

Seasonal Activity and Reproduction of Two Syntopic White-Toothed Shrews (*Crocidura attenuata* and *C. kurodai*) from a Subtropical Montane Forest in Central Taiwan

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Hon-Tsen Yu, Ting-Wen Cheng and Wen-Hao Chou (2001) Seasonal activity and reproduction of two syntopic white-toothed shrews (*Crocidura attenuata* and *C. kurodai*) from a subtropical montane forest in central Taiwan. *Zoological Studies* 40(2): 163-169. We studied seasonal changes in age structure and reproduction for 2 species of white-toothed shrews, *Crocidura attenuata* and *C. kurodai*, on a mid-elevation forested slope in subtropical Taiwan. In total, 564 shrews were collected by pitfall traps from Aug. 1995 through May 1997. Neither species had a conspicuous annual breeding season. The 2 species may have different social organizations and mating systems, judging from their sex ratios and proportions of breeding adults in the populations. A 3rd species of shrew, *Chodsigoa sodalis*, and a murid rodent, *Niviventer coxingi*, were syntopic with the 2 *Crocidura* species. Our study reveals that insectivores have been neglected in previous surveys of small mammals in Southeast Asia.

Key words: *Crocidura*, White-toothed shrew, Breeding season, Pitfall trap, Soricidae.

Studies on the population biology of Asian white-toothed shrews (genus *Crocidura*) have been rare because shrews are difficult to catch by conventional traps that are normally used for studying small mammals. Low capture rates for shrews are particularly typical in tropical and subtropical Asia, even though various types of bait have been applied (Ruedi et al. 1990, Walker and Rabinowitz 1992, Yu 1994, Fang et al. 1997), but see Rickart et al. (1991) and Heaney et al. (1999). Shrews are important members of forest ecosystems throughout the Holarctic and Old World tropics (Kirkland 1991) and are likely to be so as well in subtropical Taiwan and Asia. Yet we know little about their biology in these regions beyond their taxonomy (Heaney and Ruedi 1994, Ruedi 1995 1996, Ruedi and Vogel 1995, Motokawa et al. 1996, Fang et al. 1997).

While using pitfall traps to study the reptilian fauna in a montane forest in central Taiwan, we unexpectedly obtained samples of 3 shrews, including large number of 2 white-toothed shrews, *Crocidura attenuata* and *C. kurodai*. This confirms that appro-

priate deployment of pitfall traps, in combination with drift fences, is useful in obtaining large sample sizes of shrews (Kirkland and Sheppard 1994).

Based on these samples, we report herein the seasonal patterns of age structure and reproduction, and other aspects of natural history for 2 syntopic white-toothed shrews in Taiwan. A depauperate small mammal community at elevations from 800-1200 m in Taiwan was reported (Yu 1993 1994), and similar situations were found elsewhere in Southeast Asia (discussed in MD Nor 2000). Our findings on the shrew community at these elevations appear to counterbalance the deficiency of previous surveys that often neglected insectivores due to methodological constraints.

MATERIALS AND METHODS

Study site

The study site is located at the Fong-Huang-Gu

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Bird Park (23°36'N, 120°46'E; elevation 650-800 m) in central Taiwan, where dozens of large bird cages have been built in a montane forest. The climate, divided into wet and dry seasons, is typical of montane areas in central Taiwan (Yu 1993, Yu and Lin 1999). The average annual rainfall is about 2220 mm. Most rainfall (80%) occurs during the wet season, from Apr. through Sept.. The copious precipitation is largely from local thunderstorms and typhoons. The dry season lasts from Oct. through Mar.. The mean annual temperature is 18.6 °C. The highest monthly temperature occurs in July or Aug. (ca. 22.4 °C) and the lowest in Jan. or Feb. (ca. 12.7 °C). The average monthly relative humidity is always greater than 80%.

The natural vegetation of the area is typical of low-middle elevations in central Taiwan, and is comprised of evergreen broadleaf forests dominated by the trees *Ilex formosana*, *Dendropanax pellucidopunctata*, *Fatsia polycarpa*, *Litsea acuminata*, *Stachyurus himalaicus*, *Symplocos cochichinensis*, *Machilus zuihoensis*, *Celtis formosana*, *Machilus japonica*, *Turpinia formosana*, and *Ficus fistulosa*. However, large proportions of the virgin forests have been replaced by fir plantations (*Cryptomeria japonica* and *Taiwania cryptomerioides*), bamboo groves (*Phyllostachys pubescens* and *Dendrocalamus latiflorus*), and secondary forest consisting of trees such as *Trema orientalis*, *Schefflera octophylla*, *Mallotus paniculatus*, *M. japonicus*, *Macaranga tanarius*, *Morus australis*, *Broussonetia papyrifera*, *Gordonia axillaris*, etc. In open (cleared) areas, herbaceous plants thrive, including *Miscanthus floridulus*, *Crassocephalum rabens*, *Sambucus formosana*, *Torenia concolor*, *Mazus faurei*, *Alocasia macrorrhiza*, *Bidens chilensis*, *Drymaria diandra*, *Setaria palmifolia*, and *Amischotolype chinensis*.

Animal capture

Shrews were captured in pitfall traps originally established to sample ground-dwelling reptiles. Four pitfall traps (30 cm in diameter, 45 cm deep) and drift-fences (6 m long) were arranged in a Y-shaped array. Three arms of the drift-fences radiated from a central pitfall and each was terminated by a distal pitfall. The 3 arms were separated by arcs of approximately 120°. A detailed account of a similar design can be found in Kirkland and Sheppard (1994). The pitfalls were left open with 20-25 cm of formalin in them and checked approximately every 10 d. A rain shade was added to each pitfall to prevent overflow. In total, seven arrays of pitfalls and drift-fences were set up in various habitats roughly

500-1500 m apart from each other: two in bamboo groves, two in conifer plantations, two in open areas, and one in natural forest. Trapping lasted from Aug. 1995 through May 1997. All pitfall sets were not operated for the same time period. In general, two sets of pitfalls were operated the entire time of trapping duration: one in conifer plantation and one in bamboo groves. Three sets of pitfalls were operated from Oct.-Nov. 1995 to May-July 1996: one in bamboo groves, one in natural forest, and one in open area. One set in an open area was open for just 2 mo, from June to July 1996.

Data analysis

At autopsy, since many shrews were convoluted or deformed during preservation, we took only 2 body measurements, tail length (TL) and hind foot length (HF), which were least affected. Reproductive status was then evaluated. For males, we recorded length of 1 testis and visibility of tubules in the cauda epididymis, indicating the presence of sperm. For females, we recorded the presence of enlarged nipples, indicating lactation, and the presence and number of embryos in uteri, indicating pregnancy. Checks of tubule visibility in males and embryos in females were performed under a dissecting microscope. A male was considered to be in breeding condition when the tubules in the cauda epididymis were visible (Yu 1993). A female was considered to be in breeding condition when either pregnant or lactating (Yu 1993).

Skulls of shrews were extracted, cleaned, and measured for condyloincisive length (CIL). Since the CIL is a good indicator of sizes in small mammals (Patton and Brylski 1987), histograms of CIL were used to analyze the age structure for each season. Since a sample of shrews can be composed of more than 1 cohort (age class), the frequency distribution of CIL in the sample is usually complicated by representation of different cohorts, thereby creating a polymodal distribution. Consequently, the hidden multiple modes in a CIL distribution are determined to be different age classes, and cut-off points are chosen by looking for the inflection points on probability plots of CIL. See Cassie (1954) and Harding (1949) for detailed examples of this method, and Yu (1993) and Chou et al. (1998) for its application in studies of small mammals. The PLOT procedure in the PC-version of SYSTAT (1990) was used to generate probability plots of CIL.

Seasonal changes in age structure and reproduction were analyzed by dividing the sampling time into 7 periods spanning from 1995 to 1997. We de-

fined each period based on the corresponding season as follows: fall (Sept.-Nov.), winter (Dec.-Feb.), spring (Mar.-May), and summer (June-Aug.).

All specimens were deposited as vouchers in the National Museum of Natural Science, Taichung, Taiwan.

RESULTS

In total, 564 shrews were captured, including 3 species (*Crocidura attenuata*, *C. kurodai*, and *Chodsigoa sodalis*). *C. kurodai* was by far the most abundant species (410 or 72.6% of the total captures), followed by *C. attenuata* (146 or 25.9% of the total captures), while only 8 (1.5%) *Chodsigoa sodalis* were captured. When the data were analyzed by season and habitat type, this abundance trend consistently held. The only conspicuous exception was in the open area during fall 1995, which

showed a reverse trend with the capture of 18 *C. attenuata* and 10 *C. kurodai*.

Table 1 indicates the average measurements in body size. *C. attenuata* is the larger species of the two. Both species show sexual dimorphism in tail length and hind foot length. However, sexual difference in skull length occurs only in *C. kurodai*.

Sex ratios differ in the 2 species (Table 2). While the sex ratio is strongly biased toward males in *C. kurodai* (more than 3:1, $\chi^2 = 90.3$, $p < 0.001$), the bias is less conspicuous in *C. attenuata* (roughly 1.5:1, $\chi^2 = 6.23$, $p < 0.05$). Moreover, when data were analyzed by season, the bias in *C. attenuata* disappeared. In contrast, the male-biased sex ratio in *C. kurodai* was always greater than 2:1, reaching as high as 5.7:1 in spring 1996.

Testis length in both species significantly differed between mature and immature individuals (Table 2). These results further justify our use of visibility of tubules in the cauda epididymis as a valid

Table 1. Body sizes (mean \pm SD mm, n = sample size) and t -test for sexual dimorphism of 2 white-toothed shrews from a subtropical montane forest in central Taiwan

Species	Condylolincisive length	Tail length	Hind foot length
<i>Crocidura attenuata</i>			
Female	20.29 \pm 0.54	47.73 \pm 2.28	14.18 \pm 0.57
<i>n</i>	53	60	60
Male	20.47 \pm 1.00	49.84 \pm 2.45	14.56 \pm 0.85
<i>n</i>	82	89	89
<i>t</i> -value	1.07	5.69***	2.58*
<i>Crocidura kurodai</i>			
Female	17.16 \pm 0.37	43.74 \pm 2.56	12.32 \pm 0.71
<i>n</i>	85	101	101
Male	17.41 \pm 0.41	45.91 \pm 2.49	12.77 \pm 0.68
<i>n</i>	266	292	292
<i>t</i> -value	4.09***	5.50***	3.40***

* $p < 0.05$.

*** $p < 0.001$.

Table 2. Sex ratios and reproductive characteristics (mean \pm SD, n = sample size) of 2 white-toothed shrews from a subtropical montane forest in central Taiwan

Species	Sex ratio ♀: ♂	Litter size	Immature testis length (mm)	Mature testis length (mm)
<i>Crocidura attenuata</i>	53: 82*. ^a	2.00 \pm 1.00 ($n = 3$)	3.25 \pm 0.53 ($n = 24$)	3.75 \pm 0.59 ^b ($n = 57$)
<i>Crocidura kurodai</i>	85: 262***	2.46 \pm 0.88 ($n = 13$)	2.11 \pm 0.53 ($n = 121$)	2.34 \pm 0.45 ^b ($n = 141$)

* and *** indicate a significant deviation from an equal sex ratio at the 5% and 0.1% levels, respectively.

^aNo difference from an equal sex ratio when data are analyzed by season.

^bSignificantly larger than those of immature shrews at the 0.1% level.

means to judge reproductive status in these shrews.

Embryo counts were greater in *Crociodura kurodai* than in *C. attenuata*, at 2.46 versus 2.00 (Table 2), but limited data on the latter ($n = 3$) may have biased the comparison. A female *C. attenuata* caught alive in Nov. 1998 gave birth to 3 stillborn young.

The percentages of breeding females in the 2 species differed (Figs. 1, 2). In *C. attenuata*, only 4 of 53 (8%) females showed signs of reproduction, whereas in *C. kurodai*, 23 of 85 (27%) were reproductively active. A heterogeneity test (Sokal and Rohlf 1981) indicates that the difference is significant ($G_H = 44.8, p < 0.001$). In contrast, a greater proportion of breeding males was found in *C. attenuata* than in *C. kurodai* ($G_H = 7.14, p < 0.01$). In *C. attenuata*, 57 of 81 (70%) of the males were reproductively active, whereas in *C. kurodai* only 141 of 262 (54%) were reproductively active.

Probability plot analyses of CIL in *C. attenuata* indicate that the entire sample contains 3 separate normal distributions. The cut-off points of the 3 distributions are 20 and 21 mm. However, studies of

laboratory-raised shrews (Hellwing 1973, Ishikawa and Namikawa 1991) indicate that, once reaching adulthood, shrews have an extremely low growth rate or even cease to grow. Consequently, shrews in any particular season can be treated, at most, as 2 cohorts. Shrews with CIL < 20 mm can be treated as in the young cohort; CIL \geq 20 but < 21 mm as in the adult cohort; and CIL \geq 21 mm as possibly older individuals in the adult cohort (Fig. 1). Likewise, in *C. kurodai*, shrews with CIL < 16.8 mm belong to the young cohort; CIL \geq 16.8 but < 18 mm to the adult cohort; and CIL \geq 18 mm to the older shrews in the adult cohort (Fig. 2).

Seasonal shifts in the CIL histograms were apparent for both species, at least from fall 1995 through spring 1996 when sample sizes were large (Figs. 1, 2). In *C. attenuata*, shrews of the young cohort for both sexes were present in every season (Fig. 1). The results suggest that *C. attenuata* may not have a conspicuous breeding season. Many male *C. attenuata* appeared to begin to mature sexually in their first year. The majority of the adult cohort and some members of the young cohort had sperm in their cauda epididymis. In contrast, few female *C. attenuata* were reproductively active in their first year, as indicated by only 1 of the adult cohort and

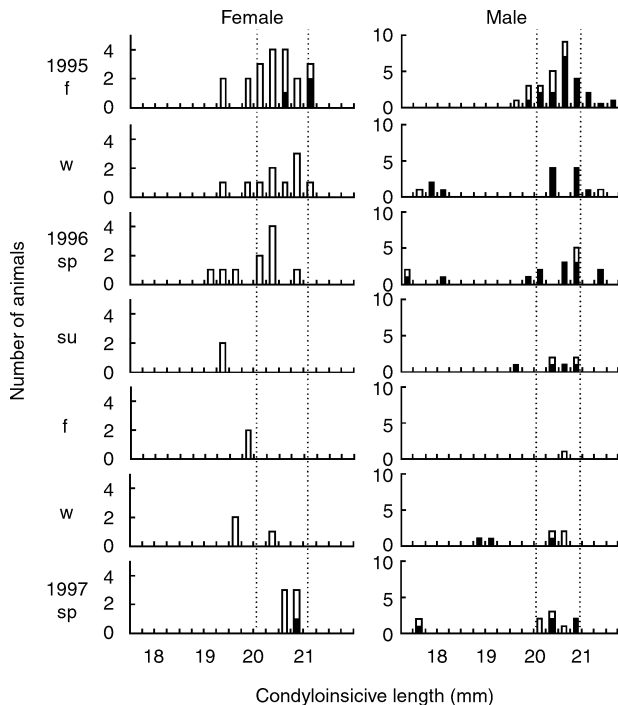


Fig. 1. Seasonal change in age structure and reproductive status for *Crociodura attenuata* from a low-elevation montane forest in subtropical central Taiwan. Age structures are displayed by histograms of CIL length. demarcates 3 CIL distributions (see text) that were detected by probability plot analysis. ■: breeding individuals; □: non-breeding individuals; f: fall; w: winter; sp: spring; su: summer.

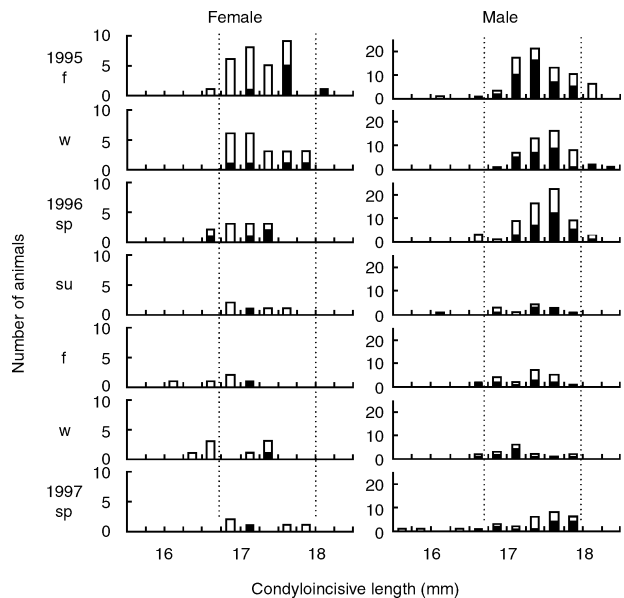


Fig. 2. Seasonal change in age structure and reproductive status for *Crociodura kurodai* from a low-elevation montane forest in subtropical central Taiwan. Age structures are displayed by histograms of CIL length. demarcates 3 distributions that were detected by probability plot analysis. ■: breeding individuals; □: non-breeding individuals; f: fall; w: winter; sp: spring; su: summer.

none of the young cohort recorded as pregnant or lactating. However, early pregnancy of some females may be undetected since no histological examinations were performed.

Crocidura kurodai shows a similar trend of non-seasonal breeding activity. Reproducing shrews occurred in every season, and young shrews were present in every season except in winter 1995 (Fig. 2). Unlike *C. attenuata*, however, both female and male *C. kurodai* tended to become sexually mature in their first year as evidenced by the substantial numbers of breeding shrews in the adult and young cohorts.

Among the 8 *Chodsigoa sodalis* caught, four were males and 4 were females, all of which were sexually immature.

Finally, the other mammals caught were 12 *Niviventer coxingi*, a murid rodent. The sole presence of this rat is consistent with previous records that small terrestrial mammal (body weight < 200 g) communities at elevations of 800-1200 m are depauperate, comprising just 1 rodent *N. coxingi* (Yu 1994, Yu and Lin 1999). The gap is filled by 3 species of shrews as revealed here.

DISCUSSION

Despite the conspicuous seasonal phenology in montane areas of Taiwan (Yu 1993, Yu and Lin 1999), the reproductive activities in the 2 crocidurine shrews do not seem to respond to seasonality. This greatly differs from the case of 2 soricine shrews, *Anourosorex squamipes* and *Soriculus fumidus*, which inhabit higher elevations in Taiwan and have distinct breeding seasons (Yu 1993). On one hand, the crocidurines are supposed to have evolved in tropical regions (Churchfield 1990) and are subjected to less seasonal fluctuation as occurs in temperate regions or in the high elevations of Taiwan (Lin and Shiraishi 1992a b, Yu 1993 1994, Huang et al. 1997). On the other hand, food is probably seldom in short supply at lower elevations. Insects and other invertebrates are active year-round as recorded in our pitfall traps. As long as energy demands are met, mammals usually breed continuously to maximize the life-time reproductive output (Bronson 1989, Bronson and Heideman 1994). However, in temperate regions, where food supplies are low in winter, crocidurine shrews may have a distinct breeding season, e.g., *C. suaveolens* (Rood 1965) and *C. russula* (Cantoni and Vogel 1989).

Notwithstanding, two aspects of reproduction in the 2 *Crocidura* species are noteworthy. First, the

sex ratios of the 2 species caught in pitfall traps differ. Although the combined sex ratio was slightly male-biased in *C. attenuata*, the seasonal sex ratio did not differ from 1:1. In contrast, the combined and seasonal sex ratios in *C. kurodai* were much more biased toward males. Second, although it is likely to be underestimated, the proportion of reproductive females of *C. attenuata* was extremely low; many shrews of the old cohort showed no signs of reproduction.

Social and mating systems in Soricidae have been reviewed by Churchfield (1990), Rychlik (1998), and Stockley and Searle (1998). So far, the majority of studies has concentrated on a few common species in temperate regions of the Northern Hemisphere, including a detailed study on free-ranging *C. russula* (Cantoni and Vogel 1989). During the breeding season, when the sex ratio is unbiased, female *C. russula* becomes territorial and forms monogamous pairs with a single male. The pair probably defends a territory and rears the young together. Furthermore, given the nearly equal sex ratio in *C. attenuata*, a monogamous mating system is quite possible for the species. For *C. kurodai*, in contrast, the excess of males and higher proportion of reproductive females suggest a promiscuous mating system and vagrant tendency in the species.

Although shrew communities above middle elevations (ca. 1400 m) in Taiwan are well known (Yu 1994), we know little about shrew assemblages in the forests at lower elevations. Previous attempts to study small mammals at these elevations have failed to uncover shrew communities because they focused on rodents (Yu and Lin 1999) or lacked long-term efforts (Fang et al. 1997). Consequently, trapping protocols used were not optimal for catching shrews, and the results revealed were incomplete. The co-occurrence of 3 species (*C. attenuata*, *C. kurodai* and *Chodsigoa sodalis*) at our study site is unprecedented for Taiwan. Moreover, the presence of *Chodsigoa sodalis* is somewhat unexpected because previous records (Yu 1994, Motokawa et al. 1997) indicated that it occurs at higher elevations and in very low numbers. The terrestrial mammal community at mid elevations (ca. 500-1400 m) of Taiwan is depauperate (Yu 1994, Yu and Lin 1999), with *N. coxingi* the sole mammalian species syntopic with the shrews.

In temperate regions, coexisting shrews tend to have different body sizes, presumably resulting from "competition in the past" (Kirkland 1991, Hanski 1994). Similar situations are found in subtropical Taiwan; *C. attenuata* (8-10 g) is larger than *C. kurodai* (4-6 g) (also see Table 1). A 3rd species

(*Chodsigoa sodalis*) is of a similar size (5.5 g) (Yu 1993) to *C. kurodai*. However, *C. sodalis*, having a prehensile tail, large hind feet, and well-developed toe pads, may be scansorial (unpubl. data). In lowland Taiwan, *C. attenuata* is syntopic with another smaller shrew (3-5 g), *C. suaveolens* (Fang et al. 1997).

Two conclusions can be drawn from this study. First, the 2 species of white-toothed shrews (*C. attenuata* and *C. kurodai*) show no seasonality of breeding activities, even though climatic seasonality is obvious in the montane areas of Taiwan. The continuous breeding activity may be due to abundant food supplies in their natural habitats. However, the 2 species may have different social structures and mating systems in view of their sex ratios and proportions of reproductively active individuals. Second, the shrew community revealed by an efficient collecting method has augmented our previous knowledge of the small mammal community that is often considered depauperate at mid elevations because of insufficient information on insectivores. In addition to 2 species of *Crocidura*, *Chodsigoa sodalis* also occurs in these general elevations (650-1200 m) and could be separated in niche occupation from the 2 *Crocidura* due to its climbing capability.

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臺灣中部亞熱帶山地森林共域白齒鼯鼠的季節週期研究

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我們研究臺灣低海拔山地森林下兩種白齒鼯鼠年齡結構和生殖活動的季節變化，包括灰鼯鼠 (*Crocidura attenuata*) 和長尾鼯鼠 (*C. kurodai*)。分析的 564 隻鼯鼠，乃利用攔截籬直落式陷阱 (drift-fence pit-fall traps) 自 1995 年八月至 1997 年五月於南投縣鹿谷鄉的鳳凰谷鳥園採得。兩種鼯鼠都無明顯的年生殖週期，然而從性別比例和生殖中的成熟個體比例推測兩種鼯鼠的社會組織和交配制度可能不同。此外，樣本中包括另一種稀有的鼯鼠，細尾長尾鼯 (*Chodsigoa sodalis*) 8 隻，以及一種鼠類，刺鼠 (*Niviventer coxingi*) 12 隻。本研究顯示過去東南亞地區的小型哺乳類研究往往忽視對食蟲目動物的調查。

關鍵詞： *Crocidura*，白齒鼯鼠，生殖季節，攔截籬直落式陷阱，鼯鼠科。

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