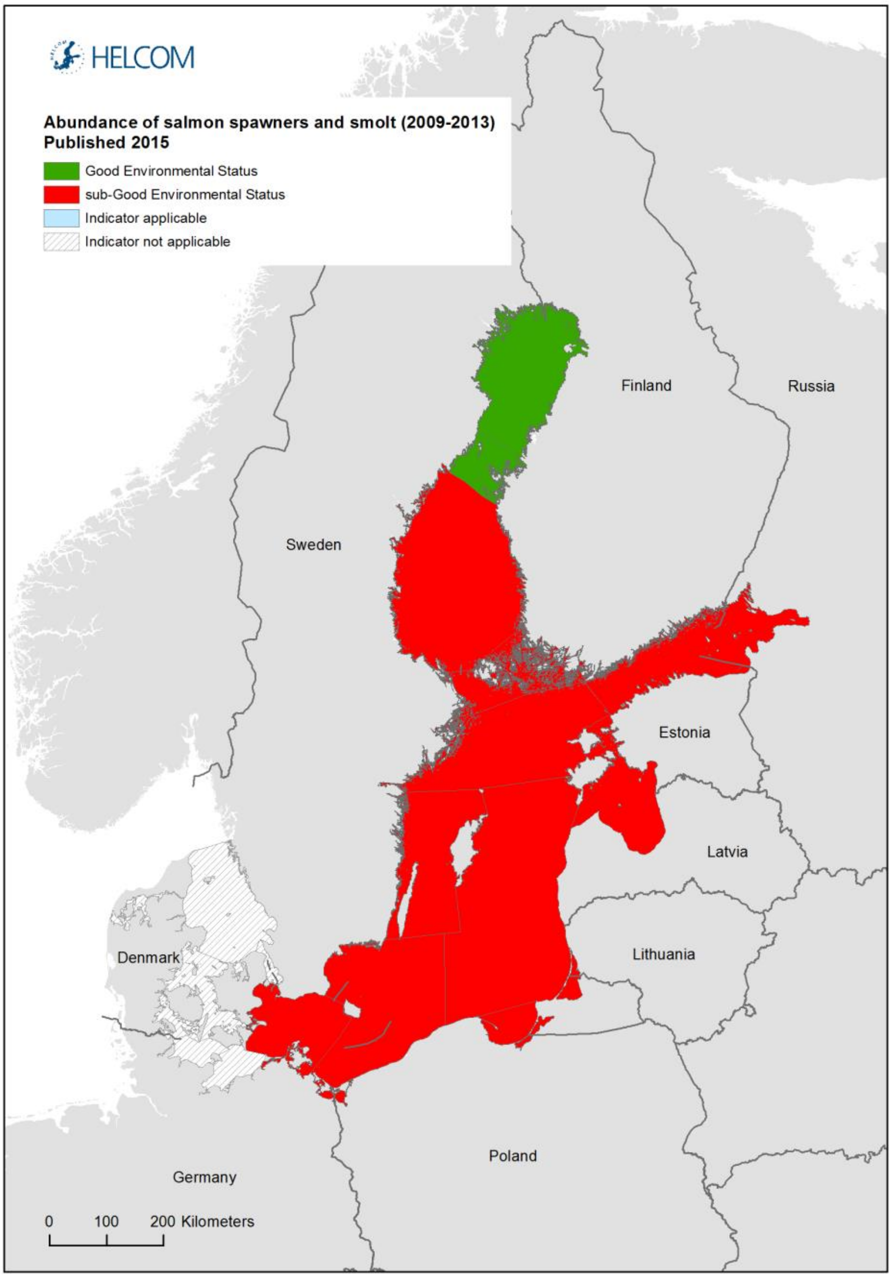
Abundance of salmon spawners and smolt

Key message



Current evaluations are mainly based on 2014 data. The indicator evaluates the environmental status of the sea area based on the salmon smolt production in rivers flowing into the sea, and also considers numbers of adult fish.

In the Bothnian Bay and Quark area, smolt production has increased in recent years due higher number of adult spawners to ascending the rivers because of stricter management measures. GES is achieved in 3 out of 15 rivers, and in the next few years probably in 1-3 more rivers. In the Bothnian Sea area, the smolt production is low although showing slight increase. In the Gulf of Finland the smolt production is low but has shown signs of improvement recently and three Estonian rivers are evaluated as having achieved GES based on expert judgment. Smolt production in rivers flowing into the Baltic Proper is low and does not show any signs of improvement.

The confidence in the indicators status evaluation is moderate.

The indicator is applicable in the rivers of all HELCOM member states, except Denmark and Germany.

Relevance of the core indicator

Salmon is a long-distance migrating big predatory fish species in the Baltic Sea marine ecosystem. Salmon abundance is mainly affected by commercial fishing at sea and barriers to reproduction areas. The adult spawners ascend the spawning rivers after the feeding period and the number of smolts estimated based on the measured parr densities or smolt counts from the rivers reflect the abundance of the adult spawners and success of recruitment.

The indicator evaluates GES by comparing the salmon smolt production with potential smolt production capacity (PSPC) by river. The parameter has a linkage to the number of adult spawners ascending the rivers and, hence, indirectly to the commercial and recreational fishing pressure at the sea and in the river. The indicator also reflects the ecosystem status as smolt production is dependent on river connectivity (effect of dams) and quality of spawning habitats.

Policy relevance of the core indicator

	BSAP **Segment and Objective**	**MSFD** **Descriptors and Criteria**
Primary link	Biodiversity • Thriving and balanced communities of plants and animals • Viable populations of species	D1 Biodiversity 1.2. Population size (abundance, biomass)
Secondary link		D4 Food-web 4.1 Productivity of key species or trophic groups (productivity) 4.3 Abundance/distribution of key trophic groups and species D3 Commercial fish and shellfish 3.2 Reproductive capacity of the stock

Cite this indicator

[Author’s name(s)], [2015]. [Indicator name]**.** HELCOM core indicator report. Online. [Date Viewed], [Web link].

Indicator concept

Good Environmental Status

The assessment of good environmental status (GES) is based on the smolt production in the rivers of wild salmon stocks. The estimated smolt production is compared to an estimated potential smolt production capacity (PSPC) of rivers and the GES boundary is to reach 75% of the PSPC. This level of production compares to a stock size at maximum sustainable yield (MSY) practically for all stocks.

The PSPC is estimated using a life history model developed by ICES WGBAST. Some uncertainty in the method still exists, and thus the potential production capacity may be over-estimated for some river areas. Accordingly the precautionary principle is applied when making estimates of the PSPC against the GES boundary, and there is a small risk of falsely evaluating river as being below the GES boundary. Hence, when evaluating the status of an assessment unit, a one-out-all-out approach is considered unsuitable and a weighted evaluation is to be applied.

The number of adult spawners is used as a supporting parameter in the indicator for areas where such monitoring data are available. Changes in the level of pressures affecting the salmon populations are expected to show with a shorter time-lag in the number of spawners compared to the smolt production capacity, and thus any significant changes in the trend is to be considered as an early warning signal.

Due mainly to the availability of the model and good availability of data from several areas, the confidence of the accuracy of the GES boundary is considered moderate to high.

Anthropogenic pressures linked to the indicator

	General	MSFD Annex III, Table 2
Strong link	Fishing of salmon as well as habitat quality degradation are the main pressures on salmon	Biological disturbance selective extraction of species
Weak link	There might also be effects of hazardous substances on the health of salmon	Potentially also: Contamination by hazardous substances -introduction of synthetic compounds -introduction of non-synthetic substances and compounds

Salmon abundance is mainly affected by commercial and recreational fishing at sea and in rivers, and also barriers to reproduction areas and natural causes. It is possible to determine which human activities give rise to unsustainable levels of pressures on the salmon populations in all cases. However typical problems are due to fishery (legal and poaching) in the rivers and river mouths, quality of the river habitat (barriers, channelization, eutrophication, dangerous substances, predation) and other factors like hybridization with trout, negative effects of stocking, water regulations and diseases.

For salmon to successfully reproduce in rivers, the following environmental criteria must be met: the sufficient quantity and quality of spawning grounds, access to those areas (barriers, such as dams, in rivers) and efficient river fisheries management. In the rivers, the most detrimental activities to salmon have been damming, dredging and channelizing rivers for hydropower, log driving and agricultural purposes. Dams have been mainly constructed in the mid-20th century as a response to the growing demand for electricity.

Also indirect impacts of human activities such as elevated nutrient and sediment loads from agriculture and forestry practices and from discharges of domestic sewage have adversely affected the ecological condition of Baltic salmon rivers.

Salmon is a target species for intensive offshore, coastal and river fishing. Catches of salmon by commercial fishery at sea has decreased since the 1990s, but the river fishing has stayed at a rather stable level. Figure 1. shows the temporal development of the salmon catches.

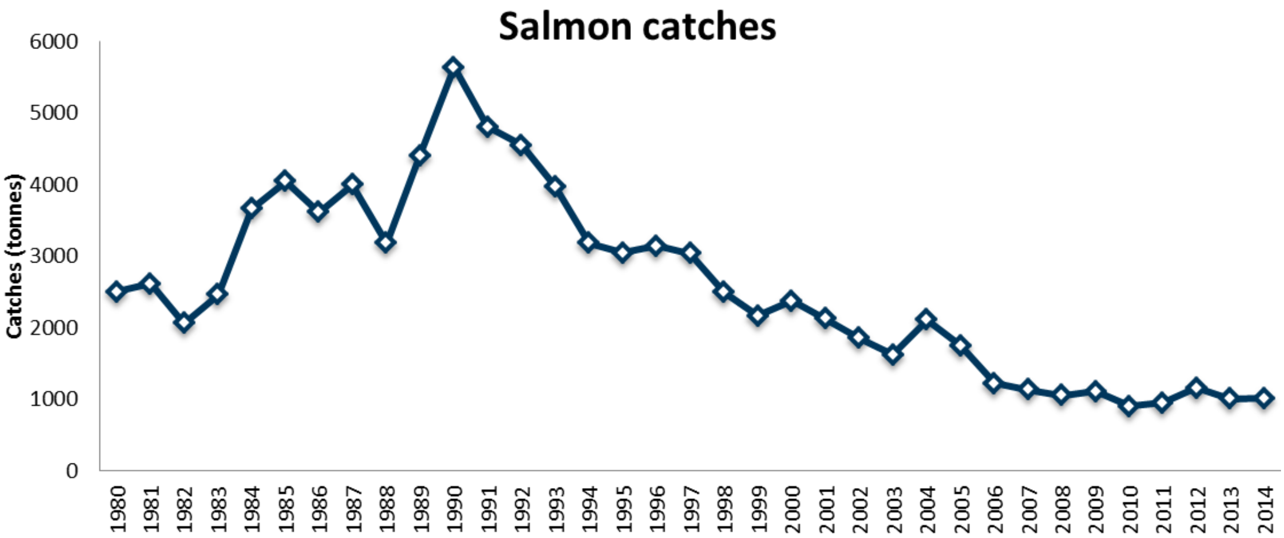


Figure 1. Sea catches of Baltic salmon. The figure is made on the basis of ICES 2015.

The driftnet ban in 2008 resulted in record low mortality in off-shore fisheries, however this low mortality was quickly compensated by the increase of long-line fishery until 2011. In 2012 there was a substantial decline in the long-line fishery and harvest rate has leveled off since then. Decline in the off shore fishing effort is partly a result of an act by Sweden and Finland to stop salmon fishing in the Main Basin from 2013 onwards and partly of improved fisheries control which has decreased the illegal fishing in the area. The coastal trapnet fishery declined from mid-1990s to mid-2000s, but has remained stable after that.

In 2014 ICES WGBAST estimated that the commercial fishery exploited 72% of the total allowable catch (TAC) in the Main basin and Gulf of Bothnia, but if estimated non-commercial catches, discards and unreported fishing are taken into account, the TAC was clearly exceeded (ICES 2015). In 2014 the total catch was 1020 tonnes (whole Baltic Sea), where 88% were landings, 5% discards, and 7% unreported catches. Recreational fisheries contributed 48% of the total nominal catch (sea and rivers). This equals to 161 401 individuals and when discards, misreporting and non-reporting estimates are added to the figure, a total of 191 500 individuals (range of the estimate 185 800-200 500) was caught in 2014.

Assessment protocol

Annually the monitoring data is collated from each river and processed so that updated estimates of smolt production and PSPC is obtained. The procedure for obtaining the PSPC is described e.g. in ICES 2015.

Assessment units and evaluation units

The Baltic salmon river stocks are divided into six evaluation units on the basis of biological and genetic characteristics of the stocks and associated management objectives (Figure 2, Table 1). Stocks of a particular evaluation unit assumedly exhibit similar migration patterns and are subjected to the same fisheries, experience the same exploitation rates and are affected by management in the same way. In addition, the genetic variability between stocks of an evaluation unit is smaller than the genetic variability between stocks of different units. Salmon is highly mobile species, migrating long distances to feeding areas in the southern Baltic Proper where also the main fishing pressure takes place.

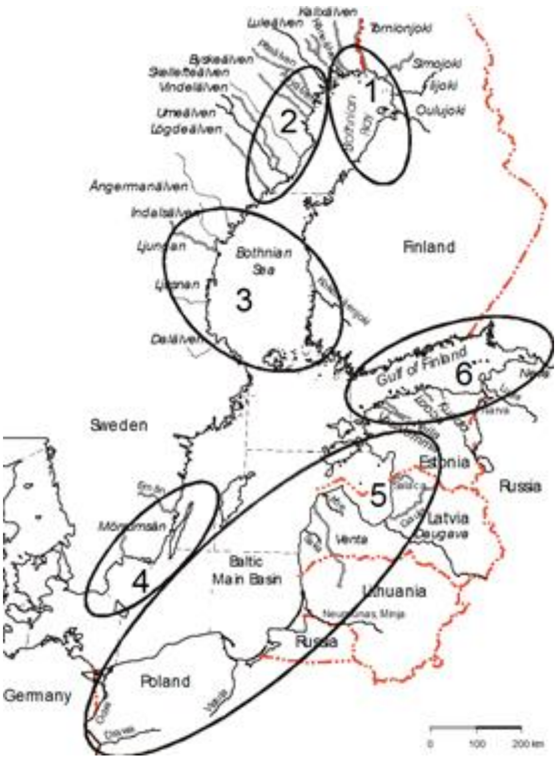


Figure 2. Evaluation units defined based on migration patterns and genetic structure of the salmon populations.

As the indicator mainly focusses on the spawning rivers and the spawning success, in this indicator an approach has been selected where the monitoring data from rivers is used in evaluating the sub-basins of the Baltic Sea, i.e. the HELCOM assessment units on scale 2.

Table 1. The wild salmon rivers in the assessment units in the Baltic Sea (ICES 2013).

Evaluation unit	HELCOM assessment units	Rivers included
1	Bothnian Bay	Simojoki (FI), Torniojoki/Torneälven (FI/SE), Kalixälven (SE), Råneälven (SE)
2	Bothnian Bay, The Quark	Piteälven (SE), Åbyälven (SE), Byskeälven (SE), Rickleån (SE), Sävarån (SE), Ume/Vindelälven (SE), Öreälven (SE), Lögdeälven (SE), Kågeaäven (SE)
3	Bothnian Sea	Ljungan (SE), Testeboån (SE)
4	Western Baltic Proper	Emån (SE), Mörrumsån (SE)
5	Gulf of Riga, Eastern Baltic Proper	Pärnu (EE), Salaca (LV), Vitrupe (LV), Peterupe (LV), Gauja (LV), Irbe (LV), Uzava (LV), Saka (LV), Barta/Bartuva (LV/LT), Zeimena (LT)
6	Gulf of Finland	Kunda (EE), Keila (EE), Vasalemma (EE)

Relevance of the indicator

Policy Relevance

The proposed core indicator of the Baltic salmon addresses the Baltic Sea Action Plan's Biodiversity and nature conservation Segment ecological objectives 'Thriving and balanced communities of plants and animals' and "Viable populations of species" (HELCOM 2007).

Also, the indicator has relevance to the BSAP actions of:

- 'Classification and inventorying of rivers with historic and existing migratory fish species no later than by 2012',
- 'Development of restoration plans (including restoration of spawning sites and migration routes) in suitable rivers to reinstate migratory fish species, by 2010', and
- 'Active conservation of at least ten endangered/threatened wild salmon river populations in the Baltic Sea region as well as the reintroduction of native Baltic Sea salmon in at least four potential salmon rivers by 2009'.

The proposed core indicator also addresses the following qualitative descriptors of the MSFD for determining good environmental status (Anon. 2008):

- Descriptor 1: 'Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions'; and

- Descriptor 3: 'Populations of commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock';

- Descriptor 4: 'All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity'.

and the following criteria of the Commission Decision (Anon. 2010):

- Criterion 1.1 (species distribution),
- Criterion 1.2 (population size),
- Criterion 1.3 (population condition, particularly the genetic structure)

- Criterion 1.5 (habitat extent),
- Criterion 3.1 (level of pressure of the fishing activity),
- Criterion 3.2 (reproductive capacity of the stock), and
- Criterion 4.3 (abundance/distribution of key trophic species).

The European Union is launching a multi-annual management plan for the Baltic Salmon, which is currently in the European Parliament. Salmon is listed as a species of community interest in the EU Habitats Directive (Annex II).

Role of salmon to the ecosystem

Salmon is uniquely adapted to utilize and link the low-productive, fast-flowing river habitat, which is a good environment for reproduction, with the pelagic sea habitat, which offers good conditions for fast growth due to the high abundance of prey species. The adult spawners ascend the spawning rivers after the feeding period and the number of smolts measured from the rivers reflect the abundance of the adult spawners and success of recruitment. Even though some of the anthropogenic pressures affecting the state of salmon populations occur in the rivers and not in the seas, it is very important to have a clear understanding of the state of the salmon populations in order to make informed assessments of the integrity of the food web.

Salmon is a long-distance migrating big predatory fish species that is a top-predatory fish in the Baltic Sea marine ecosystem next to cod. Adult salmon feed mainly in the pelagic areas of Baltic Main Basin and also to some extent in the Bothnian Sea. Adult salmon feed nearly exclusively on sprat and herring, in the south mainly sprat and towards the north increasingly on herring. Less frequently salmon feed also other species like sticklebacks, garpike and Mysis spp. Salmon does not cause a significant natural mortality to these stocks. Salmon compete for this food with cod being, however, a marginal rival since cod outnumbers salmon in terms of stock size. Being at the top of the food chain salmon accumulates harmful substances, i.e. various environmental toxins, which may have detrimental effects on their health. Salmon are frequent prey species of grey seals, especially in the Gulf of Bothnia. The increasing population of grey seals is likely to consume also more salmonids, which is expected to impact salmon and sea trout population principally in a similar manner as fishing.

Wild salmon populations spawned in at least 60 rivers in the middle of the 19th century, but today the majority of Baltic rivers are unsuitable for salmon due to damming, mainly for hydroelectric power production, as well as pollution. The environmental degradation has been partly compensated by smolts and parr releases. Due to these measures, the current 58 Baltic salmon rivers are divided into four main categories: wild stock (28 rivers), mixed stock (13 rivers), reared (partly or completely) (18 rivers) and potential rivers (HELCOM 2011, ICES 2015). The salmon wild river stocks differ genetically from each other and therefore their well-being is of high importance from population genetics point of view.

Rivers have been ranked for conservation purposes according to the actual production in relation to the potential production (PSPC), so that the populations with the lowest ratio belong to the red list and with the highest ratio to the green list (see more about the criteria and classification in HELCOM SALAR Report, HELCOM 2011) (Figure 3). Blue rivers represent potential- or historical salmon rivers that either have ongoing reintroduction programs or occasional reproduction by wild salmon (Figure 3). Most of the potential rivers show only low and irregular wild reproduction in spite even of large stocking programmes and other rebuilding efforts (ICES 2015).

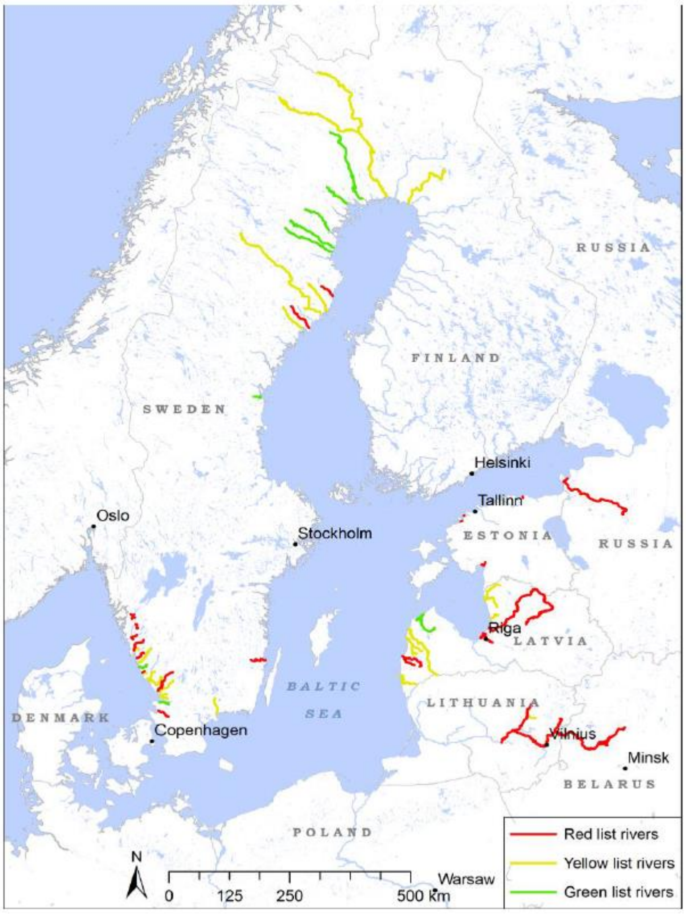


Figure 3. HELCOM SALAR lists salmon rivers according to their status (HELCOM 2011). Blue rivers are potential or historical salmon rivers.

Post-smolt survival

Several physiological, behavioral and environmental factors affect salmon smolt survival (McCormick et al 1998). Some of these are predation, feeding opportunities, smolt size and habitat conditions (marine and river environment) (Mäntyniemi et al. 2012; Saloniemi et al. 2004; Salminen et al. 1995; Russell et al. 2012).

When smolts enter the sea, they must have enough suitable food items along their migration paths and they must be able to avoid predation and by-catch in other fisheries in order to survive over the first critical year. Predation may occur during the downward river migration stage by other predatory fish or by birds (Jepsen et al. 1998) or at the sea by seals (HELCOM 2012; Mäntyniemi et al. 2012). Sufficient quantity and composition of the food items (herring and sprat being the main food items of salmon) is important at the sea (Karlsson et al. 1999; Mäntyniemi et al. 2012). A linkage between sea-surface temperatures and smolt survival has also been observed (Salminen et. al in 2008; Friedland et al. 2000). However, the factors affecting salmon smolt survival at sea are not yet fully understood and further research is needed (ICES 2012).

The post-smolt survival of salmon in the Baltic Sea has declined during the last 15 years, and has remained at very low levels since 2005 (Figure 4). The decreased post-smolt survival has been explained by predation from the growing seal population, environmental change and increased by-catch of salmon in pelagic trawling fisheries targeted on other species in the Baltic Sea (ICES 2013, Mäntyniemi et al. 2012). The post-smolt survival of the southern stocks in the evaluation units 4 and 5 is not well known.

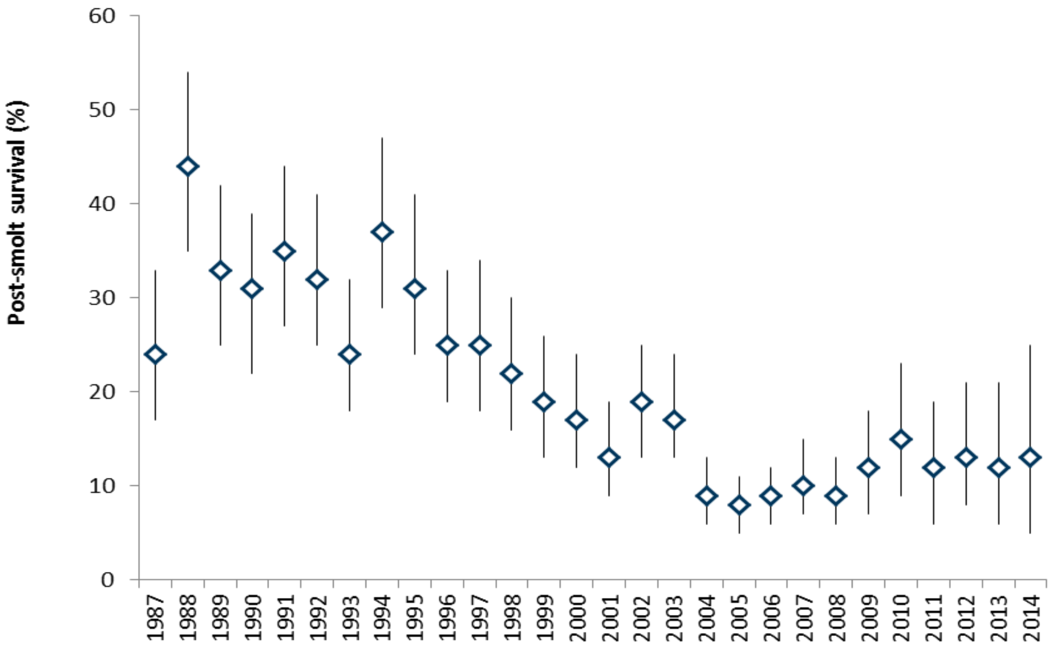


Figure 4. Post-smolt survival (%, 90 % CI) of the wild Baltic salmon stocks (modified from ICES 2015).

Factors affecting smolt production

The main factor affecting the smolt production is the number of adult spawners reproducing in the rivers. Hence, the indicator has a direct linkage to the number of fish and their size (i.e. the bigger females produce more offspring). Figure 5 shows the relationship between smolt production and adult spawners.

The M74 -syndrome, a reproduction disorder found in the sea-run Baltic salmon, caused major reductions in smolt production in the northern parts of the Baltic in the 1990s (the peak) after which the mortality decreased but increased again at the turn of the century. The M74 syndrome is being monitored in many Baltic Sea rivers on a yearly basis (Keinänen et al. 2008).

The smolt production capacity of salmon in rivers is restricted by space and by behavior. There is a maximum production level which is determined by physical, chemical and biological characteristics of the environment. River specific potential smolt production capacities (PSPC) have been estimated as a reference point in order to relate how much salmon currently utilize the capacity of the spawning habitat.

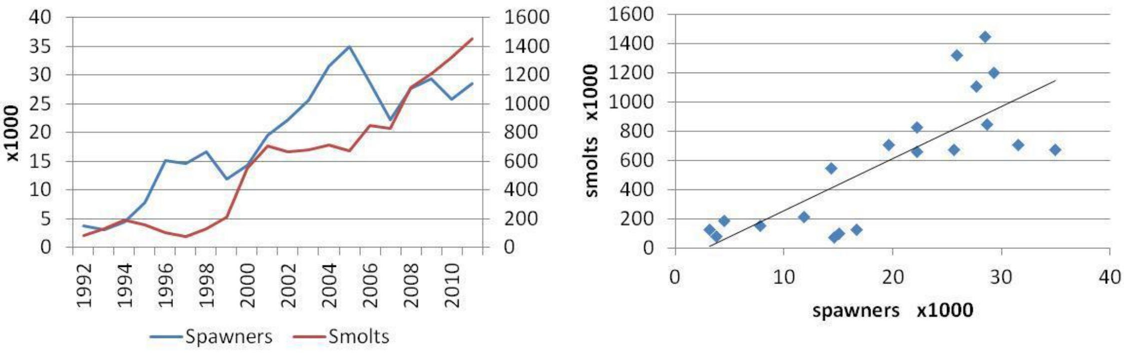
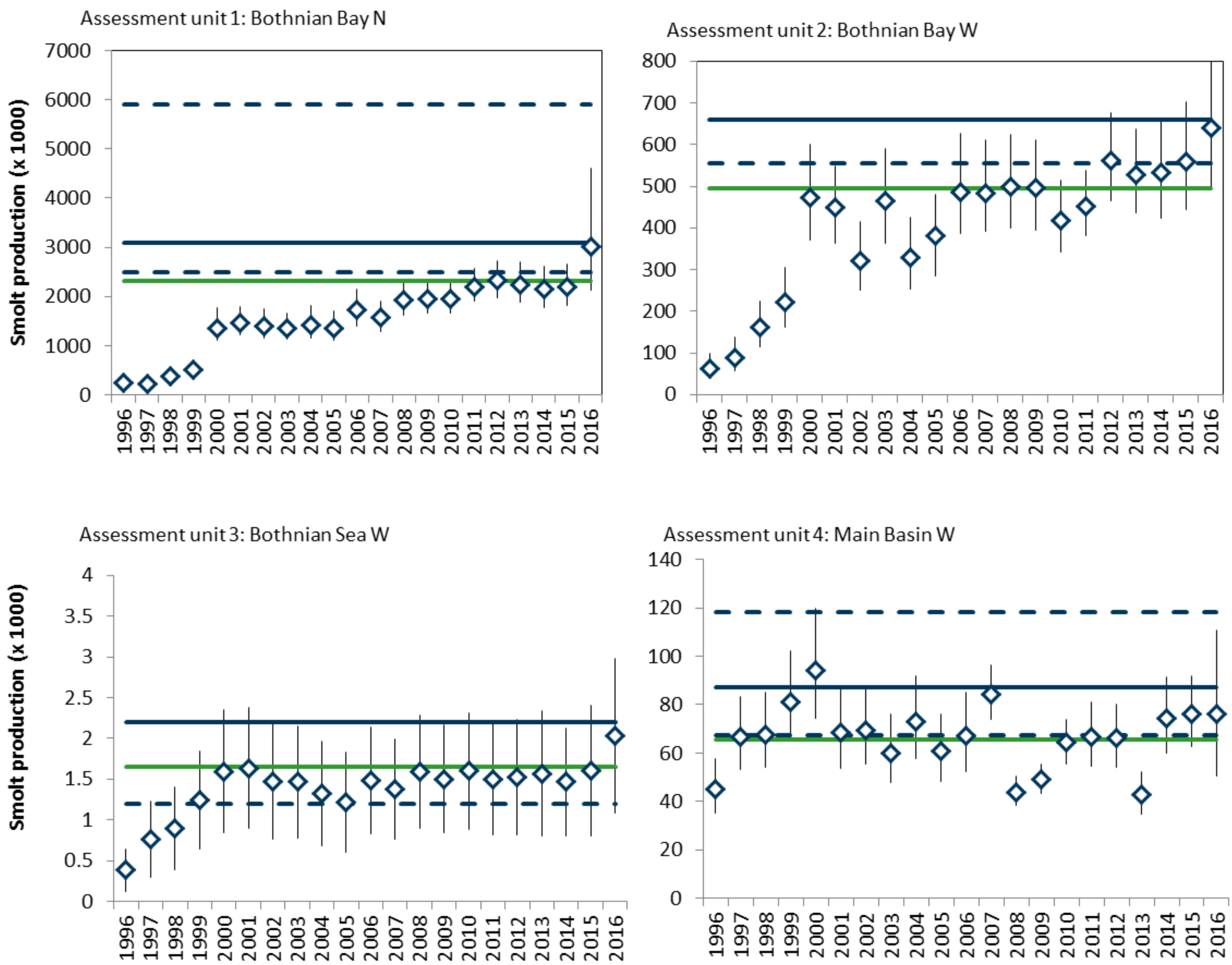


Figure 5. Relationship between the abundance of salmon smolts and adult spawners in a time series plot (A) and in a correlation plot (B). Figure based on ICES 2012.

Results and confidence

Current status of salmon stocks

Of the 41 assessed salmon river stocks only Kalixälven, Piteåälven and Byskeälven in the Bothnian Bay , Mörrumsån in the western Main Basin and Keila in the Gulf of Finland likely or very likely reached 75 % of the PSPC in 2014 and can be considered to be in good environmental status (GES). As a result of the strong smolt production in Kalixälven and Torneåälven in the northern Bothnian Bay, the entire evaluation unit 1 will very likely reach GES (Figure 6). Also the good smolt production in several rivers in the western Bothnian Bay supported the evaluation unit 2 to very likely reach GES.



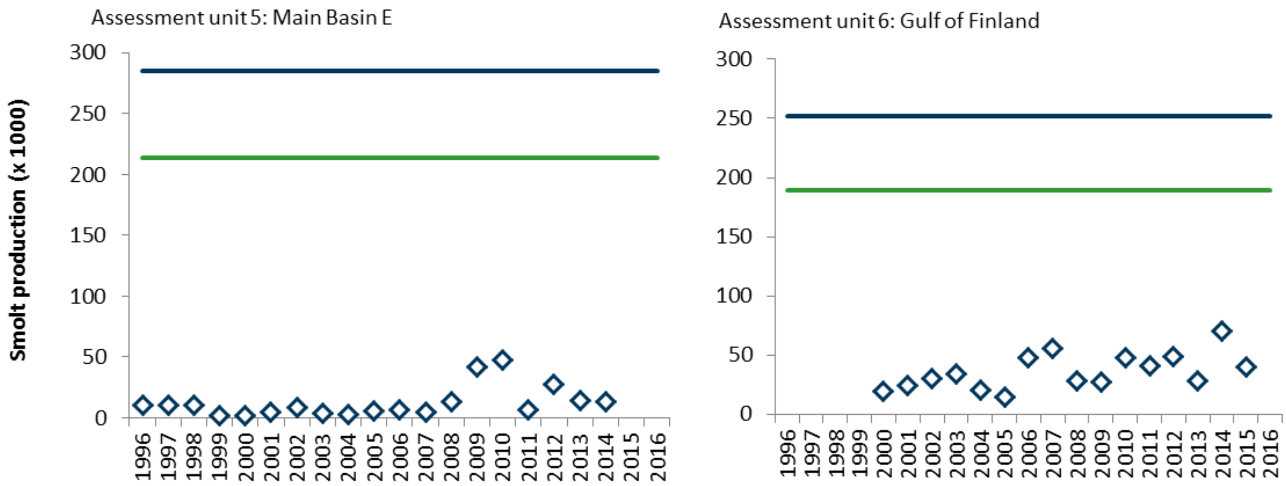


Figure 6. Status of salmon abundance in 1996–2016 (2015-2016 are model predictions), addressed by natural smolt production (median and 90 % PI), in the six evaluation units. The sixth evaluation unit (Gulf of Finland) was assessed without the model, based on field observations and expert judgment. The potential smolt production capacity (PSPC) is shown by the solid blue line (median) and the 90% probability interval of PSPC is shown by the dashed lines. GES boundary (green line) is 75% of the PSPC, presented here as the median of the probability distribution (for simplicity the 90% PI of the 75% target is not shown). Evaluation unit 5 do not have quantitative estimates for 2015 and evaluation unit 6 not for 2016. Figure modified from ICES 2015.

There are 13 rivers, mainly from the Gulf of Bothnia and Gulf of Finland, which are likely or very likely to reach 50% of the PSPC in 2014. For six rivers it is uncertain and for 17 rivers unlikely that they reached the 50% objective in 2014. Many of the rivers with weaker status are situated in the Baltic Proper and Gulf of Finland.

There are large differences in the rate of the smolt production between the salmon spawning stocks. The situation in the northern Baltic rivers has improved significantly and many stocks have, or almost have reached good environmental status, but most of the rivers in the southern Baltic are far from reaching their potential. However, the current overall production of nearly 3 million has increased six-fold from the 1996's when it was less than 500,000 smolts. The Gulf of Finland evaluation unit, which is considered as a separate evaluation unit, produced in 2014 in the Estonian, Finnish, and Russian rivers about 62,000 wild smolts (ICES 2015).

The exploitation of salmon has decreased in the Gulf of Bothnia, which at least partly explains the improved status. Also decreasing trend in M74 mortality has played a role. The number of ascending adult spawners – counted in some rivers only – shows that the increase in smolt production is a result of more abundant spawning stock (Figure 7).

In the evaluation unit 2 on the Swedish side of the Bothnian Bay, the smolt production is at a good level and the river Ljungan in the Bothnian Sea – the only salmon river with natural reproduction in the evaluation unit 3 – is close to GES and is expected to reach GES status in 2016.

The status in the southern parts of the Baltic (evaluation units 4 and 5) is a different story: the production is currently less than 30% of the potential smolt production capacity (Figure 6). The slow recovery of these stocks has been explained by overfishing, environmental problems (pollution and eutrophication) and increased predation (in the river). Also there is indication of increased poaching in some rivers.

Wild salmon stocks in the Gulf of Finland (three Estonian rivers, evaluation unit 6) show a clear recovery but the state of mixed stocks (releases and natural reproduction occur parallel) is mostly not good.

There is no single reason for the poor state of many of the wild salmon stocks. In the report of the ICES WGBAST, the following factors are discussed: overfishing, eutrophication or local pollution of a river, turbine mortality, poor fish ladders, hybridization with sea trout and stochastic events (ICES 2013). The likely reasons for the state of the southern stocks (evaluation units 4 and 5) are in the river quality, poaching and/or declined post-smolt survival.

The WGBAST report (ICES 2015) shows the development of parr densities in the salmon rivers and can be used to see the patterns behind the observed smolt production results.

Number of ascending adult spawners in the rivers of Bothnian Bay and the Quark

The number of ascending adult spawners is considered as a supporting parameter in the areas where monitoring data are available when evaluating GES compliance.

The number of adult spawners has been monitored in some rivers by fish counters. The numbers have increased since mid-1990s and a strong increase have taken place since 2012 (Figure 7). Older data from mid-1970s, shows that the increase in the numbers of spawners began to increase in the 1990s and 2000s, coinciding with the management measures at sea.

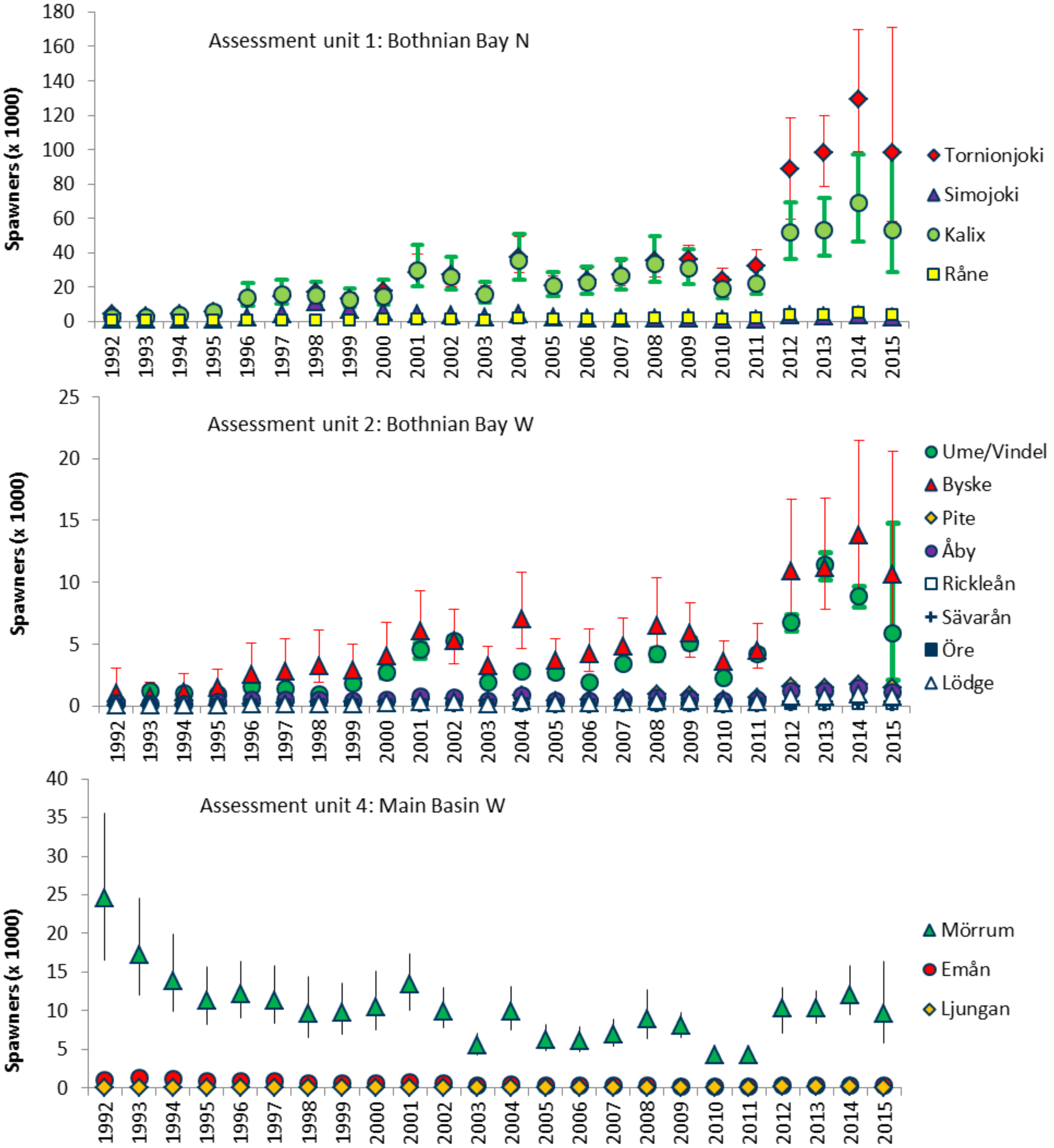


Figure 7. Number of wild salmon (median and 90 % PI) in fish ladders in rivers in assessment units 1-4 in 1992–2014. Figure modified from ICES 2015.

Confidence of indicator status evaluation

The estimation of the smolt production and PSPC is based on the assessment model for 16 wild salmon stocks and on the expert evaluation in 25 wild salmon rivers. The modelled stocks locate in the Gulf of Bothnia and in southern Sweden meanwhile the expert evaluated stocks located in the Baltic countries. The model based estimates are considered to give in most cases more accurate estimate on PCPS than expert evaluation and consequently there is a regional difference in the confidence of indicator.

Currently, few rivers in the Baltic Sea provide a full set of information (monitoring of spawning runs, smolt runs and river catches, and parr densities). This type of monitoring takes place only in Finland and Sweden. Apart of these so called index-river in all wild salmon rivers in the Baltic Sea area parr densities are followed by electrofishing surveys. In general the confidence of indicator status is higher in the Gulf of Bothnian rivers that in rivers in the Main Basin and Gulf of Finland.

Monitoring requirements

Monitoring methodology

Monitoring practices for salmon spawners and smolt are described on a general level in the HELCOM Monitroing Manual in the sub-programme: Migratory fish.

Specific guidelines are under development, with the aim to publish them in the manual during 2015.

Description of optimal monitoring

Establishing one index river in each management unit should be given a high priority. Currently, few rivers in the Baltic provide a full set of information (monitoring of spawning runs, smolt runs and river catches, and parr densities) required from index rivers. The collection of data concerning parr densities, smolt counts and number of spawners has high priority in these rivers. Electrofishing surveys in index rivers should preferably cover more sites than in non-index rivers, and should be distributed over all parr rearing habitats of different quality to give representative estimates. Tagging of smolts has also high priority.

Electrofishing surveys in non-index salmon rivers should be carried out, but it is not necessary to have annual surveys in every river. They could be carried out for instance every second or third year. A decision whether monitoring would be carried out in a particular year should by no means be influenced by expected changes in abundance of salmon. Smolt trapping may be carried out in a river for a couple of years and then moved along to another river. Monitoring in all non-index salmon rivers should be arranged so that each juvenile cohort is sampled at least once before smoltification.

Current monitoring

HELCOM Contracting Parties currently carrying out monitoring activities relevant to the indicator are described in the HELCOM Monitoring Manual in the Monitoring Concepts table.

Sub-programme: Migratory fish
Monitoring Concepts table

Description of data and up-dating

Metadata

The data on salmon smolt production, number of spawners and other data from national monitoring is brought by the CPs to the annual meeting of ICES Working Group for Baltic Sea Salmon and Sea Trout (WGBAST). The data is documented in the reports of the group and forms the basis on which the model for salmon smolt production is run by WGBAST. Currently there is no commonly agreed database where the data would be stored.

The stock data from Kattegat originated from HELCOM SALAR project (HELCOM 2011).

River surveys: parr density estimates, smolt trapping, monitoring of spawning runs and river catches;
Sea surveys: catch data, fishing effort data and catch composition estimates;
Joint river and sea surveys: tagging data (tagging in rivers, recaptures from sea and river fishery).

The table of river-monitored parameters per country e.g. in ICES (2015), page 159.

Contributors, archive and references

Contributors

Tapani Pakarinen, Antti Lappalainen, Wojciech Pelczarski, ICES Working Group for Baltic Salmon and Sea trout (WGBAST) and results of the HELCOM SALAR project.

Archive

2013 Indicator report

References

Anon. (2008): Directive 2008/56/EC of the European Parliament and the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union, L 164/19, 25.06.2008.

Anon. (2010): Commission decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (2010/477/EU). OJ L 232/14, 2.9.2010.

Friedland K.D., Hansen, L.P., Dunkley D.A., MacLean J. (2000). Linkage between ocean climate, post-smolt growth, and survival of Atlantic salmon (Salmo salar L.) in the North Sea area. ICES Journal of Marine Science, 57: 419–429. ICES Journal of Marine Science, 57: 419–429. Available online at: http://icesjms.oxfordjournals.org/content/57/2/419.full.pdf+html.

HELCOM (2007): Baltic Sea Action Plan. Available at: http://www.helcom.fi/Documents/Baltic%20sea%20action%20plan/BSAP_Final.pdf.

HELCOM (2011). Salmon and Sea Trout Populations and Rivers in the Baltic Sea - HELCOM assessment of salmon (Salmo salar) and sea trout (Salmo trutta) populations and habitats in rivers flowing to the Baltic Sea. Balt. Sea Environ. Proc. No. 126A.

HELCOM (2012). Development of a set of core indicators: Interim report of the HELCOM CORESET project. PART B. pp. 167-169.

ICES (2012). Report of the Baltic Salmon and Trout Assessment Working Group (WGBAST), 15–23 March 2012, Uppsala, Sweden. ICES 2012/ACOM: 08. 347 pp. Available at: http://www.ices.dk/reports/ACOM/2012/WGBAST/wgbast_final_2012.pdf.

ICES (2013) Report of the Baltic Salmon and Trout Assessment Working Group (WGBAST), 3–12 March 2013, Tallinn, Estonia. ICES CM 2013/ACOM:08 332 pp.

ICES (2015) Report of the Baltic Salmon and Trout Assessment Working Group (WGBAST), 23-31 March 2015, Rostock, Germany. ICES CM 2015/ACOM:08 362 pp.

Jepsen, N., Aarestrup, K., Økland, F., Rasmussen, G. (1998). Survival of radiotagged Atlantic salmon (Salmo salar L.) – and trout (Salmo trutta L.) smolts passing a reservoir during seaward migration. Hydrobiologia 371-372 (0): 347-353.

Karlsson, L., Ikonen, E., Mitans, A., Hansson, S (1999) The diet of salmon (Salmo salar) in the Baltic Sea and connections with the M74 Syndrome. Ambio 28 (1): 37-42.

Keinänen, M., Uddström, A., Mikkonen, J., Rytilahti, J., Juntunen, E.-P., Nikonen, S. & Vuorinen, P. J. (2008). Itämeren lohen M74-oireyhtymä: Suomen jokien seurantatulokset kevääseen 2007 saakka. Riista ja kalatalous – Selvityksiä 4/2008. 21 p. http://www.rktl.fi/www/uploads/pdf/uudet%20julkaisut/selvityksia_4_2008.pdf.

McCormick, S., Hansen, L., Quinn, T., Saunders R. (1998). Movement, migration, and smolting of Atlantic salmon (Salmo salar). Can. J. Fish. Aquat. Sci. 22 (Suppl. 1): 77-92.

Mäntyniemi, S., Romakkaniemi, A., Dannewitz, J., Palm, S., Pakarinen, T., Pulkkinen, H., Gårdmark, A., and Karlsson, O. (2012). Both predation and feeding opportunities may explain changes in survival of Baltic salmon post-smolts. – ICES Journal of Marine Science, 69 (9):1574-1579 doi: 10.1093/icesjms/fss088.

Russell, I., Aprahamian, M., Barry, J., Fiske, P., Ibbotson, A., Kennedy, R., Maclean, J., Moore, A., Otero, J., Potter T., Todd, C. (2012). The influence of the freshwater environment and the biological characteristics of Atlantic salmon smolts on their subsequent marine survival. ICES Journal of Marine Science, 69 (9): 1563-1573 doi:10.1093/icesjms/fsr208 .

Salminen, M., Kuikka, S., Erkamo, E. (1995). Annual variability in survival of sea-ranched Baltic salmon, Salmo salar L: significance of smolt size and marine conditions. Fisheries Management and Ecology 2 (3): 171-184.

Saloniemi, I., Jokikokko, E., Kallio-Nyberg, I., Jutila, E., Pasanen, P. (2004). Survival of reared and wild Atlantic salmon smolts: size matters more in bad years. ICES Journal of Marine Science, 61: 782-787.