Pest Risk Assessment for landlocked Atlantic salmon (*Salmo salar*) in Oregon

Identity
Name: *Salmo salar*
Taxonomic Position
Order: Salmoniformes
Family: Salmonidae
Common Name: Atlantic salmon, Ouananiche, Sebago salmon

The family Salmonidae is comprised of 66 species of salmon, trout, whitefish, char, and grayling. Species in this family are native to the northern hemisphere and are some of the most important commercial and sport fishes in the world. Due to their popularity they have been widely introduced beyond their native range. Salmonids have four life history forms: anadromous, fluvial, adfluvial, and resident. Some species die immediately after spawning (semelparity), and some are able to spawn multiple times throughout their life (iteroparous). Salmonids require cold, clean waters to survive and spawn.

Atlantic salmon are similar to Pacific salmon (*Oncorhynchus* spp.), steelhead and rainbow trout (*O. mykiss*). Both *O. mykiss* and Atlantic salmon are iteroparous and represent all salmonid life history forms. Although in Oregon, populations of Atlantic salmon are considered to be resident or adfluvial. Additionally, as juveniles both species will occupy the same stream habitat. However, unlike steelhead who spawn in the winter, Atlantic salmon spawn in the fall similar to Chinook salmon (*O. tshawytscha*) and coho salmon (*O. kisutch*).

In previous years, some considered the anadromous form and the landlocked form of Atlantic salmon to be different species or at least subspecies (Atkins, C.G. 1898). Currently, ichthyologists agree that all life history forms are the same species (Behnke 1988). However, two life history forms have been introduced into Pacific Northwest (PNW) waters; therefore two independent (i.e. marine and coastal environment and land-locked) Assessments of Risk will be reported.

Identification: The average size of Atlantic salmon is 28-30 inches long and 8-12 pounds after two years at sea. Although uncommon, adults can grow to be as large as 30 pounds (Fay et al. 2006). The land-locked form is smaller than the anadromous type, averaging 3 to 5 pounds in weight. Coloration varies, but generally it is brownish along the back with silvery sides and belly. Black spots are on the gill covers and on their back. The tail is deeply forked and has no spots on it.

Risk Rating Summary
Relative Risk Rating:
Numerical Score: 1 (On a scale of 1-9)
Uncertainty: Very Low

The low level of uncertainty attributed to this risk assessment is due to several factors. The format this risk assessment follows was developed for forest pest species and, as such, it fails to take into consideration characteristics of invasive species that may be unique to aquatic organisms. Also, the risk of establishment and potential ecological and economic impact for the state of Oregon is low due to the distribution of Atlantic salmon is limited to "closed" waterbodies (i.e. Hosmer and East lakes). Moreover, in Hosmer and East lakes Atlantic salmon may have produced a successful fishery, but their population is maintained through hatchery spawning. Lastly, little information is available regarding escaped land-locked Atlantic salmon.

Rules and regulations:
In Oregon, Atlantic salmon are managed as a game fish under Oregon Revised Statues (ORS) 498.009. Also a permit is required to transport, hold or release fish in Oregon under ORS498.222 and Oregon Administrative Rules (OAR) 635-007-0600. Furthermore, under OAR 635-007-0615 it is unlawful to import or release fish into Oregon.

Overview:

Atlantic salmon are native to Atlantic Coast drainages from Quebec to Connecticut and Eastern Atlantic drainages from the Arctic Circle to Portugal (Page and Burr 1991). Atlantic salmon are non-native to the Western United States. Oregon Department of Fish and Wildlife (ODFW) had the first successful rearing in the nation of Atlantic salmon at Wizard Falls Hatchery in 1950 (D. Curtis, ODFW Wizard Falls Hatchery, personal communication). Attempts were made to establish populations of land-locked Atlantic salmon in Davis, East, Hosmer and Lost lakes (Appendix Table 1). Currently, ODFW stocks Atlantic salmon in East and Hosmer lakes; due to low survivability rates stocking in Lost and Davis lakes was discontinued after 1993 and 1994 (D. Curtis, ODFW Wizard Falls Hatchery, personal communication).

During spawning land-locked Atlantic salmon enter streams to spawn, then returns to the lake after spawning is completed. Atlantic salmon in the PNW have been unsuccessful in achieving self-sustaining populations. The land-locked form is adaptable to lakes where suitable environmental conditions exist, but even in desirable habitat very little spawning has been documented.

According to Cooper and Mangel (1999) "the observation of a given species does not necessarily constitute documentation of a self-sustaining population because low levels of dispersal from large source populations may create the appearance of a population where in fact there is only a sink".

Risk Rating Details:
Establishment Potential is LOW
Justification:

Even though Oregon has the preferred habitat (cold and clean waterbodies), food resources, and climate to start and sustain an independent Atlantic salmon population, none have established (Wydoski and Whitney 2003). Many attempts have been made to establish self-sustaining populations throughout the U.S., but none have been met with success; Waknitz et al. (2002) reported that all of the 170 attempts in 34 states were unsuccessful.

Atlantic salmon are highly variable within each life history and stage (Page and Burr 1991). Atlantic salmon inhabit rivers where temperature rises above 10° C for about 3 months per year, but does not exceed 20° C for more than a few weeks (Kottelat and Freyhof 2007). Juveniles feed mainly on aquatic insects (blackflies, stoneflies, caddisflies and chironomids), mollusks, crustaceans and fish (Scott and Scott 1988). Land-locked populations move to tributaries to spawn (Kottelat and Freyhof 2007) in the fall. Atlantic salmon spawning habits and requirements are similar to Pacific salmon: clean, cold, fast moving water, appropriate cobble size. Female egg production is variable from 2,500 to 20,000; it is directly correlated to the size of the fish (Wydoski and Whitney 2003). Incubation times vary from 88 to 191 days, and are related to temperature (33 to 42^{o}F, respectively).

Spread Potential is LOW
Justification:
The probability of Atlantic salmon spreading into other Oregon waters is very low. They are currently found in only two lakes, which happen to be land-locked. Additionally, there have no reported escapees from the Wizard Falls Hatchery, which is the only rearing site in Oregon for Atlantic salmon. Moreover, successful establishment of Atlantic salmon outside their native range has been very rare.

The Oregon department of Fish and Wildlife has been stocking Atlantic salmon in lakes since 1958. Between 1978 and 2010, ODFW has stocked over 524,000 Atlantic salmon in four lakes, with an average of 3,903 per year. In 2010, ODFW stocked 2,273 and 2,998 Atlantic salmon in East and Hosmer lakes (ODFW, unpublished data). In 1993 and 1994 stocking of Atlantic salmon in other lakes (i.e. Davis and Lost lakes) was discontinued due to a "failure to thrive" and low survivability rates (D. Curtis, ODFW Wizard Falls Hatchery, 2010). In the 1960's, the California Department of Fish and Game (CDFG) initiated a review of Oregon's history of Atlantic salmon production and stocking. Their desire was to have an Atlantic salmon fishery similar to Oregon's Hosmer Lake. The CDFG found that the Hosmer Lake Atlantic salmon fishery is hatchery supported and represents the only success out of eight or 10 lakes stocked with this species. Also, in the hatchery phase Atlantic salmon require special care, space, and constant observation (Dill and Cordone 1997).

Environmental Impact Potential is LOW
Justification:
There are few studies regarding competition between *Oncorhynchus* spp. and Atlantic salmon. The studies that have addressed the issue of competition among steelhead and Atlantic salmon concluded that they are likely to compete for resources with some degree

of success that is likely to vary with environmental parameters (Gibson 1981; Hearn and Kynard 1986; Jones and Stanfield 1993). Volpe et al. (2001) studied behavioral interactions between Atlantic salmon and steelhead; Steelhead were five times more aggressive than Atlantic salmon, but more often they targeted other steelhead instead of Atlantic salmon. Conversely, Atlantic salmon were more likely to show aggression towards steelhead. Overall, Atlantic salmon did not perform as well as steelhead.

There has been almost no documentation of escaped (intentional or otherwise) Atlantic salmon in Oregon. The only known incident of recovery in Oregon occurred on the Columbia River at McNary Dam in the 1990's. Juvenile Atlantic salmon reared in Lake Roosevelt (above Grand Coulee Dam) escaped from a damaged net pen and traveled down stream to Rocky Reach, Rock Island, and McNary dams collection sites (Wydoski and Whitney 2003). Atlantic salmon juveniles have been recovered in three streams on Vancouver Island, British Columbia, in 1998 (Volpe et al. 2000), which could be indicative of successful spawning by net pen-reared fish in the wild. According to the Aquatic Nuisance Species Project (http://www.aquaticnuisance.org/) no sightings (based on literature searches in 2006) of juvenile Atlantic salmon have been recorded on the West Coast since the Vancouver Island sightings in 2000.

Economic Impact Potential is LOW
Justification:
The economic impact to Oregon would be low. Currently, Oregon provides the opportunity to catch land-locked Atlantic salmon, and they are managed as a game fish. In both East and Hosmer lakes the species provides a unique and highly popular recreational fishery. Hosmer Lake, in particular, attracts anglers from throughout the West for the opportunity to fly fish for Atlantic salmon. This generates significant revenue for Deschutes County. Additionally, the Washington Department of Fish and Wildlife (WDFW) produces over 10 million pounds of farmed Atlantic salmon annually; which supplements Washington's economy by at least $40 million. About 100 million pounds of salmon (80% Atlantic salmon) are produced in B.C., annually (WDFW website http://wdfw.wa.gov/ais/species.php?Name=salmo_salar). In 1998, Whoriskey and Glebe estimated salmon fishing infuses at least $250 -300 million into the Canadian economy annually.

Human Health Impact Potential is LOW
Justification:
Atlantic salmon have the same potential of disease transmission to humans as do Pacific salmon and trout (serratia, salmonella, and E. coli). Therefore, as long as individuals are purchasing fish from a reputable purveyor, fully cooking, and cleaning surfaces that come into contact with raw fish this should diminish any disease transmission.

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Format

This pest risk assessment (PRA) is based on the format used by the Exotic Forest Pest Information System for North America. For a description of the evaluation process used, see Pest Risk Assessment Guidelines at: http://spfnic.fs.fed.us/exfor/download.cfm

Authors:
Martyne J. Reesman
Rick Boatner
Rebbecca L. Hill
Oregon Department of Fish and Wildlife
Wildlife Division
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Appendix A

APPENDIX TABLE 1. Number and location of stocked Atlantic salmon by the Oregon Department of Fish and Wildlife, 1978 – 2010.

	Waterbody			
Year	Davis[a]	East	Hosmer	Lost[b]
1978			8,300	
1979			10,431	
1980			23,533	
1981			15,692	
1982			18,274	
1983			20,476	
1984			74,794	
1985			67,394	
1986			37,355	
1987			25,874	225
1988			6,330	504
1989	20,391		1,000	1,814
1990	189	8,994	999	2,000
1991	997	4,652	1,986	998
1992		25,280	2,082	799
1993	4,989	19,322	3,389	1,002
1994	2,000	8,734	3,152	
1995		2,769	2,981	
1996		4,287	3,018	
1997		1,395	3,000	
1998		4,520	2,999	
1999		4,550	3,000	
2000			2,584	
2001		6,270	3,000	
2002			2,999	
2003		8,981	3,000	
2004		8,554	3,999	
2005			990	
2006		6,816	2,998	
2007			2,198	
2008		4,015	2,997	
2009			2,666	
2010		2,273	2,998	

[a] Stocking in Davis Lake was discontinued after 1994.
[b] Stocking in Lost Lake was discontinued after 1993.