

Non-native fishes in the Indian Himalaya: an emerging concern for freshwater scientists

Nishikant Gupta¹ and Mark Everard²

¹International Centre for Integrated Mountain Development (ICIMOD), Post Box # 3226, Kathmandu, Nepal

²University of the West of England (UWE), Coldharbour Lane, Frenchay Campus, Bristol BS16 1QY, UK

*Corresponding Author: nishikantgupta@live.in

Abstract

Anthropogenic activities impose major threats to global biodiversity, compounded by changing climatic variables. Freshwater ecosystems are amongst the most vulnerable habitats, integrating multiple pressures across catchment landscapes. Introductions of non-native fish species exert multiple direct and indirect impacts on native species and the ecosystems of which they are part, with further impacts on the socio-economic wellbeing of communities. Field studies and an in-depth literature survey have recorded 15 non-native freshwater fish species from the Indian Himalaya. Three of these species (common carp, brown trout and rainbow trout, all highly invasive fish species globally) were documented from multiple locations between 2010 and 2017, raising environmental concern among scientists. In the wake of changing climatic variables and a range of linked population, land use and river impoundment and conversion pressures across the Indian Himalaya, there is an urgent need to understand the behaviour of these non-native fish species, and identify factors which provide them an ecological advantage over native fish species. This can support a case for cessation of stocking with alien species. Further collection of long-term field data, integrative quantitative models, public awareness and education programmes could greatly assist in addressing these knowledge gaps and identification of effective control measures.

Keywords: anthropogenic stressors, brown trout, climate change, common carp, invasive species, freshwater, rainbow trout, stocking.

Global freshwater ecosystems harbour disproportionately high levels of biodiversity, yet also integrate diverse direct and indirect pressures from human activities across broad catchment landscapes leading to an equally disproportionate decline in species and ecological processes and resources (Brautigam, 1999; Millennium Ecosystem Assessment, 2005a; Dudgeon *et al.*, 2006). A diversity of anthropogenic threats, from riverine and riparian habitat modification or destruction, to overexploitation of resources, point and non-point sources of pollution, unregulated water abstraction, hydropower projects and introduction of non-native species contribute to biodiversity loss (Beaumont *et al.*, 2011; Gupta *et al.*, 2015). These pressures are further compounded by changing climatic variables that affect species in multiple ways (Buisson & Grenouillet, 2009; Chessman, 2013). A range of linked climate change, resource exploitation, urbanisation and land use change impacts are exerting significant effects on

rain-fed water sources and rivers in the Middle Himalayan Ranges across the Western and Eastern Himalaya (Valdiya and Bartarya, 1991; Tiwari and Joshi, 2012 and 2013) leading to significant drying out of springs and rivers exerting adverse impacts on livelihoods and ecosystems (Becker and Bugmann, 2001; Dixit *et al.*, 2009). Freshwater fish species rely on their surrounding environment for spawning, maintaining fitness, refuge and food, development and growth (Däll & Zhang, 2010; Balcombe *et al.*, 2011; Booth *et al.*, 2011; Leuven *et al.*, 2011; Everard; 2015). Whilst different fish species can adapt to changes within limited environmental and temporal bounds (Booth *et al.*, 2011; Isaak *et al.*, 2012), stressors which restrict or exceed this adaptive equilibrium (Booth *et al.*, 2011; Isaak *et al.*, 2012) can negatively affect fish species and the ecosystems of which they are part. In this Communication, we present a quick overview of the current extent of non-native fish species across the Indian Himalaya, potential impacts on the already stressed native fish fauna, and identify further research and awareness-raising needs.

Non-native fish species are defined as those introduced beyond their native range and that are released into a new, non-native habitat (Strayer, 2010). Species transfers can occur deliberately, for example to support aquaculture, enhance a reservoir or a recreational fishery, by the ornamental fish trade or for mosquito control (Knight, 2010; Strayer, 2010). However, species transfers can also occur accidentally through angling bait releases, aquaculture escapes, ballast water transport, or water transfer schemes (Gozlan *et al.*, 2010; Olden *et al.*, 2008). Furthermore, simplification of river habitats through modifications such as damming tend to favour more invasive over locally adapted species of fish and other organisms, including blocking their migratory and other behaviours (Mooney & Hobbs, 2000). If a non-native (henceforth introduced) fish species then becomes established and dominates or otherwise negatively impacts native fish species by producing a greater number of offspring per year, predated native species particularly their early life stages, having a higher growth rate, a larger body size, an increased life span, or competes for similar food resources and habitat (Gozlan, 2008), it is referred to as an 'invasive fish species' (Hellmann *et al.*, 2008). Globally, invasive fish species have been implicated in the extinction or posed a significant threat to a wide range of native fish species (Mainka & Howard, 2010). This has caused economic losses running into billions of US\$ (Allendorf & Lundquist, 2003; Smith *et al.*, 2012), imposing strains on the socio-ecological wellbeing and opportunities of communities, especially in developing countries.

A wide diversity of freshwater ecosystems and endemic, threatened fish species is found across the Indian Himalayan region (Gupta *et al.*, 2015). Unfortunately, along with existing and emerging anthropogenic stressors including those relating to climate change (Gupta *et al.*, 2015; Gupta *et al.*, 2014), the uncontrolled, unscientific introduction of non-native fish species is slowly degrading the character, integrity and functioning of freshwater bodies in this region (Sehgal, 1999). Field studies and an in-depth literature survey (326 peer-reviewed and non-peer reviewed papers, and a range of grey literature articles) have revealed 15 introduced fish species in the region (see Table 1). There are reports of tilapia and *Clarius gariepinus* introductions too, albeit not yet reported in the peer-reviewed literature and so not included in the structured findings of this study. It is important to note that although the table

provided suggests that only three introduced species have established populations, this is based on the available information and could be underestimating the true situation (currently under assessment through field studies). The presence of these alien fish species is a cause of environmental concern as they could negatively affect native fish species and the ecosystems that support them (Pejchar & Mooney, 2009) (see Table 1), give rise to hybridization (native x introduced fish), spread fish pathogens, and have a detrimental effect on local food web structure and contaminant transfer (Gozlan *et al.*, 2010).

Brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) are regularly stocked into freshwater bodies from various hatcheries in the Indian Himalayan region (Bhatt & Pandit, 2015). In addition, common carp (*Cyprinus carpio*) are captive-bred and widely stocked, whilst the native golden mahseer (*Tor putitora*) is also extensively stocked including into waters where it did not naturally occur on occasions leading to the loss of locally native species and potentially also leading to genetic simplification. Stockings of non-native species and other fishes potentially beyond their natural ranges in the Indian Himalayas is extensive, for example with the ICAR-Directorate of Coldwater Fisheries Research captive breeding 2.34 lakh (2.34×10^5) eyed rainbow trout ova, 1.3 lakh fry of 'improved' Hungarian common carp, and 45,000 golden mahseer fingerlings in 2015-2016 (ICAR-Directorate of Coldwater Fisheries Research, 2016). Aquaculture of these species is primarily carried out to support the nutritional needs and economic viability of local people as well as to support the catch-and-release angling sector at higher altitudes, but has resulted in these species establishing self-reproducing populations – there have been instances of species from these hatcheries ending up in the main channels during floods and other natural/manmade disasters. Increasing reports of common carp, brown trout and rainbow trout in Himalayan waters in recent years (2010-2017) in comparison to previous years (1970-2010) could be attributed to an increase in their distribution through the establishment of viable breeding populations aided by stocking. Further, an extension in the distribution range of the brown trout in the upper Himalayan region of Uttarakhand has been observed between 2007 and 2017 (unpublished data).

Semi-structured interviews conducted with local, small-scale commercial fishing communities (n=47; 41 males, 6 females; 18-45 years) in the western region of the Indian Himalaya to understand the knowledge and impact of introduced species in the region reveals an alarming picture. Twenty-three respondents (49%) mentioned that there was an increase in occurrence of introduced species (trout species and common carp) during fishing in the last five years. Nineteen individuals (40%) stated that both the palatable and market value of introduced species was comparatively lower than native fish, and hence had impacted the value of local fisheries. There was an urgent demand among respondents (n=39; 83%) for legislative control of introduced species, as there was a fear that they could negatively affect socio-economically important fish species such as native mahseer (*Tor spp.*). The authors would like to point out that given the landscape and the size of the geographic range, there are numerable communities to survey. However, the small sample size is because a large-scale social science survey was not conducted for this Commentary, something the authors intend to do for the next full-length paper.

Various anthropogenic stressors continue to plague the Indian Himalayan region, and the existing introduced fish species need to be viewed with caution by scientists given their capacity to compound already worrying pressures from changing climatic variables (Shreshtha *et al.*, 2015). Where the spread of some fish species would be checked by the fluctuating temperature, common carp and brown trout are likely to expand their distribution in the Indian Himalaya due to a favourable temperature regime (Rahel *et al.*, 2008). Rainbow trout have a higher temperature tolerance than brown trout (Molony, 2001), suggesting that they too will adapt to changing temperature regimes in the Himalayas. Existing/proposed barrages and dams in the region (Rajvanshi & Maletha, 2012) could restrict the movement of these introduced fish species. However, these man-made barriers often modify riverine habitats and, aided by simplified and generally insufficient ecological flows and repeated stocking, tend to benefit introduced fish species (Melles *et al.*, 2015). Over the last few decades, the construction of dams has transformed the Himalayan landscape, resulting in the creation of vast areas of lacustrine habitats which have been embraced by fisheries departments as opportunities to stock and rear fishes which are often not indigenous to the recipient river catchment. The multiple environmental and social impacts of dams include disruption of movement of species from a variety of taxa, including potentially blocking access to spawning streams. Progressive river simplification further compromises habitat used by species and their prey, and may favour other species that are less adapted to naturally variable flow regimes. As well as reducing water quantity in rivers through abstraction and diversion, this smoothing of flow regimes can disrupt the ecology and population performance of native fishes. Worryingly, current proposals to interlink Indian Himalayan Rivers could further assist with spread of introduced fishes (and other taxa), which could result in them out-competing or perturbing native fish populations (Däll & Zhang, 2010), increase the distribution and abundance of non-native fishes, mix formerly separated genetic strains and leave few adaptive opportunities for native fish species (Comte *et al.*, 2013).

In view of the above, identifying factors that give introduced species an ecological advantage over native species should be an urgent requirement in the Indian Himalayan region (Morrongiello *et al.*, 2011). There is a need to further investigate the population status and distribution of introduced fish species, including long-term monitoring of freshwater bodies (Isaak *et al.*, 2012) especially at the margins of the range of introduced species (Hellmann *et al.*, 2008). Quantitative models integrating abiotic and biotic data, validated through large-scale long-term field ecological data, can help predict the distribution of existing introduced fish species in the region (Smith *et al.*, 2012; Strayer, 2010). The uncontrolled, unscientific stocking of introduced fish species needs to be reviewed and addressed by concerned authorities to minimise potential disruptions to the ecological functions of native aquatic communities (Allendorf & Lundquist, 2003; Rahel *et al.*, 2008). There is a related need for regulatory capacity-building and empowerment as, despite the successful establishment of institutions to conserve water birds and wetland habitats, there is at present a lower priority for conservation of freshwater biodiversity in terms of species and habitats leading to limited allocation of resources to increase knowledge and understanding of freshwater ecosystems and impact assessment of management practices and development projects that affect them

(Brautigam, 1999). The status of fish as a taxonomic group with wide conservation, utilitarian and other cultural values also needs to be addressed, for example redressing their conspicuous exclusion from India's Wildlife Protection Act 1972 offering protection of wild animals and plants where animals are defined only as "...amphibians, birds, mammals, and reptiles". Attempts should also be made to understand and avoid or mitigate other anthropogenic threats compounding the potentially synergistic impacts of introduced species and changing climatic variables on aquatic species (Rahel *et al.*, 2008). Public awareness and educational programs targeting local stakeholders could play a key role in spreading knowledge regarding the significance of introduced fish species (Sahgal, 1999) and the conservation of native fishes (Gupta *et al.*, 2014) in the Himalayan region.

References

- Allendorf, F.W.F. and Lundquist, L.L. (2003). Introduction: population biology, evolution, and control of invasive species. *Conservation Biology*, 17(1), pp.24–30.
- Balcombe, S.R., Sheldon, F., Capon, S.J., Bond, N.R., Hadwen, W.L., Marsh, N. and Bernays, S.J. (2011). Climate-change threats to native fish in degraded rivers and floodplains of the Murray-Darling Basin, Australia. *Marine and Freshwater Research*, 62(9), 1099–1114.
- Beaumont, L.J., Pitman, A., Perkins, S., Zimmermann, N.E. and Yoccoz, N.G. (2011). Impacts of climate change on the world's most exceptional ecoregions. *Proceedings of the National Academy of Sciences of the United States of America*, 108(6), 2306–2311.
- Becker, A. and Bugmann H. (2001). *Global change and mountain regions*. The Mountain Research Initiative (IGBP Report 49). International Geosphere-Biosphere Programme, Stockholm.
- Bhatt, J.P. and Pandit, M.K. (2016). Endangered Golden mahseer *Tor putitora* Hamilton: a review of natural history. *Reviews in Fish Biology and Fisheries*, 26(1), pp.25–38.
- Booth, D.J., Bond, N. and Macreadie, P. (2011). Detecting range shifts among Australian fishes in response to climate change. *Marine and Freshwater Research*, 62(9), pp.1027–1042.
- Brautigam A. (1999). The freshwater biodiversity crisis. *World Conservation*, 2, pp.4-5.
- Buisson, L. and Grenouillet, G. (2009). Contrasted impacts of climate change on stream fish assemblages along an environmental gradient. *Diversity and Distributions*, 15, pp.613–626.
- Chessman, B.C. (2013). Identifying species at risk from climate change: Traits predict the drought vulnerability of freshwater fishes. *Biological Conservation*, 160, pp.40–49.
- Comte, L., Buisson, L., Daufresne, M. and Grenouillet, G. (2013). Climate-induced changes in the distribution of freshwater fish: observed and predicted trends. *Freshwater Biology*, 58(4), pp.625–639.
- Däll, P. and Zhang, J. (2010). Impact of climate change on freshwater ecosystems: A global-scale analysis of ecologically relevant river flow alterations. *Hydrology and Earth System Sciences*, 14(5), pp.783–799.
- Dixit, A., Upadhyay, M., Dixit, K., Pokhrel, A. and Rai, D.R. (2009). *Living with water stress in the Hills of the Koshi Basin, Nepal*. ICIMOD, Lalitpur.
- Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z-I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A-H., Soto, D., Stiassny, M.L.J. and Sullivan, C.A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews*, 81, pp.163–182.
- Esmaeili, H.R., Teimori, A., Owfi, F., Abbasi, K. and Coad, B.W. (2014). Alien and invasive freshwater fish species in Iran : Diversity, environmental impacts and management. *Iranian Journal of Ichthyology*, 1, pp.61–72.
- Everard, M. (2015). *River Habitats for Coarse Fish: How Fish Use Rivers and How We Can Help Them*. Old Pond Publishing, Sheffield.
- Gozlan, R.E. (2008). Introduction of non-native freshwater fish: is it all bad? *Fish and Fisheries*, 9(1), pp.106–115.
- Gozlan, R.E., Britton, J.R., Cowx, I. and Copp, G.H. (2010). Current knowledge on non-native

- freshwater fish introductions. *Journal of Fish Biology*, 76(4), pp.751–786.
- Grabowska, J., Kotusz, J. and Witkowski, A. (2010). Alien invasive fish species in Polish waters: An overview. *Folia Zoologica*, 59(1), pp.73–85.
- Gupta, N., Rajvanshi, A., Sathyakumar, S., Johnson, J.A., Sivakumar, K., Rawat, G.S. and Mathur, V. B. (2015). Need for targeted education programme for preparedness and formulating adaptive strategies in the Indian Himalayan region. *Current Science*, 109(7), pp.1233–1234.
- Gupta, N., Sivakumar, K., Mathur, V.B. and Chadwick, M.A. (2014). The “tiger of Indian rivers”: stakeholders’ perspectives on the golden mahseer as a flagship fish species. *Area*, 46(4), pp.389–397.
- Hellmann, J.J., Bierwagen, B.G. and Dukes, J.S. (2008). Five Potential Consequences of Climate Change for Invasive Species. *Conservation Biology*, 22(3), pp.534–543.
- ICAR-Directorate of Coldwater Fisheries Research. (2016). *Annual Report 2015-2016*. ICAR-Directorate of Coldwater Fisheries Research, Bhimtal, Uttarakhand.
- Isaak, D.J., Wollrab, S., Horan, D. and Chandler, G. (2012). Climate change effects on stream and river temperatures across the northwest U.S. from 1980–2009 and implications for salmonid fishes. *Climatic Change*, 113(2), pp.499–524.
- Knight, J.D.M. (2010). Invasive ornamental fish: a potential threat to aquatic biodiversity in peninsular India. *Journal of Threatened Taxa*, 2, pp.700–704.
- Leuven, R.S.E.W., Hendriks, A.J., Huijbregts, M.A.J., Lenders, H.J.R., Matthews, J. and van der Velde, G. (2011). Differences in sensitivity of native and exotic fish species to changes in river temperature. *Current Zoology*, 57(6), pp.852–862.
- Mainka, S.A. and Howard, G.W. (2010). Climate change and invasive species: Double jeopardy. *Integrative Zoology*, 5(2), pp.102–111.
- Melles, S.J., Chu, C., Alofs, K.M. and Jackson, D.A. (2015). Potential spread of Great Lakes fishes given climate change and proposed dams: an approach using circuit theory to evaluate invasion risk. *Landscape Ecology*, 30, pp.919–935.
- Millennium Ecosystem Assessment. (2005a). *Ecosystems and Human Well-being: Wetlands and Water Synthesis*. World Resources Institute, Washington, DC.
- Molony, B. (2001). *Environmental requirements and tolerances of Rainbow trout (Oncorhynchus mykiss) and Brown trout (Salmo trutta) with special reference to Western Australia: A review*. Fisheries Research Report No. 130. Department of Fisheries, Government of Western Australia. (<https://pdfs.semanticscholar.org/49a0/2fe711b5e76b425bba7bcbeac1361f6c2361.pdf>, accessed 25th August 2017.)
- Mooney, H.A. and Hobbs, R.J. (2000). *Invasive Species in a Changing World*. Island Press, Washington DC.
- Morrongiello, J.R., Beatty, S.J., Bennett, J.C., Crook, D.A., Ikedife, D.N.E.N., Kennard, M. J., Kerezsy, A., Lintermans, M., McNeil, D.G., Pusey, B.J. and Rayner, T. (2011). Climate change and its implications for Australia’s freshwater fish. *Marine and Freshwater Research*, 62(9), pp.1082–1098.
- Olden, J.D., Kennard, M.J. and Pusey, B. J. (2008). Species invasions and the changing biogeography of Australian freshwater fishes. *Global Ecology and Biogeography*, 17(1), pp.25–37.
- Pejchar, L. and Mooney, H.A. (2009). Invasive species, ecosystem services and human well-being. *Trends in Ecology & Evolution*, 24(9), pp.497–504.
- Rahel, F.J., Bierwagen, B. and Taniguchi, Y. (2008). Managing Aquatic Species of Conservation Concern in the Face of Climate Change and Invasive Species. *Conservation Biology*, 22(3), pp.551–561.
- Rajvanshi, A., Arora, R., Mathur, V.B., Sivakumar, K., Sathyakumar, S., Rawat, G.S., Johnson, J.A., Ramesh, K., Dimri, N. and Maletha, A. (2012). Assessment of Cumulative Impacts of Hydroelectric Projects on Aquatic and Terrestrial Biodiversity in Alaknanda and Bhagirathi Basins, Uttarakhand. Wildlife Institute of India, Technical Report. (<http://www.indiaenvironmentportal.org.in/files/file/SEA-Hydro-Report.pdf>, accessed 25th August 2017.)
- Sarkar, U.K., Dubey, V.K., Singh, A.K., Gupta, B.K., Pandey, A., Sani, R.K. and Lakra, W.S. (2012). The recent occurrence of exotic freshwater fishes in the tributaries of river Ganga basin: Abundance, distribution, risk, and conservation issues. *Environmentalist*, 32(4), pp.476–484.

- Sehgal, K.L. (1999). Coldwater fish and fisheries in the Indian Himalayas: rivers and streams. In: Petr, T. (ed.) *Fish and fisheries at higher altitudes*. FAO Fisheries Technical Paper 385. pp.41-63.
- Shreshtha, A.B., Agarwal, N.K., Alfthan, B., Bajracharya, S.R., Marechal, J., van Oort, B. (eds). (2015). The Himalayan Climate and Water Atlas: Impact of climate change on water resources in five of Asia's major river basins. *ICIMOD, GRID-Arendal and CICERO*, pp.1-96.
- Simon, K.S. and Townsend, C.R. (2003). Impacts of freshwater invaders at different levels of ecological organisation, with emphasis on salmonids and ecosystem consequences. *Freshwater Biology*, 48(6), pp.982-994.
- Smith, A.L., Hewitt, N., Klenk, N., Bazely, D.R., Yan, N., Wood, S., Henriques, I., MacLellan, J.I. and Lipsig-Mummé, C. (2012). Effects of climate change on the distribution of invasive alien species in Canada: a knowledge synthesis of range change projections in a warming world. *Environmental Reviews*, 20(1), pp.1-16.
- Strayer, D.L. (2010). Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future. *Freshwater Biology*, 55, pp.152-174.
- Tiwari, P.C. and Joshi, B. (2012). Environmental changes and sustainable development of water resources in the Himalayan headwaters of India. *International Journal of Water Resource Management*, 26(4), pp.883-907.
- Tiwari, P.C. and Joshi, B. (2013). Changing Monsoon Pattern and its Impact on Water Resources in Himalaya: Responses and Adaptation. In: Palutikof, J. et al. (eds.) *Climate Adaptation Futures*. Wiley, Chichester. Chapter 29, pp.633-644.
- Valdiya, K.S. and Bartarya, S.K. (1991). Hydrological studies of springs in the catchment of Gaula River, Kumaon Lesser Himalaya, India. *Mountain Research and Development*, 11, pp.239-258.

Table 1: Documented non-native fish species in the Indian Himalayan biodiversity hotspot
(Key: J&K = Jammu & Kashmir; HP = Himachal Pradesh; UK = Uttarakhand; SK = Sikkim; AP = Arunachal Pradesh; * = not known, under investigation)

Common Name	Scientific name	Native habitat [^]	Year; and region of introduction ^{@#}	Current distribution ^{@§}	Population status in the wild ^{@§}	Interaction with native fish species and ecosystem (Esmaili, Teimori, Owfi, Abbasi, & Coad, 2014; Gozlan <i>et al.</i> , 2010; Grabowska, Kotusz, & Witkowski, 2010; Mainka & Howard, 2010; Rahel <i>et al.</i> , 2008; Sarkar <i>et al.</i> , 2012; Simon & Townsend, 2003; Strayer, 2010)
Common carp	<i>Cyprinus carpio</i>	Europe, Central Asia	1956; J&K	J&K, HP, UK, AP	Established	Disturbs the ecosystem; decreases water quality; destroys nesting and feeding habitat of native fish
Brown trout	<i>Salmo trutta</i>	Europe, Russia	1899; J&K	J&K, HP, UK, SK, AP	Established	Displaces top predators; threatens native fish; changes activity/habitat selection of invertebrate prey
Rainbow trout	<i>Oncorhynchus mykiss</i>	Asia, United States	1904; J&K	J&K, HP, UK, AP	Established	Eliminates native fish population; affects the ecosystem
Mirror carp	<i>Cyprinus carpio specularies</i>	Europe	1947; HP, UK	HP, UK	*	Disturbs the ecosystem; decreases water quality; destroys nesting and feeding habitat of native fish
Silver carp	<i>Hypophthalmichthys Molitrix</i>	China, Mongolia, Russia	1971; HP	J&K, HP, UK, AP	*	Affects native fish, (i.e. surface feeders), and ecosystem
Grass carp	<i>Ctenopharyngodon Idella</i>	East Asia	1971; UK	J&K, HP, UK, AP	*	Affects habitat vegetation; decreases refuge area for native fish
Crucian carp	<i>Carassius carassius</i>	Europe, Russia	1956-1958; J&K	J&K, UK	*	*
Eastern Mosquitofish	<i>Gambusia holbrooki</i>	United States	*	J&K	*	Competes for food; preys on the eggs of native fish
Western Mosquitofish	<i>Gambusia affinis</i>	Mexico, United States	*	J&K, UK	*	*
Eastern brook Trout	<i>Salvelinus fontinalis</i>	United States, Canada	1969; J&K	*	Not established	*
Splake trout	<i>Salvelinus namaycush</i> x <i>Salvelinus fontinalis</i>	Canada	1959-1970; J&K	*	Not established	*
Atlantic salmon	<i>Salmo salar</i>	Europe, United States, Canada, Russia	1959-1970; J&K	*	Not established	*
Bighead carp	<i>Hypophthalmichthys Nobilis</i>	China	*	*	*	Influences native ecosystem
Mozambique tilapia	<i>Oreochromis mossambicus</i>	South Africa	*	*	*	Competes for food and spawning habitat with native fish
Nile tilapia	<i>Oreochromis niloticus</i>	Africa	*	J&K	*	Competes for food and spawning habitat with native fish

[^]IUCN Red List of Threatened Species (2016); www.fishbase.org

[@]based on in-depth literature survey (peer and non-peer reviewed, grey literature)

[#]potentially for aquaculture, to support local fisheries, and for recreational (catch-and-release) angling

[§]potentially aided by unregulated stocking and the spread of non-native fish species