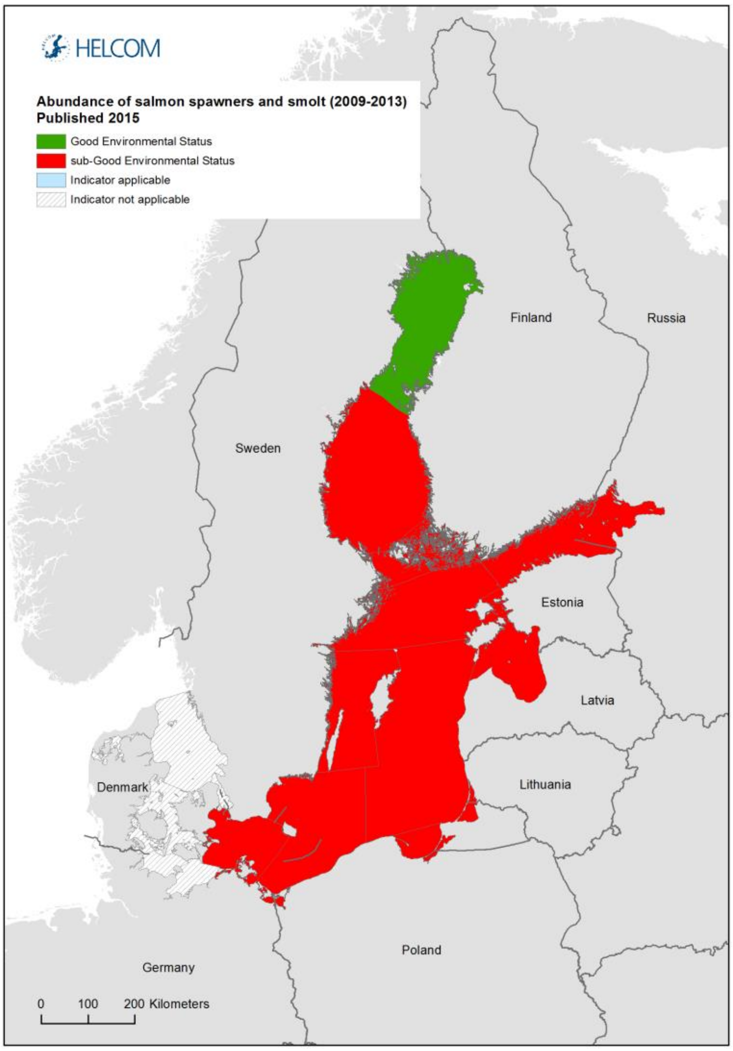
HELCOM core indicator report
October 2015

Abundance of salmon spawners and smolt

Key message

This indicator evaluates the status of the Baltic Sea area based on salmon smolt production in rivers flowing into the sea, also making use of additional supporting data on numbers of adult spawners. Determination of whether Good Environmental Status (GES) is reached is based on a comparison of estimated smolt production with an estimated potential smolt production capacity. The evaluation results presented are mainly based on data from 2014.



Key message figure 1: Status assessment results based evaluation of the indicator 'abundance of salmon spawners and smolt'. The assessment is carried out using Scale 2 HELCOM assessment units (detailed in the HELCOM Monitoring and Assessment Strategy Annex 4. Click to enlarge.

In the Bothnian Bay and The Quark areas, smolt production has increased in recent years due to higher numbers of adult spawners ascending the rivers as a result of stricter management measures. GES is achieved in three out of 15 rivers associated with these assessment units, and it is probable that it will be achieved in 1-3 more rivers within the next few years. In the Bothnian Sea area, smolt production is low although showing slight signs of increase. In the Gulf of Finland, smolt production is low but has recently shown signs of improvement 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 level of confidence of the evaluation is moderate.

The indicator is applicable in all the countries bordering the Baltic Sea, except Denmark and Germany.

Relevance of the core indicator

Salmon is a long-distance migratory large predatory fish species in the Baltic Sea marine ecosystem. Salmon abundance is mainly affected by commercial fishing at sea and by barriers in rivers to reproduction areas. This indicator 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 state of the ecosystem as smolt production is dependent on river connectivity (effect of dams) and the quality of spawning habitats.

Policy relevance of the core indicator

	BSAP Segment and Objectives	**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

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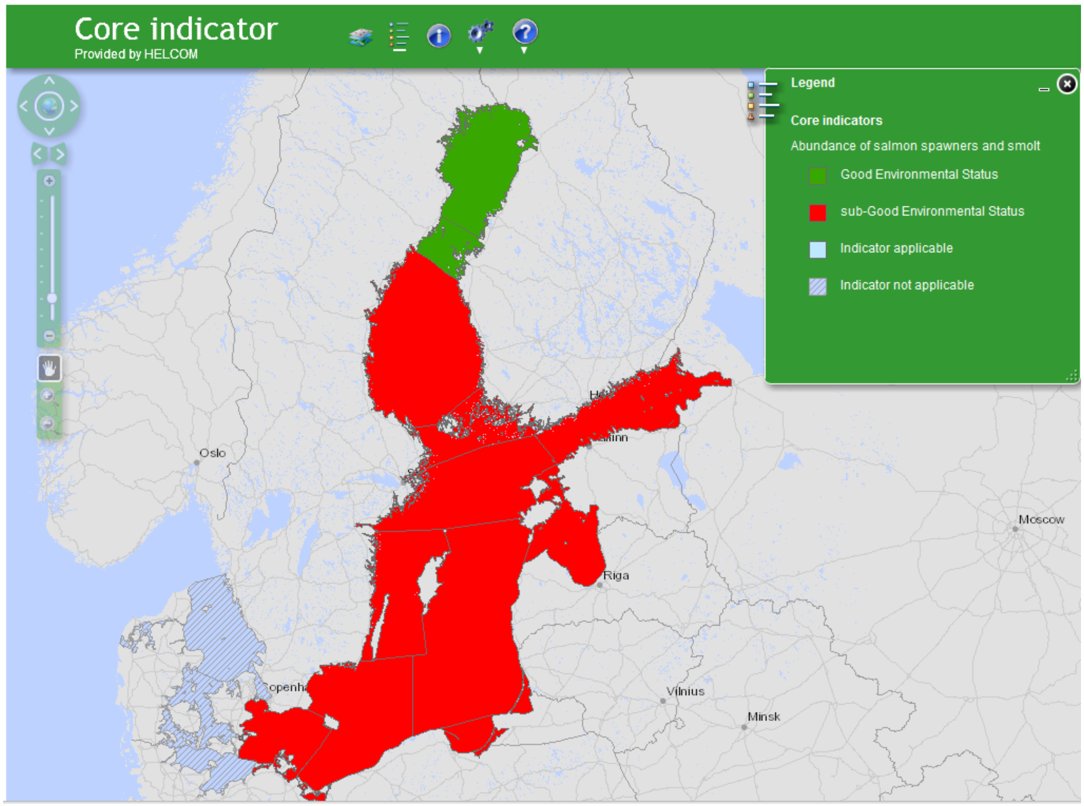
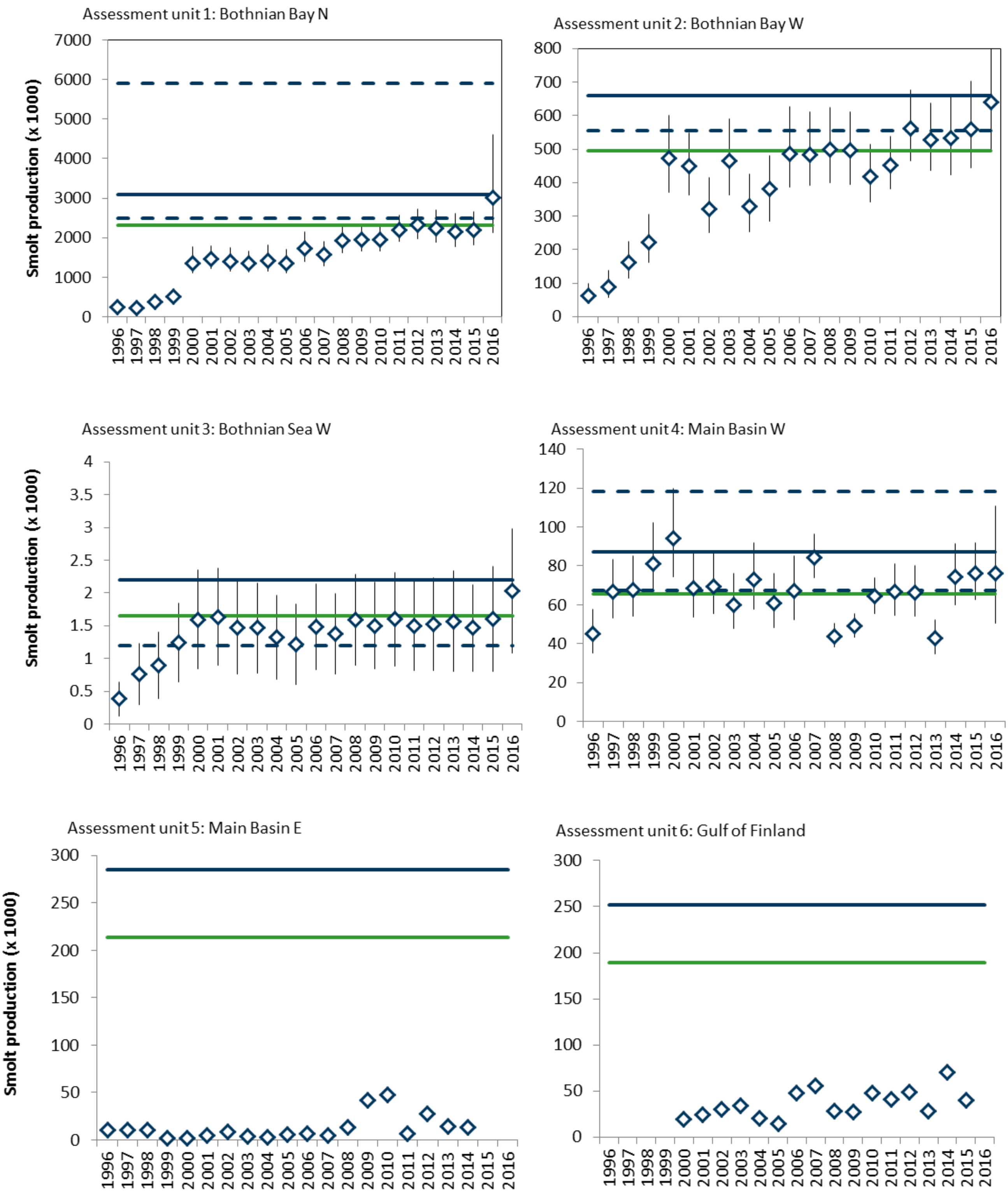
Results and confidence

Current status of salmon stocks

According to the current core indicator assessment good environmental status (GES) is achieved in the Bothnian Bay and The Quark areas, where smolt production has increased in recent years due to higher numbers of adult spawners ascending the rivers. In all other basins, the status of salmon spawners and smolt is sub-GES.



The status of 41 salmon stock rivers have been evaluated by the International Council for the Exploration of the Sea Assessment Working Group on Baltic Salmon and Trout (ICES WGBAST). The results presented here are conclusions from ICES 2015 and aggregated by ICES evaluation area as presented in the area-specific graphs in Results figure 1.



Results figure 1. Status of salmon abundance in 1996–2016 (2015-2016 are model predictions), addressed by natural smolt production (median and 90% PI), in the six assessment units. The sixth assessment 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). Assessment Unit 5 does not have quantitative estimates for 2015 and nor assessment unit 6 for 2016. Figure modified from ICES 2015.

Of the 41 assessed salmon river stocks, only Kalixälven, Piteåälven and Byskeälven in the Bothnian Bay, Mörrumsån in the Bornholm Basin and Keila in the Gulf of Finland likely, or very likely, reached 75% of the potential smolt production capacity (PSPC) in 2014 and can be considered to achieve GES. As a result of the strong smolt production in Kalixälven and Torneåälven in the northern Bothnian Bay, the entire evaluation area 1 (northern Bothnian Bay) will very likely reach GES (Results figure 1). Also, the good smolt production in several rivers in the western Bothnian Bay indicates that evaluation area 2 (western Bothnian Bay) is very likely reach to achieve GES.

Thirteen rivers, mainly in the Gulf of Bothnia and Gulf of Finland, are sub-GES but likely, or very likely, to have reached 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 achieved GES, but most of the rivers in the southern Baltic are far from reaching their potential. However, the current overall production of nearly 3 million smolts has increased six-fold since 1996 when it was less than 500,000 smolts. Estonian, Finnish, and Russian rivers in the Gulf of Finland evaluation area produced about 62,000 wild smolts in 2014.

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

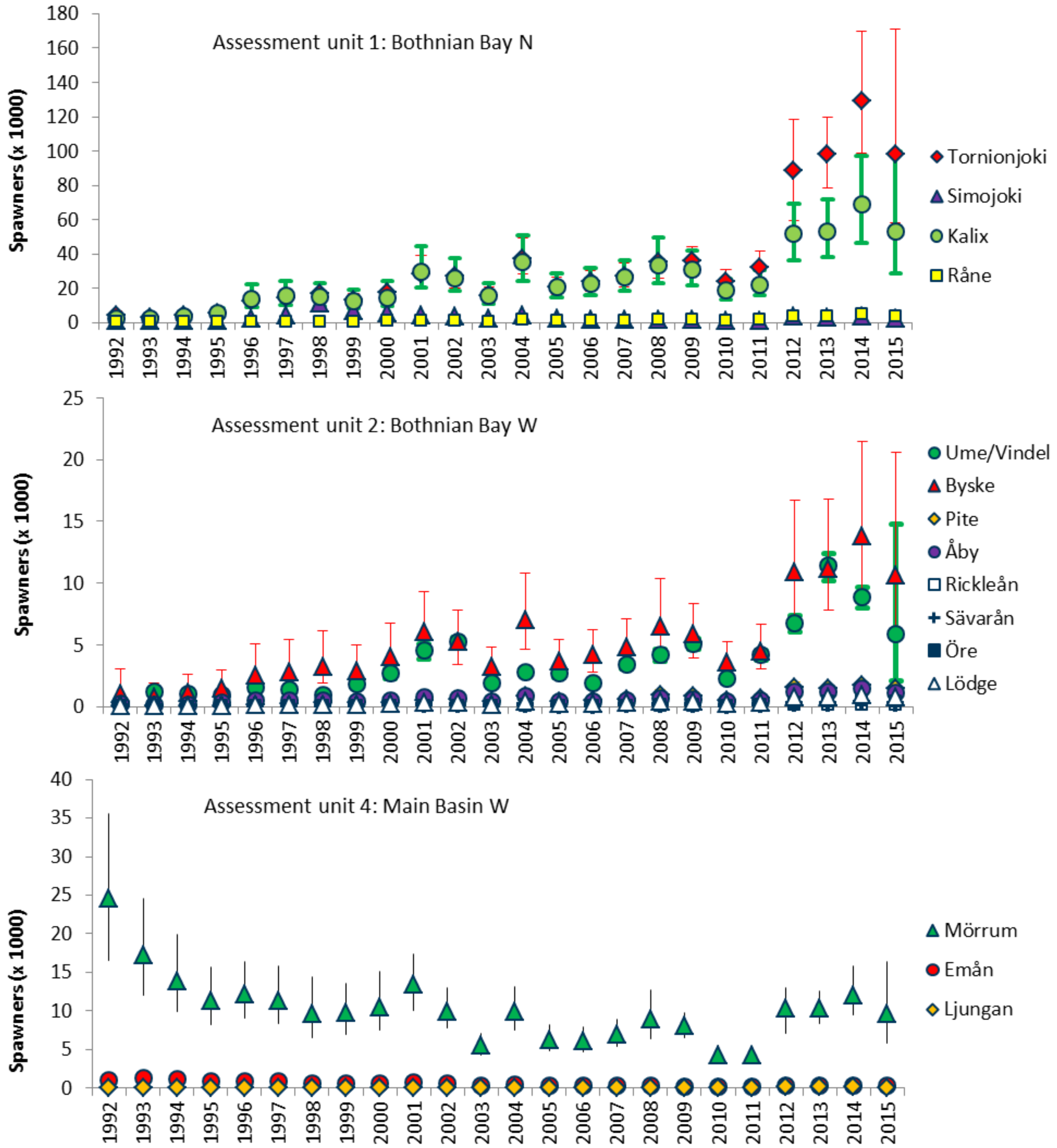
In the evaluation area 2 on the Swedish side of the Bothnian Bay, the smolt production is at a good level and achieved GES. The river Ljungan in the Bothnian Sea (the only salmon river with natural reproduction in the evaluation area 3) is close to GES and is expected to achieve GES in 2016.

The status in the southern parts of the Baltic Sea (evaluation areas 4 and 5) is a different story: the production is currently less than 30% of PSPC (Results figure 1). The slow recovery of these stocks has been explained by overfishing, river water quality (pollution and eutrophication) and increased predation (in rivers). Also there is indication of increased poaching in some rivers.

Wild salmon stocks in the Gulf of Finland (three Estonian rivers, evaluation area 6) show a clear recovery but the status of mixed stocks (releases and natural reproduction occurring in parallel) is mostly at a sub-GES level.

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

The number of ascending adult spawners is considered a supporting parameter for evaluating GES compliance in areas where monitoring data are available. The number of adult spawners has been monitored in some rivers using fish counters. The numbers have increased since the mid-1990s and a strong increase has taken place since 2012 (Results figure 2). Older data from the mid-1970s indicate that the number of spawners began to increase in the 1990s and 2000s, coinciding with management measures taken at sea.



Results figure 2.The number of wild salmon (median and 90% PI) in fish ladders in rivers in assessment units (evaluation areas) 1-4 during 1992–2014. Figure modified from ICES 2015.

Confidence of the indicator status evaluation

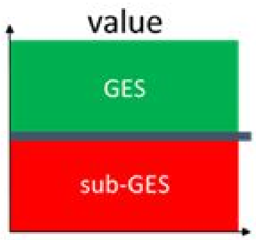
The estimation of smolt production and PSPC has been made using the assessment model for 16 wild salmon stocks and by expert evaluation in 25 wild salmon rivers. The modelled stocks are located in the Gulf of Bothnia and in southern Sweden whereas the expert evaluated stocks are located in the Baltic countries. In most cases the model based estimates are considered to give more accurate estimates of PSPC than expert evaluation and consequently there are regional differences in the confidence of indicator.

Currently, there is a full set of information (monitoring of spawning runs, smolt runs and river catches, and parr densities) only for a few rivers in the Baltic Sea, with this type of monitoring taking place only in Finland and Sweden. Apart of these so called index-rivers, parr densities are followed using electrofishing surveys in all wild salmon rivers in the Baltic Sea area.

In general, the confidence of indicator status is higher for rivers in the Gulf of Bothnian than in the Baltic Proper and Gulf of Finland.

Good environmental status

The assessment of environmental status is based on the smolt production in rivers with wild salmon stocks. The estimated smolt production is compared to an estimated potential smolt production capacity (PSPC) of rivers and the GES boundary is defined as 75% of the PSPC (see Good environmental status figure 1). This level of production compares to a stock size at maximum sustainable yield (MSY) practically for all stocks.



Good environmental status figure 1. 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.

The PSPC is estimated using a life history model developed by the International Council for the Exploration of the Sea Assessment Working Group on Baltic Salmon and Trout (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 a river as being below the GES boundary. Hence, when evaluating the status of an assessment unit that includes several rivers, a one-out-all-out approach is considered unsuitable and a weighted evaluation is applied instead.

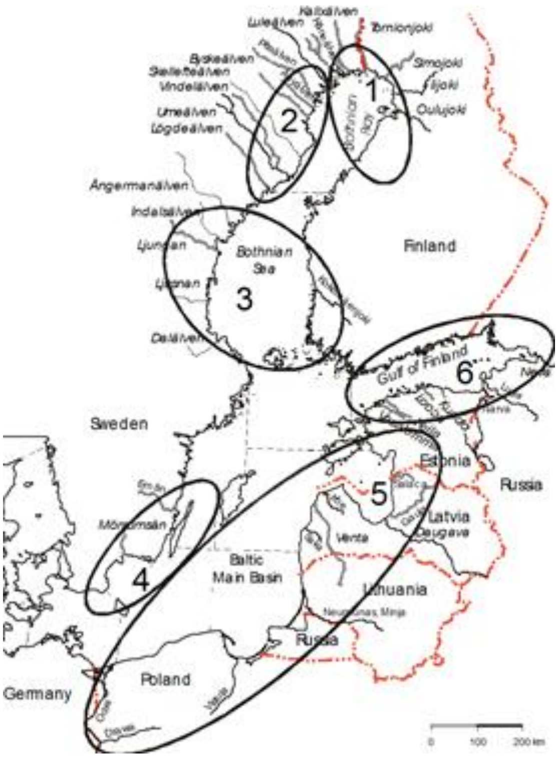
The adult spawners ascend the spawning rivers after the feeding period and the number of smolts (estimated based on the measured parr densities or smolt counts from the rivers) reflect the abundance of the adult spawners and the success of recruitment. The number of adult spawners is used as a supporting 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 be noticeable, with a shorter time lag, in the number of spawners compared to the smolt production capacity, and thus any significant changes in trend are to be considered as early warning signals.

Mainly due to the use of the model and good availability of data from several areas, the confidence of the accuracy of the GES boundary is considered to be moderate to high.

Assessment protocol

Monitoring data from each river are annually collated and processed so that updated estimates of smolt production and potential smolt production capacity (PSPC) are obtained. The procedure for obtaining the PSPC is described e.g. in ICES 2015.

The Baltic salmon river stocks are divided into six evaluation areas based on the biological and genetic characteristics of the stocks and associated management objectives (see Assessment protocol figure 1). Stocks of a particular evaluation area are assumed to exhibit similar migration patterns and to be subjected to the same fisheries, experience the same exploitation rates and be affected by management in the same ways. In addition, the genetic variability between stocks of an evaluation area is smaller than the genetic variability between stocks of different areas.



Assessment protocol figure 1. The evaluation areas defined based on migration patterns and genetic structure of the salmon populations.

Assessment units and evaluation areas

This indicator mainly focusses on the spawning rivers and the spawning success of the adult fish returning from feeding migrations in the open sea areas. Due to the wide ranging feeding migrations of the adult fish, an approach has been selected where the monitoring data from rivers are used to evaluate status at the Baltic Sea sub-basins level, i.e. the HELCOM assessment unit scale 2. The assessment units are defined in the HELCOM Monitoring and Assessment Strategy Annex 4.

Assessment protocol table 1. Wild salmon rivers included in the ICES evaluation areas and HELCOM assessment units by Baltic Sea sub-basin (ICES 2013).

Evaluation area	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

Biodiversity assessment

The status of biodiversity is assessed using several core indicators. Each indicator focuses on one important aspect of the complex issue. In addition to providing an indicator-based evaluation of the abundance of salmon spawners and smolt, this indicator will also contribute to the next overall biodiversity assessment to be completed in 2018, along with the other biodiversity core indicators.

Policy relevance

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

The core indicator has relevance to the following specific BSAP actions:

- '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 core indicator also addresses the following qualitative descriptors of the MSFD for determining good environmental status (European Commission 2010):

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'

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)
- 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 in the ecosystem

Salmon is a long-distance migrating big predatory fish species that is a top-predatory fish in the Baltic Sea marine ecosystem, and hence has an important role in regulating food webs and contributing to maintaining the general balance of ecosystems. Adult salmon mainly feed in the pelagic areas of Baltic Proper and also to some extent in the Bothnian Sea. Adult salmon feed nearly exclusively on sprat and herring, in the south mainly on sprat and towards the north increasingly on herring. Less frequently, salmon feed also on other species such as sticklebacks, garpike and mysids. Salmon does not cause a significant natural mortality to these stocks. Although salmon compete for these food resources with cod, it is a marginal rival since cod outnumbers salmon in terms of stock size.

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 the success of recruitment. It is important to have a clear understanding of the status of the salmon populations in order to make informed assessments of the integrity of the food web.

Salmon play an important role in maintaining the balance in riverine food webs, both by harvesting invertebrate populations and also serving as an important food source for other predatory species (ICES 2015).

Human pressures linked to the indicator

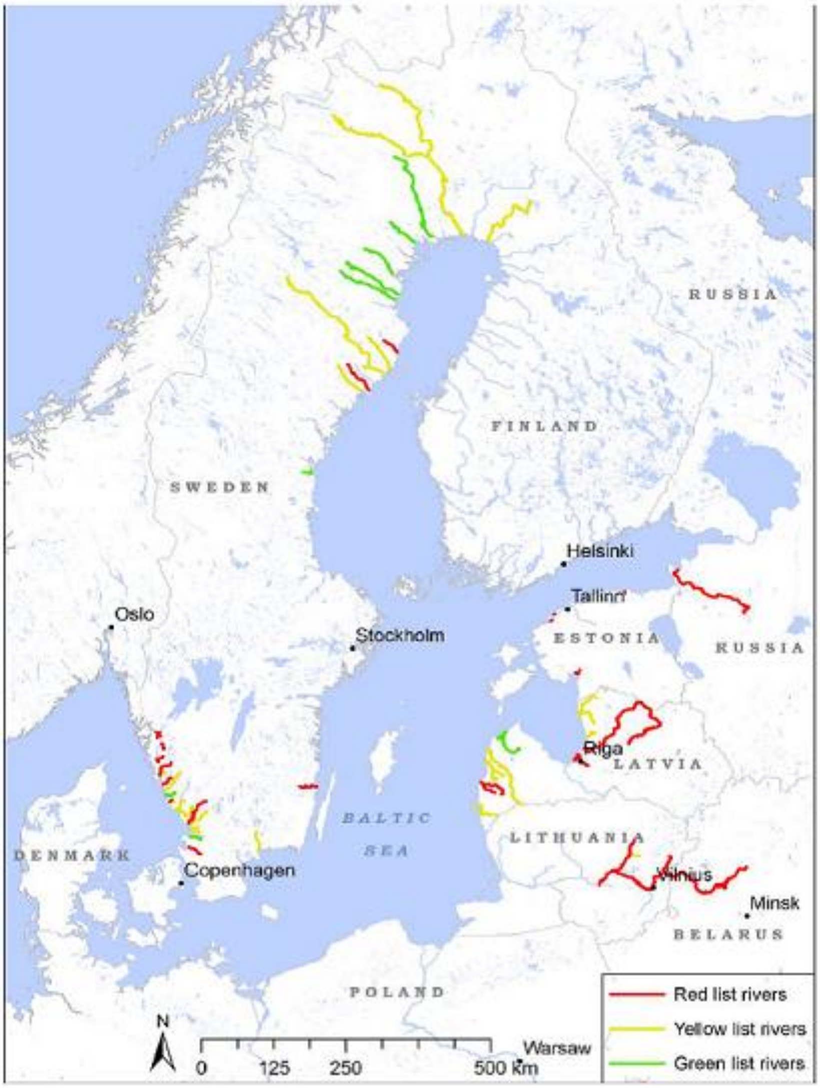
	General	MSFD Annex III, Table 2
Strong link	Fishing of salmon as well as habitat quality degradation are the main pressures on salmon	Biological disturbance -selective extraction of species
Weak link	There might also be effects of hazardous substances on the health of salmon	Potentially also: Contamination 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 by barriers to reproduction areas and natural causes. It is not possible to determine which human activities give rise to unsustainable levels of pressures on the salmon populations in all cases. However, typical pressures include fishery (legal and poaching) in the rivers and river mouths, access to spawning grounds, the quality of the river habitats and other factors such as 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: sufficient quantity and quality of spawning grounds, access to those areas (no barriers, such as dams, in rivers) and efficient river fisheries management. In rivers, the most detrimental activities to salmon have been damming, dredging and channelizing of 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 water quality of Baltic salmon rivers.

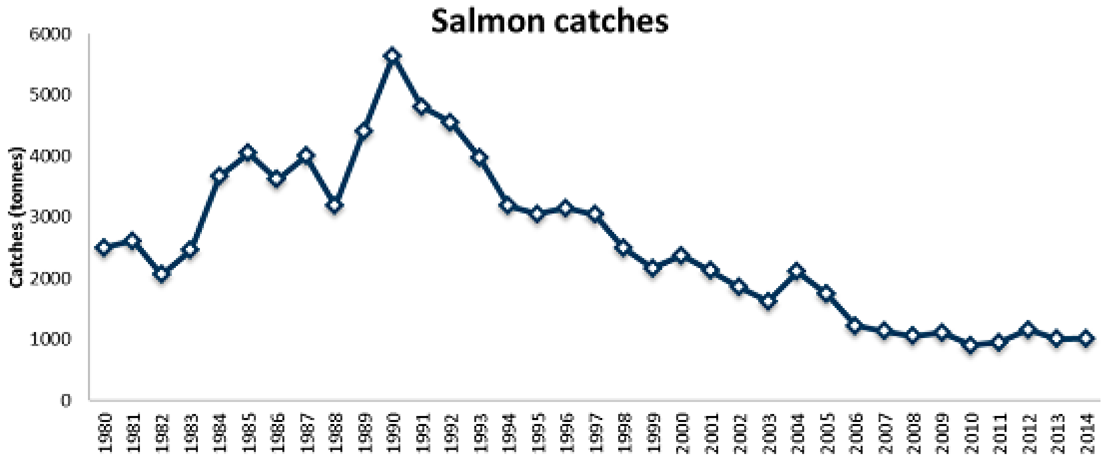
In the middle of the 19th century wild salmon populations spawned in at least 60 rivers. Today the majority of Baltic rivers are unsuitable for salmon, but environmental degradation has been partly compensated for by releases of smolts and parr. Due to these measures, the current 58 Baltic salmon rivers 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 wild salmon river stocks differ genetically from each other and therefore their well-being is of high importance from a population genetics point of view.

The salmon 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 those with the highest ratio to the green list (Relevance figure 1). For more information about the criteria and classification, see HELCOM 2011.



Relevance figure 1. HELCOM SALAR salmon rivers according to their status (HELCOM 2011).

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 river fishing has stayed at a rather stable level (Relevance figure 2).



Relevance figure 2. Sea catches of Baltic salmon. Based on ICES 2015.

The ban on driftnets in 2008 resulted in record low mortality in offshore fisheries, however, this low mortality was quickly compensated for by the increase of long-line fishery until 2011. In 2012 there was a substantial decline in long-line fishery and the harvest rate has since levelled off. Decline in the offshore fishing effort is partly the result of an act by Sweden and Finland to stop salmon fishing in the Baltic Proper from 2013 onwards and partly due to improved fisheries control which has decreased illegal fishing in the area. The coastal trapnet fishery declined from mid-1990s to mid-2000s, but has remained stable after that. For more information about fishing pressure on salmon, see ICES 2015.

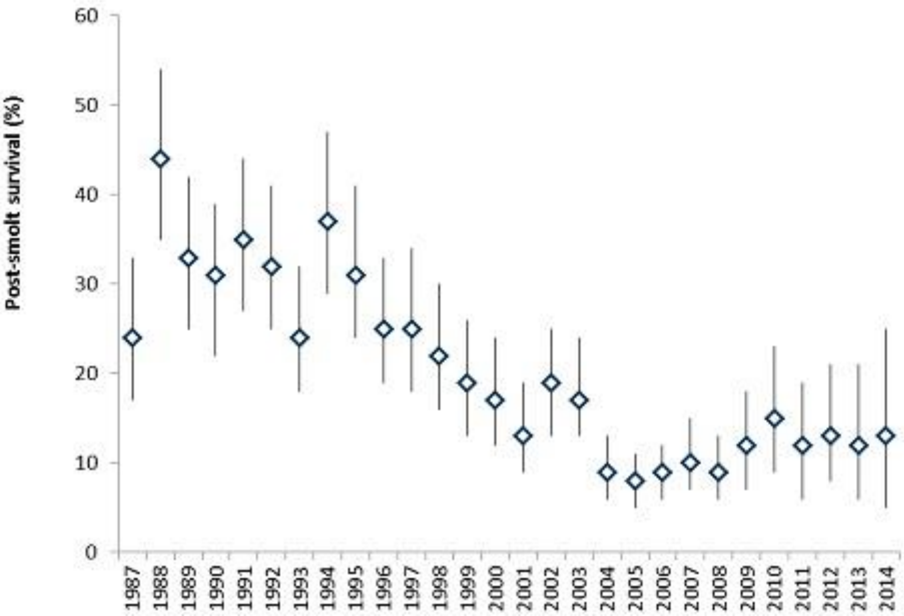
Being at the top of the food chain, salmon accumulates harmful substances, i.e. various environmental toxins, which may have detrimental effects on their health.

Salmon are also 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 populations in a manner similar to fishing.

Post-smolt survival

Several physiological, behavioural and environmental factors affect salmon smolt survival (McCormick et al. 1998), including predation, feeding opportunities, smolt size and habitat conditions (Mäntyniemi et al. 2012; Saloniemi et al. 2004; Salminen et al. 1995; Russell et al. 2012). When smolts enter the sea, they need enough suitable food along their migration paths and 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 sea by seals (HELCOM 2012; Mäntyniemi et al. 2012). Sufficient quantity and composition of the food items at the sea (mainly herring and sprat) is also important (Karlsson et al. 1999; Mäntyniemi et al. 2012). A linkage between sea surface temperatures and smolt survival has also been observed (Salminen et. al 2008; Friedland et al. 2000). The factors affecting salmon smolt survival at sea are not yet fully understood and further research is needed (ICES 2012).

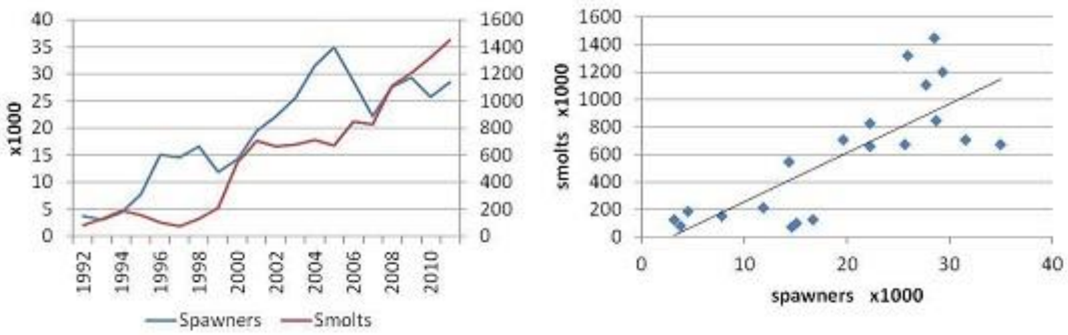
The post-smolt survival of salmon in the Baltic Sea has declined during the last 15 years, and has remained at very low levels since 2005 (Relevance figure 3). The decreased post-smolt survival has been explained by predation from the growing seal population, environmental change and increased by-catch 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 evaluation areas 4 and 5 is not well known.



Relevance figure 3. Post-smolt survival (%, 90% CI) of the wild Baltic salmon stocks. Modified from ICES 2015.

Factors affecting smolt production

The main factors affecting smolt production are the number and size (i.e. bigger females produce more offspring) of adult spawners reproducing in the rivers (Relevance figure 4). The smolt production capacity in rivers is restricted by space and behaviour; there being a maximum production level which is determined by the physical, chemical and biological characteristics of the environment.



Relevance figure 4. The relationship between the abundance of salmon smolts and adult spawners in a time series plot (A) and in a correlation plot (B). Based on ICES 2012.

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.

Monitoring requirements

Monitoring methodology

Monitoring practices for salmon spawners and smolt are described on a general level in the

HELCOM Monitoring Manual in the sub-programme: Migratory fish.

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

Current monitoring

The monitoring activities relevant to the indicator that are currently carried out by HELCOM Contracting Parties are described in the HELCOM Monitoring Manual in the Monitoring Concepts table.

Sub-programme: Migratory fish
Monitoring Concepts table

Description of optimal monitoring

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

Electrofishing surveys should be carried out also in non-index salmon rivers, but it is not necessary for surveys to be carried out annually in every river - it would suffice with surveys carried out every second or third year for instance. The decision of whether monitoring should be carried out in a particular year should not 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 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.

Data and updating

Access and use

The data and resulting data products (tables, figures and maps) available on the indicator web pages can be used freely given that the source is cited. The indicator should be cited as following:

HELCOM (2015) Abundance of salmon spawners and smolt. HELCOM core indicator report. Online. [Date Viewed], [Web link]

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Metadata

The data on salmon smolt production, number of spawners and other data from national monitoring is brought by the national representatives to the annual meeting of the 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. There is currently no common database.

The stock data from Kattegat originates from the HELCOM SALAR project report (HELCOM 2011).

River surveys include: parr density estimates, smolt trapping, monitoring of spawning runs and river catches.

Sea surveys include: catch data, fishing effort data and catch composition estimates.

Joint river and sea surveys include: tagging data (tagging in rivers, recaptures from sea and river fishery).

A table of parameters monitored in rivers by country is included in ICES 2015 (page 159).

Contributors and references

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

Archive

This version of the HELCOM core indicator report was published in October 2015:
Core indicator report – web-based version October 2015 (pdf)

Extended core indicator report – outcome of CORESET II project (pdf)

Older versions of the indicator report are available:
2013 Indicator report

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