NOBANIS - Invasive Alien Species Fact Sheet

Salmo salar

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Species description

Scientific names: *Salmo salar* (Linnaeus, 1758), Salmonidae.
Note: this fact sheet focuses on escaped *Salmo salar*; the species as such is native to the region.
Synonyms: none
Common names: Atlantic salmon (GB), losos obecný CZ), laks (DK), Lachs (DE), Lõhe (EE), Lax (IS), lasis (LV), Atlanto lašiša (LT), laks (NO), Lax (SE), Łosoś (PL).

Fig. 1. Escaped farmed salmon (*Salmo salar*) (right) often show wavy fin rays, while wild salmon (left) has more even rays, photos by Roar A. Lund.

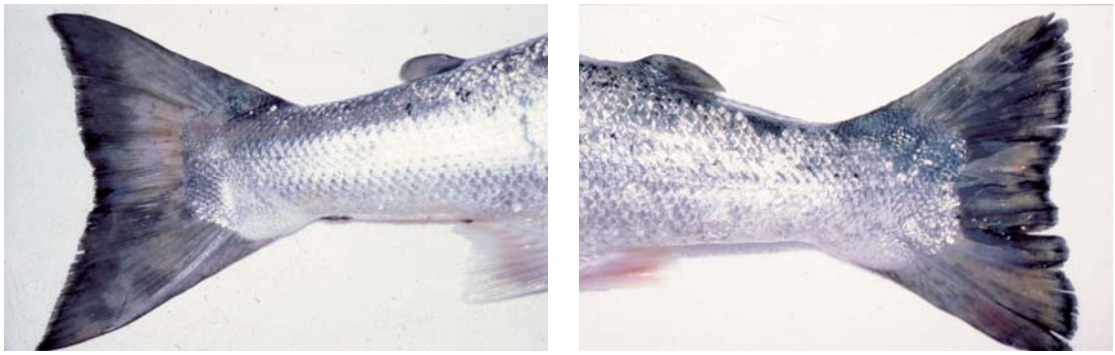

Fig. 2. Salmon that recently has escaped from net pens (right) often have rounded tails, while wild salmon (left) have more sharp tails, photos by Roar A. Lund.

Species identification
The appearance of Atlantic salmon changes from the juvenile freshwater stage, via a silvery stage in the ocean to a more ornamented appearance close to spawning in the rivers. Adult *Salmo salar* in the sea has silvery sides and belly, and a darker back. They normally have relatively few spots below the lateral line, a relatively slender caudal peduncle (tail root), and a v-formed tail. *Salmo salar* and sea-trout (*Salmo trutta*) may be difficult to separate, especially large individuals. Farmed salmon look similar to their wild con-specifics, but they often have worn fins with wavy fin-rays and more spots both above and below the lateral line than wild salmon. Thus, farmed salmon may at occasions look similar to sea trout. Furthermore, the growth pattern in the scales distinctively separates farmed from wild salmon (Lund and Hansen, 1991; Fiske *et al.*, 2005a).

Native range
Salmo salar originally occurred in every country with rivers flowing into the North Atlantic Ocean and the Baltic Sea and is thus native to the region (Mills, 1989). Today, the species distribution has decreased in its southern range on both sides of the Atlantic. In the Baltic Sea large numbers of reared smolts have been released to supplement local populations (for example: Saloniemi *et al*, 2004). In Poland the last salmon population were lost from the Drawa River in the mid 1980s. For restoration of salmon in Polish waters Daugava salmon were used. The first salmon smolt stocking was in 1994. In 1996 the first spawners in rivers were observed. Returning salmon have been captured and used for artificial spawning (Bartel 2001). *Salmo salar* has been restocked in Latvia since 1885 (Latvijas Daba)

Alien distribution

History of introduction and geographical spread
Farming of *Salmo salar* in net pens in the sea started in 1969 in Norway (Gjedrem, 1981). In 1971 a systematic selection program started, based on broodstock salmon sampled from 40 different Norwegian rivers and one Swedish river (Gjedrem *et al.*, 1991). The production of farmed salmon in Norway has increased tremendously from 100 tonnes in 1971 to 509 554 tonnes in 2003 (Gjedrem, 1981; Hansen *et al.*, 2005). Today, *Salmo salar* is produced within (main producers: Norway, Scotland, Ireland, USA and Canada) and outside (main producers: Chile, USA and Canada) the species natural range. Farmed *Salmo salar* today by far outnumber their wild con-specifics (Gross, 1998). In the 1980s escaped farmed salmon started to be noted in catches from Norwegian rivers and sea fisheries (Moen and Gausen, 1989; Gausen and Moen, 1991), and from 1989 river and sea fisheries in Norway have been surveyed yearly for the occurrence of escaped farmed salmon (Lund *et al.*, 1991; Fiske *et al.*, 2001). Norwegian strains of salmon were introduced to Iceland in 1989 for rearing in land based facilities and later in sea-cages.

Pathways of introduction
The reported number of escaped farmed salmon from Norwegian fish farms has varied between approximately 250 000 and approximately 600 000 individuals yearly since 1994 (Norwegian fish – statistics – on line). As a comparison, the yearly population of adult salmon returning to the Norwegian coast has been estimated to have varied between approximately 500 000 and 1 000 000 individuals in the same period (Hansen *et al.*, 2005). The real number of escapees is probably higher than the reported numbers as some fish may escape without being noticed by the fish farmers. Even though many of the escapees die before they are ready to spawn, many also reach the rivers and spawn together with wild *Salmo salar* (Lura *et al.*, 1993). Progeny of escaped farmed salmon and hybrids between escaped farmed salmon and local wild salmon seem to have lower success than progeny from wild salmon (Fleming *et al.*, 1996; Fleming *et al.*, 2000; McGinnity *et*

al., 2003; McGinnity *et al.*, 2004), but still genes from the farmed salmon can enter the wild populations. This may lead to less genetic differentiation among wild populations because many of them are affected by repeated introgressions from farmed salmon (Tufto, 2001).

Alien status in region

Escaped farmed salmon have been found in catches of wild salmon in Norway (Fiske *et al.*, 2001), the British Isles (Webb *et al.*, 1993; Crozier, 1998; Milner and Evans, 2003), Iceland (Gudjonsson, 1991) and in the high seas close to the Faroe Islands (Hansen *et al.*, 1999), see also Table 1. Relatively few farm escapees are probably found in the Baltic Sea, but they are regularly found in Danish rivers. In one river, escapees were found to make up a significant proportion (up to 20 %) of the annual run (Jepsen et al. 2004, Jepsen et al. 2003).. In Finland, fish farm escapees can occasionally be found in the River Tana forming the border between Norway and Finland (Fiske *et al.*, 2001). Note that since *Salmo salar* occurs naturally in the region, the fish farm escapees are found together with their wild con-specifics and are not as an alien species as such.

Country	Not found	Not established	Rare	Local	Common	Very common	Not known
Austria	X						
Belgium		X					
Czech republic			X				
Denmark				X			
Estonia	X						
European part of Russia				X			
Finland		X					
Faroe Islands					X		
Germany	X						
Greenland					Native		
Iceland				X			
Ireland			X				
Latvia				X			
Lithuania			X				
Netherlands							
Norway						X	
Poland			X				
Slovakia							
Sweden			X				

Table 1. The frequency and establishment of escaped *Salmo salar*, please refer also to the information provided for this species at www.nobanis.org/search.asp. Legend for this table: **Not found** –The species is not found in the country; **Not established** - The species has not formed self-reproducing populations (but is found as a casual or incidental species); **Rare** - Few sites where it is found in the country; **Local** - Locally abundant, many individuals in some areas of the country; **Common** - Many sites in the country; **Very common** - Many sites and many individuals; **Not known** – No information was available.

Ecology

Habitat description

Salmo salar juveniles are found in a wide variety of rivers draining to the sea (Elliott *et al.*, 1998). The habitat requirements varies among different life stages (Bardonnet and Baglinière, 2000), as the young will be found in faster currents and in deeper water as they grow older (Heggenes *et al.*, 1999). Where the two species are found together *Salmo salar* seem to prefer areas with faster water currents than brown trout (Heggenes *et al.*, 1999). Offspring of escaped farmed salmon will probably use similar habitats as wild salmon, and thus compete with the wild fish.

The size of adult salmon vary among rivers, and rivers seem to have to be above a certain size to carry populations of large multi-sea-winter salmon (Jonsson *et al.*, 1991). Escaped farmed salmon seem to enter the rivers later in the season than wild salmon (Fiske *et al.*, 2001).

Postsmolts and adults of *Salmo salar* are distributed over large areas in the North Atlantic Ocean during their migration between fresh water and their feeding grounds at sea (Hansen and Jacobsen, 2000). The smolts seem to enter the sea in spring or summer when the sea surface temperature in coastal areas is above 8 ^{o}C (Hvidsten *et al.*, 1998). Their survival seems to be correlated with the distribution of relatively warm sea water in the areas they reach shortly after their entrance to the sea (Friedland *et al.*, 1998). Escaped farmed salmon occur in the same feeding grounds in the ocean as wild salmon, though more farm escapees have been found close to the Faroe Islands (Hansen *et al.*, 1993) than close to Greenland (Hansen *et al.*, 1997).

Reproduction and life cycle

Several authors have described the life cycle of the *Salmo salar* in detail (historical review in: Mills, 1989). *Salmo salar* spawn in rivers in the autumn, and the fry hatch in the spring or early summer. The young spend from 1-6 years in the river before they move to sea as smolts. In the ocean they grow fast and return to the rivers after one to five years (normally 1-3) in the sea. In larger rivers most males return after one year at sea, while most females return after two years at sea. In smaller rivers both most males and females return after one year at sea. Not all salmon die after spawning and a variable proportion spawn repeatedly, seemingly more so in populations of mostly one-sea-winter salmon than in populations of multi-sea-winter salmon (Jonsson *et al.*, 1991). Offspring of escaped farmed salmon will probably behave rather similarly to wild salmon, though they seem to incur higher mortality than wild salmon (Fleming *et al.*, 2000; McGinnity *et al.*, 2003).

Dispersal and spread

Farmed smolts that are released into the wild tend to return to the same area where they were released (Hansen and Jonsson, 1991), while adult salmon that escape tend to disperse more widely (Hansen, 2005; Hansen, 2006a; Hansen, 2006b; Skilbrei *et al.*, 2006).

Impact

Affected habitats and indigenous organisms

Wild populations of *Salmo salar* and brown trout may be affected directly by competition or interference at the spawning grounds (Lura and Sægrov, 1991; Fleming *et al.*, 1996), indirectly by gene flow from farmed to wild populations (McGinnity *et al.*, 1997; Fleming *et al.*, 2000; McGinnity *et al.*, 2004), or through the spreading of deceases or parasites (Heuch and Moe, 2001; Bjørn and Finstad, 2002).

Genetic effects
Theoretical models suggest that if high proportions of escaped farmed salmon continue to spawn together with wild salmon, the genetic variation among wild populations may diminish and the wild stocks may become genetically more similar to farmed salmon than at present (Tufto, 2001; Hindar *et al.*, 2005; Hindar *et al.*, 2006). In some rivers with high occurrences of escaped farmed salmon and weak populations of wild salmon there also appear to have been a change in the genetic profile over time (Skaala *et al.*, 2005). There are indications that the occurrence of escaped farmed salmon in rivers may have lead to increased occurrence of hybrids between *Salmo salar* and brown trout (Youngson *et al.*, 1993; Matthews *et al.*, 2000).

Human health effects
Consumption of escaped farmed fish recently treated with antibiotics may lead to the development of pathogens with resistance towards antibiotics. However, the use of antibiotics in the farming industry has decreased dramatically since the 1980s (Grave and Horsberg, 2005).

Economic and societal effects (positive/negative)
The salmon farming industry is one of Norway's largest export industries, providing work for people in remote areas of the country. River owners and anglers in several countries (Norway, Island) have raised concerns that the image of the highly priced angling fisheries for salmon may be harmed if high numbers of escaped farmed salmon enter the rivers. Also in other countries angling of *salmo salar* is very important – as an example the annual catch of this species is 350 - 600 tons in Latvia (Latvijas Daba).

Management approaches

Prevention methods
The fish farming industry has increased their efforts to prevent escapes from happening. This includes new technical standards for fish farms, overviews of the most common causes of escapes to learn from previous mistakes, and increased awareness of the problem by the personnel working at the fish farms (Valland, 2005).

Eradication, control and monitoring efforts
Shortly after reported escapes, it is common practice to allow fishing with nets in the sea close to the site of the escape. Furthermore, fishing with nets and bag-nets in the sea has also been allowed in the autumn in many counties in Norway (*e.g.* Syvertsen and Vatne, 2000; Fiske, 2004). This is a fishery mainly targeting escaped farmed salmon since most wild salmon are either in the rivers or at the high seas at that time. Fishing in the outlets of rivers in the autumn with rods or bag-nets has also been used to reduce the number of farmed salmon entering rivers (Fiske *et al.*, 2005b). A monitoring program to access the proportion of escaped farmed salmon in catches and in spawning populations has been running in Norway since 1989 (Fiske *et al.*, 2001). In Island 10 % of the salmon in sea-cages have to be tagged. The usual tagging method is microtags with adipose fin clips as an external mark. Estonia has been running a program for monitoring the ratio between wild and ranched salmon

Information and awareness
The Directorate for Nature Management in Norway, Norwegian Institute for Nature Research and the Institute of Marine Research have all produced information brochures about escaped farmed salmon. In Iceland the use of tags for identifying salmon from sea-cages is advertised and a lottery is used for enhancement of tag returns.

Knowledge and research
There has been much research about escaped farmed salmon, the latest update about both escapees and other impacts of fish farming was given at a symposium in Bergen in October 2005 (Anon, 2005). Information presented at this symposium is published in a special issue of ICES Journal of Marine Science (Vol. 63, no 7, August 2006). Two similar symposia have previously been arranged in Loen, Norway (1991) and in Bath, Great Britain (1997).

Recommendations or comments from experts and local communities
Even though the fish farming industry has increased its awareness of escapees, it is important that the industry continue to work with improving their standards in handling of fish in order to keep the fish inside the net pens. Little can be done once the fish has escaped so the most important efforts are those that are done to prevent salmon from escaping.

References and other resources

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Links

Norwegian Institute for Nature Research
Institute of Marine Research
Directorate for Nature Management
Statistics Norway
Directorate for Fisheries Management - statistics
Institute of Freshwater Fisheries (Icelandic)

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