

# Population status and distribution of freshwater turtles in Taiwan

T I E N - H S I C H E N and K U A N G - Y A N G L U E

**Abstract** Because of burgeoning demand in the Chinese market and extensive habitat loss more than half of the freshwater turtle and tortoise species in Asia are categorized as Endangered or Critically Endangered on the IUCN Red List. To investigate the distribution and status of the native freshwater turtle species of Taiwan a trapping programme was conducted during 2001–2007, yielding a total of 1,828 individuals of four native species at 103 sites. *Mauremys sinensis* was the most abundant and widely distributed species; it was collected from 70 sites and accounted for 78.6% of all turtles captures. *Mauremys mutica* comprised 17.8% at 46 sites. *Pelodiscus sinensis* were captured in low numbers at 19 sites. No *Mauremys reevesii* were collected on the main island of Taiwan but the species was found on Kinmen Island near mainland China. Capture success was low at most sites and overall sex ratios were significantly male-biased in all species, suggesting that the freshwater turtles have suffered from the negative effects of habitat disturbance and extensive exploitation. Effective conservation measures are urgently required to ensure the viability of the native freshwater turtle species of Taiwan.

**Keywords** Distribution, freshwater, *Mauremys*, *Pelodiscus sinensis*, population, status, turtle, Taiwan

This paper contains supplementary material that can be found online at <http://journals.cambridge.org>

## Introduction

Many freshwater turtles and tortoises in Asia are threatened because of a burgeoning demand for them as food and for use in traditional medicines (van Dijk et al., 2000). Of the 87 non-marine chelonian species recorded in Asia, 47 are categorized as Endangered or Critically Endangered on the IUCN Red List (IUCN, 2008). The demand for turtles in China has severely affected the turtle fauna in adjacent countries (Cheung & Dudgeon, 2006). In Taiwan there are four native freshwater turtles:

T I E N - H S I C H E N\* (Corresponding author) and K U A N G - Y A N G L U E Department of Life Science, National Taiwan Normal University, Taipei, Taiwan. E-mail [cuora.flavo@msa.hinet.net](mailto:cuora.flavo@msa.hinet.net)

\*Current address: Ching Kuo Institute of Management and Health, Keelung 203, Taiwan

Received 9 April 2008. Revision requested 25 June 2008.  
Accepted 16 August 2008.

the Chinese stripe-necked turtle *Mauremys sinensis*, Asian yellow pond turtle *Mauremys mutica*, Chinese three-keeled pond turtle *Mauremys reevesii* and Chinese softshell turtle *Pelodiscus sinensis* (Mao, 1971; Iverson, 1992). With both a high commercial value and high demand the four species have suffered intensive harvesting pressure (Chen et al., 2000). Because these species have been commonly consumed and farmed in China (Cheung & Dudgeon, 2006; Shi et al., 2008) they are susceptible to illegal cross-border trade, especially smuggling. Furthermore, while *M. sinensis* and *P. sinensis* have also been farmed (or ranched) and are released as prayer animals in traditional rituals in Taiwan, the wild populations are threatened by extensive collection for replenishment of breeding stock and ritual release (Chen et al., 2000).

These species were formerly widely distributed in lowland aquatic habitats (Lue et al., 2002). However, *M. mutica*, *M. reevesii* and *M. sinensis* are now categorized as Endangered and *P. sinensis* as Vulnerable on the IUCN Red List (IUCN, 2008; we use the genus names provided by Turtle Taxonomy Working Group, 2009: *Mauremys reevesii* = *Chinemys reevesii* and *Mauremys sinensis* = *Ocadia sinensis*). Extensive habitat loss and commercial exploitation are the main threats. The Taiwanese populations of *M. mutica* and *M. reevesii* are protected under the Wildlife Conservation Act. With little information available on the current status and distribution of the freshwater turtles of Taiwan it is difficult to plan appropriate conservation measures. The objective of the study reported here was, therefore, to obtain this information.

## Methods

We conducted an island-wide trapping programme (including Kinmen Island near mainland China) of the freshwater turtles of Taiwan from February 2001 to December 2007. Based on 1:25,000 maps published by the Ministry of Interior, Republic of China, we identified 182 potentially suitable habitats for freshwater turtles (Fig. 1), i.e. permanent and temporary ponds, slow-moving rivers and streams, agricultural ditches, wet meadows and wetlands. Turtles were collected with home-made funnel traps (with 2 × 2 cm mesh) baited with canned cat food. We have successfully used this trap in previous studies (Chen & Lue, 1998a,b, 2009; Chen, 2006). Usually 3–5 traps were set at each site along riverbanks or at the margins of other water bodies and were checked once or twice per week. If no turtles were captured after 2 weeks of trapping at a site we

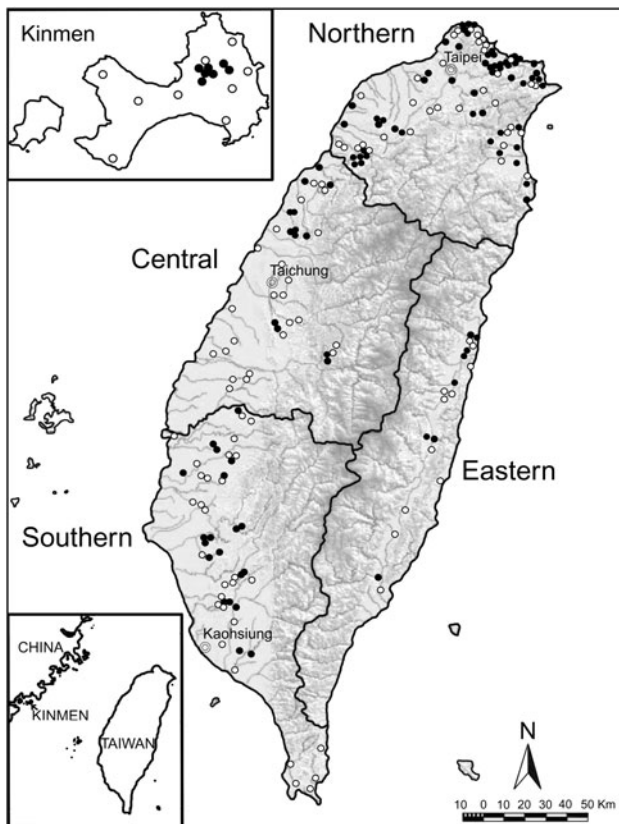


FIG. 1 The 182 sites at which we set traps for native freshwater turtles in Taiwan during 2001–2007. The black and white dots indicate sites where one or more native species were or were not trapped, respectively.

assumed that turtles were not present or that their density was very low. As this study was carried out in conjunction with a trapping programme for the analysis of the population genetics of native turtle species we tried to collect at least 10 individuals of each native species at each site. We moved the trapping to a new site after 10 individuals were captured or after 1–2 months of trapping, except at six sites where we trapped for > 1 year in conjunction with population studies. Because trapping efficiency is related to season and weather condition we did not estimate trapping efficiency. Trapped turtles were marked with individual marginal notches, with a hand-saw or triangular file, for further identification (Cagle, 1939), sexed using external secondary sexual characteristics, measured (straight carapace length) to the nearest 0.1 mm with vernier callipers, and then released at point of capture. In the population analyses we pooled samples of sites < 1 km apart.

## Results

A total of 2,109 individual freshwater turtles were trapped from 111 sites, including 281 individuals of four non-native species (*Trachemys scripta elegans*, *Pseudemys nelsoni* and *Graptemys pseudogeographica* from North America, and

*Cuora trifasciata* from South-east Asia), and 1,824 individuals of four native species and four hybrids at 103 of the 111 sites (Table 1, Appendix). *M. sinensis* was the most abundant and widely distributed species, comprising 78.6% of the native turtles captured (Fig. 2a). *M. mutica* comprised 17.8% of the turtles caught (Fig. 2b). *M. reevesii* was trapped at only seven sites, on Kinmen Island (Fig. 2c). *P. sinensis*, the most important commercial species, comprised only 2.3% of the total trapped (Fig. 2d). The numbers of turtles captured at most sites were low (Appendix); > 20 individuals of *M. sinensis* and *M. mutica* were trapped at only nine and six sites, respectively. The sex ratio of all native species was significantly male-biased (Table 1).

*M. sinensis* was mostly trapped in northern, central and southern Taiwan, with only two individuals trapped in the east, in slow-moving rivers and ditches at low elevations, and in wetlands, agricultural reservoirs and ponds on plains, plateaus and in montane areas. It was also trapped in brackish water near estuaries such as the lower section of the Houlong River.

*M. mutica* was most commonly trapped in the northern region, in small water bodies in montane or plateau areas, including agricultural and temporary forested ponds, irrigation ditches and wet meadows, and none were trapped in the southern region. A few individuals were captured in riverine habitats or larger-sized water bodies in lowland areas. The localities in which the species was trapped were mostly associated with forest.

*M. reevesii* was not trapped on the main island of Taiwan. However, four *M. reevesii*-related hybrids were captured at three sites in northern Taiwan, indicating that this species has either declined to an extremely low density there or disappeared.

*P. sinensis* was trapped at 19 sites in rivers, streams, wetlands and ponds. None were captured from southern Taiwan. On Kinmen Island only one hatchling *P. sinensis* was caught.

## Discussion

*M. sinensis* was formerly a common species in southern and northern Taiwan (Stejneger, 1907; Pope, 1935), inhabiting slow-moving water of open country at low elevations, and was regarded as distributed island-wide (Takahashi, 1934). Although it was the most widely distributed turtle in our survey, capture success at most sites was low, suggesting that population sizes are small.

*M. mutica* is regarded as a semi-aquatic species (Ernst & Barbour, 1989), occurring in water bodies with slow currents in mountain basins or river valleys and making occasional terrestrial excursions (Pope, 1935; Mao, 1971; Wang et al., 1984; Ernst & Barbour, 1989). We trapped *M. mutica* in the vicinity of broad-leaf woodland or secondary forest. Similar to our findings, earlier surveys

TABLE 1 Summary of the numbers of the four native species of freshwater turtles, and the number of hybrid individuals, trapped during 2001–2007 in the northern, central, southern and eastern regions of Taiwan and on the island of Kinmen (Figs 1 & 2) and overall, the total numbers of males, females and juveniles trapped, the total number of survey sites, and the collection dates for each area. Numbers in parentheses indicate numbers of sites out of a total of 111 at which native species were captured. For detailed results see Appendix.

	Region					Total	No. of males*	No. of females*	No. of juveniles
	Northern	Central	Southern	Eastern	Kinmen				
<i>Mauremys sinensis</i>	1,244 (40)	91 (8)	100 (20)	2 (2)	0	1,437 (70)	1,018	299	120
<i>Mauremys mutica</i>	297 (36)	17 (5)	0	11 (5)	0	325 (46)	178	113	34
<i>Mauremys reevesii</i>	0	0	0	0	20 (7)	20 (7)	14	3	3
<i>Pelodiscus sinensis</i>	27 (13)	7 (2)	0	7 (3)	1 (1)	42 (19)	22	7	13
Hybrids	4 (3)	0	0	0	0	4 (3)	3	1	0
No. of sites	91 (55)	37 (13)	49 (20)	19 (8)	16 (7)	182 (103)			
Survey dates	Feb. 2001–Dec. 2007	May 2002–Dec. 2004	Sep. 2002–Apr. 2005	May 2003–Oct. 2003	Apr. 2004–Sept. 2005				

\*All sex ratios were significantly male-biased: *M. sinensis*,  $G = 414.81$ ,  $P < 0.001$ ; *M. mutica*,  $G = 14.24$ ,  $P < 0.001$ ; *M. reevesii*,  $G = 7.72$ ,  $P < 0.01$ ; *P. sinensis*,  $G = 8.15$ ,  $P < 0.01$

in central and southern Taiwan detected only a few individuals in the central region (Nantou County) and none in the southern region (Lin, 1996; Peng, 1997a,b, 2000a,b, 2001).

Although *M. reevesii* occurs throughout China, Korea and Japan we located only a few individuals, on Kinmen Island. Compared to other species this turtle was recorded relatively late in Taiwan, suggesting that, even formerly, it was less abundant or had a narrow geographical range. It was first reported on the basis of a specimen collected near Taipei, in 1931 (Horikawa, 1934). Kuntz & Dien (1970) collected some specimens from the Taipei basin (detailed localities are accessible in the collection database of the Field Museum of Natural History, Chicago, USA). Although Mao (1971) collected a few specimens near Taipei and in central Taiwan (Nantou) the species has not been found in central Taiwan in more recent surveys (Lin, 1996; Peng, 1997a,b). However, although we did not locate *M. reevesii* on mainland Taiwan the finding of *M. reevesii*-related hybrids in northern Taiwan indicates that this turtle may exist at a low density or may have been recently extirpated. Analyses of mtDNA of these hybrids indicate that they are closely related to *M. reevesii* (T.-H. Chen, unpubl. data).

*P. sinensis* was rarely captured in this study although it was earlier reported as a widespread species (Chen, 1969). This species is highly aquatic and carnivorous, preferring slow-moving habitats with a bottom substrate of soft mud or sand (Wang et al., 1984; Ernst & Barbour, 1989). It has been commonly found in central and southern Taiwan, although at low densities (Lin, 1996; Peng, 1997a,b, 2000a,b, 2001). *P. sinensis* may be underrepresented in our survey because of its specialized food habits and habitat preference. Wild-caught *P. sinensis* are regarded as a valuable food and have been harvested extensively. Collection pressure may be higher in southern Taiwan, where most of the turtle farms are located, than in other regions, and we did not locate any individuals in this region. The single *P. sinensis* that we located on Kinmen Island may be an accidental escapee or intentional release from experimental turtle farming conducted by the local government.

Although we did not evaluate trapping efficiency in this study the highly male-biased sex ratios of captured turtles and the generally low capture success raise concerns regarding the population stability and persistence of the four native species. Unbalanced sex ratios seem to be common in natural populations of turtles (Bury, 1979). This could be explained by sampling biases, differential mortality of the sexes or differences between the sexes in age at maturity (Gibbons, 1990). In northern Taiwan the male bias of the turtle sex ratio increased dramatically following a flood control project (Chen & Lue, 2009), suggesting that male-biased sex ratios are unlikely to be due only to sampling bias.

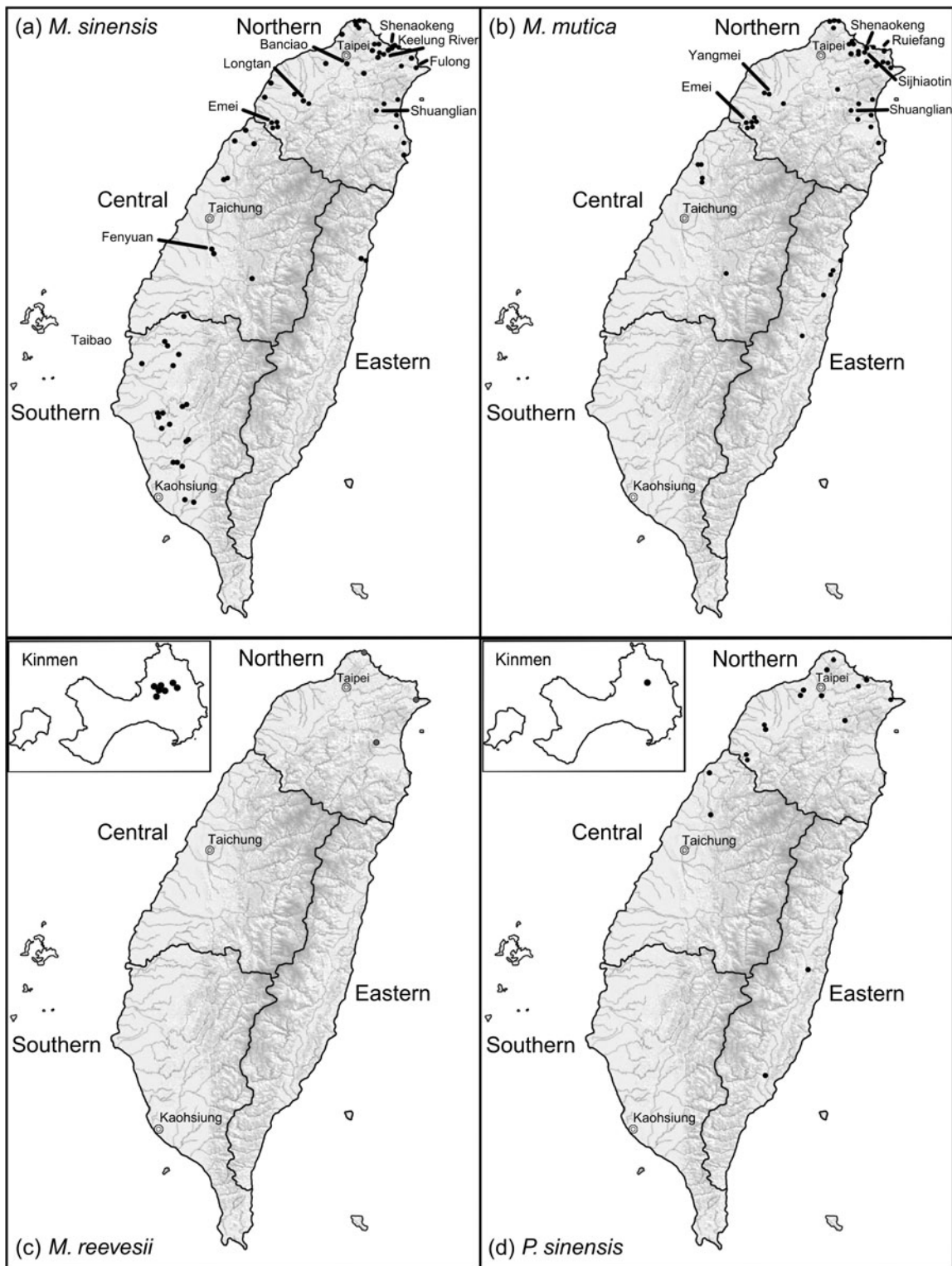


FIG. 2 Distribution of the four native freshwater turtles captured on Taiwan, including Kinmen, an island near mainland China, in 2001–2007: (a) *Mauremys sinensis*, (b) *Mauremys mutica*, (c) *Mauremys reevesii*, (d) *Pelodiscus sinensis*. The black and white dots indicate sites where the species were and were not located, respectively; the grey dots in (c) indicate the locations of *M. reevesii*-related hybrids.

The structure of freshwater turtle populations may be affected by disturbances such as road mortality, habitat fragmentation and recreational activities (Dodd, 1990; Garber & Burger, 1995; Rizkalla & Swihart, 2006). In

disturbed habitats the population structure of freshwater turtles may become male-biased and adult-dominated because of differential mortality between sexes and decrease in recruitment (Marchand & Litvaitis, 2004; Gibbs & Steen,

2005), and the increasingly male-biased sex ratios are associated with differential road mortality between the sexes (Gibbs & Shriver, 2002; Marchand & Litvaitis, 2004; Steen & Gibbs, 2004). The unbalanced sex ratios found in our surveys were probably caused by a combination of habitat alteration and sex-biased road mortality.

Habitat destruction and loss, particularly in riparian and aquatic habitats, may be the greatest threat to freshwater turtles in Taiwan. In most river management projects the requirements of aquatic fauna are not considered and rapid habitat alteration in such projects has had negative impacts on turtle populations (Bodie, 2001; Chen & Lue, 2009). Taiwan has experienced rapid human population expansion in the past 50 years and this has resulted in extensive urban and suburban development and consequent loss of many important aquatic habitats for freshwater turtles. In addition, the extension of the road network has had localized impacts on turtle populations.

Although the Taiwanese rarely consume the meat of hard-shelled turtles because of religious beliefs and cultural factors, many wild turtles (mainly *M. sinensis*) have been collected for the pet trade, replenishment of turtle farm breeding stocks, and illegal trade to China (Chen et al., 2000). The harvest of turtle species that are not on the protected wildlife list (*M. sinensis* and *P. sinensis*) has never been closely regulated in Taiwan. The sustainability of unmanaged freshwater turtle resources has therefore been questioned (Thorbjarnarson et al., 2000; Cheung & Dudgeon, 2006). The regional commercial trade of freshwater turtles is a large-scale business in Asia, mostly associated with mainland China (van Dijk et al., 2000). The native freshwater turtles in Taiwan, both the species with legal conservation status and the unlisted species, are also at risk of being traded illegally to China. Without effective management of commercial harvests, extirpation of populations of freshwater turtles in Taiwan is likely unless conservation efforts are undertaken soon.

Based on our results the conservation status of the freshwater turtles of Taiwan was re-evaluated in 2008 and *M. reevesii* was upgraded under the Wildlife Conservation Act from Rare and Valuable to Endangered because of the species' limited distribution range and low population density. More effective management plans are still nevertheless needed for the long-term survival of all of the freshwater turtle species of Taiwan.

## Acknowledgements

We thank E.Y. Tsoa and two anonymous reviewers for their valuable comments on this manuscript. We greatly appreciate the help of S.-L. Liu, Y.-D. Lue and T.-W. Tzeng, who assisted in fieldwork. This study was supported by the National Science Council and Council of Agriculture, Republic of China. Studies were conducted under the

permits of the Wildlife Conservation Law from the Council of Agriculture (Permits to T.-H. Chen: 0920127668, 0931614045, 0941611580).

## References

- BODIE, J.R. (2001) Stream and riparian management for freshwater turtles. *Journal of Environmental Management*, 62, 443–455.
- BURY, R.B. (1979) Population ecology of freshwater turtles. In *Turtles: Perspectives and Research* (eds M. Harless & H. Morlock), pp. 571–602. Wiley and Sons, New York, USA.
- CAGLE, F.R. (1939) A system of marking turtles for future identification. *Copeia*, 1939, 170–173.
- CHEN, J.T.F. (1969) *A Synopsis of the Vertebrates of Taiwan*. Commercial Press, Taipei, Taiwan. [in Chinese]
- CHEN, T.-H. (2006) Distribution and status of the introduced red-eared slider (*Trachemys scripta elegans*) in Taiwan. In *Assessment and Control of Biological Invasion Risks* (eds F. Koike, M.N. Clout, M. Kawamichi, M. de Poorter & K. Iwatsuki), pp. 187–196. Shoukadoh Book Sellers, Tokyo, Japan, and IUCN, Gland, Switzerland.
- CHEN, T.-H., LIN, H.-C. & CHANG, H.-C. (2000) Current status and utilization of the chelonians in Taiwan. *Chelonian Research Monographs*, 2, 45–51.
- CHEN, T.-H. & LUE, K.-Y. (1998a) Ecology of the Chinese stripe-necked turtle, *Ocadia sinensis* (Testudines: Emydidae), in the Keelung River, northern Taiwan. *Copeia*, 1998, 944–952.
- CHEN, T.-H. & LUE, K.-Y. (1998b) Ecological notes on feral populations of *Trachemys scripta elegans* in northern Taiwan. *Chelonian Conservation and Biology*, 3, 87–90.
- CHEN, T.-H. & LUE, K.-Y. (2009) Changes in population structure and diet of the Chinese stripe-necked turtle (*Mauremys sinensis*) inhabiting a disturbed river in northern Taiwan. *Zoological Studies*, 48, 95–105.
- CHEUNG, S.M. & DUDGEON, D. (2006) Quantifying the Asian turtle crisis: market surveys in southern China, 2000–2003. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 16, 751–770.
- DODD, C.K., JR. (1990) Effects of habitat fragmentation on a stream-dwelling species, the flattened musk turtle *Sternotherus depressus*. *Biological Conservation*, 54, 33–45.
- ERNST, C.H. & BARBOUR, R.W. (1989) *Turtles of the World*. Smithsonian Institution Press, Washington, DC, USA.
- GARBER, S.D. & BURGER, J. (1995) A 20-year study documenting the relationship between turtle decline and human recreation. *Ecological Applications*, 5, 1151–1162.
- GIBBONS, J.W. (1990) Sex ratios and their significance among turtle populations. In *Life History and Ecology of the Slider Turtle* (ed. J.W. Gibbons), pp. 172–182. Smithsonian Institution Press, Washington, DC, USA.
- GIBBS, J.P. & SHRIVER, W.G. (2002) Estimating the effects of road mortality on turtle populations. *Conservation Biology*, 16, 1647–1652.
- GIBBS, J.P. & STEEN, D.A. (2005) Trends in sex ratios of turtles in the United States: implications of road mortality. *Conservation Biology*, 19, 552–556.
- HORIKAWA, Y. (1934) Turtles of Taiwan. *The Taiwan Jihō*, 181, 7–16. [in Japanese]
- IVERSON, J.B. (1992) *A Revised Checklist with Distribution Maps of the Turtles of the World*. Privately printed, Richmond, Indiana, USA.
- IUCN (2008) *2008 IUCN Red List of Threatened Species*. IUCN, Gland, Switzerland. <http://www.iucnredlist.org> [accessed 18 June 2009].

- KUNTZ, R.E. & DIEN, Z.M. (1970) Vertebrates of Taiwan taken for parasitological and biomedical studies by US Naval Medical Research Unit No. 2, Taipei, Taiwan, Republic of China. *Quarterly Journal of Taiwan Museum*, 23, 1–37.
- LIN, H.-C. (1996) *Reptiles of Nantou County*. Taiwan Endemic Species Research Institute, Chichi, Taiwan. [in Chinese]
- LUE, K.-Y., TU, M.-C. & SHIANG, K.-S. (2002) *A Field Guide to Amphibians and Reptiles of Taiwan*. Society for Wildlife and Nature, Taipei, Taiwan. [in Chinese]
- MAO, S.H. (1971) *Turtles of Taiwan*. Commercial Press, Taipei, Taiwan.
- MARCHAND, M.N. & LITVAITIS, J.A. (2004) Effects of habitat features and landscape composition on the population structure of a common aquatic turtle in a region undergoing rapid development. *Conservation Biology*, 18, 758–767.
- PENG, K.-D. (ed.) (1997a) *The Biological Resources of Yunlin County: A Preliminary Bioinventory Report*. Taiwan Endemic Species Research Institute, Chichi, Taiwan. [in Chinese]
- PENG, K.-D. (ed.) (1997b) *Wildlife of Taichung County and Taichung City*. Taiwan Endemic Species Research Institute, Chichi, Taiwan. [in Chinese]
- PENG, K.-D. (ed.) (2000a) *Amphibians and Reptiles of Tainan County and Tainan City*. Taiwan Endemic Species Research Institute, Chichi, Taiwan. [in Chinese]
- PENG, K.-D. (ed.) (2000b) *Wildlife of Kaohsiung County and Kaohsiung City*. Taiwan Endemic Species Research Institute, Chichi, Taiwan. [in Chinese]
- PENG, K.-D. (ed.) (2001) *Wildlife of Pintung County*. Taiwan Endemic Species Research Institute, Chichi, Taiwan. [in Chinese]
- POPE, C.H. (1935) *The Reptiles of China. Turtles, Crocodilians, Snakes, Lizards. Natural History of Central Asia*, Vol. X. The American Museum of Natural History, New York, USA.
- RIZKALLA, C.E. & SWIHART, R.K. (2006) Community structure and differential responses of aquatic turtles to agriculturally induced habitat fragmentation. *Landscape Ecology*, 21, 1361–1375.
- SHI, H., PARHAM, J.F., FAN, Z., HONG, M. & YIN, F. (2008) Evidence for the massive scale of turtle farming in China. *Oryx*, 42, 147–150.
- STEEN, D.A. & GIBBS, J.P. (2004) Effects of roads on the structure of freshwater turtle populations. *Conservation Biology*, 18, 1143–1148.
- STEJNEGER, L. (1907) *Herpetology of Japan and Adjacent Territory*. Smithsonian Institution, Washington, DC, USA.
- TAKAHASHI, S. (1934) Notes on breeding of *Ocadia sinensis*. *Kagaku*, 4, 7–8. [in Japanese]
- THORBJARNARSON, J., LAGUEUX, C.J., BOLZE, D., KLEMENS, M.W. & MEYLAN, A.B. (2000) Human use of turtles: a worldwide perspective. In *Turtle Conservation* (ed. M.W. Klemens), pp. 33–84. Smithsonian Institution Press, Washington, DC, USA.
- TURTLE TAXONOMY WORKING GROUP (2009) *Turtles of the World: Annotated Checklist of Taxonomy and Synonymy, 2009 Update, with Conservation Status Summary*. IUCN/Species Survival Commission Tortoise and Freshwater Turtle Specialist Group. <http://www.iucn-tftsg.org/checklist/> [accessed 21 December 2009].
- VAN DIJK, P.P., STUART, B.L. & RHODIN, A.G.J. (eds) (2000) *Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia*. Chelonian Research Foundation, Lunenburg, USA.
- WANG, Y., CHEN, L., HSIA, C. & CHEN, P. (1984) A preliminary study of the ecology of *Clemmys mutica*. *Chinese Wildlife*, Harbin, 1984, 25–29. [in Chinese]

## Appendix

The appendix for this article is available online at <http://journals.cambridge.org>

## Biographical sketches

TIEN-HSI CHEN is a member of the IUCN Tortoise and Freshwater Turtle Specialist Group and has worked mainly on the ecology, status and conservation of the freshwater turtles and marine turtles of Taiwan. He is also concerned about the potential impacts of introduced red-eared sliders on the native fauna and has studied the turtle shell trade in the traditional Chinese medicine market. KUANG-YANG LUE's research focuses on the biogeography and phylogeny of amphibians and reptiles in East Asia, life histories of amphibians in Taiwan, and expansion of introduced amphibians and reptiles. He has described several new species of frogs, salamanders and lizards from Taiwan and has also been widely involved in biodiversity conservation education.