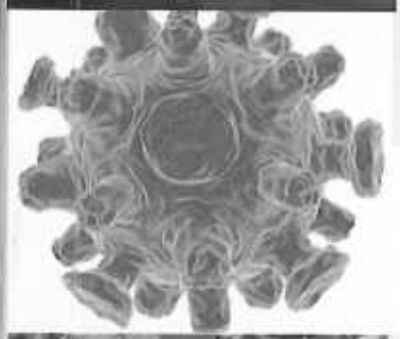

Dr. K. K. Vijayan

Souvenir

INTERNATIONAL DAY FOR BIOLOGICAL DIVERSITY

(22 May 2009)

INVASIVE ALIEN SPECIES

A Threat to Biodiversity

सत्यमेव जयते

Indian Council of Agricultural Research

कृषि अनुसंधान एवं शिक्षा विभाग
ICAR

National Biodiversity Authority

NATIONAL BIODIVERSITY AUTHORITY
INDIA

Ministry of Environment and Forests

जहाँ है हरियाली ।
वहाँ है खुशहाली ।।

3. Invasive Alien Species: Animals including Fishes and their Pests

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Alien species cause major environmental and economic problems worldwide and India is not an exception. Many native species are threatened by competition and predation from the invaders, resulting in the ecosystem modification and loss of biodiversity. Quantification of the ecosystem damage and loss to biodiversity due to alien species invasion is complex due to the interaction of many biotic and abiotic factors. Because of human population growth and human activities related to trade and tourism, the present time is witnessing increased risks associated with alien species introductions. This damage is further aggravated by climate change, pollution, habitat loss and human-induced disturbance. The cost of the worldwide damage from invasive species is estimated at $400 billion a year and, is particularly one of the greatest threats to aquatic biodiversity.

Indian subcontinent with Himalayas in north and three seas in the east, south and west, harbors very rich animal diversity. As we share forests, rivers and plains along with our different neighbours, historically there have always been the incidents of movement of terrestrial and aquatic animals intentionally and un-intentionally across our borders. But of late, when the animal husbandry has become an economic activity and the operations have become intensive, there were records of the introduction of alien animals. At times this has been done as hobby, in bringing the pet animals. While the introduction of alien species of terrestrial animals is limited and mostly the farmed ones were done with the knowledge of government agencies, the incidence of introduction of aquatic organisms, shellfish and finfish are numerous in our country, where most of the introductions are done through illegal means. This has raised serious biosecurity issues, especially due to the introduction of lethal microbial pathogens and outbreak of diseases resulting in huge economic losses, such as the collapse of shrimp farming industry in India due to the outbreak of viral pathogen, the white spot syndrome virus (WSSV) since nineties.

The threat posed by invasive species to biological communities was pointed out by English ecologist, Charles Elton in 1958, but the issue of alien species did not become a concern until the late 1990s. The Convention on Biological Diversity came into effect in 1993. Understanding the importance of invasion by alien species, Article 8 of the Treaty states that: "Each Contracting Party shall, as far as possible and as appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species." At the Fifth Biodiversity Treaty Convention held in 2000, an interim statement of 'guiding principles for the prevention, introduction and mitigation of the impact of alien species that threaten ecosystems, habitat or species' was put forward and were finally adopted in 2002.

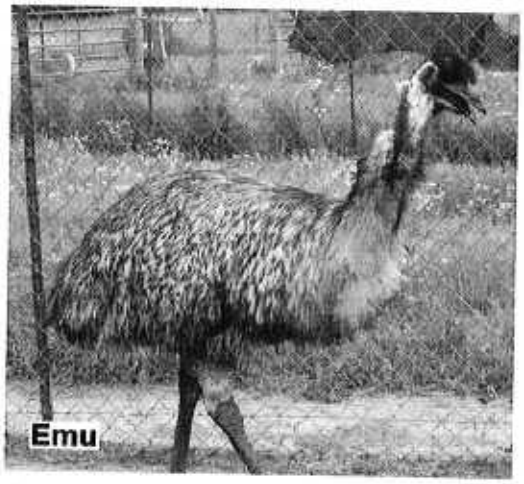
Exotic Animal Introductions

This includes species that are transported unintentionally with cargo, crops, ornamental plants, in ballast water, on vehicles/airplanes etc. Many species/strains of pathogens can also be catalogued under the invasive species. Similarly, many alien species of vectors of various pathogens are also encountered. A typical example is that of the mosquito and rats, several species of which are invasive and are spreading fast through-out the world, thereby providing opportunity for the invasion of new diseases in various countries. *Gambusia affinis*, a native of the United States has been intentionally promoted as a biological control for mosquitoes and has become a pest in many waterways around the world. The highly predatory mosquito fish eats the eggs of economically desirable fish and preys on and endangers rare indigenous fish and invertebrate species. Giant African snail, *Achatina fulica*, a voracious plant eater is a common sight in many parts of the country and nobody knows whether this was introduced intentionally or accidentally. Euglandina rosea, another predatory snail which was introduced as a biological control agent against the giant African snail in many countries has displaced many local species, causing significant loss of biodiversity.


Gambusia affinis


Achatina fulica

Generally accidental introductions are rare in the case of large animals. Almost all the breeds of high yielding farm animals/birds have been purposefully introduced into the country. Same is the case with various breeds of pets like dogs, cats, ornamental birds etc. But off late there have been disturbing reports of ostrich and emu being farmed in many places in the country which raises many unanswered questions. The extent of invasion of alien species in India is given in Table 1 (Pimentel *et al.*, 2001).


Emu

Many small mammals such as rodents, rats, house mouse, rabbit, domestic cat and dogs have been introduced worldwide, including India. Notable animal species considered as alien in the Indian context are the Stoat or weasel (*Mustela ermine)*, Coypu (*Myocastor coypus)* a rodent, Wild boar *(Sus Scrofa)*, Eastern Grey Squirrel (*Sciurus carolineus)* and the Grey Wolf (*Canis lupus)*. These animals must have brought disease agents affecting the humans and livestock. On an estimate, the rat in India alone costs damage to the tune of $25 billion annually.

Table 1. Extent of Invasion in India

Category	Total	Alien
Mammals	316	30
Birds	1221	4
Reptiles and Amphibians	741	NA


Mytilopsis sallei

Ships have been identified as one of the important vectors in the translocation of organisms from one bioregion to another leading to bio-invasion. In this context, harbours serve as gateways for the introduction of various alien species. Ballast water plays an important role in the case of introduction of many marine plants, organisms/larvae/eggs worldwide. This is an example in which species are introduced via activities other than originally intended for them, a case of unintentional introduction (Singh and Lakra, 2006). Comparison of the pre-1960 faunal survey data for the Indian Seas with that for the post-1960 period showed that 205 non-indigenous taxa were introduced in the post-1960 period; shipping activity is considered a plausible major vector for many of these introductions (Subba Rao, 2004). Surveys carried out in the vicinity of ports of Mumbai shows that 14 polychaete species are recently introduced to this area. Of the introduced species, the bivalve *Mytilopsis sallei* and the serpulid *Ficopomatus enigmaticus* have become pests in the Indian Seas (Anil *et al.*, 2002; Gaonkar *et al.*, 2009).

Exotic diseases are on the rise because of increased transportation and encroachment of humans into previously remote ecosystems. Introduced birds, rodents and insects including mosquitoes, fleas and tsetse flies can all serve as vectors and reservoirs of human diseases (Anonymous, 2009). It is a fact that all the invasive species whether introduced or not, invariably carry with them a baggage of pathogens into the new geographic area. The behavior of these pathogens in the new habitats can never be predicted, most of which may exhibit more virulence and the fact that their new hosts do not have any previous immunity, paves way for epidemics. Diseases such as cholera

can be transported with introduced species, establish in local shellfish populations in the new area, and then infect humans. The appearance of many viral infections including SARS & various strains of influenza including the present H1N1- influenza can be linked to the presence of their vectors/carriers.

Following reasons can be attributed to the increase in the rate of invasion:

- Normally introduced species often seem to do better in their new home than in their place of origin, perhaps because of a paucity of natural enemies or competitors.
- The term "natural" is becoming an increasingly elusive concept, as virtually all ecosystems have a strong and increasing anthropogenic component. People are designing - either on purpose or by accident - the kinds of ecosystems they find congenial.
- The growing trade in ornamental species has also meant a great increase in the introduction of aliens, often leading to a net increase in species richness in their destination. It is quite likely, for example, that many parts of the temperature world have far more species now than ever before, and this may also be the case in a least certain parts of the tropics (such as Sri Lanka and most other island nations where geographical barriers exist), though this great increase of species numbers is usually at the expense of indigenous species (and thus reduces global species diversity).
- Moving goods around the world quickly provides ideal opportunities for the accidental introduction of species ranging from zebra mussels to disease-carrying mosquitoes to bacteria and viruses.
- The most purposeful introductions have been done for economic reasons, but usually without a careful consideration of the full cost involved.

These issues are complex and do not lend themselves to clear-cut solutions under current conditions.

Effects of Invasion

Introduction of alien species always carries a cost with it, though it may not be apparent always.

- Damages at ecological level include the appearance of pathogens/vectors and disease, predation, competition, major habitat modification/destruction/loss, hybridization, decline of native species, loss of biodiversity.
- Damages at economical level include financial loss caused by the above mentioned changes, loss of livelihood and cost for control.
- Damages done to the quality of life include nuisance.
- As much as 80% of imperiled species are threatened by invasive species in many parts of the world and the threats occur everywhere, terrestrial, freshwater and marine ecosystems.

- Invasives rank second only to habitat loss as threats to native ecosystems and species worldwide.

Decision-makers need to invest more in assessing the potential impacts before allowing introductions and to incorporate more bio-safety measures once the species has been introduced. Whereas purposeful introductions might be controlled by legislation or regulation, accidents may be far more important in the spread of introduced species and much more difficult to control.

Introductions in Fisheries - Indian Scenario

Although the threats posed by alien fish species can be severe, there is considerable uncertainty about the nature of their impacts on species and ecosystems (Bartley and Casal, 1998). Currently, aquaculture is practiced by adopting alien fish species in many countries including India, raising questions about how best to meet food demands and preserve environmental quality. Four broad categories exist for ecological impacts of alien fish species. They are (i) basic species interactions such as predation and competition (ii) genetic impacts (iii) disease impacts and (iv) habitat alteration (IUCN/SSC, 2000). The increased frequency of international transfers of exotic fish species carried out over the last two decades has invited attention over its potential for debasement of integrity of aquatic communities (IUCN/SSC, 2000; DIAS 2004) as well as introduction of novel pathogens in the country (Arthur, 2005).

Demise or Displacement of the Native *Artemia parthenogenetica* from India


Artemia franciscana

In India, the occurrence of Parthenogenetic Artemia populations were reported from various geographical regions throughout the hypersaline salt pans/waterbodies in the country as early as in 1950s. The ever increasing demand for the Artemia cysts used as a larval feed in finfish & shellfish hatcheries (The yearly requirement of *Artemia* cysts in Indian Aquaculture industry is 100 metric tons) paved the way for the intentional introduction of exotic *Artemia franciscana.* Since the eighties, various research organizations and some private players have intentionally introduced *A. franciscana* in the salt production ponds for enhancing the commercial artemia cyst production. *A. franciscana* cysts were dispersed to neighboring saline ecosystems by humans as well as by the wind, water and water birds aiding its rapid spread and establishment. Presently, *A. franciscana* has totally decimated & replaced the native parthenogenetic artemia populations from almost all the hypersaline waterbodies throughout the length & breadth of the country (CMFRI-DBT 2009). There are many more cases in which insects and plants are introduced by accidental/unintentional introduction.

It is believed that the introduction of fishes started in India by the British with the trout for angling. This was followed by a series of introductions for aquaculture purposes like tench, many varieties of trouts, tilapia, Chinese carps, catfishes and exotic shrimps. However, many fish species were introduced for aquaculture diversification and immediate gains without any concern for their ecological consequences. Notable introductions include Common carp (*Cyprinus carpio*), Silver carp (*Hypophthalmichthys molitrix*), African catfish (*Clarias gariepinus*), Thai-magur (*Clarias gariepinus* x *C. macrocephalus*), bighead (*Aristichthys nobilis*), red tilapia (*Oreochromis niloticus*), *Pangasius*

Table 2. Alien Food Fishes Introduced into Indian aquaculture

Sl. No	Common name	Species	Year of introduction	Source	Place where originally introduced	Reason for introduction
1	Brown trout	*Salmo trutta fario*	1863-1908	England Japan	Nilgiris(TN), Harwan (Kashmir), Kerala	For planting reservoirs, lakes and streams
2	Loach Leven trout	*Salmo levensis*	1863	England	Nilgiris (TN)	-do-
3	Rainbow trout	*Onchorhyn-chusmykiss*	1909	SriLanka, NewZealand Germany,	-do-	-do-
4	Steelhead trout	*Salmo gairdneri irideus*	1867, 1940	Europe, England Srilanka	Nilgiris(TN), Kashmir, Kerala	-do-
5	Steelhead trout	*Salmo gairdneri shasta*	1941	England	Kerala	-do-
6	Lake brook	*Salvelinus fontinalis*	1951	Canada	-do-	-do-
7	Splake trout	*Salvelinus namaykush*	1968	Japan	Nilgiris	-do-
8	Sockey salmon	*Onchorhyn-chus nerka*	1968, 1970	Canada	-do-	-do-
9	Atlantic salmon	*Salmo salar*	1968	North America	Kashmir	-do-
10	Golden carp	*Carassius carassius*	1974	England	Nilgiris	Experimental culture
11	Tench	*Tinca tinca*	1870	England	-do-	-do-
12	Gourami	*Osphronemus gourami*	1856	Java	Kolkata	-do-
13	Silver barb	*Barbodes gonionotus*	1972	Indonesia	West Bengal	Aquaculture
14	Mozambique tilapia	*Orechromis mossambicus*	1952, 1962, 1985	Indonesia Bangkok Sri Lanka Bangladesh Nepal	West Bengal Tamil Nadu Rajasthan	-do-
15	Nile tilapia	*Oreochromis niloticus*		Thailand Israel	Tamil Nadu, West Bengal Rajasthan	-do- Now in sewage fed fisheries in W. Bengal
16	Tilapia	*Orechromis zilli*	1986	Thailand	Indira Gandhi canal, Rajasthan	For reducing aquatic weeds in irrigation system
17	Tilapia	*Oreochromis urolepis*	-	-	Coastal waters of Andaman & Nicobar	For aquaculture
18	Red tilapia	Hybrid strain of *O.niloticus*	1980	Philippines Israel	Chengulpattu (Chennai), Kolkata, CCMB Hyderabad Orion Chemicals Chennai	Experimental culture for Aquaculture in distillery wastes
19	Common carp	*Cyprinus carpio*	1939	Sri Lanka	Cuttack	Aquaculture

		communis	1957	Bangkok		(Composite Fish Culture)
20	Mirror carp	*Cyprinus carpio* specularis	1939 1957	Sri Lanka, Bangkok	Nilgiris	Aquaculture at high altitudes
21	Leather carp	*Cyprinus carpio* nudus	1939 1957	Sri Lanka, Bangkok	Cuttack	Aquaculture now established in pond culture
22	Grass carp	*Ctenopharyngodon idella*	1959	Japan, Hongkong	Cuttack	Aquaculture (Composite Fish Culture)
23	Silver carp	*Hypophthalmichthys molitrix*	1959	Japan Hongkong	-do-	Aquaculture (Composite Fish Culture) now established in some reservoirs
24	Bighead	*Aristichthys nobils*	1980	Possibly Honkong Bangladesh & Nepal	West Bengal	Pond culture (Unauthorized introduction), now available in some lakes
25	Channel catfish	*Ictalurus* sp.	1990	Not known	Thajavur (TN) West Bengal	Pond culture (Unauthorized introduction)
26	African catfish	*Clarias gariepinus*	Not known	Neighbouring countries	West Bengal	West Bengal (Unauthorized introduction) now found in some reservoirs and river stretches.
27	Piyasi	*Pangasius sutchi*	Not known	Neighbouring countries	West Bengal	West Bengal (Unauthorized introduction)
28	White leg shrimp	*Litopenaeus. vannamei*	2001	Taiwan	exclusive culture in Tamilnadu/AP	West Bengal and A P Aquaculture particularly in Andhra Pradesh and Tamil Nadu.

Source: Singh and Lakra, 2006

sutchi, *Litopenaeus vannamei* and many ornamental fishes including red piranhas. Many of these recent introductions are unauthorized and have been carried out illegally (Singh and Lakra, 2006). These exotic fishes were brought for aquaculture, but in due course moved into open waters inadvertently and may cause ecological problems (Table 2 & 3). Similarly the scenario from marine waters is also receiving attention where ships carrying ballast water transfers microorganisms and invasive exotic species that distort and destroy the delicate aquatic integrity (Singh and Lakra, 2006).

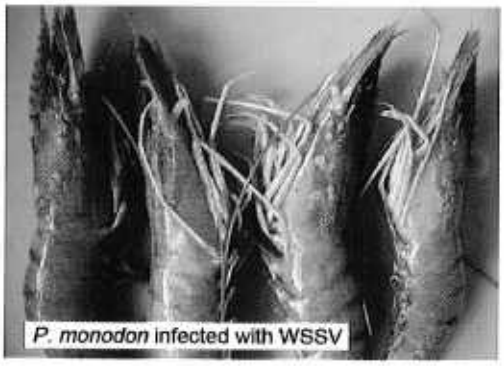
Exotic Diseases and Indian Aquaculture

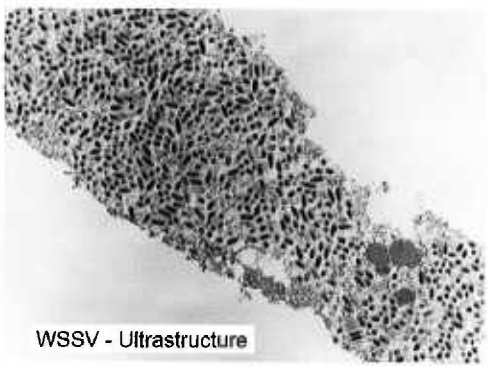
Shrimp and carp farming has been the face of aquaculture in India. In India, the largest economic losses from aquatic animal diseases have been reported from the shrimp farming regions, due to exotic viral pathogens introduced through illegally in the nineties. By the end of 1993, diseases, especially those of viral etiology have emerged as the major

Table 3. Environmental Impact of Alien Fish Introductions

Aquaculture Introduction	Environmental Impact
Oreochromis mossambicus	Displaced Gangetic carps, replaced *Puntius dubius* and *Labeo kontius* and now posing threat to *Etroplus suratensis*
Osphronemus goramy	Naturalized, but ecological implication is minimal
Aristichthys nobilis	Displacement of Catla and silver carp, hybridization with silver carp
Cyprinus carpio	Displacement of local spp. *Schizothorax, Osteobrama belangiri, Tor putitora* etc
C. carpio	Naturalized and available in rivers.
O. niloticus	Reduced catches of indigenous fish species
Clarias gariepinus	Environmental problem, started appearing in wild posing threat to biodiversity. Risks of hybridization with native fishes, loss to local culturable fishes.
Carassius auratus	Hybridization with common carp in nature
Hypophthalmichthys molitrix	Naturalized in some reservoirs and displacement of Catla
Ctenopharyngodon idella	Not known
Oncorhynchus mykiss	Unknown
Salmo trutta fario	Eradication of local spp.

Source: Singh and Lakra, 2006





constraint for the sustainability and growth of shrimp aquaculture (Vijayan *et al*, 2007, Karunasagar *et al* , 2008). The pandemics due to the penaeid viruses, WSSV (White spot syndrome virus), have cost the penaeid shrimp industry millions of dollars in lost crops, jobs and export revenue, raising doubts about the very sustainability and economic viability of the shrimp farming industry. The accumulated loss due to WSSV in Indian shrimp farming is about Rs. 4000 crores during the last one decade.

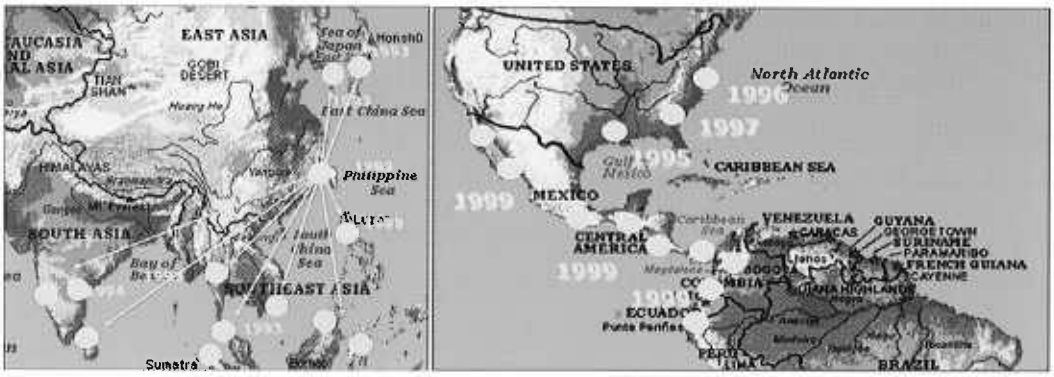
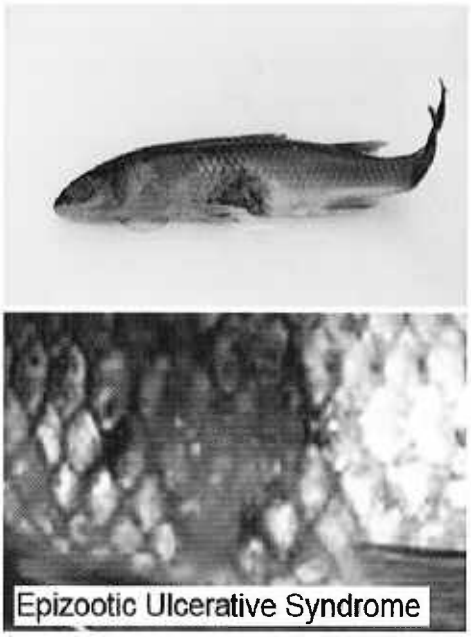


Fig. 2 Global spread of WSSV

Outbreaks of WSSV were first found in *Penaeus japonicus* in China in 1992 (Lo *et al.*, 2005). The disease first spread geographically within the species *P. japonicus* and only later, in 1993, spread to other species including *Penaeus chinensis*, which is the major cultured species in China. No one knows how the virus spread throughout Asia after that, but the common practice of moving grossly normal broodstock and PL freely amongst countries was probably the most rapid and effective means of spread (Fig. 2).



In finfishes, the Epizootic Ulcerative Syndrome (EUS) is the highly pathogenic, invasive, fungal infection caused by the fungus, *Aphanomyces invadans* in freshwater and estuarine fishes. EUS with its high epizootic potential and mortality rates has believed to be entered Indian waters through

Table 4. Threats and Risks of Introducing Exotic *Litopaeneus vannamei* for Aquaculture

Issues and Concerns	Problems
Biodiversity issues	Escapees can effect on wild stock, impact of escapees on indigenous shrimp stocks particularly.
Disease risks	Viral diseases (WSSV, TSV, IHHNV etc.)
Consumers problems	May affect consumers acceptability, preference and image on account of its negative environmental problems (Diseases)
Regional and global trade effects	Inter-regional, between regions of the country as well as culture and capture competitions may affect the socio-economics and biodiversity

(Singh and Lakra, 2006)

the common river system with the neighboring countries such as Bangladesh. The pathogen already established in freshwater systems in many North eastern and some Southern states of India, and losses due to EUS has been estimated at 42.5 million US $ during the period 1992-95 (Lilley, 2002; Gopal Rao *et al.*, 1992).

Introduction of American White Shrimp *(Penaeus (Litopenaeus) vannamei)* Lessons to be Learnt


Litopenaeus vannamei

The white leg shrimp (*Litopenaeus vannamei*) formerly known as *Penaeus vannamei* has spread from Taiwan in 1995 to almost all Asian shrimp farming countries. In India, it was introduced clandestinely during 2001 in the states of Tamilnadu and Andhra Pradesh under the belief that it outperforms *P. monodon* on all aspects of aquaculture. The rapid growth in the farming of this species has had its set back. Despite the rapid expansion of farming of *L. vannamei*, farmers have suffered significant economic losses due to diseases (WSSV, TSV, IHHNV etc). It is suspected that the Taura Syndrome Virus and IHHNV, exotic viral pathogens are introduced to Indian shrimp farms through *L. vannamei*. Various possible problems including its impact on the wild and indigenous stocks, potential to act as carriers of diseases, biodiversity issues etc remains to be studied (Table 4). The introduction of *L. vannamei* and its consequences points to the importance of precautionary approach that should be taken before introductions are allowed.

What Can be Done ?

In the history of introduction of alien fishes to India, with touts, Chinese carps, tilapia and artemia in the past and catfish and American white shrimp recently, in depth studies are not available to draw a conclusion on the positives and negatives. However, enough indicators are available to show the negative impact on the native population due to the invaded species (Table 3 & 4). Hence the best technical approach is the prevention over the significant higher costs associated with control and management of already established invasions. Implementation of suitable biosecurity measures is absolutely essential to prevent invasions. Governments, businesses and farming community should be very careful before deciding on species choice for planned introductions. Strategies for control/prevention should be in tandem with neighbouring states and countries because invasives do not have political boundaries. Since the pathways of introductions are regional or even international, border controls, sanitary measures in shipments etc are some of the actions countries can agree upon in a co-operative way.

Legislation

In most countries, there is no clear distinction between terrestrial and aquatic animal health legislation. In cases where specific regulations for aquaculture exist, their enforcement is applied mostly as an emergency procedure to deal with a specific problem, and not as the result of an established program for surveillance and monitoring of the health status of cultured organisms. Several countries have specific legislations to regulate the import and export of live aquatic organisms and their products for use in aquaculture, for human consumption, or other purposes. Generally, these laws and regulations are in conformity with the rules of the OIE and WTO-SPS.

A draft legislation on "Live aquatic organisms' importation Act 2006" has been proposed (Lakra *et al* 2006). Based on the existing international agreements and codes of practices for the transboundary movement of aquatic animals, the recommendations made in various consultations on invasiveness, disease diagnostics, risk analysis, emergency preparedness, capacity building etc., and existing legal provisions adopted by different countries, an act becomes inevitable to strictly implement the provisions needed in safeguarding the existing conservation and management of aquatic animal diseases and biodiversity in Indian fisheries.

Suitable central and state legislations aid the control of various diseases of livestock entering the country through introductions. The Livestock Importation (Amendment) Act, 2001 provides modalities of International Animal Health Certification. The regulation of import and export of livestock and livestock products, control of exotic disease and certification as per OIE regulations is done through the Animal Quarantine and Certification Services (AQ&CS) under the control of Department of Animal Husbandry & Dairying (DHAD) at New Delhi, Mumbai, Kolkata and Chennai. In recent past, diseases like Bovine Viral Diarrhea, Malignant Catarrh Fever, Rabbit Hemorrhagic Disease, Avian Influenza and the very recent H1N1 have been diagnosed in the imported livestock and poultry at the entry point of quarantine. If not intercepted and controlled, these diseases would have played havoc with our livestock and poultry.

Conclusion

Introduction of non-native/invasive alien species whether deliberately or accidentally, has been a major threat to biological diversity worldwide. One of the main reasons for the increase in invasive alien species is the significant increase in world trade, transport and tourism, combined with a general and severe degradation of habitats. Ships have been identified as one of the most important vectors in the translocation of organisms from one bioregion to another leading to bio-invasion. All the exotic species bring with them an array of pathogens into the new geographic area creating hitherto unknown diseases/epidemics.

Shrimp and Carp farming is synonymous of Indian aquaculture, where the largest economic losses from have been reported, due to exotic fungal and viral pathogens introduced in eighties and nineties. In India, *Artemia franciscana* introduced in the eighties had totally replaced the native parthenogenetic species.

The consequences of invasion are far reaching. Introductions of alien biota could pose a threat to the highly productive tropical coastal waters, estuaries and mariculture sites and could cause economic impacts and ecological surprises. While on the economic front it can exacerbate poverty and threaten development through their impact on agriculture, forestry, fisheries and natural systems, which are an important basis of peoples' livelihoods in developing countries. Governments and businesses should be very careful and should keep the legal format in place through scientific methods before deciding on species choice for planned introductions. Implementation of suitable biosecurity measures along with necessary legislation is absolutely essential to control/ prevent such invasions.

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