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Conservation et commerce des tortues d'eau douce et des tortues terrestres
[résolution Conf. 11.9 (Rev. CoP12) et décision 12.43]

PREPARATION DE MESURES DE CONSERVATION A MOYEN ET A LONG TERMES
POUR LES TORTUES TERRESTRES ET LES TORTUES D'EAU DOUCE

1. Le présent document a été préparé par l'Autorité scientifique de l'Allemagne; il est fondé sur les conclusions techniques d'un projet de recherche et de développement réalisé par TRAFFIC Asie du sud-est[1].

Contexte

2. Plusieurs autorités de pays d'importation et de pays d'exportation ont mis en lumière la situation précaire dans laquelle se trouvent depuis quelques années les tortues terrestres et les tortues d'eau douce d'Asie du sud-est. Le déclin dramatique persistant de quelque 90 espèces, combiné à la volonté de coopérer manifestée par les Etats de l'aire de répartition pour traiter cette question, a entraîné l'établissement du Groupe de travail sur les tortues terrestres et les tortues d'eau douce par le Comité pour les animaux. En outre, un atelier tenu à Phnom Penh (Cambodge) en 1999 a fait part d'importantes découvertes sur les mécanismes du commerce et son niveau. A la 11e session de la Conférence des Parties, la proposition d'inscrire le genre *Cuora* à l'Annexe II soumise par l'Allemagne a été adoptée.

3. Les travaux de recherche de l'Allemagne concernant le commerce et la conservation des tortues terrestres et des tortues d'eau douce ont continué avec le lancement du projet sur la "Préparation de mesures de conservation à moyen et à long termes pour les tortues terrestres et les tortues d'eau douce", réalisé par TRAFFIC Asie du sud-est par le biais du WWF Allemagne. Outre la préparation de propositions d'inscription à soumettre à la 12e session de la Conférence des Parties, le projet visait à réunir et évaluer des informations sur l'élevage à des fins commerciales et la possibilité qu'il réduise l'intérêt pour les spécimens sauvages, et à aborder la question du risque pouvant résulter de l'élevage en captivité d'espèces exotiques. En outre, les activités d'élevage actuelles et celles requises aux fins de conservation pour les espèces d'Asie du sud-est ont été évoquées.

4. Les résultats préliminaires ont été présentés lors des discussions au sein des organismes internationaux pertinents (Comité pour les animaux, groupe de travail de ce Comité, atelier tenu en 2002 à Kunming, Chine). Les résultats finals sont maintenant présentés par l'Allemagne et par TRAFFIC Asie du sud-est à l'appui des activités en cours du groupe de travail du Comité pour les animaux et pour encourager la communauté internationale à poursuivre son action en vue de la conservation de ce groupe d'espèces sérieusement menacé.

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Brève présentation des conclusions techniques

5. Lors de l'atelier sur le commerce des tortues d'Asie tenu à Phnom Penh en 1999, l'on a constaté que l'élevage en ferme à des fins commerciales des tortues d'eau douce était important et largement répandu en Asie. Celui des tortues molles de Chine (*Pelodiscus sinensis*) remonte au 19e siècle au Japon et a connu plusieurs cycles d'expansion et de régression, en particulier à Taïwan, et a atteint un pic en Malaisie et en Thaïlande à la fin des années 1990. Les participants à l'atelier ont également pris conscience de l'existence d'établissements d'élevage commercial à grande échelle qui produisent chaque année à Taïwan des dizaines ou des centaines de milliers de nouveau-nés d'*Ocadia sinensis*. Enfin, il est apparu que de petits établissements ou des établissements de taille moyenne produisaient en Chine continentale des centaines, voire des milliers, de spécimens de taille commercialisable de *Cuora trifasciata*, *Mauremys mutica* et peut-être d'autres espèces de tortues d'eau douce à carapace dure.

6. L'existence d'un élevage commercial en ferme a suscité une préoccupation générale car il porte souvent sur des espèces qui ne proviennent pas de la zone où l'élevage ou la commercialisation sont pratiqués, si bien que des populations viables pourraient s'établir à partir d'animaux qui s'échappent ou qui sont relâchés délibérément. L'on s'est largement interrogé sur les effets de ces populations, qui pourraient aller de la compétition avec les espèces de tortues d'eau douce indigènes et la pollution génétique jusqu'à des altérations fondamentales des écosystèmes locaux – même si l'on a reconnu qu'il existait très peu de données de terrain objectives.

7. L'annexe 1 au présent document présente en détail deux études de terrain sur l'élevage de tortues en ferme faites pour le projet réalisé par TRAFFIC Asie du sud-est au nom de l'Agence fédérale allemande pour la conservation de la nature (*Bundesamt für Naturschutz*, BfN). La première, en octobre 2001, a été entreprise en conjonction avec une mission de recherche de l'Université de Berkeley (Californie) pour étudier la génétique des tortues d'élevage. Dans le cadre de cette étude, une grande ferme du centre de l'île de Hainan (Chine) abritant 40 espèces différentes de tortues d'eau douce, des établissements de la province de Guangdong, le marché de Qing Ping de la ville de Guangzhou, et des marchés de produits alimentaires et d'animaux de compagnie de Hong Kong ont été visités. L'augmentation considérable récente de l'élevage de tortues en ferme en Chine continentale, qui remonte au moins aux années 1980, a été confirmé. La seconde étude a été faite en septembre 2002 pour évaluer la situation actuelle de l'élevage des tortues molles en Thaïlande. Les résultats sont frappants: alors qu'il existait des milliers de fermes il y a trois ans, une seule dispose encore d'un stock de ces tortues: toutes les autres se sont reconverties dans l'élevage de crevettes, de tilapias, de gouramis et autres poissons.

8. Au titre de ce projet, des informations sur l'élevage commercial des tortues d'eau douce ont été recherchées et compilées. Il y a peu d'indications dans la littérature technique internationale, que ce soit dans le domaine de l'herpétologie ou celui de l'aquaculture, et il y en a également peu dans les sources informelles telles que journaux, statistiques officielles et autres documents. Cependant, l'on trouve de nombreuses informations en Chine et en Thaïlande dans les langues locales, sous forme de manuels d'instruction à l'intention des futurs éleveurs de tortues et de ceux qui sont en activité; ces manuels sont publiés avec la participation de sociétés fournissant des matériels d'aquaculture et des aliments, et des services de vulgarisation du gouvernement en matière d'aquaculture. Ces manuels se présentent sous forme de petites brochures bon marché, valant l'équivalent d'un ou de quelques euros mais aussi de CD vidéo en Chine, à des prix similaires.

9. L'annexe 2 au présent document présente en détail les informations résultant d'un examen de l'élevage de tortues d'eau douce à des fins de conservation dans le cadre du même projet BfN/TRAFFIC Asie du sud-est. La plupart des informations factuelles proviennent de revues d'amateurs de la dernière décennie mais des informations supplémentaires précieuses sur les activités en cours ont été reçues par courriel et grâce à des contacts personnels. Le Colloque international sur les tortues marines et terrestres, tenu à Vienne en janvier 2002, a revêtu une importance particulière en ce qu'il a réuni des amateurs de plus de 20 pays qui ont présenté et écouté quelque 85 présentations sur l'élevage en captivité de certaines espèces de tortues, sur les avancées en matière de soins vétérinaires, et sur la situation et la biologie des tortues dans la nature. Le principal chercheur a participé autant que possible aux activités de *Turtle Survival Alliance* et s'est efforcé de se tenir informé des derniers développements dans les pays non anglophones d'Europe et en Asie, ce qui, bien sûr, a été une tâche ardue compte tenu de l'ampleur des activités réalisées, entreprises et planifiées dans ces régions. La section 2 de l'annexe donne des indications sur les tendances et présente quelques unes des réalisations de l'élevage de ces espèces à des fins de conservation.

Review of Commercial Breeding of Turtles concerning Asia

Species of freshwater turtles widely bred for Asian trade

Turtle breeding operations in Asia are dominated by farming of the Chinese softshell turtle, *Pelodiscus sinensis* (previously known as *Trionyx sinensis* or *Trionyx japonicus*), and its culture and trade history is described in some detail below. This species is favoured for commercial culture by its combination of suitable characteristics, being rapid growth rate, relatively high annual reproductive output, widespread consumer acceptance, and extensive understanding of conditions for farming.

Other species of freshwater turtles are also bred commercially in varying quantities and at varying degrees of self-sustainability. Reasons for breeding species other than the Chinese softshell turtle include higher value per animal or per kg for some species, convenient local availability of founder stock of certain species, or environmental conditions that are better suited for farming of particular species.

At least one farm exists in Hainan, China, whose owner claims to breed 10,000 hatchlings of the softshell turtle species *Palea steindachneri*. While it is difficult to verify the number, there is no doubt that significant numbers of eggs and hatchlings are produced within the confines of the farm, and that additions of wild-caught founder stock, if any, are infrequent. Thus, this farm is well on its way to self-sustaining, closed-cycle captive breeding of this highly valuable species (Shi & Parham, 2001; Shi, Parham & van Dijk, pers. obs. 2001).

A number of enterprising individuals in Thailand and perhaps elsewhere have investigated the possibilities to farm the native *Amyda cartilaginea* softshell turtle. This species, however, proved to have slower growth and lower annual reproductive output than the Chinese softshell turtle, particularly under similar tropical conditions, and any increased value per kg of *Amyda* was insufficient to compete financially with the higher productivity of *Pelodiscus*. All these operations eventually switched to farming only Chinese softshell turtles.

In rural parts of India, various forms of ranching and breeding of the Flapshell Turtle, *Lissemys punctata*, are undertaken by persons and communities. The primary aim of such activities is protein production for the owner, as the species is partly vegetarian and ponds are stocked at such low densities that feeding is not necessary. No quantitative information is available on the number of ponds involved or the total quantities produced annually, but given the levels of subsistence consumption and the legal protection status of the species under Indian legislation, trade in this species is not significant at present. The species does, however, present a potential additional subject for large-scale farming, with a much lower associated risk of becoming an invasive species in its native range (Whitaker, 1998; Whitaker, pers. comm. to van Dijk, Dec 2001).

Fewer farming operations concern themselves with hard-shelled freshwater turtles, mainly because most hardshelled turtle species grow and reproduce significantly slower than soft-shelled turtle species while fetching similar or lower market prices per kg. Farming hard-shelled turtles is thus a market that cannot compete directly against softshell farming in the general food trade. It is thus restricted to niche markets, such as the supply of turtles to the medicinal trade, for release at temple ponds and other waters for purposes of religious merit, and supply to the international pet trade, Species farmed in great quantities for these purposes are predominantly Reeves' Turtle *Chinemys reevesii*, and the Chinese Pond Turtle *Mauremys mutica* in mainland China, and the Chinese stripe-necked turtle *Ocadia sinensis*, in Taiwan (Chen *et al.,* 2000).

Beyond these species there is a wide variety of captive breeding efforts for a wide variety of turtle species in a wide variety of locations. These include pilot and small-scale projects to investigate the potential of particular species for mass or high-value production, as well as operations breeding small or modest numbers of turtle species specifically for the international pet trade. Although the numbers may be moderately significant in the pet trade and from a conservation perspective, these species and quantities are insignificant compared to the total commercial production for the mass consumption market.

Noteworthy in particular is that rearing and farming efforts have encompassed a range of North American species, including species such as *Trachemys scripta elegans* and *Chelydra serpentina* which have raised concerns about their invasive potential elsewhere. Species recorded in farming statistics and observed at turtle farms in China are listed in Table 1.

Table 1. Species of freshwater turtles involved in commercial farming in China.

Extensively farmed [over 10,000 hatchlings produced annually, according to statistics of the Endangered Species Import and Export Management Office of P.R. China (Shi & Fan, 2002)]	*Pelodiscus sinensis* *Palea steindachneri* *Chinemys reevesii* *Mauremys mutica* *Ocadia sinensis* *Trachemys scripta elegans*
Farmed in modest quantities [Annual hatchling production between 1000 and 10,000 individuals]	*Cuora trifasciata* *Geoemyda spengleri* *Chelydra serpentina* *Macroclemys temminckii* *Cuora amboinensis, C.* flavomarginata – likely in this category
Observed in farms but not confirmed to be bred in significant quantities	*Platysternon megacephalum* *Lissemys punctata* *Lissemys scutata* *Cuora galbinifrons* *Cyclemys species complex* *Heosemys grandis, H. spinosa* *Malayemys subtrijuga* *Mauremys annamensis* *Orlitia borneensis* *Pyxidea mouhotii* *Sacalia bealei, S. quadriocellata* *Siebenrockiella crassicollis* *Indotestudo elongata* *Manouria emys* *Chrysemys picta* *Graptemys pseudogeographica* *Sternotherus odoratus* *Chelodina species*

Based on statistics from the Endangered Species Import and Export Management Office of P.R. China (Shi & Fan, 2002), Shi & Parham (2001), and Shi, Parham & van Dijk (pers. obs. 2001).

A noteworthy amount of applied scientific research is carried out in China on refining farming methodologies for hardshelled turtles. Much of this research is unknown and almost inaccessible in the West, but an indication can be gained from the observation that Volume 8 of *Cultum Herpetologica Sinica*, published in June 2000, contained a wide range of herpetological papers regarding taxonomy and geographic distribution, but also a paper on advances in Chinese softshell culture (Li, 2000), two papers on different aspects of captive breeding of *Cuora flavomarginata* (Lu *et al*, 2000a, 2000b), a paper on temperature sensitivity of 'Color turtle of Brazil' [=Trachemys scripta elegans] (Wang, 2000) and a detailed paper on inducing early oviposition in *Chinemys reevesii* and *Mauremys mutica* through injecting chorionic gonadotropin and its application to increased farm productivity (Li & Tang, 2000).

Noteworthy is that all commercial production systems involving freshwater turtles are closed or nearly-closed operations. Adult breeder animals are kept in enclosed conditions at the farm until their death, or sale. Additional adult brood-stock may be acquired from the wild, either from local native populations or through regional and international trade in wild-harvested turtles; however, no hatchlings or head-started animals are ever released and no attempts have been made for management of animals living free at part of their life stages. This is likely to results from the combination of biological factors and issues of community resource stewardship (or more specifically, the lack thereof). In the case of small, high-value, tolerant animals, it makes economic sense to keep the animals under tight control and security at all times. Thus, ranching of freshwater turtles does not occur and does not appear to be a viable approach in the near or medium-term future. The stock management at most Asian turtle farms examined appears to be haphazard: additional breeder animals from varying sources are added whenever convenient. Documentation of stock acquisition and stock movements are apparently absent. As a result, verification of farms as Captive Breeding operations in the sense of CITES Resolution Conf. 10.16 (Rev), whereby closed-cycle reproduction to the second captive-bred generation is required, appears not feasible in the near future except for most operations farming *Pelodiscus sinensis*.

<u>Markets for commercially bred turtles</u>

Traditionally, farmed Chinese softshell turtles produced in Japan and Taiwan were mainly used for domestic consumption as a delicacy, and very little exports occurred. Following the success of Chinese athletes coached by Ma Junren in the late 1980s and their widely-publicised diet including turtle blood, demand for turtle meat and "health supplements" containing turtle parts increased greatly in Eastern Asia. To meet this demand, imports from abroad increased, as did domestic farming of Chinese softshell turtles in mainland China. Demand also developed in Chinese communities elsewhere, as evidenced by the import into the USA of 28,683 medicinal preparates involving softshell turtle between 1989 and July 1994 (Bright *in* Salzberg, 1994).

During the 1990's, almost the complete production of Chinese softshells in Thailand was exported to Hong Kong, Taiwan and China, which were guaranteed markets. The domestic consumption market in Thailand was insignificant, though as native *Amyda* stocks in Thailand declined, farmed *Pelodiscus* were offered more frequently in domestic markets in the mid-1990's. By about 1997, wholesale export prices had risen to levels that domestic Thai consumers were unwilling to pay, and softshells disappeared from Thai markets and domestic trade outside the seafood speciality sector. Farms in Malaysia and Indonesia likewise exported almost their entire production to mainland China, with Singapore being an important additional market.

An important secondary market for farmed turtles is the demand for turtles as part of medicinal preparations. The full extent of the nature and preparation of turtles for medicinal purposes is poorly documented in western languages, but is known to involve jelly and powder preparations containing variously the shell bones of tortoises and hard-shelled freshwater turtles, shell bones of softshelled turtles, and whole tortoises and freshwater turtles. The Pharmacopoeia of the People's Republic of China specifies the use of *Chinemys reevesii* for this purpose (Liu et al., 1999). However, much of the demand for turtle shell bones is thought to be met by use of shells from a wide variety of wild-collected turtle species (Wu et al., 1998), which is partly a by-product of the consumption trade. Farming of *Chinemys reevesii* is extensive, as indicated by annual production of about 910,000 hatchlings per year, and increasing annual production values of 266 to 427 metric tonnes in the period 2000-2002. The percentage of reported production which is specifically destined for medicinal purposes is unknown. *Ocadia sinensis* also has significant potential for mass production to meet the demand for turtle shell bone as a component in Traditional Oriental Medicine, particularly in Taiwan where the Pharmacopoeia does not prescribe the exclusive use of *Chinemys reevesii* (Chen et al., 2000).

The third significant destination for farmed freshwater turtles is the international pet trade. Hatchlings of *Ocadia sinensis* have been traded in significant numbers in recent years in Asian and global pet markets, and these are understood to have originated from the Taiwanese farming industry. The substantial numbers of hatchlings and small juveniles of *Cuora flavomarginata* and *Geoemyda spengleri* on offer in pet markets in mainland China, Hong Kong and beyond are likely to originate from captive farming operations, as such hatchlings are extremely difficult to find and collect in the wild (e.g. Chen & Lue, in press) and the animals are in good, healthy condition when traded. That hatchlings and juveniles of Cuora trifasciata and Mauremys mutica recorded in the pet trade originate from captive breeding is without much doubt given the documentation of extensive farming of these two species.

Trends in Asian turtle farming

Commercial culture of freshwater turtles in controlled conditions was pioneered in Japan by a Mr. Hattori near Tokyo, who started with locally native *Pelodiscus sinensis* softshells in 1866. At the turn of the 19th century, softshell farming was still a very small segment of aquaculture activities in Japan, involving the Hattori business with about 13.6 hectares of pond devoted to the species and "several minor turtle farms". The Hattori establishments were expected to produce 82,000 eggs in 1904, expected to yield about 60,000 animals of market size in 1907 (Mitsukuri, 1904).

Softshell farming developed in Taiwan in the 1950's and was a small component of aquacultural activities until about 1970, when production increased quickly, to collapse during the early 1990s and increase exponentially again in the late 1990s. Farming of softshell and other freshwater turtles in mainland China developed with economic liberalisation in the 1980s. In the mid- to late 1980s, farming of Chinese softshells *Pelodiscus sinensis* also gained interest in tropical Asia. The origin of the initial founder stock is not clear, but is likely to have originated from Taiwan.

In Singapore, Choo & Chou (1984, 1986, 1992) studied various aspects of aquaculture practices and biological parameters of the Chinese Softshell and Singaporean entrepreneurs developed softshell farms in nearby southern Peninsular Malaysia (Heng, 1998). Many of these farms initially experienced problems developing suitable husbandry practices and failed to succeed. By 1985, a few aquaculturists in Thailand also experimented with the species, with varying dedication and success. In Thailand, the Agricultural Foundation included a softshell farming manual (Kamneung, 1989) in its widely-sold series of illustrated booklets advising rural farmers on agricultural opportunities and improvements. The Thai aquaculture supply-industry noticed the emerging sector as well, and started publishing infomercials, booklets with tips, techniques and advertisements for food pellets, pumps and other items, and organised seminars. In the 1990's, farming of Chinese softshell turtles expanded exponentially in both Malaysia and Thailand and two types of 'softshell turtle farm' developed. A small number of farms maintained brood-stock of Chinese softshell turtles, usually imported from Taiwan, to produce eggs and incubate these. A small proportion of the resulting hatchlings were retained and raised for sale to the consumption trade and for expanding and rejuvenating the adult founder stock, while the larger part of the produced hatchlings were sold to the second type of farms, the rearing operations. These operators raise the purchased hatchlings to a marketable weight of about 500 grams each in about one year. The size of rearing farms in Thailand ranged from 24 to 3520 square meters pond surface (Anonymous, 1998). These rearing farms, mainly small independent aquaculturists working on commission or through co-operatives, were located all over Malaysia and Thailand, but concentrated in Johor in southern Malaysia and Rayong, Chanthaburi and Trat in south-eastern Thailand. By 1998, Thailand contained over 10,000 farming and rearing operations (Plengmaneepun, 2001); the total number of turtle farms in Malaysia has not been reported but is likely to have been hundreds if not thousands.

Perception of regulations in effect has limited farming developments in Indonesia, where rearing of hatchlings imported from Thailand, Malaysia or Taiwan was initiated in North Sumatra in 1997 (Samedi & Iskandar, 2000).

In 1999, China imposed restrictions on imports of farmed softshell turtles because of contamination with *Salmonella* bacteria. This was followed by further restrictions on farmed softshell turtles as well as wild-collected turtles as part of China's tightening of wildlife conservation and trade regulations. Around the same time, domestic supply of farmed softshell turtles reached peak levels and prices began to drop through normal market mechanisms. By 2000, prices for softshell turtles and other high-value freshwater aquaculture products had diminished by as much as 50 percent (Wang, 2001).

As a result, export volumes from Thailand and Malaysia plummeted and wholesale prices slumped correspondingly, leading many farmers to close or switch activities. Of over 10,000 farms operating in Thailand in 1998, 6000 remained in 2001 (Plengmaneepun, 2001), and these were reduced to a handful of moribund operations in September 2002, most operators having switched to culturing freshwater prawns or fish. Of 30 farms operating in Langkap, Malaysia, in 1997, only 4 were left in May 2000 (Mimi Syed Yusof, 2000).

As the main export market closed, softshell turtle farmers outside mainland China looked for alternative markets to sell their production. This remains a challenge, since consumption of turtle meat in Hong Kong, Korea and Japan combined has been reported as only 5% of the consumption in China (Plengmaneepun, 2001) and Singapore remains a limited market. Many hatchlings were traded into the global aquarium and pet trade. New markets are sought for prepared gourmet soups, meat and other dishes from farmed Chinese softshell turtles, including internet marketing in Germany (Bennett's Trading, 2002).

The only Asian country currently experiencing an increase in softshell turtle farming is Viet Nam, where aquaculturists are understood to have started only recently to culture softshell turtles, presumably *Pelodiscus sinensis*, and where production mainly supplies the domestic market.

Brief summary of farming practices

Chen (1990) pointed out that farming of softshell turtles (and most other turtles), like farming predatory fish, is a net protein reduction. Turtles are a culinary novelty, to be marketed in up-market and exclusive restaurants and to a lesser extent for high-end home-cooking. Softshell farming will not provide protein to the starving poor, and while many rural aquaculturists earned well during the period of peak demand, many have subsequently been affected severely when turtle prices slumped below production costs and incomes were insufficient to meet loan obligations and operating expenses. Thus softshell farming has proven a temporarily very profitable activity for some, but the very rapid developments have also brought debts and other problems to many farmers and investors.

Turtle farms usually have separate spawning ponds, hatching enclosures, nursery ponds and grow-out ponds. Usually all walls are vertical concrete, often with a protruding lip at the top to avoid escape. Mitsukuri (1904), Kamneung (1989), Chen (1990), Heng (1998) and Zhou (2000) provide detailed descriptions of various pond constructions, feeding regimes and husbandry techniques in different countries. Open-air ponds are standard in tropical and sub-tropical areas, including southern China, but partly or entirely enclosed and seasonally heated operations are widespread in areas with cooler climates. Farms range in size from a few square metres on a balcony or a spare room to several hectares in the countryside. At their peak, large farms in Thailand and Malaysia would each contain, at any particular moment, 10 to 25,000 turtles of marketable size (400-600 grams) (Mimi Syed Yusof, 2000).

Mitsukuri (1904) reported that in Japan the softshell turtles spent long periods in hibernation and grew slowly as a result of the climatic conditions in the Tokyo area, yet produced about 20 eggs per clutch and 2 to 4 clutches per female per year. Hatchlings measure on average 27 mm, one-year olds 45 mm and 28 g, two-year-olds 105 mm at 169 g, 3-yr animals 125 mm at 300 g, 4-yr-olds 160 mm at 563 g and five-year old animals to reach 175 mm Carapace Length (CL) at a weight of 750 g. These animals were fed on a diet of mainly crushed fresh clams, as well as dried fish scraps, silkworm pupae, boiled wheat grain etc. In Taiwan, hatchling turtles (2-3 cm, 2-4 g) are fed daily with a mixture of trash fish paste and eel feed pellets. Daily feed ration is about 10% food weight per weight of stocked turtle for small animals, and 5% for larger animals. The feed conversion factor is 8-12, meaning that 8-12 g fish paste is required to produce 1 g of softshell turtle (Chen, 1990). Ideally, after 3 months their average size is 4-5 cm at 10g and after 10 months 10 cm and 40-70 g. Average survival during this period is 70%. Under good conditions, with 2 feedings per day, 50% of hatchlings reach the “large” category (over 500 g), 35% reach medium (300-500 g) and 15% stay below medium and are thus not marketable. In Taiwan, Chinese softshell turtles reach sexual maturity at the age of one year and a weight of about 500 g, but older founder stock (6-9 years) is preferred as eggs of young females are small and believed to hatch inferior juveniles. Up to 6 or 7 clutches (50-200 eggs) may be laid by a female annually (Chen, 1990). Similar rates of growth to marketable size and sexual maturity were reported for mainland Chinese turtle farming operations (Zhou, 2000).

Current productivity of commercial breeding

In the past two decades, farming of freshwater turtles has developed and expanded exponentially in mainland China. Data on production levels and trends were not available outside the Chinese-language literature until very recently; the only available source of quantitative information are the statistics from the Endangered Species Import and Export Management Office of P.R. China (Shi & Fan, 2002, Table 2). Some of these figures are unfortunately not entirely clear, particularly the reported quantities held and bred in Guangxi and Zhejiang Provinces appear optimistic. Including values for these provinces, some 303 million *Pelodiscus sinensis* are held in P.R. China, of which 150 million in Guangxi and 120 million in Zhejiang. From this, Zhejiang produced 25 million commercially traded animals in 2000, 30 million in 2001 and 35 million in 2002, while the corresponding figures for Guangxi were 17.2, 13.0 and 10.8 million animals, respectively. In contrast, the 23 million animals held elsewhere led to market supplies of 46, 48 and 52 million traded animals during those years. Such proportional differences are not fully consistent with known growth rates in farm conditions, and it appears that hatchlings traded to rearing farms are included in the statistics for ‘commercial individuals’. Production statistics by weight are similarly dominated by the quantities provided for Zhejiang and Guangxi – of 52 thousand metric tons (mt) produced throughout P.R. China in 2000, 20,000 mt was produced in Zhejiang and 8,900 mt in Guangxi. For 2001 the total was over 62 thousand mt, of which 30,000 mt from Zhejiang and 7,800 from Guangxi; in 2002 the quantities were over 67 thousand mt for the country as a whole, with 35,000 mt from Zhejiang and 6,500 mt from Guangxi. Thus, total production increases reported for all of China are caused solely by reported production increases in Zhejiang.

Probably a better statistic to gauge the extent of Mainland Chinese softshell farming would be the reported numbers of adult breeder animals, a total of over 37 million animals, producing 375 million eggs from which 286 million hatchlings emerge.

Table 2 Total Production of Chinese Softshell turtles in P.R. China as recorded in statistics of the Endangered Species Import and Export Management Office of P.R. China (Shi & Fan, 2002).

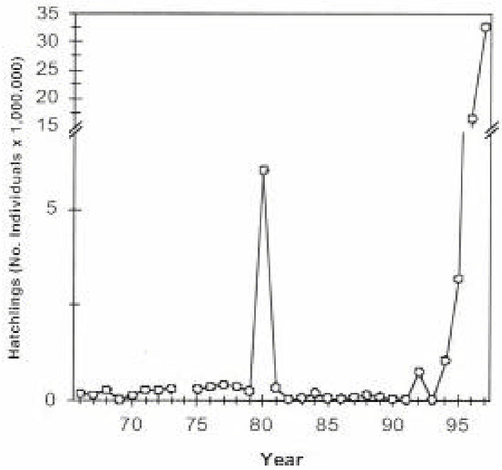
Year	Annual *Pelodiscus sinensis* production by number of animals, in millions				Annual *Pelodiscus sinensis* production by weight, in 1000 metric tons			
	P.R. China	Guangxi	Zhejiang	Other provinces	P.R. China	Guangxi	Zhejiang	Other provinces
2000	88.77	17.20	25.00	46.57	52.37	8.90	20.00	23.47
2001	91.03	13.00	30.00	48.03	62.49	7.80	30.00	24.69
2002	98.01	10.80	35.00	52.21	67.65	6.50	35.00	26.15

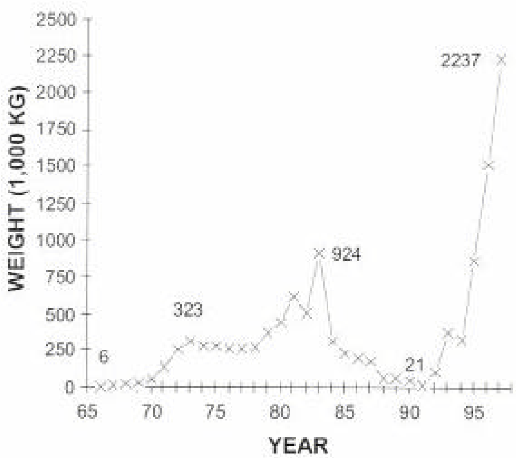
Thus, while most of P.R. China produces animals averaging 500 grams, Zhejiang consistently reports production figures that represent an average value of 1 kg per animal. Production values in provinces other than Zhejiang and Guangxi show a very gradual increase over the 3-year period, though production of Chinese softshells in Guangxi is actually reported to be in decline, while production in Zhejiang is increasing in size at a proportionally very rapid rate, reputedly making annual gains greater than the rest of China combined over the 3-year period.

Despite uncertainty in the available data, it appears evident that the People's Republic of China, particularly in Hainan and the southern mainland, possesses an extensive sector in the aquaculture industry producing Chinese Softshell Turtles. If reported figures are correct, Mainland China has surpassed the combined production of Thailand, Taiwan and other formerly dominant turtle farming regions by an order of magnitude.

In Taiwan, a few metric tons (mt) of Chinese Softshells were produced annually in the 1960s, increasing steeply in the early 1970s to yield 323 mt in 1973 (Chen *et al*., 2000). Production declined slowly after that, and by 1978 172 ha of softshell culture ponds produced 282 mt of turtle. The decline continued during the 1980s, due to a declining market demand, with production down to 186 mt of turtles and down to "probably not much more than a handful" of turtle farms encompassing 32 hectares by the late 1980s (Chen, 1990). The deepest point was reached in 1991, when only 21 tons were produced. As domestic economic conditions improved, while exports to China, Hong Kong, Macao and Southeast Asia developed since 1995, and thus demand grew throughout the 1990s, farm output shot up to reach 2237 mt in 1997 (Chen *et al*., 2000). Available production figures for Taiwan are provided in figures 1 and 2; no quantitative data are available after 1997.

Figure 1. Annual production of hatchlings Chinese Softshells, *Pelodiscus sinensis*. From





Chen *et al*., 2000.

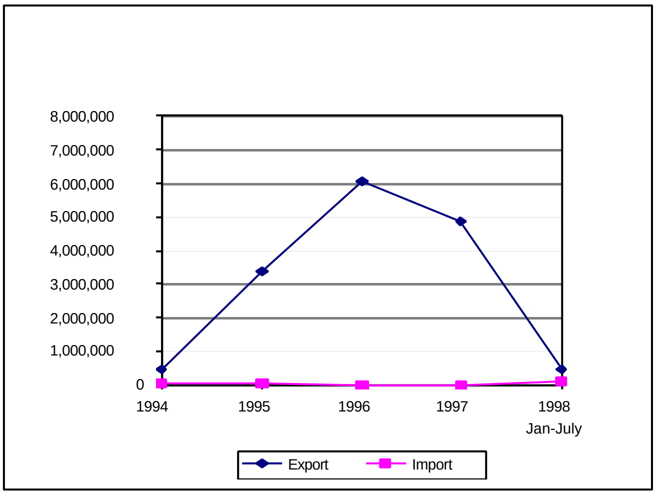
Figure 2. Annual production of Chinese Softshells, *Pelodiscus sinensis*, by weight. From Chen *et al*., 2000

The country that pioneered commercial culture of freshwater turtles, Japan, is not known to have produced significant quantities of Chinese softshells or other non-marine turtle species for a long time.

The total number of individual turtles recorded as exported by the Fisheries Department of Thailand pertains almost completely to farmed Chinese Softshells, since native turtle species are protected under domestic legislation and therefore should not be exported. Re-export numbers for exotic pet species are negligible, and production and export of Red-eared Sliders, *Trachemys scripta elegans*, are not known to be significant in Thailand. Thus total turtle export records are assumed to indicate exports of farmed Chinese Softshells, *Pelodiscus sinensis*, and since only a minimal part of farm production was marketed domestically, these export records in Table 3 give a fair indication of total productivity. The number of just over 470,000 in the first 7 months of 1998 (van Dijk & Palasuwan, 2000) does not include the bulk of that year's export, as most harvesting occurs at the end of the wet season, in time for the peak demand in East Asia as winter falls, thus most consumption exports occur at the end of the year.

Table 3 Total exports of turtles from Thailand as recorded in statistics of the Fisheries Department of Thailand (in van Dijk & Palasuwan, 2000). Units are individual animals.

Year	*Export*	*Import*
1994	469,578	38,962
1995	3,394,842	28,120
1996	6,045,667	8,049
1997	4,832,346	6,503
1998 Jan-July	472,130	90,500



Peak production levels for the Thai farming industry were probably even higher. By October 2001, the remaining 6000 farms in Thailand were reported to be producing 300,000 hatchling turtles and 25 metric tons of market-sized turtles for consumption (about 55,000 animals of 450 grams each) per day, presumably during peak season only. These quantities were stated to be half the peak quantities produced in 1998 (Plengmaneepun, 2001).

Production quantities for Indonesia, Malaysia and Viet Nam are not available.

Farmed softshell turtles generally fetch good prices. Mitsukuri, in 1904, noted softshell price in Japan as about 6.50 to 7.50 yen per kwan (=8.25 lb/3.75 kg), equivalent to about USD 1.00 per kg (1904 dollar). In 1995, price for softshell turtles in Thailand irrespective of species had increased to about THB 150 per kg of whole animal, about USD 6.00. At the peak of the trade, during 1997 and 1998, prices reached THB 500 to THB 900 (USD 20-30) per kg in Thailand and MYR 43 (USD 11.30) per kg in Malaysia. Following the collapse of exports to China, prices per kg slumped to MYR 15 (USD 3.95) in Malaysia in early 2000 and to THB 80 (USD 2.00) in Thailand in late 2001, by which time production costs were THB 120 per kg (Mimi Syed Yusof, 2000; Plengmaneepun, 2001). Prices of hatchling turtles shipped from Thailand to China for local rearing dropped from THB 7 (USD 0.18) to THB 1 (USD 0.03) over the same period, also suffering from competition with hatchlings produced by large-scale Taiwanese farms (Plengmaneepun, 2001). By September 2002, wholesale price for market-sized softshell turtles was no longer known as there was no wholesale demand anymore; it appeared unlikely that prices over THB 50 per kg could be realised. As noted previously, wholesale prices in China also reduced by up to 50% by the late 1990's (Wang, 2001).

Production quantities for hard-shelled turtles in Mainland China are even more difficult to determine than for production of Chinese Softshells. The only available quantitative statistics, those from the Endangered Species Import and Export Management Office of P.R. China (Shi & Fan, 2002), indicate remarkably optimistic population and production quantities in some provinces, notably Guangxi, while other production data (e.g. *Cuora trifasciata* in Hainan) appears underestimated from observed farm stock sizes. Given the very high individual value of some of these species, farmers working with these species are extremely secretive about their holdings and production (Shi & Parham, 2001; Shi & Fan, 2002).

With so much uncertainty associated with the available data, it is impossible to draw reliable conclusions on the extent of farming of hard-shelled turtles, though all available information indicates that production is extensive and involves a multitude of species.

There is little doubt that mass farming and rearing of the American Red-eared Slider (*Trachemys scripta elegans*) occurs in mainland China, as evidenced by significant quantities of obviously captive-born and raised animals being offered in East Asian food markets, including animals of captive-bred colour varieties. According to statistics from the Endangered Species Import and Export Management Office of P.R. China (Shi & Fan, 2002), about half a million *Trachemys scripta* have been produced for commerce annually in the past three years. This is still less than recorded exports of T. scripta hatchlings from the USA to P.R. China in recent years, which amount amounted to 4.65 million animals in 1998, 4.71 million in 1999, 7.50 million in 2000, and 1.74 million in the first 10 months of 2001 (LEMIS data), suggesting rearing of imported hatchlings represents a very significant part of the total trade volume. The dynamics of this are likely to be significantly affected in the near future by China's termination of allowing imports of turtles smaller than 10 cm shell length (Endangered Species Import and Export Management Office of P.R. China, 2002).

Other hard-shelled turtle species are also apparently farmed in great numbers. These include *Chinemys reevesii*, an adaptable species native to temperate parts of China. Some 234 thousand adult breeder animals are reportedly in farms, nearly all in Hunan Province, producing some 1.88 million eggs annually, from which 910 thousand hatchlings emerge, producing from 630,000 to 93,000 animals for trade annually in the past three years (Shi & Fan, 2002). *Ocadia sinensis* is farmed in both mainland China and Taiwan, with close to 400,000 adult breeder animals mainly in Hubei and Guangxi producing between 1.5 and 2 million animals for trade annually in the past three years (Shi & Fan, 2002). Available data for Taiwan does allow an estimate of total annual production, but this is likely very substantial as many farms are thought to exist and the largest of these produce over 30,000 hatchlings annually (Chen *et al*., 2000). Statistics from the Endangered Species Import and Export Management Office of P.R. China (Shi & Fan, 2002) indicate that close to a quarter of a million hatchlings of *Mauremys mutica* are produced annually, mostly in Guangxi Province. Substantial production of this species, at a level of at least a thousand hatchlings in a single large farm, has been verified independently in Hainan (Shi & Parham, 2001; Shi, Parham & van Dijk, pers. obs. 2001).

In mainland China there is a number of farms that concentrate on breeding an extremely valuable turtle species, the Chinese Three-striped Box Turtle *Cuora trifasciata*. This species is perceived to have cancer-preventing and cancer-curing properties (Lee, 1999), and may retail at USD 1500 for an adult animal weighing about one kg (2001 price). Given the very high value of these animals, farmers working with these species are extremely secretive about their holdings and production, and reliable data are difficult to obtain. There is little doubt, however, that production is extensive, given that dozens or hundreds of modest-sized farms exist, and that the largest of these may produce up to a thousand hatchlings annually from up to 500-700 adult breeding animals (Shi & Parham, 2001; Shi, Parham & van Dijk, pers. obs. 2001). Statistics from the Endangered Species Import and Export Management Office of P.R. China (Shi & Fan, 2002) generally correspond to these perceptions, while indications remain to be confirmed that some 60,000 hatchlings of *C. trifasciata* are produced annually in Guangxi province.

<u>The issue of exotic turtle species and their potential as invasive species</u>

Chinese softshell turtles are easily cultured in the Southeast Asian tropics, and the animals have been traded alive locally in Thailand, Malaysia, and Singapore (van Dijk & Palasuwan, 2000; Sharma & Tisen, 2000), as well as China, Taiwan, Hong Kong and Macao. Escaped or liberated animals have been reported from a number of places, including Thailand and Sarawak, and nests have been observed in the wild. The species' staying power can be observed in Hawaii, where small populations of *Pelodiscus sinensis*, and *P. steindachneri*, persist in limited habitat despite apparently incidental exploitation (Ernst *et al*., 1994). One possible result may be that feral tropical populations of Chinese Softshells will be larger, in numbers and possibly in biomass, than current populations of native *Amyda cartilaginea* softshell turtles. Growing rapidly and reproducing within one to three years, Chinese softshells have a much higher potential recruitment than native *A. cartilaginea*, which may require a considerable size and up to a decade to reach sexual maturity. At current hunting pressures, most *A. cartilaginea* are caught before they reach reproductive age, and recruitment is below what natural levels should be.

It is not certain what effect, if any, the anticipated establishment of *Pelodiscus sinensis* will have on tropical ecosystems. Precise data are lacking, but one may assume that *P. sinensis* ecologically approximates juvenile *Amyda cartilaginea* of similar size. The tropical Southeast Asian ecosystems, or what remains, have evolved in the presence of softshells since at least the Miocene. It is worth noting that *Pelodiscus* species, which have been present in Central and East Asia for at least 12 million years (Kordikova, 1991), did not successfully invade tropical ecosystems in the presence of larger native softshell turtle species. It is also worth noting that Thai softshell farmers consider that adult Chinese softshells are physically exhausted at the age of four or five years, in contrast to maximum ages of well over a decade attained in native subtropical or temperate habitats; it appears that 'Life in the Fast Lane' in the tropics does not suit the species long-term. Thus, while feral populations of *Pelodiscus sinensis* may establish themselves and reproduce successfully, particularly in human-dominated landscapes, it is far from certain that it would survive long-term in the presence of healthy populations of native *Amyda* softshells. Whether feral populations of Chinese Softshell Turtles would succeed in reaching and establishing themselves in the slope forest stream habitat inhabited by the Malayan Softshell Turtle, *Dogania subplana*, in the Thai-Malay Peninsula and Indo-Malayan Archipelago remains to be determined.

Three other species of freshwater turtles have been widely traded and raised in Asia in recent years, all from temperate North America: The Red-eared Slider Turtle, *Trachemys scripta elegans*, the Snapping Turtle, *Chelydra serpentina*, and the Alligator Snapping Turtle, *Macroclemys temminckii*. In particular, the Red-eared Slider Turtle has established feral populations throughout the world through release or escape of pet animals, and these populations are seen with varying degrees of concern in many parts of the world, including France, Italy, California, South Africa, Israel, Taiwan, Thailand, Cambodia, Malaysia and Australia (e.g. Bouskila, 1986; Dupré, 1996; Ferri & di Cerbo, 1996; Chen & Lue, 1998). In the context of the European situation, unsupported speculation that the larger Red-eared Slider Turtles would be significant competitors for the smaller native species, and could predate juvenile of the native species, has assumed the status of incontrovertible fact. The European Union went as far as to prohibit the importation of the subspecies in 1997 because it is assumed to represent a potential threat to European native freshwater turtle species. Yet in its documentation on the import ban, the European Union admitted that it was not aware of documented ecological damage. Luiselli *et al*. (1997) documented significantly lower winter survivorship of introduced juvenile Red-eared Slider Turtles compared to juvenile native European Pond Turtles *Emys orbicularis*. *Chelydra* and *Macroclemys* have been traded in much smaller numbers and because of their cryptic lifestyle are unlikely to be noticed even if they established feral populations, but the potential for establishment is high and particularly *Chelydra serpentina* shares the adaptability to a wide range of habitat, food and other ecological conditions that *Trachemys scripta* possesses. So do these species represent a significant potential threat to native Asian turtle populations and ecosystems? The information needed to give an answer with certainty does not yet exist, but a number of considerations are relevant.

When considering the potential ecological impacts of established Sliders Turtles in tropical and subtropical Asia, it is important to remember that in its native area *Trachemys scripta* is an integral part of a diverse community of freshwater turtles. It has evolved to share its habitat with many other turtle species, some larger and some smaller than itself. These include turtles of the genera *Chrysemys*, *Pseudemys*, rarely *Graptemys*, *Deirochelys*, *Kinosternon*, *Sternotherus*, *Chelydra* and *Apalone*, with varying degrees of overlap in habitat and food preferences (Gibbons, 1990; Ernst *et al*., 1994). *Trachemys scripta* is an opportunistic species, but generally does not occupy new opportunities to the exclusion of other turtle species, and has even less success penetrating existing communities.

When humans create new habitats, such as reservoirs, within the natural range of *Trachemys scripta*, the turtle community that develops to take advantages of the new opportunities is closely related to the evolved habitat selection of the various species. In reservoirs in the Tennessee Valley, *Trachemys scripta*, normally a species of lentic water, occurs mainly at the shallow end of coves where creeks enter, *Pseudemys concinna* occurs further towards the main lake, while the riverine *Graptemys pseudogeographica*, *P.ouachitensis* and *Apalone mutica* prefer the deep water area at the mouth of the cove (Lindeman, 1997).

One long-term experiment exists of the effects of Slider Turtle introduction into an ecosystem where Emydid turtles did not form part of the evolving community: the invasion of Meso-America by Slider Turtles since the Pleistocene. As climatic and geological conditions permitted, *Trachemys* turtles have expanded their range southwards from the USA and Mexico and now occur throughout Central America, Colombia, and Venezuela, and localised in Brazil, Paraguay, Uruguay and Argentina. As the Slider Turtle expanded southward, it encountered resident turtle communities of *Staurotypus*, *Claudius*, *Dermatemys*, *Rhinoclemmys*, Podocnemids and Chelids. Many of these turtles have very different habits and would not experience potential impact from the invading *Trachemys*, but other species theoretically could be impacted by competition, viz. *Dermatemys mawii* and *Podocnemis lewyana*. Yet an overview of the region's fossil turtles and the present distribution and natural history of turtles in Central and South America shows that the established groups have largely stood their ground, and *Trachemys* is an uncommon species restricted to pond habitats in isolated areas (Moll & Legler, 1971; Wood & Diaz de Gamero, 1971; Pritchard & Trebbau, 1984; Iverson, 1992). The fact that the species has diversified greatly in colouration and sexual dimorphism in the course of its invasion (a dozen or more subspecies in Latin America: Legler, 1990) while apparently no evolutionary pressures worked to force reproductive adaptation to a tropical climate (Moll & Legler, 1971) suggests that Slider Turtle populations were relatively small and isolated for much of the history of their Latin American venture.

So what developments can be predicted resulting from the existing or imminent establishment of Slider Turtles in Asia? Asia has developed rich and complex turtle faunas in adjoining regions. Relatively few turtle fossils are known from Asia, but known information indicates that species, genus and family ranges have expanded and contracted, invaded and become extinct. A dynamic community formed under such conditions is likely to adjust to the arrival of another species. The Red-eared Slider Turtle, faced with this resident community, will likely find its niche where it has developed it in its native region and become a part of the fauna of vegetated lowland ponds, lakes, canals and other slow-flowing waterbodies. There is little chance of

Red-eared Slider Turtles establishing dominant populations in either hill or forest streams or in large open rivers and reservoirs. Competition for food may occur with several native freshwater turtle species, but food supply seems hardly a limiting factor in Asian wetlands. Any competition for food will be between the various species of turtles, fish, waterfowl, various invertebrates and other animals, rather than simply restricted to inter-turtle competition. The possibility that a large Red-eared Slider Turtle might prey on a hatchling of a native turtle species is undeniable, but the native turtle species have long proven to survive in an ecosystem where their young may be preyed upon by large native softshells or other turtles, monitor lizards, herons, storks and other large wading birds, raptors, large predatory fish and other predators. Hatchling predation is partly a function of hatchling density and tendency to swim in open water and the density of predators, rather than the simple number of potential predatory turtle species present in the ecosystem. Conversely, Red-eared Slider Turtles may become food for native predatory species as well. Displacement of native turtles from basking sites by boisterous Slider Turtles is a potential problem in areas where the native species bask, such as mainland China and Taiwan, yet only in exceptional circumstances are suitable basking sites a limiting factor. It seems very unlikely that Slider Turtle populations would not be controlled by the ecological components that control native turtle populations. Slider Turtles are not inedible or poisonous, and are thus subject to density-related predatory controls. Indeed, humans may impact sufficiently on adult Red-eared Slider Turtles to keep their populations well below ecological tolerances.

It is obvious that feral Red-eared Slider Turtle populations are most likely to establish in areas intensively impacted by humans, such as urban and agricultural areas, which are precisely the areas where native turtle communities have been most impacted. Declines of native turtle species in human-impacted landscapes have been widely documented throughout the world. It is convenient to blame observed declines in native species on the presence of a non-native species, but without a convincing causal link, this is not justified.

Thus, the potential ecological threat posed by the establishment of feral populations of *Trachemys scripta elegans*, or *Chelydra serpentina* or *Macroclemys temminckii* by analogy, cannot be predicted based on our current understanding of the species' biology in non-native areas. It is possible that these exotic freshwater turtle species may never become properly established long-term in Asia, in which case they would not represent cause for concern. They might establish, locally or regionally, and become part of a balanced local community of freshwater turtle species and other organisms. Or they might become a pervasive ecological menace. Only continued monitoring of non-native freshwater turtle distribution combined with ecological studies of turtle communities in Asia and beyond can provide answers and suggest methods for active management of non-native freshwater turtle populations.

<u>Outlook for the Asian turtle farming industry and its effects on conservation of Asian freshwater turtle species</u>

What has become clear is that the Asian freshwater turtle farming industry has been and continues to be a very dynamic aquaculture activity. Turtle farming, particularly of Chinese Softshells, has developed, grown and declined in Japan, Thailand, and Malaysia, it appears to be in a peak phase in mainland China, and may be on the second decline cycle in Taiwan. Clearly, turtle farming has developed into an established activity where profits are made and lost by many farmers and investors based on the economic forces of supply and demand. A vast consumer market exists, with deep-rooted traditions to consume turtles, and thus demand is likely to persist as long as the underlying cultural traditions of East Asia remain intact. The novelty of consuming turtle has worn off for a large part of the potential consumers, and farmed turtles have become a mass commodity. Declining prices and relatively steady reported production quantities indicate that the demand is not likely to increase further in East Asia. What may increase, though, is the demand for more variety or better quality turtles for consumption, demands which are anticipated by current farming developments emphasizing high-quality product output (Zhou, 2000) and diversification of the number of softshell and hardshell turtles farmed in significant numbers (Shi & Fan, 2002).

To the South, softshell turtles are esteemed as a delicacy among parts, though not all, of the human population of tropical Southeast Asia. Traditionally, a steady supply of *Amyda cartilaginea* softshells was collected from the wild, partly through targeted collection and partly as by-catch from general rural fisheries activities and during agricultural activities. As this supply was diverted from domestic markets towards the more lucrative export trade, domestic restaurants and markets were supplied with production overruns from farms culturing Chinese Softshells. While many consumers professed a preference for wild-collected native softshell turtles, few if any consumers were able to differentiate between the species when alive or whole frozen, and even fewer when butchered or as prepared dishes. Wholesale export prices rose to record levels by 1997-1998, exactly at the time that Southeast Asian countries were trying to recover from the regional economic collapse of October 1997. Thus, the entire production of farmed and wild-collected softshells was exported, and softshell turtle disappeared from domestic markets for several years. When the Chinese market for farmed softshells began to close incrementally from 1999, there were no active domestic markets to divert local farm production supply to. A combination of factors seems to have prevented re-establishing softshell turtles as a mainstream consumption item in Southeast Asia, particularly Thailand; these factors probably included continuing economic austerity, a reduction of conspicuous consumerism, an increased general awareness of and sympathy towards wildlife conservation, and a shift towards acquiring more prepared meals and raw produce from supermarkets rather than wet markets.

Farming of the Chinese softshell turtle is almost completely self-sufficient wherever farming occurs. Adult breeder animals are rarely collected from the wild to be added to farm brood-stock. As such, the industry does not appear to represent a significant threat to the species' existence, but neither does it encourage effective protection and conservation of remaining wild populations of this species.

What has become apparent is that in the past few years, the numbers and volumes of freshwater turtles produced in farms has substantially exceeded the numbers that are collected from the wild for international trade. At peak levels, the international trade in Asian freshwater turtles was estimated to amount to 12 to 20 million turtles annually in the late 1990's, of which half was farmed (van Dijk, 2002). Current production statistics indicate that up to 125 million freshwater turtles may be farmed for consumption (Shi & Fan, 2002), exceeding even the highest estimates of collection levels from the wild by an order of magnitude. While such farmed supplies do not eliminate the demand for wild-collected turtles entirely, indications are that the supply of farmed turtles has stabilised market prices and prevented excessive prices leading to excessive exploitation of all wild turtle populations.

To what extent the availability of Viagra has led to a reduction in demand for wildlife dishes reputed to increase sexual performance is impossible to assess at present, but this development has been claimed to have played a role in the trends of demand for tiger products.

More importantly, though, is that current farm production levels are sufficient to meet consumer demand, and that farming practices are diversifying and improving to offer the consumer a wider variety of better-quality products. No longer dependent on imports to meet consumer demands, regulatory authorities in major importing countries can now take measures to address negative international perceptions that their citizens' purchasing power is ravaging Southeast Asian and global biodiversity. Combined with an understandable desire to protect their domestic aquaculture industry from the threat of diseases introduced through imported freshwater turtles, and the desirability to reduce the outflow of currency as payment for imported commodities, imports into major Asian consumer states have gradually been restricted in recent years, and it is likely that that trend will continue. As the major export markets for South and Southeast Asian turtle traders disappear, so will the incentive to collect their native turtle populations for the export trade. Subsistence exploitation and regional trade will continue, but no longer driven by the power of international commerce.

In conclusion,

Can turtle farming supply enough turtles to meet all market demand for turtles?

> No, because demand is open-ended and turtle farming will never be able to compete economically with fish or chicken production.

Can turtle farming replace imports of wild-collected turtles for the Asian consumption markets?

> Most likely, because already farm production is significantly larger than the total amount of turtles collected from the wild for export to East Asia. Consumer demand for more variety and better quality turtles for consumption are challenges that turtle farmers are already addressing.

Can turtle farming reduce exploitation pressures on wild populations of freshwater turtles?

> Probably, because 1. farmed turtles represent a consumer alternative that keep overall turtle prices stable, and thus prevent excessive price developments leading to excessive exploitation pressures on wild populations, and 2. farming supplies are large enough that importing nations are no longer dependent on import supplies and are increasingly free to restrict imports of wild-collected freshwater turtles, which represent veterinary, economic and public relations liabilities.

Are there any negative aspects to turtle farming?

Yes, founder stock collection, genetic pollution and invasive exotics are but three of the potential threats associated with turtle farming. The alternative, however, is unmanaged exploitation of remaining Asian and global tortoise and freshwater turtle populations, which is vastly worse.

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A Review of Conservation Breeding of Threatened Asian Tortoises and Freshwater Turtles

The concept of conservation breeding

A widespread and widely accepted definition of Conservation Breeding is not yet available, but for the purposes of this report the concept of Conservation Breeding is considered to refer to breeding of animals in confined and controlled conditions whose primary objective is to maintain or increase the number of individuals for purposes of biological conservation. Thus the objectives of Conservation Breeding are distinct from commercial breeding or recreational animal keeping, although the practical actions may have much in common. In an ideal world, Conservation Breeding would not be necessary because species conservation action at the habitat level would be sufficient to safeguard species survival; in the real world, however, populations and species may be depleted faster than they could recover in Nature, through a variety of reasons, and maintaining a number of animals in secure conditions acts as a safeguard. Should primary, habitat-based conservation actions fail to secure the species in Nature, then the species could be re-introduced to the wild with animals bred in captivity. Captive-bred individuals can also strengthen population numbers of declining or depleted populations. Re-introduction generally can only occur successfully when the original factors leading to the decline and/or extinction of the population or species no longer operate, at least not at levels that threaten the survival of the re-introduced population. Examples of successful conservation breeding programs include the Père David's Deer, the Arabian Oryx, the Pink Pigeon of Mauritius, and the Hood Island (sub-species of Galapagos Tortoise (*Geochelone* [*nigra*] *hoodensis*).

Conservation breeding and the Asian turtle crisis

As the Asian Turtle Crisis developed during the 1990's, many people with an interest in tortoises and freshwater turtles became gravely concerned that the economic forces for exploitation, combined with extensive habitat degradation, would lead to the extinction of a number of populations and even species of Asian turtles. The severity of the threats facing Asia's turtles became clear during the Phnom Penh workshop: more than half of all species were considered more threatened in 1999 than in 1996, including 18 Critically Endangered species among 67 threatened species, out of a total of 90 species. Conservation NGOs obviously took notice and began or continued to address some of the threats. Yet many of the most concerned people were not professional conservationists, but European and American hobbyists who objected to the thought that a species that they lovingly keep in their home might become extinct in Nature. Among these people, who in their daily lives were occupied with a regular job, children's education and a mortgage, a determination developed to do something tangible to help the survival of Asia's threatened turtle species, something where THEY can make a difference. The problem is simple: too many turtles are disappearing from Nature. The solution can also be simple: more turtles can be produced. But neither the problem nor the solution are that straightforward.

The solution to the Asian Turtle Crisis is not to produce more individuals of as many turtles species as possible; in this respect, conservation breeding efforts could never match the production levels of commercial farms. When addressing conservation issues regarding Asia's turtles, the goal should be to ensure the long-term occurrence of turtle species in their natural range and habitat. If some turtle species are threatened with extinction in the wild throughout their range, then it is desirable to establish a captive assurance colony in a different place, to allow the species to survive until the threats have been eliminated or at least reduced substantially. When threats have ceased, animals from the assurance population can be re-introduced to the wild to re-establish the species in Nature. Thus the goal of conservation breeding is to maintain a captive population whose individuals are maximally suited to eventual re-introduction. The principal aim of any re-introduction should be to establish a viable, free-ranging population in the wild of a species, subspecies or race, which has become globally or locally extinct, or extirpated, in the wild. It should be re-introduced within the species' former natural habitat and range and should require minimal long-term management (IUCN, 1998).

Assurance populations

Assurance animals maintained in captivity with the eventual aim of re-introduction into depleted or extirpated populations therefore must have maximal chances of survival in their original range and habitat, and must not do damage to any remaining wild population of the species or its ecosystem. Specifically, this means that animals in assurance colonies must meet a number of criteria (IUCN, 1998), among which the most pertinent are:

- Release animals drawn from captive or artificially propagated stock should be from a population which has been soundly managed demographically and genetically, according to the principles of contemporary conservation biology.

- Prospective release stock must be subject to a thorough veterinary screening process before shipment from the original source; animals with less than ideal health should not be used. Transport should occur in a manner that minimises risk of contagion or disease during shipment.

Clearly, these conditions are fundamental to the establishment and management of assurance populations for Asian tortoises and freshwater turtles. There is a strong case for the establishment and management of ex-situ assurance colonies of certain species of Asian tortoises and freshwater turtles, a case that has wide support among many conservationists and concerned individuals. But the need to move beyond maintaining in captivity a large number of individuals of a large number of species is not always understood clearly.

A particular concern with conservation breeding of Asian turtles is that most efforts occur in facilities where a variety of species are kept together or in close proximity. As a result, transmission of bacteria, viruses and multicellular parasites between different species is almost unavoidable, and a number of cases are known or suspected where a non-damaging commensal organism associated with one tortoise species has given rise to serious disease problems in another species. Nevertheless, veterinary issues can be dealt with at the level of individuals or populations in particular facilities, and should not represent systemic concerns for re-introduction from assurance populations.

<u>Genetic issues concerning conservation breeding of turtles</u>

A more pervasive concern for assurance colonies for Asian tortoises and freshwater turtles involves their genetics. Several of the species where assurance colonies are highly desirable are widespread but severely depleted in Nature; examples include *Batagur baska*, *Chinemys reevesii*, *Cuora galbinifrons*, *C. trifasciata*, *Mauremys mutica*, *Pyxidea mouhotii* and *Sacalia quadriocellata*. These species, and even more of the species currently under lower threat levels, are known or suspected to have differentiated into locally distinct forms at finer, more complex resolution than current taxonomy recognizes. Thus, assurance colonies for such species must take this into account and consist of founder stock from natural genetic units. For known or suspected diverse species, several separate assurance colonies may be required, representing river basins, mountain ranges or other geographical units defining natural genetic units. Collecting such genetically compatible founder stock is probably the greatest challenge to the development of true assurance colonies for Asian tortoises and freshwater turtles, because what are currently developed into conservation breeding colonies is dependent on present-day practicalities: what is available as potential founder stock are predominantly animals acquired through international trade with no reliable indication of geographic origin. Because of the realities of recent taxonomic research concerning turtles, there remains concern that even coarse determination of an individual animal's origin through its subspecies status is not always reliable, since some species or subspecies may not be taxonomically distinct but instead be selected individuals showing particular morphological characteristics (e.g. *Platysternon megacephalum*, or the *Cyclemys* complex), and for many taxa the exact range of distribution remains poorly defined or meaningless (e.g. several of the *Cuora* species). Strategies to collect genetically compatible founder stock for assurance colonies could be implemented by specific collection of a suitable number of animals from a single distinct population; there are of course substantial legal, biological, practical and logistic issues to be addressed in such a scenario, but it is possible. A proxy approach would be to acquire founder stock from a single commercial shipment, in the assumption or at least hope that the animals were collected from the same population and stocked and shipped as a group; such assumptions can subsequently be tested with molecular genetic tools. A practical complication with genetic testing of animals is that there is very little field data to 'anchor' such genetic results from captive animals: very few, if any, Asian turtle species have been properly profiled genetically, meaning determination of genetic variability and diversity within individual populations and among different populations throughout species' range. Such data is slowly accumulating, however, and with long-lived animals like turtles there is time to collect the data and adapt captive population management to the results.

The alternative to careful genetic management is the approach that 'in the absence of anything, something is better than nothing'. There is something to be said for breeding whatever animals are available right now, regardless of their geographic origin and genetic affinity. It can be argued that it is better to acquire at least some offspring from mature animals of unknown origin, than to wait for science to sort out the population and individual genetics and run the risk that the animal dies in the meantime. There is always hope that genetic results arrive early enough that animals can be re-assigned to more suitable partner animals, and their genes contributed to a proper genetically compatible assurance population, possibly after a sufficiently long 'quarantine' period to address the issue of sperm storage in female turtles. Any previous offspring, if later proven genetically undesirable, can be removed from the bloodline and conservation breeding program. At the very least, these offspring have contributed to refining captive husbandry, incubation and raising practices and skills, as well as encouraging continuing enthusiasm among the people keeping and caring for the animals and the wider public.

There are other genetic concerns inherent in ex-situ captive breeding for conservation or other purposes. A significant challenge is long-term genetic diversity, to prevent inbreeding. The particular details of inbreeding are not always fully clear, and inbreeding risks apparently differ among taxonomic groups, with reptiles being generally less susceptible to inbreeding defects than mammals, but a minimum population of 500 unrelated mature reproductive animals is generally considered appropriate in conservation biology. This is a twin problem facing many prospective assurance colonies of Asian tortoise and freshwater turtle species: 500 mature reproductive animals do not exist in captivity in the case of many species, regardless of relatedness. Also, the facilities and expertise to care for 500 adults plus several hundred offspring are simply not available. Add to this the desirability of assurance colonies for some 25 to 40 species, many with different subspecies or otherwise distinct management units, and suddenly a task of caring for some 25,000 individual turtles is faced by perhaps one hundred dedicated hobbyists, zoos and other facilities. This would clearly be an impossible prospect.

<u>Management of assurance populations</u>

Thus, choices must be made, in the number of species and genetic groups for which assurance colonies can be managed, and in the number of individual turtles that can realistically be managed. Optimal management of available animals and available facilities will be crucial. Studbooks are needed to manage available individuals, genetics and bloodlines, and taxon management plans are needed to make optimal use of available facilities and other resources. These resources, and the people in possession of them, form the taxon management group. Widest possible participation in the taxon management group is desired because this increases the numbers of participating individual turtles and thus genetic diversity, and it increases the amount of enclosures available.

Studbooks for a small number of tortoises and freshwater turtles, including several Asian taxa, were initiated by the Dutch Turtle & Tortoise Society in 1992, as they realised that wild turtle populations were declining and increasing European legislative restrictions would lead to a situation where various species would no longer become available through imports. To keep the species available for hobbyists, they had to become self-supporting, and sharing of husbandry information, inventorization of animals and genetic management of breeding were considered essential for this. Over the years the number of species for which studbooks were developed grew, as did the geographical spread of the participants. A management structure was needed and an umbrella organization, the Overkoepelend Orgaan Stamboeken (OOS) or Coordinating Body Studbooks, was established as a charitable foundation in 1997. By September 2000, studbooks were active in the Netherlands, Germany, Austria and Switzerland for 32 Asian turtle taxa. Through conservation priorities and personal interests, Chinese species became a focus of attention within the OOS, leading to the establishment of the Europäische Erhaltungszuchtinitiative für Chinesische Schildkröten (ECS) or European Conservation Breeding Initiative for Chinese Turtles, in 1997, with participation of dedicated organizations and individuals from the Netherlands, Germany, Austria, Switzerland, Hungary, the Czech Republic and Slovenia.

Similar concerns led to similar conclusions in the United States, and an all-inclusive alliance dedicated to conservation breeding of endangered species of Asian tortoises and freshwater turtles formed at the *IUCN Asian Turtle Workshop: Developing Conservation Strategies Through Captive Management*, held at the Fort Worth Zoo, Texas, on 26-28 January 2001. Initially named Chelonian Captive Survival Alliance (CCSA) and later renamed Turtle Survival Alliance (TSA), it aims to bring together all involved in maintenance and breeding of endangered species of tortoises and freshwater turtles (a global expansion from its initial Asian remit) and link these ex-situ captive activities to turtle-focused and habitat conservation actions in the countries where these species occur. The TSA has likewise structured itself into an umbrella organisation covering a substantial number of active and incipient Taxon Management Groups (TMG), with co-ordination with and partial integration of the European studbooks. While clearly dominated by North American participation as a reflection of its origin and the strength of the American conservation movement, the TSA is an inclusive global organisation that actively seeks to establish and promote links with partners in all countries, particularly in range states of threatened turtle species. The TSA itself has formalised its relations to the IUCN Tortoise & Freshwater Turtle Specialist Group and a number of other organisations by its key position within the newly-formed Turtle Conservation Fund (TCF). Thus, the organisational structure to manage conservation breeding of endangered Asian tortoises and freshwater turtles has been established.

For a successful captive conservation breeding program, a variety of technical aspects need to be addressed, including marking and recognition of individual animals, suitable enclosures in which to maintain the animals, understanding of suitable food and feeding, knowledge and provision of appropriate temperature, humidity and other environmental parameters, appropriate equipment and practices to incubate eggs, availability of veterinary care, legal permission to transfer captive animals between different countries, and options to bring in fresh bloodlines from range countries,

Marking and recognition of individual tortoises and freshwater turtles

To mark and recognize tortoises and freshwater turtles, a wide variety of techniques has been developed and applied. The oldest is the system of Cagle (1939) which marks the animal by drilling, cutting or grinding an unique arrangement of marks in the marginal scutes of a turtle. This technique, initially developed for natural history research in Nature, has been implemented by the TSA for the animals under its control. While very effective for many, but not all, turtle species, it defaces the animal in the eyes of many keepers and there is some reluctance to adopt this method universally. On the positive side, the method makes animals instantly recognizable, facilitating animal management, and also acts as a deterrent to diverting animals into trade or other avenues of loss from the program.

Another option is to implant small glass-encased Passive Integrated Transponders, also called PIT tags or ‘microchips’, which are implanted in muscle mass by the use of a specially-sized syringe. Implanted invisibly under the skin, it returns a unique code number when a transceiver is passed over the implant. The method is widely used for the identification of dogs, cats, horses and other domestic animals and, when implemented properly, is tamper-resistant to a high degree, but not impossible to alter. Identification through ‘microchipping’ is compulsory for certain species in certain countries. Unfortunately, the smallest available transponders still measure 12 mm long with a diameter of 2 mm, and cannot be implanted in small turtles; a widespread view is that no turtles smaller than 500 grams should be microchipped. This would exclude all hatchlings and many juveniles of every turtle species, and even the mature adults of several species of tortoises and freshwater turtles. Particularly in breeding programs where individual identity is important at every time, and animals remain small for several years, reliance on PIT tagging would open up various avenues for confusion. The cost of individual transponders continues to decline, but still represents a significant cost, particularly when a breeding program produces dozens of offspring annually.

A third approach relies on recognizing unique morphological features of each animal in a standard protocol. These features are usually color pattern or shape and arrangement of scutes and/or scales, but could be other features depending on species. The method has been used extensively for recognition of animals for natural history field research, particularly in salamanders and frogs, but has also been used as a supplementary recognition tool in turtle field research. Perhaps one of the earliest applications was to put Slider turtles on a photocopier at the Savannah River Ecology Lab in the USA. Recently, visual documentation of tortoises has been investigated in detail by Bender (2001) and the results demonstrate that standardized photographs of a number of tortoise species can be used to identify individual animals with a very high degree of reliability. It remains to be determined how reliable the method is to monitor individual changes as young turtles grow, and unique identifying characteristics need to be found and verified for each species, but so far the method appears promising for identification of animals of all sizes for a number of species, without physically harming or defacing the individual animal.

Maintenance of tortoises and freshwater turtles in captivity

The primary determining factor for almost any individual or institution maintaining tortoises and/or freshwater turtles in captivity is the available amount of space. The available space not only determines how many animals can be maintained in suitable conditions, but also of which species. Clearly, species reaching large maximum sizes require larger enclosures than smaller species, and for similar-sized species, species with an active lifestyle require more space than species that move little. Also of fundamental importance is the temperament of the species and the individual animal; some animals can be kept in groups in company of other species, while others can only be kept with one or more animals of the same species, or in nearly-permanent solitary confinement. Minimum sizes for appropriate enclosures have been determined for a wide range of turtle species (Bundesministerium für Ernährung, Landwirtschaft und Forsten, 1997), and these have been codified into legal requirements in Germany; proposals for similar measures exist in the Netherlands and presumably throughout the European Union.

While minimum standards are relevant, conservation breeding projects often require additional husbandry techniques to house animals in conditions that are most suitable for long-term health and wellbeing and reproduction of the animals. The extent to which enclosures are sized and structured varies widely, and optimal sizes are determined through experience and possibilities. Hofer (2000) arrived at optimal housing of *Geoemyda spengleri* by building five relatively spacious terrariums for a group of seven animals which together would fit along two walls of a small room, while H. Meier (2002) built a conservatory to the side of the house and filled it with several basins, the largest of which measures 10 square metres and contains 6000 litres of water heated to 24°Celsius to house a group of eight *Chelus fimbriatus* and a pair of *Chelodina siebenrocki*.

Similar care is taken to provide appropriate temperature, humidity and other environmental parameters to duplicate the conditions experienced by the species in its natural habitat. The Climate Atlas of Müller (1983) is frequently cited in hobbyist reports describing captive maintenance as guiding their temperature profiles, and computer-controlled systems to achieve both daily fluctuations and seasonal trends in temperature, humidity and light intensity are no longer beyond reach of many hobbyists.

Incubation of eggs is likewise a subject of much consideration and experimentation, described in hobbyist journals and extensively discussed at meetings. In the past decade, prospects for eggs during incubation has changed from uncertain to near-certain success for many species, although the issue of diapause continues to be a challenge for some species.

Food and feeding is another topic receiving extensive attention. Feeding has become both cleaner and healthier with the development of gelatin-based pudding-type foods. The exact nutrient intake requirements are being studied for several species; result for *Cuora amboinensis* and *Heosemys spinosa* have just become available (Helmink & Kuperus, 2002) and a comparable study regarding food and feeding of *Heosemys grandis*, *Orlitia borneensis* and *Siebenrockiella crassicollis*.

Ensuring good health of captive animals remains a challenge with many turtles. Wild-collected turtles carry a wide range of parasites, commensals and actual and potential diseases. Current veterinary understanding and treatment of health problems of turtles are not exactly in their infancy, but are certainly far behind those for mammals. As turtles are ectotherm, i.e. 'cold-blooded', and usually aquatic creatures, many of their diseases and health concerns are very different from ailments that afflict economically important species, and research and applied practices concerning turtle veterinary care will always remain a minor subject. Nevertheless, many parasites and diseases can be treated successfully by known and publicized veterinary treatments, and the animals themselves also assist by having robust immune systems that can tolerate and eliminate many health concerns.

Maintenance conditions as described by Elmar Meier (2000, 2002a, b) for *Cuora zhoui*, *C. trifasciata* and *Clemmys muhlenbergii*, by Victor Loehr (2002) for *Homopus signatus* and by Buley & Gibson (2002) for *Pyxis planicaude* at the Jersey Zoo are just some examples of the remarkable detail and effort that dedicated conservation breeding programs will go to.

Legal restrictions on captive stock management

A significant concern among many private individuals is what they perceive as increasing administration requirements and legal restrictions on keeping, breeding and transferring of animals. This concerns particularly those species that are included in the CITES Appendices and in the European import legislation (EG) Nr. 1968/1999. Whereas legislative regulatory authorities primarily aim to prevent or restrict unregulated, unsustainable or otherwise undesirable imports, the effect is at times counterproductive when it impedes transfer of captive-bred offspring of species on CITES Appendix I. Proper pathways to obtain legal permission and documentation to transfer animals between breeders and between countries do exist, but the hurdles to be surmounted can be high, and expensive, for an individual, and the inclination to then stop breeding such species is understandable. Similarly there are significant but not insurmountable obstacles to acquiring additional wild-collected animals to bring fresh bloodlines into breeding programs, These concerns will probably be resolved over time as authorities and applicants become more familiar with the processes and when both parties understand that each is trying to make its own contribution to the same goal, the conservation of turtles.

One message that the hobbyist community has to bring across is that they are not net consumers who support the removal of wild animals by their personal desire to possess animals at home. They need to emphasize the contribution that their captive observations make to general understanding of the natural history of turtle species, they need to involve themselves with and support conservation activities and research in the range states, and they need to present the animals that bring such fulfilment to their lives as ambassadors for their imperiled species and imperiled native ecosystems to a wider audience.

The contribution and prospects of conservation breeding to the conservation of threatened Asian turtles

In summary, conservation breeding of threatened Asian tortoises and freshwater turtles is a dynamic field where many individuals and institutions participate to work towards very ambitious goals that require enormous effort, space, money and other resources to meet very demanding requirements. Noteworthy is that much of those resources are voluntarily contributed by most of the participants, all for the vision of letting inconspicuous little turtles carry on with their lives in secure populations in the wild. Yet with all these efforts, how many Asian turtle species are actually the subject of long-term self-sustaining conservation breeding programmes anywhere in the world?

As treated in the preceding sections, a long-term self-sustaining ex-situ conservation breeding program needs to encompass a sufficiently large number of animals of a genetically compatible origin to avoid inbreeding for the next several captive generations, yet without unacceptably high levels of mixing in genes from animals that should not be part of that genetic population. A successful conservation breeding program also would have to be able to build on well-documented captive husbandry practices documenting successful captive breeding from a variety of different parent animals maintained at a variety of different facilities.

A species-by-species overview of captive breeding history, total numbers of animals held in captivity, and numbers of animals of known origin, suggests that at this moment not one Asian tortoise or freshwater turtle species meets all criteria for an undeniably successful conservation breeding program. There are a number of species that come close, such as the *Cuora trifasciata* program at Kadoorie Farm & Botanic Garden in Hong Kong which maintains and breeds animals from known Hong Kong sub-populations and integrates closely with habitat conservation and planned re-introduction activities, but even here too few animals are currently involved to assure genetic diversity for more than one or two generations unless additional wild-collected animals are added to the group. Another species coming close is *Geochelone platynota*, which is bred successfully in a project under the auspices of the Wildlife Conservation Society with ex-situ captive breeding in the United States and field research and conservation activities in its range in Myanmar.

Many of the captive breeding programmes for species known or reported to inhabit only a small area may be thought of as successful conservation breeding programs, on the assumption that these species have no discernible geographic variation and thus that genetic pollution is not an issue – any individual animal of the species may be paired with any conspecific animal and the only genetic issue of concern is inbreeding, which is minimised by active studbook keeping. Species in this category include *Cuora aurocapitata*, *C. mccordi*, *C. pani* and *C. zhoui*, *Mauremys annamensis*, *Chelodina mccordi*, all listed as Critically Endangered in the 2000 IUCN Red List, as well as *Chinemys nigricans* and *Geoemyda spengleri* which are listed as Endangered. Almost all captive breeding activities with *Ocadia sinensis* (Endangered) and *Cuora flavomarginata* (Vulnerable) concern animals originating from Taiwan, and are well on their way as conservation breeding programs if their genetic compatibility can be verified. A particular case is represented by *Cuora serrata*, *Mauremys iversoni*, *M. pritchardi* and a number of other taxa. These may represent taxonomically valid species of great conservation concern, or they may be hybrid taxa of no conservation concern; genetic and other research of the past several years has provided contradictory answers. All these taxa are subject to intensive captive breeding management in the knowledge that little is wasted if some eventually prove to be hybrids and much will be achieved if they are indeed valid threatened species.

The preceding paragraphs should not in any way be interpreted as criticism of the laudable activities that are carried out with other species, But the objective judgement must be that, if no further additions to the global captive populations were made, it would be unlikely that three to five turtle generations from now there would be sufficient numbers of animals to carry out a re-introduction program for any species that would have gone extinct in the wild in the intervening time. Enough individuals of a particular species may have been bred, but their genetic make-up would not match any population that is out in Nature now. Maybe that is irrelevant, maybe a re-introduction of mixed-gene animals will adapt perfectly well to the environmental conditions faced by currently localised populations. But current developments need to continue, to expand and to accelerate if true assurance colonies are to be developed through conservation breeding.

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