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Survival of Atlantic salmon captured in and released from a commercial trap-net: Potential for selective harvesting of stocked salmon

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Abstract

The major wild Atlantic salmon stocks in the Baltic Sea began to recover in the late 1990s. This recovery has been partly due to strict regulations in the Gulf of Bothnia that effectively prevent salmon fisheries during the peak migration. About half of the migrating salmon, however, are reared fish that could be harvested. We simulated a limited trap-net fishery that selectively harvested reared salmon and released wild fish, and studied the survival and migration of the released salmon. We tagged and released 1970 salmon caught in the trap-nets along the coast in 2001 and 2002. The mean maximum capture and release induced mortality of salmon was 11%, ranging between 4% and 21% in different release groups by year, sea age and number of releases. The cumulative mortality for the total salmon population on their spawning migration in the Gulf of Bothnia was below 5%, and it would not increase considerably after the first capture and release events, provided fishing effort is not excessive and fish are handled properly. Survival of trap-net captured and released Baltic salmon appears high and their migration behavior is not altered due to this handling. Several preconditions, however, should be considered before selective fishing is introduced in the Gulf of Bothnia salmon fishery.

Keywords: Survival; Atlantic salmon; *Salmo salar*; Release; Trap-net; Selective harvesting

1. Introduction

Since the late 1990s, the major wild Atlantic salmon (*Salmo salar*) stocks in the northern Baltic Sea have been recovering largely due to strict seasonal closures (delayed openings) along the Finnish coast of the Gulf of Bothnia (Romakkaniemi et al., 2003; Anon., 2004). In 1996–2003, the abundance of juvenile salmon in rivers increased about 10-fold and a marked increase of wild salmon was observed in the commercial catches in the sea areas (Anon., 2004). Simultaneously, an increase in the recreational fishery for salmon in major spawning rivers has occurred.

Clearly, from the conservation point of view, management of Baltic salmon fishery has recently been successful. However, the strict seasonal fishing restrictions that safeguard the spawning migration of wild salmon have effectively prevented salmon fishing during the peak migration along the coast. About half of the salmon migrating are stocked fish that do not reproduce in the wild (Anon., 2004). These fish are produced in the hatcheries and stocked as smolts in the sea to mitigate for lost salmon production in rivers that have been dammed for hydropower production (Rappe et al., 1999). They are stocked specifically for harvest in the sea areas and in the mouths of dammed rivers; the returning adults of these stockings do not have spawning areas.

The restrictions enforced to protect wild stocks together with the dramatically increased seal-induced catch damages (Kauppinen et al., 2005) have had severe socio-economic impacts to the commercial fishery along the coastal areas (Jounela et al., 2006). To allow the harvesting of stocked fish while simultaneously protecting the wild stocks, it is necessary to introduce a fishery where stocked fish can be selectively harvested. Such selective fisheries have been tested

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for Pacific salmon (*Oncorhynchus* sp.) on the West Coast of North America using hook and line (Anon., 2005) and in the Columbia River using tangle-nets (Vander Haegen et al., 2004).

The major precondition for a successful selective fishery is that released fish would survive and continue their spawning migration. Fishermen should also be able to easily identify wild fish from stocked fish. If operational and successful, selective fishing would offer a system that could mitigate the economic drawbacks caused by the present closures and simultaneously safeguard wild salmon stocks. With the selective fishery, there would be less need to regulate the coastal salmon fishery with strict closures.

Very little is known about the potential injury and mortality of salmon that are released from a commercial trap-net. Several studies have shown that salmonids are stressed immediately after a capture and release from nets and hooks (e.g. Booth et al., 1995; Milligan, 1996; Brobbel et al., 1996; Milligan et al., 2000; Kieffer, 2000; Farrell et al., 2000, 2001a,b; Thorstad et al., 2003). These studies, however, have mainly focused on short-term physiological effects and fish have been held in tanks or net pens where they have not been exposed to factors such as predation, changes of water temperature, waves and sea currents. Only a few survival studies have been done under realistic commercial fishing conditions with adequate duration; these studies concern gillnet fisheries. Thompson et al. (1971) recorded mortality of 80–100% for chinook (*Oncorhynchus tschawytscha*) and coho (*Oncorhynchus kisutch*) salmon released from a gillnet. Thompson and Hunter (1973) suggested that scale damage alone resulted in 40% mortality, while scale damage and stress accounted for 80% of mortalities among salmon released from gillnets. Vander Haegen et al. (2004) demonstrated that the type and material of the gillnet (tangle-net), and the release practice, have a substantial effect on the injury and subsequent survival of salmon released from a net.

In this study, we conducted a full-scale experiment to simulate fishing practices of commercial salmon trap-net fishery in a situation where fishermen would be allowed to selectively catch reared salmon on the coast of the Gulf of Bothnia (Northern Baltic Sea). Migrating salmon were captured, tagged, released and re-released during the peak spawning migration in 2001 and 2002. We studied the survival and migration pattern of salmon in this simulated selective fishery.

2. Materials and methods

2.1. Study area and geographic distribution of tagging

Most salmon in the Baltic Sea originate in the Gulf of Bothnia (Rappe et al., 1999; Anon., 2004). Twelve of the 13 rivers still having wild salmon stocks in the Gulf of Bothnia are located in its northernmost part, the Bothnian Bay. The annual production of wild salmon smolts in the salmon rivers of the Gulf of Bothnia has in recent years been about one million smolts (Anon., 2004). About 3.4–3.8 million hatchery-reared salmon smolts are released annually into the Gulf of Bothnia (Anon., 2004). The feeding migration of Gulf of Bothnia salmon stocks extends to the central and southern parts of the Baltic Main Basin, but a variable proportion of salmon feed also in the Bothnian Sea (Ikonen and Vuorinen, unpublished). Fish do not migrate out of the Baltic Sea (Christensen and Larsson, 1979; Karlsson and Karlström, 1994).

In this study, the Gulf of the Bothnia was divided into five regions (A–E, Fig. 1). These regions are almost equivalent to the coastal temporal closure areas in the Finnish salmon fishery (A and B regions belong to the same closure area). The main intention of the temporal closures is to decrease the fishing mortality of the wild migrating salmon, especially of older females, which are most valuable for natural reproduction and tend to migrate earlier in the season than the reared fish (Ikonen and Kallio-Nyberg, 1993; Karlsson et al., 1994; McKinnell et al., 1994).

Mark-recapture data was collected during the salmon spawning migration season along the coast of the Gulf of Bothnia by using commercial trap-nets, hereafter referred to as study trap-nets (for description of how the traps are deployed, see Lehtonen and Suuronen, 2004; Kauppinen et al., 2005). The experiment started in May–June during the regional fishery closures to ensure a representative proportion of wild salmon. In addition, the potential future selective fishery would take place during this time, prior to the present temporal closure periods. The number of trap-nets was 61 in 2001 and 148 in 2002. The traps were distributed among different regions (A–E) in 2001 and 2002 as follows:

Region	2001	2002
A	2	6
B	23	42
C	16	48
D	10	31
E	10	21
Total	61	148

The number of salmon tagged in different regions varied substantially between 2001 and 2002 (Table 1). In 2001, tagging sites covered the whole Finnish side of the Gulf of Bothnia although they were mainly in the middle and in the northern areas. In 2002, tagging was conducted in the middle and the southern areas; no tagging took place in the north.

2.2. Tagging, recapture and re-release procedures

Salmon were tagged with Hallprint arrow tags that allowed individual recognition. The tag was hitched by a steel-made applicator below the dorsal fin so that the fluke of the tag was attached to the supporting bones of the dorsal fin. The number code was printed on four consecutive sections of the tag so that when a tagged salmon was caught, fishermen could cut off one section of the tag and re-release the fish