Introduction of Exotic Aquatic Species in Singapore

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Urbanization has changed much of Singapore's landscape and affected its natural fauna. Exotic species have been introduced for economic or commercial purposes. Two such species that have become firmly established in Singapore's inland waterways are the guppy *(Poecilia reticulata)* and the tilapia *(Oreochromis mossambicus)*. The country lacks extensive natural inland water bodies as well as indigenous inland fisheries, and the introduction of exotic species is not likely to cause much concern. No serious study on the ecological impact of introduced species has been made.

The natural landscape of Singapore has changed drastically since the island's founding in 1819. During the early days, large tracts of forests were cleared by industrious cultivators and replaced by plantations of pepper, coffee, rubber, sugar-cane, gambier and other crops. As urbanization continued, remaining forests as well as disused and existing agricultural land were systematically cleared at increasing pace for commerce, industry and housing. Today, 28.6 km^2 of nature reserves and secondary forests surrounding the reservoir catchment areas remain while land for agrotechnological use such as for agriculture and aquaculture, has been designated in ten parks intended for farming at high technology level. These parks occupy about 180 hectares, and the area is expected to increase to 2000 hectares over the next decade (Yap 1987).

The drastic changes in the environment affected the natural fauna of the island. Some species of plants and animals were reduced or even exterminated. At the same time these changes favoured the proliferation of other species that were introduced accidentally or intentionally. Some of the exotic species were brought in and raised for their ornamental, economic or commercial potential. This included indigenous ones which would otherwise have been exterminated had they not been introduced for the reasons mentioned. This paper will deal only with the aquatic animal species.

No studies have been made on the ecological significance and implications of introduced species. Aspects such as parasite and other disease introduction and transmission, their effect on the environment, and the competition of introduced species with indigenous ones have not been given attention, but warrant systematic investigation. In cases where the ecological impact of an introduced species can be predicted legislative and other measures have been taken by the government to stop their entry. An example of this is the ban on the import of piranhas under the

Fisheries (Piranhas) Rules 1971, enacted as a supplement to the Fisheries Act, 1966. It is now illegal to rear or release the fish into natural waterways.

Species Introduced for Biological Control

The only species recorded as having been introduced for biological control is the guppy, *Poecilia reticulata*. This species was introduced in 1937 for mosquito control (Herre 1940) and has since become well established in polluted waters having free ammonia concentrations of a few hundred parts per million (Johnson 1973).

Species Introduced for Culture

Freshwater Species

Trionyx sinensis (Chinese soft-shell terrapin)

In the early 1970's, some hatchlings were brought in from Taiwan by an enterprising farmer to test the viability of the species in Singapore. It adapted well to the tropical conditions. Because of its higher fecundity and faster growth rate under these conditions, it is now cultured in preference to the slower-growing native species, *T. cartilagineus*.

Endemic to China, *T. sinensis* has been successfully cultured for over 60 years in Japan and 100 years in Taiwan. The warm climate in Singapore allows a higher production rate than in the temperate region, but its culture is land intensive. Therefore, although Chinese soft-shell terrapin farming is lucrative in Singapore, it is limited to two farms.

There have been cases of escape of these terrapins into inland water systems. Although the implications have not been considered, there is every likelihood of some ecological disturbance because of their ability to reproduce faster in the tropics, and their voraciousness (live fish forming the main part of their diet), especially if they find their way into sheltered waters where fish are stocked, such as reservoirs.

Crocodilus porosus (estuarine crocodile) and

Tomistoma schlegeli (Malayan gavial)

Sharma (1973) reported that it was unlikely for any large individuals of *Crocodylus porosus* to be found in the wild although they were a major hazard in coastal waters and mangroves in the earlier days. The presence of the Malayan gavial in Singapore waters although rumoured, has never been substantiated. Both species have together with other crocodilian species, been reintroduced for farming. Their escape always causes great concern because of the apparent danger to man and occasional escapes have occurred.

Oreochromis mossambicus (common tilapia)

The very hardy tilapia was introduced by the Japanese Army during their occupation of Singapore from 1942-1945 (Harrison and Tham 1973). The constant warm climate enabled the species to breed rapidly all year round. It was not well received as a foodfish and has since become free-roaming, with feral populations inhabiting freshwater and low-salinity habitats. Most of the populations now consist of stunted individuals (Johnson 1973). The impact of this fish on the environment is yet to be fully assessed but it appears to have dominated reservoirs and man-made lakes. Khoo et al. (1977) have estimated the tilapia population in the Seletar Reservoir to consist of 10.2 million juveniles and 10.3 million adults in 1975/76. Mass mortality occurred in 1972 (about 300,000 died between October and December) due apparently to sudden oxygen decline as a result of mixing of oxygen-stratified water layers caused by climatic changes.

Carps

Common carp, *Cyprinus carpio,* Chinese carps, comprising *Ctenopharyngodon idellus* (grass carp), *Aristichthys nobilis* (bighead carp), *Hypophthalmichthys molitrix* (silver carp); and *Cirrhina molitorella* (mud carp).

Chinese carps were introduced by the Chinese immigrants during the early history of Singapore. Their culture in ponds was on a restricted scale, with fry imported from China and timed such that harvests coincided with Chinese festivals. After the Second World War, the dramatic increase in cost of marine fish made the cheaper carps a popular food item. Their culture was subsequently stepped up to produce the fish the year round (Tham 1975).

Gradually, increasing land demand led to a decline in carp culture as ponds were reclaimed. Carp culture is now confined to less than 100 hectares of ponds with prospects of further decline and to the reservoirs such as Seletar Reservoir where bighead carps are reared in floating cages without supplementary feeding to reduce algal and nutrient load as the fish feed on plankton.

Marine species

Finfish

None of the finfish species imported for culture can be considered as exotic as they can also be found in local waters. These are mainly the grouper, *Epinephelus salmoides,* and seabass, *Lates calcarifer* (Anon 1986). The impact of culture of large numbers of these fish in 65 floating fish farms in coastal waters with the attending possibility of escape and spontaneous breeding, on the environment is not known. As local collection from the wild and hatchery production are still insufficient to support the industry, seabass and grouper fingerlings have to be imported from mainly Thailand and the Philippines. As with all imported species, the potential danger from diseases is present and the possibility of introduction of new strains of pathogens exists. However, ectoparasites found on imported fingerlings are probably similar to those found locally and it is likely that these parasites were absent prior to fish importation. Other species cultured on a smaller scale because of the lack of seed supply include snappers *(Lutjanus johni, L. argentimaculatus),* coral trout (local red grouper, *Plectropomus maculatus*), yellowfish jack

(Caranx ignobilis) golden trevally *(C. speciosus),* and siganids *(Siganus canaliculatus, S. guttatus).* Other species not commonly found or not existing locally but could be considered for culture are other groupers such as the tiger grouper *(E. microdon)* imported from Indonesia and cultured with some success, and the HongKong red grouper *(E. akara).*

The red tilapia hybrid (*Oreochromis niloticus* hybrid) has been introduced for marine culture by some farmers using originally freshwater stocks acclimated to sea water conditions. Marine stocks may become available in the future. The fish has also been stocked in limited numbers (8000 fry) into the Singapore River, together with 560,000 banana prawns *(Penaeus merguiensis)* and 34,000 sea bass *(L. calcarifer)* (L. Cheong personal communication). The impact of this stocking is still uncertain.

Shellfish

The healthy market for prawns and limited land availability has encouraged farmers to culture prawns *(P. merguiensis)* semi-intensively in brackishwater ponds instead of trapping them by the traditional method. The Kuruma prawn *(P. japonicus)* has been imported by a Japanese company and initial trials in lined ponds and at intensive stocking have been sufficiently encouraging for commercial farming to be initiated. Other penaeid species such as *P. monodon* (tiger prawn), and foreign ones such as *P. stylirostris* (blue prawn), *P. vannamei, P. esculentus* (brown tiger prawn), *P. orientalis* (Oriental prawn) and *P. indicus* (Indian prawn) may be considered, if environmentally and economically suitable for culture. The tiger prawn, although indigeneous is not easily available, and culture is restricted because of the lack of suitable salinity conditions.

The spiny lobster most popularly cultured because of its availability is *Panilurus polyphagus,* although other species from neighbouring countries could be imported if available in large enough numbers for culture. It is unlikely that their escape from the farms will allow them to establish significantly in some of the marine habitats like coral reefs as they are much sought after by fishermen, collectors and enthusiasts.

The indigenous mangrove crab *(Scylla serrata),* originally from mangrove areas, and previously cultured on small scale in narrow earth furrows in the vicinity of traditional prawn ponds, are now imported for culture in wire cages at some commercial floating fish farms due to the rapid reduction of mangrove forests. They are imported from Sri Lanka and Indonesia and kept in the cages for around two weeks to fatten, and then sold locally. It is unlikely that there is sufficient wild-caught stock for this purpose, and the reduction of mangrove areas in Singapore to less than 250 hectares will have contributed to the scarcity of the mangrove crab.

Species Introduced for Ornamental Value

Johnson (1964, 1973) reported 5 species of freshwater fishes which have been introduced. *Puntius semifasciolatus* was accidentally introduced from China and being tolerant, is well established in the catchment area. Small populations of the true fighting fish, *Betta splendens,* have established in Jurong Lake and water bodies in the Sembawang area. Also well-established in the wild is the introduced *Trichogaster pectoralis,* while the mollies, *Poecilia sphenops* and *Poecilia affinis,* have established permanently in low salinity waters.

Many other species of ornamental fish are imported and/or farmed in Singapore (Table 1). Accidental escape or even deliberate release of these species into natural waterways is likely but the impact, if any, is not noticeable. They are probably unable to compete with the hardier feral guppy and tilapia.

Discussion

Singapore does not have extensive natural inland water bodies nor does it have an indigenous inland fisheries. There is also at present hardly any unique inland aquatic fauna to protect either. As such, introduction of exotic species does not cause much concern and there has not been any serious study of the impact of species introduced for farming or other purposes. However, two introduced species appear to have firmly established in Singapore's inland waterways, and these are the guppy *(P. reticuluta)* and the tilapia *(O. mossambicus)*.

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Table 1. Main species of aquarium fish imported into Singapore (information kindly provided by the Primary Production Department of Singapore).

Freshwater Fish	
Angel	*Pterophyllus altus*
	Pterophyllus scalare
Barb	*Acrossocheilus bantamensis*
	Barbodes bimaculatus
	Barbodes everetti
	Barbodes fasciatus
	Barbodes hassecti
	Barbodes hexazona
	Barbodes lateristriga
	Barbodes partipentazona
	Barbodes schwanenfeldi
	Barbus arulius
	Barbus binotatus
	Barbus cumingi
	Barbus filamentosus
	Barbus holotaenia
	Capoeta arulius
	Capoeta chola
	Capoeta oligolepis
	Capoeta semifasciolatus
	Capoeta tetrazona
	Capoeta titteya
	Esomus dannica
	Osteochilus hasselti
	Osteochilus vitattus
	Puntius asoka
	Puntius conchonius
	Puntius cumingi
	Puntius filamentosus
	Puntius gonionotus
	Puntius lineatus
	Puntius nigrofasciatus
	Puntius sachsi
	Puntius schwanenfeldi
	Puntius semifasciolatus
	Puntius stigma
	Tanichthys albonubes
Guppy	*Poecilia reticulata*
Swordtail	*Xiphophorus helleri*
Platy	*Xiphophorus maculatus*
	Xiphohorus variatus
Gouramy	*Belontia signata*
	Colisa chuna
	Colisa fasciata
	Colisa labiosa
	Colisa lalia
	Helostoma rudolfi
	Macropodus opercularis
	Osphronemus goramy
	Sphaerichthys osphromenoides
	Trichogaster leeri
	Trichogaster microlepis
	Trichogaster pectoralis
	Trichogaster trichopterus
	Trichogaster sp.
	Trichopsis vittatus

Freshwater Fish	
Cichlid	*Acarichthys heckelii*
	Aequidens curviceps
	Aequidens maroni
	Aequidens pulcher
	Aequidens tetramerus
	Apistogramma ramirezi
	Apistogramma sp.
	Astronotus ocellatus
	Aulonocara sp.
	Chromidotilapia sp.
	Cichlasoma cynogutattus
	Cichlasoma festivum
	Cichlasoma meeki
	Cichlasoma nigrofasciatus
	Cichlasoma severum
	Chiclasoma sp.
	Geophagus sp.
	Haplochromis sp.
	Hemichromis bimaculatus
	Hemichromis sp.
	Iodotropheus sprengerae
	Jordanella floridae
	Labeotropheus sp.
	Lamprologus sp.
	Melanochromis sp.
	Nannochromis nudiceps
	Nannochromis sp.
	Pelmatuchromis kribensis
	Pseudotropheus auratus
	Pseudotropheus zebra
	Pseudotropheus sp.
	Steatocranus casuarius
	Symphysodon aequifasciata
	Tilapia aurea
	Tilapia sp.
	Uaru amphiacanthoides
Molly	*Poecilia latipinna*
	Poecilia sphenops
	Poecilia velifera
Goldfish	*Carassius auratus auratus*
Tetra	*Anoptichthys jordani*
	Aphyocharax rubripinnis
	Astyanax fasciatus mexicanus
	Astyanax mexicanus
	Cheirodon axelrodi
	Gymnocorymbus ternetzi
	Hasemania nanas
	Hemigrammus caudovittatus
	Hemigrammus erythrozonus
	Hemigrammus gracilis
	Hemigrammus ocellifer
	Hemigrammus pulcher
	Hemigrammus rhodostomus
	Hyphessobrycon bentosi
	Hyphessobrycon bifasciatus
	Hyphessobrycon flammeus
	Hyphessobrycon herbertaxelrodi
	Hyphessobrycon pulchripinnis
	Hyphessobrycon rosaceus
	Hyphessobrycon rubrostigma
	Hyphessobrycon scholzei
	Hyphessobrycon serpae

Continued

Table 1. Continued

Freshwater Fish	
	Megalamphodus megalopterus
	Metynnis maculatus
	Metynnis roosevelti
	Micralestes interruptus
	Moenkhausia oligolepis
	Nematobrycon amphiloxus
	Paracheirodon innesi
	Prionobrama filigera
	Pristella riddlei
	Thayeria obliqua
Loach	*Acanthophthalmus myersi*
	Acanthophthalmus semicinctus
	Acanthopsis choirorhynchus
	Botia horae
	Botia hymenophysa
	Botia macracantha
	Botia modesta
	Botia sidthimunki
	Cobitis taenia
	Noemacheilus botia
	Noemacheilus fasciatus
	Noemacheilus kuiperi
Danio	*Brachydanio albolineatus*
	Brachydanio frankei
	Brachydanio malabaricus
	Brachydanio rerio
	Danio malabaricus
Discus	*Symphysodon aequifasciata aequifascia*
	Symphysodon aequifasciata axelrodi
	Symphysodon aequifasciata haraldi
	Symphysodon discus
Fighting Fish	*Betta bellica*
	Betta brederi
	Betta splendens
Shark	*Balantiocheilus melanopterus*
	Labeo bicolor
	Labeo erythrunus
	Labeo variegatus
	Leptobarbus hoeveni
	Morulius chrysophekadion
Algae Eater	*Gyrinocheilus aymonieri*
Harlequin	*Rasbora dorsiocellata*
	Rasbora einthoveni
	Rasbora elegans
	Rasbora heteromorpha
	Rasbora kalochroma
	Rasbora maculata
	Rasbora pauciperforata
	Rasbora steineri
	Rasbora taeniata
	Rasbora trilineata
	Rasbora vaterifloris
Mono	*Monodactylus argenteus*
	Monodactylus sebae
Bumble Bee	*Brachygobius sp.*

Freshwater Fish	
Carp	*Aristichthys nobilis*
	Carassius gibelio
	Ctenopharyngodon idella
	Cyprinus carpio
	Hypophthalmichthys molitrix
Scat	*Scatophagus argus*
Eel	*Electrophorus electricus*
	Fluta alba
	Macrognathus aculeatus
	Mastacembelus maculatus
	Mastacembelus sp.
Scissor Tail	*Rasbora caudimaculata*
Catfish	*Brochis coeruleus*
	Chaca sp.
	Corydoras aeneus
	Corydoras hastatus
	Corydoras julii
	Corydoras melanistius
	Corydoras melanistius brevirostris
	Corydoras myersi
	Corydoras nattereri
	Corydoras paleatus
	Corydoras xinguensis
	Hypostomus plecostomus
	Kryptopterus bicirrhis
	Kryptopterus macrocephalus
	Leiocassis siamensis
	Leiocassis sp.
	Malapterurus electricus
	Microglanis parahybae
	Mystus tengera
	Ompok bimaculatus
	Pangasius sanitwongsei
	Pangasius sutchi
	Synodontis nigriventris
	Synodontis notatus
	Synodontis sp.
Marine Fish	
Clown	
Butterfly	
Damsel	
Tang	
Peacock Lion	
Trigger	
Wrasse	
Surgeon	