

Chapter 13

Conservation First: Strategic Planning to Save the Critically Endangered Singapore Freshwater Crab, *Johora singaporensis*

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Abstract The critically endangered Singapore freshwater crab, *Johora singaporensis*, is among the 100 most threatened species in the world. The species is endemic to Singapore and known from only a few hill stream localities. Conservation approaches so far have largely focused on basic descriptive research into the animal's taxonomy, autecology and distribution, and on in situ site conservation and management. In an effort to enhance and ensure the long-term survival of this flagship aquatic invertebrate, a conservation strategy was recently developed along International Union for Conservation of Nature (IUCN) guidelines to integrate efforts and approaches into a cohesive action plan. This article outlines the background, development processes (including analysis of threats), and follow-up that have led to publication of the Singapore freshwater crab species conservation strategy, which is to our knowledge, the first for a single invertebrate species.

Keywords Aquatic · Brachyura · Decapoda · Invertebrate · Potamidae · Southeast Asia · Stream · Threatened species

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13.1 Introduction

13.1.1 *Freshwater Crabs at Risk*

Primary freshwater crabs (Pseudothelphusidae, Potamidae, Potamonautidae, Gecarcinucidae, and Trichodactylidae) are a group of wholly freshwater families (Yeo et al. 2008a, 2014; Cumberlidge and Ng 2009). In the first-ever global conservation assessment of the primary freshwater crabs, Cumberlidge et al. (2009) found a significant proportion (one-sixth) of the world's close to 1300 species to be threatened with extinction, and a larger proportion (about half) to lack sufficient data to even be evaluated in the first place; they identified various threats facing this group of animals, and called for strategies to be developed to safeguard the world's threatened freshwater crabs.

Citing various sources (Ng 2008; Yeo et al. 2008b), Cumberlidge et al. (2009) highlighted the Singapore freshwater crab, *Johora singaporensis* Ng 1986 (Fig. 13.1) as a case study of an environmentally-sensitive species teetering on the edge of extinction, which, while protected, remained highly restricted spatially, and prone to sudden, random events that could possibly lead to extinction. Locally, the status of the Singapore freshwater crab had long been recognised and conservation

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Fig. 13.1 The Singapore freshwater crab (*Johora singaporensis*). Photo DJJN

efforts begun (Ng 2008; Yeo et al. 2008b), but since then, *Johora singaporensis* has now also come to represent a flagship and an international focal point for concerted conservation efforts (Chua 2014; Khew 2015; Ng et al. 2015a).

13.1.2 The Singapore Freshwater Crab, *Johora singaporensis* Ng 1986

Johora singaporensis (family Potamidae) was described relatively recently from Singapore by Ng (1986). The species is the only member of *Johora* to be found in Singapore, with the remaining members of the genus distributed through the rest of the Malay Peninsula up to southern Thailand (Ng 1988; Yeo et al. 2007). While belonging to the same phylogenetic clade and being geographically closest to species found in the state of Johor (e.g., *J. johorensis* and *J. murphyi*) just north of Singapore (Yeo et al. 2007), *J. singaporensis* is nevertheless a distinct species based on differentiation in its male first pleopod morphology (Ng 1988) and 16S rRNA, COI, and H3 genes (Yeo et al. 2007). This means that the species is entirely restricted to the island of Singapore, and this endemism carries with it important implications for conservation.

Johora singaporensis is one of three freshwater crab species that are endemic to Singapore island—the other two being *Irmengardia johnsoni* Ng and Yang, and *Parathelphusa reticulata* Ng (both Gecarcinucidae) (Yeo et al. 2008b; Yeo and Lim 2010). It is also one of only four primary freshwater crab species known from the city-state; the fourth species is *Parathelphusa maculata* (Gecarcinucidae), a fairly abundant and widespread species found in lowland forest streams in Singapore, southern Peninsular Malaysia, and southern Sumatra (Ng 1988).

As one of the very few endemic species known from Singapore, *J. singaporensis*, is regarded as an icon of both Singapore's national as well as natural heritage (Tan et al. 2010; Yeo and Lim 2010), having been featured as such in local media, on postage stamps, and in various biodiversity awareness events. Unfortunately, however, as mentioned earlier, *J. singaporensis* is also an icon of

threatened aquatic biodiversity. As a freshwater decapod crustacean, it belongs to one of the three aquatic faunal groups (freshwater fishes, freshwater decapod crustaceans, and amphibians) to have experienced the highest rates of extinctions in Singapore, mostly owing to loss of forest habitat (Brook et al. 2003).

Johora singaporensis is particularly at risk. Prior to 2008, it was known to exist in only three small, isolated hill-stream drainages on Singapore Island, which are fragmented from one another. Of these, one site (the type locality) was within a nature reserve and under strict protection; the protection afforded to this site led to the species being categorized as Endangered in a national conservation assessment (Yeo et al. 2008b). Soon after, however, it was discovered that, despite being protected, the population at the type locality had severely declined to the point of extirpation, possibly as a result of anthropogenic acidification (Ng 2008). Accordingly, as part of a global assessment, the threat status of *J. singaporensis* was re-evaluated and upgraded to Critically Endangered (Esser et al. 2008), making it the only member out of the 15 species of *Johora* to be categorized as such. As mentioned earlier, this prompted Cumberlidge et al. (2009) to feature the species as a case study. Subsequently, the plight of the species received international recognition when the Zoological Society of London in collaboration with IUCN subsequently listed *J. singaporensis* as one of the world's 100 most threatened species (Baillie and Butcher 2012).

Despite concern for its threatened status, little, apart from taxonomy and systematics and some anecdotal information on autecology and distribution, was known about the ecology and biology (especially quantitative aspects) of *J. singaporensis*. This is in part down its small size (about 30 mm carapace width), cryptic behaviour, and challenging habitat sites (e.g., hill streams with water flowing between/under large immovable granite boulders; or location within gazetted military areas).

13.1.3 *Johora singaporensis* Conservation to Date

Recognising the precarious situation of *J. singaporensis*, and especially in light of the loss of the population in the protected nature reserve (Ng 2008), collaborative efforts have been ongoing between the National Parks Board, Singapore (NParks), National University of Singapore (NUS), and Wildlife Reserves Singapore (WRS), in cooperation with other government agencies, to protect the populations from further decline. The priorities of initial immediate efforts focused on the gathering of more data on the distribution and ecology of the species through intensive stream surveys and monitoring (Ee 2013), and on protection and management of existing sites, i.e., in situ conservation approach. A positive result from these early efforts was the discovery after the 2008 study of another site within the protected nature reserve with a healthy population of *J. singaporensis* (see Ng et al. 2015b). Several other findings stemming from this aspect (research and monitoring) of the conservation effort have since been published. These include an overview of the

conservation challenges and actions taken (Ng et al. 2015c), expansion of the distribution of the species through discovery of new populations/sites (Ng et al. 2015b; Li et al. 2015); observations on feeding and reproduction (Ng and Yeo 2013; Chua et al. 2014); and a study of the characteristics of the hill stream habitats of *J. singaporensis* (see Chua et al. 2015).

Preliminary captive breeding was also attempted as a form of ex situ conservation. This was somewhat limited and ad hoc in nature owing to logistic constraints and lack of prior experience with freshwater crab breeding, but has been expanded and developed now into a dedicated breeding programme supported by a purpose-built facility at WRS (Chua 2014). However, it would take more than just publications and facilities, or the individual efforts of carcinologists and site managers, for the applied conservation of *J. singaporensis* to be successful.

What was still lacking at the beginning was a specific, encompassing and cohesive conservation strategy or plan, which would include many other stakeholders and integrate all aspects of the conservation effort, e.g., research and monitoring; site protection and management; captive breeding and husbandry; and outreach, education and awareness. Therefore, in 2014, steps were taken to develop a formal conservation strategy for *J. singaporensis* based on the guidelines and framework of the IUCN Species Conservation Planning Sub-Committee (IUCN/SSC 2008a, b). While earlier IUCN Action Plans had been previously developed for vertebrates (e.g., Asian elephant—Santiapillai et al. 1990; cetaceans—Reeves et al. 2003), and invertebrates (e.g., swallowtail butterflies—New et al. 1991; dragonflies—Moore 1997), the conservation strategy for *J. singaporensis*, which was completed in June 2015 (Ng et al. 2015a), is one of the first strategies to be developed and published using a more inclusive and participatory approach called for by the IUCN/SSC (2008b: 3); it is also the first conservation strategy for a single invertebrate species. What follows is a description of the process and follow-up that led to the development of this strategy.

13.2 Conservation Planning

13.2.1 *Freshwater Crab Conservation Round Table (FCCRT)*

The first critical step to developing the conservation strategy for *J. singaporensis* was to bring together the most relevant parties and/or experts with stakes or interests in the survival of the crab and the preservation/protection of its immediate habitats (and surrounding environments) to discuss and provide input to the process. This was achieved through a Freshwater Crab Conservation Round Table (FCCRT) co-organised by NParks, NUS, and WRS, in cooperation with the IUCN-Species Survival Commission (IUCN-SSC).

The FCCRT brought together for the first time all the key stakeholders and experts with specific and/or general interests and priorities related to the

conservation of *J. singaporensis* and its habitats. More than 40 people participated in the FCCRT, with representatives from: the co-organisers (NUS, WRS, NParks); IUCN-SSC [specifically, the Species Conservation Planning Sub-Committee (SCPSC), and Freshwater Crab and Crayfish Specialist Group (FCSG)]; several sister agencies to NParks that have stakes in ownership, protection, and/or management of the land through which the *J. singaporensis* streams drain or of the actual as well as nearby or connected water bodies/waterways; and local and international non-governmental organisations (NGOs), as well as experts in freshwater crab breeding and husbandry.

The FCCRT was conducted over three days, with closed-door discussions during the first two days, and culminating in a public forum on the third day. In summary, the FCCRT Programme ran as follows:

1. Background

- (a) Freshwater crab overview and research
- (b) In situ conservation work
- (c) Role of ex situ conservation and communications

2. Conservation planning

- (a) Setting Vision and Goals
- (b) Identifying Objectives and specifying Actions
- (c) Follow-up and implementation

3. Public forum

The first part of the two days of discussions involved consolidation of and updates on existing background information and conservation efforts for *J. singaporensis*. Specifically, the following topics were covered:

- Historical overview of freshwater crabs in Singapore
- Current and future threats to *Johora singaporensis*
- Current conservation management and policy with regards to *Johora singaporensis*
- Current research and status of *Johora singaporensis*.

This was followed by discussion of additional/new approaches and perspectives applicable to *J. singaporensis* conservation, which largely centred on the roles of ex situ conservation (specifically, sharing of expert views and experiences on freshwater crab husbandry and captive breeding) and communication and outreach. These aspects had up till then (March 2014) been less emphasised on because the priorities had been to urgently learn as much as possible about the crab and its existing distribution (research and monitoring), and to immediately manage/protect the existing sites and their in situ population from further decline (in situ conservation). However, in order to have viable long-term success in protecting *J. singaporensis*, inclusion and development of ex situ conservation and communication/outreach aspects for a more comprehensive and integrated conservation strategy was also needed.

13.2.2 *Developing the Strategy*

After the baseline was laid out, the meeting moved on to the crux of the FCCRT—the planning and development of a conservation strategy that all the stakeholders present would be able to support, i.e., one that would balance the biological/conservation needs of the species with the various human/societal needs and interests of people. This section was facilitated by the SCPSC representative, who introduced the concepts and framework of conservation strategy planning based on best practices recommended by the IUCN SCPSC (IUCN/SSC 2008a, b).

The conservation strategy essentially encompasses a hierarchical series of statements that will provide direction/guidance for conservation efforts at different levels and in various areas, with each successive and more specific level being driven by the previous level (Fig. 13.2). The strategy begins with a Vision statement that provides overarching guidance. This is followed by one or more Goals that will help to realise the Vision. At the next, more specific level, a set of Objectives outlines how the Goals will be met. And finally at the lowest level, specific Actions describe activities to be carried out in order for the Objectives to be achieved.

The FCCRT was divided into four focus groups concentrating on the following broad aspects relevant to *J. singaporensis* conservation: ecological research; site management (in situ conservation); captive breeding (ex situ conservation); and education and communication. The Vision and Goals were then crafted through a process of brainstorming, first within and then among, the four focus groups bearing in mind that the Vision is the long term or ultimate target for the particular strategy, and the Goals articulate, in practical terms, just what are needed in order to achieve the Vision. This exercise resulted in a Vision statement for *J. singaporensis* that encapsulates the FCCRT's hopes for the species and for the conservation effort as a whole (Fig. 13.3). Building on that, the FCCRT then agreed upon two broad

Fig. 13.2 Conservation strategy. Smaller number of broad statements at higher-levels (e.g., goals) drives larger number of more specific statements at lower levels (e.g., objectives, actions)



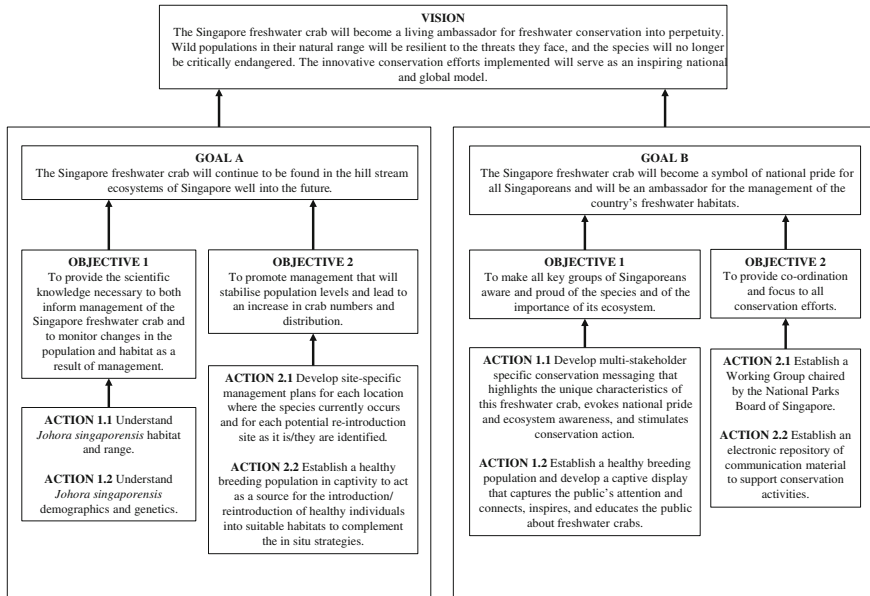


Fig. 13.3 Vision, goals, objectives and actions of the conservation strategy for *J. singaporensis* (after Ng et al. 2015a)

but practical Goals with different but complementary implications, which it felt were the key to realising the Vision (Fig. 13.3).

13.2.2.1 What Ails *Johora singaporensis*?

The next step was to identify pertinent Objectives that would essentially outline how the Vision and Goals will be turned into reality. This was done through a problem (threat) analysis, which was carried out in order to: (1) assess the various key threats facing *J. singaporensis* and the major constraints on the responses to overcoming these threats; and (2) understand the drivers of the threats in order to develop an integrated and practical way forward that maximises the species' survival chances. Brainstorming was again carried out, with participants once more divided into focal groups for more comprehensive coverage. In the discussions, stakeholders were asked to consider their respective association with the threat(s) and their potential to contribute to alleviating the threat(s).

The top few global threats to aquatic biodiversity, e.g., habitat loss or modification, pollution (including siltation), alien species, and over-exploitation (Wilcove et al. 1998), are similarly prevalent in Singapore (Yeo et al. 2011). These are manifested in various specific threats to *J. singaporensis*, some of which (loss of forest cover, habitat degradation and modification including stream acidification, reduction in water table, stream flow, and suitable habitats; aquatic pollution) have

previously been cited in local and global Red List assessments (Yeo et al. 2008b; Esser et al. 2008). The problem analysis for *J. singaporensis* identified these as well as other current threats relating to various aspects including habitat, biology, and human interactions. Below are just some examples of current key threats or constraints (to addressing the threats):

- Rarity of hill stream habitat (coupled with apparent habitat specificity of the crab)—The hill streams that *J. singaporensis* are restricted to, are themselves a rare habitat type in Singapore to begin with. Existing hill streams are restricted to a small hilly part of central Singapore; while some of these hill streams are in protected areas, others are not necessarily so. The streams are potentially under threat from loss or modification (e.g., deviation or canalization), while some of the land or watershed of these streams are at risk of being developed for alternate land use (e.g., housing) or vector control (e.g., canalization to prevent mosquito breeding). Singapore’s nature reserves do have natural forest streams capable of supporting native aquatic species including freshwater crabs (Yeo and Lim 2011). Few of these streams, however, possess the characteristics associated with *J. singaporensis* occurrence, viz., typically moderately elevated (about 50–60 m asl), with slightly acidic to neutral pH (6.3–7.2) (but see Li et al. 2015) and relatively high dissolved oxygen (81–87 %), and relatively low organic substrate cover (10–15 %) (see Chua et al. 2015); most of Singapore’s forest streams are instead low-lying and relatively more acidic (pH 5.5–6) (Yeo and Lim 2011).
- Stream acidification—one of the hill streams that *J. singaporensis* has disappeared from was found to have become more acidic compared to 15 years ago (pH 4 or lower vs pH 5–6 in the 1990s—Ng et al. 2015a, b, c; unpublished data) and in comparison to other nearby streams that still support *J. singaporensis* (pH 5 or higher—Li et al. 2015; Ng et al. 2015a, b, c; Chua et al. 2015; unpublished data). It has been postulated that the acid precipitation may have been a factor in the stream acidification (Ng et al. 2015c) but further investigation is needed to verify this. In any case, given the typically less acidic nature of streams where *J. singaporensis* does occur, stream acidification—from any source—would be a threat.
- Small population/limited distribution—*Johora singaporensis* suffers from having a very small population (a few hundred mature individuals; Ng et al. 2015a) and a very limited distribution, with an Extent of Occurrence of less than 5 km² and an Area of Occupancy of less than 0.5 km², which makes the species highly vulnerable to random catastrophic events that could lead extinction.
- Isolated populations and limited dispersal ability—Despite the small Extent of Occurrence, the five stream sites where *J. singaporensis* are currently found are independent drainages found in separate land fragments. Hence, coupled with the limited dispersal ability of these crabs, the populations are also threatened by likely absence of recruitment and gene flow among the five sites (Khew 2015).
- Lack of formal protection—Three of the five known hill stream localities where *J. singaporensis* is found, and the species itself, lack any specific formal or legal

protection. Only two sites are within a designated nature reserve. This lack of formal protection has in turn lead to a perception of lack of ownership of the problem. NParks, however, by taking responsibility for *J. singaporensis* conservation, has clearly demonstrated its ownership of the problem among government agencies. The real issue here lies in unclear ownership over the various streams situated in locations with differing legal statuses under different jurisdictions (i.e. too many official owners/stakeholders).

Associations among these and other threats/constraints were illustrated in a network analysis of problems that are ultimately driving the immediate problem of population decline of *J. singaporensis* (Ng et al. 2015a: Fig. 3). In addition, several potential threats that may become cause for concern in the future were also identified. These include for example:

- Invasive species—Singapore has numerous aquatic alien species, including freshwater decapod crustaceans, some of which could potentially be competitors or predators of *J. singaporensis* (see Yeo 2010; Yeo and Chia 2010). The likelihood of this threat, however, is low owing to the relatively inaccessible hill stream habitat of *J. singaporensis*, and the fact that most aquatic invasive species in Singapore are found in more open, artificial habitats like reservoirs, ponds, and canals (Yeo and Chia 2010; Yeo and Lim 2011). Nevertheless, the prevalence of aquatic alien species in Singapore means that this should not be ignored.
- Human interference—A potential concern for *J. singaporensis* is the potential disturbance of their habitats by humans for a variety of possible reasons ranging from poaching for pets to over-enthusiastic nature-lovers keen to see the species or explore the habitat first-hand.

The problem analysis allowed the FCCRT to then plan various Actions (Fig. 13.3) for the conservation strategy. These Actions essentially describe discrete activities to be undertaken to achieve each Objective. The Goals, Objectives and Actions, were as a whole designed to be SMART (Specific, Measurable, Attainable, Relevant, and Time-bound). Therefore, as far as possible, the Actions in particular referred to specific activities that were time-bound.

13.2.3 Forum and Feedback

The final day of the FCCRT was dedicated to outreach and dissemination of information to the public, and soliciting of feedback and views, through a public forum. The day's programme began with presentations of background information, including an introduction of the FCCRT and explanation of its importance to freshwater crab conservation, and a historical overview of freshwater crabs in Singapore. The preliminary outcomes from the previous two days of closed-door meetings of the FCCRT were summarised and presented, and this was followed by

presentation of conservation management and policy relating to *J. singaporensis*. The programme concluded with a question and answer session-panel discussion, with representative panel members from IUCN/SSC-SCPSC, IUCN/SSC-FCSG, NParks, NUS, and WRS.

13.3 Conclusions

13.3.1 Outcomes and Maintaining Momentum

Following up from the FCCRT, one of the important outcomes was the formation of a Singapore Freshwater Crab Working Group (SFCWG) soon after in 2014. The SFCWG is chaired by NParks, and also includes representatives from NUS and WRS. Other stakeholders and participants of the FCCRT, e.g., IUCN-SSC (SCPSC and FCSG) and other government agencies, are consulted and updated regularly or as and when necessary. This working group, which meets regularly (and communicates frequently), is the main channel through which subsequent discussions, decisions, actions and recommendations pertaining to the *J. singaporensis* arising from the strategy conservation are followed up on.

The SFCWG has also been responsible for initiating/driving the elaboration and implementation of specific actions. The following are some examples:

- For example, monitoring to better understand the population demographics and dynamics and research into the genetics of *J. singaporensis* is now ongoing (Ng et al. in prep.) (Under Goal A, Objective 1, Actions 1.1 and 1.2; see Fig. 13.3).
- Facilities for maintaining captive populations of *J. singaporensis* for ex situ breeding are established and running (Khew 2015); at the same time, preliminary translocation trials into new suitable habitats are ongoing (Ng et al. in prep.) (Under Goal A, Objective 2, Action 2.2; see Fig. 13.3).
- The SFCWG has reached out at various opportunities (e.g., Singapore Festival of Biodiversity) to the general public as well as to decision-makers to enhance awareness of the issues surrounding *J. singaporensis* and the conservation strategy (under Goal B, Objective 1, Action 1.1; see Fig. 13.3).

A significant outcome and milestone has been the drafting, refining, finalizing, and publication of the *J. singaporensis* conservation strategy in June 2015 (Ng et al. 2015a; Khew 2015).

13.3.2 Broader Conservation Implications

There have been some encouraging developments in the situation of *J. singaporensis*, such as the release of and publicity surrounding the formal

conservation strategy (Ng et al. 2015a; Khew 2015), and the discovery of new freshwater hill stream locations with populations of *J. singaporensis* (Ng et al. 2015b; Li et al. 2015). These have served to enhance awareness and interest and galvanise efforts, not only for *J. singaporensis* conservation, but, significantly, more broadly for freshwater stream conservation in Singapore.

The *J. singaporensis* conservation strategy also has important broader, global implications beyond Singapore. It can serve as an example of what can be done, even in a highly urbanized country with multiple competing economic and land use priorities, first and foremost for other similarly threatened freshwater crab species (Cumberlidge et al. 2009), but also for other iconic or flagship invertebrate species, which are underrepresented when it comes to specific conservation strategies (http://www.iucn.org/about/work/programmes/species/publications/species_actions_plans/).

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