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A CONSERVATION ASSESSMENT OF THE FRESHWATER CRABS OF SRI LANKA

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ABSTRACT.– Relative to its size (65,230 km^2), Sri Lanka has a significantly richer freshwater crab diversity than other tropical Asian countries. Recent and on-going exploration and studies have shown that the island has 51 species of freshwater crabs of the family Parathelphusidae, all of which are endemic, and this number is expected to rise as exploration continues. Approximately 80% of crab species are restricted to the island's rain-forested south-western 'wet zone' quarter (which includes the central mountains) that, however, represents only a quarter of the territory. High human population density (~ 700 km^{-2}); the survival of only a small extent (~ 800 km^2) of undisturbed habitat; extreme fragmentation; and poor sloping-land use practices are identified as the principal threats to Sri Lanka's carcinofauna, together with unregulated pesticide use regimes. The conservation status of each of the 51 species is assessed (based primarily on Extent of Occurrence) against the IUCN (2001) Red List criteria. We conclude that 23 species are Critically Endangered, 8 Endangered, 6 Vulnerable, 8 Near Threatened and 6 Least Concern. The present study is a first step toward developing a conservation strategy for this fauna; the results may be utilized by IUCN for future *Red Lists;* and for the purpose of developing a conservation strategy for Sri Lanka's threatened carcinofauna.

KEY WORDS.– Freshwater crabs, Parathelphusidae, Red List, conservation, Sri Lanka.

INTRODUCTION

The past decade has seen a surge in interest in Sri Lanka's freshwater crabs, following a collaborative exploration and taxonomic treatment of this fauna by the National University of Singapore and the Wildlife Heritage Trust of Sri Lanka (Ng, 1994, 1995a, b; Bahir, 1998, 1999; Ng & Tay, 2001; Bahir & Ng, 2005; Bahir & Yeo, 2005). While only eight species in four genera were recognized as valid in 1994, the fauna today stands at 51 species in seven genera, with every prospect of the species-count increasing as exploration continues. Based on the present state of knowledge of the peninsular Indian carcinofauna (Bossuyt et al., 2004; MMB & D. C. J. Yeo, in prep.), it appears that all Sri Lankan freshwater-crab species are endemic, as are the genera *Ceylonthelphusa, Perbrinckia, Mahatha, Clinothelphusa* and *Pastilla*. The lowland genera *Oziothelphusa* and *Spiralothelphusa*, however, are shared with southern India. All the Sri Lankan freshwater crabs belong to the family Parathelphusidae.

The restricted range of many species, together with extensive loss of habitat, cause concern for the security of this fauna into the future. A conservation assessment was therefore made, leading to species under threat being identified and classified according to the IUCN's Red List criteria, using quantitative data to estimate the probability/risk of extinction for each species at the global scale. By prioritising species for conservation action and gathering information on the distribution of and threats to each species through the Red List assessment process, we hope that conservation recovery plans can be developed in the future.

Sri Lanka (65,230 km^2) receives relatively low rainfall (< 2,000 mm yr^{-1}) except in the south-western 'wet zone' (~ 17,200 km^2), where precipitation ranges from ~ 2,000–5,000 mm yr^{-1}. Dry evergreen forests occupy almost the entirety of the 'dry zone', while dipterocarp-dominated rainforests occur in the lowlands of the wet zone. Approximately 220 km^2 of heavily fragmented tropical montane cloud forest still persists in the central hills, which rise to 2,524 m. Diversity, richness and endemism across all taxa are much higher in the wet (including the montane) zone than in the dry zone, the biotas of which resemble those of southern India.

The wet zone, which accounts for only a quarter of Sri Lanka's territory, contains 88% of the flowering plants occurring in the island, and 95% of the island's angiosperm endemics (Dassanayake et al., 1980–2004). This pattern repeats also for other groups for which the results of recent surveys are available, such as amphibians (Meegaskumbura et al., 2002; Manamendra-Arachchi & Pethiyagoda, 2005) and land snails (Naggs & Raheem, 2000; Naggs et al., 2005). Not surprisingly, the same is true also of the freshwater crabs, in which 41 (80%) of the 51 known species are restricted to the wet zone. Yet, only 4.6% of the wet zone (800 km^2) now contains natural forest. This surviving forest area is comprised of some 140 fragments, the largest three of which are Peak Wilderness (250 km^2), the Knuckles Hills (175 km^2) and the Sinharaja World Heritage Site (90 km^2). The vast majority of the remaining fragments are < 10 km^2 in extent. This predicament is exacerbated by the fact that the wet zone contains 67% of the island's 19 million human population (Anon., 2003)—a density of 700km^{-2}— which is exceptional by the standards of all other global biodiversity hotspots (Cincotta et al., 2000).

Given the very poor representation of Sri Lankan freshwater crabs in old museum collections, there is no reliable historical baseline against which to judge trends in distributions or populations. As a result, it is unlikely that evidence of recent extinctions will be found, unlike has been the case for flowering plants (~ 130 species: see Dassanayake et al., 1980–2004); amphibians (19 species: Manamendra-Arachchi & Pethiyagoda, 2005; Stuart et al., 2004); and freshwater fish (2 species: Pethiyagoda, 1994).

Convincing evidence is emerging from recent phylogenetic and phytogeographic studies (Ashton & Gunatilleke, 1987; Roelants et al., 2004), that the wet zone biota of Sri Lanka represent a unique relict of the Deccan-Gondwanic biota and is therefore of considerable biogeographic significance. The conservation of the freshwater crab fauna, given its remarkable diversity, richness and endemism, is therefore a matter of the highest priority.

MATERIALS AND METHODS

Each of Sri Lanka's 51 freshwater crab species was evaluated against the IUCN (2001) Red List Categories and Criteria (version 3.1) to assess their risk of extinction. A species can fall into one of the following categories: Extinct, Extinct in the Wild, Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Data Deficient (DD) or Least Concern (LC). A species is considered to be threatened with extinction at the global scale if it meets the criteria for Critically Endangered, Endangered or Vulnerable. Combinations of data on population size (decline or total number) and/or geographic range and related trends are used to assess species for inclusion into one of the Red List categories (see IUCN, 2001).

The collections of Sri Lankan freshwater crabs in the Wildlife Heritage Trust of Sri Lanka (WHT) and Zoological Reference Collection of the Raffles Museum of Biodiversity Research, Singapore (ZRC) include all 51 species sampled at some 110 sites in Sri Lanka (the selection of sampling sites depended on the existence of suitable habitats) in the period 1993–2004. As no population data are available except qualitatively (e.g. "locally common", "rare", based on the number of sites at which a species was present, and the relative abundance at each site). Presence/absence was determined for each of the 51 species at each sampling station, together with estimates of geographic range. The criteria allow for geographic range to be estimated using either Extent of Occurrence (i.e. the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the sites of present occurrence) or Area of Occupancy (i.e. the area within its Extent of Occurrence which is actually occupied by the taxon). Aquatic organisms pose special problems in evaluation given that their populations are difficult to estimate, and because the Area of Occupancy may fluctuate significantly with rainfall, and in any case is often difficult to quantify. Because many of the species are represented by small, localized populations, we chose to use estimated Extent of Occurrence as the criterion for geographic range.

Status CR and EN assessments resulted from evaluation against criteria B1(a) and (b)(iii) in those categories; VU assessments resulted from criterion D2 in that category. Continuing decline in Extent of Occurrence and/or quality of habitat was inferred if the habitat is not a protected area, or if it is a protected area subject to anthropogenic impacts such as pollution or encroachment.

A taxon is CR if its Extent of Occurrence is estimated to be less than 100 km^2 (B1); its habitat is severely fragmented or it is known to exist at only one location (B1(a)); and there is a continuing decline in the area, extent and/or quality of its habitat (b)(iii).

It is EN if its Extent of Occurrence is estimated to be less than 5,000 km^2 (B1); its habitat is severely fragmented or it is known to exist at no more than five locations (B1(a)); and there is a continuing decline in the area, extent and/or quality of its habitat (b)(iii).

It is VU if its Extent of Occurrence is estimated to be less than 20,000 km^2 (B1); its habitat is severely fragmented or it is known to exist at no more than ten locations (B1(a)); and there is a continuing decline in the area, extent and/or quality of its habitat (b)(iii). VU status was also applied to taxa that have an Extent of Occurrence estimated to be less than 100 km^2; and are known from only a single population which is at

least partly in a protected area, but is "prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming Critically Endangered or even Extinct in a very short time period" (D2).

NT status was awarded to taxa that were evaluated against the criteria but did not qualify for CR, EN or VU at present, but were likely to qualify for such a category in the near future. LC status was awarded to taxa that were evaluated against the criteria and did not qualify for CR, EN, VU or NT; in general, these taxa are widespread (Extent of Occurrence >20, 000km^2) and abundant with continuous distributions.

RESULTS

The results of the application of the IUCN Red List criteria to Sri Lanka's freshwater crab species are presented in Table 1, which is a checklist of the Sri Lankan Parathelphusidae, showing available data relevant to the IUCN (2001) Red List criteria. The assessment shows that 23 species are Critically Endangered, 8 Endangered, 6 Vulnerable, 8 Near Threatened and 6 Least Concern. None of the species fell into the categories of Extinct, Extinct in the Wild or Data Deficient.

DISCUSSION

Sri Lanka's freshwater carcinofauna is undoubtedly rich in comparison with other similar, well-studied tropical Asian countries. For example, Peninsular Malaysia and Singapore, which together have a territory about twice the extent of Sri Lanka, have about the same number of freshwater crab species (Ng, 1988), while Taiwan (36,000 km^2) has 3 4 species (Ng et al., 2001).

Given the repeated and prolonged land connections between Sri Lanka and India during Pleistocene sea-level lowstands (Siddall et al., 2003), it appears surprising that all the island's freshwater crabs should be endemic, together with five of the seven genera into which these have been allocated. Bossuyt et al. (2004) have shown however, that a similar pattern holds true for several invertebrate and vertebrate groups: biotic exchange between the island and the mainland appear to have been restricted for a long time, resulting in several remarkable insular radiations. The question then arises as to species richness and endemism in peninsular India, especially the biodiversity-rich Western Ghats, with which Sri Lanka has been treated as been united to form a Global Biodiversity Hotspot (Myers et al., 2000).

While only 20 species of freshwater crabs were previously known (Ng & Tay, 2001; Bott, 1970) from the southern Indian states of Tamil Nadu and Kerala (which together are 2.5 times the area of Sri Lanka), an informal survey of ~ 25 locations in these states has brought to light ten new species (Bahir & Yeo, pers. obs.). Clearly, India's freshwater crabs remain insufficiently well explored, and urgent measures are necessary to assess and document this fauna so that conservation actions can be planned and the plans based on solid scientific data.

With 37 of 51 species threatened with global extinction, Sri Lanka's remarkable freshwater-crab fauna is clearly in trouble. Unfortunately, several important questions remain unanswered for lack of data. Are the crab species that are known from exceedingly small populations naturally rare or cryptic, or are they the vanishing remnants of a sudden decline? Have species been reduced to extremely small Extents of Occurrence because of habitat loss (or other impacts) or are their distributions naturally so severely restricted? Given the paucity of data, especially with regard to population trends, such questions are likely to go unanswered for some time. However, molecular conservation genetic approaches are available to make historical inferences on population sizes from which recent declines can be determined (e.g., Roman & Palumbi, 2003).

We propose that a precautionary approach be adopted in determining strategies for conserving such a fauna: the IUCN (2001) conservation assessments should be accepted at face value, and recovery strategies devised accordingly, until data become available to support the conclusion that each threatened species is in fact secure.

Sri Lanka's aquatic habitats are threatened by invasive alien species (>90% of the freshwater-fish biomass comprises exotics: Pethiyagoda, 1994) and pollution, while its forests are threatened by encroachment and illegal produce extraction. The greater threats to the island's remaining wet zone habitats are perceived to be from indirect sources exacerbated by 'island effects' resulting from fragmentation — invasive species, pesticide influx, edge effects, local climate change (Schaefer, 1998), rainwater acidification and increased erosion (and consequential silt load in lotic waters).

Pesticides are a serious concern given that these substances are freely and widely used in Sri Lanka. Regulation presently addresses only human safety issues, and not impacts on other non-target organisms or the environment in general (Anon., 1980). Given that 24 of Sri Lanka's 51 freshwater crab species are restricted to montane and sub-montane habitats, poor sloping-land management and unwise land-use change in the highlands continues to be a serious problem (Hewawasam et al., 2003). An estimated 292 MT ha^{-1} yr^{-1} of topsoil is lost to erosion from these lands, degrading habitats and increasing silt loads in streams and rivers (ADB, 2003).

A handful of freshwater-crab species have wide distributions and are clearly tolerant of land-use change, given that they persist in rice fields (e.g. *Oziothelphusa* spp.) and tea plantations (e.g. *Ceylonthelphusa rugosa* and *Ceylonthelphusa soror*). Even such species, however, could suffer catastrophic declines as a result of changes, for example, in land development, hydrology or pesticide-use regimes. For example, the populations of two species of widely-distributed freshwater fishes (*Labeo lankae* and *Macrognathus aral*) assessed in 1980 as "common" (Senanayake, 1980) crashed within a decade, without warning,

Table 1. Checklist of the freshwater crabs of Sri Lanka (Parathelphusidae). Conservation status is derived using the IUCN (2001) Red List criteria. CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern. Extent occurrence is estimated based on available habitat; Number of Locations is the number of discontiguous sites from which collections of the species was made; Habitat Quality estimates the degree of protection offered to at least one site at which the species occurs— P= protected area (PA), N= site not protected; FD= PA administered by Forest Department, WD= PA administered by Department of Wildlife Conservation; Thr= PA subject to degradation because of direct human impacts. Frequency is a qualitative estimate of the abundance of the species at each site of occurrence.

Species	Conservation Status	~ Extent of occurrence (km^2)	Number of sites	Habitat quality	Criteria used	Frequency
Ceylonthelphusa alpina	EN	10	2	P FD Thr	B1ab(iii)	Rare
Ceylonthelphusa armata	EN	20	2	N Thr	B1ab(iii)	Common
Ceylonthelphusa callista	CR	5	1	N Thr	B1ab(iii)	Very rare
Ceylonthelphusa cavatrix	VU	10	3	P FD Thr	B1ab(iii), D2	Rare
Ceylonthelphusa diva	CR	10	1	N Thr	B1ab(iii)	Common
Ceylonthelphusa durrelli	CR	1	1	N Thr	B1ab(iii)	Rare
Ceylonthelphusa kandambyi	NT	1,750	5	P FD		Common
Ceylonthelphusa kotagama	CR	5	1	P FD Thr	B1ab(iii)	Very rare
Ceylonthelphusa nata	CR	5	1	N Thr	B1ab(iii)	Very rare
Ceylonthelphusa orthos	CR	5	1	N Thr	B1ab(iii)	Very rare
Ceylonthelphusa rugosa	LC	> 20,000	>10	P FD WD		Common
Ceylonthelphusa savitriae	CR	5	1	N Thr	B1ab(iii)	Common
Ceylonthelphusa sentosa	LC	5,000	>10	P FD		Common
Ceylonthelphusa sanguinea	CR	10	1	P FD Thr	B1ab(iii)	Rare
Ceylonthelphusa soror	LC	5, 600	>10	P FD WD		Common
Ceylonthelphusa venusta	NT	250	3	P FD		Common
Clinothelphusa kakoota	CR	100	1	N Thr	B1ab(iii)	Rare
Mahatha adonis	NT	2,000	3	P FD Thr		Common
Mahatha helaya	CR	5	1	N Thr	B1ab(iii)	Common
Mahatha iora	CR	100	1	N Thr	B1ab(iii)	Rare
Mahatha lacuna	CR	5	1	N Thr	B1ab(iii)	Very rare
Mahatha ornatipes	LC	5,000	>10	P FD		Common
Mahatha regina	CR	5	1	N Thr	B1ab(iii)	Common
Oziothelphusa ceylonensis	NT	12,000	5	N WD		Common
Oziothelphusa dakuna	EN	1,000	2	P WD Thr	B1ab(iii)	Common
Oziothelphusa gallicola	EN	100	2	N Thr	B1ab(iii)	Common
Oziothelphusa hippocastanum	NT	> 20,000	3	WD Thr		Common
Oziothelphusa intuta	CR	10	1	N Thr	B1ab(iii)	Common
Oziothelphusa kodagoda	CR	10	1	N Thr	B1ab(iii)	Common
Oziothelphusa mineriyaensis	LC	2,500	2	P WD		Common
Oziothelphusa populosa	EN	2,000	2	N Thr	B1ab(iii)	Common
Oziothelphusa ritigala	VU	900	1	P WD Thr	B1ab(iii), D2	Common
Oziothelphusa stricta	NT	10,000	5	P WD Thr		Common
Pastilla ruhuna	EN	350	3	P FD Thr	B1ab(iii)	Rare
Perbrinckia fenestra	VU	1	1	P FD	B1ab(iii), D2	Rare
Perbrinckia cracens	CR	10	1	N Thr	B1ab(iii)	Common
Perbrinckia enodis	CR	10	1	P WD Thr	B1ab(iii)	Very rare
Perbrinckia fido	CR	10	1	N Thr	B1ab(iii)	Very rare
Perbrinckia gabadagei	VU	10	1	P WD Thr	B1ab(iii), D2	Rare
Perbrinckia glabra	VU	50	1	P WD	B1ab(iii), D2	Common
Perbrinckia integra	NT	300	5	P FD WD Thr		Common
Perbrinckia morayensis	CR	100	1	P WD Thr	B1ab(iii)	Very rare
Perbrinckia nana	NT	1,750	5	P FD Thr		Common
Perbrinckia punctata	CR	50	1	P WD Thr	B1ab(iii)	Common
Perbrinckia quadratus	CR	5	1	N Thr	B1ab(iii)	Rare
Perbrinckia rosae	CR	5	1	N Thr	B1ab(iii)	Rare
Perbrinckia scansor	LC	6,500	>10	P FD		Rare
Perbrinckia scitula	CR	80	2	N Thr	B1ab(iii), C(iii)	Rare
Perbrinckia uva	VU	120	3	P FD Thr	B1ab(iii), D2	Common
Spiralothelphusa fernandoi	EN	1,800	2	N Thr	B1ab(iii)	Common
Spiralothelphusa parvula	EN	250	3	N Thr	B1ab(iii)	Common

for reasons still unknown— they are now presumed extinct (Pethiyagoda, 1994).

It is of immediate concern that 26 (51%) of the island's 51 crab species are known from Extents of Occurrence <100 km^2 (see Table 1). Studies in Brazil (Bierregaard et al., 2001; Ferraz et al., 2003) have shown that extreme rainforest fragmentation could lead to catastrophic declines and extinction of species in less than a decade. The long-term security of Sri Lanka's biodiversity will therefore depend on minimizing fragmentation impacts through effective land-use planning and restoration initiatives while maximizing habitat connectivity between forest sites. Such goals can be met only through a policy framework built on sound scientific data, implemented through sustained, long-term financing mechanisms. Planning on such a scale is not imminent in Sri Lanka, and in the mean time, it is best that conservation activities be aimed primarily at preserving the integrity of sites and habitats while at the same time closely monitoring key populations.

The only other Sri Lankan fauna that has been completely assessed for conservation status are the Amphibia (Stuart et al., 2004), as part of the Global Amphibian Assessment. These results show that 11, 28 and 5 of the 94 amphibian species recognized from the island at the time of the assessment were Critically Endangered, Endangered and Vulnerable, respectively (cf. 23, 8 and 6 for the crabs, respectively). A total of 19 species of amphibians are suspected to have become extinct in Sri Lanka, a result that is evidently not paralleled by the crabs. Nevertheless, the proportion of the Extinct + Threatened amphibian fauna (67%) is comparable to that of the crabs (73%).

Given that the conservation of freshwater crabs hinges almost entirely on preserving patches of natural forest large enough to maintain good water quality, it is of concern that water quality is deteriorating even in key natural habitats (Gunawardena et al., 1998). Many freshwater crabs are extremely sensitive to polluted or silted waters and will not survive when exposed to these factors. In Singapore for example, the small patch of primary forest of Bukit Timah Hill (~ 70 ha) has been sufficient to maintain a thriving population of the endemic potamid *Johora singaporensis* (see Ng, 1988; 1989; 1990a). The same is also true for *Parathelphusa reticulata,* which is known to occur in only a small remnant patch of peat-swamp forest patch of less than five hectares (Ng, 1989; 1990a, b). Decade-long monitoring of these populations demonstrates that crab species will persist even in small habitat fragments if these are managed well, though exposed to extirpation by stochastic events (Brook et al., 2003).

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