4 Present management measures and other factors influencing salmon fishery

4.1 Description of the Present Management Measures

4.1.1 International regulatory measures

International management measures adopted by IBSFC have regulated the salmon fishery in the convention area of IBSFC until end of the 2005. However, since the IBSFC was superseded by bilateral cooperation with the Russian Federation the new technical measures will be developed for the Baltic salmon fishing. European Community has provided the rules, which do not follow strictly those recommendations made by the IBSFC but should rather seek to establish a comprehensive and consistent system of technical measures for Community waters, based on existing rules. Council Regulation (EC) No 2187/2005 laid down certain measures for the conservation of fishery resources in the waters of the Baltic Sea, the Belts and the Sound (Anon. 2006). Regulatory measures to be used in the Russian federation waters are not available.

Minimum landing size

Minimum landing size of salmon is 60 cm in sub-divisions 22-30 and 32, and 50 cm in sub-division 31. Additionally, there is a rule for minimum landing size for sea trout; in subdivisions 22-25 and 29-32 (40 cm), and in sub-divisions 26-28 (50 cm).

Summer closure

In the EU Community waters there are not any more gear based summer closures. Those have been compensated by restrictions on fishing for salmon and sea trout (Article 17 of the Council Regulation (EC) No 2187/2005) and they are as follows;

1. The retention on board of salmon (*Salmo salar*) or sea trout (*Salmo trutta*) shall be prohibited

   a) From 1 June to 15 September in waters of subdivisions 22 to 31
   b) From 15 June to 30 September in waters of subdivision 32

2. The area of prohibition during the closed season shall be beyond four nautical miles measured from the baselines

3. By way of derogation from paragraph 1, the retention on board of salmon (*Salmo salar*) or sea trout (*Salmo trutta*) caught with trap-nets shall be permitted.

TAC

Since 1981 WGBAST recommended adopting a TAC to regulate the Baltic salmon fishery. In 1990, IBSFC adopted a TAC system for Baltic salmon fishery management and it was implemented for the first time in 1991. There are three separate management areas; Baltic Main Basin and Gulf of Bothnia (subdivisions 22–31) and Gulf of Finland (subdivision 32). The TACs implemented for 2007 are given in Section 2.1. EC has divided salmon fishing possibilities in the Main Basin and the Gulf of Bothnia in 2008 and in the Gulf of Finland in 2008 between EC countries as follows (Council regulation (EC) N:o 1941/2006). In the Main Basin and Gulf of Bothnia (subdivisions 22-31) the quota to be harvested by EC countries in 2008 is 15% smaller compared to year 2007. In the Gulf of Finland the EC quota is the same as in 2007. No TACs between EC and Russian federation have been agreed.

Management area: Main Basin and Gulf of Bothnia (subdivisions 22-31)

COUNTRY	ALLOCATION KEY %	QUOTA 2008
Estonia	2.0660	7,528
Denmark	20.3287	74,076
Finland	25.3485	94,157
Germany	2.2617	8,241
Latvia	12.9300	47,116
Lithuania	1.5200	5,539
Poland	6.1670	22,472
Sweden	27.4783	100,129
Russian Federation	1.9000	
Total	100	364,392

Management area: Gulf of Finland (subdivision 32)	Allocation key	Quota 2008
Country		
Estonia	9.3000	1,581
Finland	81.4000	13,836
Russian Federation	9.3000	
Total	100	15,419

4.1.2 National regulatory measures

In **Denmark** all salmon and sea trout streams with outlets wider than 2 m are protected by closed areas within 500 m of the mouth throughout the year; otherwise the closure period is four months at the time of spawning run. Estuaries are usually protected by a more extended zone. Gillnetting is not permitted within 100 m of the water mark. A closed period for salmon and sea trout has been established from November to 15 January in freshwater. In the sea this only applies for sexually mature specimens.

Salmon with weights of less than 2.0 kg (gutted weight) can be marketed for human consumption without restrictions. Salmon with weights between 2.0 and 5.5 kg (gutted weight) can be marketed for human consumption only after trimming (deep skinning) removing the skin, the layer of fat next to the skin and certain parts of the muscle tissue (BEK Nr. 861 af. 15/09/2205 and BEK nr 1117 af 10/11/2006).

Salmon with weights above 5.5 kg must be landed, cut in half and made unsuitable for human consumption.

The Danish quota was in 2007 88,836 salmon. The quota was divided into 5 time periods (from “ ”Bekendtgørelse om regulering af fiskeriet i 2006 og visse vilkår for fiskeriet i følgende år” (paragraf 82)):

1) 25% January – March
2) 15% April – June
3) 5% July – 15th. September
4) 40% 16th September – 15th November
5) 15% 16th November – 31st December.

However, due to the limited marketing possibilities, the distribution was not followed in 2007, and the quota was only utilised by less than 15 % in total.

In **Estonia** an all-year-round closed area of 1000 m radius is established at the river mouths of present or potential salmon spawning rivers Kunda, Selja, Loobu, Valgejõgi, Jägala, Pirita, Keila, and Vasalemma and at the river mouths of the sea trout spawning rivers Punapea, Õngu, and Pidula. In the case of other most important sea trout spawning rivers (Pada, Toolse, Vainupea, Mustoja, Altja, Võsu, Pudisoo, Loo, Vääna, Vihterpadu, Nõva, Riguldi, Kolga, Rannametsa, Vanajõgi, Jämaja) a closed area of 500 m is established from 15 August to 1 December. In the case of smaller sea trout spawning streams, an area of 200 m radius around the river mouths is closed from 1 September to 30 November. Apart from lamprey fishing no commercial fishery in salmon and sea trout spawning rivers is permitted. In most of these rivers also angling with natural bait is prohibited. Besides, only licensed sport fishing is permitted. A closed period for salmon and sea trout sport fishing is established in the rivers Narva, Kunda, Selja Loobu, Valgejõgi, Jägala, Pirita, Keila, Vasalemma, and Pärnu from 1 September to 30 November, in other rivers from 1 September to 31 October. Exceptions in sport fishing closure are allowed by decree of the Minister of Environment in the rivers with reared (the River Narva) or mixed salmon stock (the rivers Selja, Valgejõgi, Jägala, Pirita and Vääna). Below of dams and waterfalls all kind fishing is prohibited at a distance of 100 m. In the River Pärnu below Sindi dam this distance is 500 m.

In **Finland** the new national regulation was accepted by the Finnish government on 28.3.2008. In the Gulf of Bothnia salmon fishing is forbidden from the beginning of April until the following dates in four zones: Bothnian Sea 16th June, Quark 21st June, Southern Bothnian Bay 26th June and Northern Botnian Bay 1st July. Professional fisherman, however, may start fishing salmon one week before these dates by not more than 2 sealprotected trapnets/fisher). In addition during 3 weeks from the opening of fishery (dates above) not more then 5 trapnets per fisherman are allowed. After this for another 3 weeks 8 trapnets at maximum are allowed per fisherman. Non-professional fisherman may start fishing salmon two weeks after the opening of the fishery by one trapnet at maximum (and only in the private water areas). In the terminal fishing area of Kemi the salmon fishing may start on 11th June.

Latvia has the following national salmon fisheries regulations. In the Gulf of Riga salmon drift net and long line fishing are not permitted. In the coastal waters salmon fishing is prohibited from 1 of October to 15 of November. Salmon fishing in coastal waters has been restricted indirectly by limiting the number of gears in the fishing season. In May, October and November, only small meshed gears (mesh size below 30 mm) are permitted. In the rivers all angling and fishing for salmon and sea trout are prohibited with the exception of licensed angling of sea trout and salmon exists in the rivers Salaca and Venta in spring time season and angling and fishing in the River Daugava.. Daily bag limit is one sea trout or salmon. All fisheries by gill nets is prohibited all year round in a 3 km zone around the River Salaca outlet from 2003. Fisheries restriction zones were enlarged around the rivers Gauja and Venta from 1 to 2 km in 2004.

Special terminal fishery area in the Southern part of the Gulf of Riga was established in 2002 for increasing of the hatchery reared salmon fishing near the Rivers Daugava and Lielupe outlets. Regulatory measures for fishing in this region were mitigated to increase fishing effort:

- no salmon fishing prohibition in October- November

- no fishing gear number limitation in late autumn fishing.

The Latvian catch quota is divided between the offshore and coastal fisheries.

In **Lithuania** the coastal fishery in the Baltic Sea is limited by quotas in numbers, by mesh size and minimal fish size. Salmon and sea trout fishery is not permitted by any gears in areas within a radius of 1 km from the river outlets into the sea. Salmon and sea trout fishery is not permitted in separate regions in the sea from 15 August to 31 October. Salmon and sea trout fishery by gillnets is prohibited from 15 of June to 15 of September, and by long line from 1 April to 15 November. During salmon and sea-trout migration, commercial fishery is under regulation in Klaipėda strait and Curonian lagoon. Fishery is prohibited the whole year round in the Klaipėda strait – from northern breakwater to the northern border of the 15-th fishing bay. From September 1 till October 31, during salmon and sea-trout migration, fishing with nets is prohibited in the eastern stretch of Curonian lagoon between Klaipeda and Skirvyte, in 2 km distance from the eastern shore. From September 15 till October 31 fishing is prohibited in 1 km radius from Šventoji and Rėkstyne river mouths and from southern and northern breakwaters of Klaipėda strait. License fishing is allowed from 1st January of 2007 till 1st of October in designated stretches of the listed rivers. The minimum size of salmon and sea-trout for commercial fishery is L – 60 cm.

In **Poland** the international fishery rules are extended to the coast line. Salmon fishery in the mouths of Pomeranian rivers, in the River Drweca and in the Vistula River and tributaries from the dam in Wloclawek to the mouth is forbidden from 1st October to 31st December. From dam in Wloclawek to the mouth fishing is prohibited in July-August. In the Vistula River forbidden commercial catch on Fridays, Saturdays and Sundays. In 2003 a vessel monitoring system was introduced. No changes in the fishery rules in 2006-07.

The TAC for Poland for 2007 was set as 26 950 fish. For year 2007 a system of granting the individual salmon quota for Polish fishermen was set in accordance with Regulation of Ministry of Agriculture and Rural Development of 27.12.2006 on following principles:

- Out of the whole TAC 6% (1 617 fish) was given to vessels smaller than 10 metres without dividing into individual quota.
- The rest – 94% (25 333 fish) was divided equally among vessels of length at least of 10 metres (408 salmon per vessel).

Since 2005 commercial fisheries for salmon/sea trout in rivers is based on new implemented rules. Fisheries opportunities were sold in 2005 by the state on a tender basis, where the bidder had to submit a fishing ten-year operational plan including restocking. There is difficult to get real figures on catch and effort from companies which lease water areas.

In **Russia** the international fishery rules are extended to the coast line. In all rivers and within one nautical mile of their mouth fishing and angling for salmon is prohibited during all year, except fishing for breeding purposes for hatcheries. No changes in fishery regulations in 2001-2007.

In **Sweden** south of latitude 62º55’N, coastal salmon fishery is allowed from the start of the fishing season. North of this latitude salmon fishery could start in coastal area outside of protected areas on the 11th June. Exemptions from this early season regulation of salmon fishery was allowed to professional fishermen by the local county board in the area north of 62º55′N up to the border between the counties Västernorrland and Västerbotten.

Terminal fishing areas were introduced in 1997 in the coastal region around three rivers with reared production (River Luleälven, Skellefteälven and Gideälven). In these areas salmon fishery was allowed from the start of the fishing season.

In the protected areas outside the river mouths of all wild salmon rivers, usually divided into an inner and outer part, generally all salmon and sea trout fishery was generally forbidden. Fishery with trap nets for other was allowed in these areas from the 26th of June. In the outer parts, exemptions from this early season regulation of salmon fishery may be allowed for licensed fishermen by the local county board after the 10th of June, however outside the rivers Örealven, Vindelälven, Sävarån, Rickleån, Kågeälven, Piteälven and Råneälven not until 18th of June. In the areas outside the rivers Ume älv, Ljungan and Kalix älv fish lacking adipose fin could be caught, even when catch of fish with adipose fin was banned.

Angling for salmon was allowed in all wild salmon rivers in the Gulf of Bothnia until the 31th of August. In the rivers Öreälven, Vindelälven, Sävarån, Rickleån, Kågeälven, Piteälven and Råneälven the angling period was limited to the period 19 June-31 August. There was a bag limit of one salmon per fisherman and day in all rivers. In the rivers Eman and Morrumsan, angling was allowed from the 1th of March to the 30th of September.

Since 1997 fishing regulations in the border part of river Torneälven are decided upon by the Swedish Ministry of Agriculture and the Finnish Ministry of Agriculture and Forestry. In 2005-07 angling was allowed in the river from 1 May to 15 August. There was a bag limit of one salmon per day. In addition there were possibilities for a limited river fishery with traditional driftnets during two days. The regulations also provided possibilities for exemptions for licensed fishermen to use trap nets in parts of the protected area outside the river mouth.

To comply with the EU regulation 88/98 that implies that the effort in the drift net fishery should be gradually reduced until drift nets are completely prohibited in the Baltic in 2008, the Swedish Board of fishery has reduced the number of permissions to use drift nets from 55 in 2005 to 35 in 2006. In order to be allowed to fish with in 2007 the fishermen must have been active fishing in 2006.

In order to improve the situation for the poor sea trout stocks in Subdiv 31 a number of changes were implemented from July 1 2006. The minimum size for sea trout was raised from 40 to 50 cm in the sea. Furthermore a ban of fishing with nets in areas with a depth of less than 3 meters during the period 1 April-10 June and 1 October-31 December in order to decrease the bycatch of trout in other fishery. In the period 1 October-31 October fishery with nets with a mesh size of less than 37 mm (knot to knot) is allowed.

4.2 Evaluation of the Management Measures

4.2.1 International regulatory measures

An evaluation of the effects of minimum landing size and minimum hook size was provided in ICES (2000). However, the changes in the regulatory measures in the EC waters (Council Regulation (EC) 2187/2005) might change the situation compared to previous years. The minimum landing size in subdivision 31 has been decreased from 60 cm to 50 cm. The evaluation of the decreased landing size in the subdivision 31 has been provided in ICES 2007.

There is no longer a minimum hook size in long lining in EC waters.

The increased fishing period with long lining, especially in sub-divisions 22-31 will probably have small effects on the fishery. This fishery is possible only during the winter months, from November / December to February or possibly March. The rule concerning a maximum number of hooks per vessel (previously 2000) has also been dropped from the EC Council regulation. This measure might contribute to an increased fishing effort by long lining. As long line fishery is very labour intense, it is not possible to increase the number of hooks so much.

In November 2005 the Council of Ministers reached unanimously a political agreement on a new set of technical measures for the conservation of fishery resources in the Baltic Sea. This new Regulation denied use of driftnets in the Baltic Sea. The closure of drift net fishing entered in force in January 1 2008.

Due to this measure, harvesting of feeding salmon will be reduced to a very limited amount compared to the year 2007, and before when the proportion of salmon catch taken by offshore fishing have been around 80% in 1970s and 1980s but decreased since then, but being still about 70% in 2000s. In the northern feeding areas Bothnian Sea (SD 30) and Gulf of Finland (SD32), offshore fishing with long lines would be possible with small boats and small crew (1-2) but due to all the time increasing grey sea population and their predation on hooked salmon, this fishing is not any more profitable. This kind of fishing with small boats would be possible in the southern Baltic Proper (near Bornholm), but the scale will be far from that compared to time period before 2008 when drift net and long line fishing was carried out with large vessels in the Baltic Proper.

4.3 Other factors influencing the salmon fishery

The incitement to fish salmon as an alternative to other species is likely to be influenced by a number of factors, such as the possibilities for selling the fish, problems with damage to the catches from seal, the market price for salmon compared to other species and possibilities to fish on other species.

In the following section a number of factors which may affect the salmon fishery are considered.

4.3.1 Dioxin

The level of dioxin in salmon of the Baltic has been monitored by authorities in Sweden since 2000 and in Finland since 2001. The maximum level of dioxin and dioxin like PCB set for the flesh from salmon will be 8 pg WHO-PCDD/F-PCBTEQ (COMMISSION REGULATION (EC) No 1881/2006). Overall levels of dioxin and related substances tend to increase with size (sea age) of the salmon, but varies also in different parts of the fish flesh with fat contents (Persson *et al.* 2007). In general the levels found are above the maximum EU level.

In Denmark investigations on the dioxin level have the implication that as from 22. November 2006 salmon above 5.5 kg (gutted weight) are not permitted to be marketed, but must be brought to the harbour and destroyed. Salmon with a weight below 2 kg (gutted weight) can be marketed without restrictions, while salmon with weight between 2 and 5.5 kg can be marketed only after deep skinning and trimming. By this process the more fatty parts of the salmon are removed.

In Latvia dioxin analyses of salmon demonstrated results similar to the Danish results. Dioxin level in fish exceeds the maximum allowed level in the all salmon with a sea age of 2-3 years.

After an initial ban on marketing salmon it has after 30. November 2005 again been possible market salmon in Latvia. Salmon with ungutted (whole) weight below 4.4 kg (length limit 72 cm) can be marketed on the home market without restrictions and salmon with weight below 6 kg (ungutted) can be marketed if the ventral part of the fillet is cut off.

Sweden and Finland both have derogation from the EU until 2011 allowing national use of the salmon if dietary advice is given to the public. Export to other countries is not permitted.

While there is no information available from Germany, Polish samples of salmon were examined in 2005 and 2006. The results from these have not resulted in marketing restrictions.

For the Baltic area as such it seems to be only in Denmark and Latvia that the possibilities for marketing has been affected from dioxin levels and rules, probably influencing incitement to fish salmon also in future.

4.3.2 Size (weight) distributions of catches

The enforced and future weight limits for marketable salmon strongly affects the fishing practice and possibilities in the future. It is likely that, if possible, specific marketable sizes will be targeted by the fishery.

Size limits may also affect the reported size distribution of catches. Weight distribution of sampled Polish (years 2005 and 2006) and Danish (years 2003-2006) are presented in Figures 4.3.2.1- 2.

For the Danish samples the fraction of marketable salmon (weight classes below 7 kg) increased in 2006 and 2007 compared to previous years. On average 89 % of the sampled salmon were below 7 kg for the years 2003 – 2006, while it was 99.5% in 2007, while it on average was 88.2% in the Polish samples.

Also in the Polish salmon sampled, the proportion of salmon being below the 7 kg constituted the majority, but the fraction was much lower, on average 88.2% for the years 2005-7, than in the Danish catches.

4.3.3 Predation on salmon by seals and damage caused by seals to fishing gears and to salmon in fishing gears

The effects of seal on salmon and salmon fishery have consequences at several levels:

1) Direct catch loss due to damaged or escaped fish.
2) Capital losses due to damage of gear.
3) Indirect effects through seals disturbing the fishing operations.
4) Changes of fishing grounds or methods as a response to seal interaction.
5) Reduced value of catches due to scars and parasite infections.
6) Effects on fishery through competition for the salmon resource and / or altered fish behaviour.

All effects are difficult to quantify. Item number 1 and 2 are the parts of the total damage where the best data is available for quantitative estimate, but still with substantial uncertainty. The indirect effects can only be estimated in a very crude manner, and an estimate of the seal population effect on recruitment of commercial species is not possible, since this requires a good knowledge of the total seal population size and also the composition of the diet.

In Denmark, Russia and Poland influence by seals on salmon fishery is insignificant. No data are available from Germany or Lithuania.

In Estonia the seal damage is most accentuated in the salmon and sea trout gill net fishery. Damage has increased in recent years (pers. comm. of fishermen). Quantitative assessment of damage is not available as fishermen in most cases did not present claims for gear compensation.

In Finland the share of discarded fish is reported by fishermen in numbers of salmon damaged. According to recorded data about 7,838 salmon (40 t) salmon were discarded due to seal damages. Seals caused severe damages to all fisheries mainly in sub-divisions 29-32 where seal damages comprised 17 % of the total commercial catch in the region. Other discards were about 785 salmon (4 t). This can be compared to 8,111 salmon in 2006, 10,800 in 2005 and 12,171 salmon in 2004. Most of the damaged fish has to be discarded.

In Latvia, direct catch losses of salmon by seal damages increased significantly from 2003. In the most affected area, the southern part of the Gulf of Riga, the percentage of salmon damaged by seal in coastal fishery increased from 5% in 2002 to 40% in 2003 and 60% in 2004. Due to increasing of catch looses salmon fisheries in the autumn of 2005- 2007 carried out in the lower part of the river Daugava. Seal caused salmon damages were not observed in the river. The number of discarded salmon due to seal damage was in 2004 525 individuals (4.2 tonnes). Seal caused salmon damages were not observed in the river.

In Sweden the total percentage of the salmon catch in trap nets that is discarded due to damage by seals is estimated to be about 15% and this leads to an estimated discard in 2007 of 25 tonnes (35 tonnes in 2006 or 6,192 salmon, 2005 49 tonnes and 9,860 salmon).

4.3.4 Fisheries economics

Figure 4.3.4.1 presents the monthly salmon price per kilogram paid for fishermen in Bornholm 1998-2007. During the period 1998 – 2004 prices were relatively stable. During the winter 2003 – 2004 catches of salmon were very high in the sea close to Bornholm. Later in 2004 dioxin levels in Danish samples were found to be above levels set by EU authorities, resulting in a closure of the fishery for part of the year 2004. This meant that the market situation for the salmon fishermen was very uncertain and the changes in the prices in 2004 are most likely a result of these facts.

The price of salmon has increased gradually from 2005 through 2007. This could be due to the increase in salmon world market prices and decrease in landings. The salmon import from Norway to Denmark has level out since 2006 (Fig. 4.3.4.2).

The salmon price in Finland was on average 4.75 €/kg in 2007 (2006: 4.80 €/kg). In Sweden, the annual average salmon price in 2007 was 4.25 €/kg (2006: 3.29 €/kg).

4.3.5 Reductions in drift netting

According to Council regulation (EC) No. 812/2004 of 26.4.2004 the use of drift nets in the fishery is banned from 1 January 2008.

2007 was the last year when drift nets were allowed for fishing in whole Baltic. Polish authorities made several attempts to EC DG Fisheries in order to make derogation from Council Regulation (EC) No. 812/2004, which in their opinion, was prepared without sound proof of high mortality of cetaceans in central Baltic driftnet fishery. A special observer programme paid by state was conducted by the Polish Sea Fisheries Institute to estimate cetacean mortality in drift nets. Hardly any cetaceans were caught in drift nets, which was base to present an interpellation to parliament and further personally to Joel Borg Commissioner for Fisheries. There was no cooperation with other Baltic countries and Polish authorities did not receive the derogation.

4.4 Development in post-smolt survival and factors affecting it

4.4.1 Objective

The ToR for 2008 explicitly states that the group should "evaluate the possible reasons for the low at-sea survival of salmon stocks". This chapter describes analyses that have been carried out on this subject so far. The work is in an initial stage, which means that results presented should be viewed as preliminary, and more detailed analyses will appear in the future. It is important to highlight the fact that a correlative approach has been applied, which means that observed associations between survival estimates and biological predictors are not necessary due to causal relationships.

4.4.2 Background

The post-smolt survival of salmon in the Baltic Sea is believed to have decreased in recent years, both for wild and hatchery produced smolt (ICES 2007a). According to post-smolt survival estimates generated from the assessment model, this decline started in the mid 90s and has continued since then. The reasons behind the observed decline are unclear, but at least two main hypotheses exist.

The "ecosystem hypothesis" states that changes in the Baltic Sea ecosystem have affected salmon post-smolt survival rates negatively, for example due to changes in prey species abundances and increased competition or predation from other species. The Baltic Sea ecosystem has gone through pronounced changes in the last 2 decades, characterised by several regime shifts in species composition (ICES 2007b). Climate changes affecting salinity, oxygen levels and temperature are believed to be the main drivers of this process, but fisheries and eutrophication also have impacts on the observed changes. The fish community has changed rather dramatically. In the Main Basin, cod and herring total biomasses have declined, whereas sprat total biomass has increased in the 1990s. At the same time, mean weight at age has declined for sprat, indicating a clear density-dependent response in individual growth. The seal population has increased during the last two decades. The observed changes in the ecosystem have likely affected also the salmon. Herring and sprat are important food sources when the salmon become piscivorous, but these species may also act as competitors for food when the post-smolts enter the sea and are dependent on zooplankton and insects (Haugland et al. 2006).

The "smolt quality hypothesis" states that the increased mortality among hatchery produced smolts is due to changed practices in hatcheries. Hatchery practices have continually been improved. One factor that has been changed considerably is the composition of the feed. Higher fat and energy contents, in combination with favourable river temperatures especially in autumn, have resulted in improved growth rates in hatcheries and continually larger smolts. There is a general concern that the large size of reared smolts may have negative fitness consequences in the wild environment. Results from field studies indicate that migration abilities of reared smolts in rivers and estuaries may be disturbed, which could make them more vulnerable to predation (Rivinoja et al. 2007).

Below we briefly describe methods used to study reasons behind variation in sea survival. The initial analyses have been divided into separate sections depending on whether non-Bayesian or Bayesian approaches were applied. We then formulated more precise hypotheses focusing on factors that were judged, based on initial analyses, to be potentially important in describing the reasons behind variation in salmon sea survival. These were analysed using multivariate analyses. A section evaluating different estimates of post-smolt survival rates is included at the end of the chapter.

4.4.3 Methods

Predictor variables

Data on potential explanatory variables characterising the Baltic Sea ecosystem and the smolt releasing hatcheries has been collected. Contacts have been established with other ICES working groups which kindly have agreed to let WGBAST get access to their data. Data has also been collected from other organisations. In total, data on 102 predictor variables was obtained.

Response variables: estimates of post-smolt survival rates

In initial non-Bayesian analyses of predictor variables, we used post-smolt survival rates from the assessment model (years 1987-2005). In this model, the mortality for wild post-smolts were estimated based on tag-recapture rates of reared smolts, assuming a relative difference between wild and reared fish that is constant over the years. This assumption may not necessary be true. Therefore, more direct estimates of survival rates at sea of reared and wild smolts were also included in the initial analyses.

For reared fish in subdivisions 30 and 31, the average Carlin-tag recapture rate (1987-2005) for the Swedish rivers Luleälven, Skellefteälven, Umeälven, Ångermanlandälven, Indalsälven, Ljusnan and Dalälven was used as a response variable (Figure 4.4.1). All populations have experienced a pronounced decline in tag recapture rates during the study period. These tag-recapture rates are not corrected for variation in fishing effort during the period. Therefore, in analyses based on tag-recapture rates, fishing effort in offshore and coastal fisheries was included as a predictor variable when evaluating different explanatory variables. As a complement, we also ran analyses in which residuals from the regression of total fishing effort in the Baltic Sea on tag recapture rates were used when evaluating single predictor variables. By using residuals, any long-term trend in survival rate is removed, thus focusing more on annual variations when investigating the effects of different biological predictors.

For initial analyses of wild fish, we used 0+ parr density and number of ascending spawners registered in fish ladders in Kalixälven (years 1991-2007) and Vindelälven (years 1994-2007) to calculate survival indices (number ascending spawners of a given year class/average historical 0+ parr density for that year class), which was used as response variables. Only MSW (Multi Sea Winter) fish were included. The smolt age was assumed to be 3 years, and the age composition among ascending spawners was assumed to be fixed during the study period (50% 2SW and 50% 3SW). Based on this information, the number of ascending spawners for each year class was calculated and then divided by the relevant parr density (Figure 4.4.2). This index does not take into account variation in fishing effort. However, fishing effort did only explain a small, non-significant amount of the total variation in these survival indices (data not shown).

The other initial analysis followed the Bayesian approach. Estimates of survival of wild smolts were extracted from the results of the assessment model. These estimates come in the form of posterior probability distribution, which also includes the correlation between the estimates of annual mortality. The covariance of the estimates was taken into account by using the annual median as an observation, and the covariance matrix of the estimates as a description of measurement error of the observations.

4.4.4 Results from initial analyses of predictor variables

Non-Bayesian approach

In a first step, linear regressions were performed to investigate each of 39 selected predictor variables, judged to be potentially important (Table 4.4.1). In all analyses, we tested the relationship between response and predictor variables during the smolt year (i.e. survival index for e.g. smolting year 2000 was tested against temperature, abundance of other species etc in year 2000), except for M74, which effect was analysed by comparing the survival index of a smolting year with the M74 level experienced by these fish in their hatching year, i.e. three years earlier.

The results from the simple regressions (Table 4.4.2) indicate that many variables might be of importance. However, it is important to note that significant associations do not necessarily indicate causal relationships between response and predictor variables. For the Swedish wild salmon from Kalixälven and Vindelälven, there was a strong positive relationship between M74 and survival index. The obvious explanation for this association is that M74 affects 0+ parr densities negatively, and a closer examination showed that 0+ parr density is negatively correlated with survival index for these rivers (Figure 4.4.3). These results indicate that survival rates for these rivers may be density dependent. The number of released hatchery smolts along the Swedish coast, and the estimated total smolt production in the Baltic Sea, are both negatively correlated with several survival estimates (Table 4.4.2), also indicating that density dependent mortality may take place in the sea.

The two approaches used to take into account fishing effort in analyses of Swedish tag-recapture rates (effort included as a predictor vs. residual based analyses) gave very similar results, except that the effect of sprat abundance in SD30 disappeared when the long-term trends in tag reporting rates were removed by using residual analyses. This indicates that sprat abundance may not be associated with salmon survival as sprat abundance did not explain a significant amount of the annual variation in salmon survival rates.

Some survival indices were still negatively correlated with abundance estimates of sprat (in subdivision 30) (table 4.4.2). Survival estimates were positively associated with different measures of herring abundance and weight. Also, there was a strong negative association between seal abundance and many survival indices.

Bayesian approach

The assessment model-based estimates of survival were analysed in the Bayesian framework by screening all the 102 explanatory variables that were collected as potential covariates. The idea was to try each variable as the only covariate in the context of a log-linear regression model. Based on the predictive ability of each model, posterior probabilities were calculated for each alternative. The posterior probability describes the relative credibility of a model compared to other competing models considered in the analysis. A high posterior probability of a regression model indicates strong covariation which may or may not be due to direct or latent causal relationship.

The highest probability (0.38) was assigned to positive association between survival and landings of herring. The landings of herring have steadily decreased with a rate similar to survival of smolts, which creates the result. Due to difficulties in understanding the possible direct or latent causality, the landings were dropped from further analysis.

Probability of 0.33 was assigned to negative correlation between Swedish seal counts and the survival of smolts due to rapid increase in seal counts in parallel to decrease in salmon survival. If seals are found to regularly feed on salmon smolts, increase in seal abundance would increase the pressure on smolt population and in this case the association detected here would be at least partly due to causal relationship. Therefore the seal counts were included also in more detailed analysis.

The 3rd highest probability (0.07) was assigned to a model where the estimated number of wild smolts produced in assessment unit 1 was used as a covariate. The smolt abundance had a negative association with the survival, which suggest that density dependence could be present during the first summer at sea. According to biological understanding, density dependent mortality could most likely occur in the estuary, but intra-specific competition could theoretically take place also at a later stage of feeding migration if the prey populations are highly concentrated to patches. Based on these ideas, the abundance of smolts was selected for more detailed analysis.

Because the estimated survival of smolts has a clear decreasing trend, the analysis that included only one predictor at a time is likely to bring up covariates with either increasing or decreasing trajectory in time, and predictors associated with annual variation are not that easily recognised. Therefore, variables that were assigned relatively low probability during the initial analysis were not excluded from further analysis.

4.4.5 Formulating relevant hypotheses for salmon survival

It is of course difficult to discriminate between biologically meaningful associations and nonsense correlations solely on the basis of the initial analyses presented above. Therefore, selection of variables for further analyses had to be based also on the common biological knowledge within the WGBAST group. The group agreed on the following more specific hypotheses, to be tested in more refined multivariate analyses.

Competition hypothesis

In this analysis, the idea was to test if intra-specific competition for food is important in explaining variation in post-smolt survival. In this case the survival of smolts would decrease when the smolt abundance increases.

Seal predation hypothesis

If salmon smolts are under seal-predation, then the increase in number of seals along the migration path of post-smolts should coincide with lower survival. If such a pattern will be revealed, the predation hypothesis remains possible, but not necessary more likely than other hypotheses that might lead to similar predictions.

Food availability hypothesis

Young herring are considered as important prey for young salmon. Therefore increased recruitment of 0+ herring in the smolt year should lead to higher survival if herring abundance is a limiting factor. This hypothesis is strongly connected to the competition hypothesis above. If herring recruitment directly affects survival, then by definition, at-sea survival is density dependent and should be affected by smolt production in rivers and hatcheries.

Smolt quality hypothesis

This hypothesis is relevant only for reared smolts and states that the increased mortality is due to changed practices in hatcheries. Factors suggested to be important include size at release, condition factor and fin damage (see 4.4.2 Background).

4.4.6 Results from multivariate analyses of predictor variables

The hypotheses mentioned above are not mutually exclusive, i.e. all of them can be true at the same time. In order to analyse the relative credibility of the possible combinations of the first three hypotheses, the Bayesian approach was taken to calculate posterior probability for each combination. In addition to these biological hypotheses, there is uncertainty about whether the pelagic trawling in Bothnian Sea may decrease the survival of smolts by catching them as by-catch. Consequently, each combination of biological hypotheses was analysed with and without such an assumption.

The three first hypotheses were studied by using tag return rates of reared smolts from Swedish, Finnish and Latvian hatchery stocks as a response variable and the abundance of smolts, seals and herring recruitment as biological predictors. In addition, fishing effort in coastal (EC) and offshore (EO) fisheries were also used in order to remove their effect on the tag return rate. The expected tag return rate ($s_{t,r}$) was assumed to depend on these variables through the following model structure:

$$\log(s_{t,r}) = \log(1-\exp\{-q_r (p_1 EO_t+(1-p_2)EC_t)\})-f{*}TRAWL_t$$

$$+M_r+e_t+b{*}SMOLTS_t+c{*}SEALS_t+d{*}HERRING_t$$

where q_r is the catchability coefficient, p_1 and p_2 are unknown weighting factors for efforts, parameters f, b, c and d are the effects of the covariates, M_r is river specific mortality rate and e_t is a year specific effect which should capture common patterns to all rivers and to reveal any unexplained variation.

According to joint estimation of all models, the model which includes only the seal counts as a predictor gets assigned the highest probability (0.48) (table 4.4.3). Models including estimated smolt abundance are assigned small probability compared to other combinations. A model with no predictors is equally likely with a model including seal counts and herring recruitment.

The smolt quality hypothesis was tested by including information on smolt size and condition factor, and was tested for two rivers separately, Luleälven and Umeälven. Multiple regressions, using tag return rates from Luleälven and Umeälven, total effort in the Baltic Sea, and information on smolt length were used to test effects of smolt length on survival rates at sea. No significant effects of smolt length were observed for these rivers. In a similar way, no significant effects of length at smolt release were found in analyses using residuals from the regression between tag return rate and total effort as a response variable.

Considering condition factor, the dataset is very limited, only covering the years 1998 to 2005. Because of the low statistical power in these analyses, results should be viewed with caution. In analyses including total effort and smolt condition factor as predictor variables, no significant effects of condition factor on tag return rate were observed for these two populations.

4.4.7 Evaluation of different estimates of post-smolt survival

In order to obtain information about the changes in post smolt survival that would be independent of tagging data and reared smolts, analyses to develop new estimates of post-smolt survival rates have been conducted in parallel with analyses of biological predictors. The fishladder counts of wild MSW spawners were compared to estimates of corresponding smolt production estimates. Smolt production estimates of rivers Vindelälven and Kalixälven were obtained from the hierarchical Bayesian model which used to estimate the smolt production in Gulf of Bothnia rivers based on electrofishing of parr and trapping of smolts. In rivers Vindelälven and Kalixälven smolt trapping is not conducted, thus the estimate of smolt production is reflecting the previous findings in electrofishing studies.

The expected number of spawners in fishladders was modelled using a similar type of model than was used to analyse the tag return rate. The difference is, however, that unlike with return rate of tags, the fishing effort is assumed to decrease the survival to fishladders. Another difference is that no biological explanatory variables were used, but the delayed opening of the coastal fishery was used as an explanatory variable. A common year effect was assumed for both rivers, and variation in this effect can be interpreted to reflect changes in post-smolt mortality, although changes in catchability would be confounded here as in the analysis of tagging data as well.

The model provides a close fit to fishladder counts in both rivers (Figure 4.4.4). This is not surprising in the sense that the post smolt mortality (year effect e_t) is let to vary freely between years. However, the fact that the same year effects provide a good fit to both rivers indicates that both stocks could be affected by the same process during the sea phase.

The annual variation in post-smolt survival estimated using fishladder data show similar type of variation as the survival estimated by the full life history model using only River Tornionjoki data (figure 4.4.5). The survival estimates based on tagging data set analysed with different models indicate similar pattern to each other, but an indication of different variation can be seen in the beginning of the time series. However, all approaches seem to roughly agree about the decrease in survival towards the end of the time series.

4.4.8 Conclusions

Variation in survival

Tag return rate has varied with rather strong year effects across stocks. This suggests that the same cause would be affecting all stocks in the same way. This supports a view that important causes behind the variation would be Baltic wide changes in environment or factors acting in the main feeding area of post-smolts. However, the variation between stocks is approximately equal to variation within stocks, which means that also stock specific covariates (related to estuaries for example) should be further analysed. The predictor variables included in the Bayesian approach managed to explain the decreasing trend in sea survival, but were not able to explain all annual variation observed (figure 4.4.6).

Competition hypothesis

Our results indicate that survival of post-smolts in the Baltic Sea could be density-dependent. In initial analyses, several survival indices were negatively correlated with the total production of wild and reared smolts in the Baltic. Similar results were obtained in a study of Chinook salmon in Snake River, USA (Levin et al. 2001). A strong negative relationship between sea survival and the number of released hatchery produced fish were observed, especially under years with poor ocean conditions. In a similar way, survival rates in the Baltic may be affected by both the natural production of smolts, and the number of reared smolts released from hatcheries.

The Bayesian multivariate analyses did not give as strong support for this hypothesis as the initial analyses. One explanation for this might be that the competition and the food availability hypotheses are strongly connected, but were in this study analysed separately. These two hypotheses should be combined in the next year meeting. One alternative is to estimate number of herring recruits per smolt to see if this ratio is able to explain variation is survival rates. Ideally, also sprat recruitment should be included in these analyses.

These ideas also highlight the possible influences of ecosystem changes in the Baltic Sea, because following the logic of this hypothesis, changes in the ecosystem could potentially affect the sea carrying capacity for salmon, which may vary between years. Density dependence at sea combined with different carrying capacities in rivers could lead to opposite developments in river stocks. While others are increasing, others are decreasing. This has implications for sensible management objectives and how to achieve them.

Density dependence at sea could be experimentally tested because a large proportion of smolts still consist of reared fish. The releases could be reduced randomly in future years to manipulate the density. If density dependence then seems likely, the releases should be stopped or reduced to help the wild stocks achieve their full capacity. Also, sea trout tag returns should be analysed together with salmon tags to reveal possible common patterns in survival. Since the migration and fishery patterns are different, this analysis could help to pinpoint the areas where the effects of other factors could take place.

Predation hypothesis

Initial analyses, but particularly the Bayesian multivariate analyses, indicated that seals may affect survival of salmon. However, at this stage, we have limited knowledge about grey seal food preferences, and much more information on seal ecology is necessary to evaluate these relationships. One way to further test this relationship is to base analyses on longer time series, spanning over periods including both increases and decreases in seal abundance and tag return rates. Further questions to explore includes: 1) To what extent are seals feeding on smolts? 2) Is the survival higher for stocks that are less exposed to seals? This requires improved information on post-smolt migration routes and the spatial distribution of seals in spring and summer months.

The smolt quality hypothesis

Considering the effects of rearing conditions on post-smolt survival rates, the available data is very limited, making it difficult to draw any general conclusions. There was no direct evidence for a negative association between length of reared smolts and their survival at sea. However, more detailed studies of these relationships are necessary, including possible non-linear associations between these variables.

The ecosystem approach

More research about causality chains including the whole Baltic ecosystem is needed, from nutrients to top-predators.

Evaluation of different estimates of post-smolt survival

The pattern in post-smolt survival estimated by fishladder, effort, and smolt abundance data, resembles the pattern estimated by tagging data which is used in the estimation model. The pattern also provides sensible fit to fishladder counts of spawners. This might lead to following conclusions

- Changes in reporting rate of tags is probably not fully responsible for the decrease in observed tag recovery rate, but also a decrease in the post-smolt survival seem to explain the changes.
- If there would have been major increases in catchability then the models based on constant catchability would lead to decreasing estimates of post smolt survival and models based on fish ladder data would show increasing estimates of survival to explain the number of spawners observed in the fishladder. Currently both data sets show downward development in survival, which points to the direction that the estimated decrease in survival would not be caused by unaccounted severe increase in catchability.
- Simple model for predicting fishladder counts fits quite well with a similar survival pattern than estimated by the full assessment model. However, the full assessment model is not able to pick up the development seen in fishladders that well regardless of the similar survival pattern. The major difference between the models is that the delayed opening of the coastal fishery is not taken into account in the full life history model. Also the relative harvest rates of the fishery have been estimated to be higher by the simplistic model than the life history model. The estimation of harvest rates could be further investigated in order to explore the reasons behind the unexpected behaviour of the full life history model in respect to estimation of the catches.

4.5 Conclusions for the salmon fishery

The disappearance of the drift net fishery from 2008 is expected to have considerable effect on the fishery. Driftnet fishery was conducted by vessels having specialized in using drift nets in the autumn and spring and some of them longlines in the winter months. It is not expected that catches with longlines operating in fisheries only in the winter months can fully compensate for the catches previously taken by driftnets.

The effort in the offshore long line and coastal trap net fisheries is expected to increase in the future (Table 4.5.1, Figure 5.4.2.1). This is due to the fact that the long lines will be the only possible gear in the offshore and changes in the coastal regulation will allow for an increase in trapnet fishery. Nevertheless, increase of effort in coastal fisheries is uncertain due to several factors, e.g. increase in seal damages and changes in national regulatory measures.

Dioxin contents in the salmon is not expected to influence fishing in Sweden, Finland, Poland, Lithuanian, Estonia and Germany, because the countries either have a derogation from the EU rules, have asked for a derogation or have results from analysis of dioxin contents that permits marketing of the salmon.

As a consequence of the reduced possibilities to market salmon due to the EU regulations on dioxin and dioxin related PCB’s together with the driftnet ban as of

2008, the incitement to fish salmon in Denmark is presently so low, that the fishery most likely will continue at a very low level. Only a very few Danish boats are expected to be active in this fishery in the future, and many salmon fishing gears have already been sold or destroyed. At the same time the fishing fleet is continuously decreasing as a result of scrapping. The ban for marketing of Baltic salmon due to high dioxin levels was implemented in Latvia too. That will reduce the salmon fisheries in Latvia to a very low level.

The utilizing of the TAC in the Baltic Main Basin and the Gulf of Bothnia was in 2007 at a historical low level of only 47%. The utilizing of the TAC in the Gulf of Finland was in 2007 also at a level of 84%. It seems very likely that the utilizing of the TAC in future also will be at a low level because of the above mentioned limiting factors. First of all, disappearing of drift net fishery will considerably decrease the total catch of salmon in 2008. At the same time the proportion of the catch by non-commercial fisheries continued to increase, and as these catches in numbers were close to 20% of the reported total commercial catch, it is expected that the non-commercial catches will increasingly influence the fishery in the coming years.

A factor that may affect the future salmon fishery is the recently observed rise in prices for Baltic salmon. This could be a natural incitement to fish salmon, but is of course very much dependent on the development of fishing costs and possibilities to catch other species.

Table 4.4.1. Predictor variables used in the analyses.

Predictor variable	**Unit**	**Area**	**Season**	**Abbreviation**	**Source**
Cod Total biomass	Tonnes	22-24	-	CodBM22-24	WGBFAS
Cod Total biomass	Tonnes	25-32	-	CodBM25-32	WGBFAS
Herring Total biomass	Tonnes	25-32 exkl GoR and SD 30,31	-	HerringBM25-32	WGBFAS
Herring Weight (age 1)	kg	25-32 exkl GoR and SD 30,31	-	HerringW25-32	WGBFAS
Herring Total biomass	Tonnes	30	-	HerringBM30	WGBFAS
Herring Weight (age 1)	kg	30	-	HerringW30	WGBFAS
Herring recruitement (age1)	Thousands	30	-	HerringR30	WGBFAS
Herring Total biomass	Tonnes	Gulf of Riga	-	HerringBMGoR	WGBFAS
Herring Weight (age 1)	kg	Gulf of Riga	-	HerringWGoR	WGBFAS
Sprat Total biomass	Tonnes	22-32	-	SpratBM22-32	WGBFAS
Sprat Weight (age 1)	kg	22-32	-	SpratW22-32	WGBFAS
Sprat Catch index	Number/day	30, Forsmark nuclear power plant	-	SpratCI30	Swedish Board of Fisheries
NAO	-	-	Average Apr-Sept	NAO	-
Baltic Sea Index		Central Baltic		BSI	IFM
Sea Surface Temp	°C	Gotland Basin	Spring	TempGBSp	WGIAB
Sea Surface Temp	°C	Gotland Basin	Summer	TempGBSu	WGIAB
Sea Surface Temp	°C	Bothnian Sea	Summer	TempBSSu	WGIAB
Sea Surface Salinity	psu	Gotland Basin	Spring	SalinityGBSp	WGIAB
Bottom Salinity	psu	Bothnian Sea	Winter	SalinityBSWi	WGIAB
Total Phytoplankton	mg/m3	Gotland Basin	Spring	PhytGBSp	WGIAB
Total Phytoplankton	mg/m3	Gotland Basin	Summer	PhytGBSu	WGIAB
Total Phytoplankton	mg/m3	Bothnian Sea	Summer	PhytBSSu	WGIAB
Acartia spp	mg/m3	Gotland Basin	Spring	AcartiaGBSp	WGIAB
Acartia spp	mg/m3	Gotland Basin	Summer	AcartiaGBSu	WGIAB
Temora longicornis	mg/m3	Gotland Basin	Spring	TemoraGBSp	WGIAB
Temora longicornis	mg/m3	Gotland Basin	Summer	TemoraGBSu	WGIAB
Pseudocalanus acuspes	mg/m3	Gotland Basin	Spring	PseudoGBSp	WGIAB
Pseudocalanus acuspes	mg/m3	Gotland Basin	Summer	PseudoGBSu	WGIAB
Acartia sp	mg/m3	Bothnian Sea	Summer	AcartiaBSSu	WGIAB
Bosmina sp	mg/m3	Bothnian Sea	Summer	BosminaBSSu	WGIAB
Pseudocalanus sp	mg/m3	Bothnian Sea	Summer	PseudoBSSu	WGIAB
Temora sp	mg/m3	Bothnian Sea	Summer	TemoraBSSu	WGIAB
Dissolved inorganic nitrogen	µmol/l	Bothnian Sea	Winter (surface)	NitrogenBSWi	WGIAB
Dissolved inorganic phosphorus	µmol/l	Bothnian Sea	Winter (surface)	PhosphorusBSWi	WGIAB
M74 Average frequency (%)	Proportion (%) affected females or offspring	Baltic Sea	-	M74	WGBAST
No released hatchery smolt in Sweden*	No	30-31	-	Stocked smolt	Swedish Board of Fisheries
Smolt produktion, hatchery total+wild unit 1	No	Hatchery: whole Baltic Wild: unit1	-	Total smolt	WGBAST
Mean smolt size*	mm	30-31	-	Smolt size	Swedish Board of Fisheries
Seal abundance	No	Swedish Baltic coast	May-June	Seal	Natural History Museum

Table 4.4.2. Associations between a number of predictor variables and post-smolt survival. Estimates of post-smolt survival rates are based on different methods described in the text. Statistics (Beta-values) from simple regressions on each predictor variable separately. Bold indicate statistically significant associations ($p<0.05$, not corrected for multiple tests).

Predictor variable	**Kalixälven wild[1]**	**Vindelälven wild[1]**	**Swedish hatchery stocks[2]**	**Torneälven wild[3]**	**Torneälven hatchery[3]**	**Baltic wild[3]**	**Baltic hatchery[3]**
CodBM22-24	**0.54**	0.49	-0.02	0.22	0.04	0.00	-0.01
CodBM25-32	0.24	0.18	0.18	0.23	0.21	**0.55**	**0.56**
HerringBM25-32	-0.32	-0.35	0.33	0.24	0.19	**0.63**	**0.64**
HerringW25-32	-0.32	-0.07	0.27	0.32	0.39	**0.69**	**0.69**
HerringBM30	-0.16	-0.30	0.28	0.30	0.20	0.08	0.08
HerringW30	-0.33	-0.07	0.16	0.39	0.04	**0.60**	**0.60**
HerringR30	-0.18	-0.18	0.18	0.19	0.36	0.21	0.22
HerringBMGoR	0.05	-0.22	0.23	0.45	0.19	0.00	-0.01
HerringWGoR	0.01	0.44	0.08	0.29	0.14	0.32	0.32
SpratBM22-32	**0.61**	0.32	0.14	0.06	0.09	-0.37	-0.37
SpratW22-32	-0.49	-0.55	0.25	0.33	0.35	**0.53**	**0.52**
SpratCI30	0.09	0.14	**-1.04**	**-0.69**	-0.44	**-0.82**	**-0.82**
NAO	-0.41	-0.20	0.17	0.04	0.42	0.41	0.40
BSI	-0.21	-0.05	0.07	0.12	-0.04	0.15	0.15
TempGBSp	-0.31	-0.30	0.18	0.16	0.13	0.40	0.40
TempGBSu	-0.42	-0.13	0.24	0.14	0.28	0.30	0.30
TempBSSu	-0.22	-0.10	**0.42**	0.19	0.41	0.07	0.08
SalinityGBSp	0.08	-0.13	0.13	0.30	0.18	0.20	0.19
SalinityBSWi	-0.21	0.23	-0.12	-0.42	-0.33	0.04	0.06
PhytGBSp	0.28	0.25	0.11	-0.03	0.20	-0.29	-0.29
PhytGBSu	0.18	0.50	-0.14	-0.12	-0.07	0.03	0.03
PhytBSSu	-0.11	-0.15	0.16	0.11	0.08	-0.02	-0.02
AcartiaGBSp	0.13	0.05	0.16	-0.21	-0.19	**-0.54**	**-0.53**
AcartiaGBSu	-0.41	-0.23	-0.15	-0.27	-0.21	-0.30	-0.31
TemoraGBSp	0.07	0.48	-0.03	0.22	-0.26	-0.14	-0.15
TemoraGBSu	0.02	-0.33	**-0.40**	-0.20	-0.18	-0.14	-0.15
PseudoGBSp	-0.30	0.11	0.22	0.08	0.01	**0.48**	**0.48**
PseudoGBSu	0.07	-0.11	-0.19	-0.19	-0.20	-0.11	-0.12
AcartiaBSSu	-0.10	-0.42	-0.03	0.27	0.23	0.20	0.19
BosminaBSSu	-0.16	-0.36	-0.02	0.16	0.24	-0.09	-0.10
PseudoBSSu	0.27	0.03	-0.14	0.22	0.14	0.32	0.32
TemoraBSSu	-0.14	-0.41	0.13	0.13	0.26	0.27	0.26
NitrogenBSWi	-0.23	-0.45	0.01	0.19	0.24	0.36	0.35
PhosphorusBSWi	0.12	-0.02	0.25	-0.10	0.15	0.24	0.26
M74	**0.79**	**0.69**	0.20	0.06	0.20	-0.04	-0.05
Stocked smolt	-0.50	0.00	**-0.46**	-0.34	**-0.48**	-0.06	-0.07
Total smolt	-0.29	-0.53	**-0.47**	**-0.70**	**-0.57**	**-0.55**	**-0.54**
Smolt size	-0.16	-0.14	0.04	-0.14	0.03	-0.45	-0.45
Seal	-0.30	-0.37	-0.40	**-0.63**	-0.47	**-0.75**	**-0.74**

[1] Post-smolt survival estimated from 0+ parr densities and number of returning MSW adults.

[2] Post-smolt survival estimated from Carlin-tag recapture rates.

[3] Post-smolt survival estimates from the WGBAST bayesian model.

Table 4.4.3. Explored combinations of potential covariates for tag return rate. Left column shows the probability of the combination of covariates. An empty cell indicates that the covariate is not included. “+” denotes positive and “-“ indicates negative association.

	Covariates			
P(Combination)	SMOLTS	SEALS	HERRING	TRAWL
0.446		-		
0.15				
0.144		-	+	
0.088		-		-
0.036		-	+	-
0.035	-	-		
0.025	-			
0.02				-
0.017	-	-	+	-
0.006	-	-		-
0.005			+	
0.005	-	-	+	-
0.004	-			-
0.001	-		+	
0.001	-		+	-
0			+	

Table 4.5.1 Effort scenarios for the main Baltic salmon fishing effort country based on experts opinions.
Factors are relative to the corresponding fishing effort in 2007.
1) indicates the most likely value

Fishery	Year	DK	PL	EE	FI	LV	SE	LT	RU	DE
Offshore DN	2008	No fishing								
	2009-2016									
Offshore LL	2008	1	1.2	No fishing	1.5	No fishing	1	No fishing		
	2009-2016	0.7-1.3 1.0 1)	0.8-1.4 1.0 1)	No fishing	0.7-2.0 1.5 1)	No fishing	0.4-1.2 0.8 1)	0-2 vessels; No fishing		
Coastal TN	2008	No fishing	No fishing	1	1.3	0.8	1	No fishing		
	2009-2016	No fishing	No fishing	0.5-1.0 0.9 1)	0.7-2.0 1.2 1)	0.4-1.0 0.6 1)	0.6-1.2 0.8 1)	No fishing		

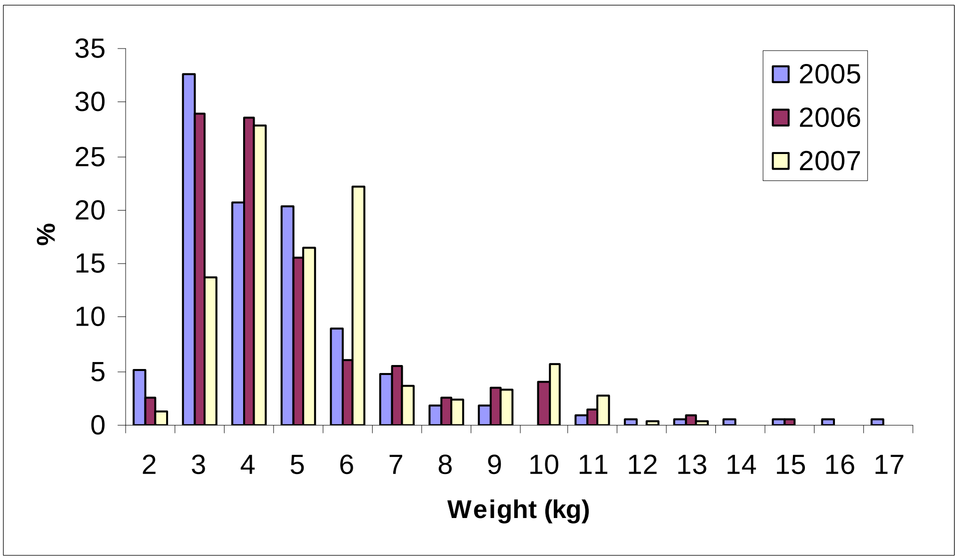


Figure 4.3.2.1
Weight distribution of sampled Polish catches of salmon 2005-2007.

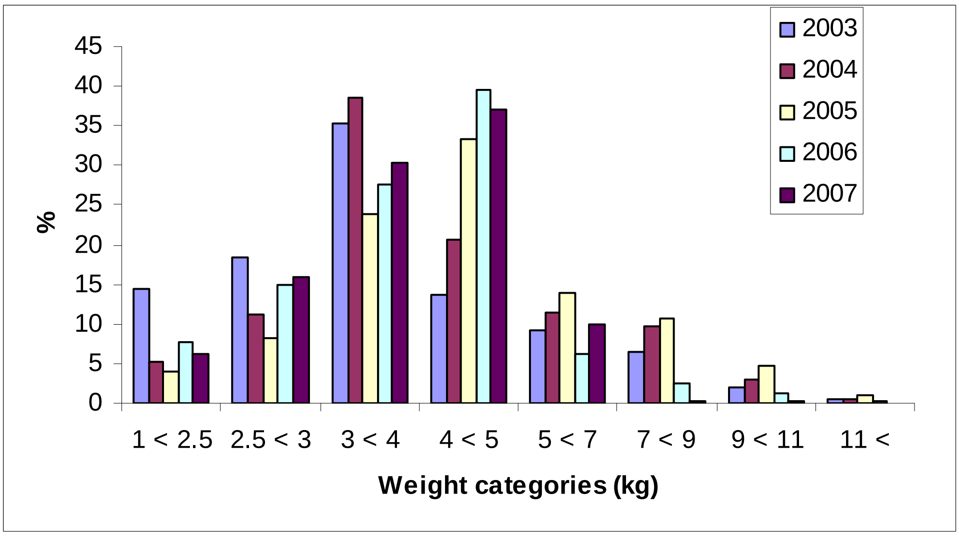


Figure 4.3.2.2
Weight distribution of sampled Danish salmon 2003-2007

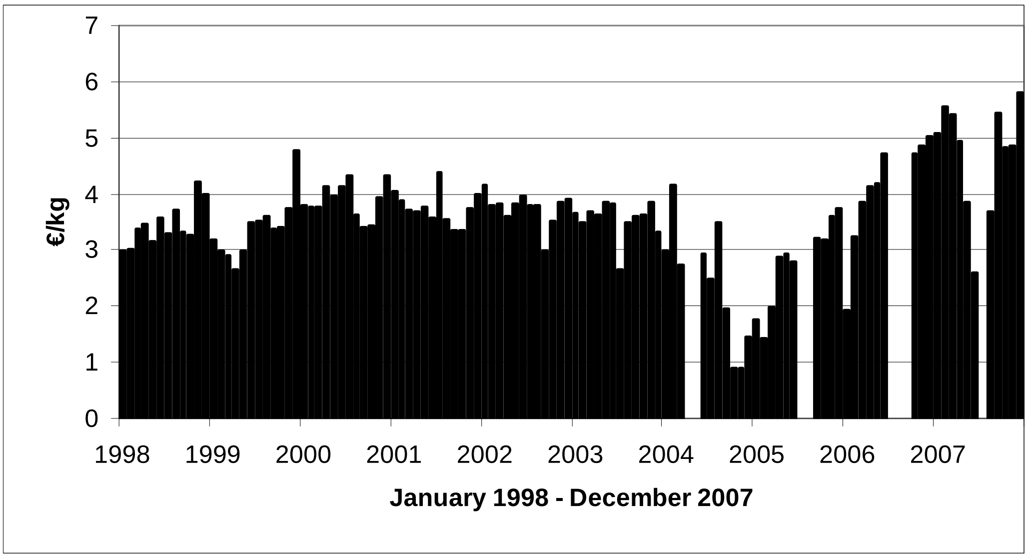


Figure 4.3.4.1. Monthly real salmon prices in Denmark. Empty spaces denotes months without landings in Denmark. Salmon prices (http://www.fd.dk) are converted to real values by using the Danish consumer price index (2000=100) (http://www.statistikbanken.dk). Value in Danish kroners have been changed using the rate 1 DKK=0.13457 EURO.

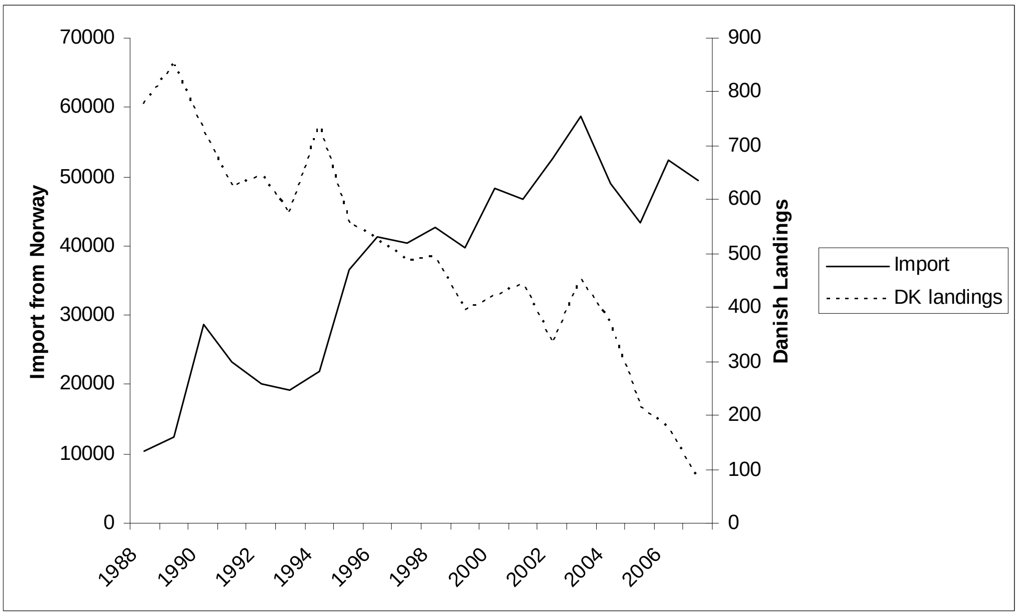


Figure 4.3.4.2

Danish landings of salmon and import to Denmark of farmed salmon from Norway during the period 1988 – 2007. Source: Statbank Denmark, http://www.statistikbanken.dk

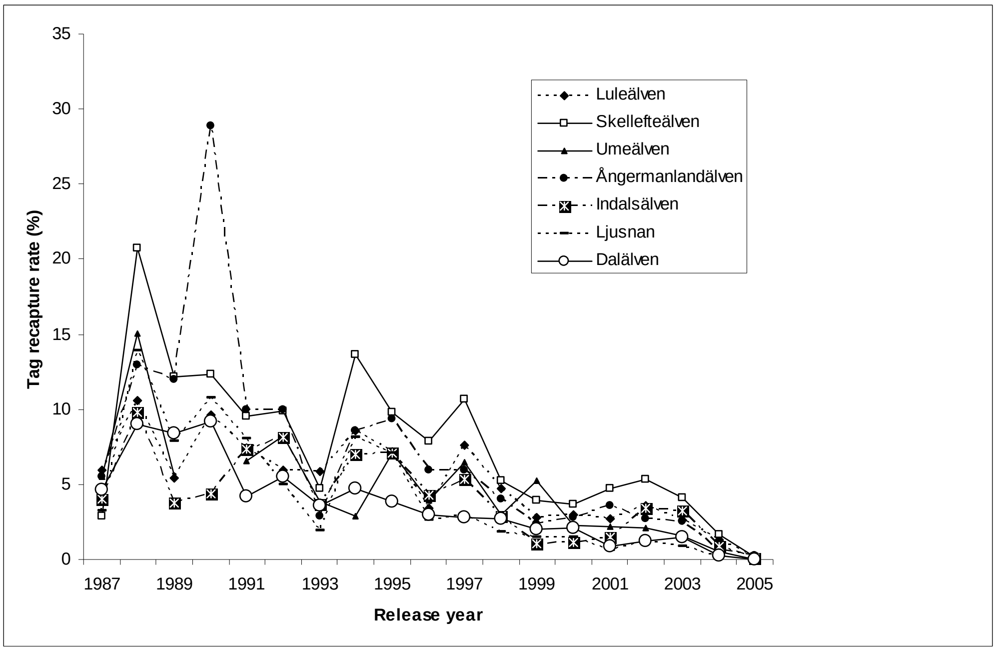


Figure 4.4.1. Tag recapture rates of Swedish hatchery stocks included in the analyses.

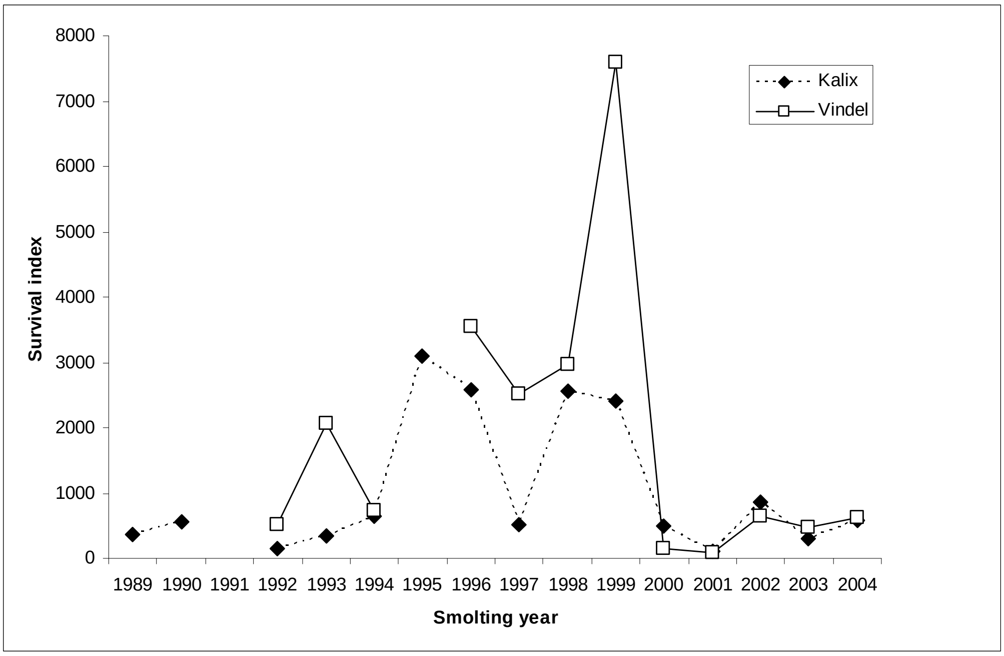
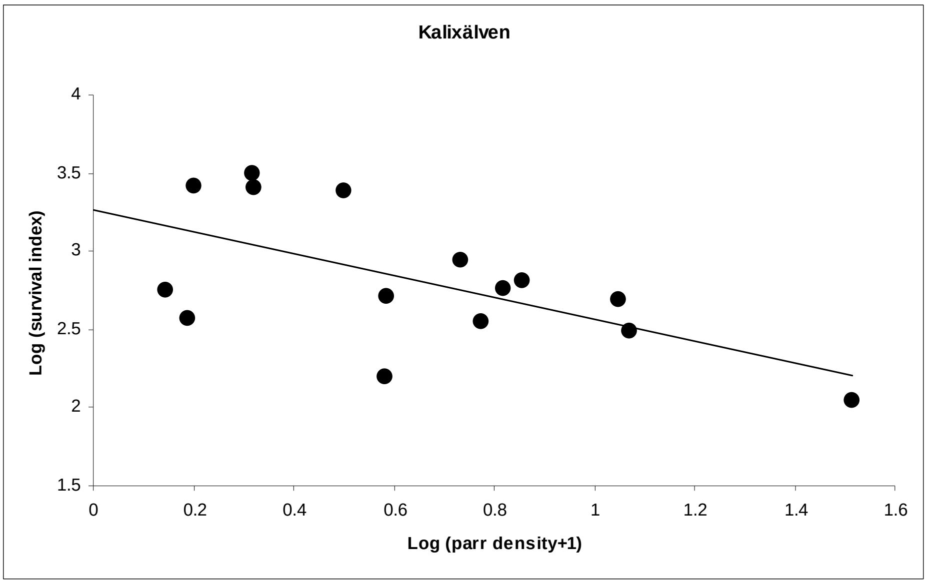


Figure 4.4.2. Survival index of salmon from Kalixälven and Vindelälven during the study period. See text for a description of the survival index.



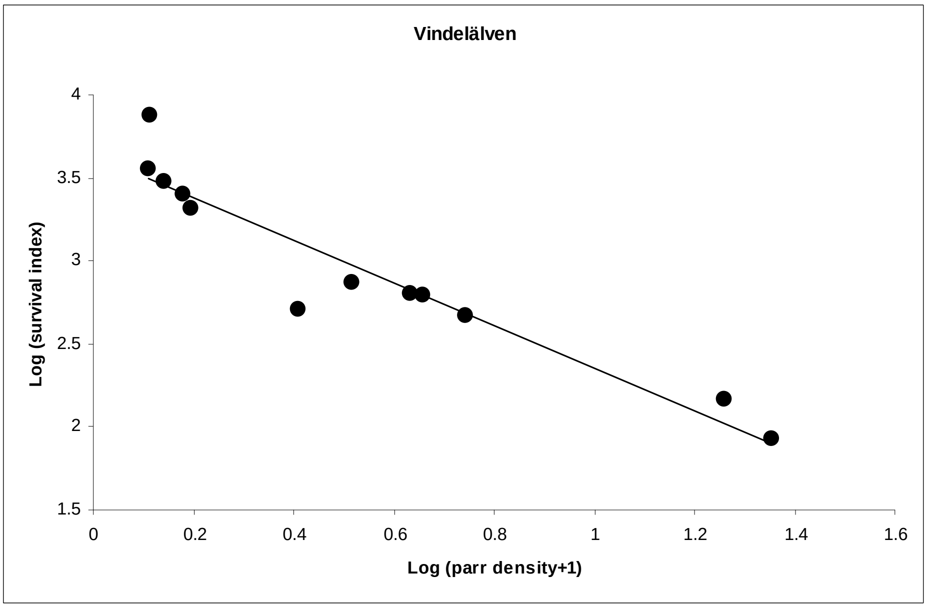
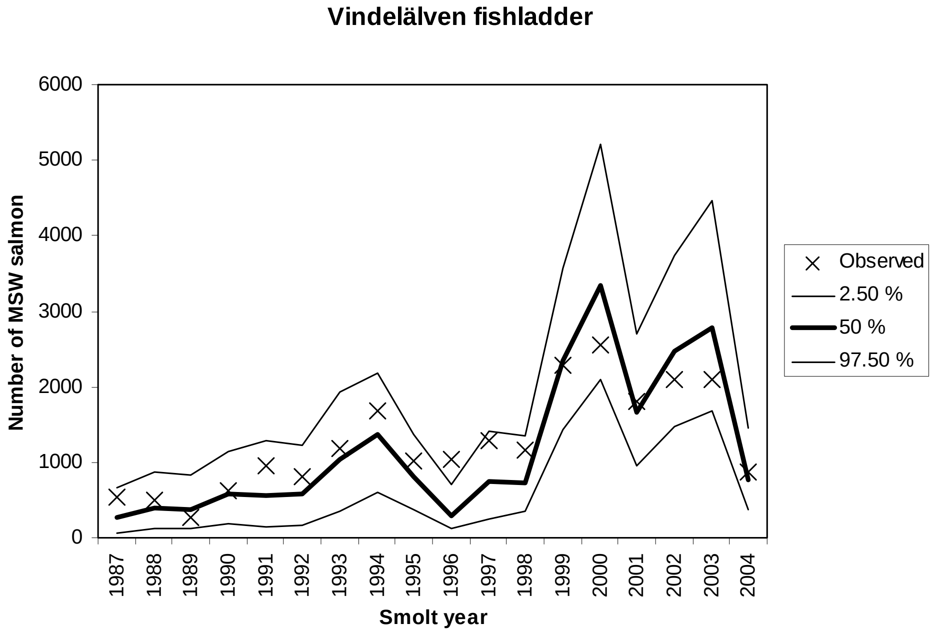


Figure 4.4.3. Associations between 0+ parr density and survival index in Kalixälven and Vindelälven. Linear regression results: Kalixälven (r^2=0.37, $p<0.05$); Vindelälven (r^2=0.90, $p<0.001$).



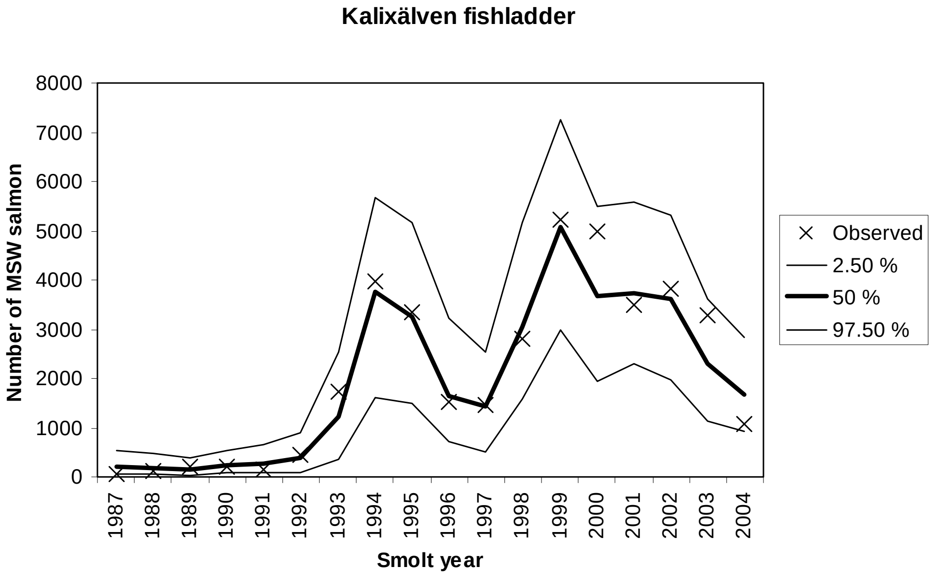


Figure 4.4.4. Observed number of MSW spawners by smolt year in fishladders located in rivers Vindelälven and Kalixälven. The posterior 95% PI of corresponding expected number of MSW spawners calculated by the model.

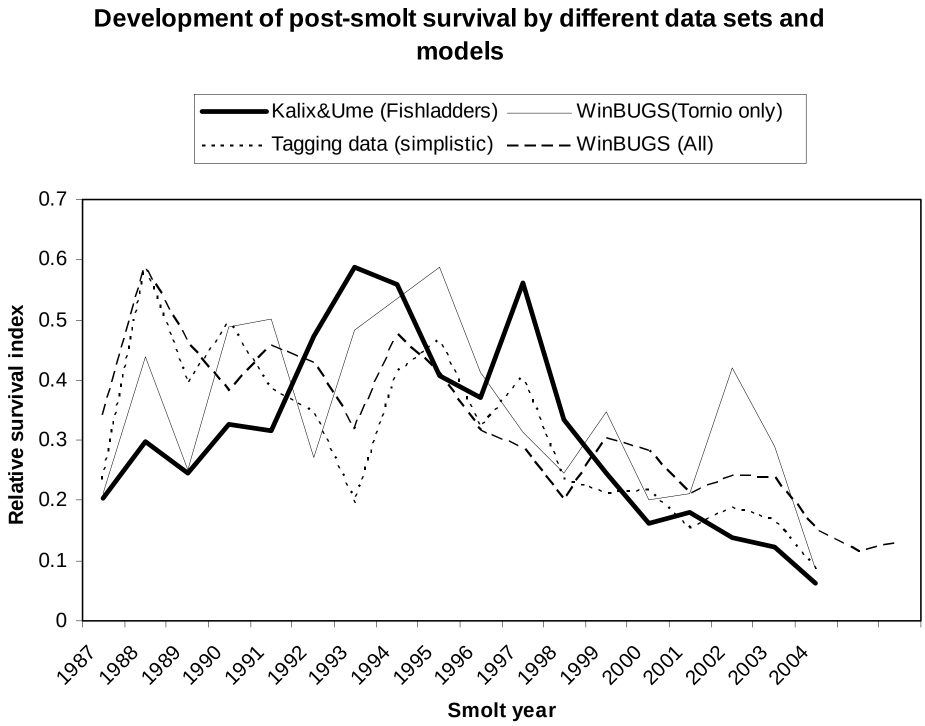


Figure 4.4.5. Variation of post-smolt survival estimated by different models and data sets. “Kalix&Ume” is based on fishladder, fishing effort and electrofishing data. “Tagging data” is a simplistic survival analysis of tag returns with biological covariates and fishing effort data. “WinBUGS (all)” is the full life history model based on all data used in assessment and “WinBUGS (Tornio)” is the same model including only the river Tornionjoki data.

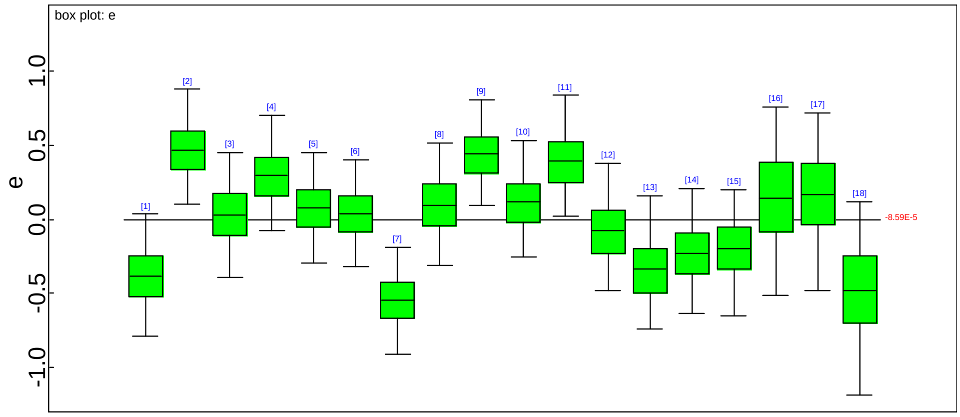


Figure 4.4.6. Year specific random effects describing the interannual variation that is common to all stocks. The plot shows that the explanatory variables were able to remove the trend in smolt survival, but there is still yearly variation that is not explained by the covariates.