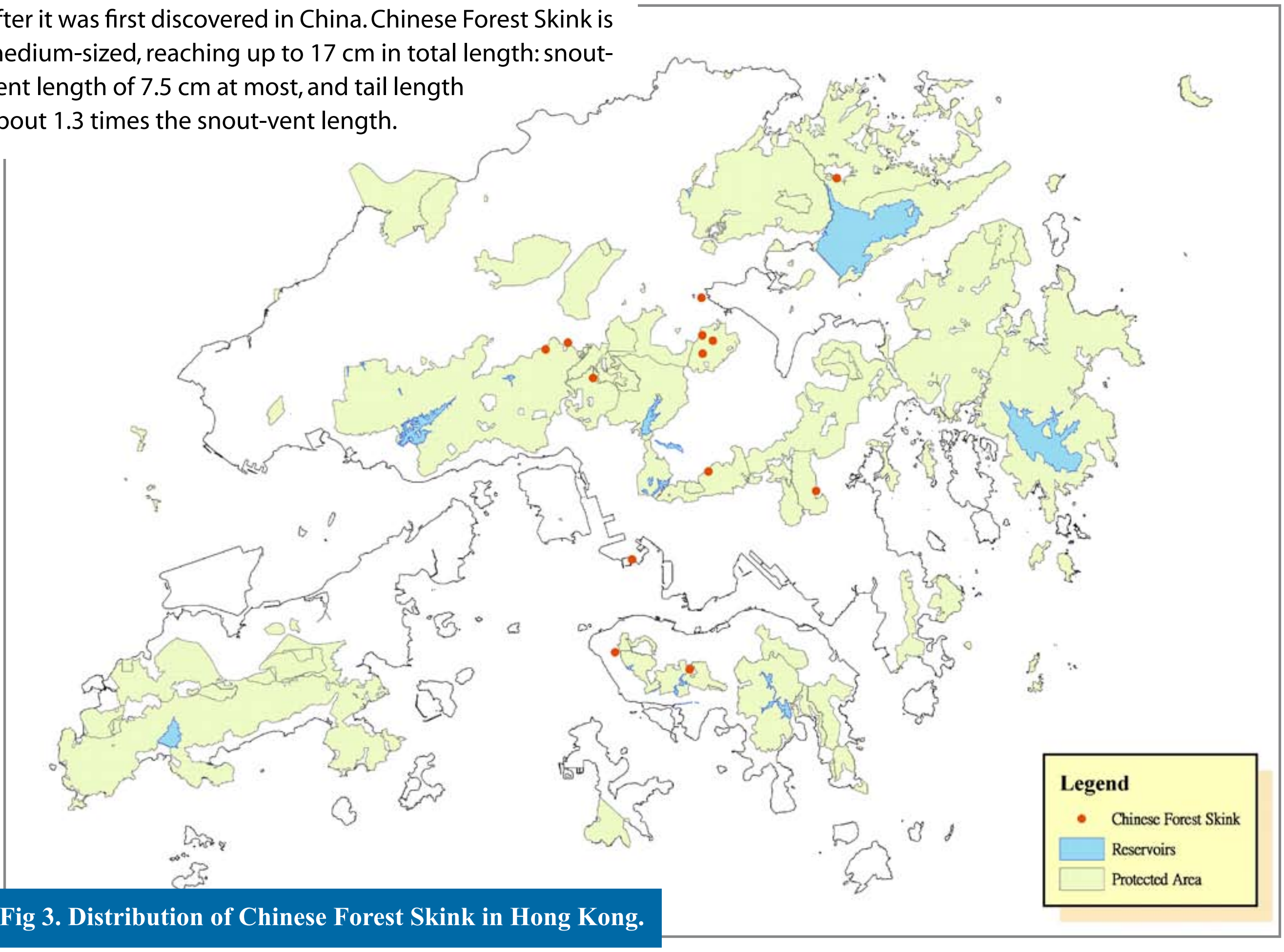

Fig 3. Distribution of Chinese Forest Skink in Hong Kong.

Fig 2. Juvenile Chinese Forest Skink.

Chinese Forest Skink inhabits secondary forest and woodland, and prefers to forage among damp leaf litter, where it feeds on small insects such as termites or other invertebrates such as earthworms. The species is active both by day and night, but is secretive and at night often hides beneath rocks or other objects. It is oviparous, laying 4-5 oval eggs in a clutch among leaf litter.

Chinese Forest Skink has been recorded from central and southern China and Vietnam. Within Hong Kong, this species has been found in woodlands in Country Parks and Special Areas (Fig. 3), such as the Tai Po Kau Nature Reserve, Sai Kung West Country Park, Tai Mo Shan Country Park and Tai Lam Country Park. Chinese Forest Skink is an uncommon species in Hong Kong.

Chinese Skink (*Eumeces chinensis chinensis*) (Fig. 4)

Chinese Skink is a heavily built skink, reaching a total length of 30 cm. The back is greyish brown, while the underside is creamy. The scales are glossily smooth. The flanks are mottled with numerous tiny red spots on the flanks in front of and behind the forelimbs. The head is triangular, and the snout is obtuse.

This skink is primarily found in lowlands, in habitats including shrubby areas, cultivated fields and mangrove swamp edges. It is active by day, and feeds on a wide variety of arthropods and even small lizards such as Grass Lizard. This species is oviparous, laying 5-7 eggs in a clutch beneath rocks or among crevices of tree roots.

Fig 4. Chinese Skink.

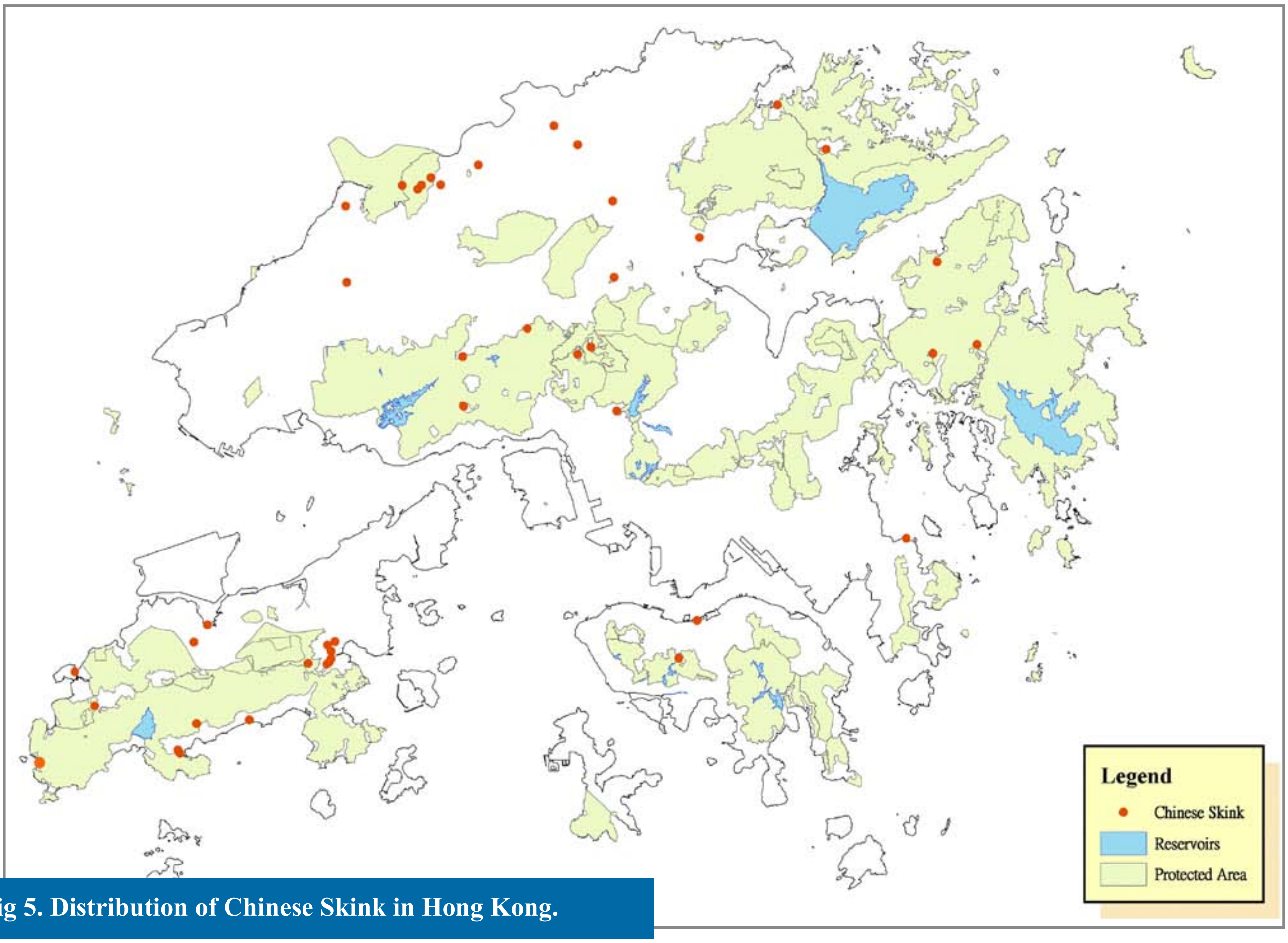

Fig 5. Distribution of Chinese Skink in Hong Kong.

Chinese Skink is commonly reported in China and Vietnam. Locally, it is mainly distributed in the central, northern and eastern New Territories as well as on Lantau Island (Fig. 5). Chinese Forest Skink is a common species in Hong Kong.

Five-striped Blue-tailed Skink (*Eumeces elegans*) (Fig. 6)

Five-striped Blue-tailed Skink is a small - to medium - sized lizard, growing to a maximum length of about 22 cm. Its dorsal surface is brown to black. Five-striped Blue-tailed Skink has five yellowish-white stripes – three dorsal and two lateral – running from the snout to the tail base on its back, with the mid-dorsal stripe dividing into a two-pronged fork marking on the head. Its ventral surface is greyish white. This species has an iridescent blue tail.

This skink is diurnal, and prefers open areas such as edges of woodlands and high-altitude grasslands as it favours sun-basking. It is oviparous, laying 4-9 eggs per clutch. Females care for the young. This species forages on small insects. When frightened, it often darts into leaf litter or even breaks its tail.

Worldwide, this species is recorded from central and southern China, Taiwan and the southern Ryukyus. In Hong Kong, it is distributed in woodlands of the central New Territories, Ma On Shan Country Park and on Cheung Chau (Fig. 7). Five-striped Blue-tailed Skink is a rare species in Hong Kong.

Fig 6. Five-striped Blue-tailed Skink.

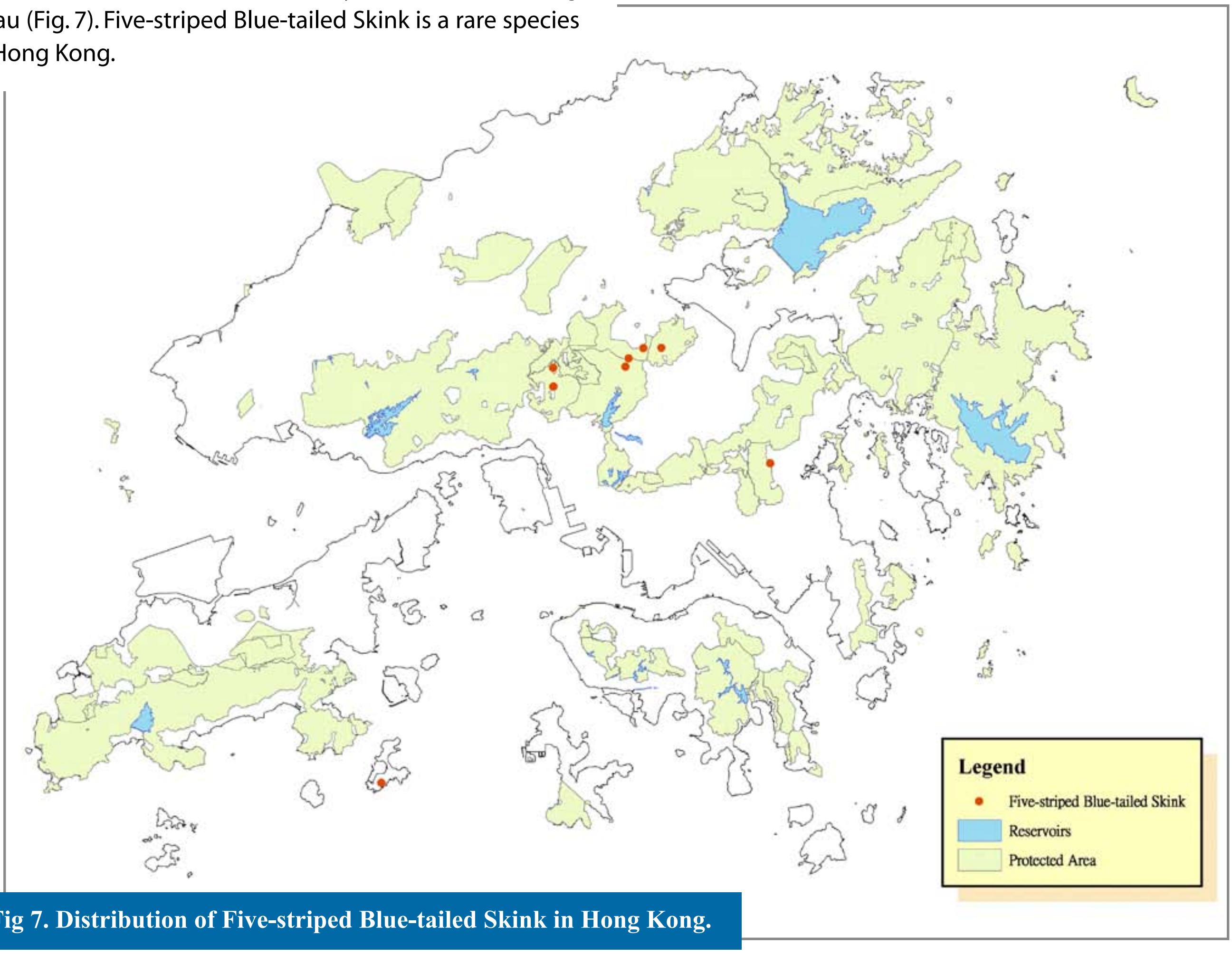

Fig 7. Distribution of Five-striped Blue-tailed Skink in Hong Kong.

Blue-tailed Skink (*Eumeces quadrilineatus*) (Fig. 8)

Blue-tailed Skink is an intermediate-sized skink, reaching around 21 cm in total length. Its back is principally greyish brown, with two pronounced silvery white stripes extending from the tip of the snout to the base of the tail. On both sides below the eyes are two thinner white lateral stripes. These four stripes merge at the anterior part of its brilliant blue tail. The underside is white to grey. The scales are shiny smooth, which is a common feature of the genus *Eumeces*. The lower labials and part of the throat have a bright yellowish pink streak, which is absent in Five-striped Blue-tailed Skink.

Fig 8. Blue-tailed Skink.

This species is active by day and often seen basking under the sun. It resides in dry woodlands and rocky areas where there is plenty of sunshine. This skink is agile and alert. It feeds on small insects and invertebrates. Like other *Eumeces*, it is oviparous.

Blue-tailed Skink is recorded from South China, Thailand, Cambodia and Vietnam. Within Hong Kong, it is encountered in woodlands in Ma On Shan, Tuen Mun, and on Lantau Island, Sunshine Island, Cheung Chau, Soko Islands as well as Hong Kong Island (Fig. 9). Blue-tailed Skink is an uncommon species in Hong Kong.

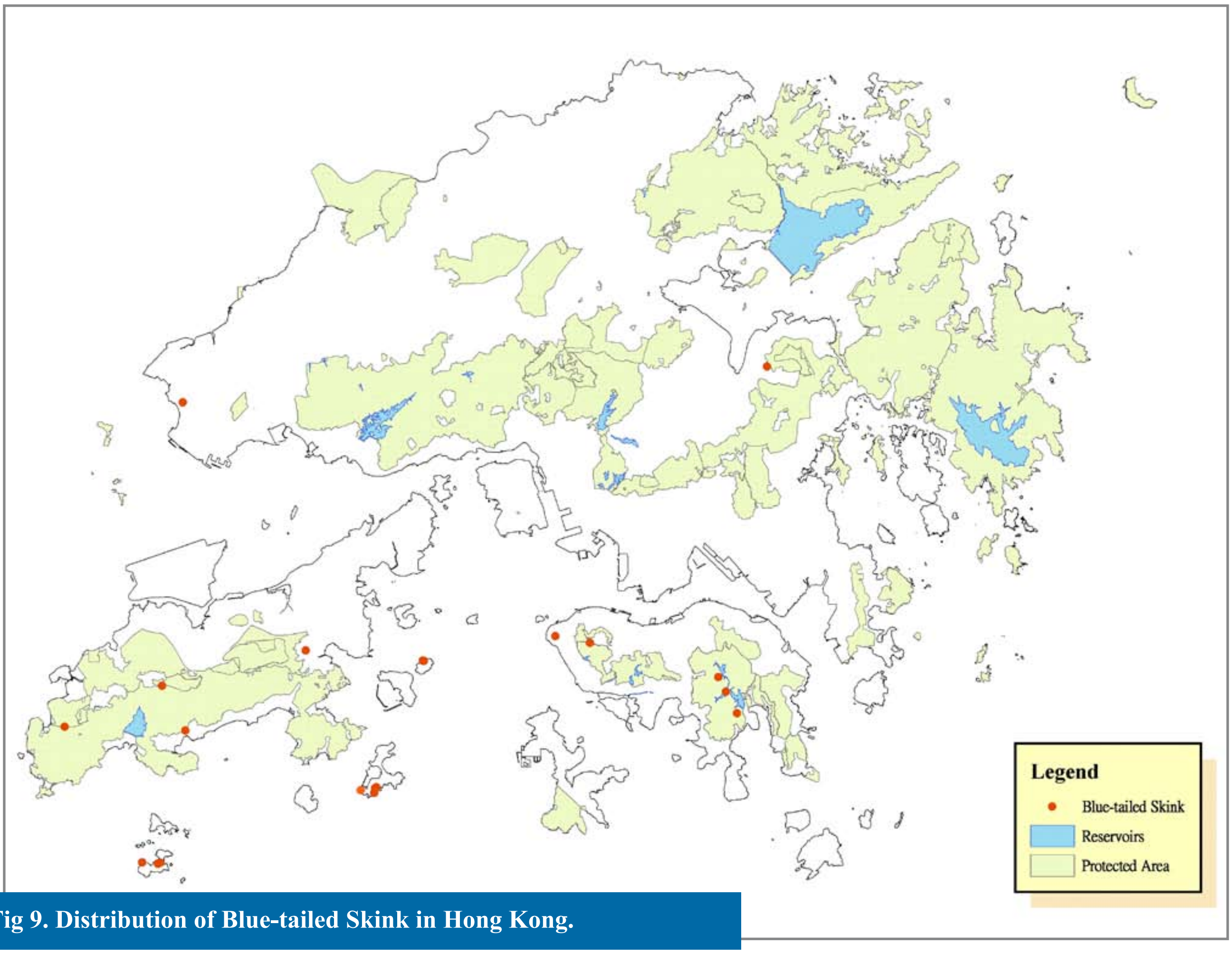

Fig 9. Distribution of Blue-tailed Skink in Hong Kong.

Fig 10. Long-tailed Skink.

Long-tailed Skink (*Mabuya longicaudata*) (Fig. 10)

Long-tailed Skink is a large skink, with a total length of up to 37 cm. This species is the largest skink in terms of body length in both Hong Kong and Taiwan. The distinctive feature of this species is its extremely long, whip-like tail, which can be over twice as long as the snout-vent length.

The upper body is reddish tan brown, with a dark wide stripe extending from the eye to the hind leg along each side. Its underside is creamy yellow. The mid-dorsal scales are slightly keeled.

Long-tailed Skink is a diurnal lizard that typically inhabits dry hilly areas with tall grass, shrublands, and even artificial facilities such as weep holes of catchments. This skink is a heat-loving species, mostly occurring in places with direct sun. Therefore, individuals are often observed in weep holes facing direct sunshine, and sun-basking on rocks.

This species can be found in China, Taiwan and Southeast Asia. It is a common, widely distributed species in Hong Kong (Fig. 11).

Long-tailed Skink is oviparous, laying 6-12 eggs per clutch, under rocks or in holes of walls. Females exhibit maternal care of eggs, guarding them against predators such as egg-eating snakes. Its diet consists mostly of insects and earthworms, together with occasional plant material including seeds, leaves and fruits. When confronted, it can readily detach its tail, and scurry swiftly into crevices.

Vietnamese Five-lined Skink (*Plestiodon tamdaoensis*) (Fig. 12)

Vietnamese Five-lined Skink is native to Vietnam. Its body is cylindrical and covered with smooth scales. This species has a black, glossy dorsal surface and five thin yellowish-white stripes – three dorsal and two lateral – with an "X" mark on the top of the head and snout. The dorsal side of its tail is bright blue.

Vietnamese Five-lined Skink was formerly considered to belong to the genus *Eumeces*, but has recently been assigned to a new genus *Plestiodon* based on molecular studies. This species is oviparous, and probably feeds on small insects and invertebrates in woodland. It was initially only known from Vietnam only, and was only recently discovered in Hong Kong (Fig. 13), where it is a rare species.

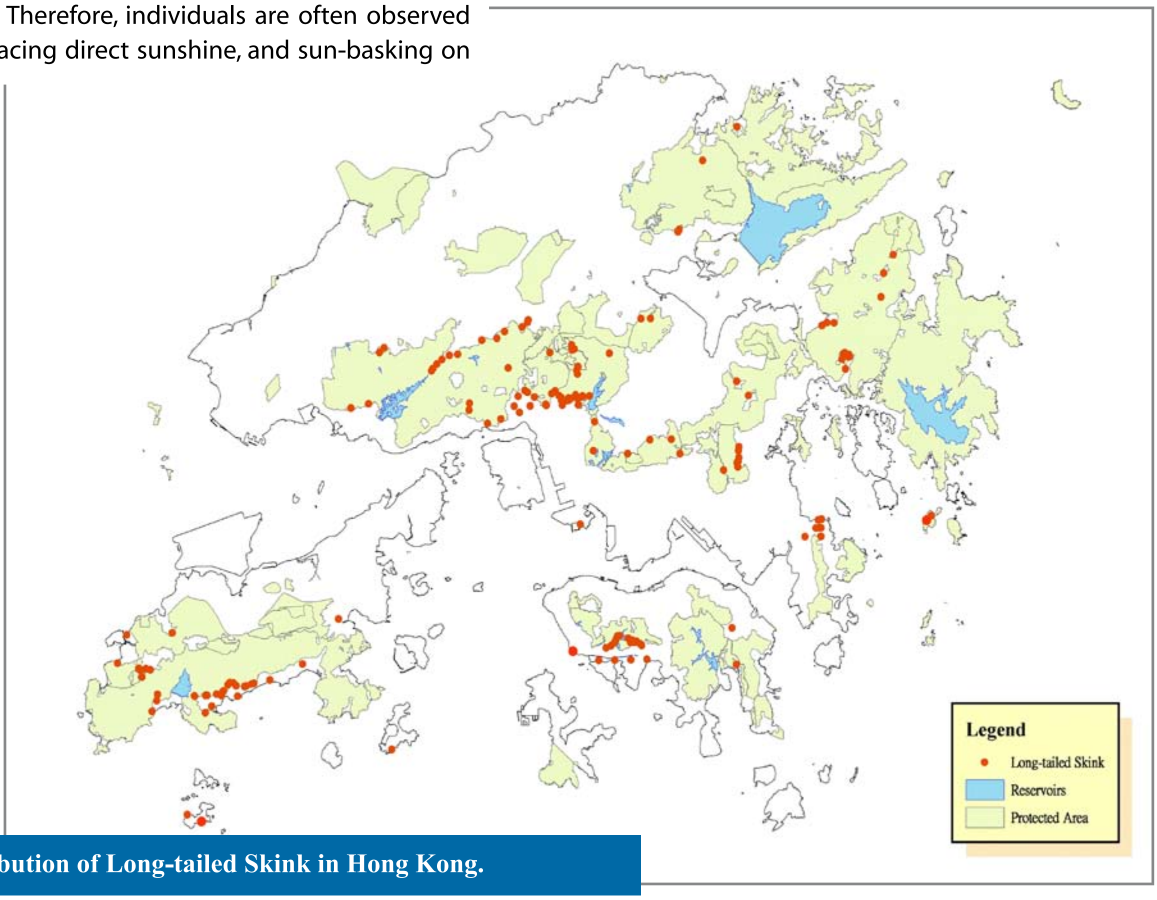

Fig 11. Distribution of Long-tailed Skink in Hong Kong.

Fig 12. Vietnamese Five-lined Skink. (Photo: Christophe Barthelemy)

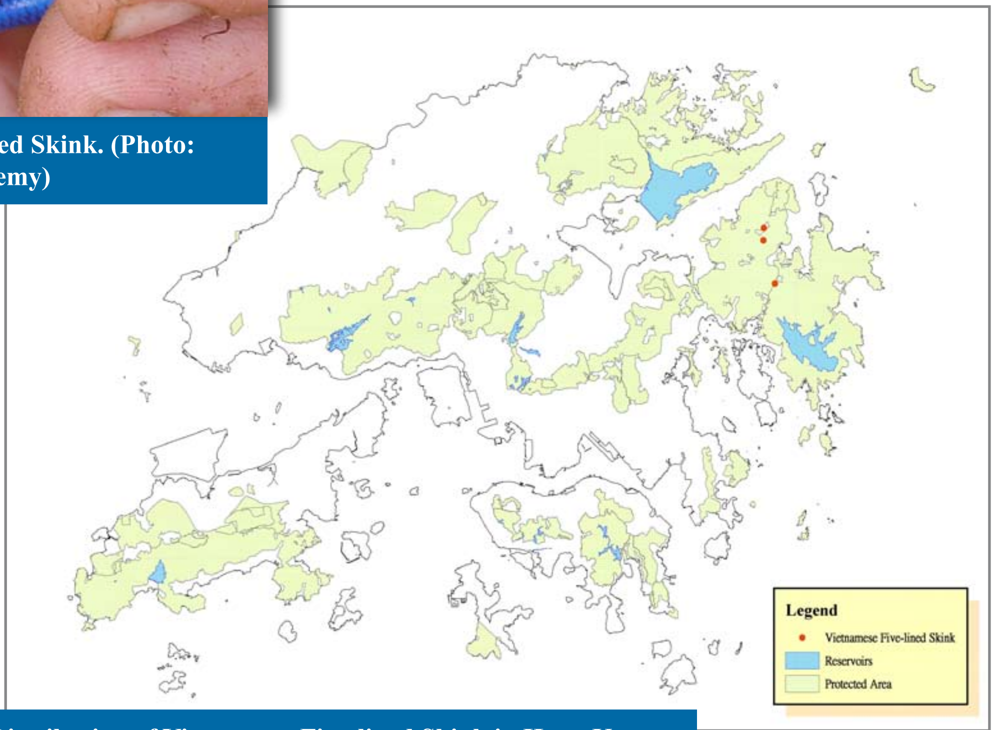

Fig 13. Distribution of Vietnamese Five-lined Skink in Hong Kong.

Slender Forest Skink (*Scincella modesta*) (Fig. 14)

Scincella species are typically slender and fossorial lizards, so are commonly referred to as ground skinks. The Slender Forest Skink is also known as Modest Ground Skink.

Slender Forest Skink is small, with a total length of 10 cm. The head is very small and narrow. The upper body is tan brown, and speckled with fine dark marbling. Along each side, a thin black line forms a dorso-lateral stripe from the eye to the anterior two-thirds of the tail. The underside of the tail is bright coppery red (Fig. 15).

This slender lizard is diurnal, and inhabits soil layers of forests, where it is chiefly found beneath objects or among leaf litter. It feeds on a wide variety of arthropods, such as ants and spiders. It is oviparous, laying 5-9 eggs, which it buries in soil.

Fig 14. Slender Forest Skink.

Fig 15. Slender Forest Skink, showing its underside.

Slender Forest Skink has a discontinuous range, throughout northern China to Hebei in the east. In Hong Kong, this species can be found in woodlands in a few scattered sites in the New Territories, and on Lantau Island and Hong Kong Island (Fig. 16). Slender Forest Skink is a common species in Hong Kong.

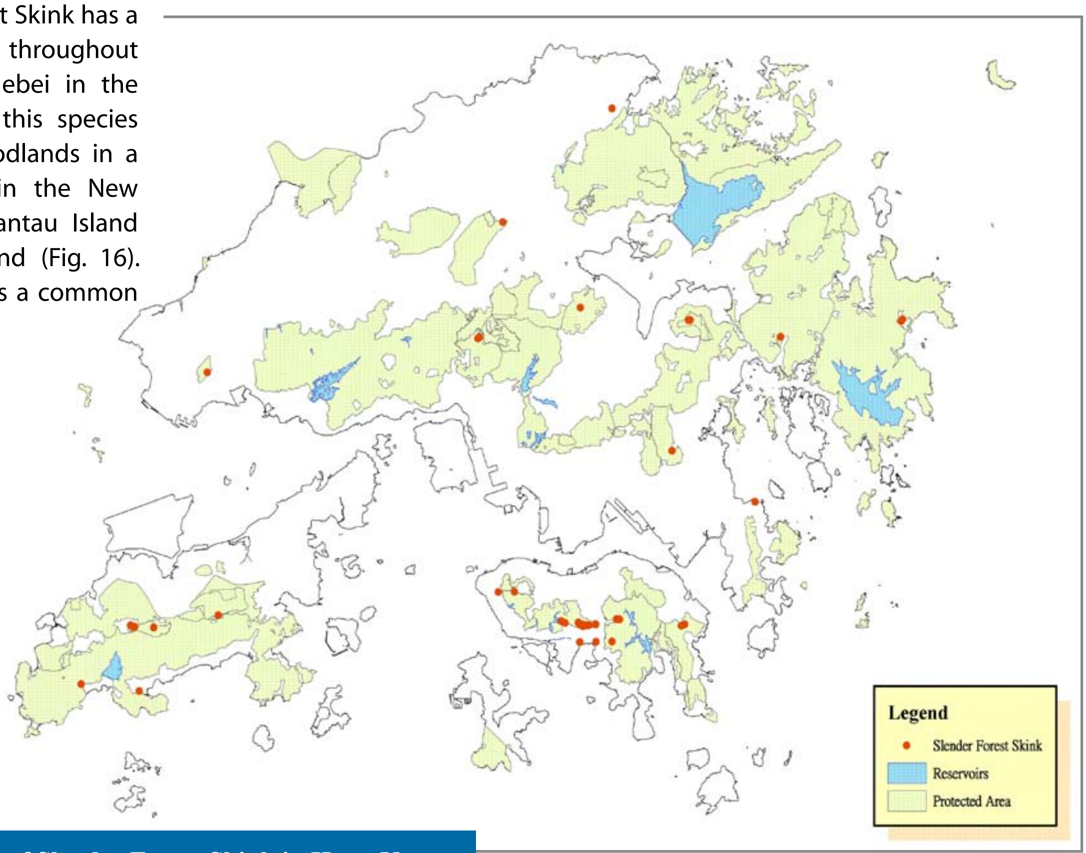

Fig 16. Distribution of Slender Forest Skink in Hong Kong.

Reeves' Smooth Skink (*Scincella reevesii*) (Fig. 17)

Reeves' Smooth Skink is slender and small, with a maximum total length of 13 cm. Its head is small and the snout is pointed. The tail is long and slim. This skink species has bronze brown back with scattered tiny black spots. Its underside is whitish. On the flank, a black dorso-lateral stripe extends from the eye to the tip of the tail, and is heavily speckled with light brown dots along the entire length. The dorsal scales are smooth and slightly larger than the lateral ones.

Fig 17. Reeves' Smooth Skink.

Reeves' Smooth Skink is primarily fossorial, and inhabits a wide range of habitats such as cultivated lowlands, shrubby areas and forest underground. It is typically diurnal, and forages on small insects and other arthropods. This skink is ovoviviparous, giving birth to 2-3 hatchlings.

This species is found in South China, Indo-China west to Myanmar, Thailand, Vietnam, south to west Malaysia, India, Korea and Bangladesh. It is widely distributed in woodlands throughout Hong Kong (Fig. 18). Reeves' Smooth Skink is common in Hong Kong.

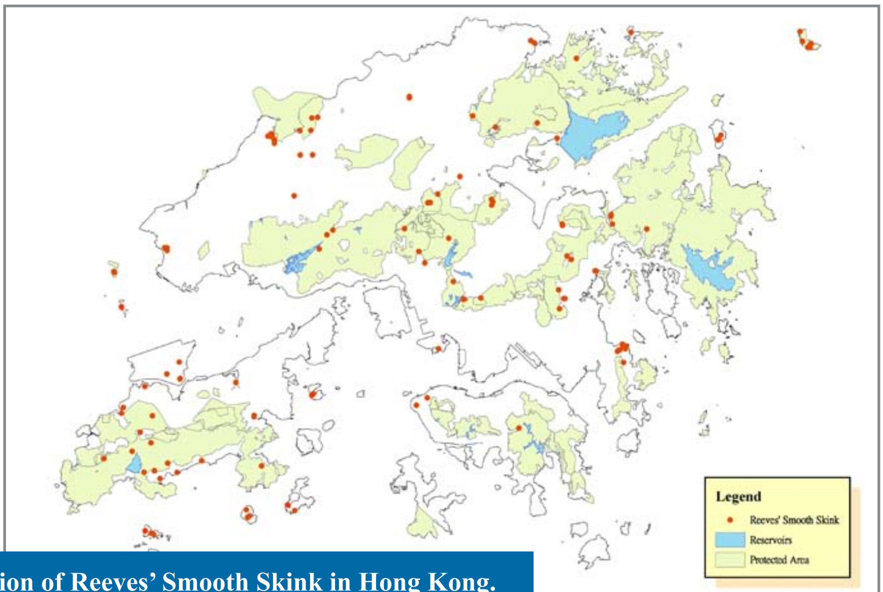

Fig 18. Distribution of Reeves' Smooth Skink in Hong Kong.

Indian Forest Skink (*Sphenomorphus indicus*) (Fig. 19)

Indian Forest Skink is stocky, reaching up to 24 cm in total length, with a tail 1.5 times as long as the snout-vent length. This species is more or less uniformly brown or olive above, with scattered darker dots. Along each side, a dark brown dorso-lateral stripe extends from the snout via the eye to the base of the tail. The underside of the body is creamy yellow. The scales are completely smooth.

This species is chiefly encountered among forest leaf litter, where it forages on small insects and other invertebrates. In China, Indian Forest Skink has been reported to be effective at eliminating pests. This skink is ovoviviparous, giving birth to 5-11 young.

Fig 19. Indian Forest Skink.

Worldwide, Indian Forest Skink can be found in South China, Bhutan, Taiwan, Thailand, Vietnam, Cambodia, from India east to Indo-China and south to west Malaysia, and Bangladesh. In Hong Kong, this species is commonly distributed in woodlands in the eastern and central New Territories (Fig. 20). Indian Forest Skink is common in Hong Kong.

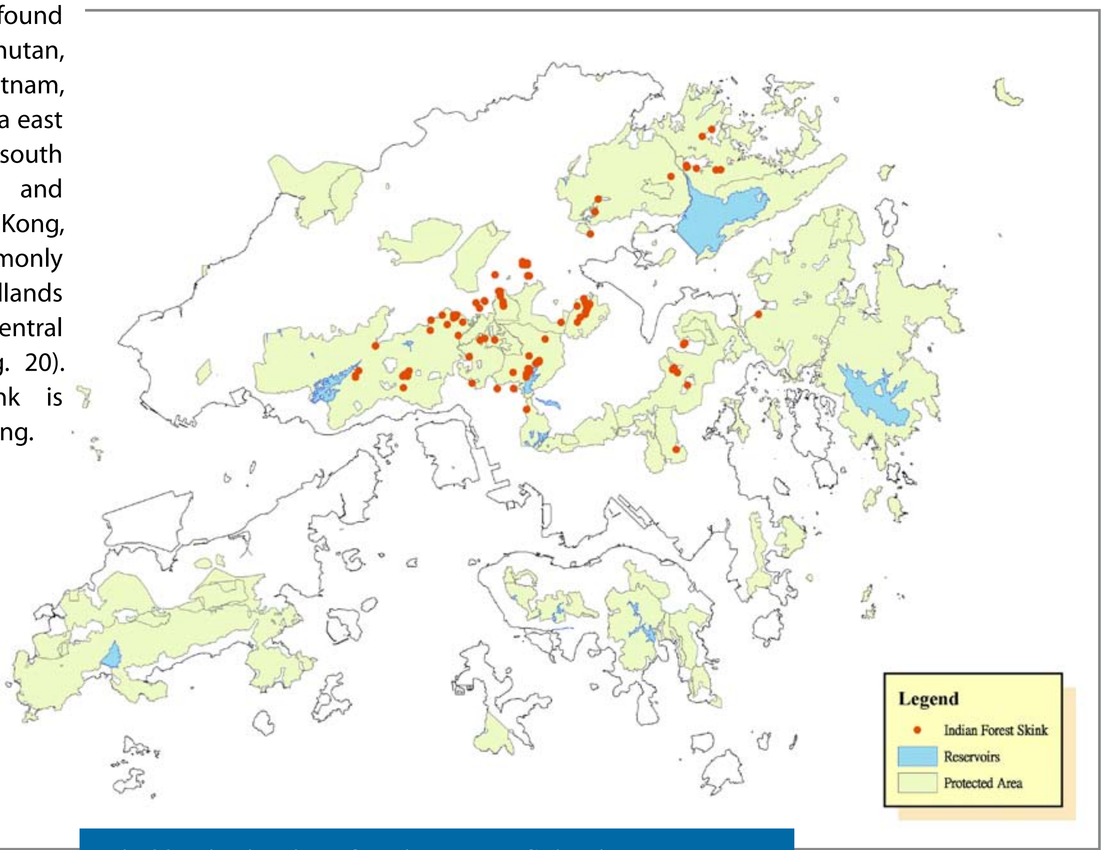

Fig 20. Distribution of Indian Forest Skink in Hong Kong.

Brown Forest Skink (*Sphenomorphus incognitus*) (Fig. 21)

Adult Brown Forest Skink is generally larger than Indian Forest Skink, reaching up to 28 cm in total body length. The snout-vent length of males can exceed 9 cm. Dorsally, Brown Forest Skink is bronze in colour, and speckled with light and dark spots. On each side, a black dorso-lateral line runs from the snout via the eye to the hind limb. The underside is whitish.

Fig 21. Brown Forest Skink.

In contrast to Indian Forest Skink, the upper edge of the dark lateral stripe is jagged on Brown Forest Skink. Also, this species has a patch of enlarged scales at the back of the thigh (Fig. 22). Brown Forest Skink feeds on small insects and invertebrates. Like Indian Forest Skink, it readily sheds its tail when confronted by a potential predator. It is oviparous, laying 1-6 eggs per clutch.

Brown Forest Skink is endemic to China, so is also known as South China Forest Skink. This species can be found in South China as well as Taiwan. In Hong Kong, Brown Forest Skink favours riparian forests, and is often seen basking on stream banks in the central, northeastern and western New Territories (Fig. 23). Brown Forest Skink is common in Hong Kong.

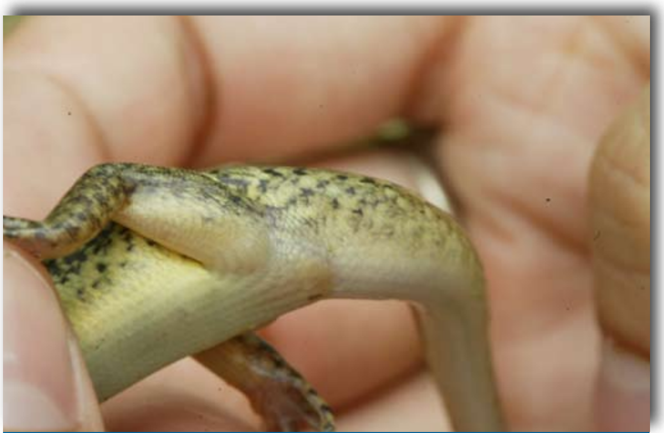

Fig 22. Rear thigh scales of Brown Forest Skink.

Chinese Waterside Skink (*Tropidophorus sinicus*) (Fig. 24)

Chinese Waterside Skink is a robust, medium-sized skink, growing up to about 15 cm in total length. It is dark brown to black above, with irregularly arranged rusty brown diamond patterns. The underside of its body is creamy orange, with some white dots. The species has a narrow head and pointed snout. Its labials are dark brown, with a few light grey or white vertical marks. It has a thick, muscular and laterally compressed tail. All scales except the ventral ones are strongly keeled.

This skink is active day and night. It frequents stony areas and scrub along streams. When disturbed, it often retreats into the water, or hides under objects such as rocks and branches. It consumes small insects, invertebrates and lizards. This species is ovoviviparous, giving birth to 3-6 young.

Fig 24. Chinese Waterside Skink.

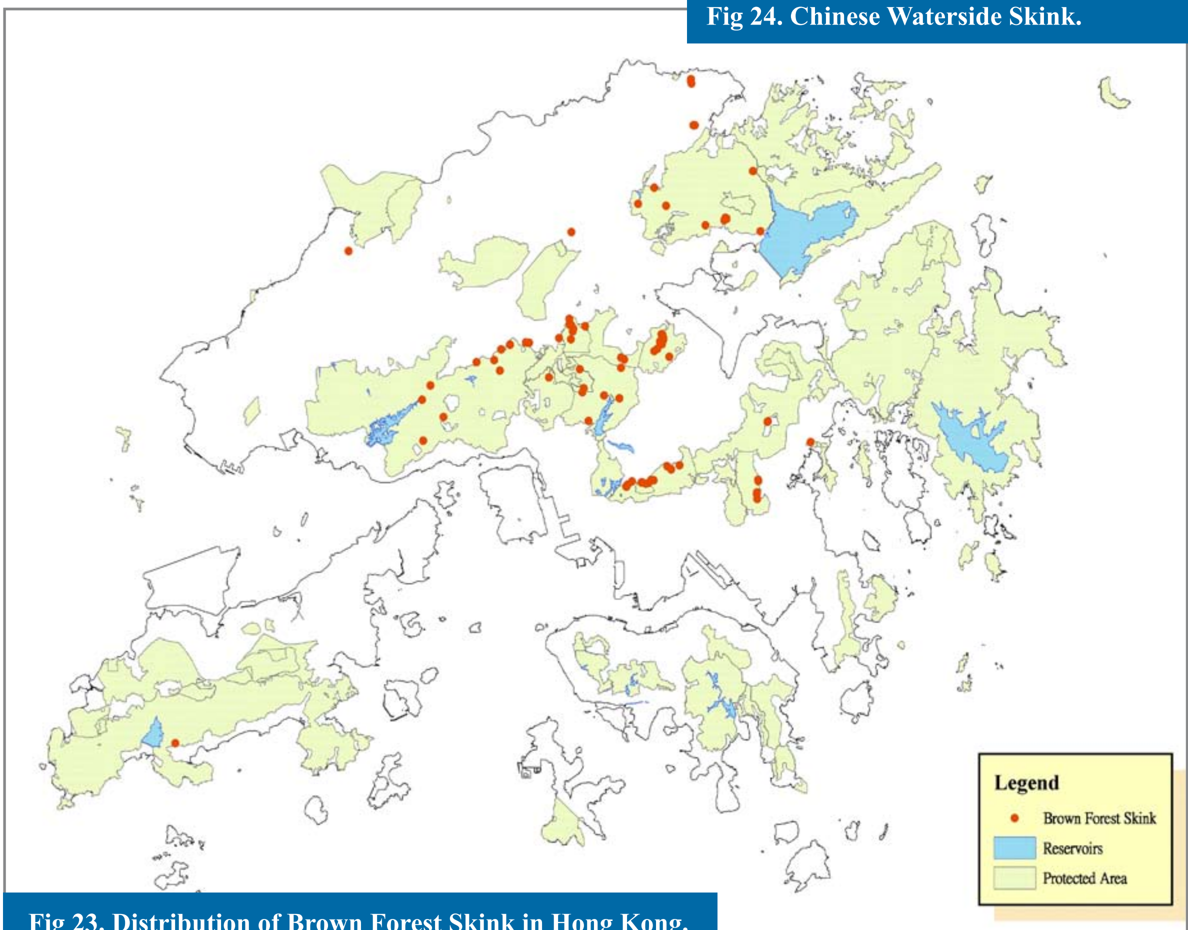

Fig 23. Distribution of Brown Forest Skink in Hong Kong.

Chinese Waterside Skink can be found in South China and Vietnam. It is commonly encountered in streams throughout Hong Kong (Fig. 25). Chinese Waterside Skink is a common species in Hong Kong.

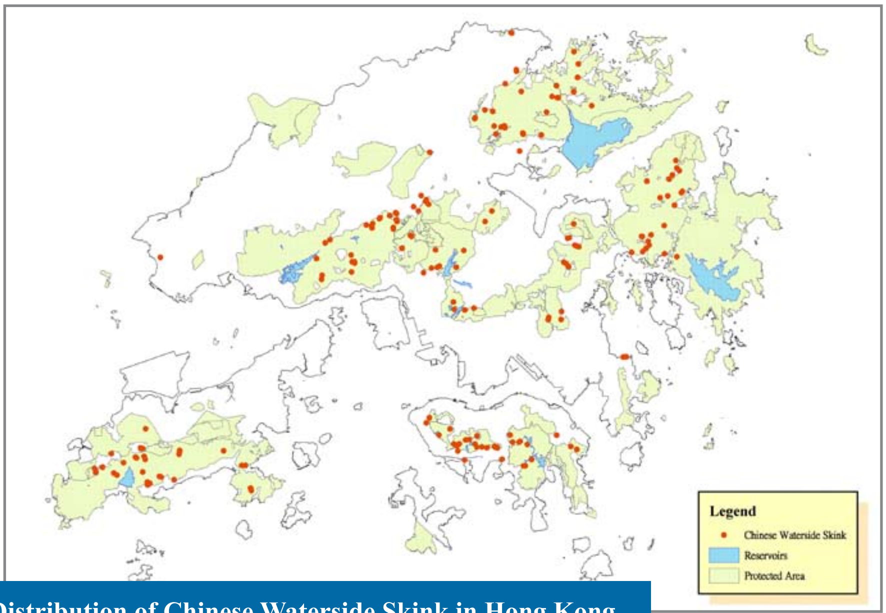

Fig 25. Distribution of Chinese Waterside Skink in Hong Kong.

Conservation

Major threats to skinks worldwide mainly arise from introduced predators and habitat loss/degradation. In Hong Kong, the wide coverage of Country Parks and Special Areas designated under the Cap. 208 Country Parks Ordinance and its subsidiary legislation offer protection to skinks and their habitats. Illegal acts such as hunting and trapping of wildlife or destruction of vegetation are prohibited under the Ordinance. Planning controls against incompatible land use for other protected areas such as Sites of Special Scientific Interest and Conservation Areas afford further protection to skink habitats.

Ongoing field surveys undertaken by AFCD reveal that all skink species in Hong Kong can be found inside the protected areas, and none of the species is currently under threat. However, ongoing, regular monitoring of the important sites for the various skink species will track their statuses in Hong Kong. Particular attention will be paid to the environmental conditions of these sites, to check they remain suitable habitats for skinks. Other conservation measures, such as habitat enhancements, will be considered should the need arise.

A Summary of Skinks of Hong Kong

Species	*Ateuchosaurus chinensis*	*Eumeces chinensis chinensis*	*Eumeces elegans*	*Eumeces quadrilineatus*
中文名	光蜥	中國石龍子	藍尾石龍子	四綫石龍子
Common Name	Chinese Forest Skink	Chinese Skink	Five-striped Blue-tailed Skink	Blue-tailed Skink
Maximum	17 cm	30 cm	22 cm	21 cm
Habitat	Damp forests and woodland.	Lowland areas.	Open areas with sunshine.	Dry woodlands and rocky areas with sunshine.
Diet	Small insects and invertebrates.	Small insects, invertebrates and lizards.	Small insects.	Small insects and invertebrates.
Reproduction	Oviparous	Oviparous	Oviparous	Oviparous
Distribution	Native. Occurs throughout Hong Kong, especially in Country Parks.	Native. Occurs throughout Hong Kong.	Native. Occurs in woodlands in the central New Territories and on Cheung Chau.	Native. Commonly found in woodlands on islands.
Identification	• Indistinct neck. • Short limbs. • Brownish above. • Black and white spots on flanks.	• Large and robust. • Greyish brown above. • Red spots on flanks. • Glossy and smooth scales.	• Brown to black above. • Five yellowish stripes on back and sides. • Fork mark on head. • Iridescent blue tail.	• Greyish brown above. • Two silvery white stripes on back and two white stripes on sides. • Yellowish pink lower labials and throat. • Brilliant blue tail.

Species	*Mabuya longicaudata*	*Plestiodon tamdaoensis*	*Scincella modesta*	*Scincella reevesii*
中文名	長尾南蜥	越南五線石龍子	寧波滑蜥	南滑蜥
Common Name	Long-tailed Skink	Vietnamese Five-lined Skink	Slender Forest Skink	Reeves' Smooth Skink
Maximum Length	37 cm	unknown	10 cm	13 cm
Habitat	Dry hilly areas and concrete holes.	Lowland areas, probably in woodlands.	Soil layers of forests.	Lowland areas.
Diet	Insects, invertebrates and occasionally plant material.	Small insects and invertebrates.	Small insects and invertebrates.	Small insects and invertebrates.
Reproduction	Oviparous	Oviparous	Oviparous	Ovoviviparous
Distribution	Native. Occurs throughout Hong Kong.	Local status uncertain. Rare, only known from the eastern New Territories.	Native. Occurs in scattered sites in the New Territories and on some islands.	Native. Occurs throughout Hong Kong
Identification	• Tail twice as long as body. • Tan brown above • Dark wide stripe from the eye to the hind limb on each side.	• Shiny black above. • Five yellowish stripes on back and sides. • "X" mark on head. • Bright blue dorsal tail.	• Tiny and slender. • Tan brown above with dark speckles. • Thin black dorso-lateral lines. • Bright coppery red underside to tail.	• Small and slim. • Bronze brown above with black spots. • Black dorso-lateral stripes with light brown dots. • Whitish underside.

Species	*Sphenomorphus incognitus*	*Sphenomorphus indicus*	*Tropidophorus sinicus*
中文名	股鱗蜓蜥	銅蜓蜥	中國棱蜥
Common Name	Brown Forest Skink	Indian Forest Skink	Chinese Waterside Skink
Maximum Length	28 cm	24 cm	15 cm
Habitat	Dry hilly areas and concrete holes.	Lowland areas, probably in woodlands.	Scrub and rocky areas along streams.
Diet	Small insects and invertebrates.	Small insects and invertebrates.	Small insects and invertebrates.
Reproduction	Oviparous	Ovoviviparous	Ovoviviparous
Distribution	Native. Occurs in streams in the New Territories.	Native. Occurs in woodlands in the eastern and central New Territories.	Native. Occurs in streams throughout Hong Kong.
Identification	• Bronze with dark speckles above. • Black dorso-lateral lines with jagged upper edge. • Whitish underside.	• Uniform brown above. • Dark brown dorso-lateral stripes. • Creamy yellow underside. • Smooth scales.	• Dark brown to black above. • Rusty brown diamond patterns on back. • Keeled scales. • Laterally compressed and muscular tail.

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Division Column

Field Study on the Effectiveness of Using *Cuscuta* (菟絲子) Species in Control of *Mikania micrantha* (薇甘菊)

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Introduction

In 2006, the Agriculture, Fisheries and Conservation Department (AFCD) commissioned The Chinese University of Hong Kong to conduct a field study on the effectiveness of using *Cuscuta* (菟絲子) species for control of *Mikania micrantha* (薇甘菊). This paper summarises the study's major findings, and discusses the potential application of *Cuscuta* as a biological control agent for *Mikania micrantha*.

Background

Mikania (*Mikania micrantha* Kunth) is an exotic perennial herbaceous vine belonging to the family Compositae. It is native to tropical South and Central America, but is now widely distributed in India, Southeast Asia and South China including Guangdong and Hong Kong. Mikania spreads rapidly in spring and summer, leading to it also being known as "mile-a-minute weed". This perennial herbaceous vine climbs on other plants to reach the canopy for better sunlight, often covering them, so the plants are eventually damaged or even killed. Hence, in many countries Mikania is regarded as a noxious weed.

In Hong Kong, Mikania is usually found in low-lying, moist and disturbed areas with ample sunlight, such as abandoned fields, fishpond bunds, roadside areas, and woodland margins around village environs. Mikania has not caused significant adverse impacts on established woodland areas. However, as Mikania spreads rapidly, there is a growing concern about the potential impacts of Mikania on natural vegetation, especially at woodland margins.

There are different approaches to Mikania control. The vines can be cleared through physical means, by cutting their stems, but there will be re-growth from lower and underground sections, and repeated clearing may be needed. Chemical control with herbicides can kill the entire plants, but the herbicides have side-effects on nearby vegetation, so are not suitable for sites near water sources, areas with high ecological value, agricultural land that is in active use, gardens and residential areas.

Biological control is a potential alternative means of controlling invasive species, with one benefit being that its action may be long-lasting and specific, so will not adversely affect non-target species. However, there are as yet no conclusive results of field application of a suitable biological control agent for Mikania.

Cuscuta species, commonly known as dodders, are a group of parasitic plants that have low abilities to photosynthesis themselves, as they have very low levels of chlorophyll, and thus are entirely dependent on their host plants for nutrition. There are several species of dodders in Hong Kong, and preliminary field observations revealed that *Cuscuta campestris* (田野菟絲子) often naturally infests Mikania in abandoned fields (Fig. 26). There have been a few studies in South China showing that dodder is potentially an effective biological agent for controlling Mikania, as its parasitic action can suppress Mikania's growth and inhibit its reproduction (Liao *et al*, 2002; Deng *et al*, 2003; Zan *et al*, 2003 and Shen *et al*, 2005). However, the effectiveness of its field application has not been studied in detail.

Fig 26. Dodder infesting Mikania in abandoned field.

Ways of Delivering Dodders to Mikania

The early stage of the field experiments, carried out in Tai Tong Nursery, studied three different ways of delivering dodders to Mikania: (1) sowing seeds, (2) transfer of fresh stem cuttings, and (3) transfer through an intermediary host.

(1) Sowing seeds

Field observations showed that dodder seeds could germinate rather readily in wet seasons when the capsules were broken but still hanging on Mikania branches. However, once dried, the seeds would become dormant. Literature reports claimed that the seeds could stay dormant for 10 years (Wang *et al*, 2002), unless treated with sulphuric acid to break the dormancy (Fig. 27). This study showed a dose-dependent relationship between germination rate and the duration of soaking dodder seeds in 95% sulphuric acid. (Fig. 28).

Fig 27. Dodder seeds after sulphuric acid treatment: (a) the outer seed coat of the smaller seed on the right has been removed, exposing the firm inner seed coat; (b) the larger seed on the left has a translucent inner seed coat, a coiled embryo inside, and partially exposed radical.

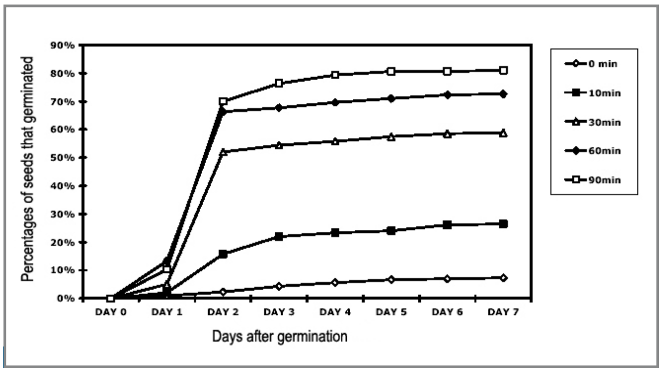

Fig 28. Germination rates of dodder seeds with different duration of acid scarification at 30ºC.

An experiment was conducted to check if *C. campestris* seedlings developed from seeds could successfully infest Mikania. Seeds of *C. campestris* were sown in seven pots with Mikania. Dodder seedlings were found in all pots, and they started to twine round Mikania from 2 to 4 weeks after sowing. On the dodders that successfully infested Mikania, flowers and fruits were observed in about 2 to 3 months.

(2) Transfer of fresh stem cuttings

Fresh filaments of *C. campestris* were cut and collected from a population near Tai Tong. A jar filled with water and several *C. campestris* filaments was placed on the soil in five pots with Mikania. It was found that in all pots, within around one week the filaments grew longer and infested the Mikania. Dodders were found to bear flowers and fruits in about 1 to 2 months.

(3) Transfer through an intermediary host

As *Bidens pilosa* (鬼針草) was found to be commonly infested by *C. campestris*, it was chosen as an intermediary host. Ten pots of Mikania were planted in Tai Tong Nursery. Beside each of the Mikania was placed a bottle of water with a single healthy branch of *B. pilosa* infested with *C. campestris*. Dodders were found to infest Mikania in only three pots.

The above results showed that all three methods achieved some degree of success in infesting Mikania. The best results were achieved through transferring fresh cuttings. Hence, this method was used for the subsequent field experiments.

Effectiveness of Using Dodder in Mikania Control

Field experiments were conducted on experimental beds constructed at Tai Tong Nursery, and at selected sites with different habitats in the New Territories. The experiments were supplemented by observations on natural interactions between Mikania and *C. campestris* in the field. Additionally, Centre Island in Tolo Harbour was chosen as a site for a comprehensive field trial, as it had a problem with Mikania, and was free from human disturbance and physically isolated from the rest of the territory.

Cut shoots from terminal branches of *C. campestris* were collected from wild populations. The cut ends of the dodder shoots were immersed in a plastic bag filled with water. The dodder cuttings were then hooked onto the stems of Mikania (Fig. 29).

Fig 29. Delivering dodder cutting to Mikania.

(1) Experimental plots in Tai Tong Nursery

Experimental plots were set up in Tai Tong Nursery. Root branches of Mikania were planted in the plots. Cutting of *C. campestris* were then added to some of the experimental plots. There were also control plots, where the Mikania was not inoculated with dodder.

Results showed that dodder cuttings could readily infest Mikania. Once it had infested Mikania, dodder thrived on the experimental plots throughout the study period. Dodder cuttings flowered 1-2 months after inoculation, and some of the seeds from the first crop were found to germinate *in-situ*. Dodder could cause topical damage to but could not completely eradicate Mikania (Fig. 30). The infestation caused a dramatic 80% reduction in Mikania's flowering capacity (Fig. 31).

Fig 30. Dodder infesting Mikania and affecting its growth.

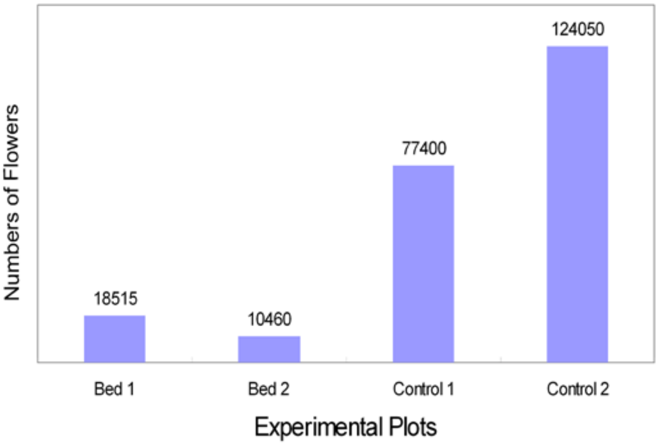

Fig 31. Impacts of dodder on Mikania's capacity for sexual reproduction.

(2) A cut slope

On a cut slope with about 95% Mikania coverage, a 5 m x 5 m plot holding an extensive Mikania population was selected and divided into 25 x 1 m^2 quadrates. Areas surrounding the plot were used as control sites. Dodder cuttings were planted on the 25 quadrates, and changes in these quadrates were regularly monitored. After 6 months, the aerial parts of all vegetation in randomly selected quadrates were harvested, and dried for biomass analysis.

Mikania in the infested quadrates showed obvious damage over time, and the resulting space was colonised by other plants. Within these quadrates, the biomass of Mikania was dramatically reduced, while the biomass of other plants substantially increased (Fig. 32). The averages of the Mikania biomasses in infested and control quadrates were 20.5 g and 83 g, respectively. The averages of the biomasses of other plants in infested and control quadrates were 87 g and 27.4 g, respectively. During follow-up observations, neither Mikania nor dodder were observed in the experimental plot. The site was mainly occupied by other plants, predominantly *Cyrtococcum patens* (弓果黍). By contrast, the areas around the plot were still extensively colonised by Mikania.

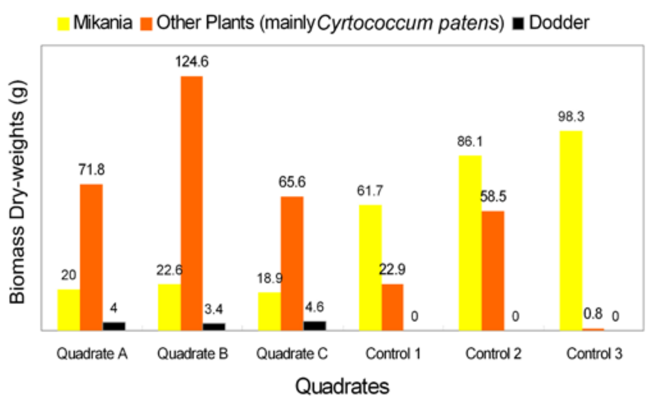

Fig 32. Biomass dry-weights of plants in infested and control quadrates.

(3) Abandoned field in the New Territories

Two experimental plots were set up in an abandoned field with dense Mikania coverage, in the New Territories. In the first 25 m^2 plot, one packet with a dodder cutting was attached to Mikania branches in every one-square metre quadrate. The Mikania and dodder were regularly monitored. After 12 months, the aerial parts of plants in the two experimental 1 m^2 quadrates and two control quadrates were harvested for biomass measurement.

In the second plot, the impact of dodder in reducing Mikania's sexual reproductive capacity was investigated. Dodder cuttings were placed in three experimental 1 m^2 quadrates in the plot, and regularly monitored. After 3 months, numbers of Mikania flowers in the three experimental quadrates and three control quadrates were counted.

In the first plot, Mikania growth was significantly reduced by dodder infestation. Substantially less Mikania biomasses (19 and 39 gm^{-2} dry weights) were recorded in the two experimental quadrates than in the control plots (206 and 240 gm^{-2} dry weights; Fig. 33). In the second plot, the numbers of capitula and individual flowers plummeted from averages of 40,000 and 190,000 to 290 and 1,400, respectively (Fig. 34). Dodder demonstrated potency in suppressing Mikania's growth and flowering, and hence its spread and reproduction.

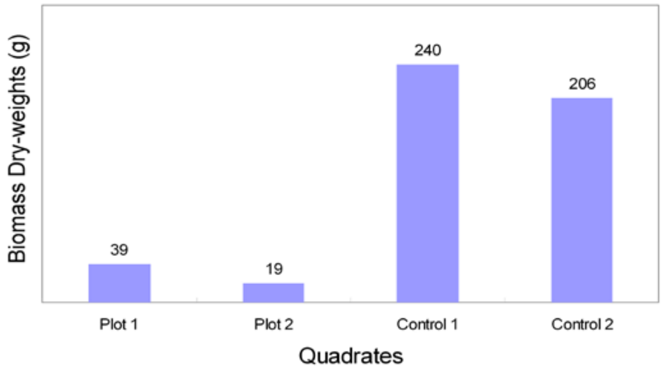

Fig 33. Mikania biomass dry-weights in infested and control quadrates.

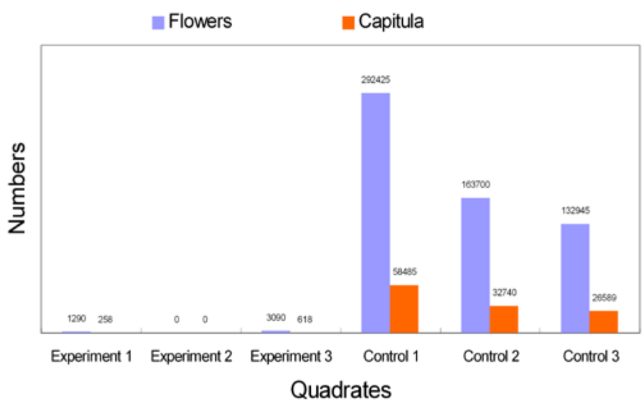

Fig 34. Numbers of Mikania flowers and capitula in infested and control quadrates.

(4) Shrubby habitat on Centre Island

At Centre Island, trial plantings of two dodders (*C. campestris* and *C. japonica* 金燈藤) were conducted in selected areas with substantial Mikania growth.

Dodder cuttings introduced during mid summer – when the temperature was higher than 30°C – all died, probably due to the hot weather.

Other *C. campestris* cuttings succeeded in infesting Mikania in about a month, and were effective in killing Mikania in the experimental area. Neighbouring control areas, however, were not much affected by this dodder, as it spread rather slowly. Cuttings of *C. japonica* also succeeded in infesting Mikania in about a month after introduction, and killed all Mikania in the experimental area. This dodder spread rather quickly, and also killed Mikania in neighbouring areas.

Discussion

The above results show that use of fresh cuttings of *C. campestris* was an effective way of delivering dodders to Mikania. *C. campestris* was found to effectively inhibit Mikania growth in both the experimental plots and in the field, particularly on abandoned fields and slopes that are humid with ample sunlight. *C. campestris* also demonstrated potency in killing Mikania. However, after the dodder killed the Mikania branches it infested, it also flowered, fruited, and then withered. Hence, the impact was only topical, and further Mikania control would depend on the vegetative and sexual reproduction ability of the dodder remaining *in-situ*.

In addition, *C. campestris* demonstrated potency in suppressing Mikania flowering. This indicate that *C. campestris* can significantly reduce Mikania's reproductive ability. The reduction of seed production could limit the dispersal of Mikania, and thus diminish its spread.

Hence, a sensible approach would be to apply *C. campestris* in spring, to lessen the virulence of Mikania in summer, while a mid-summer application would help reduce Mikania flowering in the latter part of the year. However, *C. campestris* did not do well in dry, windy and shaded sites. Moreover, temperatures higher than 30°C or lower than 10°C are generally less favourable for dodder application. The high temperatures in summer might thus be a limiting factor for mid-summer application.

Field studies revealed that in addition to Mikania, *C. campestris* could also infest and grow on many other plants, including trees (e.g. *Acacia auriculiformis* 耳果相思, *Aporusa dioica* 銀柴), horticulture plants (e.g. *Clerodendrum thomsonae* 龍吐珠, *Wedelia trilobata* 三裂葉蟛蜞菊) and crops (e.g. *Ipomoea batatas* 番薯, *Cucurbita moschata* 南瓜). However, damage to these plants by *C. campestris* in Hong Kong is considered minor. Infestations on trees were rare and the damages have been observed to be minor and very localized. Potential damage by *C. campestris* to agriculture and horticulture industries in Hong Kong would also be minimal, as local agricultural fields are normally under intensive management, and any weeds (including dodders, if present) will be promptly cleared by farmers. It should also be noted that *C. campestris* is already widespread in Hong Kong.

Recommendations

Although there are still some limitations in the application of *C. campestris* in certain habitats and seasons, it is recommended to continue trial applications of *C. campestris* as a potential biological control agent for Mikania, to monitor its effectiveness. These trials should be small-scale, and conducted at various sites under the management of AFCD. A standardised monitoring form will be developed for recording the coverage and flowering of Mikania, as well as the growth of *C. campestris* . The results of the monitoring should be used to refine the protocols for such application, to further assess the possible side effects on the local ecology, and to review whether *C. campestris* is suitable for large-scale application for Mikania control.

The experimental beds at Tai Tong Nursery and the field study sites on Centre Island should be retained for further observations, in order to fill gaps in information regarding the growth of *C. campestris* in the wet season and at high temperatures, and to try different approaches of applying dodders, together with the introduction of other plant species that could take over the space vacated by Mikania immediately after it is weakened or killed by dodders.

Further studies should be carried out on the effectiveness of using other dodder species such as *C. japonica*, as a biological control agent for Mikania (Fig. 35). Initial field observations showed that *C. japonica* appears to be potent in killing Mikania and would be a more effective biological control agent than *C. campestris*. Nevertheless, as this dodder species is relatively more aggressive in infesting its host plants, and is less common, further studies are needed to ascertain its side effects and safety as a biological agent for Mikania in Hong Kong.

Fig 35. *C. japonica* infesting Mikania.

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Working Group Column

Preliminary Study on the Effectiveness of Using Native Freshwater Fish for Mosquito Control in Hong Kong

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Introduction

There are over 1,600 mosquito species in the world, 71 of which can be found in Hong Kong. Some mosquito species (e.g. *Aedes albopictus*, *Culex tritaeniorhynchus* and *Anopheles minimus*) are known to transmit vector-borne diseases such as Malaria, Dengue Fever, Japanese Encephalitis and Filariasis. The Government is aware of the importance of controlling mosquitoes and adopts an integrated approach – emphasising the importance of maintaining environmental hygiene together with appropriate control measures – to combat mosquitoes that may be disease vectors.

The increasing awareness of the need to control mosquitoes, particularly in the larval stage, has coincided with growing concern over the widespread use of pesticides to combat disease vectors. Pesticides used for combating mosquito-borne diseases carry their own toxicity risks, and repeated use of the chemicals may reduce their effectiveness. Given this scenario, biological control – i.e. the use of biological organisms to control mosquitoes – has become one of the most important means of combating mosquito-borne diseases.

Biological control of mosquitoes has been implemented or tried experimentally in many overseas countries, with varying degrees of success. Biological control has some obvious advantages, including minimal environmental pollution, little or no effect on beneficial and non-target organisms, and as an alternative pest suppression method, especially when other measures of pest prevention, containment and eradication are unfeasible. However, factors such as knowledge of the pest-control agent's population dynamics, possible threats the control agent poses to non-target species and availability of the control agent should be considered.

In considering biological control, it is extremely important to assess the potential impacts of the introduced organisms on the environment. For example, *Gambusia affinis* (Mosquito Fish 食蚊魚) is now widespread throughout the world, including Hong Kong, after being introduced from America for mosquito control. Due to its aggressive nature and omnivorous feeding habit, the fish has been found to attack and compete with many native freshwater fish and aquatic organisms for food and habitats. As this example indicates, native species are always preferred over exotic organisms in the context of biological control.

The present study focuses on the potential of native freshwater fish species as biological mosquito control agents. The results are discussed, and recommendations are made regarding selection of native fish species.

Materials and Methods

Fish selection


Fig 36. *Macropodus opercularis.*


Fig 37. *Macropodus hongkongensis.*


Fig 38. *Oryzias curvinotus.*


Fig 39. *Parazacco spilurus.*


Fig 40. *Puntius semifasciolatus.*


Fig 41. *Tanichthys albonubes.*


Fig 42. *Gambusia affinis.*

Six native freshwater fish species – *Macropodus opercularis* (Chinese Paradise Fish 中國鬥魚, Fig. 36), *M. hongkongensis* (Hong Kong Paradise Fish 香港鬥魚, Fig. 37), *Oryzias curvinotus* (Rice Fish 弓背青鱂, Fig. 38), *Parazacco spilurus* (Predaceous Chub 異鱲, Fig. 39), *Puntius semifasciolatus* (Chinese Barb 五線無鬚䰾, Fig. 40) and *Tanichthys albonubes* (White Cloud Mountain Minnow 白雲山魚, Fig. 41), were selected for the trials. These fish are omnivorous and known to feed on mosquito larvae, and dwell in a range of habitats. *M. opercularis* and *M. hongkongensis* mainly live in marshes while *O. curvinotus* and *P. semifasciolatus* inhabit ponds and reservoirs. *P. spilurus* and *T. albonubes* are encountered in streams and pools.

The efficiencies of the selected fish species in consuming mosquito larvae were assessed, and compared to the exotic *Gambusia affinis* (Fig. 42).

Collection of mosquito larvae

Mosquito larvae were collected from natural environments such as pools and small ponds, and identified to genus level. To minimise the effect of differences in species and prey sizes, only the third and fourth instars of *Culex* species were used for the trials.

Feeding trials

The experiments were conducted in laboratory conditions. Fish collected from the wild were placed in fish tanks (29 cm × 29 cm × 59 cm) with 44 litres of de-chlorinated water, at least 48 hours prior to the tests, so they could acclimatise to laboratory conditions and eliminate food items from their guts. Water temperatures from 21.2 to 22.9°C, pH from 6.9 to 7.9, and dissolved oxygen content from 6.5 to 9.9 mg/L were maintained throughout the experiments. Only adult fish were used.

Preliminary assessments were carried out to determine the approximate daily mosquito larvae consumption by different fish species. Results showed that, on average, in each 24-hour period each individual of *G. affinis*, *O. curvinotus*, *T. albonubes* and *M. opercularis* (Group 1) consumed about 80 larvae, while *P. semifasciatus*, *M. hongkongensis* and *P. spilurus* (Group 2) consumed about 600 larvae.

In the feeding experiments, two randomly selected individuals of each species were placed in each tank. Based on the preliminary assessments, 200 mosquito larvae were added for Group 1, and 1600 for Group 2. The fish were allowed to feed for 24 hours. The numbers of remaining mosquito larvae (dead and alive) were counted after the experiments.

The experiments were repeated three times under similar conditions. Each individual fish was only used once in the experiments, i.e. new individuals were used each time a test was repeated.

Statistical analysis

Analyses of variances (ANOVA) and comparisons of means by Tukey Kramer HSD Tests (p=0.05) were employed to compare mosquito larvae consumption by the seven fish species.

Results

Mean numbers of mosquito larvae consumed by the seven fish species and mean sizes of the fish are given in Table 1. Results of ANOVA tests showed significant differences ($p<0.0001$) in mean consumption between the seven species. Means comparisons revealed that *P. spilurus* consumed significantly ($p<0.05$) more *Culex* larvae than the others, followed by *M. hongkongensis* and *P. semifasciatus*. Their daily consumptions were also significantly higher than those of other four species. There were no significant differences between consumptions by *G. affinis*, *T. albonubes*, *M. opercularis* and *O. curvinotus* (Fig. 43).

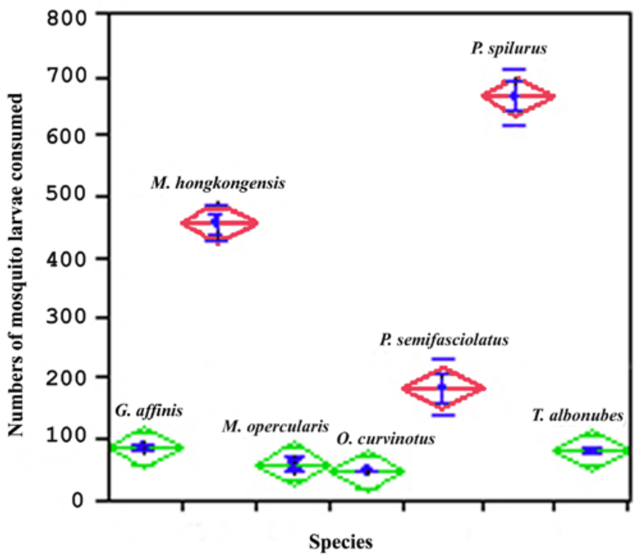

Fig 43. ***P. spilurus*, *M. hongkongensis* and *P. semifasciatus* (shown in red) consumed significantly more mosquito larvae than the other four species (shown in green).**

Discussion and Recommendations

The study demonstrated that some native freshwater fish are more efficient at mosquito larvae control than the exotic *G. affinis*, at least in laboratory conditions. The native cyprinid, *P. spilurus*, was the most effective predator of *Culex* species mosquito larvae, and both *M. hongkongensis* and *P. semifasciolatus* were more effective than the exotic *G. affinis*. Other native fishes - *M. opercularis*, *O. curvinotus*, and *T. albonubes* - displayed similar mosquito larvae feeding effectiveness to *G. affinis*.

Native species, which occur naturally in the local environment, are less likely to cause ecological disturbances to indigenous communities, and are thus considered more ecologically friendly. Additionally, they are more adapted to local environments and reproduce naturally in most water bodies, to form sustainable populations that are large enough to control mosquito larvae. Introduction of native fishes into natural environments also helps enhance species diversity of the recipient sites.

The potential for using native freshwater fish species for mosquito control is not only determined by their consumption of target species, but also a combination of physical and biological factors:

Firstly, the habitat requirement of the fish species should be considered when determining a control species. *P. spilurus* favours rocky streams with large pools, while *M. hongkongensis* requires sluggish and swampy water bodies. *P. semifasciolatus* has a wider habitat tolerance, including reservoirs, streams and artificial ponds. General biology, habitat requirements and descriptions of these three species are given in Annex I.

Secondly, the selected species should be hardy, and able to tolerate a wide range of environmental conditions, notably polluted and stagnant waters, which are important breeding grounds for mosquitoes. *P. spilurus* consumed the most *Culex* larvae in this study, it prefers flowing and well-oxygenated waters, and cannot tolerate habitats with very poor water quality. Besides, *P. spilurus* and *O. curvinotus* showed poor survival during collection and transportation. These factors limit their suitability as mosquito control agents, which must be transferred to and are often released in contaminated and unstable environments.

Thirdly, the reproductive biology and requirements of the species may affect the availability and establishment of self-sustaining populations for long-term mosquito control. For instance, though *O. curvinotus* readily died during collection and transportation, it reproduces all year round, making this a candidate for relatively easy "mass production". By contrast, *Macropodus* species require specific tranquil and marshy habitats for spawning and hatching.

Further studies on the effectiveness of using freshwater fish for mosquito control *in-situ* are recommended. It is also necessary to establish methods and facilities for "mass production" of these fish. The results of the present study suggest that *P. spilurus*, *M. hongkongensis* and *P. semifasciolatus* are suitable candidates for further studies.

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Annex I – A brief account of the three most effective mosquito lavae consuming species

Family	Cyprinidae	Belontiidae	Cyprinidae
Scientific name	*Parazacco spilurus*	*Macropodus hongkongensis*	*Puntius semifasciolatus*
Common name	Predaceous Chub	Hong Kong Paradise Fish	Chinese Barb, Chinese Half-striped Barb
Chinese name	異鱲	香港鬥魚	五線無鬚鲃 /七星魚
Maximum size	150 mm	100 mm	100 mm
Habitat	Hill and lowland streams with clear water.	Usually found in marshes. Adults can also be found in rocky hill streams.	Wide range of habitats, including upland and lowland streams, ponds and reservoirs.
Physical tolerance	Temperature: 14-30ºC; pH: 5.7-8.7; dissolved oxygen: 2.8-11.6 mg/L	Temperature: 13-26ºC; pH: 2.8-8.1; dissolved oxygen: 1.5-12.8 mg/L	Temperature: 14-29ºC; pH: 5.7-8.2; dissolved oxygen: 2.2-12.3 mg/L
Diet	Zooplankton, aquatic insects, small crustaceans and small fishes.	Aquatic crustaceans and insects including mosquito larvae.	Worms, aquatic insects, small crustaceans, plant matters and detritus.
Description	Has a long, streamlined and laterally compressed body and a protrusible lower jaw. Distinct dark mid-lateral band runs from operculum to caudal peduncle, and ends with a black spot on caudal fin base. The black band and spot become less prominent in adults.	Body is elliptical, laterally compressed, and mainly black to greyish. The dorsal and anal fins are elongate, and the caudal fin is deeply forked.	Has a slightly elongated body, with a pair of barbels on its upper jaw. Has five to seven diagnostic dark vertical bars on its yellowish body.