FISH INTRODUCTION IN LATVIA

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Fish are simultaneously one of the most introduced and most threatened animal groups (Gozlan et al. 2010). Fish introductions have been made for many different reasons, but have mainly been driven by aquaculture (Welcomme, 1992). Aquaculture also includes the trade, import, transport, and intentional or accidental release of live freshwater fish (Btitton et al., 2011). It is and will remain the most important pathway for fish introductions (Rabitsch et al., 2013). In Latvia, most of the non-native species were initially introduced for stocking into natural watercourses, but were subsequently reintroduced later, both for aquaculture and for release.

In Europe, the introduction of fish began with the spread of Christianity (Balon, 1995), but on a larger scale began in the 19th century with the development of artificial fish farming technologies and improvements in the transport of alive fish (Welcomme, 1992). After World War II, it increased, declining substantially from the 1990s (Britton and Gozlan, 2013). In Latvia, the introduction and translocation of non- native fish species was a common fisheries management practice from the 19th century onwards (Andrušaitis, 1960; Aleksejevs and Birzaks 2011), which has persisted to some extent today.

History of fish introduction in Latvia

In total 28 species have been introduced into Latvian inland waters, of which four have naturalised. They represented 9.5% of the Latvian freshwater fish fauna, which includes 42 fish and lamprey species (Aleksejevs and Birzaks, 2011).

The introduction of fish into Latvia can be divided into three periods: 1) from the Middle Ages to 1940, 2) the Soviet period from 1940 to 1990, when Latvia was occupied and incorporated into the USSR, and 3) from the 1990s to the present.

Six fish species were introduced into Latvia during the first introduction period: carp *Cyprinus carpio*, sterlet *Acipenser ruthenus*, rainbow trout *Oncorhynchus mykiss*, Peipsi whitefish *Coregonus maraenoides*, brook trout *Salvelinus fontinalis*. Carp is believed to have been cultivated in ponds belonging to monasteries from the 13th century (Andrušaitis, 1960).

In Latvia, the highest number of alien species was introduced between 1940 and 1990 (second period) - 21 species: Prussian carp *Carassius gibelio*, ripus *Coregonus ladogae*, ludoga *Coregonus luttoka*, Baikal cisco *Coregonus migratorius*, inconnu *Stenodus nelma*, peled *Coregonus peled*, broad whitefish *Coregonus nasus*, volkhov witefish *Coregonus baerii*, striped bass *Morone saxatilis*, grass carp *Ctenopharyngodon idella*, black carp *Mylopharyngodon piceushardson*, bighead carp *Hypophthalmichthys nobilis*, silver carp *Hypophthalmichthys molitrix*, beluga *Huso huso*, Russian sturgeon *Acipenser gueldenstaedtii*, Siberian sturgeon *Acipenser baerii*, chum salmon *Oncorhynchus keta*, pink salmon

Oncorhynchus gorbuscha, coho salmon *Oncorhynchus kisutch* and Amur sleeper *Percottus glenii*. Most of the species introduced during this period were from the European and Asian parts of the former USSR.

Since 1990 (third period), only one species Atlantic sturgeon *Acipenser oxyrinchus* has been introduced into Latvia.

Objectives, rationale and results of fish introductions

The goals and motivation of the introduction of non-native fish species have been very diverse. In Eastern Europe, it has typically been carried out through the introduction of new species for aquaculture, supplementation of existing stocks with new species for fisheries or angling purposes, ornamental and aquarium purposes, accidental releases, biomanipulations and unknown ("trivial") reasons (Holčik, 1991).

The first hatchery in Latvia was established in 1885, followed by several others built between then and 1939. In 1929, a state-owned and subsidized hatcheries was established. Their main function was the rearing of juveniles of native fish species for restocking, as well as the hatching of non-native fish species (Andrušaitis, 1960).

Table 1. Stocking of non- indigenous fish in waterbodies by periods

Period		Type of waterbody			Rate of introduction	
		Lakes	Rivers	Reservoirs	Number of stockings	Number of introduced species
I	<1940	38	14	0	116	6
II	1941- 1990	308	16	40	2007	21
II	>1990	66	10	19	233	1

Latvia's occupation and incorporation into the USSR in 1940 and until its collapse in 1990-1991 (second period), the most extensive introductions were carried out. This was largely driven by the post-war recovery and ambitious plans of hydropower development in the region. Significant losses to fisheries were predicted due to the loss of reproductive habitats of diadromous species in the rivers and a decline of the biological productivity of the Gulf of Riga (Pischula, 1960; Malikova, 1966; Surin at al., 1967; Golovkov and Kuzmin, 1969; Rimsh, 1977).

Fish introductions have been significantly reduced since 1990 (Table 1). This was linked to the sturgeon recovery plan in the Baltic Sea basin, when Atlantic sturgeon stocking material was imported from Canada. Recent research suggests (Popovic et al., 2014) that it is the

introduction of a non-native species, which would perhaps fill the ecological niche of a lost native species.

In most cases, the introduced species failed to reproduce and disappeared from the recipient biota. Acclimatization does not necessarily result in increased fisheries and economic benefits. In the former USSR, which was a leader in fish introductions in Europe, only 3% of the stocking of alien fish resulted in a significant increase in commercial catches (Lifshits and Belousov, 1987). The results of the introduction and subsequent acclimatization were often over-optimistic and did not match the expected results.

Catches of introduced species in commercial, subsistence and recreational fisheries have in some years been no more than 3% of the total catch in inland waters of Latvia. Rainbow trout, carp, charr and Acipenseridae family and "Chinese carps" (grass, silver, bighead, and black carp) species are able to acclimatise to Latvian conditions and their populations (casual populations) can only persist with human help. Stocking of Coregonidae family species resulted in the establishment of small and economically insignificant populations of Peipus whitefish and peled in the lakes Rāznas, Alauksts, Lielais Nabas and Mazais Nabas (Aleksejevs and Birzaks, 2012). Prussian carp and Amur sleeper naturalized and are found throughout the country and inte coastal waters of the Gulf of Riga (Vetemaa, 2005; Birzaks and Nitcis, 2023). Overall, the introduction of alien species into the natural waters of Latvia has failed; it did not provide new opportunities for economically important food fisheries.

In contrast to the generally ineffective introduction of fish by stocking in the wild, some species have become beneficial in aquaculture. Latvia's modern aquaculture structure was established after the collapse of the USSR in 1991. Total aquaculture production, driven by carp farming in ponds, fell from 3000 to 500 t. In addition to the carp and rainbow trout farmed during the Soviet period, the Acipenseridae (Siberian sturgeon, sterlet, and hybrid bester) and Salmonidae (artic charr) were introduced, while peled farming was discontinued. Aquaculture is the only fishery sector in Latvia that has benefited from fish introductions in terms of increased diversity of production.

Impact of introduced species

In addition to the clear benefits for aquaculture, fish introductions have had a wide range of negative impacts and associated consequences. The integration of an introduced species into an ecosystem is associated with risks to biodiversity through habitat modification, predation and competition, and the spread of new diseases and parasites (Cucherousset et al., 2011). The impact of Amur sleeper as a predator on biota has been more extensively studied. In Latvia, its impact on protected species of toads and newts has been assessed as negative (Pupins et al., 2023).

C. gibelio can cause significant changes in the structure of fish communities, becoming the dominant species. Recently, gibel carp has become one of the most abundant and dominant Cyprinidae species in the coastal waters of the Gulf of Riga, likely having a significant impact on food chains (Vetemaa et al., 2005).

Introduced species can carry diseases and parasites that can infect native fish species. The eel nematode Anguillicolla crassus and the Asian fish tapeworm (*Bothriocephalus acheilognathi*) were introduced into Europe and are now also found in Latvia during transport of live fish for aquaculture (Koops an Haartmann 1989; Vismanis, 1998).

Conclusions and prospects

Aquaculture and related trade, import, transport and intentional or accidental release of live freshwater fish are the most important factors for fish introductions in Latvia. Although no significant impacts of introduced fish species on biodiversity have been observed in Latvia so far, the situation may change in the future. This will be determined by the potential impacts of climate change and their interactions with anthropogenic modifications to freshwater ecosystems that have taken place in the past, In particular, the breaking down of geographical barriers between rivers created potential implementation pathways.

Due to current climate change and its interaction with other natural and anthropogenic changes in freshwater ecosystems, species (including invasive) introduced and able to naturalize in milder climates are spreading northwards (Carosi et al., 2023). In Latvia, a small country in terms of area, changes in the distribution ranges and abundance of warm- and cold-water species are also being observed (Aleksejevs and Birzaks, 2010; Aleksejevs and Birzaks, 2011). It can be foreseen that species already naturalized in geographically close areas to the SE of Latvia in Lithuania and Belarussia could potentially be introduced into Latvian freshwaters. Potentially, these could be Ictiluriade (Ameiurus spp.) and Centrarchiade (Lepomis spp.) families.

Experience also shows that even the most stringent control measures have been ineffective or insufficiently effective because the pathways of spread are so diverse and often uncontrolled. Given that alien species are still being introduced for both aquaculture and fisheries enhancement, it is more likely that introductions of species, with all their consequences, will continue (Britton et al., 2010). Nevertheless, even with the best management strategies and practices, new species will be introduced. Specific management measures for mixed fish communities with both native and non-native components will need to be developed to protect native species. There is also a need for a better understanding of the interaction between anthropogenic environmental change and climate warming on the distribution of alien species and their effects on native species, their communities, and their habitats.

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