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Non-native fishes in the inland fish production of Kerala (South India)

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Abstract
In Kerala (South India), introduction of exotic fishes was started as early as 19th century by British rulers, mainly for sport fishing. Later non- native species were introduced with a view to increase fish production from untapped water bodies to ensure nutritional security. Though introduction of non- native species may result in negative impacts, their positive impacts cannot be overlooked especially with regard to enhancement of fish production, protein supply, provision of livelihood to masses and increase in income. The present paper is an attempt to examine the extent of contribution of non- native species of fishes to the inland fish production of the state of Kerala, based on secondary data. The study revealed that non- native species of fishes contribute to the inland fish production substantially. There is a gradual increase in percentage contribution of non- native fishes to the total inland fish production of the state from 21.05% to 47.59% during the last 20 years viz., 1994- 95 to 2014- 15. An attempt was also made to trace the history of introduction of non- native species of fishes to India with special reference to Kerala.

Keywords: non-native species, exotic fishes, alien fishes, inland fish production

1. Introduction
In Kerala (South India), the introduction of exotic fishes was started as early as 19th century by British rulers. Initially fishes were introduced for sport purpose. Later non-native species were introduced with a view to increase fish production from untapped water bodies to ensure nutritional security.
Introduction of exotic fishes has both beneficial and adverse impacts. The benefits of introduced exotic species are generally felt immediately while the adverse effects are evident only after a fairly long period [1].
Studies on the negative impacts of introduction of native species of fishes in India and in the state of Kerala are many [2-10]. While discussion on the negative effects of introduction of non- native fishes is appreciated their positive impacts cannot be overlooked especially with regard to aspects like enhancement of production, protein supply, provision of livelihood to masses and increase in income. In the present paper an attempt is made to examine the extent of contribution of non- native species of fishes to the inland fish production of the state of Kerala. An attempt is also made to trace the history of introduction of non- native species of fishes to India with special reference to the state of Kerala.

2. Materials and methods
The present study was primarily based on published secondary data. Information on aquaculture production and species contributing to inland fisheries were also collected from the office of the Department of Fisheries, Government of Kerala.
Various authors used different terms to denote a fish introduced into an ecosystem from outside, with little or slight difference in meaning. They are exotic fish, alien fish, introduced fish and non- native fish. In the present paper all these terms are used synonymously. The terms are used to mean a fish species that is not native to the state of Kerala.

3. Results
3.1 History of introduction of exotic fishes
Attempts to introduce exotic fishes to India were started with the introduction of brown trout (*Salmo trutta*) in 1863 from England [11]. The first two attempts to transplant trout from England made by Sir Francis Day in 1863 and 1866 were unsuccessful. In 1867, MacIvor imported a new consignment of trout fry from Scotland, which, in 1869 were first transferred to the Government House Gardens. Ootacamund and then to the Ootacamund lake, the Kundah and other places [12]. This consignment was reported to have perished. The same story of unsuccessful efforts by enthusiastic amateurs continued till 1905. It was in 1906 that Wilson succeeded in not only transplanting trout in Nilgiris but also in putting trout culture in that area on a scientific footing [11]. The tench (*Tinca tinca*) and crucian carp (*Carassius carassius)* were first introduced from England in 1870 by MacIvor in Ooty lake [11]. Subsequently the fishes established themselves in the ponds and lakes in Nilgiri hills.
The top minnow (*Gambusia affinis*) was introduced into Mysore from Italy in 1928 [13]. The fish bred out of this consignment was transplanted into different parts of the country from Travancore in the South to Punjab in the North. Another consignment of *Gambusia* was brought from Sri Lanka in 1929 by the Madras Fisheries Department and stocked in the waters of Krusadi Island. Yet another one was taken from Bangalore to Madras city in 1930 [14].
Later many species were brought to the country for sport, food, mosquito control and for ornamental purposes. During the last several decades over 300 species have been reported to have been brought into India for experimental aquaculture, sport fishing, mosquito control and aquarium keeping [2]. Details of fishes introduced in India for aquaculture, sport and mosquito control are provided in table 1. It does not include fishes introduced for ornamental purpose.

Table 1: History of introduction of exotic fishes to India for sport, food and mosquito control.

Species	Common name	Source	Year of introduction	Purpose	Ref.
Salmo trutta fario	Brown trout	England	1863 (Succeeded in 1906)	As game fish for planting streams, lakes and reservoirs	11
Carassius carassius	Crucian carp	England	1870	As food fish for experimental culture	11
Tinca tinca	Tench	England	1870	As food fish for experimental culture	11
Salmo gairdneri	Rainbow trout	Sri Lanka and Germany England	1907 1911	As game fish for planting streams, lakes and reservoirs	11
Poecilia reticulatus	Guppy	South America	1908	Mosquito control	11
Osphronemus goramy	Giant gourami	Mauritius Java	1865 1916	As food fish for experimental culture	11, 15
Gambusia affinis	Mosquito fish	Italy	1928	Mosquito control	11
Cyprinus carpio German strain	Common carp	Sri Lanka	1939	As food fish for experimental culture	11
Oreochromis mossambicus	Tilapia	Bangkok	1952	As food fish for experimental culture	11
Cyprinus carpio Bankok strain	Common carp	Bangkok	1957	As food fish for experimental culture	11
Hypophthalmichys molitrix	Silver carp	Hong Kong	1959	As food fish for experimental culture	11
Salvelinus fontinalis	Brook trout	Canada	1959	As game fish for planting streams, lakes and reservoirs	11
Ctenopharyngodon idella	Grass carp	Japan	1959	As food fish for experimental culture	11
Onchorhyncus nerka	Sockeye salmon	Japan	1968	As game fish for planting streams, lakes and reservoirs	11
Salamo salar	Atlantic salmon	USA	1968	As game fish for planting streams, lakes and reservoirs	11
Puntius javanicus	Tawes	Indonesia	1972	For experiments to determine its efficiency in weed control	11
Aristichthys nobilis	Bighead carp	Bangladesh	1987	Unauthorized introduction for aquaculture	15
Clarias gariepinus	African cat fish	Thailand	1978	Unauthorized introduction for aquaculture	16
Tilapia zilli		Thailand	1986	Aquatic weed control	16
Oreochromis niloticus	Nile tilapia	Thailand	1987	Unauthorized introduction for aquaculture	17
Serrasalmus nattereri	Red piranha	-	-	Unauthorized introduction for aquaculture/ aquarium keeping	2
Pangasianodon hypophthalmus	Striped cat fish	Bangladesh	1997	Unauthorized introduction for aquaculture. Later Government of India permitted its culture	18
Piaractus brachypomus	Pacu	-	2003/ 2004	Unauthorized introduction for aquaculture. Later Government of India permitted its culture	19
Ictalurus punctatus	Channel cat fish	USA	-	Unauthorized introduction for aquaculture	20
Penaeus vannamei	White leg shrimp	Taiwan	2001	As food fish for aquaculture	21

Introduction of exotic species of fishes to Kerala began with the introduction of brown trout (S*almotrutta fario*) into Travancore high ranges. Brown trout ova were first introduced in the Kannan Devan Hills (Munnar High Range) of erstwhile Travancore in 1909 from Howieton in Stringshire, Scotland [11]. This consignment, however, did not lead to the establishment of the fish in the state. Renewed attempts to establish brown trout in Travancore continued from 1909 to 1930 but met with little success. Rainbow trout (*S. gairdneri*) was first introduced in the high range of Travncore in 1932. Later fresh consignments of eyed ova were brought to Rajamallay hatchery from Sri Lanka and Nilgiris from where trout fry were released in Eravikolam river and other suitable waters of Kerala. By 1941-42, rainbow trout was reported to have established itself in the high range of Travancore [13, 22]. In 1952, eyed ova of *S. gairdneri shasta* were imported from United Kingdom. Later many non- native species were introduced into the state principally for aquaculture, reservoir stocking and for ornamental purposes.

Parallel to the introduction from outside India there were attempts for cross regional transplantation of fishes within the country. One of the earliest attempts of transplantation of fishes in India was that of milk fish (*Chanos chanos*) during the later part of 18th century by Hyder Ali of Mysore [23]. An attempt to transplant *Hilsa ilisha* into Kerala was made by Nicholson [24]. The ova of fish were transferred to Ponnani River in the erstwhile Malabar but there is no evidence of the fish being established in the river system.

Successful transplantation of catla in South India was achieved by Madras Fisheries Department [25]. The fingerlings from Godavari River were introduced into Gunddapah in Kurnool canal where they established themselves and spread into the Pennar River and the connected tanks in Nellore district. Catla fingerlings from the Godavari were introduced in the year 1921 into the Cauvery River and into the Bhavani [26], where the fish now supports a sizeable fishery. Catla fingerlings were sent to Cochin (Kerala) in1945 where they thrived well [23]. Fry from the Godavari River was also introduced into the Periyar Lake in Travancore- Cochin [27]. The Bombay Fisheries Department transplanted catla from Patna (Bihar) into the Powai Lake in Bombay where it bred and established itself [28].

Earliest attempt to transplant rohu was made when fingerlings were taken from Calcutta and introduced into the freshwaters of Andamans. From the records of Annadale and Hora [29] and Mukerjii [30] the fish was found to grow well but it is doubtful whether it bred there. The Madras Fisheries Department had been regularly stocking this fish in the state from 1944 to 1949 with fry obtained from Bengal and Orissa and attempts were made to transplant the fish in the river Cauvery also [31]. In Bombay, fry from Patna (Bihar) were introduced into the Powai Lake along with *Labeo calbasu* where both were reported to have bred [28]. Fry of mrigal were introduced regularly from 1943 to 1947 into the waters of Madras including the Cauvery [31]. Mrigal introduced as fry into the Powai lake in Bombay from Patna (Bihar) were reported to have bred there [29].

3.2. Non- native species in inland fish production of Kerala

Non- native species contribute to the inland fish production (capture and culture) of Kerala significantly (table 2) [32]. These include both the species introduced with legitimate approval of the concerned bodies and those introduced in a clandestine way. All these species were introduced for aquaculture purpose. They reached the natural water bodies escaping from the aquaculture systems and/ or through open water ranching programmes being implemented by the Department of Fisheries [32].

Table 2: Non- native food fishes represented in the commercial production (capture and culture) of Kerala [32].

S. No.	Scientific name	Common name	Family	Native place	Purpose of introduction	Principal route to the natural water bodies
1	*Catla catla*	Catla	Cyprinidae	Gangetic region (India)	Aquaculture	Open water ranching and escape from aquaculture systems
2	*Labeo rohita*	Rohu	Cyprinidae	Gangetic region (India)	Aquaculture	Open water ranching and escape from aquaculture systems
3	*Cirrhinus mrigala*	Mrigal	Cyprinidae	Gangetic region (India)	Aquaculture	Open water ranching and escape from aquaculture systems
4	*Cyprinus carpio*	Common carp	Cyprinidae	East Asia	Aquaculture	Open water ranching and escape from aquaculture systems
5	*Ctenopharyngodon idella*	Grass carp	Cyprinidae	East Asia	Aquaculture	Open water ranching and escape from aquaculture systems
6	*Hypophthalmichthys molitrix*	Silver carp	Cyprinidae	East Asia	Aquaculture	Open water ranching and escape from aquaculture systems
7	*Labeo fimbriatus*	Fringe lipped carp	Cyprinidae	Asia (Pakistan, India, Nepal, Myanmar and Bangladesh)	Aquaculture	Open water ranching and escape from aquaculture systems
8	*Piaractus brachypomum*	Pacu	Serrasalmidae	South America	Aquaculture	Escape from aquaculture systems
9	*Pygocentrus nattereri*	Red piranha	Serrasalmidae	South America	Auaculture/ aquarium keeping	Escape from aquaculture systems
10	*Pangasianodon hypophthalmus*	Striped catfish	Pangasiidae	Asia (Mekong, Chao Phraya, and Maeklong basins)	Aquaculture	Escape from aquaculture systems
11	*Osphronemus goramy*	Gourami	Anabantidae	Indonesia, Thailand, Malaysia, Cambodia and Vietnam	Aquaculture	Escape from aquaculture systems
12	*Clarias gariepinus*	African cat fish	Clariidae	Africa	Aquaculture	Escape from aquaculture systems
13	*Oreochromis mossambicus*	Mossambique tilapia	Cichlidae	East coast of Africa	Aquaculture	Escape from aquaculture systems
14	*Oreochromis niloticus*	Nile tilapia	Cichlidae	Africa	Aquaculture	Escape from aquaculture systems
15	*Litopenaeus vannamei*	White leg shrimp	Penaeidae	Eastern Pacific coast	Aquaculture	-

Production of fishes in the inland sector of Kerala (from culture and capture sector) during the last two decades is presented in fig. 1. Figure 2 depicts the trends in production of indigenous and non- native fishes in the state. In Kerala the contribution of non- native species to the total inland fish production in the year 1994-95 was 21.05%. It grew to 47.59% by the year 2014-15. Correspondingly there is a gradual decrease in contribution of native species in the state. In the year 2014-2015 the contribution of indigenous species of fishes to the inland fish production was 52.40% which was 78.95% twenty years back (table 3). The principal non- native species contributing to inland fish production of the state in the year 2014- 2015 were catla (14.46%), rohu (13.48%), mrigal (6.78%), tilapia (5.99%), common carp (5.29%) and fringe lipped carp (1.60%).

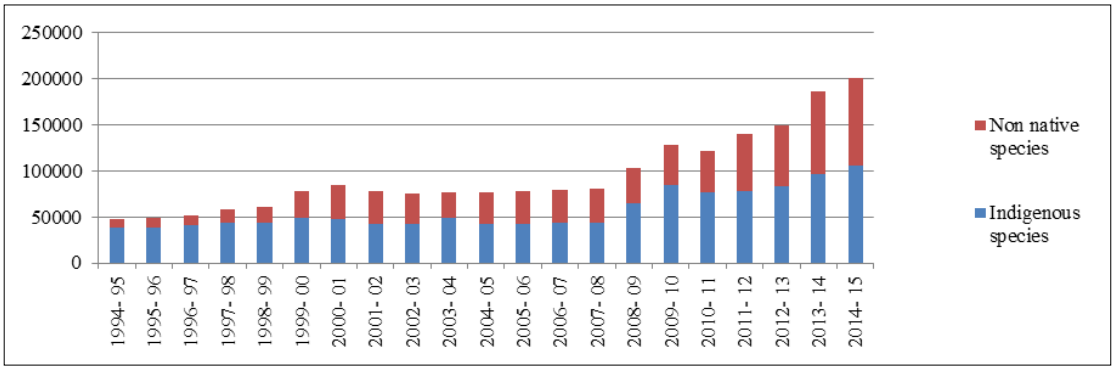

Fig 1: Contribution of non- native species to the inland fish production of Kerala (Based on DoF [33]).

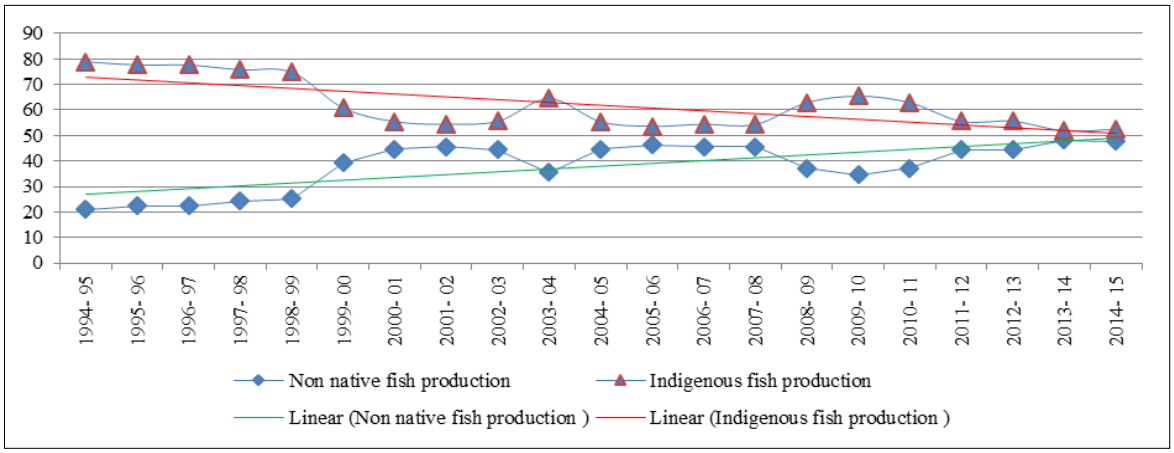

Fig 2: Trend in contribution of non- native species and indigenous species to the inland fish production of Kerala as percentage of total inland fish production (Based on DoF [33]).

Table 3: Contribution of non- native species in inland fish production of Kerala in 2013- 2014 (Based on Sahadevan [32] and DoF [33]).

S. No.	Scientific name	Common name	Contribution to the total inland fish production (ton)	Contribution to the total inland fish production (%)
1	*Catla catla* (Hamilton)	Catla	29139	14.46
2	*Labeo rohita* (Hamilton)	Rohu	27161	13.48
3	*Cirrhinus mrigala* (Hamilton)	Mrigal	13666	6.78
4	*Cyprinus carpio* (Linnaeus)	Common carp	10663	5.29
5	*Ctenopharyngodon idella* (Valenciennes)	Grass carp	N	N
6	*Hypophthalmichthys molitrix* ((Valenciennes	Silver carp	N	N
7	*Labeo fimbriatus* (Bloch)	Fringe lipped carp	3228	1.60
8	*Piaractus brachypomum* (Cuvier)	Pacu	N	N
9	*Pangasius pangasius* (Hamilton)	Pangas	N	N
10	*Osphronemus goramy* Lacepede	Gourami	N	N
11	*Clarias gariepinus* (Burchell)	African cat fish	N	N
12	*Oreochromis mossambicus* (Peters)	Mossambique tilapia	12064	5.99
13	*Oreochromis niloticus* (Linnaeus)	Nile tilapia	N	N
14	*Litopenaeus vannamei* (Boone)	White leg shrimp	N	N
	Indigenous species	-	105624	52.40

N: Negligible/ not quantified

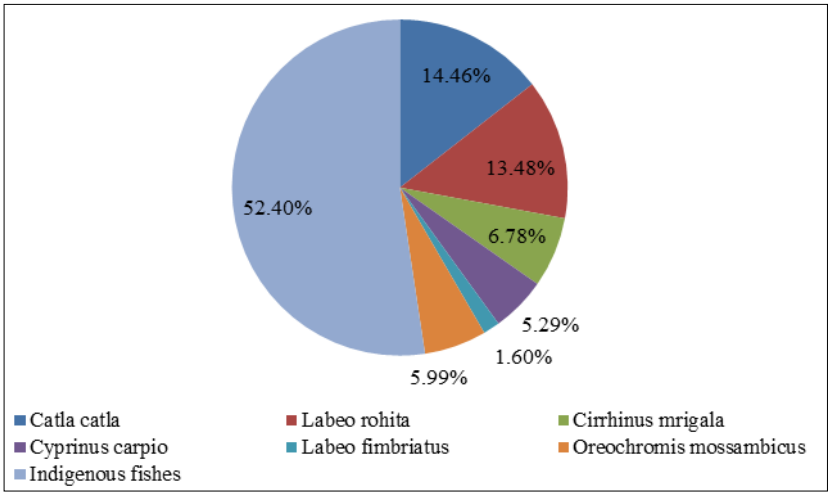

Fig 3: Share of different species in the inland fish production of Kerala (Basesd on DoF [33]).

4. Discussion

Although major introductions of alien fishes into Kerala are a relatively recent phenomenon, alien species particularly Indian major carps, tilapia and Chinese carps have been playing an important role in the development of Inland fish production in the state for long. There is a gradual increase in percentage contribution of alien fishes to the total inland fish production of the state from 21.05% to 47.59% during the last 20 years viz., 1994- 95 to 2014- 15.

There are many reports of exotic fishes contributing to nutritional security and resulting in other positive impacts from other parts of the world. Yakupitiyage and Bhujel [34] reported significant roles played by exotic fishes in ensuring food security in Cambodia, Lao People's Democratic

Republic, Thailand and Viet Nam. These fishes accounted for about 49, 100, 26 and 73% of the total aquaculture production in Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam, respectively. According to Dowall[35] introduced Nile tilapia and common carp maximized the natural fertility of the paddy fields in Cambodia. Introduced trout has been reported to increase benthic phosphorous availability and stimulate the primary production [36].

The gradual increase in the contribution of non- native species and corresponding decrease in the contribution of native species in Kerala are also on account of the popularization of freshwater aquaculture which is centred round Indian major carps (IMC) viz., catla, rohu and mrigal and the exotic carps like common carp, grass carp and silver carp [37]. All these fishes are exotic to the state of Kerala. Carps became the centre of attraction of aqua culturists in view of the availability of commercially viable and easily adoptable technology for mass production of seeds, in addition to other attributes required for cultivable species like fast growth rate, market acceptability, fairly high price etc. [37].

Of late, a shift from the carp centric approach is also clearly discernible. In Kerala people generally prefer sea fishes and demand for carps is limited. Under the circumstance a felt need of the farming sector is to go for alternative species. Indigenous fresh water fishes like the murrels (*Channa diplogramma*, *C. marulius* etc.), cat fishes (*Clarias dussumieri*) and giant freshwater prawn (*Macrobrachium rosenbergii*) are good alternative candidate species for farming in the freshwater areas in suitable locations. Though basically brackish water fishes pearl spot (*Etroplus suratensis*), milk fish (*Chanos chanos*) grey mullet (*Mugil cephalus*) and sea bass (*Lates calcarifer*) are also suitable for farming in freshwater areas, if properly acclimatized. However, in the absence of commercial hatcheries, there is acute shortage of seeds of the murrels, cat fish, pearl spot, milk fish, grey mullet and sea bass in the state [37]. In the context of non-availability of seeds of indigenous cultivable fishes and in the context of lower preference for carps, farmers are fast shifting to non-native species like pangasius, pacu, piranha, African cat fish, tilapia etc. which may cause damage to the ecosystem sooner than later. Similarly white leg prawn (*L vannamei*) is slowly emerging as a candidate species for farming. in brackish water areas, in view of the recurring disease problems associated with tiger prawn farming. Here too farmers are unable to shift to alternative indigenous species (like *Lates calcarifer*, *Mugil cephalus*, *Chanos chanos* etc.) as hatchery produced seeds of these fishes are not readily available in the state. In the context of scarcity or near total absence of hatchery produced seeds of the indigenous fishes the dependence on non- native species by the farming sector is expected to continue, in the years to come.

Many of the alien species in Kerala have reached the natural waters by escaping from aquaculture systems. Indian major carps and common carp have also reached the natural waters also through regular open water ranching done by the State Department of Fisheries and agencies under it. Non- native fishes have been introduced for augmenting the fishery in many rivers and reservoirs of Kerala. In fact reservoir ranching with non- native carps (Indian major carps and Chinese carps) is a regular programme being implemented by the State Fisheries Department for the last couple of decades. As a direct result, fisheries of most of the reservoirs in the state are dominated by non- native fishes.

Non- native species introduced into a water body may establish in the system due to non-existence of natural enemies. They may also occupy the niche of the indigenous species and may replace it partly or completely. It is a well-established fact that when two species compete for a limited resource, one species eventually drives the populations of the other species to extinction. Competing species cannot co-exist for long. The Competitive Exclusion Principle [38] states that two species are not able to co-exist at constant population values competing for the same resource. It means that species cannot co-exist if they have the same niche. The word "niche" refers to a species' requirements for survival and reproduction. These requirements include both resources (like food) and proper habitat conditions (like temperature, pH etc.). If two species have identical niches they would attempt to live in the same area and would compete for the same resources. If this happens, the species that is better adapted would exclude its competitors from that area. To understand competition we need not only consider conditions and population attributes that lead to competitive exclusion but also situations under which similar species co-exist, since large numbers of species do share common resources in the open system of nature [39].

It must be remembered that some of the introduced varieties do not breed in the natural waters of Kerala while others do breed. In the first category come fishes like catla, rohu, mrigal, grass carp and silver carp. The fishes which breed in the natural water bodies of Kerala include fishes like African cat fish, Mossambique tilapia, Nile tilapia and gourami. In the case of fringe lipped carp, pacu, pirana and white leg shrimp no scientific studies on their natural breeding in the water bodies of Kerala have been reported. It must be mentioned here that the case of fishes which readily breed in the natural bodies of water is more serious as they multiply and establish in the system very fast and are likely to have a more long-standing effect on the ecosystem.

Globally, alien species of plants and animals are considered a major threat to native biodiversity, with the International Union for Conservation of Nature (IUCN) citing their impacts as "immense, insidious, and usually irreversible" [40]. Whether introduced accidentally or deliberately into a natural environment alien species threaten the ecological stability of invaded habitats and native species therein, as these are highly sensitive to various interactions with these non-native species (e.g. predation, competition and herbivory) [41]. Impacts include serious biodiversity loss (sometimes even the extinction of native species), transmission of disease to humans, and economic damage. A multiplicity of pathways (e.g. increased international trade and travel) and vectors (e.g. crop seed, angling equipment) currently exist to facilitate and indeed hasten the introduction and spread of alien species throughout the globe. Climate change may exacerbate the problem. Although not all non- native species introductions result in harmful or damaging outcomes, current evidence indicates that the increasing scale of alien species introductions necessitates serious scrutiny and, moreover, a coordinated international response [41].

5. Conclusion

Introduction of exotic fishes has both positive and negative impacts. Studies on the negative impacts of introduction of native species in India and in the state of Kerala are many

While discussion on the negative effects of introduction of non- native species is appreciated their positive impacts cannot be overlooked especially its importance in providing nutritional security and livelihood to masses. The present paper is an attempt to examine the extent of contribution of non- native species of fishes to the inland fish production of the state of Kerala.

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