

# INTRODUCED AND INVASIVE FISH SPECIES

**Key words: Invasion, Exotic species, Native species**



**Fig – 14.1**

## INTRODUCTION

**"Invasive species"** is a phrase with several definitions. The first definition expresses the phrase in terms of non-indigenous species (e.g. plants or animals) that adversely affect the habitats they invade economically, environmentally or ecologically. It has been used in this sense by government organizations as well as conservation groups such as the IUCN (International Union for Conservation of Nature).

The second definition broadens the boundaries to include both native and non-native species that heavily colonize a particular habitat.

The third definition is an expansion of the first and defines an invasive species as a widespread non-indigenous species. This last definition is arguably too broad as not all non-indigenous species necessarily have an adverse effect on their adopted environment. An example of this broader use would include the claim that the common goldfish (*Carassius auratus*) is invasive. Although it is common outside its range globally, it almost never appears in harmful densities.

### **Conditions that lead to invasion:**

Scientists propose several mechanisms to explain invasive species, including species-based mechanisms and ecosystem-based mechanisms. It is most likely a combination of several mechanisms that cause an invasive situation to occur, since most introduced plants and animals do not become invasive.

## **Species-based mechanisms:**

Species-based characteristics focus on competition. While all species compete to survive, invasive species appear to have specific traits or combinations of specific traits that allow them to outcompete native species. Sometimes they just have the ability to grow and reproduce more rapidly than native species; other times it's more complex, involving a multiplex of traits and interactions.

Studies seem to indicate that certain traits mark a species as potentially invasive. One study found that of a list of invasive and non-invasive species, 86% of the invasive species could be identified from the traits alone. Another study found that invasive species tended only to have a small subset of the invasive traits and that many of these invasive traits were found in non-invasive species as well indicating that invasiveness involves complex interaction not easily categorized. Common invasive species traits include:

- The ability to reproduce both asexually as well as sexually
- Fast growth
- Rapid reproduction
- High dispersal ability
- Phenotypic plasticity (the ability to alter one's growth form to suit current conditions)
- Tolerance of a wide range of environmental conditions (generalist)
- Ability to live off of a wide range of food types (generalist)
- Association with humans
- Other successful invasions

Typically an introduced species must survive at low population densities before it becomes invasive in a new location. At low population densities, it can be difficult for the introduced species to reproduce and maintain itself in a new location, so a species might be transported to a location a number of times before it become established. Repeated patterns of human movement from one location to another, such as ships sailing to and from ports or cars driving up and down highways, allow for species to have multiple opportunities for establishment (also known as a high propagule pressure).

An introduced species might become invasive if it can out-compete native species for resources such as nutrients, light, physical space, water or food. If these species evolved under great competition or predation, the new environment may allow them to proliferate quickly. Ecosystems in which all available resources are being used to their fullest capacity by native species can be modeled as zero-sum systems, where any gain for the invader is a loss for the native. However, such unilateral competitive superiority (and extinction of native species with increased populations of the invader) is not the rule. Invasive species often coexist with native species for an extended time, and gradually the superior competitive ability of an invasive species becomes apparent as its population grows larger and denser and it adapts to its new location.

Facilitation is the mechanism by which some species can alter their environment using chemicals or manipulating abiotic factors, allowing the species to thrive while making the environment less favorable to other species with which it competes. One such facilitative mechanism is allelopathy, also known as chemical competition or interference competition. Facilitation also occurs when one species physically modifies a habitat and that modification is advantageous to other species. For example, zebra mussels increase habitat complexity on

lake floors providing crevasses in which invertebrates live. This increase in complexity, together with the nutrition provided by the waste products of mussel filter-feeding increases the density and diversity of benthic invertebrate communities.

### **Ecosystem-based mechanisms:**

In ecosystems, the amount of available resources and the extent to which those resources are utilized by organisms determines the effects of additional species on the ecosystem. In stable ecosystems, equilibrium exists in the utilization of available resources. These mechanisms describe a situation in which the ecosystem has suffered a disturbance which changes the fundamental nature of the ecosystem. With the introduction of a species that can multiply and spread faster than the native species, the balance is changed and the resources that would have been used by the native species are now utilized by an invader. This impacts the ecosystem and changes its composition of organisms and their use of available resources. Nitrogen and phosphorus are often the limiting factors in these situations.

Every species has a role to play in its native ecosystem; some species fill large and varied roles while others are highly specialized. These roles are known as niches. Some invading species are able to fill niches that are not utilized by native species, and they also can create niches that did not exist.

When changes occur to ecosystems, conditions change that impact the dynamics of species interaction and niche development. This can cause once rare species to replace other species, because they now can utilize greater available resources that did not exist before, an example would be the edge effect. The changes can favour the expansion of a species that would not have been able to colonize areas and niches that did not exist before.

### **Ecology:**

Although an invasive species is often defined as an introduced species that has spread widely and causes harm, some species native to a particular area can, under the influence of natural events such as long-term rainfall changes or human modifications to the habitat, increase in numbers and become invasive.

All species go through changes in population numbers, in many cases accompanied by expansion or contraction of range. Human landscape alterations are especially significant. This anthropogenic alteration of an environment may enable the expansion of a species into a geographical area where it had not been seen before and thus that species could be described as invasive. In essence, one must define "native" with care, as it refers to some natural geographic range of a species, and is not coincident with human political boundaries. Whether noticed increases in population numbers and expanding geographical ranges is sufficient reason to regard a native species as "invasive" requires a broad definition of the term but some native species in disrupted ecosystems can spread widely and cause harm and in that sense become invasive.

### **Traits of invaded ecosystems:**

In 1958, Charles S. Elton argued that ecosystems with higher species diversity were less subject to invasive species because of fewer available niches. Since then, other ecologists have pointed to highly diverse, but heavily invaded ecosystems and have argued that

ecosystems with high species diversity seem to be more susceptible to invasion. This debate seems largely to hinge on the spatial scale at which invasion studies are performed, and the issue of how diversity affects community susceptibility to invasion remains unresolved. Small-scale studies tend to show a negative relationship between diversity and invasion, while large-scale studies tend to show a positive relationship. The latter result may be an artifact of invasive or non-native species capitalizing on increased resource availability and weaker overall species interactions that are more common when larger samples are considered.

Invasion is more likely if an ecosystem is similar to the one in which the potential invader evolved. Island ecosystems may be prone to invasion because their species are “naïve” and have faced few strong competitors and predators throughout their existence, or because their distance from colonizing species populations makes them more likely to have “open” niches. Alternately, invaded ecosystems may lack the natural competitors and predators that keep introduced species in check in their native ecosystems. Lastly, invaded ecosystems have often experienced disturbance, usually human-induced. This disturbance may give invasive species, which are not otherwise co-evolved with the ecosystem, a chance to establish themselves with less competition from more adapted species.

#### **Vectors:**



**Fig – 14.2**

Non-native species have many vectors, including many biogenic ones, but most species considered "invasive" are associated with human activity. Natural range extensions are common in many species, but the rate and magnitude of human-mediated extensions in these species tend to be much larger than natural extensions, and the distances that species can travel to colonize are also often much greater with human agency.

Invasive species also come from organisms stowed away on every type of transport vehicle. For example, ballast water taken up at sea and released in port is a major source of exotic marine life. The invasive freshwater zebra mussels, native to the Black, Caspian and Azov seas, were probably transported to the Great Lakes via ballast water from a transoceanic vessel. The arrival of invasive propagules to a new site is a function of the site's invasibility. Species have also been introduced intentionally. For example, to feel more "at home", American colonists formed "Acclimation Societies" that repeatedly released birds that were native to Europe until they finally established along the east coast of North America. Economics play a major role in exotic species introduction. The scarcity and demand for the

valuable Chinese mitten crab is one explanation for the possible intentional release of the species in foreign waters.

Invasive freshwater fish species in Australia include carp, brown trout, rainbow trout, redfin perch, mosquitofish (*Gambusia* spp), weather loach, and spotted tilapia to name a few. Some introduced freshwater fish species have had devastating impacts on Australia's endemic freshwater fish species and other native aquatic life. For example in much of south eastern Australia's freshwater systems introduced carp (often incorrectly called "European" carp) dominate the lowland reaches, while introduced trout species almost completely dominate the upland reaches. While the damaging impact of carp is well recognised, little in the way of control measures have been employed to control their spread. Their ability to colonise almost any body of water, even those previously considered to be beyond their physical tolerances, is now well established.

### **The Northern Snakehead: An Invasive Fish Species**

During the summer of 2002, several individuals of an exotic fish species called the Northern Snakehead were found in a pond in Crofton, Maryland, about 20 miles north east of Washington, D.C. The potential impact of this introduced species was considered so damaging that the event made national headlines. Officials posted signs encouraging anglers to kill any snakeheads that they caught.



**Fig – 14.3 - Adult Snakehead**

Source: Maryland Department of Natural Resources

The Northern Snakehead, *Channa argus*, is no ordinary fish, biologists explain. It is a voracious top-level predator, meaning that it has no natural enemies, and could decimate populations of native fish. About 90% of its diet consists of other fish, though it also eats crustaceans, insects, and plants. In its native range it can live in water with temperatures ranging from 0 to 30 degrees C; it is found in muddy or vegetated ponds, swamps, and slow-moving streams. Snakeheads can breathe air and survive for up to four days out of water, and can survive for longer periods of time when burrowed in the mud. They are capable of traveling over land to new bodies of water by wriggling their bodies over the ground. These features are adaptations to the seasonal drying of shallow bodies of water in the snakeheads native habitat in China and allow it to disperse widely should local conditions become unfavorable. It is capable of surviving in much of North America should it become established. An established population of snakeheads in Maryland could have long-term disastrous consequences for the ecology of the region.



### **Effect of Invasive Fish Species on Freshwater and Estuarine Fishes in California:**

Freshwater and estuarine environments are among the most altered ecosystems in California, because they are subject to water diversions and intense human use. They are also among the most invaded ecosystems, especially by fishes. Of the 112 freshwater and estuarine fishes established in California, 54 are exotic species.



**Fig – 14.4**

About two-thirds of the native species are in serious decline. The linkage between the abundance of exotic species and the decline of native species is surprisingly poorly documented. While invading species have undoubtedly been responsible declines of native fishes, the invaded environments are typically already severely altered by human activity. Because invasion is a natural process (although not at the rate observed today), many native fishes seem to have the capacity to adjust to invaders. Populations of resident organisms may be reduced in response to a fish invader but extinctions that are solely the result of an invasion are surprisingly uncommon, at least in the time frames in which invasions have been studied. In California, such extinctions are most likely to occur when the successful invader is a top carnivore, when the invaded ecosystem has naturally low diversity, and/or when the native species have already been stressed by other factors. The role of invading piscivores has received particular attention in recent years including: (1) the Sacramento pikeminnow invasion of the Eel River, (2) the introduction and eradication of northern pike in two reservoirs, and (3) the proposed enhancement of striped bass populations. The pikeminnow example demonstrates that an invader can cause major alterations to fish communities. Although the prediction of such effects for northern pike has led to expensive eradication operations, the denial that such effects occur with striped bass (although they almost certainly do) has led to official proposals to greatly increase the number of striped bass in the wild. The contradictions and misunderstandings apparent in these examples indicate the need to for better public education on invasive species and need improve our predictive abilities of the effects of invasions.

### **Invasive Fish Species Successfully Eliminated from Ireland:**

The Central and Shannon Regional Fisheries Boards have reported that chub, an invasive fish species, has been successfully eradicated from the Inny River system in Co. Westmeath. This invasive species was reported to have been illegally introduced to the country by anglers attempting to establish a viable chub population in Ireland. Chub were identified in the River Inny system in 2005 by Dr Joe Caffrey, a Senior Research Officer in the Central Fisheries Board.

Between 2006 and 2009, the Central and Shannon Regional Fisheries Boards implemented a rigorous monitoring and control programme in an attempt to eliminate this invasive fish species from Ireland. In 2006, a removal operation was conducted on a forty kilometer stretch of the river, between Lough Derravaragh and Lough Ree. At Shrule Bridge, seventeen mature chub, capable of breeding were captured and killed. Subsequent chub removals saw four fish removed in 2007 and two in 2008. In a further removal operation in 2009 two male chub were removed.

The policy of the Central & Regional Fisheries Boards has been to prioritise the removal of invasive species. In the case of the recent River Inny survey, it was imperative that the fish were removed before they had a chance to spawn and when water levels were suitable for conducting such an exercise. The Boards have considerable experience in fish removal and relocation operations and conduct all surveys in accordance with best practice and incur minimum fish mortality.

The Fisheries Boards are confident that the potentially invasive chub has been eradicated from this river system and from Ireland. However, it is proposed to monitor the status of the River Inny fishery over the coming years. Non-native invasive species have a negative impact on native Irish fish and their habitats. They can cause considerable irreversible environmental and socio-economic impacts at genetic, species and ecosystem levels.

### **Impact:**

- **Ecological impacts**

- i. Land clearing and human habitation put significant pressure on local species. This disturbed habitat is prone to invasions that can have adverse effects on local ecosystems, changing ecosystem functions.
- ii. Invasive species can change the functions of ecosystems.
- iii. Invasive species that are closely related with rare native species have the potential to hybridize with the native species. Harmful effects of hybridization have led to a decline and even extinction of native species.

- **Genetic pollution**

Natural, wild species can be threatened with extinction through the process of genetic pollution. Genetic pollution is uncontrolled hybridization and introgression which leads to homogenization or replacement of local genotypes as a result of either a numerical or fitness advantage of the introduced species. Genetic pollution can bring about a form of extinction either through purposeful introduction or through habitat modification, bringing previously isolated species into contact. These phenomena can be especially detrimental for rare species coming into contact with more abundant ones where the abundant ones can interbreed with them, creating hybrids and swamping the entire rarer gene pool, thus driving the native species to extinction.

Attention has to be focused on the extent of this problem, it is not always apparent from morphological observations alone. Some degree of gene flow may be a normal, evolutionarily constructive process, and all constellations of genes and genotypes cannot be preserved. However, hybridization with or without introgression may, nevertheless, threaten a rare species' existence.

### **Economic impacts:**

- **Benefits**

Often overlooked, economic benefits from "invasive" species should also be accounted. The wide range of benefits from many "invasive species" is both well-documented and under-reported. (In most cases invasive species have benefits, but the negative effects almost always outweigh the positive.)

- **Costs**

Economic costs from invasive species can be separated into direct costs through production loss in agriculture and forestry, and management costs of invasive species. Estimated damage and control cost of invasive species in the U.S. alone amount to more than \$138 billion annually. In addition to these costs, economic losses can occur through loss of recreational and tourism revenues. Economic costs of invasions, when calculated as production loss and management costs, are low because they do not usually consider environmental damages. If monetary values could be assigned to the extinction of species, loss in biodiversity, and loss of ecosystem services, costs from impacts of invasive species would drastically increase.

- **Economic Opportunities**

For many invasive species there are commercial benefits, either existent or capable of being developed. For instance, Silver Carp and Common Carp where heavy metals are not excessive in their flesh can be harvested for human food and exported to markets already familiar with the product, or into pet foods, or mink food. The depletion or exploitation of any unwanted species is dependent on officials who recognize the need for a solution. Commercial enterprises need assurances that the exploitation can continue long enough for a reasonable profit to be generated and that taxation of the 'resource' is given a sufficiently long period of grace that an enterprise is attracted to the proposition.

### **Introduced species:**

An **introduced, alien, exotic, non-indigenous, or non-native species**, or simply an introduction, is a species living outside its native distributional range, which has arrived there by human activity, either deliberate or accidental. Some introduced species are damaging to the ecosystem they are introduced into, others negatively affect agriculture and other human uses of natural resources, or impact on the health of animals and humans. Introduced species and their effects on natural environments is a controversial subject and one that has gained much scrutiny by scientists, governments, farmers and others.

### **Nature of introductions:**

By definition, a species is considered "introduced" when its transport into an area outside of its native range is human mediated. Introductions by humans can be described as either intentional or accidental. Intentional introductions have been motivated by individuals or



groups who believe that the newly introduced species will be in some way beneficial to humans in its new location. Unintentional or accidental introductions are most often a byproduct of human movements, and are thus unbound to human motivations. Subsequent range expansion of introduced species may or may not involve human activity.

### **Intentional introductions:**

Species that humans intentionally transport to new regions can subsequently become successfully established in two ways. In the first case, organisms are purposely released for establishment in the wild. It is sometimes difficult to predict whether a species will become established upon release, and if not initially successful, humans have made repeated introductions to improve the probability that the species will survive and eventually reproduce in the wild. In these cases it is clear that the introduction is directly facilitated by human desires.

In the second case, species intentionally transported into a new region may escape from captive or cultivated populations and subsequently establish independent breeding populations. Escaped organisms are included in this category because their initial transport to a new region is human motivated.

Perhaps the most common motivation for introducing a species into a new place is that of economic gain. Examples of species introduced for the purposes of benefiting agriculture, aquaculture or other economic activities are widespread. Eurasian carp was first introduced to the United States as a potential food source. These examples represent only a small subsample of species that have been moved by humans for economic interests.

Introductions have also been important in supporting recreation activities or otherwise increasing human enjoyment. Numerous fish and game animals have been introduced for the purposes of sport fishing and hunting. The introduced amphibian (*Ambystoma tigrinum*) that threatens the endemic California salamander (*Ambystoma californiense*) was introduced to California as a source of bait for fishermen.

A special case of introduction is the reintroduction of a species that has become locally endangered or extinct, done in the interests of conservation. Introductions or translocations of species have also been proposed in the interest of genetic conservation, which advocates the introduction of new individuals into genetically depauperate populations of endangered or threatened species.

An example: The plague minnow (*Gambusia holbrooki*) is a small fish sometimes called the mosquito fish. It was originally introduced to control mosquitoes but was not successful in doing this. It is now common and widespread, and known to eat native frog eggs and tadpoles.

Other exotic fish - such as trout, carp and goldfish - also eat native frog eggs and tadpoles. These species should not be used to stock garden ponds or dams that are prone to flooding. They should never be released into the wild (although trout can be released into some streams with the approval of relevant authorities).

In the Caucasus, Lake Sevan in Armenia was famous in the past for the presence of the salmonid Sevan trout (*Salmo ischchan*), but the extreme water level manipulation has led to

this species almost disappearing. Its successful translocation into Lake Issyk-kul in Kyrgyzstan, although having negative consequences for the indigenous Issyk-kul fish fauna, probably saved this fish from extinction. Introduced pelagic whitefish (*Coregonus lavaretus*) then became the major commercial fish replacing Sevan trout and Sevan khramulya (*Varicorhinus capoeta*).

High altitude rivers and streams mostly have a low fish production and hence no importance for fisheries, except at subsistence level. Fishery management of rivers and streams has concentrated on introductions of fish for recreational and sport fishery, with mainly brown trout being stocked. In some streams this exotic fish has established self-sustaining populations. In the Western Ghats, rainbow trout has also been successful in some streams with the same result, but in other mountainous areas of Asia where conditions are suitable, rainbow trout is cultured. Common carp is another exotic which has been widely introduced, and is now stocked regularly in a variety of cold waters, such as Tarbela Reservoir on the Indus River in Pakistan, high altitude lakes in the Western Ghats, and the high altitude (2000 m) ricefields of Arunachal Pradesh in India. Production of marketable size trout on fish farms is still low, as the final product is too costly for wider consumption. The best results with farm production of market-size trout have been achieved in northern Pakistan and in Kashmir (India).

#### **Accidental introductions:**



**Fig – 14.5**

Unintentional introductions occur when species are transported by human vectors. For example, numerous marine organisms are transported in ballast water, one being the zebra mussel. Over 200 species have been introduced to the San Francisco Bay in this manner making it the most heavily invaded estuary in the world. Increasing rates of human travel are providing accelerating opportunities for species to be accidentally transported into areas in which they are not considered native.

Damming of the Chu River in Kyrgyzstan provided new habitat for reservoir fish and resulted in higher fish production than in the wild river. On the other hand, diversion of water for

irrigation reduced the river's flow downstream where it fed a series of lakes in the desert. As a result, these lakes, formerly rich in fish, are now largely desiccated. The profit from the reservoirs just makes up for losses from the lakes. Damming of the Himalayan rivers in India has flooded many spawning grounds of schizothoracines and mahseers (*Tor* spp) in Pakistan and India, or made it impossible for them to reach spawning grounds.

### **Introduced species on islands:**

Perhaps the best place to study problems associated with introduced species is on islands. Depending upon the isolation (how far an island is located from continental biotas), native island biological communities may be poorly adapted to the threat posed by exotic introductions. Often this can mean that no natural predator of an introduced species is present, and the non-native spreads uncontrollably into open or occupied niche. The field of island restoration has developed as a field of conservation biology and ecological restoration, a great deal of which deals with the eradication of introduced species.

### **Genetic pollution:**

Purebred naturally evolved region specific wild species can be threatened with extinction in a big way through the process of genetic pollution i.e. uncontrolled hybridization, introgression and genetic swamping which leads to homogenization or replacement of local genotypes as a result of either a numerical and/or fitness advantage of introduced plant or animal. Nonnative species can bring about a form of extinction of native fishes by hybridization and introgression either through purposeful introduction by humans or through habitat modification, bringing previously isolated species into contact. These phenomena can be especially detrimental for rare species coming into contact with more abundant ones where the abundant ones can interbreed with them swamping the entire rarer gene pool creating hybrids thus driving the entire original purebred native stock to complete extinction. Attention has to be focused on the extent of this under appreciated problem that is not always apparent from morphological (outward appearance) observations alone. Some degree of gene flow may be a normal, evolutionarily constructive process, and all constellations of genes and genotypes cannot be preserved however, hybridization with or without introgression may, nevertheless, threaten a rare species' existence.

Mountain rivers of Tien Shan and Pamir have largely unexploited fish stocks, as they are poor in species and numbers. Many of such streams and rivers remain a welcome reserve of indigenous fish. Only a few introductions of exotics have been done. The introduction of rainbow trout in some Tien Shan lakes initially resulted in spectacular growth rates, but within several generations the growth rate slowed down, fecundity of females declined, and eventually cannibalism took place. Coregonids (six species) introduced into lakes in northeastern Kazakhstan with the purpose of increasing commercial catches also showed a decline in growth rates in response to the depletion of food supplies.

Multispecies introductions took place especially in water bodies of Kazakhstan. For many years the fish faunas of Lake Balkhash, its major tributary Ili River and Kapchagay Reservoir, situated on the Ili, have been manipulated by introductions and commercial fisheries. The result is that the indigenous fish species now form a meaningless proportion in total fish catches (Petr and Mitrofanov, 1998). In addition, the manipulation of fish fauna in

Lake Balkhash, despite scientifically coordinated efforts over many years, has not led to any significant increase in fish landings.

There is general agreement, that protection of catchments should be high on the list of priorities, as well as protecting good water quality through prevention of pollution, from both point and non-point sources. A further priority is the need for enforcement of fishery laws and regulations, which should assist in the preservation of the most threatened fish species. Often stocks of indigenous species can be saved or replenished only with the help of regular stocking of hatchery produced fingerlings. For many such species hatchery production technologies are either unavailable or need to be refined to produce viable fingerlings for releases on a regular basis. Shortage of specialist manpower is often a hindrance to speeding up the development of such technologies.

Source:

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