WORKSHOP ON BALTIC SALMON MANAGEMENT PLAN (WKBALTSALMP)

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Contents

i Executive summary

This report contains the output of the International Council for the Exploration of the Seas (ICES) workshop on evaluating a draft Baltic salmon management plan (WKBaltSalMP). The main aim was to provide scientifically based responses to a special request received from the European Commission (EC). The process included two meetings attended by scientific experts, national managers and stakeholder representatives.

As requested, information on river size and estimated potential productivity was compiled and updated following consultation with national experts within ICES WGBAST (Baltic Salmon and Trout Assessment Working Group). Existing and alternative reference points for assessment of stock status and fishing opportunities were also examined. The group concluded that the currently used targets (50% and 75% of the potential smolt production capacity, PSPC) are inconsistent with the overall objective in the draft plan of achieving maximum sustainable yield (MSY). As a precautionary reference point R_{lim} was evaluated, defined as the lowest level of smolt production from which the stock would be expected to recover to its specific MSY-level (R_{MSY}) in one salmon generation, if all fishing was completely closed.

Simulations developed specifically for the workshop allowed evaluation of requested recovery rates of individual wild salmon stocks under alternative commercial fishing scenarios. The simulations examined commercial harvest rates ranging from 0 to 0.9 (encompassing rates that gives maximum yield in the commercial sea fisheries, located between 0.2 and 0.3; Figure 5.1.1), with additional values examined below 0.1 to better illustrate impacts on less productive river stocks.

Neither the EC request nor the draft multiannual plan specify criteria for when (i.e. with what probability) a target has been reached. Therefore, stock-specific tables with simulation-based probabilities of smolt production being above alternative targets for each fishing scenario are presented. These analyses only included river stocks currently assessed analytically by ICES. For remaining stocks, such river specific probabilities could not be determined.

For river stocks not assessed analytically, correlative analyses between total estimated sea survival and recruitment over generations were performed. These results indicate that sea survival seem to play an important role in the development also for these stocks, similar to for those currently included in the ICES model.

A simplified stable-state population dynamics model was constructed to study trade-offs between mixed (sea) and stock-specific (river) fisheries in terms of achievable catches and proportions of stocks above/below reference points. This analysis illustrated that when the mixed fishery harvest rate is low all river stocks can achieve MSY, whereas when this harvest rate increases, smaller (less resilient) stocks fall below this target. That some smaller stocks fall below MSY (or even goes towards extinction) does not make a noticeable difference to the total yield. Hence, there exists an inbuilt conflict between overall production aims and protection of weak stocks that can only be resolved if mixed-stock sea fisheries for Baltic salmon are kept at a low level.

The report also contains requested comments on the draft management plan. The workshop identified that the draft has a strict focus on commercial sea fisheries, although the relative importance of recreational fisheries for Baltic salmon has increased significantly over time. The current two management units for EU commercial fisheries (subdivisions 22 to 31 and Subdivision 32) are further maintained in the draft, whereas evidence has accumulated that salmon are migrating between these areas more than previously recognized. The draft finally does not address management of hatchery-reared Baltic salmon more than marginally, despite large ongoing releases for various purposes in most countries.

ii Expert group information

Expert group name	**Workshop on Evaluating the Draft Baltic Salmon Management Plan (WKBaltSalMP)**
Expert group cycle	Annual
Year cycle started	2029
Reporting year in cycle	1/1
Chairs	Stefan Palm, Sweden (ICES chair)
	Eskild Kirkegaard, Denmark (External chair)
Meeting venue(s) and dates	4–5 November 2019, Copenhagen, Denmark (20 participants)
	24–28 February 2020, Riga, Latvia (21 participants)

1 Introduction

This report summarizes the output of two workshops held by the International Council for the Exploration of the Seas (ICES) on evaluating a draft Baltic salmon management plan (WKBaltSalMP). The overall aim has been to provide scientifically based responses to special requests for advice received from the European Commission (EC; Annex 1). In brief, ICES has been requested to:

1. Provide information on river size and potential productivity of wild Baltic salmon stocks in rivers included in Annex I of the draft management plan (Annex 2);
2. Propose alternative options for stock productivity proxies and/or reference points;
3. Provide an analytical evaluation of the recovery rate of individual wild salmon stocks (ICES subdivisions 22–31) under alternative fishing scenarios, including an estimation of the number of salmon generations and years required to reach the targets under different F-values for commercial fisheries;
4. Propose candidate definitions for "MSYsalmon" in accordance with the ICES MSY approach;
5. Provide information on the likely impact that alternative time limits, with associated F-values, are expected to have on stock projections to achieve MSY-targets and future ICES advice on fishing possibilities.

Aim of the first meeting WKBaltSalMP I (4–5 November 2019, ICES Secretariat in Copenhagen, Denmark) was to scope efforts needed in order to evaluate the drafted management plan and to respond to the above EC specific requests. Twenty persons attended, including ICES experts, managers from Baltic Sea countries (BALTFISH) and stakeholder representatives (Annex 3). Based on presentations and discussions, the group produced a work plan for continued work that included a timeline and identified needs for intersessional work (Annex 4).

The second meeting WKBaltSalMP II took place 24–28 February 2020 at BIOR Fish Resources Research Department in Riga, Latvia. Thirteen experts attended, including one invited external reviewer. Most of the time at this meeting was devoted to discussions and planning of the final reporting and advice. However, during one afternoon (February 26th) results were presented and discussed with manager and stakeholder representatives (eight additional persons participating).

The report begins with some background on Baltic salmon biology, fisheries, and present management (Section 2), followed by information requested on size and productivity of wild salmon rivers (Section 3). Next chapter (Section 4) briefly describes current targets used to assess stock status and provides information responding to the request on alternative reference points. In Section 5, a set of "management strategy simulations" have been used as basis for responding to the specific requests on stock recovery and time limits. In Section 6 general comments received from the group on the draft management plan are listed, followed by additional topics raised during the workshop meetings on alternative options for the future management of Baltic salmon and data needs (Section 7).

Included as annexes are copies of the full EC request (Annex 1) and the draft management plan (Annex 2), technical details on methods used (Annex 5) and a complete set of river-specific tables with simulation results (Annex 6).

1.1 Terms of Reference

2018/2/FRSG55 The **Workshop on Evaluating the Draft Baltic Salmon Management Plan** (WKBaltSalMP I) will meet in Copenhagen, Denmark, on 4–5 November 2019, chaired by ICES Chair Stefan Palm (Sweden) and External Chair Eskild Kirkegaard (Denmark) and attended by invited external expert, Carrie Holt (Canada), to scope what efforts are needed in order to evaluate the draft of a multiannual management plan for the salmon stocks in the Baltic Sea proposed by BALTFISH.

The first workshop should address the following Terms of Reference:

ToR a) Clarify the essential factors in the draft management plan upon which basis ICES will give advice. This should include principal discussions regarding:

i. Use of the current MSY proxy versus river-specific MSYs as management targets;
ii. "Adequate time lines" for stocks to achieve management targets, including whether biological reference points (PSPC) and estimates of current smolt production should be based on the most recent year or an average of several years;
iii. Probability levels of attaining management targets.

ToR b) If required following on the discussions under ToR a), identify potential modifications to the proposed management plan that would improve its effectiveness.

ToR c) Produce a clear plan and timeline for the work to be completed by WKBaltSalMP II (anticipated to take place early 2020).

The second workshop WKBaltSalMP II will take place in Riga, Latvia on 24–28 February 2020 to address the specific questions in the request from DGMARE. WKBaltSalMP will report to ACOM 15 April 2020.

Supporting information:

Priority	High
Scientific justification	The goal of this process is to evaluate certain aspects of the proposed multiannual plan for the Baltic salmon stock and the fisheries exploitnig it (COM(2011) 470 of 12 August 2011), which aims to restore and maintain stocks of salmon in the Baltic Sea to sustainable levels. This includes evaluating the appropriateness of management targets in alignment with the requirements of the Common Fisheries Policy adopted in 2013. This scoping workshop serves to clarify essential factors in the draft plan between managers and scientists, which will inform on the basis for which ICES gives advice for Baltic salmon.
Resource requirements	-
Participants	Experts from WGBAST; members of relevant management bodies (e.g. BALTFISH); scientific experts familiar with aspects of modeling, salmon assessment, and management issues.
Secretariat facilities	Secretariat support; meeting room at ICES HQ
Financial	-
Linkages to Advisory Committees	ACOM
Linkages to other committees or groups	WGBAST; WGDIAD; FRSG; ACOM.
Linkages to other organizations	-

1.2 ICES Code of Conduct

In 2018, ICES introduced a Code of Conduct that provides guidelines to its expert groups on identifying and handling actual, potential or perceived Conflicts of Interest. It further defines the standard for behaviours of experts contributing to ICES science. The aim is to safeguard the reputation of ICES as an impartial knowledge provider by ensuring the credibility, salience, legitimacy, transparency, and accountability in ICES work. Therefore, all contributors to ICES work are required to abide by the ICES Code of Conduct.

At the beginning of the two WKBaltSalMP meetings (Copenhagen 2019 and Riga 2020) the ICES Code of Conduct was raised. In particular, meeting attendants were requested to identify and disclose any actual, potential or perceived Conflict of Interest. After reflection, none identified a conflict of interest that challenged the scientific independence, integrity, and impartiality of ICES.

1.3 Participants

The following experts, managers and stakeholder representatives have participated in WKBaltSalMP (first and/or second meeting; see affiliations in Annex 3):

Name	Country (of institute)
Olga Adamenko	Latvia
Jānis Bajinskis	Latvia
Inese Bartule	Latvia
Orian Bondestam	Finland
Håkan Carlstrand	Sweden
Sally Clink	Denmark
Anne Cooper	Denmark
Johan Dannewitz	Sweden
Glenn Douglas	Sweden
Sonja Feldthaus	Denmark
Marianne Goffeng-Raakil	Sweden
Carrie Holt, Invited Expert	Canada
Thomas Johansson	Sweden
Martin Kesler	Estonia
Eskild Kirkegaard, Invited Expert/External Chair	Denmark
Heikki Lehtinen	Finland
Adam Lejk	Poland
Samu Mäntyniemi	Finland
David Miller	Denmark
Katarzyna Nadolna-Ałtyn	Poland
Matti Ovaska	Finland
Tapani Pakarinen	Finland
Stefan Palm	Sweden
Filip Podgorski	Poland
Henni Pulkkinen	Finland
Normunds Riekstins	Latvia
Atso Romakkaniemi	Finland
Didzis Ustups	Latvia

2 Background

This section contains summaries intended to provide a basic background on Baltic salmon biology, fisheries and the current management. More detailed descriptions (with references) can be found in annual reports by the Baltic Salmon and Trout Assessment Working Group within ICES (WGBAST) and the associated stock annex (e.g. ICES 2019a).

2.1 Baltic salmon biology

Baltic salmon belongs to the same biological species as salmon in the Atlantic (*Salmo salar*), but is often referred to as a separate subgroup or race, according to regional genetic differences (e.g. Verspoor *et al*., 2007; Bourret *et al*., 2013). Salmon exist in rivers around the Baltic Sea, with the largest and most productive ones being located in the northern part (Gulf of Bothnia).

Salmon are anadromous, i.e. they hatch in freshwater, spend 1–5 years in the river and additionally 1–4 years of fast growth at sea, followed by migration back to freshwater for spawning. Individuals from different rivers occur mixed in the Southern Baltic while feeding, but then become gradually segregated on their migration routes back to their natal rivers. Tagging studies have revealed that salmon rarely leaves the Baltic Sea during the feeding migration.

Because of precise homing to the place of birth, each river (and in some cases even tributary or river section) may have a genetically unique and demographically largely independent salmon population. Consequently, the species is characterized by a marked population structure with clear genetic differences existing both between different rivers and between groups of rivers at a larger geographical scale. Throughout this report, we use the term "river stock" for salmon belonging to a particular river, which in most cases also represents a genetically distinct population.

According to Säisä *et al*. (2005) three distinct genetic groups exist in the Baltic Sea, each of which consist of several river stocks: 1) Gulf of Bothnia populations, 2) populations in southern Sweden, and 3) eastern populations (Gulf of Finland and eastern Main Basin). These main population groups are assumed to mirror past post-glacial colonization events following the last ice retreat. Because of its pronounced genetic structure, salmon in the Baltic Sea should not be regarded as one single unit. Rather, stock assessment and fisheries management needs to be focused on rivers and restricted geographic areas ("assessment units"; see below). Likewise, conservation of biodiversity requires safeguarding genetic variation and integrity of local salmon populations.

To compensate for losses of salmon reproduction in rivers exploited for hydropower production, large releases of hatchery reared smolts have been ongoing for decades in the Baltic Sea area. Releases for other purposes are also carried out in certain rivers. See Section 6.5 for further information on stocking of salmon and a discussion of related genetic issues.

2.2 Stock definitions

Originally, some 80–120 salmon rivers existed around the Baltic Sea (e.g. Verspoor *et al*., 2007). ICES divide current Baltic salmon rivers into four main categories: those holding either wild, mixed or hatchery reared river stocks, and those with potential to hold (but which currently do not hold) a wild or mixed river stock (e.g. ICES 2008a; 2018a).

In brief, wild salmon rivers should be self-sustainable with no or limited releases of reared fish (see ICES, 2018a for details). Mixed rivers have some wild production but are subject to considerable stocking (note that in some larger river systems, currently defined as mixed, individual tributaries like Zeimena, Nemunas river basin, may hold wild populations). Reared rivers currently are entirely dependent on stocking. River stocks in potential rivers are currently not regarded as self-sustainable but may become so in future. At present, there are 27 wild, 14 mixed and 17 reared rivers. In addition, a relatively large number of potential salmon rivers exist, often with ongoing reintroduction programmes and/or occasional natural reproduction (ICES, 2019a).

2.3 Fisheries

The salmon fishery in the Baltic region is heterogeneous, including both commercial and recreational fisheries at sea and in rivers. The fishing for returning spawners in rivers has a very long history that goes back until when humans colonized the Baltic Sea area. Until the mid-20th century nets and weirs were used in many rivers throughout the area, and in some cases those gears were not phased out until in the mid-1990s.

The present river fisheries vary between regions and countries, depending on type of river (wild, reared, etc.), local fishing rules and traditions. The river fishery for wild salmon is entirely recreational and to a major part restricted to angling (rod and reel fishing). Different types of tackles are used, the most popular ones being fly and lures. Fishing is usually carried out from river banks or by wading, but in some larger rivers angling from boat is practiced too. In some cases, drifting gillnets, beach seines, and/or traditional dipnets are allowed at designated sites. Also in rivers with hatchery reared salmon recreational angling dominates, although commercial freshwater fisheries with trapnets exist in some cases.

Offshore sea fisheries mainly occur in the Southern Baltic Sea (Main Basin). Earlier, driftnets were important, but after a ban enforced in 2008 commercial offshore fisheries consist mainly of longlining. Today commercial offshore fisheries are limited to Denmark and Poland, whereas in previous decades several additional countries were involved. Since the 1990s, recreational trolling has also become an increasingly popular and common method in several countries for catching salmon in the offshore, especially in the Main Basin. Commercial coastal trapnetting of spawning migrating salmon is conducted mainly in Sweden and Finland. In Sweden some recreational fishermen also use trapnets, whereas in Finland recreational coastal gillnetting for salmon exists. Further descriptions of Baltic salmon sea fisheries and its development, with descriptions of gears used in different countries, can be found in ICES (2003) and ICES (2019, Stock annex).

As illustrated in Figure 2.3.1 total Baltic salmon catches have decreased significantly since the 1980s. This long-term development mainly reflects decreased commercial fishing effort caused by a combination of economic factors, high dioxin contents, and reduced fishing quotas to allow recovery of wild river stocks. In contrast the level of recreational salmon catches has remained more stable. As a consequence, the relative importance of recreational Baltic salmon fisheries in sea and rivers have increased over time; at present the recreational catches in sea and rivers account for close to 50% of the total removal (ICES, 2020).

The past driftnetting and ongoing longlining and trolling in the Main Basin represent true mixed-stock fisheries, as the catches include salmon from river stocks across the entire Baltic Sea area. Also coastal fisheries for spawning migrating salmon are targeting mixtures of river stocks, although with varying compositions depending on geographical location and time of the season (Whitlock *et al*., 2018). In contrast, salmon fisheries in rivers and at some restricted sea areas close to river mouths typically catches a single river stock, although local subpopulations with different genetic and phenotypic characteristics (e.g. migration timing) may occur within larger river systems. Mixed-stock sea fisheries of wild and reared salmon present particular threats to weak wild river stocks (i.e. that do not have a healthy status) as these stocks need a lower fishing mortality to allow recovery than do more healthy wild stocks.

It should be underlined that Baltic salmon fisheries occur sequentially, beginning with offshore sea fisheries for feeding salmon, followed by coastal fisheries for spawning migrating salmon and, finally, ending with fishing in rivers. Hence, the total cumulative fishing mortality may be high even though it is not high in any specific fishery. Moreover, fishing opportunities in freshwater largely depend on what has earlier been harvested in the sea, highlighting that sustainable salmon management requires coordinated planning and actions involving both the international (offshore/coast) and national (freshwater) level.

2.4 Present management

2.4.1 Assessment units

ICES has established six different assessment units (AUs) for Baltic salmon (Figure 2.4.1). The partition of wild, mixed and hatchery reared salmon rivers into assessment units is based on both biological characteristics and management considerations. River stocks of a particular unit are believed to exhibit similar migration patterns at sea, and it can be assumed that they are subjected to the same sea fisheries, experience the same exploitation rates and are commonly affected by the same management actions. In addition, the genetic variability between river stocks of an assessment unit is smaller than the genetic variability between river stocks of different units (see above).

The six assessment units of salmon in the Baltic Sea (Figure 2.4.1) consist of:

- AU 1: Northeastern Bothnian Bay river stocks, starting at Perhonjoki (Finland) up until Råneälven (Sweden).
- AU 2: Western Bothnian Bay river stocks, from Lögdeälven to Luleälven (Sweden).
- AU 3: Bothnian Sea river stocks, from Dalälven to Gideälven (Sweden) and from Paimionjoki to Kyrönjoki (Finland).
- AU 4: Western Main Basin river stocks, i.e. southeastern part of Sweden.
- AU 5: Eastern Main Basin river stocks, i.e. rivers in Estonia, Latvia and Lithuania.
- AU 6: Gulf of Finland river stocks, i.e. rivers in Estonia, Finland and Russia.

Although high current and potential levels of smolt production in AUs 1–3 are of particular importance for sustaining sea fisheries, southern salmon rivers (AUs 4–6) have significant conservation values as they represent a large proportion of the overall genetic variability in Baltic salmon. In the freshwater environment, salmon stocks also have important local values from ecological, recreational and economical perspectives.

2.4.2 TAC

In 1993, the former International Baltic Sea Fishery Commission (IBSFC) implemented the current TAC system for Baltic salmon fishery management that includes two separate management areas: Baltic Main Basin together with Gulf of Bothnia (ICES subdivisions 22–31) and Gulf of Finland (ICES Subdivision 32). The two salmon TACs annually agreed upon (Main Basin and Gulf of Bothnia, and Gulf of Finland) are divided between EC countries according to allocation keys (Table 2.4.1). There is no similar agreement on TACs between EC and the Russian federation. However, Russia currently has no specific salmon fishery in the Baltic Sea, and river fishing for salmon (or sea trout) is not allowed.

2.4.3 Catch advice

The two annual ICES advices to the EC on fishing opportunities regarding salmon in the Baltic Sea are based on assessed status for wild salmon stocks affected by sea fisheries in the respective areas, accounting for presence of hatchery reared salmon in catches. ICES evaluate present stock status and fishing opportunities with respect to prevailing river conditions (i.e. presence of migration obstacles and current habitat quality). Therefore, efforts made to allow recolonization of past production areas in rivers by removal of dams or construction of fish ways increases the assessed potential production capacity of a river, which in turn at least temporally decreases the evaluated stock status (calculated as current vs. potential smolt production). Low initial stock status is also expected in "new" wild rivers (i.e. following reclassification of previously potential or mixed rivers by ICES).

The current mix of healthy (mainly northern) and weak (mainly southern) river stocks (Section 4.1) poses a particular challenge when giving advice. So far there are no decided guidelines for how quickly weak salmon stocks should recover and what proportion of recovered stocks could be regarded as "acceptable" (until a certain time-period). As a result, any catch advice for mixed-stock sea fisheries is associated with trade-offs between time required to achieve management objectives, exploitation possibilities, and conservation aspects. The current management also includes trade-offs between commercial exploitation rates at sea (regulated by TAC) and fisheries in rivers (regulated at the national level), although no "allocation keys" exists for how the salmon resource should be divided among sea and freshwater interests.

The surplus currently produced by several strong river stocks could in theory be utilized to a higher extent if being increasingly stock specific (Section 6.4). However, under the current management system, TAC is set at a relatively low level to safeguard weaker salmon stocks, which prevents such local surpluses to be fully utilized by the sea fishery. In a similar way, there exists a surplus of hatchery reared salmon that cannot be fully utilized since these stocks are included in the TAC, and because commercial river fisheries targeting reared stocks in freshwater (not counted against the quota) are still uncommon.

Long-term decreases in harvest rates and fishing mortalities implies that natural processes, mainly post-smolt mortality and adult natural mortality, have become increasingly important in determining salmon stock development. Hence, to allow recovery of weak stocks, fisheries regulations in the sea may need to be supplemented by additional actions including fishery restrictions in estuaries and rivers, habitat restorations, and removal of physical barriers.

Table 2.4.1. Allocation of TAC between EC countries (Council regulation (EC) 2010/0247 (NLE)).

COUNTRY	ALLOCATION KEY (%)
Management area: Main Basin and Gulf of Bothnia (subdivisions 22–31):	
Estonia	2.0660
Denmark	20.3287
Finland	25.3485
Germany	2.2617
Latvia	12.9300
Lithuania	1.5200
Poland	6.1670
Sweden	27.4783
Russian Federation*	1.9000
Total	100
Management area: Gulf of Finland (Subdivision 32):	
Estonia	9.3000
Finland	81.4000
Russian Federation*	9.3000
Total	100

*** No agreed TAC.**

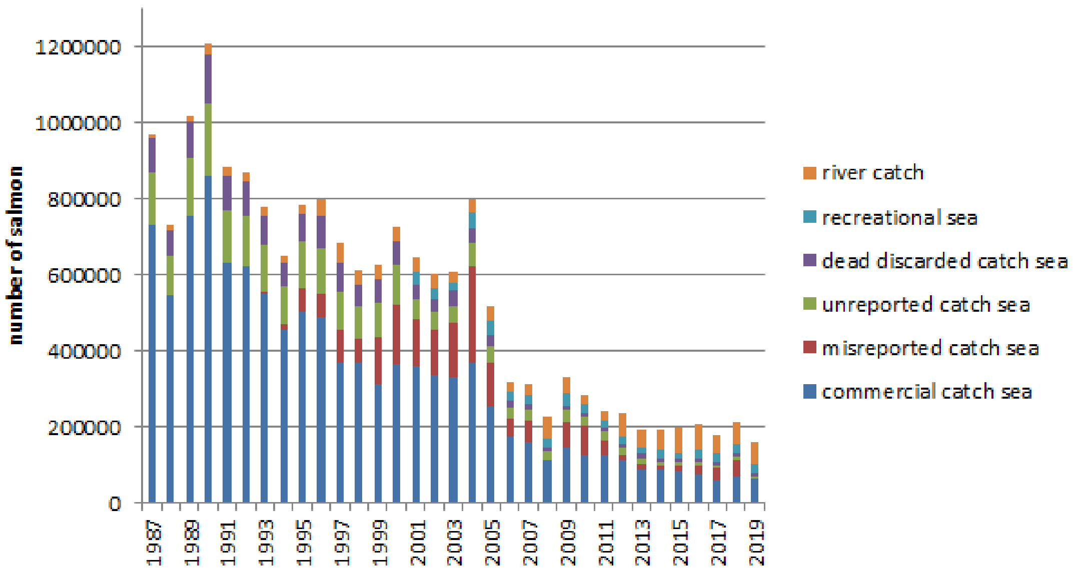


Figure 2.3.1. Share of commercial and recreational salmon catches at sea, river catches (including unreporting and commercial fishing), and discard/unreporting/misreporting of total sea catches in ICES subdivisions 22–31 in years 1987–2019 (from ICES, 2020).

Figure 2.4.1. Grouping of Baltic salmon river stocks in six assessment units. The genetic variability between river stocks of an assessment unit is smaller than the genetic variability between river stocks of different units. In addition, the river stocks of a particular unit exhibit similar migration patterns and harvest regimes. Accessible parts of salmon rivers marked with colours (wild = dark blue, mixed = light blue, reared = red).

3 River size and productivity

According to the EC request, ICES should "provide information on river size and potential productivity of wild stocks in the rivers included in Annex I". In response to this request, the Workshop decided to collect available information for the 29 listed rivers on their length, average water flow, estimated salmon habitat area and maximum smolt production capacity (ICES, 2017; 2019a). The selection of variables was thereafter discussed with national experts within WGBAST during the 2020 working group meeting, which resulted in some updates and additions of previously missing information. The information compiled is shown in Table 3.1.

Note that two of the rivers listed in the drafted multiannual management plan (MAP, Annex I) do currently have mixed status according to ICES. In river Pärnu (Estonia) large stocking activities are carried out to facilitate recolonization of production areas located above a recently removed dam. Therefore, Pärnu at present does not fulfill the ICES criteria for wild rivers (ICES, 2018a). Zeimena is a second order tributary in the Nemunas river basin (Lithuania). Because of stocking in several other tributaries, ICES has classified the entire Nemunas river basin as mixed, whereas single river tributaries have not been classified separately. Therefore ICES earlier recommended that the Zeimena tributary should be removed from Annex I in the MAP until further evidence was available to determine if it can be considered as a separate wild salmon river (ICES, 2018a).

Table 3.1. Size and productivity of salmon rivers listed in Annex I (draft MAP). River length (with part accessible for salmon) and average annual water flow from ICES (2017) with some updates, and estimates of available habitat and posterior potential smolt production capacities (PSPC's) from ICES (2019a; Table 4.2.3.3).

River	Country	Category (ICES)	AU (ICES)	Length, km (accessible)	Flow, m^3/s	Habitat, ha (90% range)	PSPC x 1000 (90% range)
Simojoki	Finland	Wild	1	175	45	252 (222-285)	61 (50-98)
Tornionjoki/ Torneälven	Finland/ Sweden	Wild	1	522	383	5409 (4282-6835)	1703 (1507-2044)
Kalixälven	Sweden	Wild	1	461 (323)	295	2604 (2124-3200)	641 (504-865)
Råneälven	Sweden	Wild	1	217	44	386 (332-449)	67 (42-125)
Piteälven	Sweden	Wild	2	402 (85)	168	576 (488-632)	27 (22-33)
Åbyälven	Sweden	Wild	2	175	15	86 (70-105)[1]	20 (12-46)
Byskeälven	Sweden	Wild	2	228	40	563 (482-659)	146 (102-246)
Kågeälven	Sweden	Wild	2	96 (34)	10	96 (67-139)	44 (27-72)
Rickleån	Sweden	Wild	2	147 (41)	16	31 (22-44)	11 (6-21)
Sävarån	Sweden	Wild	2	142 (75)	12	22 (14-36)	19 (9-58)
Ume/Vindelälven	Sweden	Wild	2	467 (453)	190	1768 (1394-2246)	236 (194-304)[2]
Öreälven	Sweden	Wild	2	240 (70)	34	107 (88-131)	47 (18-128)
Lögdeälven	Sweden	Wild	2	204 (100)	19	106 (86-131)	46 (13-155)
Ljungan	Sweden	Wild	3	399 (19)	138	20 (11-35)	1.9 (1-8)
Testeboån	Sweden	Wild	3	113 (21)	12	10	2.9 (2-5)[3]
Emån	Sweden	Wild	4	229 (45)	30	40 (30-49)	17 (8-33)
Mörrumsån	Sweden	Wild	4	186 (31)	28	56 (44-75)	42 (33-56)
Nemunas (Zeimena[4])	Lithuania	Mixed	5	80	27	15 (12-18)	12 (8-15)
Barta/Bartuva	Lithuania/Latvia	Wild	5	101 (49)	22	0.6	0.2
Salaca	Latvia	Wild	5	95	33	47	30
Vitrupe	Latvia	Wild	5	33	2	5	4
Peterupe	Latvia	Wild	5	42	2	5	5
Irbe	Latvia	Wild	5	32	17	0.2	0.1
Uzava	Latvia	Wild	5	56	6	0.6	0.2

River	Country	Cate-gory (ICES)	AU (ICES)	Length, km (ac-cessible)	Flow, m^3/s	Habitat, ha (90% range)	PSPC x 1000 (90% range)
Saka	Latvia	Wild	5	75	12	2.4	1
Pärnu[5]	Estonia	Mixed	5	144	49	50	30
Kunda	Estonia	Wild	6	82	4	1.9	2.1
Keila	Estonia	Wild	6	127	6	3.5	5.4
Vasalemma	Estonia	Wild	6	64	3.5	5	4

[1] Est. needs to be revisited; [2] Currently, reduced PSPC due to health-issues (ICES, 2019a); [3] PSPC likely underestimated (ICES, 2019a); [4] Flows into Neris (main tributary in mixed Nemunas basin); [5] Recently reclassified to mixed by ICES (2018a).

4 Reference points

4.1 Currently used reference points

In the Baltic Sea region, there is already a half-century long tradition of using smolt production as the main metric of abundance, productivity and status of salmon stocks (e.g. Lindroth, 1965). Focusing on smolts instead of e.g. spawners is at least partly explained by the fact that artificial rearing and stocking of salmon smolts was developed soon after the second world war, and for several decades stocking of smolts for sea fisheries (sea ranching) became the major tool for salmon management. Also, in the former IBSFC national smolt production statistics (especially reared but also wild) were used as part of the international negotiations about the share of sea fishing rights between the Baltic Sea countries, together with catch histories and other factors.

Estimating the potential productivity of salmon rivers in terms of their maximal smolt production became topical during the last century, when stocking hatchery-reared smolts was widely adopted as the means to compensate the lost wild salmon reproduction in rivers where dams were built up for hydropower production. Various methods were used to estimate this Potential Smolt Production Capacity (PSPC) (see review of the oldest method by Karlsson and Karlström, 1999). These original estimates were updated by expert elicitation in the early 2000s for many wild Swedish and Finnish rivers, as a result of which especially the PSPC's of the largest rivers became estimated larger than earlier (Uusitalo *et al.*, 2005; see Annex 5 for details).

Development of the Full Life History Model (FLHM) for the ICES assessment of Baltic Sea salmon in early 2000s generated river-specific time-series of spawner and smolt abundance estimates (Michielsens *et al.*, 2008). This further enabled Bayesian modelling of river-specific stock–recruit dynamics and consequently also updating the estimates of river specific PSPCs in AU 1–4 rivers (Annex 5).

During the years 1997–2010, the management of salmon in the Baltic Sea was covered by the IBSFC Salmon Action Plan (SAP). The objective of this plan was to re-establish/recover wild Baltic salmon to attain for each salmon river a natural smolt production of at least 50% of the river-specific (best estimate of) PSPC until 2010.

In 2008, the SAP was already obsolete relative to fishing, and the European Commission decided to develop options for a new SAP to address all life stages of salmon and all human impacts on salmon. EC requested ICES to provide scientific advice on management of Baltic Sea salmon including:

- Biological evaluation of SAP, especially asking why some smaller salmon populations did not respond on measures taken under the SAP;
- Provide a range of options (including objectives and measures) for the future management plan for salmon.

Based on the work of the expert group WKBALSAL (ICES, 2008a), ICES responded to the EC's request by stating, among other things, that the SAP has several key weaknesses and should not be continued in its current form. In particular, the current target of smolt production of 50% of its potential should be increased to at least 75%, if a goal of the plan was to recover salmon populations to the MSY level. According to analyses of WKBALSAL, the estimated production of smolt at MSY varied among rivers from about 60 to 80% of the potential smolt production, and an objective of recovering or maintaining smolt production at or above 75% of the potential smolt production was considered to approximately correspond to a management following the MSY-principle.

Since the termination of the SAP and in absence of any new management plan, ICES has annually been evaluating the probability to reach both 50% and 75% of the PSPC in each river stock. Reaching at least 50% of the PSPC thus serves as an extended follow-up of the main objective of the former SAP, while reaching at least 75% of the PSPC serves as a rough evaluation of attaining the MSY level. Because these both reference points are defined against river-specific PSPCs, the estimates of PSPCs form the basis of the reference points. However, there is a considerable amount of uncertainty associated to estimating PSPCs and annual updates of assessment have remarkably changed some of these estimates. The latest modelled estimates of AU 1–4 river-specific PSPCs (ICES, 2019a) are shown in Section 3 (Table 3.1), together with expert-based point estimates for rivers in AU 5–6 (currently without analytical assessment).

4.1.1 Present stock status

There is large variation in current stock status, both between single rivers and parts of the Baltic Sea area (assessment units). Using reference points and methods described in Annex 5, ICES performed its latest analytical assessment in 2019. Table 4.1.1 (copied from ICES, 2019a) contains the most recent estimates of stock status (probability to reach 50% or 75% of PSPC) in AU 1–4 wild Baltic salmon rivers, assessed as the 2018 smolt production compared with PSPC for the same smolt cohort. Included are also corresponding estimates for AU 5–6 wild and mixed salmon stocks, for which status is assessed by expert judgement.

Among the analytically assessed 17 wild (AU 1–4) stocks, the probability that smolt production reached 75% of PSPC (the current MSY proxy) in 2018 was above 50% for ten and above 70% for seven rivers (Table 4.1.1). The probability that smolt production reached 50% of PSPC was above 50% for 12 rivers and above 70% for ten rivers. Five of the rivers in AUs 1–4 did not reach 50% of PSPC with 50% probability in 2018. In AU 5, all seven wild stocks were uncertain or unlikely to have reached even the 50% target, whereas in AU 6, two of the wild rivers had reached 75% of PCPC and one remained below 50% (Table 4.1.1). As discussed further below, an alternative is to assess current stock status based on stock-specific smolt production levels at MSY (R_{MSY}). See Table 5.1.1 and Annex 6 for such estimates.

4.2 Alternative reference points

4.2.1 Assessment units 1–4

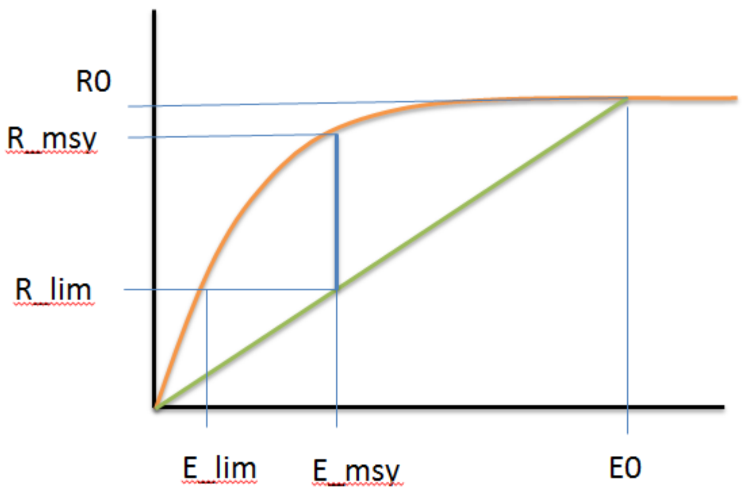
Salmon river stocks in AU 1–4 are included in the Full Life History Model (FLHM), which makes it possible to obtain quantitative estimates of reference points. In this section, we discuss alternative reference points that could be potentially used in Baltic salmon management. Technical details on how these reference points have been calculated are presented in Annex 5.

R_{MSY} is defined as the smolt production level which results from exploitation at the harvest level that leads to the maximum long-term yield. River stocks that are highly resilient to fishing produce their MSY at higher harvest rates than less resilient ones. If the mixed-fishery fishing pressure in the sea is adjusted to match the MSY level of resilient stocks, the smolt production in the less resilient river stocks falls below the MSY level. However, this does not necessarily mean that the stock would be endangered or that the fishing would not be sustainable (cf. Section 4.3).

R_0 is the expected long-term average smolt production if all fishing has been closed. This is also called potential smolt production capacity (PSPC). Estimates of river-specific R_{MSY} were first produced by WKBALSAL in 2008 (ICES, 2008a). However, following that workshop 75% of R_0 has been used by WGBAST as a proxy for R_{MSY} for all stocks (all AU:s), and the same proxy is also reiterated in the draft management plan.

In order to assess the status of stocks that are under the MSY level, other reference points could potentially be used. For example, 0.5×R_0, 0.75×R_{MSY} and 0.5×R_{MSY} could be used as minimum levels to be reached in case the MSY-level is deemed unrealistic (cf. discussion in Section 6.4). One such proposition is **R_{lim}** (Annex 5, Section A5.3), which is the smolt production level from which the smolt production would be expected to recover to R_{MSY} in one salmon generation, if fishing was completely closed (cf. Holt *et al.*, 2009).

The below figure illustrates R_{lim} and R_{MSY} with corresponding levels of egg deposition (E) in a hypothetical stock (Beverton–Holt stock–recruitment curve with straight replacement line) and a maximum smolt production under no fishing at R_0 (PSPC):



For highly resilient rivers (i.e. with steep stock–recruit curves) R_{lim} will be much below R_{MSY}, while for less resilient rivers with smaller recovery potential (less steep S–R curves) the difference is going to be smaller. R_{lim} has the potential to be used as a limit reference point, above which the population should reside with very high probability (e.g. 0.95). For example, a management plan could assert that all rives should have 95% probability to be above their R_{lim}, and the total long-term catch from all fisheries could be optimised within these limits.

To take account for uncertainties in the assessments consistent with the ICES precautionary approach, **R_{PA}** may thus be defined as the value of the estimated smolt production that ensures that true smolt production has less than 5% probability of being below R_{lim}.

As shown in Figure 4.2.1, R_{MSY}/R_0 varies considerably between rivers. For most rivers R_{MSY}/R_0 is lower than the current proxy target of 0.75×R_0. As expected, R_{lim}/R_0 is lower than R_{MSY}/R_0 and has a clear inverse pattern: when R_{MSY}/R_0 is high, R_{lim}/R_0 is low, and vice versa. The reason for the pattern is that both reference points depend on the resilience of the stock. Stocks highly resilient to fishing (with steep stock–recruit curves) have high R_{MSY}/R_0 ratios. They also recover quickly, which means that R_{lim}/R_0 can be low. Stocks less resilient to fishing react more linearly to the fishing pressure, which means that R_{MSY}/R_0 is lower. Those rivers also recover slower, which result in that R_{lim}/R_0 is not far below R_{MSY}/R_0. The river with lowest R_{MSY}/R_0 has the highest R_{lim}/R_0.

It should be noted, finally, that R_{MSY}, R_{lim} or R_{PA}, like other production related reference points, do not account for the absolute size or inherent production capacity of river stocks. Small biological populations generally experience higher extinction risks due to random demographic and genetic factors than larger ones (cf. Section 4.3).

4.2.2 Assessment units 5–6

Because of the lack of an analytic life-history model containing a loop over salmon generations, little is known about the reproduction dynamics for AU 5–6 river stocks and no stock–recruitment (S/R) curves have so far been established. Expert judgements based on various background information and limited data provides rough estimates of the stock specific PSPCs or R_0s (see Annex 5, Section A5.1). However, it is not known at what level stock-specific MSYs are reached in these AU:s (neither in absolute terms nor proportionally to PSPC).

For AU 6 (Gulf of Finland) stocks, a modified version of the FLHM has been under development since 2018 (ICES, 2018c; 2019a). Once the model will become operational, it should be possible to assess the stock–recruit dynamics with corresponding PSPC and reference points, similar to what has been done for the AU 1–4 stocks. There are, however, several complications to model stock dynamics of AU 6 stocks in a trustworthy manner.

Many Gulf of Finland rivers have various special characteristics (migration obstacles, straying of spawners, intensive stocking programmes, etc.) which are challenging to properly take into account in modelling (see further discussion below). Moreover, sea migration routes of AU 6 salmon are not fully known, but it appears that these stocks only partially share the same feeding grounds as AU 1–4 salmon. How large proportion of AU 6 salmon that becomes targeted by the offshore fishing in the Southern Baltic, and how this proportion varies among years, remain largely unknown issues.

The response of AU 5 river stocks on past changes in the sea fishing pressure may give rough indications on shapes of S/R curves in these stocks in relation to the corresponding curves among AU 1–4 stocks. Such an examination requires the assumptions that:

- AU 5 stocks are harvested similarly to AU 4 stocks, i.e. only by offshore fishing (Main Basin) and river fishing, and that the harvest rates in these fisheries are similar to the harvest rates of other stocks (e.g., no effective poaching takes place); and
- Post-smolt and adult natural mortalities of AU 5 stocks are similar to those of AU 4 stocks; and
- PSPC levels of the AU 5 stocks are higher than their current stock size (i.e. a positive development for these stocks is not prevented by them being already near their maximum achievable level of smolt production).

If these assumptions hold, the similar (non-positive) development of the southern AU 4 and 5 stocks over the past two decades (ICES, 2019a; b) may indicate that these stocks are similarly less productive (they have less steep S/R curves) than most northern stocks in AU 1–3. Less steep S/R curves would mean that the MSY levels in the AU 5 stocks are located well below 75% of PSPC, perhaps on the level of 60–70% of PSPC as estimated for Emån and Mörrumsån in AU 4 (Figure 4.2.1). Some AU 5 stocks may have MSY levels that are even a lower percentage of their respective PSPCs, especially those rivers where the present smolt abundance has been judged to be at a lower level (smaller percentages of their respective PSPCs) than among the AU 4 stocks. This holds, however, only if fishing mortality among AU 5 stocks is not higher than among AU 4 stocks.

Characteristic for most AU 5–6 stocks (and some AU 1–4 stocks) is that their freshwater environment has been heavily altered by human activities, and that these alterations vary notably between the rivers. Moreover, natural reproduction is widely supported by stocking programmes, resulting in a large proportion of the AU 5–6 rivers to fall under the category 'mixed' (Section 2.2).

In particular, dams with associated migration problems complicate both assessment and management. When migration obstacles are partial, they restrict free distribution of spawners and therefore not all habitats suitable for reproduction will be optimally utilised by spawners. Partial migration obstacles may also delay the migration and increase mortality of smolts. Still, the habitats above partial migration obstacles are utilised by the river stock and must therefore be considered in the estimation of PSPC and reference points (cf. Section 2.4). However, partial obstacles in practice decrease the productivity of the river, but the extent of the decrease is very difficult to assess and is obviously very case-specific (depending on how reproductive habitat of the whole river is distributed above below obstacle(s), how many obstacles exist, how much they restrict migrations, etc.). Ignoring effects of partial migration obstacles is expected to result in unrealistically high PSPC estimates, while considering only rivers sections with full connectivity to the sea may lead to gross underestimation of the river specific management target, at least in some cases. As an extreme example, all reproduction habitats in River Vindelälven are located above the (only) partial migration obstacle (a fish-ladder passed by an average of c. 30% of all ascending spawners, according to tagging studies in years with normal health conditions).

Habitat restoration is an increasingly common activity to improve reproduction possibilities of migratory fish species. These activities are diverse and their focus and methods depend much on the river in concern. One major activity is to improve connectivity by removing migration obstacles or building up fishways. If successful, these measures directly improve the reproduction possibilities of the salmon stock, and in such a situation it is important to re-evaluate the PSPC and the corresponding reference points. For instance, in the River Pärnu (Estonia, AU 5) a complete migration obstacle located close to the sea was recently removed (in 2019) which increased the available and suitable habitat for salmon reproduction by more than ten times. Also, smaller scale habitat restorations (e.g. in-channel modifications to improve the quality of spawning/rearing habitats) as well as alteration of flow regimes, improved purification of effluents, decreased siltation etc. may affect the productivity of the river so much that the productivity of the salmon stock may need to be reassessed.

A large majority of the deliberate changes made in salmon rivers nowadays seem to result in better reproduction possibilities, although one must also consider the possibility of alterations with negative effects. If or when a river is heavily altered and the PSPC and reference points are re-evaluated, good salmon management should include principles and guidelines especially on the timeline by which salmon stock would be expected to meet the generic management targets set for the Baltic Sea salmon stocks. For instance, it may take long time before a salmon stock redistribute for reproduction in a river after removal of major migration obstacles. The time needed for stock rebuilding would be even longer, if less radical changes are made (e.g. only improving fish passage through fishways). Need for any (re)stocking program should also be considered and its effects evaluated as a potential additional measure. Thus, there remains a need for river specific (or even AU specific) 'recovery plans' in the future management of Baltic Sea salmon, which holistically integrate management of environment and management of fisheries.

4.3 Production vs. conservation targets

The concept of maximum sustainable yield (MSY) that is applied to Baltic salmon and other commercially harvested fish species aims at producing long-term sustainable catches as large as possible. It should be stressed that MSY and related objectives (such as R_{lim}; Section 4.2) represent production oriented targets that do not explicitly account for conservation aspects such as intra-specific genetic diversity and random effects affecting small populations. Hence, when a stock is assessed to be below MSY, this does not mean that it is necessarily 'threatened' - a common misconception; it simply means that the stock cannot produce a sustainable catch of the same magnitude as the potential maximum.

For proper assessment of threat levels, additional biological factors have to be accounted for such as random loss of genetic variation and increased extinction risks due to demographic stochasticity. Minimum viable population sizes (MVPs) are frequently defined and evaluated within the field of conservation biology. A large number of risk assessments have also been applied to Pacific salmon stocks and to some extent Atlantic salmon (e.g. Nehlsen *et al*., 1991; Sweka and Wainwright, 2014). For Pacific salmon, minimum numbers of spawners associated with different extinction risks have also been suggested (e.g. Allendorf *et al*., 1997).

So far, no population viability analyses (PVAs) have been carried out for Baltic salmon, and until such analyses have been carried out it is unclear how MSY relates to various conservation targets. Still, it appears likely that numbers of spawners corresponding to MSY in larger Baltic salmon rivers are located above any minimum conservation target. As a comparison, Allendorf *et al*. (1997) suggested total population sizes per generation of 2500 and 250 spawners in Pacific salmon to be associated with a "high" and "very high" risk of extinction, respectively. For certain smaller river stocks in the Baltic Sea area, it is possible that future studies will conclude that higher targets than those stipulated by MSY may be needed to reduce local conservation risks. Besides demographic and genetic concerns associated with population persistence, evolutionary and ecological aspects related to life history diversity and the role of salmon in their local ecosystems may also have to be considered, as a complement to evaluations of relative production status.

Table 4.1.1. Overview of the status of the Baltic Sea wild and mixed-stocks in terms of their probability to reach 50 and 75% of the smolt production capacity in 2018 compared to PSPC in that year (table copied from ICES, 2019a). Stocks are considered very likely to have reached this objective in case the probability is higher than 90%. They are likely to have reached the objective if the probability is between 70 and 90%, uncertain when the probability is between 30 and 70% and unlikely if the probability is less than 30%. For the AU 1–4 stocks, the results are based on the assessment model, whilst the categorization of AU 5–6 stocks is based on expert judgments - for those rivers there are no precise probabilities (column 'Prob').

			Prob to reach 50%					Prob to reach 75%				
	Stock	Category	Prob	V.likely	Likely	Uncert.	Unlikely	Prob	V.likely	Likely	Uncert.	Unlikely
Unit 1	Tornionjoki	wild	1.00	X				0.97	X			
	Simojoki	wild	0.96	X				0.63			X	
	Kalixälven	wild	1.00	X				0.87		X		
	Råneälven	wild	0.88		X			0.66			X	
Unit 2	Piteälven	wild	1.00	X				0.86		X		
	Åbyälven	wild	0.95	X				0.72		X		
	Byskeälven	wild	0.99	X				0.84		X		
	Kågeälven	wild	0.65			X		0.28				X
	Rickleån	wild	0.35			X		0.07				X
	Sävarån	wild	0.49			X		0.17				X
	Ume/Vindelälven	wild	0.98	X				0.60			X	
	Öreälven	wild	0.32			X		0.15				X
	Lögdeälven	wild	0.22				X	0.08				X
Unit 3	Ljungan	wild	0.69			X		0.48			X	
	Testeboån*	wild	0.93	X				0.71		X		
Unit 4	Emån	wild	0.10				X	0.02				X
	Mörrumsån	wild	0.97	X				0.70		X		
Unit 5	Pärnu	mixed	n.a.				X	n.a.				X
	Salaca	wild	n.a.			X		n.a.				X
	Vitrupe	wild	n.a.				X	n.a.				X
	Peterupe	wild	n.a.				X	n.a.				X
	Gauja	mixed	n.a.				X	n.a.				X
	Daugava	mixed	n.a.				X	n.a.				X
	Irbe	wild	n.a.				X	n.a.				X
	Venta	mixed	n.a.			X		n.a.				X
	Saka	wild	n.a.				X	n.a.				X
	Uzava	wild	n.a.				X	n.a.				X
	Barta	wild	n.a.				X	n.a.				X
	Nemunas	mixed	n.a.				X	n.a.				X
Unit 6	Kymijoki	mixed	n.a.				X	n.a.				X
	Luga	mixed	n.a.				X	n.a.				X
	Purtse	mixed	n.a.				X	n.a.				X
	Kunda	wild	n.a.	X				n.a.	X			
	Selja	mixed	n.a.				X	n.a.				X
	Loobu	mixed	n.a.				X	n.a.				X
	Pirita	mixed	n.a.	X				n.a.	X			
	Vasalemma	wild	n.a.				X	n.a.				X
	Keila	wild	n.a.	X				n.a.	X			
	Valgejõgi	mixed	n.a.				X	n.a.				X
	Jägala	mixed	n.a.				X	n.a.				X
	Vääna	mixed	n.a.				X	n.a.				X

* Status uncertain and most likely overestimated.

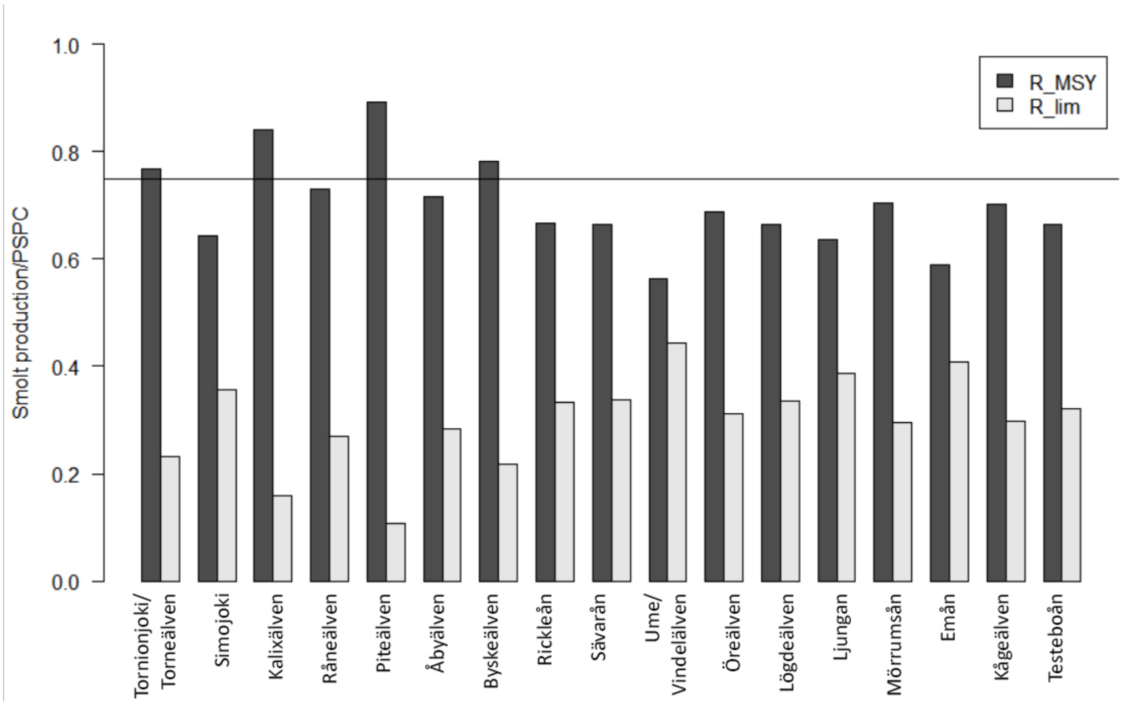


Figure 4.2.1. Point estimates of R_{MSY}/PSPC and R_{lim}/PSPC (AU 1–4 rivers). R_{MSY} is the long-term average smolt production that produces maximum sustainable yield, R_{lim} is the smolt production from which the population would recover to R_{MSY} in one generation under no fishing, and PSPC (R_0) is the long-term average smolt production under no fishing. The horizontal line shows the management target as suggested in the draft multiannual plan (i.e. 75% of R_0).

5 Stock recovery in relation to harvest rate

ICES was requested to provide an analytical evaluation of the recovery rate of individual wild salmon stocks under alternative fishing scenarios. The request refers to two targets for each stock: 75% and 50% of the potential smolt production capacity (PSPC or R_0), with the 50% target being the intermediate one for stocks that currently have a smolt production below the 50% target. ICES was also requested to evaluate the time required to reach a smolt production required to produce the MSY for each stock.

To address this request, WKBaltSalMP performed a management strategy simulation for each of the 17 wild river stocks in AU 1–4 for which the available data and information were sufficient. The simulations are described in Annex 5 with results summarised in tables provided as Annex 6 (electronic version can be downloaded (ICES, 2020d). For AU 5–6 stocks yet not analytically assessed, other approaches were used to respond to the request, as described below.

5.1 Assessment units 1–4

Stock status in 2018 formed starting points for the simulations of rivers in AU 1–4. For each stock the development in smolt production and commercial fishing yield under various harvest rates were simulated for a 25 years period, corresponding to between four and six salmon generations. The simulations are, with the exception of scenarios with no fishing, assuming that recreational fisheries continue with unchanged effort both at sea and in rivers.

Simulation results on medium term development are summarised in Table 5.1.1, showing average probabilities for years 15 to 25 (from 2018) to achieve the four targets evaluated ($0.75{\times}R_0$, $0.50{\times}R_0$, R_{MSY} and R_{lim}). See Annex 6 for complete tables with river-specific simulation results, including also short-term results (2–8 years averages).

Neither the request nor the draft MAP specify criteria for when a target is reached. WKBaltSalMP therefore choose not to indicate when (or if) a stock has met one or several of the targets. Instead, the probability of the smolt production being above the target for each stock and scenario is provided in Table 5.1.1 (and Annex 6).

Under the no fishing scenario, all stocks with the exception of Vindeälven and Emån are likely to reach all three targets with a probability of more than 85% in the medium term. With no commercial fishery and recreational fisheries at current effort level, the probability of reaching the targets drops slightly, but for most stocks it still remains high. Commercial fisheries further reduce the probabilities of reaching the targets, with expected lower probabilities for higher harvest rates. For all stocks except Tornionjoki, Kalixälven, Piteälven and Byskeälven the target of 75% of the potential smolt production capacity ($0.75{\times}R_0$) corresponds to a higher smolt production and thereby higher stock size than the MSY target, R_{MSY} (cf. Figure 4.2.1).

Figure 5.1.1 illustrates the trade-off between mixed-fishery catches and the number of rivers exceeding different targets. Short-term expected catches would be maximised with harvest rate of 0.3 (medium term: 0.2), However, at those harvest rates almost all of the stocks are below their targets of having at least 70% probability to be above R_{MSY} or $0.75{\times}R_0$. Slightly higher proportion of stocks have at least 95% probability be above R_{lim}, but still majority of stocks are below that target (green lines in Figure 5.1.1).

Current harvest rate (2018) is slightly less than 0.1. If this level would be kept for the next 30 years, the mixed-fishery catches in short and medium-term would be about 50–60% of the maximum, but the proportion of rivers reaching the objectives illustrated here would be considerably higher (40–60%). Closing the mixed fishery and leaving only recreational fisheries would enable 75–90% of the rivers to reach these objectives, depending on the objective.

The illustrations above assumed that the objective is to have at least 70% probability that the average smolt production is above $0.75 \times R_0$ or R_{MSY}. Probability of 95% was assumed for R_{lim}. It should be noted that in the case that the expected smolt production for all stocks were at R_{MSY}, the probability for each stock to exceed R_{MSY} is 50% (or less, depending on the shape of the probability distribution). If 70% probability is used when defining the objective all stocks would be classified as not reaching the objective. It also means that the expected smolt production needs to be higher than MSY, when 70% probability is required. Thus, when deciding about the required probability, it is important to consider whether the reference point is regarded as a target where the population should be on average, or a limit that the population should exceed with high probability.

5.2 Assessment unit 5

In AU 5, the wild salmon in general have not improved, and all populations still have a poor status and/or show declining trends. Most of these populations are found in relatively small rivers in terms of discharge and available habitats (cf. Table 3.1). AU 5 salmon stocks are exploited in the Main Basin by offshore commercial and recreational fisheries and by angling in rivers (only kelts in Latvia). The majority of the AU 5 stocks have not responded positively to previous reductions in fisheries exploitation (ICES, 2019a). According to the latest assessment, none of the AU 5 rivers have clearly reached 75% of their estimated smolt production capacity (ICES, 2019a) and all are considered weak.

Using the estimates of wild smolt production among AU 5 stocks and assuming the same natural sea survival, maturation and harvest rates as AU 4 salmon, one can roughly calculate the current catches and adult stock size of AU 5 wild salmon. Technically, this was done by scaling the wild smolt production in river Mörrumsån (AU 4) to equal the total of AU 5, and then apply the FLHM based natural estimates of survival and harvest rates for AU 4 salmon until 2018, after which a zero fishing scenario for the offshore fishing was applied. According to this exercise, currently about 1000–1500 AU 5 wild salmon are annually harvested by offshore fishing and 3000–4000 salmon survive back to their home rivers (and are either harvested by river fishing or spawn). If offshore fisheries were closed, the amount of returning AU 5 salmon would in short term increase to about 5000 salmon.

Existing information indicates that riverine conditions among AU 5 salmon stocks are generally worse than the conditions in the more northern Baltic Sea rivers. This raises the question, whether salmon stock dynamics in AU 5 are fully regulated by the riverine conditions, or if there is also a noticeable/remarkable role in the sea survival for their reproduction. This information is key for steering of actions either towards improving riverine conditions (which, except poaching, falls more on the side of environmental management), or towards implementing further measures by fisheries management.

In order to examine the above question, simple analyses were carried out to see if recruitment in AU 5 stocks seem to responds to changes in sea survival. For comparison, the same analyses were carried out also for the AU 4 and AU 6 (see Section 5.3) stocks. The leading idea was to look at change in recruitment (parr density) over each generation, and compare that to an index of total sea survival during the years when recruits were feeding and harvested at sea. For more details about the method used, see Annex 5 (Section A5.5).

A positive correlation between the change in recruitment and sea survival would indicate that sea survival (including survival from fishing) would play a role in the stock dynamics. Lack of such correlation, on the other hand, would indicate that factors acting in freshwater (environmental conditions, fishing etc.) override the effects of sea survival in the stock dynamics. It is good to keep in mind, however, that the amount of underlying recruitment data for these analyses is very small, consisting of only a few annually sampled electrofishing sites per river. Therefore large random variation is expected to occur among the average annual parr densities, which can easily mask any small or modest effects of sea survival on recruitment.

Post-smolt survival and survival from offshore harvesting show opposite trends over the last three decades (Figure 5.2.1). Therefore, the combined sea survival index has remained relatively stable over time, although up to 3–4 fold differences between years can be found.

Among the four analyzed stocks in AU 5, the longest time-series exists from River Salaca whereas the shortest time-series exist from Gauja and Venta (Figure 5.2.2). R-squared values are low or moderate (0.12–0.46) and correlations are always positive. These results indicate that sea survival probably plays an important role in the overall development of the AU 5 stocks, while river conditions may induce a large (annual) variation in the reproduction success. In three stocks, the trend-lines cross the X-axis at 10–15% sea survival, potentially indicating the level of survival above which development of recruitment turns on average positive. What this survival level means in terms of harvest rate depends much on the post-smolt survival. For instance, with the post-smolt survival and harvest rate levels prevailing during the 2010s, the combined survival index has been varying around 7–15% (Figure 5.2.1). In other words, in the 2010s sea survival appears not to have been high enough to allow recovery of the AU 5 stocks.

For comparison, data from AU 4 stocks (Mörrumsån and Emån) which are included in the FLHM were similarly analyzed. Somewhat surprisingly, basically no correlation (R-squared <0.03) between recruitment and sea survival was found in these two stocks. The lack of correlation in Emån can be explained by the fact that salmon in Emån have notable difficulties to spread upstream the power plants, despite fish-passages, whereas high parr densities are typically observed in the lowermost part of the river (c. 25% of the total estimated river habitat) with free access from the sea. Thus, in Emån density-dependent mortality can be expected to strongly affect average parr densities and annual variation is river conditions (affecting e.g. fish passage through fishways) may further blur dependency between recruitment and sea survival. Also Mörrumsån is subdivided in several sections where only the lowermost one (c. 45% of the total estimated habitat) has free access from the sea, whereas salmon must find their way through fish-passages to reach the river sections further upstream.

Indeed, rivers with migration obstacles and limited spawning/rearing habitats below the lowermost barrier seem to be the least reactive to changes in sea survival (see also below analyses of AU 6 stocks). In these rivers, increasing connectivity within the river would likely be the first in priority to recover salmon stocks. For instance, the primary reason for bad status of the River Pärnu salmon stock has been related to the lack of access to primary spawning areas above the Sindi dam, which is located close to the sea. The small spawning area which was accessible for salmon had very poor quality. However, the recent removal (2019) of the Sindi dam has solved the principle impediment for the Pärnu salmon stock. Also in Mörrumsån, the lowermost dam (Marieberg) will soon be removed (2020) with anticipated positive consequences for the salmon.

In most AU 5 rivers migration obstacles are factors of minor importance, apart from the Daugava (and earlier also Pärnu), where big dams in the lower part of the river have had strong negative effects on the salmon. Lack of suitable reproduction habitats and their unfavourable quality could have played a most considerable role in the poor status of salmon populations and their chance of recovery in AU 5. Electrofishing data suggest that successful spawning in some of these rivers do not occur every year. A major problem in most AU 5 rivers identified by experts is eutrophication, which leads to reproduction habitat overgrowth with vegetation. For some rivers like Gauja and Irbe, deposition of sand and silt also degrades suitable salmon habitats. For several rivers (e.g., Gauja, Irbe, Saka, Salaca, Užava and Venta) extreme summer conditions in 2018 with high water temperatures and low flow conditions were identified as the reason for low parr survival (ICES, 2019a).

Manipulation of river beds (such as straightening) has in most cases affected only upper stretches of AU 5 salmon rivers and are not considered as a significant problem, although with some exceptions. Results of recent habitat mapping in the Užava river revealed that canalization in the 1960s resulted in considerable effects on available habitats; total available and suitable habitats constitute only 0.59 ha located midstream, and restoring meanders and creating new spawning grounds could have a positive effect on the salmon population in this river. Results of suitable habitat mapping in some other wild salmon AU 5 rivers like Bārta (available reproduction habitat 0.61 ha) suggests that it is possible that there is not enough reproduction habitat for salmon to recover to a sustainable level in these kind of small rivers. Similarly as suggested for Užava, habitat restoration may be a solution.

WGBAST (ICES, 2014) conducted a survey among their national experts, asking for opinions about factors affecting so-called weak salmon rivers in the Baltic Sea (covering all AU:s). Experts were also asked to rate how strongly they saw each listed factor to affect the status of the river stock. According to the survey results, an important factor negatively affecting the development is migration obstacles/problems preventing spawning migrating salmon from reaching suitable freshwater habitats. Such obstacles may also reduce the survival of outmigrating smolts and kelts (increased predation in dams, turbine mortality, etc.). Migration obstacles/problems is actually the factor which effects were most often listed as “considerable” by national experts (in ten rivers out of 25). Local fishing pressure, in the river and/or in the river mouth, was also considered to be of significance in AUs 5–6. Likewise, negative effects of eutrophication were considered as a problem in the southeastern Baltic Sea (ICES, 2014).

The summary of the survey is found in Table 4.4.1.1 of the ICES (2014) report. The evaluation indicated that many factors are often acting in concert. On the other hand, the importance of different factors seems to differ between areas and rivers. It is therefore likely that different areas/rivers need different measures to improve the situation for weak salmon stocks. More general factors affecting salmon on a wider geographical scale are likely also of significance. One possibility is that southern stocks have a lower natural survival at sea, thus making exploitation possibilities lower for these stocks. However, comparisons of smolt production estimates and catch composition information indicated that there was no such difference in natural sea survival between weak and stronger salmon stocks (ICES, 2014). In small populations, random demographic and environmental events are also expected to result in slower population grow rate than in larger populations having the same demographic characteristics (Lande, 2002).

Whatever is the underlying reason for the poor status and the lack of response to management measures, the overall lifetime survival of salmon from weak stocks is lower compared to the survival of salmon from other areas. In order to recover these river stocks, possibilities to reduce any type of mortality (whether it is related to fishery or not) at various life stages therefore must be considered (ICES, 2014).

5.3 Assessment unit 6

Little is known about the harvest rates of AU 6 (Gulf of Finland) salmon. This reflects that various pieces of information indicate that these stocks have different feeding migration routes than salmon in the other AUs. Long time-series of tag–recapture data suggest that AU 6 salmon utilises open sea areas for feeding in the Gulf of Finland (GoF) but also in the Main Basin. Until the early 1990s, substantial catches were taken offshore in the GoF. Combined with supporting tag–

recapture data this suggested that the open sea area of GoF was an important feeding area for AU 6 salmon. Later, the open sea fishery gradually disappeared from the GoF area because of a growing seal population and increased maritime traffic, and only coastal salmon fishing has been carried out in the last 15 years. Because of the absence of an offshore fishery, it is not known whether AU 6 salmon utilizes the GoF as feeding ground to the same extent as earlier. However, an increased feeding migration over time into the Baltic Main Basin cannot be ruled out (as a result of observed changes in the GoF foodweb). The fragmentary information contained in various datasets would need a thorough joint analysis of available information in order to get even rough estimates of the migration patterns and harvest rates of AU 6 salmon (see Section 4.2 about ongoing work to develop a separate FLHM for GoF salmon).

The only wild salmon AU 6 stocks currently exist in Estonia. For several decades, until the early 2000s, these stocks were regarded to have a very poor status, even though open sea fishery in the Gulf of Finland had ceased already by the end of the 1990s. The first small signs of improving stock status were observed around 2005–2010. To decrease the harvest rate of wild and mixed Estonian populations, enlarged closed areas around river mouths have been established since 2011. During the same period, more efforts have been allocated to controls to reduce illegal fishing in rivers. With a high probability those combined measures are the main reason for the continuous positive development seen for Estonian populations.

Similar analysis of recruitment vs. sea survival index, as described for AU 5 stocks in the previous subsection (5.2), was carried out for the three Estonian wild salmon stocks. The results indicate that there is no connection between the sea survival index and the development in the recruitment (Figure 5.3.1). This analysis supports the earlier hypothesis that offshore harvesting in the southern Baltic Main Basin does not play any major role in the development of the AU 6 salmon stocks, but that more local factors in rivers (like the above-mentioned poaching) are more important management considerations.

Characteristic to AU 6 rivers are numerous migration obstacles, both manmade dams and natural waterfalls, in their lower stretches. The short accessible river stretches become crowded, and density-dependent mortality seem to start restricting reproduction already at relatively low absolute abundance levels of spawners. This holds also for the three analysed rivers in Figure 5.3.1, and may partly explain the lack of connection between sea survival and recruitment (as discussed for AU 4, above). Migration obstacles have been opened to enable access to more spawning areas in many rivers. However, the recolonization of those new areas has been slower than hoped, and little appears to be known about the timeframe of such processes. Presumably, the increase of available reproduction areas will result in larger populations in a longer perspective.

To conclude, it seems that the salmon populations in Estonian rivers have responded well to local restrictive measures and less to sea fisheries or natural sea survival. Major decreases in sea harvest rates (like the ceased offshore fishing in the Gulf of Finland) and the non-prevalence of M74 (fry mortality) in this part of the Baltic Sea have probably also helped the recovery. Considering previously mentioned factors, it is realistic that further improvement of populations will occur.

Table 5.1.1. Probabilities for stock-specific (AU 1–4) smolt production in the medium term (average for 15 to 25 years from 2018) to be above 75% and 50% of the potential smolt production capacity (PSPC or R_0), above the smolt production required to produce the MSY (R_{MSY}) and above the lowest smolt production level from which the river stock would be expected to recover to R_{MSY} in one salmon generation, if all fishing was completely closed (R_{lim}). Scenarios are presented for no fishing, only recreational fishing and at different harvest rates (from 0.05 to 0.5) for commercial fisheries. Recreational fishing effort kept constant at its current level. The commercial harvest rate of 0.075 corresponds to the 2018 level. Results extracted from Annex 6.

				Harvest rate (commercial fisheries)						
Stock	Target	No fishing	Only recreational fisheries	0.05	0.075	0.10	0.20	0.30	0.40	0.50
Simojoki	P(Smolts>0.75×R_0)	0.86	0.67	0.54	0.47	0.39	0.07	0.00	0.00	0.00
	P(Smolts>0.5×R_0)	0.97	0.87	0.78	0.71	0.64	0.27	0.02	0.00	0.00
	P(Smolts>R_{MSY})	0.93	0.78	0.64	0.57	0.50	0.14	0.01	0.00	0.00
	P(Smolts>R_{lim})	0.99	0.94	0.87	0.83	0.77	0.40	0.06	0.00	0.00
Tornionjoki	P(Smolts>0.75×R_0)	0.98	0.94	0.88	0.84	0.79	0.49	0.10	0.00	0.00
	P(Smolts>0.5×R_0)	1.00	0.99	0.99	0.98	0.97	0.85	0.42	0.01	0.00
	P(Smolts>R_{MSY})	0.98	0.92	0.86	0.82	0.77	0.45	0.08	0.00	0.00
	P(Smolts>R_{lim})	1.00	1.00	1.00	1.00	1.00	0.97	0.78	0.11	0.00
Kalixälven	P(Smolts>0.75×R_0)	1.00	0.98	0.97	0.96	0.94	0.80	0.45	0.05	0.00
	P(Smolts>0.5×R_0)	1.00	1.00	1.00	0.99	0.99	0.97	0.82	0.29	0.00
	P(Smolts>R_{MSY})	0.98	0.93	0.89	0.86	0.82	0.60	0.24	0.02	0.00
	P(Smolts>R_{lim})	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.70	0.02
Råneälven	P(Smolts>0.75×R_0)	0.98	0.89	0.84	0.79	0.75	0.45	0.11	0.01	0.00
	P(Smolts>0.5×R_0)	1.00	0.99	0.97	0.96	0.94	0.74	0.36	0.03	0.00
	P(Smolts>R_{MSY})	0.98	0.90	0.85	0.82	0.77	0.48	0.13	0.01	0.00
	P(Smolts>R_{lim})	1.00	1.00	1.00	0.99	0.98	0.91	0.61	0.11	0.00
Piteälven	P(Smolts>0.75×R_0)	1.00	0.99	0.99	0.99	0.98	0.93	0.73	0.29	0.00
	P(Smolts>0.5×R_0)	1.00	1.00	1.00	1.00	1.00	0.99	0.97	0.69	0.04
	P(Smolts>R_{MSY})	0.93	0.88	0.85	0.81	0.79	0.63	0.33	0.07	0.00
	P(Smolts>R_{lim})	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.33
Åbyälven	P(Smolts>0.75×R_0)	0.96	0.89	0.82	0.79	0.73	0.50	0.22	0.03	0.00
	P(Smolts>0.5×R_0)	1.00	0.97	0.95	0.93	0.92	0.76	0.46	0.13	0.01
	P(Smolts>R_{MSY})	0.97	0.90	0.85	0.81	0.77	0.54	0.25	0.04	0.00
	P(Smolts>R_{lim})	1.00	0.99	0.99	0.98	0.97	0.90	0.65	0.26	0.02

				Harvest rate (commercial fisheries)						
Stock	Target	No fishing	Only recreational fisheries	0.05	0.075	0.10	0.20	0.30	0.40	0.50
Byskeälven	P(Smolts>0.75×R_0)	0.98	0.94	0.91	0.88	0.86	0.68	0.33	0.07	0.00
	P(Smolts>0.5×R_0)	1.00	0.99	0.99	0.98	0.98	0.91	0.68	0.23	0.01
	P(Smolts>R_{MSY})	0.97	0.93	0.88	0.85	0.82	0.61	0.28	0.05	0.00
	P(Smolts>R_{lim})	1.00	1.00	1.00	1.00	1.00	0.98	0.91	0.52	0.03
Kågeälven	P(Smolts>0.75×R_0)	0.91	0.81	0.74	0.71	0.66	0.44	0.21	0.06	0.01
	P(Smolts>0.5×R_0)	0.98	0.93	0.90	0.86	0.84	0.68	0.42	0.15	0.01
	P(Smolts>R_{MSY})	0.93	0.84	0.79	0.76	0.71	0.50	0.26	0.08	0.01
	P(Smolts>R_{lim})	0.99	0.97	0.95	0.93	0.91	0.79	0.56	0.22	0.02
Rickleån	P(Smolts>0.75×R_0)	0.91	0.73	0.62	0.54	0.48	0.14	0.02	0.00	0.00
	P(Smolts>0.5×R_0)	0.99	0.93	0.86	0.81	0.75	0.41	0.06	0.00	0.00
	P(Smolts>R_{MSY})	0.95	0.81	0.71	0.65	0.57	0.23	0.03	0.00	0.00
	P(Smolts>R_{lim})	1.00	0.97	0.94	0.92	0.88	0.60	0.16	0.01	0.00
Sävarån	P(Smolts>0.75×R_0)	0.91	0.77	0.67	0.60	0.53	0.21	0.03	0.00	0.00
	P(Smolts>0.5×R_0)	0.99	0.93	0.89	0.85	0.80	0.48	0.10	0.00	0.00
	P(Smolts>R_{MSY})	0.96	0.85	0.76	0.70	0.63	0.30	0.04	0.00	0.00
	P(Smolts>R_{lim})	1.00	0.98	0.95	0.94	0.90	0.64	0.22	0.01	0.00
Vindeälven*	P(Smolts>0.75×R_0)	0.64	0.39	0.24	0.18	0.14	0.03	0.01	0.01	0.01
	P(Smolts>0.5×R_0)	0.80	0.53	0.40	0.33	0.25	0.06	0.02	0.01	0.01
	P(Smolts>R_{MSY})	0.76	0.51	0.37	0.29	0.21	0.05	0.02	0.01	0.01
	P(Smolts>R_{lim})	0.82	0.59	0.44	0.37	0.29	0.07	0.02	0.01	0.01
Öreälven	P(Smolts>0.75×R_0)	0.94	0.80	0.72	0.66	0.60	0.27	0.03	0.00	0.00
	P(Smolts>0.5×R_0)	0.99	0.96	0.92	0.88	0.85	0.58	0.16	0.01	0.00
	P(Smolts>R_{MSY})	0.97	0.86	0.77	0.72	0.68	0.35	0.06	0.00	0.00
	P(Smolts>R_{lim})	1.00	0.98	0.98	0.96	0.95	0.77	0.34	0.02	0.00
Lögdeälven	P(Smolts>0.75×R_0)	0.92	0.75	0.65	0.55	0.48	0.17	0.01	0.00	0.00
	P(Smolts>0.5×R_0)	0.99	0.93	0.87	0.82	0.76	0.42	0.08	0.00	0.00
	P(Smolts>R_{MSY})	0.97	0.83	0.73	0.67	0.59	0.25	0.03	0.00	0.00

Stock	Target	No fishing	Only recre-ational fisheries	Harvest rate (commercial fisheries)						
				0.05	0.075	0.10	0.20	0.30	0.40	0.50
	P(Smolts>R_{lim})	1.00	0.97	0.94	0.92	0.89	0.61	0.17	0.01	0.00
Ljungan	P(Smolts>0.75×R_0)	0.88	0.75	0.66	0.63	0.56	0.34	0.19	0.05	0.00
	P(Smolts>0.5×R_0)	0.97	0.88	0.81	0.77	0.73	0.51	0.29	0.11	0.01
	P(Smolts>R_{MSY})	0.93	0.81	0.74	0.70	0.64	0.42	0.24	0.07	0.01
	P(Smolts>R_{lim})	0.98	0.92	0.86	0.83	0.79	0.58	0.34	0.14	0.01
Testeboån	P(Smolts>0.75×R_0)	0.92	0.81	0.75	0.71	0.65	0.47	0.27	0.09	0.01
	P(Smolts>0.5×R_0)	0.97	0.93	0.89	0.87	0.83	0.64	0.44	0.19	0.03
	P(Smolts>R_{MSY})	0.95	0.87	0.81	0.77	0.73	0.53	0.33	0.12	0.02
	P(Smolts>R_{lim})	0.99	0.96	0.94	0.92	0.90	0.76	0.56	0.28	0.03
Emån	P(Smolts>0.75×R_0)	0.76	0.51	0.39	0.34	0.27	0.09	0.01	0.00	0.00
	P(Smolts>0.5×R_0)	0.90	0.68	0.58	0.52	0.45	0.20	0.04	0.00	0.00
	P(Smolts>R_{MSY})	0.85	0.62	0.51	0.45	0.39	0.16	0.03	0.00	0.00
	P(Smolts>R_{lim})	0.93	0.74	0.63	0.58	0.52	0.25	0.06	0.00	0.00
Mörrumsån	P(Smolts>0.75×R_0)	0.93	0.85	0.79	0.76	0.72	0.57	0.42	0.26	0.11
	P(Smolts>0.5×R_0)	0.98	0.95	0.92	0.91	0.89	0.77	0.60	0.39	0.19
	P(Smolts>R_{MSY})	0.94	0.88	0.83	0.80	0.77	0.63	0.45	0.28	0.13
	P(Smolts>R_{lim})	0.99	0.98	0.97	0.96	0.96	0.87	0.72	0.50	0.24

*** Due to severe health issues in recent years, reduced smolt production is expected according to the last assessment.**

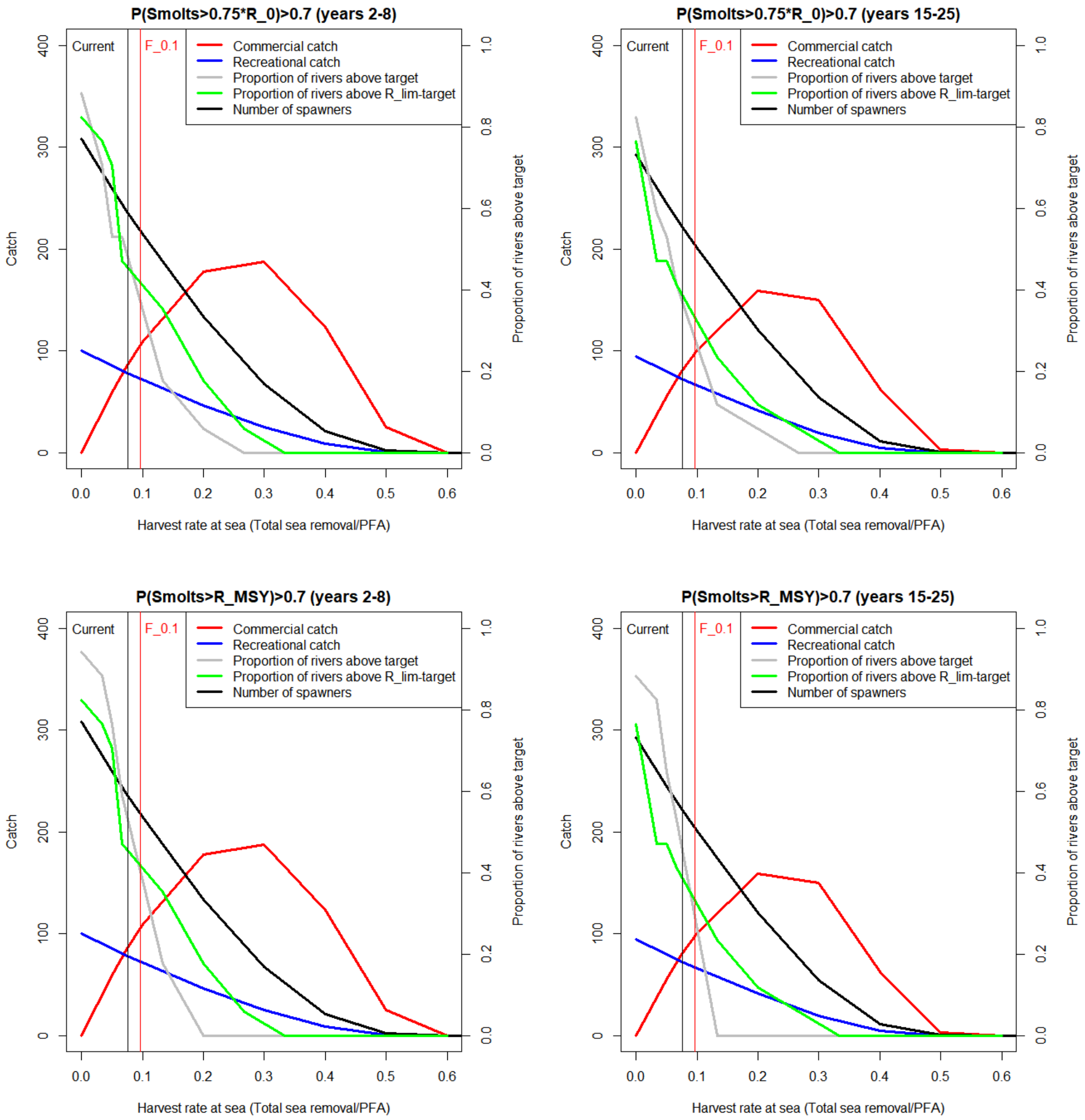


Figure 5.1.1. Trade-off between number of rivers meeting different management objectives, total number of spawners in rivers, and the commercial catch at sea. Panels show different combinations of applied target (i.e. 0.75×R_0-proxy and stock-specific R_{MSY}; cf. Figure 4.2.1) and timeframe (2–8 and 15–25 years). Green line shows the number of rivers for which P(Smolts >R_{lim}).

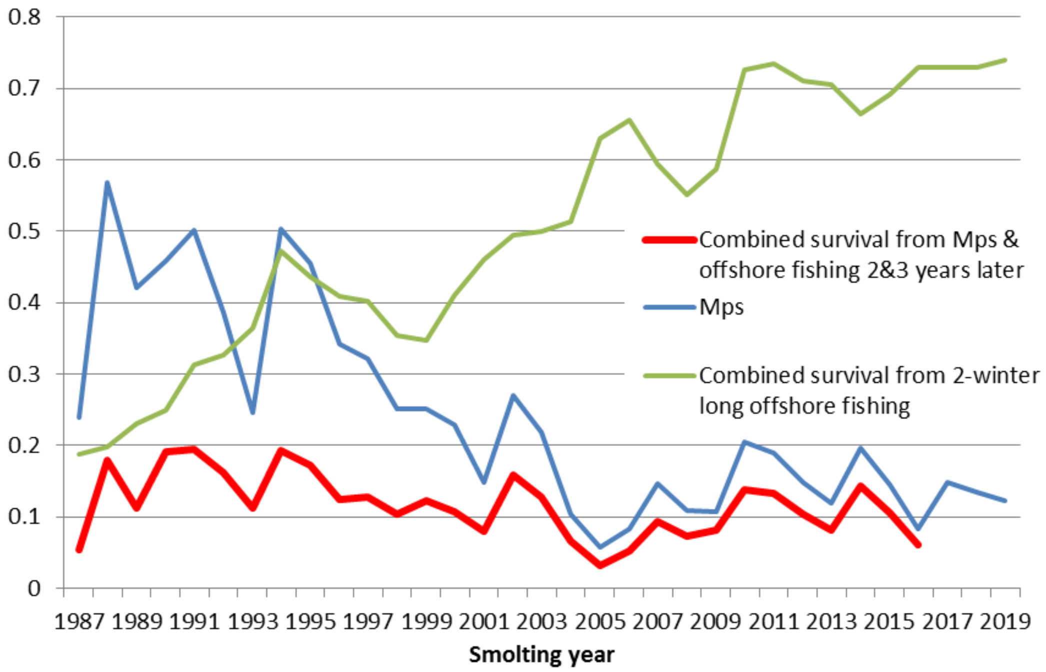


Figure 5.2.1. Time-series of post-smolt survival (Mps), combined survival from 2-winter harvesting by offshore fishing, and the resulting combined survival index of these two time-series in the Baltic Sea.

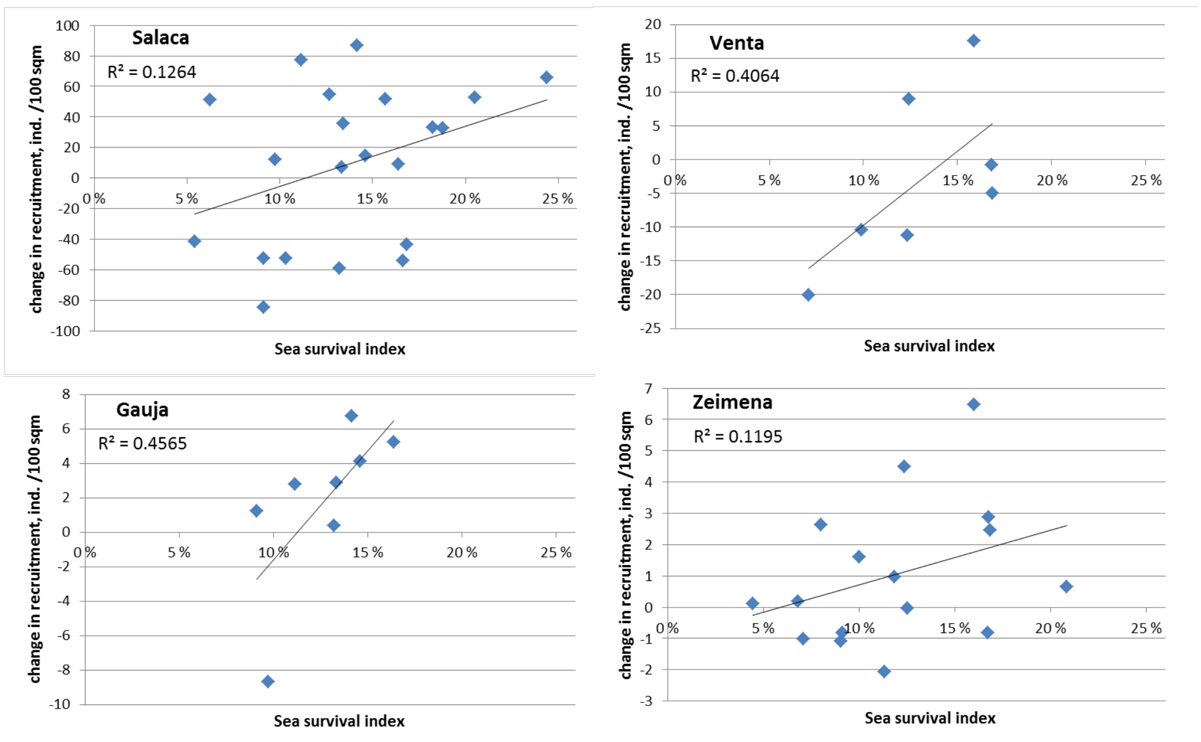


Figure 5.2.2. Correlation between the change in recruitment over one generation and sea survival (index) affecting the generation in four AU 5 salmon stocks.

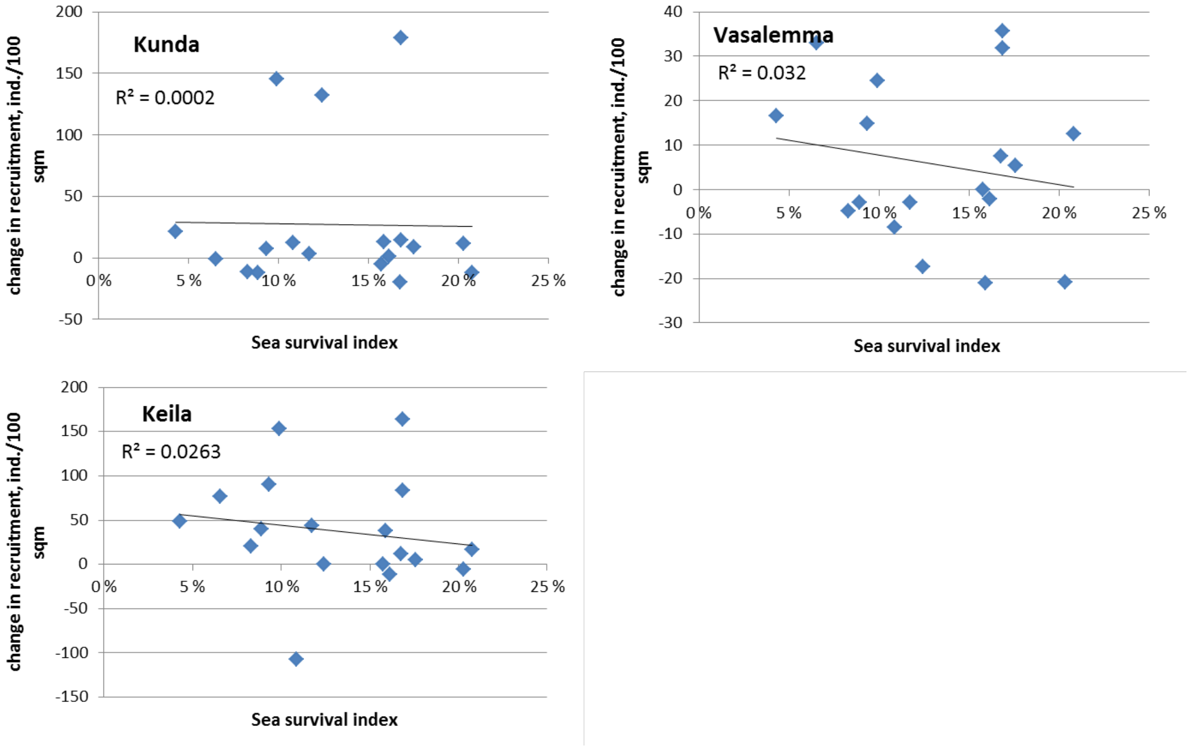


Figure 5.3.1. Correlation between the change in recruitment over one generation and sea survival (index) affecting the generation in three AU 6 wild salmon stocks.

6 Comments on the draft management plan

At the first workshop meeting (Copenhagen, 4–5 November 2019) it was clarified by attending managers within BALTFISH that they would like to also receive more general comments from ICES on the draft management plan (MAP; Annex 2), in addition to the specific questions in the EC request. WKBaltSalMP therefore had a general discussion of the draft plan with focus on its scope (commercial fisheries and two management units), objectives (including the reference to MSY and potential smolt production capacity), and stocking of reared salmon.

This section contains a summary of issues raised in that discussion. Note that it should not be regarded as a complete review of the total content of the draft MAP.

6.1 Scope and objectives

The draft (dated 30.01.2018; Annex 2) addresses the Baltic Sea salmon stocks and Union fishing vessels exploiting the stocks in Union waters. With respect to exploitation, the draft plan operates with the same two management units currently used: subdivisions 22–31 and Subdivision 32.

In addition to contributing to achieve the objectives of the Common Fisheries Policy and to fulfil relevant descriptors contained in the Marine Strategy Framework Directive (Directive 2008/56/EC), a number of specific objectives and targets for the Baltic Sea salmon are listed in the draft plan, including the following:

- The plan shall contribute to the biodiversity, genetic integrity and diversity of the Baltic Sea salmon stock.
- The plan shall aim at achieving maximum sustainable yield (MSY) as soon as possible or on a progressive, incremental basis at the latest by 2020 and maintaining thereafter the Baltic Sea salmon stock at the levels which can produce maximum sustainable yield.
- The plan furthermore sets stock-specific targets for the wild stocks in terms of minimum proportion of potential smolt production capacity to be achieved. The overall aim is to reach at least 75% of the potential smolt production capacity for each stock by a given time limit. The time limit is not defined in the draft plan, but part of the special request to ICES.
- The link between MSY and the potential smolt production is not specified in the draft plan. However, it seems to be assumed that being at or above 75% of the potential smolt production capacity is consistent with MSY (i.e. the current proxy; ICES, 2008a).

6.1.1 Fishing opportunities

The draft plan specifies that fishing opportunities shall be fixed in accordance with the objectives and the targets. For ICES subdivisions 22–31, the fishing opportunities shall be set at the level corresponding to a fishing mortality within a range. The range is to be decided based on scientific advice. For salmon in Subdivision 32, the fishing opportunities shall be set at the level improving the wild salmon stock status with a high probability towards the MSY.

The draft plan does not specify what fishing mortality is referred to. However, as the plan only applies to Union fishing vessels in the Union waters of the Baltic Sea, WKBaltSalMP has assumed that the mortality referred to is the one generated by commercial Union fisheries on the total abundance of salmon available to the fisheries in subdivisions 22–31 and Subdivision 32.

6.1.2 Member State measures to protect weak wild salmon stocks

For wild salmon stocks, which have not reached 50% of their potential smolt production capacity by the time of the entry into force of the plan, the draft plan stipulates that relevant Member States shall establish national technical conservation measures in the waters of the Baltic Sea to be applied to its own fishing vessels exploiting the relevant salmon stocks.

6.1.3 Releases of reared salmon

The draft plan does not address the management of reared salmon released in the Baltic Sea. The only references to releases of salmon are in article 14 and article 15. According to article 14 of the draft plan, all released parr or older salmon, excluding releases done to establish new salmon stocks or to support existing weak salmon stocks must be fin-clipped before stocking. Article 15 specifies that direct re-stocking of salmon may be considered as a conservation measure when conducted in order to support the achievement of the objectives and targets of the draft plan.

6.2 Management units

The draft plan maintains two management units for EU commercial fisheries (one for subdivisions 22 to 31 and one for Subdivision 32) as in the current management. The rationale for keeping these TAC management units is not given in the draft. However, it may be related to the former understanding of the stock dynamics, indicating that salmon caught in SD 32 (Gulf of Finland) were all of local origin and that almost all local wild and released reared salmon stay in this area throughout their sea life period with very limited migration to other parts of the Baltic Sea, thus supporting the current two management units.

The current understanding of the stock dynamics in SD 32 is that the natural production in the area has increased over time, and that salmon from local wild and mixed rivers constitute a larger proportion of the total production in the Gulf of Finland than earlier (ICES, 2019a). Although a majority of SD 32 salmon seem to remain in the Gulf of Finland and northern Main Basin throughout their sea life, a part migrate to the feeding grounds in the southern Main Basin. In addition, more recent information show that some of the Gulf of Bothnia stocks pass into Gulf of Finland during their spawning migration from the southern feeding areas to their rivers in Gulf of Bothnia. According to genetic estimates these stocks are caught in SD 32, especially by the Finnish coastal fishery at sites located more to the west (ICES, 2019a). However, the total number of Gulf of Bothnia salmon caught in the SD 32 fisheries is likely to be low (as a major part of the total catch, 6000–8000 salmon in recent years, is taken in the eastern Gulf of Finland).

This means that fisheries in SD 22–31 should be taken into account when developing a management plan for the salmon stocks in SD 32, and the Workshop considered that the mixing of salmon between the two current management units could be too high to justify keeping two separate management units. However, this does not mean that a separate quota for SD 32 may not be a useful tool to limit the exploitation of wild salmon in that subdivision. In general, separate quotas for the different fisheries may improve management by allowing further protection of weak river stocks and support the MSY objective.

6.3 Salmon fisheries

The fisheries on Baltic salmon may roughly be divided into five different categories (Table 6.3.1):

1. **Offshore sea fisheries** on feeding grounds in the southern Baltic Sea harvesting a mixture of reared and wild salmon from all assessment units. Can be subdivided into:
   a) Commercial fisheries, mainly longline fisheries. Catches included in the current SD 22–31 TAC.
   b) Recreational fisheries, mainly trolling, not covered by the TAC. Trolling fishery in Swedish waters is subject to measures aiming at limiting the mortality on wild salmon (since 2013, only fin-clipped salmon can be retained).
2. **Coastal fisheries in SD 30–31** for salmon during the spawning migration back to their natal rivers. Mainly commercial trapnet fisheries harvesting a mixture of wild and reared salmon from AU 1–3. Catches included in the current SD 22–31 TAC.
3. **Coastal fisheries in SD 32**. Harvesting a mixture of wild and reared salmon, mainly with origin from AU 6 but partly also from AU 1–3. Catches are included in the SD 32 TAC.
4. **Fisheries in wild rivers**. Almost entirely recreational. Harvests salmon from the river concerned. Not covered by a TAC.
5. **Fisheries in reared rivers**. Recreational and commercial. Harvests reared salmon. Not covered by a TAC.

The above fisheries are exploiting salmon at different life stages, starting with the offshore fisheries followed by the coastal fisheries and ending with river fisheries. This means that the number of salmon available to the coastal fisheries depends on catches taken in the offshore fisheries, whereas the number available to river fisheries depends on both offshore and coastal catches.

In 2019, commercial sea fisheries accounted for 51% of the total catch of Baltic salmon (SD 22–32), recreational sea fisheries for 16% and river fisheries for 33%. Approximately 85% of the commercial sea fishery catch was reported and counted against the quotas. The remaining 15% of the commercial sea catches consisted of misreported catches (salmon reported as sea trout), unreported catches and discards. The recreational sea catches and river catches were not counted against the quotas.

The relative distribution of catches between fisheries varies between stocks. Salmon from all river stocks in AU 1–5 are assumed to mix in the feeding area in the southern Baltic Sea together with reared salmon, and the offshore fisheries are assumed to generate the same mortality rate on all river stocks. Salmon from AU 6 are considered to feed predominantly further north, in Gulf of Finland and northern Main Basin, but some are migrating to the southern Baltic Sea where they mix with salmon from the other assessment units.

The coastal fisheries are targeting salmon on their migration back to their natal rivers to spawn. The fisheries are mainly located in SD 30–31, and in SD 32. The fisheries in SD 30 and 31 are therefore mainly exploiting wild and reared river stocks belonging to AU 1–3, whereas the fishery in SD 32 mainly targets AU 6 stocks. This means that the coastal fisheries in the Gulf of Bothnia and Gulf of Finland have little impact on the southern and eastern stocks in AU 4 and 5.

6.3.1 Fisheries included in the management plan

The draft management plan has a strict focus on commercial sea fisheries. Although a substantial number of salmon are nowadays taken in recreational fisheries, those fisheries are not addressed.

Hence, there is an obvious risk that a management plan not including tools to regulate exploitation by all important fisheries may become less effective and could fail in fulfilling its objectives and targets.

6.4 Mixed vs. stock-specific fishing

In order to study the trade-off between mixed and stock-specific fisheries, a simplified stable-state population dynamics model was constructed. The basic assumption was that mixed-fishery at sea operates first, and then river-specific fisheries catch what is left to reach MSY for each particular river stock. If the mixed-sea fishery would drive a river stock below MSY, then the river fishing for that particular stock would be closed.

The model was based on the following assumptions and background information:

- Point estimates of the stock-recruitment parameters from the FLHM were used for 17 rivers (AU 1–4) included.
- Point Estimates of R_{MSY} from scenario projections were taken to represent the MSY situation.
- Each stock was assumed to output all their smolt production into the same pool, where mixed-fishery harvest rate operates on all river stocks, reducing the number of fish from each stock by the same percentage.
- Note that because of the simplified nature of the model, natural mortality rates at sea do not match the ones used in the FLHM and scenario models used by WGBAST. This means that the results should not be interpreted as absolute values. Results only indicate the basic principles.
- For each mixed-fishery harvest rate, the stable state catch and smolt production were computed and summarized across rivers.
- If the stable state catch in the mixed fishery was smaller than MSY for a river, and smolt production was <u>higher</u> than R_{MSY}, then the river harvest rate for that river was adjusted so that the population stabilizes to MSY.
- If the stable-state catch in the mixed fishery was smaller than MSY for a river, and smolt production was <u>lower</u> than R_{MSY}, then the river harvest rate for that river was set to zero.
- The resulting stable-state smolt production for each river was compared to R_{MSY} of that river. Status of river stocks was classified based on this ratio.

The results of the analysis are illustrated in Figures 6.4.1 and 6.4.2. Figure 6.4.1 shows how the total stable-state catch and the division of catches between sea and rivers changes as a function of mixed-fishery harvest rate. Figure 6.4.2 shows how many of the stocks will stabilize below MSY at each mixed-fishery harvest rate. Note that, due to the simplified assumptions used, these results are not directly comparable to those from simulation presented in Section 5 (Figure 5.1.1).

When the mixed-fishery harvest rate is small, all stocks can achieve their MSY, due to river-specific optimization of fishing in rivers. When mixed-fishery harvest rate increases, some stocks fall below their MSY levels. However, these stocks happen to be small compared to ones that are more resilient to fishing. The fact that few of the smaller stocks go below MSY or even go to extinction, does not make a noticeable difference to the total yield, because a few large and resilient rivers dominate the salmon production in the Baltic.

The message is clear. If the goal is to obtain maximum sustainable yield for all river stocks, then the mixed-fishing pressure should be planned using the river that is least resilient to fishing as a reference. If the goal is to obtain almost maximum sustainable yield ("pretty good yield") from the Baltic salmon population as a whole, while maintaining a noticeable mixed-stock sea fishery, then it must be accepted that some rivers will not reach MSY and can even go extinct.

6.5 Reared salmon

Releases of hatchery-reared salmon in natural waters are carried out for various reasons, including compensation to fisheries for loss of natural production in rivers exploited by hydropower (compensatory releases), support to weak wild river stocks (supplementary releases), reintroduction of salmon in rivers where the original stock has been extinct, or to increase fishing possibilities on the local scale without any primary aims of increasing the natural production (put-and-take releases). It also seems to be rather common that releases of reared salmon are carried out without any clear objectives, or possibly because of historical reasons that may not be relevant anymore.

The total amount of salmon released annually in the Baltic Sea (corresponding to between 4 and 7 million smolts annually) has for several decades outnumbered the amount of wild salmon produced in rivers (Figure 6.5.1). Despite obvious genetic and ecological risks associated with such large scale releases (e.g. Ford, 2002; Araki and Schmid, 2010; ICES, 2016a; Hagen *et al*., 2019), stocking activities are only to a minor extent covered in the draft MAP.

Although reared salmon is an important resource for the Baltic Sea fisheries and is included in the current TAC system, releases of reared salmon constitute a genetic risk to wild populations. Thus, many different interactions between wild and reared salmon exist in the Baltic Sea, including ecological and genetic interactions, spread of diseases and resource utilization in the fishery. It is therefore evident that a multiannual management plan must relate to the variety of ongoing stocking activities and take into account interactions between wild and reared salmon (cf. ICES, 2008a; b), even if the plan is mainly dealing with wild salmon stocks. Member States in the Baltic Sea area should agree on a long-term plan how stocking activities with different purposes, including compensatory releases (see below), should be managed in the future, based on latest scientific information. Furthermore, a management plan should provide recommendations/guidelines for management of hatchery populations and stocking activities with different aims so that negative impacts on wild stocks are minimized. There is also a need to implement “genetic monitoring” to evaluate the outcome of stocking activities and potential detrimental effects on wild stocks (ICES 2008b, Laikre *et al*., 2008; Palmé *et al*., 2012).

6.5.1 Compensatory salmon releases

The main bulk of releases in the Baltic Sea area are carried out in rivers exploited by hydropower, with the aim to compensate fisheries for the loss of natural production and fishing opportunities. Despite obvious genetic and ecological risks associated with large scale releases (e.g. Ford, 2002; Araki and Schmid, 2010; ICES, 2016a; Hagen *et al*., 2019), the long-term effects of the compensatory stocking programmes in the Baltic Sea is largely unknown (Palmé *et al*., 2012), although research on this topic is ongoing (Östergren *et al*., In prep). The original draft MAP proposed by the EC (EC, 2011) included a phasing out of compensatory releases of reared salmon in the Baltic Sea, whereas the current MAP draft does not address these releases. The background of this change is not clear to us.

Reared salmon released for compensatory purposes should be exploited as much as possible to minimize ecological and genetic interactions with wild stocks. In recent years, the "surplus" of reared salmon returning to rivers has increased due to declining exploitation rates at sea and improved conditions for survival, and the increasing amounts of reared salmon poses a potential threat to wild stocks (see above). Possible solutions to this problem include a complete phase-out of the compensatory stocking programmes, as suggested in the initial draft MAP from the EC (2011), or at least an adjustment of stocking amounts (in relation to fishery demands) to keep the surplus of reared salmon at low levels and minimize detrimental effects on wild stocks (ICES, 2008a, cf. recommendations from the Hatchery Scientific Review Group, 2017). Until stocking amounts have been adjusted to lower levels, an immediate action to reduce the surplus of reared salmon could be to temporally open up possibilities to fish reared salmon outside the quota in restricted coastal areas where scientific information indicate that reared salmon clearly dominates, or to increase fisheries in rivers with only reared salmon.

6.5.2 Direct restocking to support wild river stocks

The formulation of Article 15 in the draft MAP makes it possible to stock reared salmon in rivers with wild stocks to achieve the objectives and target levels listed in Articles 3 and 4. Released reared fish tend to be adapted to the rearing environment (e.g. Petersson and Järvi, 1995; Einum and Fleming, 2001) and when they breed with wild conspecifics in the natural environment the overall fitness of the integrated population can be reduced (e.g. Ford, 2002, Araki and Schmid, 2010).

Further challenges exist when reared salmon stray into rivers of wild stocks, compromising their genetic integrity and fitness (ICES, 2016a; Hagen *et al.*, 2019). The possibility to release reared salmon directly in wild rivers should therefore only be considered a strict temporary conservation measure if there is a high risk of extinction of a particular river stock, and all other fishery management and habitat restoration interventions have been realised (ICES, 2018b). Furthermore, any decision to supplement wild river stocks by releasing reared salmon should be based on latest scientific guidelines regarding rearing and stocking (e.g. Frankham *et al.*, 2014; Hatchery Scientific Review Group, 2017; Withler *et al.*, 2018) and carefully monitored. More specifically, for the following reasons, we strongly recommend against the possibility to use stocking as a general measure to fulfil the objectives of the management plan (as the article is formulated now):

- There is an apparent risk that stocking of reared salmon will negatively affect the genetic diversity and integrity, as well as the fitness and recovery possibilities, of wild river stocks. Thus, this measure may counteract the objectives of the management plan listed in Articles 3 and 4. Even when the reared salmon originate from the local wild river stock, there are genetic concerns to be considered (see e.g. Wang and Ryman, 2001; Ford, 2002; Araki *et al.*, 2007). As mentioned above, stocking of reared salmon to support wild populations should only be initiated under special circumstances, with clear aims and follow-ups.
- Supporting wild rivers stocks by releasing reared salmon interfere with the current definition of a wild salmon river stock (cf. ICES, 2013, pages 89–91).
- The possibility to stock reared salmon to fulfil the objectives of the plan may reduce the incentive to introduce necessary measures (regulations of fisheries, habitat restorations, etc.) to give self-reproducing weak river stocks a chance to recover. With the current formulation of the article, there is even a potential for misuse since increased releases of reared salmon in rivers with weak wild stocks (to fulfil management objectives) may be used to enable an increased fishing pressure.

6.5.3 Guidelines for rearing and stocking fish

The fact that continuous massive releases of reared salmon in the Baltic Sea potentially may affect wild salmon stocks, and reared salmon at the same time constitute an important and valuable resource for fisheries, suggests that guidelines for production and release of reared salmon for different purposes should be part of a multiannual management plan. During a symposium and workshop in 2012 focused on compensatory releases of salmon in the Baltic Sea (Palmé *et al.*, 2012) it was concluded that (1) conservation genetic goals and recommendations for rearing and releasing salmon should be established within three years (i.e. 2015), (2) genetic monitoring programs should be initiated and (3) that research on the occurrence and rates of straying was urgently needed. Since then, research on genetic effects of stocking in Baltic salmon has been initiated (Östergren et al. in prep.), but it is too early to summarize results of this research. To our knowledge, however, no effort has been directed towards establishing internationally accepted conservation genetic goals for Baltic salmon and/or recommendations for rearing and stocking.

In Canada and the U.S., governmental bodies have recently developed guidelines for hatchery production and stocking of reared salmon in the wild (e.g. Hatchery Scientific Review Group, 2017; Withler *et al*., 2018). These guidelines are rather broad and cover stocking programmes with different aims including for example conservation (supplemental) releases and releases aimed at supporting fisheries. They also cover the whole chain from defining goals for both hatchery stocks and wild populations, establishing and managing broodstocks, procedures for releasing reared fish in the wild, adverse effects of hatchery fish on natural populations including threats to genetic integrity and diversity as well as fitness, and monitoring and adaptive management of hatchery programs. Furthermore, purpose, operation, and management of hatchery programmes need to be scientifically defensible, and assumptions under which hatchery programmes operate must be consistent with the best available information. These guidelines were developed primarily for Pacific salmon, but should be transferable to Atlantic salmon populations where they could serve as templates when developing guidelines and recommendations regarding hatchery production and stocking of Baltic salmon.

6.6 Additional comments

In addition to the comments provided above, WKBaltSalMP has a few additional comments to Articles 2 and 14 of the draft multiannual plan:

- Article 2 (paragraph 7). The definition of “potential salmon stock” is unclear. Does it include only rivers with a known historical occurrence of salmon or all rivers that may today harbour a salmon population, for example a river upstream a previously definite migration barrier where a fish way has been (or could be) installed?
- Article 2 (paragraph 8). The term “direct re-stocking” is normally not used and it is questioned whether the term is needed (see comment on Article 15 above).
- Article 2 (new paragraph). A definition of fin-clipping would be useful.
- Article 14. Why are salmon releases for conservation purposes excluded from fin-clipping? Although not aimed at supporting fisheries directly, these releases may also have genetic impacts. If the purpose is to enable stocking of younger life stages (fertilised eggs, fry) for conservation purposes, the aim of these releases (“supportive releases” and/or “reintroductions”) needs to be clearly defined, to avoid possible misuse of these exemptions from the obligatory fin-clipping.

Table 6.3.1. Summary of Baltic salmon fisheries, divided into 5 main categories with information on type of fishery (commercial and/or recreational), gear(s) used and salmon stocks targeted (salmon from wild/reared rivers in SD22–31 and SD 32). Shown is also which commercial fisheries are TAC-regulated, and if mixed or single river stocks are targeted. Parentheses indicate less common gears and stocks. SD 22–29 = Main Basin; SD 30–31 = Gulf of Bothnia; SD 32 = Gulf of Finland.

			Stocks harvested					
	Type of fishery		Wild			Reared		
Main fishing category	Commercial	Recreational	AU 1-3	AU 4-5	AU 6	AU 1-3	AU 5*	AU 6
Offshore sea SD 22-29	longlines TAC (SD 22-31)	trolling	mixed	mixed	(mixed)	mixed	mixed	(mixed)
Coastal sea SD 30-31	trapnets TAC (SD 22-31)	gillnets (trolling, trapnets)	mixed			mixed		
Coastal sea SD 32	gillnets, trapnets TAC (SD 32)	(gillnets, trolling)	(mixed)		mixed	(mixed)		mixed
Wild river SD 22-32		angling (gillnets, dipnets, seines)	single	single	single			
Reared river SD 22-32	trapnets	angling				single	single	single

*** no releases of hatchery reared salmon in AU 4.**

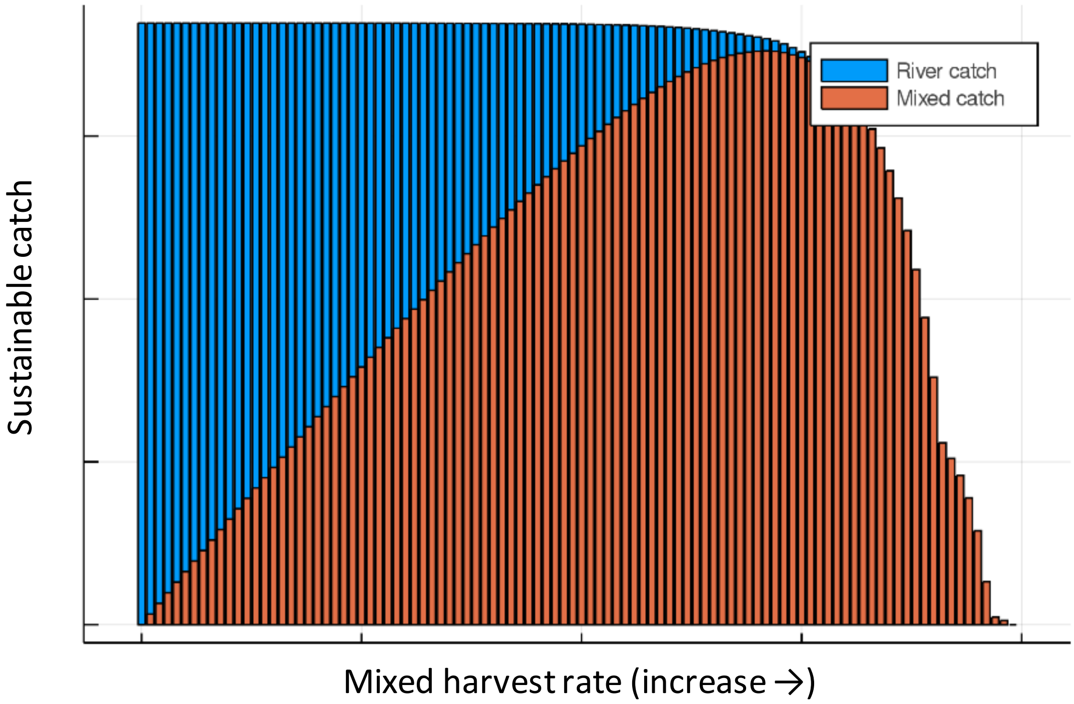


Figure 6.4.1. Total stable state catch and the division of catches between sea and rivers versus mixed sea fishery harvest rate. See text for details.

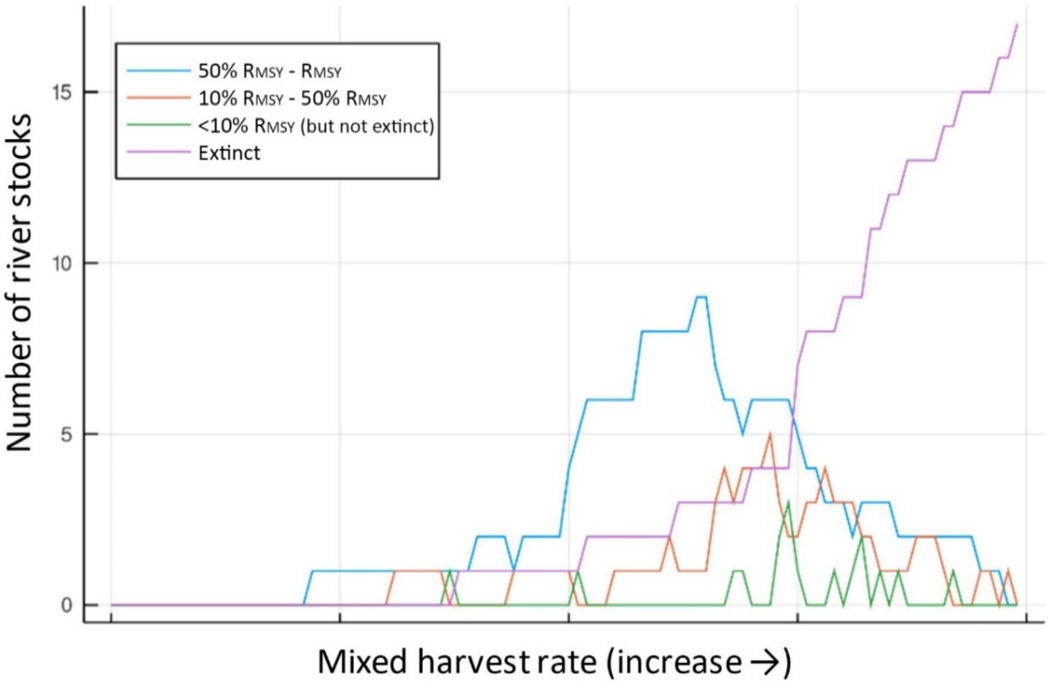


Figure 6.4.2. Status of stocks as a function of mixed-stock harvest rate. Stocks start to fall into probable extinction when harvest rate increase above a certain harvest rate. The x-axis covers the same range of harvest rates as in Figure 6.4.1, from zero to the level where all river stocks would become extinct. The blue line indicates the number of stocks having smolt production in the range 50–100% of R_{MSY}, the orange line indicates the number of stocks having smolt production in the range 10–50% of R_{MSY}, the green line indicates stocks with smolt production less than 10% of R_{MSY} ("barely alive"); and the pink line indicates the number of stocks that have gone extinct. Number of stocks above R_{MSY} not shown.

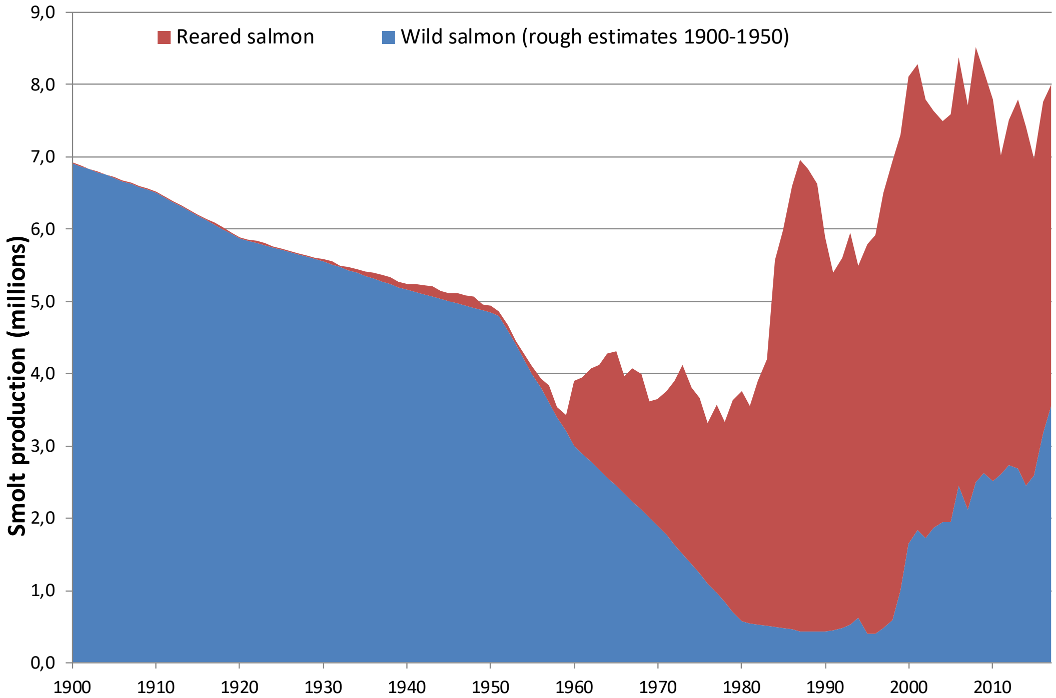


Figure 6.5.1. Wild smolt production and stocking amounts of reared salmon during the period 1900–2017. Releases of younger life stages (eyed eggs, fry and parr) have been converted to "smolt equivalents" to make stocking amounts comparable to wild smolt production.

7 Additional topics

7.1 Flexible management

The management of Baltic salmon and its fisheries is focused primarily on the status of salmon stocks in rivers with natural production (wild and mixed). As discussed in other sections, present status of these stocks differs significantly. Rivers also differ in many other respects, such as size and potential productivity, environmental conditions and fishing patterns, with associated biological differences existing among the local salmon populations (genetics, life-history traits). In many rivers actions are ongoing or planned to improve habitats and migration possibilities (connectivity) for salmon and other organisms. In the discussions, the Workshop concluded that due to this heterogeneity and anticipated future changes for salmon stocks and environments, it is central that management (and the MAP) remains flexible so that it can be adjusted accordingly.

For example, it is important that the list of wild salmon rivers (Annex I) in the management plan is allowed to be regularly updated so that "new" wild rivers can be added (or removed). In potential salmon rivers actions such as stocking and habitat improvements are often performed with the aim of gradually transforming these into self-sustainable rivers that ultimately may receive status as wild following the ICES criteria (ICES, 2018a). Likewise, if (when) supplementary stocking programs are ended in presently mixed rivers (AU 5–6) it is just a matter of years before these could receive status as wild. Sometimes wild rivers may also be downgraded (temporarily) to mixed status by ICES, as is currently the case with Pärnu (Estonia) where large-scaled stocking has been initiated to facilitate recolonization of large production areas located above a recently removed dam that earlier prevented salmon migration (ICES, 2018a).

Another example is the likely need for revision of the reference points. The reference points are estimated using the current population dynamic parameters and fishing pattern. These will likely change over time, and the reference points should be updated accordingly. The need to revise the reference points should be taken into account when developing a management plan.

Although an overarching goal stated in the draft management plan is to achieve "maximum sustainable yield (MSY) as soon as possible", there are good reasons to believe that the present situation with a mix of weak and strong wild river stocks (below/above MSY) will endure, since this is not just related to how fisheries are managed. When new wild salmon rivers are appointed, as described above, these stocks initially (per definition) will have a low status. Similarly, when the total production capacity in existing wild rivers is increased due to enlarged production habitats (e.g. following dam removals) and/or habitat modifications, status will likely be assessed as lower than before. A further reason for weakened stock status not related to fisheries may be local disease problems that decreases the production capacity (such as recently occurred in River Vindelälven). Hence, it can be foreseen that a certain portion of weak wild stocks will always occur, and it is important that that the management system is capable of handling that situation, for example, by accepting "transition periods" for certain weak stocks where the reason(s) for the low status is understood and recovery is to be expected.

7.2 Harvest strategy

The harvest rule suggested in article 5 of the draft multiannual plan (MAP) is relatively simple. It specifies that fishing opportunities for salmon in subdivisions 22 to 31 "shall be fixed in accordance with the objectives and the targets of the plan" and "corresponding to a fishing mortality rate between [… to …]". The range is not defined in the draft plan.

For salmon in Subdivision 32 (Gulf of Finland) the draft MAP operates with an interim harvest rule "until a quantitative assessment is available defining fishing mortality value(s) or a range of values". The interim rule specifies that the fishing opportunities "shall be set at the level improving the wild salmon stock status with a high probability towards the MSYsalmon target levels".

Achieving MSY will require a change in harvest strategy from mixed-stock fisheries towards stock-specific harvesting; as illustrated and discussed in Section 6.4, it will difficult or impossible to achieve the objectives and targets only by managing the commercial sea fisheries, unless the fisheries are at a very low level or closed. At present, four larger northern rivers (Torneälven/Tornionjoki, Kalixälven, Byskeälven and Vindelälven) together account for almost 90% of the total natural smolt production in the Baltic Sea. This means that the contributions to the total yield from most other wild and mixed stocks are limited, and that fishing opportunities are driven by a few large stocks (but note the local stocks typically dominate in coastal catches taken close to the respective river mouths; Whitlock *et al.*, 2018). Because of the need to protect weak stocks, a strategy based on harvesting salmon when they are mixed at the feeding grounds will be suboptimal in terms of the utilization of the most productive stocks. Optimization of the fishing opportunities will require a more stock-specific strategy, where the fisheries are targeting the productive stocks (and reared salmon) and avoid catching salmon from the weak stocks.

The current advice on fishing opportunities for commercial sea fisheries provided by ICES is a compromise between protecting the weak stocks (via expected gradual improvement) and still allow some exploitation of salmon by the commercial sea fisheries. The current harvest rate in the commercial fishery is below the level that would provide MSY for the most productive stocks. However, with the current fishing strategy, increasing the harvest rate towards MSY levels will increase the risk to the weak stocks.

Under the current harvest strategy, only focusing on the mixed-stock fisheries in the offshore and along coasts, the harvest rate will have to be kept at a low level to give some protection to the weak stocks. This means that the need for annual adjustments of the fishing opportunities in the mixed fisheries is limited. WKBaltSalMP does therefore not see the need for annual advice on fishing opportunities for the commercial sea fisheries, and an alternative harvest strategy could be a constant TAC covering a three/four year's period.

7.3 Data needs

The full life-history assessment model of ICES WGBAST has basic data needs that exist independently of the prevailing management regime and implemented objectives. In general, the data collection for Baltic salmon needs to be somewhat improved from its present state in terms of areal coverage, in order to fully meet the data requirements of assessment and management. Ongoing and planned work to develop a separate assessment model for AU 6 stocks as well as potential development towards stock-specific management and consequently stock-specific modelling, also will require maintenance and development of the present data collection in all Baltic Sea riparian countries. Coordination of the data collection takes place both via WGBAST and regional coordination of the EU-MAP data collection.

At present, much focus in the data collection is on monitoring of the largest and most productive salmon rivers, but frequent monitoring is also required for reliable assessment of smaller and weak(er) rivers. Apart from recurrently collected biological data (i.e. parr densities, smolt and spawner counts from river monitoring), fisheries data (catch and effort) from the commercial and recreational fisheries in sea and rivers, including discards, unreporting, misreporting and catch-and-release, are necessary as a solid foundation for the Baltic salmon stock assessment. In addition, river habitat information, tagging and mark–recapture data as well as annual stocking statistics and M74 monitoring (fry mortality) are used. Migration models have also been recently developed (which utilise DNA combined with other information) to provide more precise estimates of stock composition of catches from different coastal areas and time periods (Whitlock *et al*., 2018). Present data requirements and other information used in current assessment is described further in the ICES WGBAST Stock Annex.

Questions on data quality and improvements have been discussed earlier by WGBAST, e.g. at the latest benchmark workshop (ICES, 2017). A particular focus has been on improvements of data on recreational fisheries in sea and rivers, since those fisheries today play a substantial role in the harvesting of Baltic salmon. For example, at present only a few years with data for the offshore trolling exist, even from countries where this fishery has a longer history (going back to the 1990s). Hence, estimates derived by expert elicitation have supplemented earlier parts of these missing time-series. In addition, catch and effort data from relevant rivers in all assessment units is expected to improve estimation of fishing mortality, as just few salmon rivers provide presumed high quality catch data at present.

In line with the 2017 benchmark, WKBaltSalMP particularly recognised the need to improve data quality and coverage in AU 5 and to some extent in AU 6 (both biological and fisheries data). At present, data available from most salmon population in AU 5–6 consists only of parr densities from electrofishing. To allow better understanding of reasons for poor status of river stocks in these areas, additional data on survival between the parr to the smolt stage and for salmon during the sea phase are needed. More information is also required from additional rivers on numbers of smolts and ascending spawners than what is presently available. Further, habitat quality of rearing habitats should be reinvented in many of these rivers, good quality catch data from the whole migration area in sea and in rivers would be needed, and existing estimates (by expert elicitation) on potential unreported or illegal catches should to be re-evaluated. Finally, note that data needs similar to those highlighted above exist also for certain rivers in other parts of the Baltic area (AU 1–4; ICES, 2017).

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Annex 1: EC Request

ICES Request Form

Request from	European Commission, DG MARE, Unit C1
Contact within organisation	David Barba Creo, David.BARBA-CREO@ext.ec.europa.eu +32 22983505
Content contact person	Antoine Kopp, antoine.kopp@ec.europa.eu +3222950418.
Request announced	18/10/2018
Request received	First version: 18/10/2018 Final version:
Answer deadline client	*Date for ICES to make an offer (usually 3 weeks after announcement)* Initial response with clarifying questions: 15 November 2018; follow-up 2 February 2019 Client response to clarifying questions: 15 April 2019 ICES follow-up, suggested approach and further clarification questions: 29 May 2019 Agreement from client on approach: 27 June 2019 Amended request (based on discussions) sent to clients: 10 July 2019 Request accepted: XX xxxx 2019
Request code (client)	1813_Baltic Salmon
Request code (ICES)	
Request	**Evaluation of certain provisions of a draft Baltic salmon management plan**

Background: In 2011 the European Commission adopted a proposal for a regulation of the European Parliament and the Council establishing a multiannual plan for the Baltic salmon stock and the fisheries exploiting it (COM(2011) 470 of 12 August 2011). The proposal aims at restoring and maintaining stocks of salmon in the Baltic Sea at sustainable levels. As the legislator has not yet adopted the plan it should be aligned with the requirements of the Common Fisheries Policy adopted in 2013 taking into account the latest information and status of the salmon stocks.

ICES is requested to advise the Commission on the attached draft of a multiannual management plan for the salmon stocks in the Baltic Sea proposed by BALTFISH ('draft plan').

Like the initial Commission proposal, the draft plan contains in its Annex I a list of the rivers in which wild salmon stocks occur in the Baltic Sea. The draft plan was prepared prior to ICES' advice of 31 May 2018 reviewing the list of the initial Commission proposal. The draft plan includes the addition of the two Swedish rivers but not the deletion of an Estonian river and a Lithuanian river basin For its evaluation, ICES is requested to use Annex I as updated by ICES' advice of 31 May 2018 and not Annex I of the BALTFISH draft plan.

Request:

1) ICES is requested to provide information on river size and potential productivity of wild stocks in the rivers included in Annex I.

2) Article 4 of the draft plan provides that the wild salmon smolt production of each stock listed in Annex I should eventually reach at least 75% of its potential smolt production capacity (i.e. the current MSY-proxy). Depending on the status of a given wild salmon stock at the time of entry into force of the plan, the plan should provide, taking into account the life cycle of salmon, adequate time limits to achieve certain targets: a first target is to reach 50% of the potential smolt production capacity, the second target to reach 75% thereof. The related time limits are marked in the draft plan as 'XX' in Article 4 (2)–(4).

ICES is encouraged to propose alternative options for stock productivity proxies and/or reference points, if more appropriate proxies or values can be determined and estimated.

3) Furthermore, the plan should provide in its Article 5 (2) a fishing mortality range (marked 'between …to…') applicable to the ICES subdivisions 22-31 which is closely linked to the time limits to be defined in Article 4.

ICES is requested to provide an analytical evaluation of the recovery rate of individual wild salmon stocks under alternative fishing scenarios, including an estimation of the number of salmon generations and years required to reach the targets under different F-values for commercial fisheries. The evaluation of the time limits should be based on the stock projections and include fishing scenarios with the exploration rates ranging from F=0 to a level that corresponds to a fishing mortality that will give "MSYsalmon" (Fmsy or Fmsy Upper). In addition, ICES is requested to provide stock projections and stock developments with F-value range in close vicinity of F=0.1, including the relevant time limits.

Defining the MSY approach for salmon in the Baltic ("MSYsalmon") is complicated due to a number of reasons (many wild river stocks of variable status, high proportion of reared salmon exploited in mixed stocks fisheries etc.). Both time to reach the target (per stock) and the proportion of river stocks having reached the target at a certain time, needs to considered when defining Fmsy or Fmsy Upper for salmon in subdivisions 22-31. ICES is request to propose candidate definitions for "MSYsalmon" that are in accordance with the ICES MSY approach.

4) ICES is requested to provide information on the likely impact that alternative time limits, with associated F-values, would have on the stock projections to achieve MSY-targets and the future ICES advice on the fishing possibilities.

Deadline: TBD

Planning ICES	This request will be addressed through two workshops with intersessional work conducted remotely. Following the clarifications during e-mail discussion between Nov 2018 and June 2019, the initial request has been amended slightly. ICES has agreed to provide initial matrices of alternative combinations of MSY, PSPC and probability for attainment of targets based on already available assessment results from WGBAST 2019 (for the analytically assessed AU 1–4 stocks and a range of F-values, showing estimates of expected years until reaching the target). These will be used to inform on the significance of the choices to be made and enable informed discussion in advance of the first scoping meeting. *First ICES Scoping workshop* (WKBaltSalMP I): 2 days, 1–2 October 2019 proposed (the timing and location for the workshop depends on proposals from BALTFISH after the summer break). The first ICES scoping workshop is to be held in conjunction with BALTFISH to ensure good participation of both managers and scientific experts. The aim of this workshop is to facilitate good discussion between managers and scientists to clarify the essential factors in the plan on which basis ICES will give advice (MSY proxy or river specific MSY, most recent PSPC or e.g. PSPC for the last three years and the probability for attainment of the targets etc.). The outcome should include a clear plan for the analyses to be conducted and the results to be presented. A realistic timeline should be agreed between the experts (given the workload and the computing time) and the managers (given their needs for this work to feed into their process). *Second workshop* (WKBaltSalMP II): (TBD at scoping workshop) At the final workshop, results from the agreed analyses will be examined and discussed. A final report will be produced as well as a draft advice responding to the questions in the request. Three external experts will review the report. WGBAST 2020: 31 March to 8 April 2020 During the annual WGBAST meeting, all participants will be able to discuss methods and results. *Advice drafting group* (ADGBaltSalMP): 2 days, (TBD at scoping workshop) Final draft of advice prepared. *Advisory committee web conference* (WCBaltSalMP): (TBD at scoping workshop) Final advice approved Advice release: (TBD at scoping workshop)
Request (budget) accepted	€XXX The complex modelling work needed to answer this request requires significant computing time. Depending on the outcomes of the first scoping workshop, additional budget for high-powered computing time (that would significantly reduce computing time) could be requested, depending on the urgency of the work.
ICES contact person	David Miller (david.miller@ices.dk)
WG(s) involved	WGBAST

Preparation timing	WKBaltSalMP I: 1–2 October 2019 (TBD in consultation with BALTFISH) WKBaltSalMP II: (TBD at scoping workshop) ADGBaltSalMP: (TBD at scoping workshop) WCBaltSalMP: (TBD at scoping workshop) Advice release: (TBD at scoping workshop)
Review group	Three external experts will review the final report. Experts will attend one or both of the workshops to ensure feedback is received throughout the process.
Advice drafting group	ADGBaltSalMP/ADGSalmon
ACOM WebEx	WCBaltSalMP/WCSalmon
Release date	(end of) May 2020

Grey cells to be filled in by ICES.

Annex 2: Draft Multiannual Management Plan

Please see below for the Draft Multiannual Management Plan.

Regulation of the European parliament and of the Council establishing a multiannual plan for the Baltic Salmon stock and the fisheries exploiting that stock

CHAPTER I
SUBJECT MATTER, SCOPE AND DEFINITIONS

Article 1

Subject-matter and scope

1. This Regulation establishes a multiannual plan ('plan') for the Baltic Sea salmon stock and for the fisheries exploiting the salmon stock concerned in the Union waters of the Baltic Sea:

(a) salmon (Salmo salar) in ICES Subdivision 22-31

(b) salmon (Salmo salar) in ICES Subdivision 32

2. The plan shall apply to Union fishing vessels in the Union waters of the Baltic Sea.

Article 2

Definitions

1. For the purposes of this Regulation, in addition to those laid down in Article 4 of Regulation (EU) No 1380/2013 of the European Parliament and of the Council, Article 4 of Council Regulation (EC) No 1224/2009 and Article 2 of Council Regulation (EC) No 2187/2005**,** the following definitions apply:

(1) "Baltic Sea" means ICES Subdivisions 22-32
(2) "Baltic Sea salmon stock" means all salmon stocks in the Baltic Sea;

(3) "wild salmon stock" means a wild salmon stock originating from a river with self-sustaining salmon stock with no or limited releases of reared salmon as listed in the Annex 1.

(4) "potential smolt production capacity" means the production capacity of smolts calculated for each wild salmon stock on the basis of relevant stock -specific parameters;

(5) "stocking" means the deliberate release of smolt or earlier life stages of reared salmon.

(6) “MSYsalmon” (Maximum Sustainable Yield for salmon) means the highest theoretical equilibrium yield that can be continuously taken on average from a stock under existing average environmental conditions without significantly affecting the reproduction process. For wild salmon stocks, MSY and status of individual wild salmon stock is evaluated based on current smolt production in relation to the potential smolt production capacity.

(7) “potential salmon stock” means a salmon stock with little or no natural reproduction and which has the potential for developing into a self-sustaining wild salmon stock.

(8) ‘direct re-stocking’ means the release of smolt or earlier life stages of reared salmon in wild salmon rivers or potential salmon rivers.

CHAPTER II
OBJECTIVES AND TARGETS

Article 3

Objectives of the plan

1. The plan shall contribute to the achievement of the objectives of the common fisheries policy listed in Article 2 of Regulation (EU) No 1380/2013, in particular applying the precautionary approach to fisheries management, and shall aim to ensure that exploitation of the marine biological resources restores and maintains populations of harvested species above levels which can produce the maximum sustainable yield.

2. The plan shall contribute to the elimination of discards, by avoiding and reducing, as far as possible, unwanted catches, and to the implementation of the landing obligation established in Article 15 of Regulation (EU) No 1380/2013 for the Baltic Sea salmon stock covered by this Regulation.

3. The plan shall implement the ecosystem-based approach to fisheries management in order to ensure that negative impacts of fishing activities on the marine ecosystem are minimised. It shall be coherent with the Union environmental legislation, in particular with the objective of achieving good environmental status by 2020 as set out in Article 1(1) of Directive 2008/56/EC and with the objectives of Directive 2000/60/EY.

In particular, the plan shall:

(a) aim to ensure that the conditions described in descriptor 3 contained in Annex I to Directive 2008/56/EC are fulfilled; and

(b) aim to contribute to the fulfilment of other relevant descriptors contained in Annex I to Directive in proportion to the role played by fisheries in their fulfilment.

4. The plan shall contribute to the biodiversity, genetic integrity and diversity of the Baltic Sea salmon stock.

5. Measures under the plan shall be taken in accordance with the best available scientific advice.

Article 4

MSYsalmon target levels for the wild salmon stocks smolt production

1. The plan shall aim at achieving maximum sustainable yield as soon as possible or on a progressive, incremental basis at the latest by 2020 and maintaining thereafter the Baltic Sea salmon stock at the levels which can produce maximum sustainable yield. Such MSY is defined as MSYsalmon.

2. For wild salmon stocks which have reached 50 % of the potential smolt production capacity by the time of the entry into force of this Regulation, the wild smolt production shall reach at least 75% of the potential smolt production capacity for each stock in XX years after the entry into force of this Regulation.

3. For wild salmon stocks which have not reached 50 % of the potential smolt production capacity by the time of the entry into force of this Regulation, the wild smolt production shall reach 50 % of the potential smolt production capacity for each stock in XX years and 75% in XX years after the entry into force of this Regulation.

4. For wild salmon stocks added to the Annex I after the entry into force of this Regulation, the smolt production shall reach 50 % of the potential smolt production capacity within XX years, and reach at least 75% of the potential smolt production capacity in XX years after being added to the Annex I.

5. Wild salmon stocks that have reached a smolt production of 75 % of the potential smolt production capacity shall be maintained at least at that level thereafter.

6. The achievement of the MSYsalmon target levels for the wild salmon production level of the potential production level set in paragraph 2, 3 and 4 shall be estimated as a an average of the three last years salmon smolt production level in each wild salmon stock listed in Annex I.

7. By way of derogation to paragraph 6, for rivers with a catchment area of less than 1000 square kilometers, the achievement of MSY target levels for the wild salmon production level of the potential production level shall be calculated as an average of the best three years out of the last five years of salmon smolt production level in each salmon river.

8. In addition to targets in paragraphs 2, 3 and 4, Member States may set, for each wild salmon stock, additional and/or other more stringent targets and express such additional targets by other means, such as the number of ascending salmon or by other comparable targets.

9. Where, on the basis of a scientific advice, the Commission considers that the salmon stocks listed in Annex I do not correspond to the wild salmon stocks in the Baltic Sea, the Commission may, as a matter of urgency, submit a proposal for the revision of Annex I.

10. Where, on the basis of a scientific advice, the Commission considers that the MSYsalmon target level of 75 % does not correspond to the stock characteristics of a specific salmon stock listed in Annex I, the Commission may, as a matter of urgency, submit a proposal for the revision of the target levels for a specific salmon stock.

CHAPTER III
CONSERVATION REFERENCE POINTS

Article 5

Fishing opportunities

1. In accordance with Article 16(4) of Regulation (EU) No 1380/2013, the fishing opportunities shall be fixed in accordance with the objectives and targets of the plan.

2. With reference to paragraph 1, the fishing opportunities for the Baltic Sea salmon stock in ICES subdivisions 22-31 shall be set at the level corresponding to a fishing mortality rate between […to…].

3. Until a quantitative assessment is available defining fishing mortality value(s) or a range of values, the fishing opportunities for the Baltic Sea salmon stock in the ICES subdivision 32 shall be set at the level improving the wild salmon stock status with a high probability towards the MSYsalmon target levels set in Article 4.

4. A Member State having fishing opportunities of salmon both in the ICES subdivisions 22-31 and in the ICES subdivision 32 may transfer annually no more than 15 % of the fishing opportunities available to that Member in ICES subdivision 22-31 to ICES subdivision 32. Such transfer is allowed, if the sustainability of such transfer for the Baltic Sea salmon stock is supported by scientific advice and if the Member State concerned can demonstrate that majority of the salmon is caught in ICES area 32 as a by-catch that causes choke species situations.

5. Where, on the basis of a scientific advice, the Commission considers that the fishing mortality values or ranges set in paragraph 2 no longer correctly express the objectives of the plan, the Commission may, as a matter of urgency, submit a proposal for revision of those values or ranges.

Article 6

Safeguards

1. When scientific advice indicates that Baltic Sea salmon stock conditions have deteriorated and/or the applied fishing mortality rate is not in accordance with the objectives and targets in Articles 3 and 4, appropriate remedial measures shall be adopted to ensure rapid return of the Baltic Sea salmon stock concerned to target levels as set out in Article 4. These may include Commission measures in case of serious threat to marine biological resources in accordance with Article 12 of Regulation (EU) No 1380/2013, Member State emergency measures in accordance with Article 13 of Regulation (EU) No 1380/2013 or the submission of appropriate legislative proposal for legal acts by the Commission.

2. In case of sudden outburst of diseases, critically low post smolt survival rates or other unforeseen developments, the Council may fix the fishing opportunities at a level which is lower than the one resulting from the application of paragraphs 2 and 3 in Article 5 in order to facilitate the return of the stock concerned to MSY target levels set in Article 4.

3. The choice of measures referred to in this Article shall be made in accordance with the nature, seriousness, duration and repetition of the situation and may take, if supported by the scientific advice, due account of possible choke species situations in other fisheries where salmon occurs as a by-catch.

4. Where, on the basis of scientific advice, the Commission considers that the MSYsalmon target levels set out in Article 4 no longer correctly express the objectives of the plan, the Commission may, as a matter of urgency, submit a proposal for the revision of the MSYsalmon target levels.

Article 7

Member States measures to protect weak wild salmon stocks

1. For wild salmon stocks which have not reached 50 % of the potential smolt production capacity by the time of the entry into force of this Regulation, Member States exploiting such wild salmon stocks, with the exclusion of occasional bycatch, shall establish and apply no later than three years after the entry into force of this Regulation national technical conservation measures in the waters of the Baltic Sea to be applied to its own fishing vessels exploiting salmon stocks referred to in this paragraph.

2. If after the entry into force of this Regulation, wild salmon stocks which have reached the target of 50 % set in Article 4, fall under that target, Member States shall establish and apply national additional technical conservation measures in waters of the Baltic Sea to be applied to its own fishing vessels exploiting such wild salmon stocks, with the exclusion of occasional bycatch,referred to in this paragraph. These additional measures shall be applied at least until the target of 50 % has been achieved.

3. Technical conservation measures referred to in paragraphs 1 and 2 of this Article shall be based on stock specific requirements to adequately contribute to achieving the objectives and targets set in Articles 3 and 4. The location, timing and other relevant provisions of such measures shall be based on best available information on Baltic Sea wild salmon feeding and migration routes in waters of the Baltic Sea.

4. Member States may establish technical conservation measures or other necessary stock recovery measures for potential salmon stocks to be applied to its own fishing vessels exploiting such stocks in the waters of the Baltic Sea.

5. Member States referred to in paragraphs 1 and 2 of this Article, shall notify other Baltic Sea Member States and the European Commission without any undue delays applied measures referred to in paragraphs 1 and 2.

CHAPTER IV
CONTROL AND ENFORCEMENT

Article 8

Relationship with Regulation (EC) No 1224/2009

The control measures provided for in this Chapter shall apply in addition to those provided for in Regulation (EC) No 1224/2009, save where otherwise provided for in this Chapter.

Article 9

Landing declaration

Masters of Union fishing vessels of all lengths fishing for salmon in the Baltic Sea shall provide a landing declaration concerning Baltic Sea salmon at the latest of 48 hours after the landing has ended. This requirement shall also apply for vessels of 12 meters in overall length or more exempted from the obligation to record fishing logbook data electronically.

Article 10

Prior notification

1. Member States shall establish a prior notification obligation applicable to vessels less than 12 meters in overall length and retaining onboard 10 or more individuals of salmon.

2. Member States shall notify the other Baltic Sea Member States and the European Commission of the applied systems referred to in paragraph 1 without any undue delays and no later than one year after the entry into force of this Regulation.

CHAPTER V
PROVISIONS LINKED TO THE LANDING OBLIGATION

Article 11

Provisions linked to implementation of the landing obligation

1. The Commission is empowered to adopt delegated acts in accordance with Article 16 of this Regulation and Article 18 of Regulation No 1380/2013 regarding the following measures:

(a) exemptions from the application of the landing obligation provided for in Article 15(4)(b) of Regulation (EU) No 1380/2013 for species for which scientific evidence demonstrates high survival rates, taking into account the characteristics of the gear, of the fishing practices and of the ecosystem, in order to facilitate the implementation of the landing obligation;

(b) de minimis exemptions in order to facilitate the implementation of the landing obligation; such de minimis exemptions shall be provided for cases referred to in Article 15(54)(c) of Regulation (EU) No 1380/2013 and shall not exceed the percentage points, as foreseen in that Article, of total annual catches of a species subject to the landing obligation to which this plan applies;

(c) specific provisions on documentation of catches, in particular for the purpose of monitoring the implementation of the landing obligation; and

(d) the fixing of minimum conservation reference sizes, with the aim of ensuring the protection of juveniles of marine organisms.

2. The measures referred to in paragraph 1 of this Article shall aim at to achieving the objectives set out in Article 3.

CHAPTER VI
TECHNICAL MEASURES

Article 12

Technical measures

1. The Commission is empowered to adopt delegated acts in accordance with Article 17 of this Regulation and Article 18 of Regulation No 1380/2013 regarding the following measures

(a) specifications of characteristics of fishing gears and rules governing their use to maintain or improve selectivity, to reduce unwanted catches or to minimize negative impact on the ecosystem;

(b) specifications of modifications or additional devices to the fishing gears to maintain or improve selectivity, to reduce unwanted catches or to minimize negative impact on the ecosystem;

(c) limitations or prohibitions on the use of certain fishing gears and on fishing activities or certain areas or periods in order to protect feeding or migrating fish or fish below the minimum conservation reference size or to protect weak salmon stocks; and

(d) minimum conservation reference sizes, with the aim of ensuring the protection of juveniles of marine organisms.

2. The measures referred to in paragraph 1 of this Article shall aim at achieving the objectives set out in Article 3.

CHAPTER VII
REGIONALISATION

Article 13

Regionalisation

1. Article 18 (1) to (6) of Regulation 1380/2013 shall apply to the measures referred to in Articles 11 and 12 of this Regulation.

2. For the purpose of paragraph 1 of this Article, Member States concerned may submit joint recommendations for the first time not later than XXXX and thereafter 12 months after each submission of the evaluation of the plan in accordance with Article 16. They may also submit such recommendations when deemed necessary by the Member States concerned, in particular in the event of an abrupt change in the situation for Baltic Sea salmon stock. Joint recommendations concerning a given calendar year shall be submitted well in advance during the year preceding the planned implementation year.

3. The empowerments granted under Articles 11 and 12 of this Regulation shall be without prejudice to powers conferred to the Commission under other provisions of Union law, including under Regulation (EU) No 1380/2013.

CHAPTER VIII
FIN-CLIPPING AND CONSERVATION MEASURE

Article 14

Fin-clipping

All released parr or older salmon, excluding salmon releases done to establish new salmon stocks or to support existing weak salmon stocks, to the Baltic Sea or to other water bodies with the possibility of the released salmon to migrate to the Baltic Sea must be fin-clipped before stocking.

Article 15

Conservation measure

Direct re-stocking of salmon may be considered as a conservation measure for the purpose of Article 37(2) of Regulation (EU) No 508 /2014 when conducted in order to support the achievement of the objectives and targets in Articles 3 and 4 of this Regulation.

CHAPTER IX
FOLLOW-UP

Article 16

Evaluation of the plan

The Commission shall ensure an evaluation of the impact of this plan on the wild salmon stocks covered by this Regulation and on the fisheries exploiting those stocks, in particular to take account of changes in scientific advice, at the latest three years after the entry into force of the plan or at an earlier stage if deemed necessary by all Member States concerned. Thereafter, the Commission shall ensure an evaluation at least every six years or at earlier stages if deemed necessary by all Member States concerned or by the Commission. The Commission shall submit the results of these those evaluations to the European Parliament and to the Council.

CHAPTER X
PROCEDURAL PROVISIONS

Article 17

Exercise of the delegation

1. The power to adopt delegated acts is conferred on the Commission subject to the conditions laid down in this Article.

2. The delegation of power referred to in Articles 11 and 12 shall be conferred on the Commission for five years for a period of time from the date of the entry into force of this Regulation. The delegation of power shall be tacitly extended for periods of an identical duration, unless the European Parliament or the Council opposes such extension not later than three months before the end of each period.

3. The delegation of power referred to in Articles 11 and 12 may be revoked at any time by the European Parliament or by the Council. A decision of to revoke shall put an end to the delegation of the power specified in that decision. It shall take effect the day following the publication of the decision in the *Official Journal of the European Union* or at a later date specified therein. It shall not affect the validity of any delegated acts already in force.

4. As soon as it adopts a delegated act, the Commission shall notify it simultaneously to the European Parliament and to the Council.

5. A delegated act adopted pursuant to Articles 11 and 12 shall enter into force only if no objection has been expressed either by the European Parliament or the Council within a period of 2 two months of notification of that act to the European Parliament and the Council or if, before the expiry of that period, the European Parliament and to the Council have both informed the Commission that they will not object. That period shall be extended by 2 two months at the initiative of the European Parliament or of the Council.

CHAPTER XI

FINAL PROVISIONS

Article 18

Entry into force

This Regulation shall enter into force on the fifth day following that of its publication in the *Official Journal of the European Union*.

This Regulation shall be binding in its entirety and directly applicable in all Member States.

Done at , XXXX 201 .

ANNEX I

Wild Salmon stocks in the Baltic Sea

Finland

- Simojoki

Finland/Sweden

- Tornionjoki/Torneälven

Sweden

- Kalixälven, Råneälven, Piteälven, Åbyälven, Byskeälven, Rickleån, Sävarån, Ume/Vindelälven, Öreälven, Lögdeälven, Emån, Mörrumsån, Ljungan, Testeboån, Kågeälven

Estonia

- Pärnu, Kunda, Keila, Vasalemma

Latvia

- Salaca, Vitrupe, Peterupe, Irbe, Uzava, Saka

Latvia/Lithuania

- Barta/Bartuva

Lithuania

- Nemunas river basin (Zeimena)

Annex 3: List of participants

The table below represents the experts, managers and stakeholder representatives who participated in WKBaltSalMP (first and/or second meeting):

Name	Institute	Country (of institute)	Email
Olga Adamenko	Ministry of Agriculture Fisheries Department	Latvia	olga.adamenko@zm.gov.lv
Jānis Bajinskis	Fish Resources Research Department, Institute of Food Safety Animal Health and Environment (BIOR)	Latvia	janis.bajinskis@bior.lv
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Annex 4: Summary of WKBaltSalMP I

The Workshop on Evaluating the Draft Baltic Salmon Management Plan (WKBaltSalMP I) met at ICES HQ in Copenhagen, Denmark, on 4–5 November 2019. ICES Chair Stefan Palm (Sweden) and External Chair Eskild Kirkegaard (Denmark) led the meeting. A total of 20 persons attended, including ICES experts, managers from Baltic Sea countries (BALTFISH) and stakeholder representatives (Annex 1).

The overall aim was to scope efforts needed in order to evaluate the draft of a multiannual management plan for the salmon stocks in the Baltic Sea, proposed by BALTFISH, and to respond to the associated specific request from the EC (Annex 2).

Terms of Reference (ToR:s) and the meeting agenda are provided as Annex 3 and 4. In brief, day 1 (November 4th) started with some background information from managers within BALTFISH on the draft plan and EC special request, followed by presentations by ICES/WGBAST experts on basic Baltic salmon biology, stock assessment and the current advice process. The rest of the day was focused on the separate requests, following the meeting ToR:s.

Samu Mäntyniemi (Natural Resources Institute, Finland) initialized most of the specific discussions with presentations of preliminary results. He also demonstrated two analytical tools developed by him, to assist the specific work needed when responding to the EC request:

- **SalmonSimulator** for exploring population dynamics (https://smshiny.shinyapps.io/SalmonSimulator/)
- **Smolt tester** for exploring tradeoff between mean, variance and averaging regarding the probability to exceed a certain threshold (https://smshiny.shinyapps.io/SmoltTester/)

Discussions initiated during the first day continued in day 2 (November 4th). The main purpose of that second day was to plan, in further details, coming work of the experts involved, including next workshop and final reporting. The agenda was produced in the morning, in line with discussions and decisions from day 1. Just some of the managers and stakeholder representatives attended the second meeting day.

Based on the discussions during the workshop, five main themes or "work packages" (WPs), along which continued work should proceed, were identified. Those WPs are briefly described below (with names of those to be mainly responsible) in an approximate order of prioritization. Ultimately, however, working hours available for preparations together with the outcome of the second workshop (WKBaltSalMP 2) will determine contents in the final ICES reporting.

WP1 - Management strategy simulations

Main responsible: Samu Mäntyniemi, Henni Pulkkinen

The Workshop at length discussed management strategy simulations of relevance to address the EC requests no. 2 (reference points), no. 3 (recovery rate of individual stocks), and no. 4 (time lines to achieve MSY-targets). An initial presentation by Samu Mäntyniemi on preliminary analyses of reference points and possible effect on single-stock development of different harvest rates in the commercial sea fisheries formed a good basis for this discussion.

The Workshop focused on work needed as preparation for the second Workshop meeting, and agreed that results from simulations (future projections) should provide the information described below. In particular, it was decided that simulations should be done:

- For each of the stocks/rivers listed in Table 1. The list includes all stocks/rivers for which information is considered sufficient (i.e. 17 stocks at present included in the analytical assessment by WGBAST),
- Including estimated uncertainties in all relevant parameters,
- Accounting for the common (presently used) MSY proxy of $0.75xR_0$ and stock-specific MSY-estimates presented during the meeting,
- Assuming the current fishing effort in river, and
- Assuming the current fishing pattern in the marine fisheries.

The simulations should, for a range of harvest rates from zero and upwards, provide information on:

- Yield in the commercial marine fisheries,
- Smolt production (SP) relative to the maximal theoretical smolt production (R_0) – SP/R_0,
- SP relative to SP at MSY stock level (SP_{MSY}) – SP/SP_{MSY},
- The probability that SP is above $0.75xR_0$ – $P(SP>0.75xR_0)$,
- The probability that SP is above $0.50xR_0$ – $P(SP>0.50xR_0)$,
- The probability that SP is above SP_{MSY} – $P(SP>SP_{MSY})$,
- Estimated catch in the river (river catch),
- River catch if SP is above $0.75xR_0$ with at least 70% probability,
- River catch if SP is above $0.50xR_0$ with at least 70% probability,
- River catch if SP is above SP_{MSY} with at least 50% probability.

The results should be presented by rivers in tables similar to Table 2 in the short term (average after 2 to 8 years) and in the medium term (average after 15 to 25 years).

WP2 - Comments on the draft plan

Main responsible: Johan Dannewitz, Stefan Palm

Managers within BALTFISH expressed a wish to receive general comments from ICES on their last draft plan, in addition to more specific responses to the special request. Accordingly, it was decided that ICES should include such general comments on the draft as part of their response. During the course of the meeting, the following topics related to the draft were discussed:

- The draft plan contains little guidance with respect to how Baltic salmon should be shared as a common resource among exploitation interests (e.g. commercial vs. recreational; sea vs. river).
- The current draft plan seems focused mainly on maintaining the present situation with respect to management framework and tools, fishing patterns, etc. During the meeting, the importance of an adaptive future management was pointed out repeatedly (note that some of the analyses planned within other WPs will address alternative management alternatives).
- The plan is to handle request no. 1 (river size and potential productivity) during next WGBAST-meeting. As commented earlier by ICES (2018), the list of wild Baltic salmon rivers attached to the draft (its Annex I) needs to allow addition of more rivers in the future, e.g. following successful restorations or reduced releases among presently “mixed” (i.e. wild/reared) rivers. If the list is not flexible, this risks incentives to regain viable stocks in previous salmon rivers and reducing supplementary releases.
- It was noted that the present draft contains no clear targets or guidelines regarding future levels of salmon releases, except for possibilities to perform “direct re-stocking” as a conservation measure. In addition, the Workshop discussed the need of being able to distin-

guish between wild and reared salmon, in support to the draft suggestion that all released salmon should be fin-clipped (with exception for "releases done to establish new salmon stocks or to support existing weak salmon stocks").

WP3 - Dynamic harvest rules

Main responsible: Eskild Kirkegaard, Henni Pulkkinen, Atso Romakkaniemi, Samu Mäntyniemi

A recurring theme was the potential (or need) for "dynamic harvest rules" that could assist future assessment and management to reach targets as efficiently as possible. For example, the meeting discussed possibilities and consequences of a management allowing higher fishing pressure at times with strong year classes and *vice versa*. Select examples may be evaluated using "SalmonSimulator" as a tool. Further topics discussed included the following:

- How and when could regional restrictions for the sea fishery (e.g. based on assessment units) be an effective measure to fulfill overarching goals?
- Could future assessment focus on a select subset of salmon rivers (e.g. "data-rich" ones), complemented by use of stock indices for other (data-poor) rivers?
- Could the ICES catch advice be a fixed removal ("TAC") rather than a somewhat fluctuating catch based on a fixed fishing mortality (F, as suggested in the draft plan)? Here "fixed" should mean a level that is constant until a re-evaluation indicates a need for a changed catch (or F). Such re-evaluations should be performed regularly, at least once per salmon generation (c. 5–7 years).
- Related to the point above; how regularly will it be needed to perform analytical stock assessment in the future? Apparently the chosen management strategy will have an effect on how frequently a full assessment would be required, and how often (and what kind of) a lighter assessment process would be sufficient for the management needs.

WP4 - Optimization of fishery yield

Main responsible: Tapani Pakarinen, Samu Mäntyniemi

Present sea fisheries for Baltic salmon target both reared and weak and healthy wild stocks, which are harvested together in mixed-stock fisheries offshore and along the coasts. Moving towards a stock-specific fishery, which could focus more on reared and healthy wild stocks instead of weak wild stocks, might increase the rate of recovery for the weak wild stocks. At the same time, a larger overall catch may be taken in line with the MSY-principle.

During the meeting, Samu Mäntyniemi presented calculations showing how maximum sustainable catches of wild salmon from sea and rivers are expected to vary with the "mixed harvest rate" (i.e. the share of the total catch from a true mixed-stock fishery in the offshore). Additional more realistic calculations could include also reared salmon and coastal fisheries.

WP5 - Assessment units 5 and 6

Main responsible: Atso Romakkaniemi, Martin Kesler, Didzis Uztups, Tapani Pakarinen

So far, salmon stocks in assessment units 5 (SE Baltic) and 6 (Gulf of Finland) are not assessed analytically by WGBAST. One reason is a lack of basic data and necessary expert evaluations for model parameterization. Another reason is the needed work effort for model development. Recently, however, a separate assessment model for AU 6 has been developed, although it will need further evaluations and refinements for the data input before it can be used (ICES, 2019).

According to information from mainly parr data (electrofishing) combined with expert elicitations of potential production capacities, stocks in AU 5 are considered particularly weak, and several of them have shown limited recovery to reductions in exploitation rates at sea. In addition to sea fishing mortality, many rivers in AU 5 and 6 are exposed to local anthropogenic pressures such as eutrophication and poaching, in addition to climate change and, what seems likely, inherently lower productivity (i.e. less steep stock–recruit functions) compared to most northern rivers. However, in several cases it is unclear to what extent salmon production is affected by these "river-specific problems" acting in the freshwater phase.

Hence, a basic question related to the potential recovery of weak southern Baltic rivers is the relative importance of regulating the sea fishery vs. local management actions. During the meeting, some ideas were suggested on how to evaluate this question, including trend-analyses of juvenile data and comparisons with rivers at the same latitude without known local problems. Again, the "SalmonSimulator" analysis tool could be used. It may also be of interest to produce numerical examples showing how many spawners from AU 5 rivers that might be "saved" following potential reductions of the Main Basin mixed fishery (commercial longlining and recreational trolling), in which these weak stocks are harvested together with wild and reared salmon from other parts of the Baltic Sea.

Additional topics discussed

- As an initial part of the reporting, estimates of current stock status in relation to reference points ($0.50xR_0$ and $0.75xR_0$) should be reiterated from ICES' last assessment (ICES, 2019), including a brief explanation of how status is presently assessed and how the six different assessment units are handled.
- Likewise, the estimates of stock-specific MSY presented during the workshop should be included in the report, with a description on definition and how they were derived.
- The possibility of applying ICES standard advisory framework (ICES, 2018b) Advice Basis (https://doi.org/10.17895/ices.pub.4503), including use of the precautionary approach and MSY reference points, was discussed. The Workshop agreed to explore this topic further at the next meeting.
- So far, WGBAST has not been entirely consistent in the use of "harvest rate" and "fishing mortality" in their reporting. It was pointed out that the group should be more consistent in its use of these concepts in the future.
- An evaluation of effects on future projections by assumptions regarding vital rates (e.g. future M74 and post-smolt mortality) would be valuable, as a complement to other planned analyses.
- A note would be needed in the report on how the offshore recreational trolling fishery is presently handled in the analytical assessment, and of the plans (and trials made) to add trolling as a separate fishery in the model.
- The quality of data collected from recreational fisheries at sea is of increasing importance. There is a suggestion within EU (although no decision) to make collection of such data for Baltic salmon mandatory. If so, it will be important that the legislation becomes well adapted to scientific needs.

Continued work: suggested timeline and deliverables

Given the need for ample preparations and other workloads, the meeting identified last week of February 2020 as the earliest time possible for holding the second workshop (WKBaltSalMP 2). The suggestion was to meet February 24–28 in Riga, Latvia (Institute of Food Safety, Animal Health and Environment, BIOR).

- After the 2nd workshop, a complete first draft of the final report should be prepared until March 20th, 2020, i.e. about one week before next WGBAST meeting (scheduled for March 31–April 8). During WGBAST the draft report will be presented to the whole expert group, discussed and worked further upon. A final version should then be ready for review soon after the meeting has been closed.

A draft advice, based on the final report also has to be prepared before the beginning of the RGADG (Review and Advice Group Meeting), scheduled for April 20–23 (in 2020 with one extra day allocated for dealing with the Special Request).

At the meeting, manager representatives within BALTFISH explained the importance of having the response from ICES as "early as possible" so that they will have time to handle the information before the summer. Therefore, the release of the final workshop report and ICES advice will take place already in May 4th 2020. Because of the extra work needed, the meeting raised the option of not performing a full analytical stock assessment. Upon request, ACOM within ICES has allowed a 'short-cut' advice for WGBAST 2020, to grant more time for experts involved to work on the management plan request.

References

ICES. 2018. ICES Special Request Advice: EU request to review the list of Baltic Sea wild salmon rivers in Annex I of the EC Multiannual plan on Baltic Sea salmon. https://doi.org/10.17895/ices.pub.4381

ICES. 2018b. Advice Basis. https://doi.org/10.17895/ices.pub.4503

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Table 1. List of rivers (stocks) to be included in the management strategy simulations, i.e. stocks currently included in analytical assessment (WGBAST 2019).

River
Tornionjoki
Simojoki
Kalixälven
Råneälven
Piteälven
Åbyälven
Byskeälven
Kågeälven
Rickleån
Sävarån
Ume/Vindelälven
Öreälven
Lögdeälven
Ljungan
Testeboån
Emån
Mörrumsån

Table 2. Example of table summarizing simulation results for a particular salmon stock.

	Harvest rate (commercial marine fisheries)											
	0		0.1		0.2		Current harvest rate		….		1.0	
	2–8 years average	15–25 years average	2–8 years average	15–25 years average	2–8 years average	15–25 years average	2–8 years average	15–25 years average	2–8 years average	15–25 years average	2–8 years average	15–25 years average
Yield commercial fisheries												
SP/R_0												
$SP/R\text{-}stock_{MSY}$												
P (SP>75% of R_0)												
P (SP>50% of R_0)												
P (SP>$Stock_{MSY}$)												
River catch assuming current river effort												
River catch if SP is above (SP> 75% R_0) with at least 70% Prob.												
River catch if SP is above (SP> 50% R_0) with at least 70% Prob.												
River catch if SP is above SP_{MSY} with at least 50% Prob.												

Preliminary Agenda: WKBaltSalMP, 4–5 November 2019 (1st ”scoping workshop”)
Monday, November 4

09h00–10h30: Introduction, background presentations

- Housekeeping issues, participants, purpose of WK, reporting, etc. (20 min).
- BaltSalMAP and special request (EC/BALTFISH, 30 min)
- Baltic salmon: life history, fisheries, assessment and advice (WGBAST, 40 min)

10h30–11h00: Coffee break

11h00–12h30: WK ToR:s and connections to the request

1. ToR a)

- Adequate timelines to achieve management targets? Acceptable proportion of stocks having achieved targets?
- MSY; common proxy or stock-specific reference points?
- Probability levels of obtaining management reference points?
- Definition and calculation of PSPC/R0 and current smolt production.

12h30–14h00: Lunch

14h00–15h30: WK ToR:s and connections to the request (cont.)

2. ToR b)

- Needs for potential modifications to the proposed management plan (based on discussions under ToR a)?

3. ToR c)

- Production of clear plan (ToR:s) and timeline for the work to be completed by WKBALTSALMP II.

15h30–16h00: Coffee break

16h00–18h00:

4. Additional aspects related to the request (not included in this WKs ToR:s).

- River size and potential productivity
- F_{MSY}-ranges
- “MSY salmon”

5. Assessment units 5 & 6: current situation and future possibilities
6. Other issues?

Tuesday, November 5

09h00–16h30:

Purpose of 2nd day is for experts to plan their coming work, including next WK (cont. ToR c) and reporting. The agenda will depend on discussions and decisions during day one.

Annex 5: Methods and theory

A5.1 Current methods for assessing stock status

Assessment units 1–4

A Bayesian network model (Uusitalo *et al*., 2005) or corresponding expert elicitation methods have been used to obtain the prior distribution for the PSPC of wild AU 1–4 salmon rivers (see ICES, WGBAST Stock Annex). The methods provide a formal framework for consistently collecting expert opinions or judgements of the different factors affecting the potential smolt production capacity, like area suitable for production, habitat quality and mortality of smolts during downstream migration. This structured information allows inference made of the river-specific PSPC (or K, see Stock Annex). The resulting estimates have been later renewed for some rivers, where e.g. removing migration obstacles have opened more habitat for salmon reproduction. Moreover, additional expert elicitation has been carried out to get estimates of the productivity for those AU 1–4 rivers which were not included in the work of Uusitalo *et al*. (2005).

The above-mentioned estimates are used as prior probability distributions in the Full Life History Model (FLHM) used by WGBAST. FLHM is also fed by various data collected from the Baltic Sea salmon rivers and fisheries (see Stock Annex). Among other things, the model estimates historic river specific smolt and spawner abundances. In the model run, Beverton–Holt stock–recruit functions are fitted simultaneously to the river-specific time-series of smolt and spawner abundance and the prior information about PSPC (Michielsens *et al*., 2008). The resulting posteriors of the PSPCs and smolt abundances are then used to calculate the probability that 50% or 75% of the PSPC will be exceeded in a given year.

Estimating PSPC using the above approach requires also estimation of the so-called unfished equilibrium (R_0 the corresponding smolt production of which equals to PSPC), i.e. the point at which replacement line crosses the stock–recruit curve (see Section 4.2). Before 2018, this point was estimated from the steepness of the stock–recruit curve, which did not properly take into account the vital rates of salmon. In conjunction with transferring the FLHM code between analytical platforms (from WinBUGS to JAGS) during the last benchmark (ICES, 2017) the stock–recruit dynamics was reparametrized in order to overcome this problem (for details, see Stock Annex). Under this parameterization, R_0 varies by year. A final consideration when using the new stock–recruit parameterization is the fact that status is assessed using the ratio of smolt production to unfished (R_0) equilibrium smolt production, i.e. PSPC. Now that R_0 varies by year, an annual R_0 or an average thereof must be used as reference points for status evaluations.

At present, ICES WGBAST provides forecasts for stock developments and catches for subdivisions 22 to 31 based largely on scenarios for future fishing mortality, projected by giving a selection of multipliers for the most recent estimate of instantaneous fishing mortality pattern. The consequences of each multiplier are assessed by evaluating the probability that future smolt production of a particular year exceeds 75% of the potential smolt production capacity (PSPC). This probability is calculated for each river stock for a range of future years. The fishing mortality multipliers that are used in the forecasts are determined based on different options for the total sea removal by the commercial fisheries. The options have typically included the previously advised catch along with a 20% increase and decrease compared to the previous advice (e.g. ICES, 2019b).

The magnitude of commercial fishing pressure is summarised in forecast tables as the level of instantaneous fishing mortality, which is defined as:

$$-\log(1 - HR),$$

where HR is commercial removal divided by pre-fishery abundance. It should be noted that in the case of Baltic salmon the pre-fishery abundance includes also a fraction of the population which is not vulnerable to fishing at all (i.e. immature 1SW salmon). This means that even with very high fishing effort, the harvest rate defined in this way does not approach the value of one.

Each river stock has individual uncertainty about future smolt production. This stems from the fact that different amount of information is available from different river stocks (depending on the amount and type of data collected). Thus, the maximum attainable probability to exceed the 75% PSPC target in a single future year is different for different river stocks.

The forecasts performed in ICES WGBAST are implemented using a population dynamics model which models the river stocks as separate reproduction units, from which the smolts enter the Baltic Sea and its sequential commercial and recreational fisheries. Each river stock is tracked through its life cycle. The model accounts for stochastic natural variation and uncertainty about population dynamic parameters. At present, only river stocks from assessment units in the Gulf of Bothnia and Eastern Baltic Sea main basin (AU 1–4) are included in the analytical assessment model. Work is ongoing to develop a separate model also for salmon in the Gulf of Finland (AU 6). See ICES (2019a, with Stock annex) for details on the model used.

Assessment unit 5

Salmon rivers in AU 5 (Eastern Main Basin) are yet not included in the analytical assessment (FLHM) of WGBAST. At present, the only reliable PSPC estimate for a wild salmon river exists for the Latvian salmon index river Salaca, where smolt counting has been organized annually since 1964 (except for 1984). For Salaca, the river specific PSPC estimate represents an expert's judgement based on information derived from the highest estimated smolt production numbers from the available time-series (mark–recapture data) combined with the mapped available nursery area in the river.

Similarly to Salaca, the estimated PSPCs for other Latvian rivers represent expert's judgments based on multiyear highest estimated smolt production numbers. For the other wild and mixed salmon rivers in Latvia, without smolt counting, smolt production is estimated based on salmon electrofishing data: 0+ parr density (inds./100 m^2) is multiplied by the estimated available nursery area (ha) in the river, and then multiplied with a parr to smolt survival rate derived from Salaca (estimated from parr densities and smolt counts in that river).

Unfortunately, for some of the wild salmon rivers in Latvia (Bārta, Irbe, Saka, Užava), PSPCs estimated in the past are not objective, but are in erroneous or imprecise estimates. The main reason is that past assessments of suitable reproduction areas were not based on actual mapping in the rivers but on remotely gathered information (maps and expert assumptions). Starting from 2018, a reassessment of suitable reproduction areas is carried out including actual habitat mapping in these rivers (where it was not done before), meaning that revisions of previous estimates will follow. This reassessment will be finished by the end of 2020.

For Lithuanian AU 5 rivers, there are similar uncertainties as those described for Latvia, and it is planned to start updating existing estimates of habitat areas and associated potential smolt production capacities in 2020 (to be finished by the end of 2021).

The only Estonian AU 5 river is Pärnu. Until recently, the Sindi dam on the lower part of the river prevented access of salmon to nearly all potential spawning areas. The dam was removed in 2019 and the size of the spawning and rearing areas was inventoried. There are no field data on productivity of these areas (about 40 ha), but based on expert opinion the current PSPC of Pärnu river has been estimated to 30 000 smolts.

Assessment unit 6

The first estimates of PSPC in the Estonian AU 6 rivers date back to the 1990s. At that time, no information about actual smolt production was available and all populations were in a precarious state. The PSPC estimates were based on expert opinion and data on the highest observed parr densities. It was assumed that all smolts were 2-year-old. Highest observed 2-summer-old parr density at that time was 15 ind./100 m^2, and 70% of those fish were assumed to survive to the smolt stage. Therefore, PSPC was estimated to be roughly 10 smolts/100m^2 or 1000 smolts/ha (Wahlberg and Kangur, 2001). That productivity level combined with estimates of available spawning areas formed the basis of the river specific PSPC's. This method is still used for rivers that only have parr density data available. Over the years, the size of spawning areas in Estonian AU 6 rivers have been measured in more detail, which has resulted in some updates to the PSPC estimates.

Smolt trapping and mark–recapture estimates are carried out in River Pirita since 2006. Data from Pirita shows that smolts are commonly one or 2-year-old, and that presence of 1-year-old smolts varies substantially between years (Figure A5.1.1). Abundance of 1-year-old smolts seems to be related to the parr growth during the first summer. Some year classes can migrate as 1-year-olds smolts in great numbers. The fraction of fish from those year classes that remain in the river for a second year are predominantly mature male parr and contribute poorly to a following year's smolt cohort as 2-year-old smolts. Because of above-mentioned reasons, the correlation of 2-summer-old parr density and 2-year-old smolt abundance has large uncertainty.

Actual smolt production in river Pirita has exceeded 1000 smolts/ha (i.e. the initially estimated level of PSPC; above) even if the average parr density has been lower than in neighbouring (wild) rivers. For example, average parr densities in rivers Keila and Kunda have been considerably higher during last five years. This suggests that true PSPC in those rivers could be even higher than that in Pirita.

When total salmonid (salmon and trout) parr density exceeds 100 ind./100m^2, growth is reduced (Figure A5.1.2). If average 0+ parr total length is below 85 mm, 1-year-old smolts are rare or completely lacking in the following spring. Therefore, it can be assumed that smolts in rivers with high parr density are predominantly 2-year-old. Average 2-summer-old parr density in river Keila and Kunda in past five years has been 20 and 30 ind./100 m^2, respectively. Assuming a 70% survival rate until the smolt stage, these parr densities correspond to 1400–2100 smolts/ha. This productivity range has been used as a basis of current PSPC estimates for those rivers.

The PSPC estimate for AU 6 river Kymijoki (mixed, Finland) is based on mapping of the rearing habitat combined with expert evaluations of potential smolt production per area. Whereas there is a good understanding on the available total habitat (165 ha) higher uncertainty surrounds the maximum smolt production per unit of area. No good reference data exist for such a large, regulated (with dams), deep and relatively southern river. The present PSPC for Kymijoki is based on a potential production ranging from 600–1200 smolts/ha, depending on expert. Consequently, expert elicitation suggests that total PSPC is in the range of 100 000–200 000 smolts. The original production capacity before power plants and industrial effluents has been evaluated to 250 000–420 000 smolts.

Smolt trapping has been carried out in the Russian mixed river Luga (AU 6) since 2002. The PSPC estimate is based on mapping of the rearing habitat combined with expert evaluation of potential smolt production per area. Similar to Kymijoki, there is a good understanding of the available total habitat (about 70 ha) whereas higher uncertainty surrounds the maximum smolt production per unit of area (1000–1400 smolts per hectare, depending on expert). Consequently, total PSPC in Luga has been estimated to 70 000–100 000 smolts.

For Russian AU 6 potential river Gladyshevka, without smolt counting, the PSPC estimate is based on expert opinion and data on parr densities. It was assumed that all smolts in Gladyshevka were 2-year-old. Highest observed 2-summer-old parr density was 20–25 ind./100 m^2, and 70% of those fish were assumed to survive to the smolt stage. Therefore, PSPC was estimated to be 1400–1700 smolts/ha, which together with the estimated available spawning area (about 0.7 ha) resulted in a total PSPC for the Gladyshevka in the range of 1000–1200 smolts.

A5.2 Management strategy simulations

As a basis when responding to the EC request, a population dynamic simulator used by WGBAST was further developed and used to estimate smolt production and egg deposition at the level of maximum sustainable yield (MSY). The results were achieved by first simulating the population (river stock) under the assumption of no fishing to a stable state. The long-term stable average of smolt production was then recorded as the PSPC (R_0). The full life-history model used by WGBAST for stock assessment assumes a Beverton–Holt stock–recruitment function. Knowing the values of asymptotic recruitment (K) and egg survival at low densities (alpha parameter) together with R_0 makes it possible to use a simple optimisation algorithm to solve for the smolt production (R_{MSY}) and egg deposition at MSY. Figure 4.2.1 shows a comparison of river stock-specific R_{MSY}/R_0 with the current management objective of 75% R_0 (PSPC).

In order to answer to specific questions in the EC special request, the WGBAST population dynamics simulator was used to evaluate the performance of a range of commercial sea fishing harvest rates in terms of a selection of performance statistics defined as follows:

- E(Sea catch): Expected yield in the commercial and recreational sea fisheries,
- E(Commercial catch): Expected yield in the commercial sea fisheries,
- E(River Catch): Expected catch in the river (river catch),
- E(Spawners): Expected number of spawners,
- E(Smolts/R_0): Expected smolt production (SP) relative to the maximal theoretical smolt production (R_0),
- E(Smolts/R_{MSY}): Expected SP relative to SP at MSY stock level (SP_{MSY}),
- P(Smolts>0.75×R_0): The probability that SP is above 0.75xR_0,
- P(Smolts>0.50×R_0): The probability that SP is above 0.50xR_0,
- P(Smolts>R_{MSY}): The probability that SP is above SP_{MSY},
- P(Smolts>0.75×R_{MSY}): The probability that SP is above 0.75xSP_{MSY},
- P(Smolts>0.50×R_{MSY}): The probability that SP is above 0.50xSP_{MSY},
- P(Smolts>R_{lim}): The probability that SP is above the SP level from which the river stock would be expected to recover to R_{MSY} in one salmon generation (without any fishing).

The above statistics were computed for two different time scales: short-term performance as an average of future years 2–8 and medium-term performance as an average of future years 15–25. The starting year for the simulations was the situation in 2018 (as assessed in the 2019 stock assessment by WGBAST).

The performance statistics were simulated for the following harvest scenarios:

- No fishing: All fishing closed;
- 0 harvest rate: Recreational fishing continues at the current effort level, commercial fishing closed;

- Recreational fishing continues at the current level. Commercial fishing continues at the current fishing pattern with mortalities increased or decreased in such a way that the harvest rate in the simulation period is 0.05, 0.075, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9.

Results of the simulations were compiled in tables specific to each river stock, i.e. those in AU 1–4. All 17 tables (one per river stock) are listed in Annex 6 with electronic version available (ICES, 2020d). As an example, a part of the simulation results for River Simojoki is shown below:

Expected (E) catches and spawner abundances (in 1000s), and probabilities (P) to exceed alternative management targets under different fishing scenarios for the River Simojoki stock under two different timeframes (2–8 and 15–25 years into the future). Results for harvest rates >0.50 not shown.

Harvest rate	No fishing	No fishing	0	0	0.05	0.05	0.075	0.075	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5
Time frame	2-8y	15-25y	2-8y	15-25y	2-8y	15-25y	2-8y	15-25y	2-8y	15-25y	2-8y	15-25y	2-8y	15-25y	2-8y	15-25y	2-8y	15-25y
E(Sea catch)	0	0	0.42	0.39	1.47	1.28	1.86	1.60	2.17	1.81	2.51	1.61	1.68	0.53	0.60	0.03	0.08	0
E(Commercial catch)	0	0	0	0	1.11	0.97	1.53	1.32	1.88	1.57	2.35	1.51	1.61	0.51	0.58	0.03	0.07	0
E(River Catch)	0	0	1.52	1.36	1.19	1.01	1.04	0.87	0.89	0.72	0.42	0.25	0.14	0.04	0.02	0	0	0
E(Spawners)	9.16	8.55	6.19	5.63	4.88	4.27	4.28	3.68	3.70	3.08	1.77	1.14	0.58	0.19	0.10	0.01	0	0
E(Smolts/R_0)	1.03	1.00	0.90	0.85	0.81	0.74	0.77	0.69	0.71	0.62	0.47	0.32	0.22	0.08	0.06	0	0.01	0
E(Smolts/R_{MSY})	1.60	1.56	1.40	1.32	1.27	1.15	1.19	1.06	1.11	0.96	0.73	0.50	0.34	0.12	0.09	0.01	0.01	0
P(Smolts>0.75×R_0)	0.93	0.86	0.76	0.67	0.65	0.54	0.57	0.47	0.48	0.39	0.14	0.07	0.01	0	0	0	0	0
P(Smolts>0.5×R_0)	0.99	0.97	0.94	0.87	0.89	0.78	0.84	0.71	0.79	0.64	0.44	0.27	0.07	0.02	0	0	0	0
P(Smolts>R_{MSY})	0.97	0.93	0.87	0.78	0.77	0.64	0.71	0.57	0.63	0.50	0.25	0.14	0.02	0.01	0	0	0	0
P(Smolts>0.75×R_{MSY})	0.99	0.97	0.94	0.88	0.90	0.79	0.87	0.73	0.81	0.66	0.47	0.29	0.07	0.02	0	0	0	0
P(Smolts>0.5×R_{MSY})	1.00	0.99	0.99	0.95	0.97	0.90	0.94	0.85	0.92	0.80	0.69	0.44	0.24	0.07	0.01	0	0	0
P(Smolts>R_{lim})	1.00	0.99	0.98	0.94	0.96	0.87	0.93	0.83	0.91	0.77	0.64	0.40	0.20	0.06	0.01	0	0	0

Results on the median term (15–25 years) from these stock-specific tables have been summarised in Table 5.1.1. See also Figure 5.1.1, which illustrates the trade-off between yield in mixed (commercial sea) fisheries and the number of stocks reaching their management target (0.75×R_0 or R_{MSY}).

A5.3 R_{lim} and R_{MSY}

To assess status of stocks that are below the MSY level, other reference points could potentially be used. One such proposition is R_{lim}, which is defined as the smolt production level from which the river stock would be expected to recover to R_{MSY} in one salmon generation, if fishing was completely closed. See Section 7.1 for discussion of R_{lim} as a potential reference point.

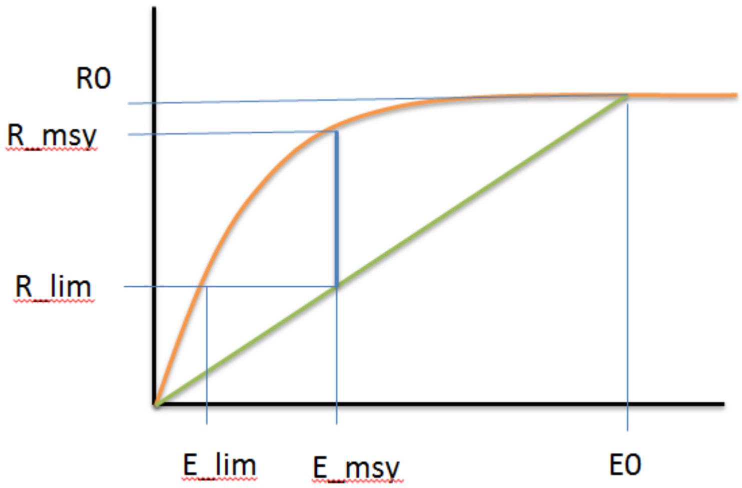
In the Beverton–Holt stock–recruit relationship, number of recruits is defined as $R = \frac{E}{\alpha + \beta E}$ where E is the number of eggs, $\alpha = \frac{1}{slope}$, $\beta = 1/K$, *slope* is the maximum survival of eggs and K is the asymptotic carrying capacity. The replacement line (showing when recruits replace the stock–spawning stock size exactly) crosses the S–R curve at [R_0,E_0]. Thus, the slope of the replacement line is $\frac{R0}{E0}$. Stock-specific values for slope, R_0 and K are estimated in the full life-history model.

We can define the point [R_{lim}, E_{lim}] as the limit at which the stock can recover to MSY-level in one generation under no fishing. Supposing that R_{MSY} and E_{MSY} are known, then:

$$Rlim = Emsy * \frac{R0}{E0}, \text{ and } Elim = {(\alpha\ Rlim)}\Big/{(1 - \beta\ Rlim)}$$

In a practical usage of point [R_{lim}, E_{lim}] in management advice could be to ensure that the probability of falling below the limit is small (say, e.g. <0.05).

The below figure illustrates R_{lim} and R_{MSY} with corresponding levels of egg deposition (E) in a hypothetical stock (Beverton–Holt stock–recruitment function with replacement line) and a maximum smolt production under no fishing at R_0 (PSPC):



A5.4 "SalmonSimulator"

In order to facilitate discussions during workshop meetings, a simplified interactive population dynamics tool, the "Salmon Simulator" (https://smshiny.shinyapps.io/SalmonSimulatorHarvestRule/), was built. The simulator tool features a graphical user interface by which the user can change population dynamic parameters and assumptions about the harvest rule regarding a fictious salmon stock. Many of the model parameters can be set to vary in time according to a mean-reverting autoregressive process, mimicking the effect of environmental variation on a salmon stock.

Uncertainty about constant model parameters is not allowed in the simulator: the main point is to study the stochasticity of the process rather than epistemic uncertainty. The tool was used in the discussions regarding averaging of smolt production in status evaluation, time lags between management decision and expected results and regarding the effects of alternative harvest-control rules to the stability of the population and of the catches.

A5.5 Relative importance of sea survival vs. local factors

To examine if recruitment in AU 5 stocks seem to responds to changes in sea survival, a set of simple statistical analyses were carried out (results in Section 5.2). For comparison, the same analyses were carried out also for the AU 4 and AU 6 (see Section 5.3) stocks. The information about recruitment used consisted of river specific average densities of one-summer old (0+) salmon parr (data included in the annual WGBAST reports; e.g. ICES, 2019a, Tables 3.1.5.1 and 3.1.5.2).

The leading idea was to look at **change in recruitment over each generation**, i.e. how 0+ parr density in year *n* is related to 0+ parr density in year *n*+*x*, where *x* is the salmon generation length. If 0+ parr density in year *n*+*x* is lower than in year *x*, then the relative recruitment has decreased (decreasing stock size over time), while in the opposite situation relative recruitment has increased (increasing stock size over time).

The used generation length estimates were river specific, relying on existing information for prevailing a) smolt age distribution and b) sea age distribution and size of female spawners. In reality both smolt age and sea age vary individually, which means that 0+ parr migrate to the sea and contribute to spawning as adults within a certain range of years (ages). This timely 'spreading' of cohort to various life stages were partially taken into account in the analyses by selecting maximum two (most important) smolt ages and maximum two sea ages, and by weighing the resulting relative contribution to spawning accordingly. For instance, if smolt age 1 and 2 are equally abundant in the stock, and females mature mostly at sea age 2 and 3 with equally large female spawning biomasses, then recruits which were 0+ parr in year *n* have been assumed to contribute to spawning in future years with the following relative weights:

n+3= 0.25
n+4= 0.5
n+5= 0.25

The total contribution of these fish in the future recruitment was calculated as a weighed mean of the years' *n*+4, *n*+5 and *n*+6 densities of 0+ parr.

The change in recruitment, either positive or negative, was then displayed against an index value of sea survival that each generation has been facing during its sea migration period. The index of sea survival consisted of:

- The FLHM result (medians) concerning post-smolt survival of the year(s) the smolts migrated to the sea;
- The FLHM results (medians) concerning offshore harvest rates, of which the two consecutive years when salmon are fully recruited to fishery were taken into account (second and third year at sea; in practice both 2SW and 3SW always constitute important proportions among spawners).

In cases when more than one smolt age must be taken into account, a weighed mean of sea survival index is calculated by using the same idea as presented above. The first ten years of this time-series could not be utilized in the analyses, because time-series of comparable electrofishing data from AU 5 rivers start at earliest in the mid-1990s. It is important to note that the resulting sea survival index is based on the FLHM which covers only AU 1–4 stocks, i.e. **here it is inherently assumed that AU 5 salmon has the same post-smolt mortality and is harvested similarly by offshore fishing as the AU 1–4 salmon**.

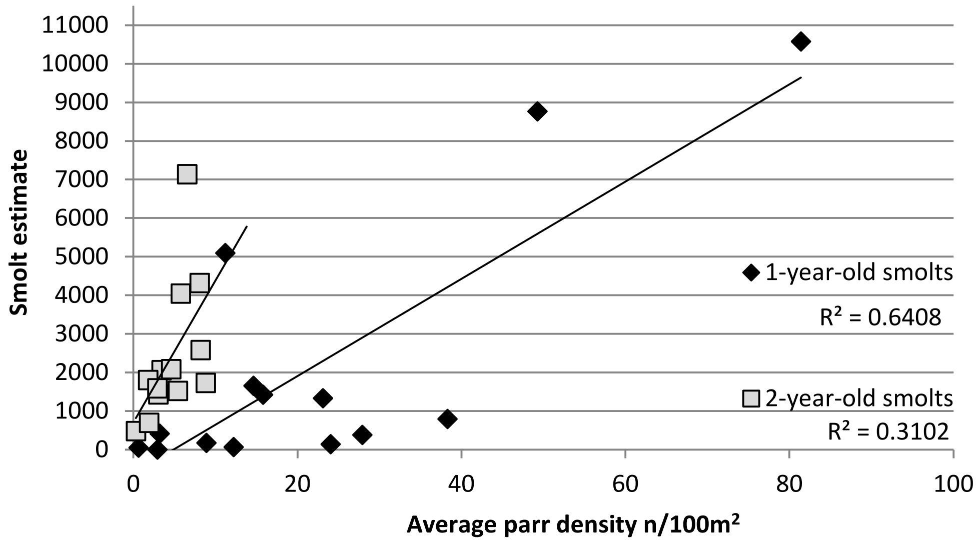


Figure A5.1.1. Relationship between average salmon parr density and smolt abundance in Estonian AU 6 wild river Pirita, 2006–2019.

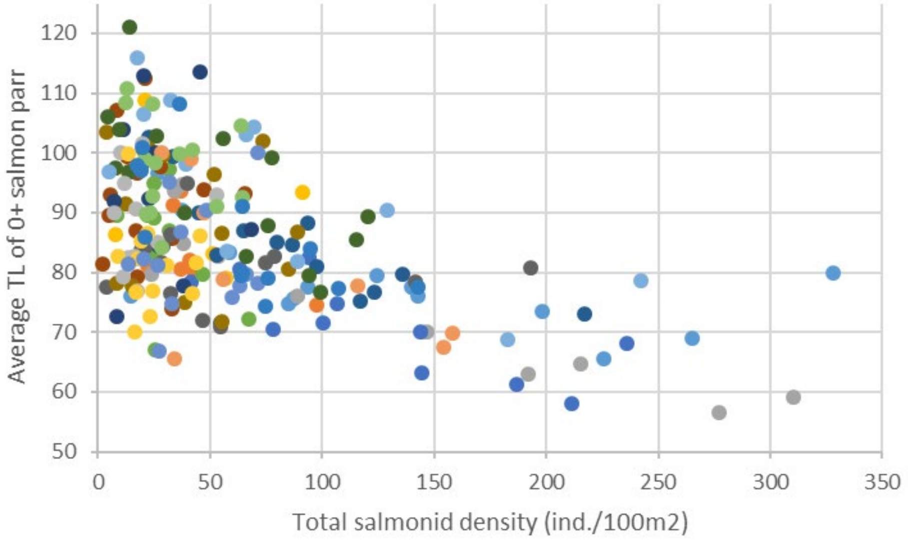


Figure A5.1.2. Relationship between 0+ salmon parr total length (mm) and average salmonid parr density (salmon + trout, all ages combined) in Estonian AU 6 rivers, 2005–2019. Colours mark individual electrofishing sites.

Annex 6: Simulation results

This annex contains 17 river stock specific tables with results from management strategy simulations described in Sections 4 and 5 (technical details in Annex 5). Shown in each table are a number of performance statistics calculated under a range of commercial fishing mortalities averaged for two time-windows into the future, as described below:

Variable (table column)	**Explanation**
Harvest rate	Commercial harvest rate, from 0 to 0.9 (0.075 = current rate)
Time frame	Short (2–8 years average) and medium (15–25 years average) term, from year 2018
E(Sea catch)	Expected yield in the commercial and recreational marine fisheries (1000s of fish)
E(Commercial catch)	Expected yield in the commercial marine fisheries (1000s of fish)
E(River Catch)	Expected catch in the river (1000s of fish)
E(Spawners)	Expected number of spawners (1000s of fish)
E(Smolts/R_0)	Expected smolt production relative to the maximal theoretical smolt production (R_0)
E(Smolts/R_{MSY})	Expected smolt production relative to smolt production at MSY stock level (SP_{MSY})
P(Smolts>0.75×R_0)	Probability that smolt production is above 0.75xR_0
P(Smolts>0.5×R_0)	Probability that smolt production is above 0.50xR_0
P(Smolts>R_{MSY})	Probability that smolt production (SP) is above SP at MSY stock level (SP_{MSY})
P(Smolts>0.75×R_{MSY})	Probability that smolt production is above 0.75xSP_{MSY}
P(Smolts>0.5×R_{MSY})	Probability that smolt production is above 0.50xSP_{MSY}
P(Smolts>R_{lim})	Probability that smolt production is above R_{lim}

The following river-specific tables are listed below, also found in electronic format (ICES, 2020d) (note that only rivers within AU 1–4 are currently included in the analytical assessment by WGBAST):

Table A6.1. Simojoki (AU 1, Finland).

Table A6.2. Tornionjoki/Torneälven (AU 1, Finland/Sweden).

Table A6.3. Kalixälven (AU 1, Sweden).

Table A6.4. Råneälven (AU 1, Sweden).

Table A6.5. Piteälven (AU 2, Sweden).

Table A6.6. Åbyälven (AU 2, Sweden).

Table A6.7. Byskeälven (AU 2, Sweden).

Table A6.8. Kågeälven (AU 2, Sweden).

Table A6.9. Rickleån (AU 2, Sweden).

Table A6.10. Sävarån (AU 2, Sweden).

Table A6.11. Vindelälven (AU 2, Sweden).

Table A6.12. Öreälven (AU 2, Sweden).

Table A6.13. Lögdeälven (AU 2, Sweden).

Table A6.14. Ljungan (AU 3, Sweden).

Table A6.15. Testeboån (AU 3, Sweden).

Table A6.16. Emån (AU 4, Sweden).

Table A6.17. Mörrumsån (AU 4, Sweden).

Table A6.1. Simojoki (AU 1, Finland).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	9.16	1.03	1.60	0.93	0.99	0.97	0.99	1.00	1.00
No fishing	15-25y	0	0	0	8.55	1.00	1.56	0.86	0.97	0.93	0.97	0.99	0.99
0	2-8y	0.42	0	1.52	6.19	0.90	1.40	0.76	0.94	0.87	0.94	0.99	0.98
0	15-25y	0.39	0	1.36	5.63	0.85	1.32	0.67	0.87	0.78	0.88	0.95	0.94
0.05	2-8y	1.47	1.11	1.19	4.88	0.81	1.27	0.65	0.89	0.77	0.90	0.97	0.96
0.05	15-25y	1.28	0.97	1.01	4.27	0.74	1.15	0.54	0.78	0.64	0.79	0.90	0.87
0.075	2-8y	1.86	1.53	1.04	4.28	0.77	1.19	0.57	0.84	0.71	0.87	0.94	0.93
0.075	15-25y	1.60	1.32	0.87	3.68	0.69	1.06	0.47	0.71	0.57	0.73	0.85	0.83
0.1	2-8y	2.17	1.88	0.89	3.70	0.71	1.11	0.48	0.79	0.63	0.81	0.92	0.91
0.1	15-25y	1.81	1.57	0.72	3.08	0.62	0.96	0.39	0.64	0.50	0.66	0.80	0.77
0.2	2-8y	2.51	2.35	0.42	1.77	0.47	0.73	0.14	0.44	0.25	0.47	0.69	0.64
0.2	15-25y	1.61	1.51	0.25	1.14	0.32	0.50	0.07	0.27	0.14	0.29	0.44	0.40
0.3	2-8y	1.68	1.61	0.14	0.58	0.22	0.34	0.01	0.07	0.02	0.07	0.24	0.20
0.3	15-25y	0.53	0.51	0.04	0.19	0.08	0.12	0	0.02	0.01	0.02	0.07	0.06
0.4	2-8y	0.60	0.58	0.02	0.10	0.06	0.09	0	0	0	0	0.01	0.01
0.4	15-25y	0.03	0.03	0	0.01	0	0.01	0	0	0	0	0	0
0.5	2-8y	0.08	0.07	0	0	0.01	0.01	0	0	0	0	0	0
0.5	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.2. Tornionjoki/Torneälven (AU 1, Finland/Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	248.46	1.01	1.31	1.00	1.00	1.00	1.00	1.00	1.00
No fishing	15-25y	0	0	0	236.07	1.00	1.30	0.98	1.00	0.98	1.00	1.00	1.00
0	2-8y	12.56	0	46.22	182.56	0.96	1.26	0.98	1.00	0.97	1.00	1.00	1.00
0	15-25y	11.91	0	43.28	172.68	0.95	1.24	0.94	0.99	0.92	0.98	1.00	1.00
0.05	2-8y	46.28	34.96	38.49	152.79	0.93	1.21	0.94	1.00	0.93	1.00	1.00	1.00
0.05	15-25y	43.46	32.81	35.75	143.21	0.91	1.18	0.88	0.99	0.86	0.98	1.00	1.00
0.075	2-8y	61.40	50.64	35.10	139.45	0.91	1.19	0.92	1.00	0.90	0.99	1.00	1.00
0.075	15-25y	57.33	47.28	32.37	130.18	0.88	1.15	0.84	0.98	0.82	0.96	0.99	1.00
0.1	2-8y	74.97	64.84	31.67	126.01	0.89	1.16	0.88	1.00	0.87	0.99	1.00	1.00
0.1	15-25y	69.66	60.24	29.03	117.08	0.86	1.12	0.79	0.97	0.77	0.95	0.99	1.00
0.2	2-8y	112.34	104.89	19.24	77.33	0.77	1.00	0.61	0.95	0.56	0.88	0.98	1.00
0.2	15-25y	100.79	94.09	16.94	69.24	0.71	0.93	0.49	0.85	0.45	0.77	0.93	0.97
0.3	2-8y	112.08	107.57	9.17	37.23	0.55	0.71	0.15	0.61	0.13	0.47	0.80	0.95
0.3	15-25y	86.16	82.69	6.81	28.72	0.44	0.57	0.10	0.42	0.08	0.31	0.59	0.78
0.4	2-8y	63.79	62.15	2.44	9.98	0.24	0.31	0	0.06	0	0.02	0.17	0.44
0.4	15-25y	22.44	21.87	0.84	3.63	0.09	0.12	0	0.01	0	0.01	0.04	0.11
0.5	2-8y	9.33	9.19	0.12	0.50	0.02	0.03	0	0	0	0	0	0
0.5	15-25y	0.08	0.08	0	0	0	0	0	0	0	0	0	0
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.3. Kalixälven (AU 1, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	93.81	1.01	1.20	1.00	1.00	1.00	1.00	1.00	1.00
No fishing	15-25y	0	0	0	89.07	1.00	1.19	1.00	1.00	0.98	1.00	1.00	1.00
0	2-8y	4.84	0	17.88	70.22	0.98	1.17	1.00	1.00	0.98	1.00	1.00	1.00
0	15-25y	4.58	0	16.84	66.57	0.97	1.16	0.98	1.00	0.93	0.99	1.00	1.00
0.05	2-8y	18.13	13.70	15.26	59.77	0.97	1.15	0.99	1.00	0.96	1.00	1.00	1.00
0.05	15-25y	17.19	12.98	14.32	56.74	0.96	1.14	0.97	1.00	0.89	0.99	1.00	1.00
0.075	2-8y	24.16	19.93	13.97	54.84	0.96	1.14	0.99	1.00	0.94	1.00	1.00	1.00
0.075	15-25y	22.86	18.85	13.11	51.88	0.94	1.12	0.96	0.99	0.86	0.99	1.00	1.00
0.1	2-8y	29.83	25.80	12.75	50.10	0.95	1.12	0.98	1.00	0.91	1.00	1.00	1.00
0.1	15-25y	28.17	24.36	11.94	47.31	0.93	1.10	0.94	0.99	0.82	0.98	0.99	1.00
0.2	2-8y	47.94	44.76	8.34	32.88	0.88	1.04	0.89	0.99	0.69	0.97	1.00	1.00
0.2	15-25y	44.71	41.74	7.74	30.66	0.85	1.01	0.80	0.97	0.60	0.92	0.98	1.00
0.3	2-8y	55.31	53.08	4.60	18.25	0.74	0.88	0.54	0.92	0.28	0.78	0.97	1.00
0.3	15-25y	49.82	47.81	4.10	16.47	0.69	0.82	0.45	0.82	0.24	0.67	0.88	0.98
0.4	2-8y	43.87	42.74	1.69	6.78	0.46	0.55	0.07	0.44	0.02	0.23	0.57	0.93
0.4	15-25y	31.55	30.74	1.19	4.93	0.35	0.41	0.05	0.29	0.02	0.15	0.40	0.70
0.5	2-8y	10.15	9.99	0.14	0.54	0.08	0.09	0	0.01	0	0	0.01	0.13
0.5	15-25y	1.38	1.36	0.02	0.08	0.01	0.01	0	0	0	0	0	0.02
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.4. Råneälven (AU 1, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	10.10	1.02	1.39	0.99	1.00	0.99	1.00	1.00	1.00
No fishing	15-25y	0	0	0	9.74	1.00	1.37	0.98	1.00	0.98	1.00	1.00	1.00
0	2-8y	0.50	0	1.84	7.30	0.96	1.32	0.95	0.99	0.96	0.99	1.00	1.00
0	15-25y	0.48	0	1.73	6.99	0.94	1.29	0.89	0.99	0.90	0.98	1.00	1.00
0.05	2-8y	1.84	1.39	1.52	6.06	0.93	1.27	0.91	0.99	0.92	0.98	1.00	1.00
0.05	15-25y	1.73	1.31	1.41	5.71	0.90	1.23	0.84	0.97	0.85	0.96	0.99	1.00
0.075	2-8y	2.40	1.98	1.37	5.45	0.90	1.24	0.87	0.98	0.88	0.97	0.99	1.00
0.075	15-25y	2.27	1.87	1.26	5.16	0.87	1.19	0.79	0.96	0.82	0.94	0.98	0.99
0.1	2-8y	2.91	2.52	1.23	4.89	0.88	1.20	0.83	0.97	0.85	0.96	0.99	1.00
0.1	15-25y	2.72	2.35	1.12	4.59	0.84	1.15	0.75	0.94	0.77	0.91	0.97	0.98
0.2	2-8y	4.16	3.89	0.72	2.87	0.73	1.00	0.54	0.87	0.58	0.84	0.94	0.97
0.2	15-25y	3.64	3.40	0.61	2.51	0.67	0.92	0.45	0.74	0.48	0.69	0.87	0.91
0.3	2-8y	3.88	3.73	0.32	1.29	0.51	0.69	0.15	0.52	0.17	0.46	0.72	0.84
0.3	15-25y	2.75	2.64	0.22	0.93	0.39	0.54	0.11	0.36	0.13	0.31	0.52	0.61
0.4	2-8y	2.06	2.01	0.08	0.32	0.22	0.30	0.01	0.08	0.01	0.05	0.18	0.31
0.4	15-25y	0.70	0.68	0.03	0.11	0.09	0.12	0.01	0.03	0.01	0.03	0.07	0.11
0.5	2-8y	0.31	0.30	0	0.02	0.02	0.03	0	0	0	0	0	0
0.5	15-25y	0.01	0.01	0	0	0	0	0	0	0	0	0	0
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.5. Piteälven (AU 2, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	2.95	1.00	1.12	1.00	1.00	0.98	1.00	1.00	1.00
No fishing	15-25y	0	0	0	2.81	1.00	1.12	1.00	1.00	0.93	1.00	1.00	1.00
0	2-8y	0.19	0	0.57	2.22	0.99	1.11	1.00	1.00	0.95	1.00	1.00	1.00
0	15-25y	0.18	0	0.54	2.11	0.98	1.10	0.99	1.00	0.88	1.00	1.00	1.00
0.05	2-8y	0.65	0.47	0.50	1.94	0.98	1.10	1.00	1.00	0.92	1.00	1.00	1.00
0.05	15-25y	0.61	0.45	0.47	1.83	0.97	1.08	0.99	1.00	0.85	1.00	1.00	1.00
0.075	2-8y	0.86	0.69	0.46	1.81	0.97	1.09	1.00	1.00	0.91	1.00	1.00	1.00
0.075	15-25y	0.82	0.66	0.44	1.72	0.96	1.08	0.99	1.00	0.81	0.99	1.00	1.00
0.1	2-8y	1.06	0.90	0.43	1.68	0.96	1.08	0.99	1.00	0.89	1.00	1.00	1.00
0.1	15-25y	1.01	0.86	0.41	1.60	0.96	1.07	0.98	1.00	0.79	0.99	1.00	1.00
0.2	2-8y	1.76	1.62	0.31	1.21	0.92	1.03	0.97	1.00	0.71	0.99	1.00	1.00
0.2	15-25y	1.66	1.54	0.29	1.15	0.91	1.02	0.93	0.99	0.63	0.97	1.00	1.00
0.3	2-8y	2.22	2.12	0.20	0.80	0.85	0.95	0.84	0.99	0.38	0.93	0.99	1.00
0.3	15-25y	2.05	1.96	0.19	0.74	0.82	0.91	0.73	0.97	0.33	0.85	0.98	1.00
0.4	2-8y	2.22	2.16	0.11	0.42	0.67	0.75	0.36	0.85	0.07	0.56	0.89	1.00
0.4	15-25y	1.91	1.85	0.09	0.37	0.60	0.67	0.29	0.69	0.07	0.43	0.76	0.98
0.5	2-8y	1.05	1.03	0.02	0.09	0.24	0.27	0	0.09	0	0.02	0.14	0.77
0.5	15-25y	0.46	0.45	0.01	0.04	0.11	0.13	0	0.04	0	0.01	0.06	0.33
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.6. Åbyälven (AU 2, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	2.91	1.03	1.44	0.98	1.00	0.99	1.00	1.00	1.00
No fishing	15-25y	0	0	0	2.79	1.01	1.41	0.96	1.00	0.97	0.99	1.00	1.00
0	2-8y	0.14	0	0.52	2.09	0.97	1.35	0.92	0.99	0.94	0.99	1.00	1.00
0	15-25y	0.14	0	0.49	1.98	0.94	1.31	0.89	0.97	0.90	0.96	0.99	0.99
0.05	2-8y	0.47	0.34	0.44	1.77	0.93	1.30	0.88	0.98	0.90	0.97	0.99	1.00
0.05	15-25y	0.45	0.32	0.41	1.68	0.90	1.25	0.82	0.95	0.85	0.94	0.98	0.99
0.075	2-8y	0.61	0.49	0.40	1.62	0.90	1.26	0.85	0.97	0.87	0.97	0.99	1.00
0.075	15-25y	0.58	0.46	0.37	1.52	0.87	1.22	0.79	0.93	0.81	0.93	0.97	0.98
0.1	2-8y	0.74	0.63	0.36	1.47	0.88	1.22	0.81	0.96	0.84	0.95	0.99	0.99
0.1	15-25y	0.69	0.58	0.34	1.37	0.85	1.18	0.73	0.92	0.77	0.90	0.95	0.97
0.2	2-8y	1.08	1.00	0.23	0.94	0.75	1.05	0.59	0.85	0.64	0.83	0.94	0.96
0.2	15-25y	0.94	0.87	0.20	0.82	0.69	0.96	0.50	0.76	0.54	0.72	0.87	0.90
0.3	2-8y	1.09	1.04	0.12	0.50	0.56	0.79	0.28	0.60	0.33	0.56	0.76	0.82
0.3	15-25y	0.79	0.76	0.09	0.36	0.46	0.64	0.22	0.46	0.25	0.41	0.58	0.65
0.4	2-8y	0.73	0.71	0.04	0.18	0.31	0.43	0.06	0.23	0.07	0.20	0.37	0.45
0.4	15-25y	0.35	0.34	0.02	0.09	0.18	0.25	0.03	0.13	0.04	0.12	0.21	0.26
0.5	2-8y	0.19	0.19	0.01	0.02	0.06	0.09	0	0.01	0	0.01	0.02	0.04
0.5	15-25y	0.03	0.03	0	0	0.01	0.02	0	0.01	0	0	0.01	0.02
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.7. Byskeälven (AU 2, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	18.82	1.01	1.29	1.00	1.00	0.99	1.00	1.00	1.00
No fishing	15-25y	0	0	0	17.91	1.00	1.28	0.98	1.00	0.97	1.00	1.00	1.00
0	2-8y	0.96	0	3.52	13.89	0.97	1.24	0.98	1.00	0.97	1.00	1.00	1.00
0	15-25y	0.91	0	3.33	13.14	0.96	1.22	0.94	0.99	0.93	0.99	1.00	1.00
0.05	2-8y	3.22	2.34	3.07	12.08	0.95	1.22	0.96	0.99	0.94	0.99	1.00	1.00
0.05	15-25y	2.99	2.17	2.84	11.21	0.92	1.18	0.91	0.99	0.88	0.98	0.99	1.00
0.075	2-8y	4.21	3.38	2.82	11.11	0.94	1.20	0.94	0.99	0.92	0.98	1.00	1.00
0.075	15-25y	3.95	3.17	2.63	10.42	0.91	1.17	0.88	0.98	0.85	0.97	0.99	1.00
0.1	2-8y	5.15	4.37	2.59	10.24	0.92	1.18	0.92	0.99	0.90	0.98	1.00	1.00
0.1	15-25y	4.81	4.08	2.41	9.56	0.90	1.15	0.86	0.98	0.82	0.95	0.99	1.00
0.2	2-8y	8.12	7.51	1.77	7.03	0.83	1.07	0.74	0.96	0.70	0.92	0.98	1.00
0.2	15-25y	7.36	6.81	1.59	6.37	0.79	1.02	0.68	0.91	0.61	0.86	0.95	0.98
0.3	2-8y	9.11	8.70	1.03	4.12	0.68	0.87	0.43	0.80	0.37	0.70	0.90	0.97
0.3	15-25y	7.67	7.32	0.86	3.48	0.60	0.77	0.33	0.68	0.28	0.57	0.77	0.91
0.4	2-8y	7.24	7.04	0.44	1.75	0.43	0.55	0.11	0.38	0.07	0.27	0.54	0.78
0.4	15-25y	4.65	4.52	0.28	1.13	0.30	0.38	0.07	0.23	0.05	0.18	0.34	0.52
0.5	2-8y	2.22	2.18	0.06	0.24	0.10	0.13	0	0.02	0	0.01	0.04	0.13
0.5	15-25y	0.45	0.44	0.01	0.05	0.03	0.03	0	0.01	0	0.01	0.01	0.03
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.8. Kågeälven (AU 2, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	5.84	1.01	1.43	0.94	0.99	0.95	0.98	1.00	1.00
No fishing	15-25y	0	0	0	5.59	0.99	1.42	0.91	0.98	0.93	0.98	0.99	0.99
0	2-8y	0.29	0	1.03	4.18	0.93	1.32	0.84	0.95	0.88	0.95	0.98	0.99
0	15-25y	0.27	0	0.97	3.96	0.91	1.29	0.81	0.93	0.84	0.92	0.96	0.97
0.05	2-8y	0.94	0.68	0.88	3.53	0.88	1.25	0.78	0.92	0.83	0.91	0.96	0.97
0.05	15-25y	0.88	0.64	0.81	3.31	0.85	1.21	0.74	0.90	0.79	0.88	0.93	0.95
0.075	2-8y	1.21	0.97	0.79	3.22	0.85	1.21	0.74	0.90	0.79	0.89	0.95	0.96
0.075	15-25y	1.14	0.92	0.74	3.03	0.82	1.17	0.71	0.86	0.76	0.85	0.92	0.93
0.1	2-8y	1.46	1.24	0.72	2.92	0.83	1.17	0.71	0.88	0.75	0.87	0.93	0.95
0.1	15-25y	1.37	1.16	0.66	2.73	0.79	1.13	0.66	0.84	0.71	0.82	0.90	0.91
0.2	2-8y	2.15	1.99	0.46	1.87	0.69	0.98	0.50	0.73	0.56	0.72	0.84	0.87
0.2	15-25y	1.89	1.75	0.40	1.65	0.63	0.89	0.44	0.68	0.50	0.65	0.76	0.79
0.3	2-8y	2.21	2.11	0.25	1.01	0.51	0.72	0.28	0.51	0.33	0.49	0.65	0.68
0.3	15-25y	1.74	1.67	0.19	0.80	0.41	0.59	0.21	0.42	0.26	0.40	0.52	0.56
0.4	2-8y	1.57	1.52	0.09	0.38	0.28	0.40	0.07	0.21	0.08	0.19	0.33	0.39
0.4	15-25y	0.95	0.92	0.05	0.23	0.18	0.25	0.06	0.15	0.08	0.14	0.20	0.22
0.5	2-8y	0.45	0.44	0.01	0.05	0.06	0.09	0.01	0.02	0.01	0.02	0.04	0.05
0.5	15-25y	0.14	0.14	0	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.02	0.02
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.9. Rickleån (AU 2, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	1.46	0.99	1.49	0.93	0.99	0.96	0.99	1.00	1.00
No fishing	15-25y	0	0	0	1.46	1.00	1.50	0.91	0.99	0.95	0.99	1.00	1.00
0	2-8y	0.07	0	0.24	0.99	0.88	1.31	0.76	0.95	0.86	0.95	0.99	0.99
0	15-25y	0.07	0	0.24	1.00	0.88	1.31	0.73	0.93	0.81	0.93	0.97	0.97
0.05	2-8y	0.21	0.15	0.19	0.80	0.80	1.20	0.63	0.90	0.75	0.90	0.97	0.97
0.05	15-25y	0.21	0.15	0.19	0.80	0.79	1.19	0.62	0.86	0.71	0.86	0.94	0.94
0.075	2-8y	0.27	0.22	0.18	0.72	0.76	1.14	0.54	0.86	0.70	0.86	0.96	0.96
0.075	15-25y	0.27	0.21	0.17	0.71	0.75	1.12	0.54	0.81	0.65	0.81	0.92	0.92
0.1	2-8y	0.32	0.27	0.15	0.64	0.72	1.08	0.47	0.83	0.61	0.82	0.93	0.93
0.1	15-25y	0.31	0.26	0.15	0.62	0.69	1.04	0.48	0.75	0.57	0.75	0.89	0.88
0.2	2-8y	0.40	0.37	0.08	0.35	0.51	0.77	0.18	0.51	0.28	0.51	0.74	0.74
0.2	15-25y	0.34	0.31	0.07	0.30	0.44	0.65	0.14	0.41	0.23	0.41	0.60	0.60
0.3	2-8y	0.30	0.28	0.03	0.14	0.27	0.41	0.02	0.15	0.04	0.15	0.33	0.32
0.3	15-25y	0.16	0.15	0.02	0.08	0.15	0.23	0.02	0.06	0.03	0.06	0.16	0.16
0.4	2-8y	0.12	0.12	0.01	0.03	0.09	0.13	0	0	0	0	0.02	0.02
0.4	15-25y	0.02	0.02	0	0.01	0.02	0.02	0	0	0	0	0.01	0.01
0.5	2-8y	0.02	0.02	0	0	0.01	0.01	0	0	0	0	0	0
0.5	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.10. Sävarån (AU 2, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	3.29	1.01	1.53	0.93	0.99	0.97	0.99	1.00	1.00
No fishing	15-25y	0	0	0	3.62	1.02	1.53	0.91	0.99	0.96	0.99	1.00	1.00
0	2-8y	0.15	0	0.53	2.21	0.90	1.36	0.80	0.95	0.87	0.95	0.98	0.98
0	15-25y	0.17	0	0.58	2.44	0.90	1.35	0.77	0.93	0.85	0.94	0.98	0.98
0.05	2-8y	0.48	0.35	0.43	1.78	0.83	1.25	0.70	0.91	0.79	0.91	0.97	0.97
0.05	15-25y	0.53	0.38	0.46	1.97	0.82	1.24	0.67	0.89	0.76	0.89	0.95	0.95
0.075	2-8y	0.60	0.48	0.38	1.58	0.79	1.20	0.64	0.89	0.74	0.89	0.96	0.96
0.075	15-25y	0.66	0.53	0.40	1.73	0.78	1.18	0.60	0.85	0.70	0.85	0.94	0.94
0.1	2-8y	0.70	0.59	0.33	1.39	0.75	1.14	0.56	0.85	0.67	0.85	0.93	0.93
0.1	15-25y	0.76	0.64	0.35	1.50	0.73	1.10	0.53	0.80	0.63	0.80	0.90	0.90
0.2	2-8y	0.85	0.79	0.18	0.75	0.56	0.84	0.25	0.59	0.36	0.59	0.79	0.78
0.2	15-25y	0.80	0.74	0.16	0.70	0.48	0.73	0.21	0.48	0.30	0.48	0.65	0.64
0.3	2-8y	0.62	0.60	0.07	0.29	0.31	0.47	0.04	0.20	0.08	0.21	0.41	0.40
0.3	15-25y	0.37	0.35	0.04	0.17	0.19	0.29	0.03	0.10	0.04	0.10	0.22	0.22
0.4	2-8y	0.26	0.25	0.02	0.07	0.11	0.16	0	0.01	0	0.01	0.05	0.05
0.4	15-25y	0.04	0.04	0	0.01	0.02	0.03	0	0	0	0	0.01	0.01
0.5	2-8y	0.04	0.04	0	0	0.01	0.02	0	0	0	0	0	0
0.5	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.11. Vindelälven (AU 2, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	2.17	0.46	0.82	0.82	0.94	0.91	0.97	0.99	0.96
No fishing	15-25y	0	0	0	1.73	0.76	1.35	0.64	0.80	0.76	0.83	0.90	0.82
0	2-8y	0.74	0	0.64	1.33	0.27	0.49	0.61	0.81	0.75	0.86	0.94	0.85
0	15-25y	0.51	0	0.41	0.91	0.53	0.93	0.39	0.53	0.51	0.60	0.70	0.59
0.05	2-8y	2.17	1.58	0.48	1.01	0.13	0.22	0.47	0.71	0.64	0.77	0.89	0.76
0.05	15-25y	1.30	0.95	0.27	0.61	0.42	0.74	0.24	0.40	0.37	0.46	0.57	0.44
0.075	2-8y	2.63	2.11	0.41	0.86	0.19	0.33	0.41	0.65	0.57	0.71	0.85	0.69
0.075	15-25y	1.47	1.18	0.21	0.49	0.39	0.69	0.18	0.33	0.29	0.38	0.49	0.37
0.1	2-8y	2.95	2.51	0.35	0.73	0.15	0.27	0.35	0.56	0.50	0.66	0.81	0.63
0.1	15-25y	1.50	1.27	0.16	0.38	0.33	0.58	0.14	0.25	0.21	0.30	0.41	0.29
0.2	2-8y	3.03	2.80	0.16	0.33	0.08	0.14	0.11	0.26	0.21	0.32	0.51	0.31
0.2	15-25y	0.83	0.77	0.04	0.09	0.10	0.19	0.03	0.06	0.05	0.08	0.12	0.07
0.3	2-8y	1.92	1.83	0.05	0.11	0.01	0.03	0.03	0.06	0.05	0.08	0.15	0.08
0.3	15-25y	0.15	0.14	0.00	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02
0.4	2-8y	0.83	0.81	0.01	0.03	0	0	0.02	0.02	0.02	0.02	0.03	0.02
0.4	15-25y	0.00	0.00	0	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01
0.5	2-8y	0.19	0.19	0	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01
0.5	15-25y	0	0	0	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.12. Öreälven (AU 2, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	7.25	0.99	1.44	0.94	0.99	0.96	0.99	1.00	1.00
No fishing	15-25y	0	0	0	7.47	1.01	1.46	0.94	0.99	0.97	0.99	1.00	1.00
0	2-8y	0.35	0	1.23	4.97	0.89	1.30	0.80	0.96	0.87	0.96	0.98	0.99
0	15-25y	0.36	0	1.28	5.17	0.91	1.32	0.80	0.96	0.86	0.96	0.98	0.98
0.05	2-8y	1.10	0.80	1.01	4.10	0.83	1.21	0.71	0.93	0.79	0.92	0.98	0.98
0.05	15-25y	1.13	0.82	1.04	4.28	0.85	1.23	0.72	0.92	0.77	0.91	0.97	0.98
0.075	2-8y	1.40	1.12	0.90	3.68	0.80	1.16	0.64	0.91	0.73	0.90	0.97	0.97
0.075	15-25y	1.43	1.15	0.92	3.81	0.81	1.17	0.66	0.88	0.72	0.87	0.96	0.96
0.1	2-8y	1.65	1.40	0.80	3.28	0.76	1.10	0.58	0.87	0.66	0.86	0.95	0.96
0.1	15-25y	1.69	1.43	0.81	3.38	0.77	1.11	0.60	0.85	0.68	0.84	0.93	0.95
0.2	2-8y	2.13	1.97	0.45	1.86	0.58	0.84	0.28	0.62	0.38	0.61	0.81	0.84
0.2	15-25y	2.08	1.92	0.43	1.83	0.55	0.80	0.27	0.58	0.35	0.57	0.74	0.77
0.3	2-8y	1.68	1.60	0.19	0.78	0.35	0.50	0.04	0.27	0.08	0.24	0.47	0.51
0.3	15-25y	1.25	1.20	0.13	0.59	0.25	0.37	0.03	0.16	0.06	0.15	0.30	0.34
0.4	2-8y	0.73	0.71	0.04	0.18	0.13	0.18	0	0.02	0	0.02	0.07	0.09
0.4	15-25y	0.21	0.20	0.01	0.06	0.04	0.05	0	0.01	0	0.01	0.02	0.02
0.5	2-8y	0.11	0.11	0	0.01	0.01	0.02	0	0	0	0	0	0
0.5	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.13. Lögdeälven (AU 2, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	6.29	0.97	1.46	0.90	0.98	0.94	0.98	0.99	0.99
No fishing	15-25y	0	0	0	6.75	1.01	1.52	0.92	0.99	0.97	0.99	1.00	1.00
0	2-8y	0.29	0	1.00	4.16	0.84	1.27	0.72	0.92	0.81	0.92	0.96	0.96
0	15-25y	0.31	0	1.11	4.56	0.88	1.33	0.75	0.93	0.83	0.93	0.97	0.97
0.05	2-8y	0.88	0.64	0.80	3.31	0.77	1.15	0.59	0.86	0.70	0.86	0.93	0.93
0.05	15-25y	0.97	0.70	0.88	3.68	0.81	1.22	0.65	0.87	0.73	0.87	0.94	0.94
0.075	2-8y	1.11	0.89	0.71	2.95	0.72	1.09	0.52	0.82	0.63	0.82	0.92	0.92
0.075	15-25y	1.20	0.96	0.76	3.22	0.75	1.14	0.55	0.82	0.67	0.82	0.92	0.92
0.1	2-8y	1.29	1.09	0.62	2.58	0.68	1.03	0.44	0.76	0.57	0.76	0.89	0.89
0.1	15-25y	1.38	1.17	0.66	2.80	0.70	1.06	0.48	0.76	0.59	0.77	0.89	0.89
0.2	2-8y	1.51	1.40	0.32	1.34	0.48	0.72	0.16	0.46	0.25	0.47	0.68	0.67
0.2	15-25y	1.47	1.36	0.30	1.32	0.45	0.67	0.17	0.42	0.25	0.43	0.61	0.61
0.3	2-8y	1.03	0.99	0.11	0.48	0.25	0.37	0.02	0.12	0.04	0.12	0.27	0.26
0.3	15-25y	0.68	0.65	0.07	0.33	0.16	0.24	0.01	0.08	0.03	0.08	0.17	0.17
0.4	2-8y	0.38	0.37	0.02	0.09	0.08	0.11	0	0.01	0	0.01	0.03	0.03
0.4	15-25y	0.07	0.07	0	0.02	0.02	0.02	0	0	0	0	0.01	0.01
0.5	2-8y	0.05	0.05	0	0.01	0.01	0.01	0	0	0	0	0	0
0.5	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.14. Ljungan (AU 3, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	0.33	1.06	1.67	0.90	0.97	0.94	0.97	0.99	0.98
No fishing	15-25y	0	0	0	0.34	1.05	1.66	0.88	0.97	0.93	0.97	0.98	0.98
0	2-8y	0.01	0	0.05	0.22	0.95	1.49	0.79	0.91	0.85	0.92	0.96	0.94
0	15-25y	0.01	0	0.05	0.22	0.92	1.45	0.75	0.88	0.81	0.89	0.94	0.92
0.05	2-8y	0.05	0.03	0.04	0.17	0.88	1.38	0.71	0.86	0.79	0.87	0.93	0.90
0.05	15-25y	0.04	0.03	0.04	0.17	0.84	1.32	0.66	0.81	0.74	0.81	0.90	0.86
0.075	2-8y	0.06	0.05	0.04	0.16	0.84	1.32	0.67	0.83	0.76	0.84	0.91	0.89
0.075	15-25y	0.05	0.04	0.03	0.15	0.80	1.25	0.63	0.77	0.70	0.78	0.86	0.83
0.1	2-8y	0.07	0.06	0.03	0.14	0.80	1.26	0.63	0.80	0.71	0.81	0.89	0.86
0.1	15-25y	0.06	0.05	0.03	0.13	0.75	1.17	0.56	0.73	0.64	0.74	0.82	0.79
0.2	2-8y	0.08	0.08	0.02	0.08	0.63	0.99	0.42	0.62	0.52	0.62	0.74	0.69
0.2	15-25y	0.07	0.06	0.01	0.06	0.53	0.84	0.34	0.51	0.42	0.53	0.63	0.58
0.3	2-8y	0.07	0.07	0.01	0.03	0.43	0.67	0.22	0.39	0.29	0.41	0.53	0.47
0.3	15-25y	0.05	0.04	0.01	0.02	0.32	0.50	0.19	0.29	0.24	0.29	0.37	0.34
0.4	2-8y	0.04	0.04	0	0.01	0.22	0.35	0.07	0.16	0.10	0.17	0.26	0.21
0.4	15-25y	0.02	0.02	0	0.01	0.13	0.21	0.05	0.11	0.07	0.12	0.16	0.14
0.5	2-8y	0.01	0.01	0	0	0.05	0.08	0	0.02	0.01	0.02	0.03	0.03
0.5	15-25y	0	0	0	0	0.01	0.02	0	0.01	0.01	0.01	0.02	0.01
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.15. Testeboån (AU 3, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	0.45	1.03	1.55	0.94	0.99	0.96	0.99	1.00	1.00
No fishing	15-25y	0	0	0	0.43	1.01	1.52	0.92	0.97	0.95	0.97	0.99	0.99
0	2-8y	0.02	0	0.08	0.32	0.95	1.43	0.86	0.94	0.90	0.94	0.98	0.98
0	15-25y	0.02	0	0.07	0.30	0.92	1.38	0.81	0.93	0.87	0.93	0.96	0.96
0.05	2-8y	0.07	0.05	0.07	0.26	0.90	1.35	0.81	0.92	0.85	0.92	0.96	0.96
0.05	15-25y	0.06	0.05	0.06	0.24	0.86	1.30	0.75	0.89	0.81	0.89	0.94	0.94
0.075	2-8y	0.09	0.07	0.06	0.24	0.88	1.32	0.78	0.90	0.84	0.90	0.95	0.95
0.075	15-25y	0.08	0.06	0.05	0.22	0.83	1.25	0.71	0.87	0.77	0.87	0.92	0.92
0.1	2-8y	0.11	0.09	0.05	0.22	0.85	1.28	0.74	0.88	0.80	0.88	0.93	0.94
0.1	15-25y	0.10	0.08	0.05	0.19	0.80	1.20	0.65	0.83	0.73	0.84	0.90	0.90
0.2	2-8y	0.15	0.14	0.03	0.14	0.71	1.07	0.55	0.75	0.64	0.75	0.85	0.85
0.2	15-25y	0.12	0.11	0.03	0.11	0.63	0.95	0.47	0.64	0.53	0.64	0.75	0.76
0.3	2-8y	0.15	0.14	0.02	0.07	0.54	0.81	0.32	0.55	0.40	0.55	0.68	0.69
0.3	15-25y	0.11	0.11	0.01	0.05	0.44	0.66	0.27	0.44	0.33	0.44	0.55	0.56
0.4	2-8y	0.11	0.11	0.01	0.03	0.32	0.48	0.12	0.27	0.16	0.28	0.39	0.41
0.4	15-25y	0.06	0.06	0	0.02	0.22	0.33	0.09	0.19	0.12	0.19	0.28	0.28
0.5	2-8y	0.04	0.04	0	0	0.09	0.13	0.01	0.04	0.02	0.04	0.07	0.07
0.5	15-25y	0.01	0.01	0	0	0.03	0.05	0.01	0.03	0.02	0.03	0.03	0.03
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.16. Emån (AU 4, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	2.06	0.97	1.65	0.75	0.89	0.86	0.92	0.97	0.93
No fishing	15-25y	0	0	0	2.20	1.01	1.71	0.76	0.90	0.85	0.91	0.96	0.93
0	2-8y	0.08	0	0.29	1.24	0.74	1.25	0.50	0.71	0.64	0.76	0.86	0.78
0	15-25y	0.08	0	0.29	1.26	0.74	1.25	0.51	0.68	0.62	0.71	0.82	0.74
0.05	2-8y	0.19	0.12	0.23	1.01	0.65	1.10	0.41	0.62	0.54	0.67	0.80	0.70
0.05	15-25y	0.18	0.12	0.22	0.99	0.62	1.05	0.39	0.58	0.51	0.62	0.72	0.63
0.075	2-8y	0.23	0.17	0.21	0.90	0.60	1.01	0.35	0.57	0.49	0.63	0.76	0.66
0.075	15-25y	0.21	0.16	0.19	0.86	0.56	0.95	0.34	0.52	0.45	0.55	0.66	0.58
0.1	2-8y	0.26	0.21	0.18	0.80	0.55	0.93	0.30	0.51	0.44	0.57	0.72	0.61
0.1	15-25y	0.23	0.19	0.16	0.74	0.50	0.84	0.27	0.45	0.39	0.50	0.60	0.52
0.2	2-8y	0.30	0.27	0.10	0.45	0.36	0.61	0.13	0.28	0.22	0.33	0.49	0.35
0.2	15-25y	0.21	0.19	0.07	0.34	0.26	0.44	0.09	0.20	0.16	0.23	0.34	0.25
0.3	2-8y	0.22	0.21	0.05	0.20	0.18	0.31	0.03	0.10	0.06	0.12	0.21	0.14
0.3	15-25y	0.10	0.09	0.02	0.09	0.09	0.14	0.01	0.04	0.03	0.05	0.09	0.06
0.4	2-8y	0.11	0.10	0.02	0.06	0.06	0.11	0	0.01	0	0.01	0.04	0.02
0.4	15-25y	0.02	0.02	0	0.01	0.01	0.02	0	0	0	0	0.01	0
0.5	2-8y	0.02	0.02	0	0.01	0.01	0.01	0	0	0	0	0	0
0.5	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Table A6.17. Mörrumsån (AU 4, Sweden).

Harvest rate	Time frame	E(Sea catch)	E(Commercial catch)	E(River Catch)	E(Spawners)	E(Smolts/R_0)	E(Smolts/R_{MSY})	P(Smolts>0.75×R_0)	P(Smolts>0.50×R_0)	P(Smolts>R_{MSY})	P(Smolts>0.75×R_{MSY})	P(Smolts>0.50×R_{MSY})	P(Smolts>R_{lim})
No fishing	2-8y	0	0	0	6.29	1.03	1.46	0.97	0.99	0.97	0.99	1.00	1.00
No fishing	15-25y	0	0	0	5.92	1.01	1.43	0.93	0.98	0.94	0.98	0.99	0.99
0	2-8y	0.28	0	1.13	4.51	0.96	1.36	0.89	0.98	0.92	0.97	0.99	1.00
0	15-25y	0.27	0	1.06	4.21	0.93	1.32	0.85	0.95	0.88	0.94	0.97	0.98
0.05	2-8y	0.74	0.49	1.00	4.01	0.93	1.32	0.85	0.96	0.88	0.96	0.98	0.99
0.05	15-25y	0.69	0.45	0.93	3.72	0.89	1.27	0.79	0.92	0.83	0.91	0.96	0.97
0.075	2-8y	0.95	0.71	0.95	3.77	0.91	1.29	0.82	0.95	0.86	0.95	0.98	0.98
0.075	15-25y	0.88	0.66	0.88	3.50	0.87	1.24	0.76	0.91	0.80	0.90	0.95	0.96
0.1	2-8y	1.14	0.92	0.89	3.54	0.89	1.27	0.79	0.94	0.83	0.94	0.98	0.98
0.1	15-25y	1.05	0.84	0.82	3.26	0.85	1.21	0.72	0.89	0.77	0.88	0.94	0.96
0.2	2-8y	1.75	1.58	0.66	2.65	0.80	1.13	0.65	0.86	0.71	0.84	0.93	0.95
0.2	15-25y	1.56	1.40	0.59	2.35	0.74	1.05	0.57	0.77	0.63	0.75	0.85	0.87
0.3	2-8y	2.03	1.91	0.46	1.82	0.67	0.95	0.46	0.69	0.51	0.67	0.81	0.85
0.3	15-25y	1.68	1.58	0.38	1.51	0.59	0.83	0.42	0.60	0.45	0.57	0.69	0.72
0.4	2-8y	1.89	1.82	0.27	1.08	0.50	0.70	0.29	0.46	0.32	0.45	0.59	0.64
0.4	15-25y	1.42	1.37	0.20	0.81	0.40	0.57	0.26	0.39	0.28	0.38	0.46	0.50
0.5	2-8y	1.22	1.20	0.11	0.45	0.26	0.38	0.12	0.23	0.14	0.21	0.29	0.32
0.5	15-25y	0.79	0.78	0.07	0.29	0.19	0.27	0.11	0.19	0.13	0.18	0.23	0.24
0.6	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.6	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.7	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.8	15-25y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	2-8y	0	0	0	0	0	0	0	0	0	0	0	0
0.9	15-25y	0	0	0	0	0	0	0	0	0	0	0	0

Annex 7: Technical minutes from the Salmon Review Group

Review of WKBALTSALMP 2020. Carrie Holt, 20 April 2020

This report provides responses to the request from the European Commission on the "Evaluation of certain provisions of a draft Baltic salmon management plan". The responses and associated advice are well supported by information compiled from previous assessments and new analytical tools and analyses. My review is aligned by request numbers 1–4, below.

Request 1 - to provide information on river size and potential productivity of wild stocks included in Annex I to the draft multiannual plan:

- No comments. The information requested is provided in Table 3.1 of the report.

Request 2 - to propose alternative options for stock productivity proxies/or reference points:

R_{MSY}

- The smolt production required to produce the maximum sustainable yield (R_{MSY}) is more closely aligned with the ICES MSY approach than previously used targets, 50% or 75% of R_0, and I support its application as a productivity reference point now that stock-specific R_{MSY} values can be estimated for rivers in AU1–4.

R_{lim}

- Also, I support ICES advice to apply the reference point R_{lim} as an interim target for weak salmon river stocks during the recovery phase, where R_{lim} is the lowest smolt production level from which the river stock would be expected to recover to R_{MSY} in one salmon generation, if all fishing were completely closed.
- I further suggest that R_{lim} can be considered a precautionary reference point as defined by ICES advice on an MSY approach (B_{lim}, a precautionary reference point, is "a deterministic biomass limit below which a stock is considered to have reduced reproductive capacity", ICES Advice 2017, Book 12).
- Even though R_{lim} is not in absolute terms (report Section 4.2 (p.16) and 4.3 (p19)) it may still be appropriate as a precautionary reference point. Although, I agree, R_{lim} has not been evaluated in a PVA for Baltic Salmon, in Canada, a similar B_{lim} is used as a lower conservation reference point for Pacific salmon (i.e. abundances associated with recovery to MSY levels in one generation in the absence of fishing). Based on a simulation evaluation on Pacific salmon, this reference point was associated with relatively low probability of extirpation and was more robust to variability in productivity than other stock–recruitment reference points (Holt 2009; Holt and Bradford 2011). The one caveat, as mentioned below, is that it should be replaced by an absolute threshold (e.g. 250, 1000, or 2500) for small populations that approach these low levels.
- As described in the report, for stocks that are consistently at low levels < 250, 1000, or 2500 because of limited freshwater capacity, the population may experience conservation risks even if abundances are > B_{lim} (smolt abundances > R_{lim}). In contrast, for dominant stocks (e.g. Torneälven/Tornionjoki), there would be significant conservation risks far before abundances dropped below 1000 (or 250 or 2500, conservation thresholds from

the ecological literature), so B_{lim} (or R_{lim}) could be a useful reference point for conservation risks when stock size > lower absolute lower limits.

- In addition, the ICES MSY approach identifies B_{pa} as a precautionary buffer above B_{lim}. "If there is less than a 5% probability that SSB < B_{lim} it is considered that SSB > B_{pa}" (ICES Advice 2017, Book 12), supporting the application of 95% probability of achieving R_{lim} in the report.
- In the application of B_{MSY} and B_{lim} for Pacific salmon, there are large uncertainties in both reference points due to uncertainty in the underlying stock–recruitment relationship, such that C*I*s overlap. Is this the case here? If B_{lim} is highly uncertain, then 95% of being > B_{lim} could be > than median estimate of B_{MSY}. (See my related question under response to request 3).
- Also, for Pacific salmon, when resilience (productivity) is extremely low, we find that this limit reference point can approach B_{MSY} such that they are indistinguishable.

References points for AU5 and AU6

- Ignoring effects of partial migration obstacles is expected to result in unrealistically high PSPC estimates. The example provided for this is in AU2 (River Vindelälven). Page 25 states "In most AU 5 rivers migration obstacles are factors of minor importance…", so this might primarily be an issue for AU 6 and not AU 5?
- This highlights a fundamental issue of shifting baselines in capacity. To what level is smolt production to be restored? (Indefinitely or pristine levels)? The goal of pristine smolt production may not feasible, given (1) it is uncertain what pristine smolt production capacity was (all potential rivers, or beyond that?), and (2) there are competing demands on land/rivers that may require barriers, etc. It is clear that removing barriers reduces apparent status, so it seems as if ICES is currently working with a moving PSPC target.
- As mentioned in the text, changes in habitat quality can affect intrinsic productivity and hence reference points. While, productivity and associated reference points should be reassessed periodically (e.g. ~3–5 years), I caution against chasing noise due to observation or assessment errors.
  - See Duplisea and Cadigan (2012) and Holt and Michielsens (2019) for some best practices when revising reference points.
- I strongly agree with "Thus, there remains a need for river specific (or even AU specific) 'recovery plans' in the future management of Baltic Sea salmon, which holistically integrate management of environment and management of fisheries." (p. 18).

Request 3 - to provide an analytical evaluation of the recovery rate of individual wild salmon stocks under alternative fishing scenarios and to propose candidate definitions for "MSYsalmon":

- The report states that neither the request nor the draft multiannual plan specify criteria for when a target is reached, but doesn't explicitly state what criteria are missing. I interpret this to mean that neither specified the probability of achieving the current targets (50% and 75% PSPC; those targets *are* specified in the MAP), if other targets (e.g. R_{MSY}, R_{lim}) should be considered, and possibly if annual or short-term averages of R_0 should be used to estimate targets. Are there other components for identifying when a target is reached that are required?
- Figure 5.1.1 shows results for probability of recovery to various targets over short and medium terms.
  - The limit reference point, R_{lim}, should be lower than target (R_{MSY} or 75% R_0), so that the proportion of rivers > R_{lim} should be higher or equal to proportion of rivers >R_{target}. The panels on the bottom row show proportion of rivers > R_{MSY} in grey. Why is

the proportion of rivers > R_{lim} (green line) sometimes lower than proportion of rivers >R_{MSY}. Is this because 95% probability being above R_{lim} is used as the threshold of meeting that criteria, instead of only a 70% probability of being above R_{MSY}? In this scenario, the R_{MSY} would not be an appropriate target, and this should be highlighted.

- For the top panels, R_{target} is the proportion of rivers >75% R_0, which could be less R_{lim} for stocks with very low productivity. In these cases, 75% R_0 may be < R_{MSY} and R_{lim}, and therefore would not reflect MSY levels and again, would not be an appropriate target.

- In general, I suggest that the management plan should include the conceptual target, e.g. "MSY levels", and ICES analysts should identify the most appropriate indices/metrics to allow flexibility for analytical improvements.
- Figure 5.1.1 provides a clear illustration of trade-offs between aggregate catch and proportion of rivers dropping below targets and limits over two timeframes. To emphasize, before making decisions based on these plots, managers and decision makers need to carefully consider acceptable probabilities of being above reference points and timeframes for being above the reference points. Furthermore, the previous benchmark report highlighted the question of whether to use annual reference points or multiyear averages and it's not clear to me if this was resolved.
- For AU 5, the conclusion that different areas/rivers will likely need different measures to recover weak salmon stocks is reasonable, and that the management of sea fisheries may be insufficient to rebuild the stocks on its own. The analyses identified that sea survival may play a role in recruitment (variation in parr densities), but other factors also contribute.
- For AU 6, parr densities were independent of sea survival, suggesting local factors may have an even stronger role in future recovery. Given the slow recolonization of newly accessibly areas, to what extent will habitat amelioration or stocking be required to improve status?

Request 4 - to provide information on the likely impact that alternative time limits, with associated F-values, would have on the stock projections to achieve MSY-targets and the future ICES advice on the fishing possibilities

- I agree that it's not realistic to set a timeframe given the only lever applied here is the mixed-stock sea fishery, and recovery will require additional management interventions. However, T_{min}, the timeframe for recovery to a specified target with a specified probability in the absence of fishing under average (current) conditions could be estimated. Stocks for which recovery is not possible without fishing given current average conditions could also be highlighted.

Additional request on other comments on the draft multiannual plan

ICES advises that the mixing of salmon between the two current management units (SD 22–31 and SD 32) is too high to justify two separate management units for Baltic Salmon.

- Given mixing among management units, this advice is reasonable.

ICES advises that to meet the objectives and targets of the draft multiannual plan, the plan should be widen to include all important fisheries and not only the commercial sea fisheries.

- Doing so would allow for a broader suite of management strategies that can better achieve multiple objectives. Identifying a suite of feasible management strategies and negotiating trade-offs among competing objectives will require in-depth and iterative dialogue among scientists, stakeholders and decision makers. If this advice is adopted, I suggest developing a more interactive collaborative framework among scientists, stakeholders, and decision makers to allow for this level of dialogue.
- I suggest further emphasizing that the focusing on the goal of aggregate MSY has significant negative impacts on the genetic diversity of Baltic salmon (objective 1 of the MAP). This could be further emphasized in Section 6.4, page 35, 2nd to last paragraph. The last paragraph mentions that some rivers could even go extinct, which is incongruent with the current objective of maintaining genetic diversity, and may threaten long-term sustainability of Baltic salmon. Note, this argument may be strengthened if evolutionary significance of genetic differences among stocks can be clearly demonstrated. Do river stocks have heritable phenotypic or behavioural differences? If so, this diversity may be necessary for adaptation to future shifts in conditions related to climate and other anthropogenic stressors.

ICES advises to include in a management plan measures to maximize the harvesting of reared salmon and guidelines for management of hatchery populations and stocking activities with different aims.

- I agree that Member States should develop a long-term plan identifying purposes of stocking and how stocking activities should be managed. These plans should also be integrated with harvest and habitat planning, as rebuilding may require the coordination of all three.
- Given current scientific evidence from ICES, US and Canada, I agree that stocking should not be used as a general measure to fulfil the objectives of the management plan.

ICES advices that the list of wild salmon rivers in the multiannual plan (Annex I) should be flexible with possibilities to regularly include (or remove) rivers also in the future.

- Agreed

Minor comments

- **In Figure 5.1.1,** $F_{0.1}$ is confusing, as here it is a harvest rate = 10%, whereas F is usually reserved for instantaneous fishing mortality, F= $-\log_e(1\text{-hr})$ where hr=proportion of biomass harvested, harvest rate.
- **Last sentence on page 22** "Current harvest rate (2018) is slightly less than 0.1. If this level would be kept for the next 30 years, the mixed-fishery catches in short and medium-term would be about 50–60% of the maximum, but the proportion of rivers reaching the objectives illustrated here would be *considerably higher* (40–60%)." Considerably higher than which? The current proportion? Table 4.1.1 shows 9/27 (~33%) wild stocks currently have >70% probability of being >75% R_0.
- For evaluation of recovery for AU 5, "If offshore fisheries were closed, the amount of returning AU 5 salmon would in short-term increase to about 5000 salmon." (page 23). Are these calculations and the specific assumptions used documented in the report?
- Note, the exchangeability between mixed and river catch in **Figure 6.4.1** may be unrealistic due to allocation objectives for various fisheries that are non-transferable. However,

this does highlight the possible benefits for river fisheries if mixed-fisheries continue to be or are further curtailed for conservation of weak stocks.

- Figure 6.4.2
  - I don’t think the results in Figure 6.4.2 are directly comparable to results from Figure 5.1.1, although both show the proportion of rivers with status relative R_{target} and R_{lim}, since analyses underlying Figure 6.4.2 did not use the management strategy simulations described in Appendix A5.2. I suggest explicitly stating this.
  - I assume the legend means: blue line number of rivers stocks with smolt production between 50% of R_{MSY} and R_{MSY}, etc? If so, I suggest explaining this explicitly in the caption.
  - When the mixed harvest rate is low, presumably, the river stocks all have smolt production > R_{MSY}, and hence are not shown on the plot?
  - Do the tic marks in Figure 6.4.1 line up with those in Figure 6.4.2, such that the steep drop off in Figure 6.4.1 starts to occur when the number of rivers stocks between 10% and 50% of R_{MSY} (orange line) peaks?
  - What does “barely alive mean”? How is extinction defined exactly? (drops to zero for one year, 1 generation, etc.)