5 Reference points and assessment of salmon in Main Basin and Gulf of Bothnia (Subdivisions 22–31)

5.1 Introduction

A Bayesian approach to statistical inference (Gelman *et al.*, 1995) has been used for the assessment of Baltic salmon. This approach permits a probabilistic approach to fisheries stock assessment in which uncertainties about unobserved quantities are formulated as probability distributions (McAllister and Kirkwood, 1998). It also allows a diverse range of data and expertise to be incorporated probabilistically into the stock assessment and the input to be specified in a formal and probabilistic manner.

The key idea of the Bayesian approach is to express the prior knowledge about parameters of interest (population parameters, catchability, tag reporting rate, etc.) in the form of probability distributions, and then update the knowledge about the parameters by using empirical observations. The distribution which describes the degree of knowledge before obtaining empirical observations is called the prior (probability) distribution. The distribution updated by empirical observations is called the posterior (probability) distribution which is seen as a formal compromise between the prior knowledge and information contained in observations. Generally, small amounts of data result in small updates of the prior knowledge and large amounts of data results in more substantial updates of knowledge. Posterior distributions obtained from the analysis of one data set can be used as prior distributions in the analysis of another data set. This way the Bayesian approach serves as a formal tool for scientific learning as the information from multiple data sets accumulates to the posterior distribution.

The probability distributions are analyzed using Monte Carlo simulation methods such as Markov Chain Monte Carlo (MCMC) methods and specialized software such as WinBUGS and Hugin have been used to calculate the probability distributions of interest based on the statistical models and prior probability distributions. The statistics most frequently used to describe a probability distribution (i.e. mode, median, mean, 95% probability interval) are illustrated by Figure 5.1.1. The data and the parameter settings used to assess the Baltic salmon have been reported according to guidelines provided by the ICES Working Group on Methods for Fish Stock Assessment (ICES 2004a).

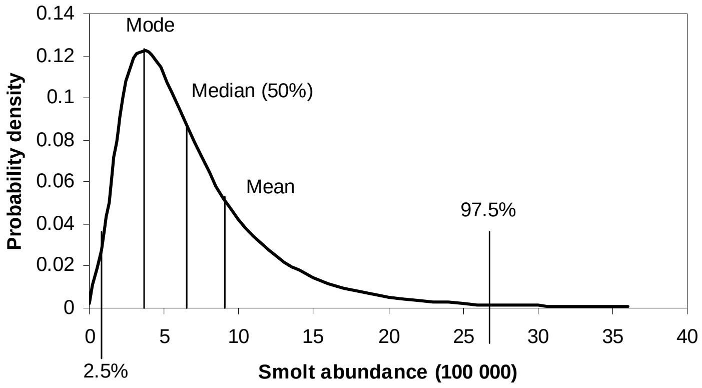


Figure 5.1.1. Example of a posterior distribution for smolt abundance. The location of different statistics which are used to describe posterior distributions in the report are indicated by vertical lines in the figure. Most of the posterior distributions calculated by assessment models have shapes similar to the one presented here, which means that the order of mean, median and mode is the same as here: the most likely value (mode) is located below the median.

5.2 Reference points for Baltic Salmon

There are no objectives with corresponding reference points agreed for the current management of Baltic salmon.

The working group evaluated the probability to reach 50% and 75% of the ***P**otential **S**molt **P**roduction **C**apacity* (PSPC) in each river. Reaching at least 50% of the PSPC by 2010 in each river has been the objective of the Salmon Action Plan (SAP), defined by the former IBSFC. Reaching at least 75% of the PSPC has been suggested by ICES if the plan is to recover salmon populations to the MSY level (ICES 2008b and ICES 2008d). The PSPC estimates therefore form the basis of the current reference points for the assessment of the Baltic salmon stocks.

There is a considerable amount of uncertainty associated to these reference points (Section 5.3.3 and Section 5.3.9). All the model parameters including PSPC are updated in this year's assessment, and a comparison of the last year's and this year's PSPC estimates is provided (Table 5.3.9.2 and Figure 5.3.9.4).

5.3 Methodology for the assessment of Baltic salmon

An overview of the entire assessment model with the different sub-models, data or information used within the sub-models and their outputs, can be found in Figure 5.3.1. The use of a Bayesian estimation procedure allows this type of systematic and integrative modeling approach which is able to utilize most of the information sources available. The following subsections of the report discuss each of the different sub-models within the assessment methodology.

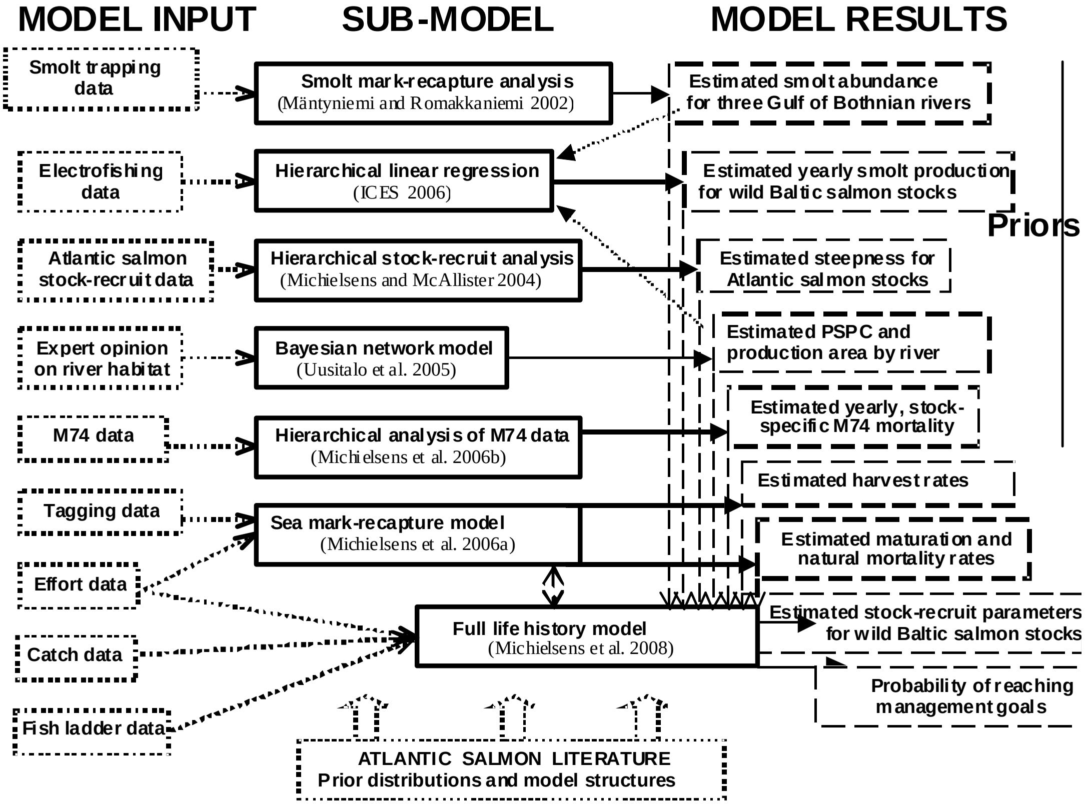


Figure 5.3.1. Overview of the assessment methodology for Baltic salmon stocks. The results from five uppermost analyses provide informative prior probability distributions for the full life history model. These priors become automatically updated by the information contained in the data and by the biological knowledge about the Baltic salmon life cycle used to build a full life history model. PSPC=Potential Smolt Production Capacity.

In order to assess the status of the salmon stocks with respect to the IBSFC SAP management objective, the first requirement is to obtain estimates of the PSPC as the reference points. A Bayesian network model (Uusitalo *et al.*, 2005) has been used to obtain the prior distribution for the PSPC of different Baltic salmon rivers. The model is based on expert opinions or judgements of the characteristics of the river environments and the corresponding salmon stocks. The resulting PSPC estimates are used as prior probability distributions when estimating the stock-recruit relationships.

In addition to the PSPC, the full life history model also requires yearly smolt production estimates in order to assess the smolt production in relationship to the PSPC. For the rivers Tornionjoki/Torneälven, Simojoki and Sävarån, smolt trapping data are available that can be analysed using a mark-recapture model in order to obtain yearly smolt production estimates for these three rivers (Mäntyniemi and Romakkaniemi, 2002). For most rivers, however, only electrofishing data are available. In order to be able to estimate the smolt production based on electrofishing data, the results for the rivers Tornionjoki/Torneälven, Simojoki and Sävarån (for which both electrofishing and smolt trapping data are available), can be used within an hierarchical linear regression analysis to estimate the smolt abundance of different rivers based on parr density estimates obtained from electrofishing data (ICES 2004b, Annex 2).

In order to be able to update the historic smolt abundance estimates and predict future smolt abundances, information regarding the relationship between the number of eggs and the resulting number of smolts is needed. Within the Baltic Sea, no stock-recruit data (egg and smolt counts) as such are available. Therefore a hierarchical analysis of Atlantic salmon stock-recruit data has been undertaken in order to estimate the likely form and parameters of the stock-recruit function (Michielsens and McAllister, 2004).

In order to be able to use the stock-recruit function and predict future smolt abundances, a full life history model is needed that can predict the number of spawners given a certain level of exploitation. A full life history model requires the estimation of life history parameters such as maturation rates, natural mortality rates and exploitation rates. In order to be able to estimate these parameters, tagging data is analysed using a mark-recapture model (Michielsens *et al*., 2006a). The results of this model are used together with the smolt abundance estimates and the priors for the stock-recruit function within a full life history model of individual Baltic salmon stocks in order to be able to estimate the stock-recruit function parameters for individual salmon stocks, and update the smolt production and PSPC estimates of the individual salmon stocks (Michielsens *et al*., 2008).

The results of the assessment models are used to calculate the probability that 50% or 75% of the PSPC will be exceeded in a given year and to assess future probabilities of reaching this objective under different assumptions about future exploitation and states of nature. The probabilistic projection of the stocks beyond 2010 has been executed using FLR (Fisheries library in R, Kell *et al*., 2007).

5.3.1 Definition of assessment units within the Baltic Sea area

Within the Baltic Sea area, currently 6 different assessment units have been established (Figure 5.3.1.1). The grouping of rivers within an assessment unit is based on management objectives and biological and genetic characteristics of the stocks contained in a unit. The partition of stocks into assessment units needs to make sense from a management perspective. Stocks of a particular unit are believed to exhibit similar migration patterns. It can therefore be assumed that they are subjected to the same fisheries, experience the same exploitation rates and are affected by management in the same way. In addition, the genetic variability between stocks of an assessment unit is smaller than the genetic variability between stocks of different units (Figure 5.3.1.2). Even though the stocks of assessment units 5 and 6 are relatively small in terms of their PSPC in comparison to stocks of the other assessment units, they are very important from a genetic perspective because of their genetic diversity.

The six assessment units in the Baltic Sea consist of:

1) Northeastern Bothnian Bay stocks, starting at Perhonjoki up till the river Råneälven.

2) Western Bothnian Bay stocks, starting at Lögdeälven up to Luleälven.

3) Bothnian Sea stocks, from Dalälven up to Gideälven and from Paimionjoki up till Kyrönjoki.

4) Western Main Basin stocks.

5) Eastern Main Basin stocks, i.e. stocks in Estonian, Latvian and Lithuanian rivers.

6) Gulf of Finland stocks.

An overview of all the rivers covered by each assessment unit can be found on Figure 5.3.1.3.

5.3.2 Data of different Baltic salmon stocks available for the assessment

An overview of the different types of data available for the different Baltic salmon stocks can be found in Table 5.3.2.1. The table indicates for which rivers the current assessment methodology is able to predict future smolt abundance to be compared to the PSPC. This estimation is based on smolt abundance estimates, spawner abundance estimates and associated stock-recruit relationships.

5.3.3 Prior probability distributions for PSPC

A Bayesian network model (Jensen, 2001) is used for the construction of the prior distribution for the PSPC of each river. The idea is to express the knowledge of salmon scientists about the PSPC in the form of probability distribution. In particular, the knowledge about the PSPC before obtaining any recent smolt abundance data is intended to be expressed here. Each expert is asked to provide their knowledge about different factors affecting the PSPC, like area suitable for production, habitat quality and mortality of smolts during downstream migration. Prior probability distributions for the PSPC are then calculated as the product of all these factors. The final prior distributions are an average over priors of all experts, which means that the diversity of different expert opinions is taken into account. Detailed description of this method can be found from Uusitalo *et al.*, 2005.

5.3.3.1 Data

No measurement data is directly used in this model. Experts are asked to not to take into account measurement data that will be used explicitly in the Bayesian stock assessment model. For example, experts are asked to ignore any smolt counts that will be used in the assessment, since these data will be used later to update the prior probability distribution for the PSPC (Section 5.3.9). However, before giving their opinion the experts look at existing additional material from the different rivers that contain information useful for the evaluation of the river areas suitable for production, the habitat quality of each river and information on mortality of smolts during downstream migration.

The data has been obtained from five salmon experts (Lars Karlsson, Ingemar Perä, Ulf Carlsson, Eero Jutila and Atso Romakkaniemi) from the northern Baltic Sea area. The experts represented different views in the controversy over the smolt production capacity. Clemen and Winkler, 1999 noted that experts who are very similar in philosophy and opinions tend to provide redundant information, and heterogeneity among experts is thus desirable. The marginal utility of information decreases as the number of experts increases, and using 3–5 experts is generally suggested (Makridakis and Winkler, 1983; Ferrell, 1985).

Eliciting the expert information has been done in three stages:

- First the experts discussed the model structure and assumptions and any differences in definitions of the parameters were ironed out. Clemen and Winkler, 1999 pointed out that great effort may be required to reach this goal. For successful combination of the estimates it is vital that experts agree on what is to be estimated and on the definitions regarding the model.

- Secondly the experts conducted a "warm up-exercise", going through the estimation using as an example a southern Swedish salmon river not included in the analysis. This was intended to help the experts become familiar with the practice of probabilistic estimation in this specific context (Morgan and Henrion, 1990). The probability distributions and conditional distributions were also explained in detail to ensure that they were understood in the same way by all experts.
- Finally, the experts estimated the probability distributions of the river-specific variables and conditional distributions that link these environmental factors to salmon reproduction. Each expert did this alone via a questionnaire form, with the possibility to hold discussions with the analyst, if desired. This arrangement was made to ensure that nobody's opinions and interpretations would affect the judgements of others, but that every expert would give the estimates in accordance with his own judgement. Hints also exist that interaction between experts at this stage may increase overconfidence and thus produce poorer results (Morgan and Henrion, 1990).

5.3.3.2 Methodology

The network model summarizes the current expert knowledge of PSPC of northern Baltic salmon rivers. The model was constructed in cooperation with salmon experts and aims to be compatible with experts' lines of reasoning rather than to describe the actual relationships of the nature in a detailed manner. Thus it describes a probabilistic justification for the expert views of salmon smolt production.

The model consists of 10 variables (Figure 5.3.3.1), five of which describe or reflect the external factors, physical and biological, to which salmon reproduction is exposed in the reproduction rivers (*chance of successful spawning, habitat quality of parr area, smoltification age, mortality during migration*, and *size of production areas*). Three variables (*parr density capacity, pre-smolt density capacity*, and *smolt production capacity*) describe the juvenile salmon stocks' response to the external factors. The remaining variables, *expert* and *river*, are auxiliary variables that enable handling of all the estimates in the same model. The first two variables have five discrete classes. The lowest class (i.e. very poor) is fixed to describe the situation in the poorest river in the northern Baltic Sea area, and the highest class (i.e. very good) the best salmon production river in the northern Baltic Sea. This relative scale is based on the fact that some part of the required knowledge is related to the intuitive understanding of experts who have spent most of their careers in studying these populations. Current knowledge is based on several small pieces of information, and the model here permits the experts to quantify this knowledge as probabilities. The variable *smoltification age* does not aim to reflect a distribution for the smoltification age, i.e. the percentage of parr that smoltify at each age, but the modal smoltification age and uncertainty connected with it. The minimum age of wild smolts in the rivers concerned is 2 years, which means that all salmon juveniles contribute to the densities of older parr (age 1+ and older) prior to smoltification. Dependencies between the variables (Figure 5.3.3.1) are described by conditional probabilities. For example, there is a table that contains the probability distribution of *parr density capacity* as a function of *chance of successful spawning, habitat quality of parr area*, and *expert*. It states the probability distribution, i.e. the probabilities of every possible value, of *parr density capacity*, given that e.g. the value of *chance of successful spawning* is "very good" and the value of *habitat quality of parr area* is "good" and *expert* is "Expert 1". A probability distribution exists stating the probabilities of different values of *parr density capacity* for every combination of values of the parent variables, in this case *chance of successful spawning, habitat quality of parr area,* and *expert*. Standard probability calculus has been used to obtain the probability distributions for carrying capacity, giving the results from the different experts an equal weight. Hugin –software package has been used for calculation of probabilities.

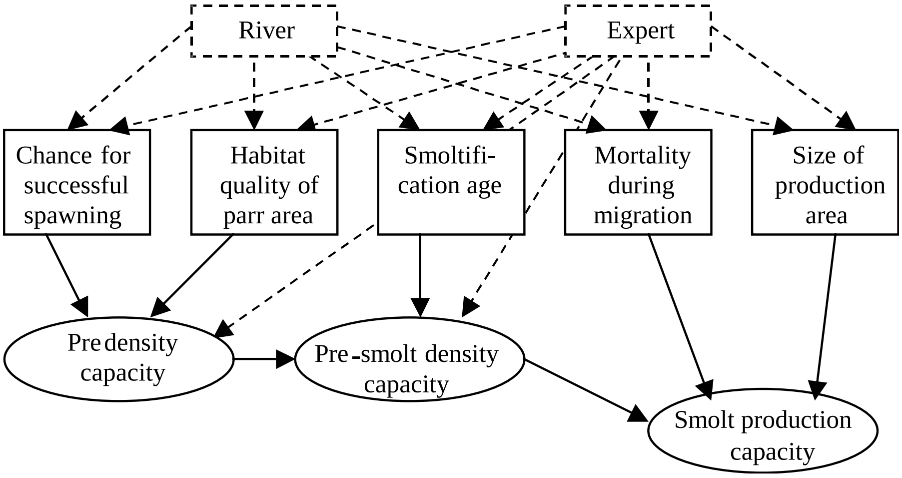


Figure 5.3.3.1. Model structure. The solid rectangular nodes denote river-specific characteristics which are estimated for each river separately by each expert; the elliptical nodes denote conditional estimates on related input arcs, e.g. smolt production capacity depends on pre-smolt density capacity, mortality during migration, and the size of production area. The dashed nodes denote the auxiliary variables. The variables that are children of river are estimated separately for each river; the variables that are children of "expert" include separate estimates from each expert (Uusitalo *et al.*, 2005).

5.3.3.3 Results

The model outputs are discrete prior distributions for the PSPC. Discrete distributions obtained directly from the model are difficult to use as such in further analysis. Therefore suitable continuous parametric distributions have been used to approximate the shape of the exact distributions obtained from this model. Lognormal distributions with median and coefficient of variation matching with the ones of exact distributions have been used for approximation. Multiple experts were used to come up with the priors for the set of rivers creates dependency between river specific prior distributions. In other words, having new information about the PSPC in one river will also change the perception of the PSPC of other rivers. This can be also seen as automatic evaluation of experts: experts whose prior coincides well with the information implied by observations from a particular river will be given more weight in the prior distribution of other rivers. This inherent correlation between river specific PSPC priors has been taken into account by approximating the prior distribution of each expert separately by a lognormal distribution. The resulting probability distributions for the PSPC can be found in Table 5.3.3.1 and Figure 5.3.9.4.

It is important to note that these probability distributions based on expert opinions only form the prior probability distributions for the PSPC. These priors will be updated when fitting stock-recruit models to the available stock-recruit data (Section 5.3.9), obtained by combining the smolt production estimates (Sections 5.3.4 and 5.3.5) with the estimates of the marine survival (Section 5.3.8). If the egg-to-smolt stock-recruit estimates for the Baltic salmon stocks appear to be informative, the probability density functions for the PSPC will then be substantially updated. Such an update can be expected in each assessment year as new data accumulates. The amount of annual change will depend on the amount of new data and the amount of information contained in the data.

5.3.4 Mark-recapture analysis of smolt trapping data

Mark-recapture experiments combined with smolt trapping have been used in three rivers (Tornionjoki, Simojoki and Sävarån). Bayesian mark-recapture model proposed by Mäntyniemi and Romakkaniemi, 2002 have been used to analyse the data sets. Simplified versions of the mark-recapture model (Bayesian Petersen method) are used in cases when data has not allowed incorporation of daily variation in parameters affecting trapping success.

5.3.4.1 Data

Mark-recapture data comprises of the number of untagged fish caught by the smolt trap, the number of tagged smolts released upstream from the trap, and the number of recaptured tagged smolts. These data are stratified according to different time intervals, like days, or presented as annual totals. Environmental covariates (daily water level and water temperature data) are also included into the analysis.

5.3.4.2 Methodology

The model structure is based on biological knowledge about the behaviour of salmon smolts during their migration. For example, their tendency to form shoals is taken into account by allowing catches to be more variable than in the case of independent behaviour. Knowledge about the sampling design is also utilised in the model structure. For example, the fact that it may take several days for a tagged smolt to pass the smolt trap again after the release is accounted for by modelling the mean and variance of the swimming speed of each marking group. A vague prior distribution is used for population size when analysing smolt trapping data sets. Posterior distributions for model parameters are calculated with the help of MCMC simulation.

Key assumptions behind the model structure:

1) Smolts migrate in schools (shoals) rather than independently.

2) Tagged and untagged smolts have equal capture probability when passing the smolt trap.

5.3.4.3 Results

The output of the mark-recapture analysis is a posterior probability distribution, which formally includes all the information about the smolt abundance contained in the mark-recapture data (see Sections 3.2.1 and 3.2.2). The smolt abundance estimates will be used in combination with parr density estimates in Section 5.3.5.

5.3.5 Hierarchical linear regression analysis to estimate wild smolt production of different salmon stocks

A relative index of parr density has been measured in many of the Baltic salmon rivers. For some rivers, like Tornionjoki, Simojoki and Sävarån, also smolt abundance estimates are available. For these rivers it is possible to look at the relationship between parr density and corresponding wild smolt production using linear regression analysis. By using a hierarchical structure based on assumed exchangeability of stock-specific parameters it is possible to predict the smolt abundance for stocks for which only parr density estimates are available.

Only for Piteälven, Emån and Mörrumsån, the smolt production estimates have been obtained differently. In Piteälven the number of eggs is estimated based on the number and size of the females passing the fishladder at the powerplant station. Using an egg-to-smolt survival rate of 1%, it is possible to estimate the corresponding smolt producton four and five years later:

Piteälven smolt forecast: = (0.01 * ((eggSY-4 * 0.62) + (eggSY-5*0.38)))

In Emån and Mörrumsån the smolt production is predicted using densities of 0+ and 1+ parr in combination with survival rates from one-summer old parr to two- summer old parr to smolts.

Also the smolt production within the rivers of assessment units 5–6 are based on parr density information, which together with expert evaluation about the size of the reproduction areas, survival from parr to smolt stage, etc. give rise to the numbers of smolts.

5.3.5.1 Data

This model requires time series of parr abundance indices for all rivers considered, and time series of smolt abundance estimates for as many rivers as possible. More specifically, the annual number of sampling sites electrofished and the corresponding estimated density of age 0+, 1+ and >1+ parr are needed. The number of sampling sites is used as a measure of precision of the parr density. Medians of the posterior distributions from mark-recapture analysis for smolt abundance are used as observations, and CVs of the posteriors are used as their measurement errors. In order to be able to assume that the parameters of the linear model are exchangeable between rivers, the smolt abundance of each river must be scaled down by the assumed production area of the river. The prior distributions for the smolt production area of each river are obtained from the domain experts by using the network model provided by Uusitalo *et al.*, 2005. Currently, parr density data from 12 rivers are used together with smolt abundance estimates from Simojoki, Tornionjoki and Sävarån.

5.3.5.2 Methodology

It is assumed that a linear model can characterize the relationship between the parr density index and the smolt abundance based on the assumption that no density dependent survival takes place in rivers of the Baltic Sea after the first summer. The parameters of this linear relationship can be learned or estimated for rivers for which time series of both parr abundance indices and smolt abundance estimates are available. It is assumed that the parameters of the linear model are not equal in all rivers, but instead they are assumed to be random draws from a distribution that characterizes the variation between rivers. In addition, mean discharge of the river is used as an explanatory variable for the slope of the linear model in each river. The residual variance can be learned from the variance of the parameters between rivers that have the necessary data. For rivers which have only parr abundance indices, the parameters of the linear model are given prior distributions which include the between river variability of the parameters and has the expected value predicted by the mean discharge of the river. This reflects the assumption that the parameters of the linear model are partially exchangeable between rivers. The model is described in detail in ICES 2004b, Annex 2.

Key assumptions of the model:

1) Parr density estimates are proportional to the true parr density.

2) Survival and smoltification rates are not density dependent after the fry stage.

3) Relative selectivity of electrofishing is equal in all rivers.

4) Knowing the name of the river would not help in the estimation of river specific survival rate. This means that rivers cannot be ordered based on survival parameters by using prior information. This is the assumption of exchangeability which in turn leads to the assumption that river-specific parameters are random draws from a probability distribution describing the variation in survival between rivers.

5.3.5.3 Results

This model produces posterior probability distributions for the annual smolt output of each river, as well as estimates of relative parr abundances, survival parameters and variation of survival parameters across rivers. The results of this analysis include all the information about smolt abundance contained in the electrofishing and smolt trapping data together (Table 5.3.5.1). Results indicate a substantial increase in smolt abundance for the last years of this decade. This will be important information when estimation the PSPC. For rivers Tornionjoki, Simojoki and Sävarån the results are more informative than for the other rivers because of the availability of smolt trapping data for these rivers. Smolt abundance estimates for 2005–2008 in Sävarån are much more precisely estimated than in other years because during those years, smolt trapping data had been collected. These four years alone do not have much influence on the river-specific slope parameter, but the situation will change in case smolt trapping is continued in Sävarån in future years. The distributions for the smolt abundances will be used to fit the models to in subsequent analyses (Section 5.3.9).

5.3.6 Estimating M74 mortality for different wild salmon stocks

Tables 3.5.1 and 3.5.2 in this report indicate the frequency of M74 mortality in terms of the percentage of females affected by M74 or the percentage of total yolk-sac-fry mortality. For assessment purposes, however, we need to know the percentage of mortality caused by M74 among the salmon offspring. These estimates allow us to integrate M74 mortality within the population dynamics of the stock.

5.3.6.1 Data

Two different data sets have been used to calculate the mortality among alevins due to M74 mortality. The first data set consists of data for 1006 females from the river Simojoki, Kemijoki and Tornionjoki/Torneälven stocks. A summary of these data can be found in Table 3.5.2. For each female it is indicated if the female suffered from the M74 syndrome and the percentage of yolk-sac-fry mortality by its offspring, calculated on the basis of the proportion of alevins from each female that die. A second data set consists of M74 information for 9 Swedish salmon stocks. A summary of these data can be found in Table 3.5.3. The data series indicate the number of females sampled and the number of females affected by the M74 syndrome for each year and for each stock.

5.3.6.2 Methodology

The data are analysed using the same Bayesian hierarchical model as described by Michielsens *et al.*, 2006b. The probability of eggs surviving the alevin stage depends on the probability of females being affected by M74. In case the females are not affected by M74, it is assumed that the probability of the eggs surviving the alevin stage is dependent on the 'normal' level of yolk-sac-fry mortality (M). If the females are affected by M74 then either all offspring die or only part of the offspring die.

Because the degree of M74 mortality is assumed to differ across years and across stocks, the model calculates the average survival from M74 mortality for each stock for each year. By separating the M74 induced yolk-sac-fry mortality from the 'normal' yolk-sac-fry mortality (YSFM), the model also removes the effect of the rearing environment on the M74 mortality estimates. It is assumed that the 'normal' YSFM can differ between offspring from different females but that the variation between the 'normal' YSFM from offspring of females of the river Simojoki, Kemijoki and Tornionjoki is the same as the variation in 'normal' YSFM between different years and between different stocks. Based on this assumption it is possible to implement an hierarchical model structure and use the estimated mean 'normal' YSFM and the associated variance among females to predict the 'normal' YSFM for years and stocks for which no data exist which would allow to estimate the 'normal' YSFM. Similarly for the M74 mortality it is assumed that this mortality can differ for each female and that there is a mean M74 mortality across the different stocks for each year and a constant variation across stocks over the years. This assumption allows to use a hierarchical structure across stocks and to predict the M74 mortality for stocks for which there is no information on M74. Because the average M74 mortality across stocks is year dependent, this methodology does not allow the prediction of future M74 mortalities.

5.3.6.3 Results

Figure 5.3.6.1 shows the estimates for M74 mortality (median and 95% probability interval). These estimates have been compared against the data traditionally assumed to approximate M74 mortality, i.e. the percentage of females with offspring affected by M74 and the total average yolk-sac-fry mortality among offspring. In general the percentage of females with offspring affected by M74 overestimates the M74 mortality due to the fact that part of the offspring will die due to normal yolk-sac-fry mortality, unrelated to M74. In addition, not all offspring necessarily die when affected by M74. Because of the decreasing trend in mortality among offspring of females affected by M74, the data on proportion of females affected by M74 especially overestimates M74 mortality in recent years. Data on the total average yolk-sac-fry mortality are much better at tracking the general trend but overestimate the actual M74 mortality because these data do not distinguish between normal yolk-sac-fry mortality and yolk-sac-fry mortality caused by the M74 syndrome. Table 5.3.6.1 shows the actual values of the M74 mortality for the different salmon stocks. Figure 5.3.6.2 represents the chance that the offspring of M74-affected females would die, this examination being available for Simojoki, Tornionjoki and unsampled Atlantic stock.

5.3.7 Hierarchical analysis of Atlantic salmon stock-recruit data

A hierarchical analysis of Atlantic salmon stock-recruit data has been undertaken to come up with prior distributions for the steepness parameter of the stock-recruit function for Baltic salmon stocks (Michielsens and McAllister, 2004).

5.3.7.1 Data

Until year 2008 assessment, data from river Ume/Vindel was used in the hierarchical stock-recruit analysis together with the data from other Atlantic salmon stocks (ICES 2008a). This reflected the idea that by incorporating the stock-recruit data of at least one Baltic salmon stock, the resulting probability distribution for steepness could be used for any unsampled stock, including Baltic salmon stocks which may in certain aspects differ from Atlantic salmon stocks from outside the Baltic Sea area. However, because of this the stock-recruit parameters of river Ume/Vindel were not updated in the full life history model and it resulted in major problems with some posterior estimates of Ume/Vindel stock-recruit parameters. As a solution to this problem, Ume/Vindel was removed from the stock-recruit analysis and it was treated similarly in the full life history model as all the other Baltic stocks.

Consequently, the stock recruit analysis to obtain priors for the Baltic stocks is now based on data only from Atlantic salmon stocks outside the Baltic Sea. This is deemed justified since the stock recruit parameter values of Ume/Vindel were not extreme compared to other Atlantic salmon stocks (ICES 2008a). It is an indication that the range of values of stock recruit parameters obtained from outside Baltic may well cover also the range of parameter values prevailing among Baltic stocks.

5.3.7.2 Methodology

A detailed description of the model used for the hierarchical analysis of stock-recruit data can be found in Michielsens and McAllister, 2004. Because the Beverton-Holt stock-recruit function has a much higher probability of being more suitable for Atlantic salmon than the Ricker function (Michielsens and McAllister, 2004), the current analysis will only be using this stock-recruit relationship.

5.3.7.3 Result

The results for the steepness parameter are presented in Table 5.3.7.1. For the Atlantic salmon stocks within the Northern Baltic Sea area (assessment units 1 to 3), it is assumed that the mean steepness across all Atlantic salmon stocks can be regarded as the prior distribution for the mean steepness and that the variance of the steepness among Atlantic salmon stocks can be used as the variance of the steepness of Northern Baltic salmon stocks. It is assumed that the mean steepness across all Southern Baltic salmon stocks (unit 4 and 5) is lower than the mean steepness across the Northern Baltic salmon stocks but the variance in steepness across the southern stocks is given the same prior probability distribution as for the northern stocks (Prévost *et al.*, 2003).

5.3.8 Sea mark-recapture model for assessing the exploitation of Baltic salmon

Based on various data from fisheries and the sea and spawning migration of salmon it is possible to estimate population dynamics and harvesting of salmon from smolt to spawner. This is dealt with under this section.

5.3.8.1 Data

For the mark-recapture model, fishing effort data and tagging data have been used. The fishing effort data have been divided in separate coastal fishing efforts for stocks of assessment unit 1 to 3 (Table 2.3.1). In this year's assessment, the Swedish trapnet effort in Subdivision 31 has been divided between assessment units 1 and 2 with respective proportions of 45% and 55%. Table 2.10.1 gives an overview of the number of tagged hatchery-reared and wild salmon released in rivers of assessment areas 1, 2 and 3. Swedish tagging data has not been available after 2005. Wild salmon have been tagged only in assessment unit 1.

For several of the parameters needed within the assessment model, basic data is fragmented and limited (e.g. tag reporting rates) or not simply not available (e.g. underreporting of catches). Instead of using the common approach of relying on expert opinions as such to extrapolate the data into parameter estimates, a more formalised approach has been used. For each parameter within the assessment model, twelve experts have been asked to provide a most likely value and a minimum and maximum value during a meeting at Bornholm in 2003 (ICES 2003). These expert opinions were based on data obtained from previous studies done, on literature, on the experts' experience or were subjective expert estimations in case no other information was available. Preliminary analyses, used for the formulation of prior probability distributions, included among others information from the broodstock fisheries, double tagging experiments, etc. Care has been taken to assure that the prior distributions were not based on data used within the mark-recapture model in order to avoid using the same data twice and thus rendering the results too informative. In general, these preliminary analyses gave often only a first indication of the model parameters but expert opinion needed to be used for example to extrapolate it to the entire Baltic Sea, or to other fisheries, etc. The use of multiple experts resulted in multiple priors for the different model parameters. Model parameters such as the reporting rates of tags are dependent on the country. As such, the probabilities distributions for each country have been weighted by the country's contribution to catches of wild and hatchery-reared salmon production and arithmetic pooling of the priors has been applied (Genest and Zidek, 1986; Spiegelhalter *et al.*, 2004). For other priors each expert is assumed to have equal expertise, arithmetic pooling without weighting of the priors has been applied. A description of the different model parameters and their prior probability distribution has been provided by ICES 2005.

5.3.8.2 Methodology

The mark-recapture model is run within the full life history model and a detailed description of this sub-model can be found in Michielsens *et al.*, 2006a. The main difference between the model used by WGBAST and the one presented in this paper is that for the working group the model has been expanded to include assessment units 1 to 4 instead of only assessment unit 1. The main assumptions about the salmon stocks in this mark-recapture model are:

1) The maturation rate for wild grilse is lower than that of the hatchery-reared grilse (Kallio-Nyberg and Koljonen, 1997; Jutila *et al.*, 2003).

2) The post-smolt mortality rate of hatchery-reared fish is higher than that of wild fish (Olla *et al.*, 1998; Brown and Laland, 2001) and the differences in post-smolt mortality rates between wild and reared salmon for assessment units 2 to 4 are the same as the differences between post-smolt mortality rates for wild and reared salmon of assessment unit 1.

3) Post-smolt mortality rates differ from year to year (Salminen *et al.*, 1995) but the relative difference in post-smolt mortality rate between wild and hatchery-reared fish is constant over years (Romakkaniemi, 2008).

4) The instantaneous natural mortality rate for adult salmon is assumed to be the same for wild and reared salmon and constant over the years.

5) It is assumed that all adults die after spawning.

6) It is assumed that the number of salmon mauled by seals in coastal areas has increased annually by 5.5% between 1995 and 2001. Since 2003, the number of salmon mauled by seals in coastal trapnets has fixed to 20% due to improvements of the fishing gear.

The main assumptions about the fishery in the mark-recapture model are:

1) Stocks belonging to the same assessment unit experience the same harvest rates.

2) Harvest rates between salmon stocks of assessment unit 1 to 4 mainly differ in the coastal fisheries and it is assumed that no coastal fishery exploits the salmon of assessment unit 4.

3) The catchability coefficients for the different offshore and coastal fisheries are assumed constant over the years.

For each year, the model estimates different fishing mortality rates depending on the fishery (offshore driftnet, offshore longline, coastal driftnet, trapnet and gillnet and river fishery), depending on the age of the fish, and depending on whether it is a wild or hatchery-reared fish.

5.3.9 Full life history model of different wild Baltic salmon stocks

Spawner abundance estimates has been obtained by using the wild smolt abundance estimates of different rivers (Section 5.3.5) with similar population dynamics as within the mark-recapture model (Section 5.3.8; Michielsens *et al.*, 2006a; Michielsens *et al.*, 2008). By linking the derived egg abundance estimates with the wild smolt abundance 4 years (in the case of Gulf of Bothnia stocks), 3 years (in case of assessment unit 4 stocks) or 2 years (in case of assessment unit 5 stocks) later, it is possible to estimate stock-recruit parameters. The resulting stock-recruit function makes the loop between salmon generations and the estimates of abundance and survival parameters become updated across the time series. The resulting posterior distributions are then used to assess the stock status and to predict abundance into the future.

5.3.9.1 Data

Both the total number of wild smolts (Table 5.3.5.1) and the number of released hatchery-reared smolts (Table 3.4.1) are used as inputs into the model. The model is also fitted to offshore, coastal and river catches. In this year's assessment the Polish catch has been calculated by multiplying Polish effort with combined Danish, Finnish, Swedish and Latvian catch per unit effort. Because assessment unit 6 has not yet been included in the model, the catches have been raised by the proportion of smolts produced in assessment unit 6 in comparison to the total smolt production. In addition the model also uses the data on the proportion of MSW (multi-sea-winter) spawners encountered in the rivers Tornionjoki, Kalixälven, Byskeälven, Ume/Vindelälven and Öreälven (Table 3.2.1.2) and data on the proportion of wild versus hatchery-reared spawners within the river catches of the river Tornionjoki.

By linking the wild spawner abundance produced from the yearly smolt production, with the smolt production 4 years after the year of spawning, it is possible to obtain stock-recruit information for wild salmon stocks. For each stock, the estimated abundances of spawners of different ages are multiplied with corresponding sex ratios and fecundity values (eggs/female) in order to estimate the total number of eggs produced in each river in each year. The resulting number of eggs has been corrected for the effect of M74 by multiplying the estimated number of eggs with the percentage of yolk-sac-fry mortality due to the occurrence of M74 (Section 5.3.6). In case no M74 data have been available for certain river stocks, the predictions of M74 related yolk-sac-fry mortality for unknown stocks are used. The resulting medians of the probability distributions for the stock-recruit estimates can be seen in Figure 5.3.9.3. These estimates are obtained prior to fitting the stock-recruit relationship. The same figure also shows the medians of the posteriors obtained by fitting the Beverton-Holt stock-recruit function to these estimates.

5.3.9.2 Methodology

The population dynamics for the total abundance of salmon is expressed by similar equations as the population dynamics for the abundance of tagged salmon (Michielsens *et al.*, 2006a). In order to estimate salmon catches, the tag reporting rates within the catch equation for tagged salmon have been replaced by the catch reporting rates. The main model outputs are the estimated stock-recruit parameters i.e. the steepness parameter and the PSPC's.

The model simultaneously models the tagged salmon population and the total salmon population. For tagged salmon, the population equations account for tagging induced mortality, tag shedding and underreporting of tagged salmon catches. Based on the tagging data, the model is able to estimate maturation rates, natural mortality rates, and harvest rates. These estimates are then used to model the total salmon population based on the number of wild and released hatchery-reared salmon smolts. In order to estimate the coastal and river catches, the corresponding equations account for possible underreporting of the salmon catches. The probability distributions for the wild smolt abundance will be used as priors until the year for which the model is able to calculate the smolt abundance using the estimated number of spawners and the stock-recruit parameters. From that year onwards, the model can be fitted to the smolt abundance estimates instead of using them as priors. The entire model has thus been fitted to tagging data, catch data, data on the composition of the spawning run and data on smolt and parr abundance.

The prior probability distributions of the smolt production capacity for the different river stocks have been obtained by Uusitalo *et al.*, 2005 (Section 5.3.3), based on expert opinions. The prior distribution for the steepness in each river has been derived by the hierarchical model described in Section 5.3.7. These priors become updated by the full life history model taking account of the available data.

For assessment unit 5, the full life history model relies on the estimates of natural mortality, maturation rates and exploitation at sea of the other units, in addition to smolt abundance estimates and coastal catch. Because of the limited amount of data available, the estimates obtained for unit 5 may not be as reliable as for the other AU's.

In this year's assessment two changes have been applied in the model structure. Fish ladder counts of spawners for river Kalixälven have been fitted with the amount of spawners ascending to the river. Probability for a spawner to be observed in the counter has been allowed to vary between years around a common mean. In addition, prior distribution for the river harvest rate (same for all rivers) has been changed from Beta(1,5) distribution into Beta(1.6,6.4), which corresponds better the present background knowledge.

5.3.9.3 Result

The results indicate a decreasing trend in the post-smolt survival and the lowest survival was estimated for salmon smolting in 2005 (Figure 5.3.9.1). Since 2005 the survival has increased and the 2007 survival was close to the same rates as in the late 1990s. However, the 2007 estimate is based on the data from fish which have so far only partially recruited to the fisheries. In 2008 the survival seems to have decreased again, but the 2008 estimate is based on very limited data (few tag returns from post-smolts) and is considered to be unreliable.

The total wild smolt production has been clearly increasing in the AU 1–2, while in the AU 3 and 5 the increase is not apparent (Figure 5.3.9.2). In the AU 4 the total smolt production has been fluctuating and currently the production is lower than in the beginning of the Salmon Action Plan (year 1997). Totally, the wild salmon production in AU 1–5 has been gradually increasing in this decade and current (year 2008) production is about 2.5 million smolts.

The full life history model allows estimating the steepness of the stock-recruit relationship (Table 5.3.9.1) and the PSPC (Table 5.3.9.2) for different salmon stocks. Figure 5.3.9.3 gives an indication of river-specific stock-recruit data (only the median values of the parameters are shown) by which the priors of stock-recruit parameters are updated in the model. The S/R curves added in the figure panels are rough approximations of posterior medians. The latest information about the recent spawner and smolt abundance has resulted in some changes in the posterior probability distributions of the PSPCs compared to last year (Figure 5.3.9.4). Clearly the largest update (downwards) is in the PSPC of Kalixälven, in which the annual smolt and spawner abundance estimates decreased as a result of adding the fish ladder data in the model. The AU specific total PSPC estimates for the AU's 1–5 did not significantly change from the last year.

By comparing the posterior smolt production (Table 5.3.9.3) against the posterior PSPC it is possible to evaluate the status of the stocks in terms of their probability to reach 50 or 75% of the PSPC (Figures 5.3.9.5, 5.3.9.6 and 5.3.9.7, Table 5.3.9.4). Because the TAC of 2010 will only affect smolt abundances beyond 2012, it is possible to evaluate the probability for smolt production in 2010 to exceed 50% or 75% of the PSPC in each river without considering catch options for 2010 (Table 5.3.9.4). Overall, the probability to reach 50% and 75% of the PSPC is highest for the largest northern stocks. For some stocks it is unlikely whether they will reach even 50% target. While the most northern stocks show strong indication of recovery over the years, those stocks within the AU 4-5 that had been depleted have been unable to recover. The situation in the rest of the stocks falls between these extremes.

The model-estimated and observed catches in various fisheries are shown in Figure 5.3.9.8. The model captures well the overall historic fluctuation of catches in various fisheries. An increasing trend in number of spawners is seen in the most of the rivers (Figure 5.3.9.9.a–b). The model captures roughly the trends seen in the fish ladder counts, but there are river specific differences in this respect. However, e.g. annual variation in the river conditions affect the success of fish to pass through ladders and therefore the ladder counts themselves are not ideal indices of spawner abundance. The spawners abundance estimates are the most accurate in the rivers with smolt trapping, i.e. where the smolt production is known with the best accuracy.

Harvest rate has been decreasing basically in every fishery (Figure 5.3.9.10.a–c). The period with the largest decrease dates back to the mid-1990s, but there has been a second decrease within this decade. The driftnet harvest rate in 2008 is larger than zero, because the 2008 estimate actually consists of offshore fishing both in the last months of the year 2007 and the first months of the year 2008.

5.4 Stock projection for different Baltic salmon stocks

In this section we describe the results of future projections of salmon abundances and catches. Parameter estimates have been taken from the full life history model as an input. Further, the stock projections are based on expert-determined fishing effort scenarios and scenarios for future post-smolt survival and M74 mortality.

5.4.1 Methods

The Fisheries Library in R (FLR) framework (Kell *et al.*, 2007) is used for the analysis of future stock projections under different scenarios. The FLR framework aims to provide a general tool to facilitate a multidisciplinary modelling work and fisheries strategy evaluation. Both R and FLR are open-source software and are freely available. FLR is implemented using object-oriented programming (OOP). The idea is to increase the transparency of modelling and facilitate exchangeability of programs among users.

In FLR, the basic objects, or classes used to store fisheries data, are called FLQuants, which is an extension of a multidimensional array in R. Arrays in R are easily translated into FLQuants and vice versa, and so while the simulations are run using arrays in R, the results of the simulations are analyzed using FLQuants taking advantage of the graphic tools integral to FLR. The Baltic salmon FLR-model is using FLCore-version 2.0–2 package, which provides a sixth dimension for iterations in the data storage needed to represent uncertainty.

In order to make forward projections, the joint posterior distributions describing the latest knowledge about the number of smolts and population parameters are stored in the form of indexed MCMC chains. Up to the year 2008 the estimates stored within the arrays are obtained from the stock assessment (Section 5.3) and the stock projections start from 2009 onwards. The arrays are 5 dimensional, storing parameters about wild (reared) salmon by age, year, river (assessment unit), migration status, and MCMC index.

5.4.2 Assumptions regarding development of fisheries and key biological parameters

Stock projections have been made for all stocks of AU's 1 to 4. The joint posterior distribution describing the latest knowledge about the status of the stocks and population model parameters was used as a basis for the forward projection. The population dynamics for the stock projection analysis is similar to the full life history model but lacks the process errors in survival parameters. Table 5.4.2.1 presents the key assumptions underlying the stock projections.

Working group members from each country were asked to provide their opinions about the development of the fishing effort of each fishery compared with the effort level in the year 2008 (Table 4.5.1). This information of country and fishery specific efforts was used as the basis for the future stock projections together with the assumption that catchabilities will remain the same as in the past (full life history model estimates based on years 1987–2008, Figure 5.4.2.1a). In short-term scenarios we assumed that all countries would simultaneously employ alternatively either minimum, mode or maximum fishing effort (scenarios 1–3 in the Table 5.4.2.1, Figure 5.4.2.1b).

Two key parameters determining the survival of the salmon, i.e. post-smolt survival (Mps) and survival from M74 mortality, were assumed to vary within the limits of the observed range of values, but assuming the same autocorrelation structure as observed in the past. The forward projection for Mps was started from the year 2008, as the highly uncertain model estimates for Mps for 2008 were replaced with the simulated values. Simulations were run for three different scenarios (Scenario a, b and c; low, medium and high) for the post-smolt survival depending on the median to which the Mps is expected to return. Figures 5.4.2.2 and 5.4.2.3 illustrate the post-smolt survival rates over the years under the three scenarios and the scenario for M74.

5.4.3 Results

According to the projections, stock size on the feeding grounds would be about 2.2 million salmon (wild and reared in total, excluding post smolts) at the beginning of year 2010. Table 5.4.3.1 illustrates the estimated total catch, in commercial and recreational sea fishery. The reported commercial catch is approximated by incorporating the underreporting factors (1.18 and 1.33) for longlines and trapnets respectively and by assuming that the share of the commercial catch from the total catch is at the same rate as in 2008 (84%).

The results indicate that depending on the effort scenario the commercial reported catch in year 2010 is 51–108% compared to TAC of 2009. Figure 5.4.3.1 illustrates the development of future catches. Table 5.4.3.2 illustrates the probability to meet 50% and 75% of PSPC in 2015 with different effort scenarios and by 2018 with the different survival scenarios. The results show that under the effort scenario 3 (maximum effort) there is the highest probability not to achieve the PSPC targets. Especially the weakest stocks have lower probabilities to meet the objectives if the maximum effort scenario would become realized, compared to the other two scenarios in which either modal or minimum effort would become realized. Figure 5.4.3.2a–c presents the river specific annual probabilities to meet 75% of the PSPC assuming effort scenario 4 (5.4.3.2a, whole effort range), or alternatively effort scenario 1 (5.4.3.2b, minimum effort) or effort scenario 3 (5.4.3.2c, maximum effort). In these simulations the survival scenario b (medium post-smolt survival) is assumed to occur. These scenarios indicate further recovery of wild stocks except in the case of the maximum effort, in which recovery is suppressed and the weakest stocks continue to have low probability for reaching a smolt production target.

Figure 5.4.3.3a–d shows uncertainty and expected values of smolt and spawner abundance for each river. Taking into account the whole range of uncertainty in the future effort, most stocks will probably show increasing trend in abundance, but a few river with low productivity (Emån, Mörrusån, Simojoki) may not recover from their present status.

Figure 5.4.3.4a–b shows estimated harvest rates for offshore long line and coastal trapnet fisheries (only presented for AU 1) with minimum and maximum effort scenarios. With minimum effort scenario, long line harvest rate stabilizes around 0.1 and trapnet harvest rate around 0.2, whereas with maximum effort scenario harvest rates are around 0.25 and 0.45, respectively.

5.5 Uncertainties affecting the assessment results

The main information on the exploitation of wild salmon in the Baltic comes from mark-recapture data. The problem with these data is that it is geographically biased. Since 2006 no Swedish tagging data have been available. This may have affected the reporting rates of Finnish tags by Swedish fishermen, thereby affecting the quality of the remaining tagging data.

The fishing effort of the Swedish coastal fisheries by trapnet and other gears (predominantly gillnet fisheries) for the entire time series have been based on the CPUE of Finnish coastal fisheries.

Within the assessment model, the uncertainty in the effort figures have been incorporated by using a state-space formulation of the mark-recapture model, thus incorporating errors on the fishing effort into the process error.

Uncertainties expressed by the prior probability distributions of the model parameters

For rivers with a lot of data such as Tornionjoki, the prior probability distributions for the smolt production capacity has been updated substantially, limiting the influence of the expert based prior probability distribution for the smolt production capacity. Other rivers such as the river Öreälven, for which not much data are available, the smolt production capacity is primarily updated due to the correlation between the smolt production capacity estimates of different rivers.

Prior probability distributions for the parameters of the sea mark-recapture model have been provided by 12 experts based on previous studies, on literature, on the experts' experience or were subjective expert estimations in case no other information was available. A table with all prior probability distributions are described in Michielsens *et al.*, 2006a. With exception of the prior probability distributions of the catchability coefficients, the prior probability distributions for the model parameters have been given rather informative distributions. The prior probability distributions for hatchery-reared salmon are updated. The prior probability distributions for wild salmon have not been updated much, thereby increasing the importance of the expert opinion. Sensitivity analyses have indicated, as could be expected, that results are to a large extent dependent on the prior probability distributions for the reporting rate and biological model parameters and to a very limited extent on the prior probability distributions for exploitation rates (Michielsens *et al.*, 2006a).

Uncertainties regarding the model assumptions and model structures of the estimation model

Given the large number of different methodologies used for the assessment of Baltic salmon stock, the model assumptions are described in the sections relating to the different methodologies. One major assumption made in the assessment methodology is that the difference in post-smolt survival between wild and reared salmon is assumed constant.

Walters and Korman, 2001 have pointed out that for depleted stocks when the spawning stocks increase rapidly after long periods of low abundance, this may result in locally intense competition within those reproduction areas that are still being used. This patchy habitat use may impose local density-dependent effects, which may diminish in the longer run (after several generations) once spawners have dispersed to fully re-establish the natural or most productive structure of habitat use (Walters and Korman, 2001). If this phenomenon is valid for the Baltic salmon populations, our analysis of the recent stock-recruit information underestimates long-term (full) carrying capacity of the Baltic rivers.

Tag shedding and mortality

Possible sources of error in application of results from tagging experiments include the question of differential mortality between tagged and untagged fish and when this (possible) mortality occurs, also tag shedding (loss of tags) and whether this is related to the size of the fish. Possible difference in growth rate of tagged and untagged fish could be a problem. Reporting rate (proportion) of the tags caught in different fisheries are also important pieces of information to be able to use tagging data.

A considerable mix-up of these different factors is likely and in most cases it is difficult to keep the different factors apart.

It is vital for the tagging studies to have at least an overall estimate for tag shedding rate. Some information on salmon can be found in the data from Swedish brood stock fisheries in Gulf of Bothnia based on numbers of fish released in each year in 1987–1998 and the number of fish recovered in year 1990–1999. It is assumed that all tags in these fisheries are reported and therefore they can be used to elucidate the combined effect of tag shedding and difference in mortality between tagged and untagged. If the recovery rate in brood stock fisheries is compared with tag recoveries in rivers and river mouth areas, data on reporting rates can be calculated.

It is assumed that the best dataset is available from River Dalälven, which has a meticulous control of the number of the fish caught in the brood stock fishery. There is also a very good organization of the angling in this river and the catch statistics in this river is therefore assumed to be of particularly high class. The data from this river suggests that the tag shedding/mortality remove about 30% of the number of tags.

Tag reporting rate

Tagging in Baltic salmon monitoring programs is mostly based on Carlin type of tags relying on tag recoveries being reported by the public. Therefore it is vital that fishermen find and report all tags. Some studies to estimate the reporting rate has been carried out in the Baltic Sea and their results indicate an obvious unreporting.

Backiel and Bartel, 1967, working on sea trout, assumed that the increased mortality, tag loss and incomplete discovery and/or return brought about an underestimation of recaptures by ca. 15%. Debowski and Bartel, 1996, based on analysis of tagging experiments in 1961 through 1986, estimated that underestimation of stocking efficiency, which was caused by not reported tags and increased mortality of tagged smolts was up to 40%. Decreasing trend in returns can be to some extent explained also bycatch limits and the attitude of fishermen, who are afraid to return tags because they think, those tags can prove, to some extent, exceeded catch limits. In Poland, increase of reward paid to fishermen does not affect seriously returning rates.

In Denmark two high rewarded-tag sea trout release experiments were conducted in 1988. Increase in return rates were 10.2% and 62.5% respectively, depending on local awareness and local fishing patterns. It is, however, doubtful if these results can be extrapolated to the whole Baltic salmon fishery.

A larger Swedish dataset exists from the offshore fishery in the Main Basin. A fisherman at Gotland, assumed to be reliable on the basis of earlier experiences, agreed to report all tags he found in the catches. When comparing the number of Swedish tags that he found in his catches, to the total number of Swedish tags reported, some underreporting from this fishery was indicated.

Observations from the offshore drift net fishery in the Main Basin in 2002, involving observers on board two salmon fishing boats suggest that slightly less than 1% of salmon caught is tagged with Carlin tags. This number may be compared to results from other analysis, assuming equal number of recaptures of tagged salmon in all samples of salmon.

Reporting rate may vary between countries. Comparison of reporting rates from two countries fishing in the Baltic Main Basin indicates, that one country can report significantly less than the other.

An experiment with different rewards for different tags (electronic Data Storage Tags-DST's) and conventional-Carlin tags, was conducted in the coastal fishery in the Gulf of Bothnia in 1995–1997. For the DST tags it was clearly stated that a substantial reward was offered. Clear differences in recapture rates were observed. However, it was not ascertained that the two tag types were mixed, and the results should be taken with caution. Nonetheless substantial differences in reporting were observed.

Comparing reporting rate from anglers in the Dalälven to observations in the brood stock fishery data from Dalälven suggests that the reporting rate by anglers in the river is about 80%.

In the Gulf of Finland studies from the late 1980s suggested that the reporting rate varied between 40–75% (median 55%).

The return rates of sea trout taggings have decreased during the last ten years in the Finnish sea trout taggings, both in the Gulf of Bothnia and Gulf of Finland (Figure

7.4.1.1). However, the post-smolt survival estimates do not follow the decreasing trend as steeply as is seen in tag return rates.

Uncertainties regarding the stock projections

There are differences between assumptions of the full life history model and the population dynamics model which is used in making predictions. These include: lack of process error in the survival process; only process error in recruitment was modeled, average values for M74 were used in the projection model instead of river specific values used in the estimation model. Excluding process error from the predictive model leads to results that are less variable than they would be if process errors in survival were included. Deterministic survival process in forward projections may underestimate the variation in probabilities to reach PSPC targets in predictions.

5.6 Conclusions of the assessment for the Main Basin and Gulf of Bothnia stocks

5.6.1 General conclusions

There are significant regional differences in trends in smolt production (Figure 5.3.9.2). For the wild salmon populations of AU 1, the very fast recovery of smolt production indicates high productivity of these rivers. Similar but less pronounced population dynamics are estimated for the stocks of AU 2 and 3. Stocks of AU 4 and 5 have been more stable in smolt production and some of these stocks have even seen a decrease in smolt abundance since the start of the IBSFC SAP in 1997. Even the clearly decreased harvest rates in sea fishery have not been able to turn the trends in smolt abundance, which suggests low productivity of these stocks. The most likely reason for the low productivity of the southern stocks may lie either in the freshwater conditions of the spawning rivers or in the regional differences in survival of post-smolts in sea. Although the effects of these factors could not have been well assessed, various information about the river conditions, migration obstacles, and tag recapture rates support these hypothesis (Sections 2 and 3). However, there are fewer sources of information to assess the stocks in AU 4 and 5, making our knowledge about the status and development of these stocks less reliable than those for AU 1 to 3.

There is a general trend in the results indicating that post-smolt survival has lowered over the years. In 2007, however, results suggest an increased survival (Figure 5.3.9.1). The reasons behind the long-term decrease in the estimated post-smolt survival are still unclear but the seal abundance, smolt production, and recruitment of 0+ and 1+ herring correlate with the survival indices of post-smolts (Section 4.4). The estimated survival is particularly low in 2004–2006.

In most of the rivers posterior modes for the PSPC remained about the same compared to last year (Figure 5.3.9.4, Table 5.3.9.2). However, some increase can be seen in the PSPC estimate of Tornionjoki and some decrease in PSPC estimate of Kalixälven The AU specific sums of PSPCs, however, remained the same compared to last year’s assessment (ICES 2008b). In total, the rivers of the units 1–5 are estimated to be able to produce about 3.5 million (2.6–5.1 million) smolts, and the current production is about 70–75% of it.

Because the management decisions for 2010 will only affect smolt abundances beyond 2012, it is possible to evaluate the probability that the smolt production in 2010 exceeds 50% and 75% of the carrying capacity in each river without considering catch options for 2010. When describing the status of the different stocks in comparison to these reference points, we consider a smaller than 30% probability to achieve this objective as an indicator that it is unlikely for the stock to achieve this objective. When the probability is higher than 70% and 90%, it is respectively considered 'likely' and 'very likely' that the stock will reach the objective, while with probability between 30 and 70%, it is considered 'uncertain' whether the objective will be reached (Table 5.3.9.4).

There are few changes in the river specific probabilities to reach the target smolt production compared to the last year's analysis (Table 5.3.9.4). In AU 2 four stocks (Åbyälven, Piteälven, Byskeälven and Ume/Vindelälven) have slightly higher probability to reach 50% or 75% of the PSPC in 2010 (Figures 5.3.9.6 and 5.3.9.7). For other rivers in AU 1–5 the probabilities to reach PSPC targets have not changed. There are altogether 10 rivers which area likely (however not very likely) reach the 75% of PSPC in short term. For the rest 17 rivers it is uncertain or unlikely to reach the 75% of PSPC.

5.6.2 Effort and post-smolt survival scenarios

In short term (2010) the catches and number of spawners under different scenarios are presented in Table 5.4.3.1. The highest effort would result in about 128 000 spawners and lowest effort 203 000 spawners. The long term (years 2015 and 2018) impacts of the different effort scenarios under different Mps regimes are presented in Table 5.4.3.2. Results suggest that if the scenario with highest effort rates would be realized, it would decrease the probability to reach PSPC objectives in most of the rivers in comparison with the modal or minimum effort scenarios. Realization of modal or low effort scenarios would result high probabilities to reach PSPC objectives in most of the rivers and the probabilities are about the same on both of these scenarios. Alternative Mps scenarios differ only slightly from each other in terms probabilities to reach PSPC objectives.

In general in most of the rivers the number of spawners and consequently the number of smolts will increase to higher numbers than observed in the last 20 years if the expected effort and medium Mps will be realized. However, in Mörrumsån and Emån a decreasing trend may continue if efforts will develop as expected (Figures 5.4.3.3.a–d).

Table 5.3.2.1 Overview of the different types of data available for the different Baltic salmon stocks. The table also indicates for which stocks the current assessment methodology is estimating smolt abundance, spawner abundance and associated stock-recruit function.

River identification						Data									Estimates		
Map number	River	ICES subdiv	Category	Country	IBSFC index river	M74 data	Electrofishing survey	smolt trap data	tagging data	fish ladder data	broodstock fishery	river catches	age structure	Genetic baseline	smolt estimates	spawner estimates	S/R parameters
Assessment group 1: North-eastern Bothnian															x	x	x
4	Råne älv	31	W	SE			x								x	x	x
3	Kalix älv	31	W	SE			x			x		x	x	x	x	x	x
1	Tornionjoki;Torne älv	31	W	FI/SE	x	x	x	x	x			x	x	x	x	x	x
81	Simojoki	31	W	FI	x	x	x	x	x			x		x	x	x	x
82	Kemijoki	31	R	FI		x			x					x			
80	Iijoki	31	R	FI					x					x			
77	Oulujoki	31	R	FI					x					x			
Assessment group 2: North-western Bothn															x	x	x
6	Pite älv	31	W	SE						x					x	x	x
7	Åby älv	31	W	SE			x			x			x		x	x	x
8	Byske älv	31	W	SE			x					x		x	x	x	x
11	Rickleån	31	W	SE			x								x	x	x
12	Sävarån	31	W	SE	x		x	x				x			x	x	x
13	Ume/Vindelälven	31	W	SE	x	x	x		x	x	x	x		x	x	x	x
15	Öre älv	31	W	SE			x			x					x	x	x
16	Lögde älv	31	W	SE			x							x	x	x	x
5	Lule älv	31	R	SE		x			x		x			x			
10	Skellefte älv	31	R	SE		x			x		x			x			
Assessment group 3: Bothnian Sea															x	x	x
21	Ljungan	30	W	SE		x	x		x					x	x	x	x
17	Gide älv	30	R	SE					x								
19	Ångerman älv	30	R	SE		x			x		x			x			
20	Indals älv	30	R	SE		x			x		x			x			
24	Dal älv	30	R	SE		x			x		x			x			
22	Ljunsnan	30	R	SE		x			x		x			x			
70	Kokemäenjoki	30	R	FI													
69	Aurajoki	29	R	FI													
68	Paimionjoki	29	R	FI													
River identification						Data									Estimates		
Nr	River	ICES subdiv	Category	Country	IBSFC index river	M74 data	Electrofishing survey	smolt trapping	tagging data	fish ladder	broodstock fishery	river catches	age structure	Genetic baseline	smolt estimates	spawner estimates	S/R parameters
Assessment group 4: Western Main Basin															x	x	x
25	Emån	27	W	SE			x							x	x	x	x
27	Mörrumsån	25	W	SE	x	x	x	x				x		x	x	x	x
Assessment group 5: Eastern Main Basin															x	x	x
53	Pärnu	28	W	EE	x									x	x	x	x
52	Salaca	28	W	LV	x		x		x						x	x	x
51	Vitrupe	28	W	LV											x	x	x
50	Peterupe	28	W	LV											x	x	x
49	Gauja	28	W	LV					x					x	x	x	x
48	Daugava	28	W	LV					x					x	x	x	x
46	Irbe	28	W	LV											x	x	x
45	Venta	28	W	LV										x	x	x	x
44	Uzava	28	W	LV											x	x	x
43	Saka	28	W	LV											x	x	x
42	Barta	28	W	LV/LT											x	x	x
40	Minija	26	W	LT	x										x	x	x
39	Nemunas	26	W	LT	x										x	x	x
47	Lielupe	28	R	LV					x								
Assessment group 6: Gulf of Finland																	
64	Neva	32	W	RU		x								x			
63	Luga	32	W	RU	x			x						x			
61	Kunda	32	W	EE	x		x							x			
60	Selja	32	W	EE			x										
59	Loobu	32	W	EE			x										
56	Pirita	32	W	EE			x	x									
55	Keila	32	W	EE	x		x							x			
54	Vasalemma	32	W	EE			x										
67	Karjaanjoki	32	R	FI													
62	Narva	32	R	RU/EE													
Total Baltic																	

Table 5.3.3.1 Prior probability distributions for the smolt production capacity (* 1000) in different Baltic salmon rivers. The prior distributions are described in terms of their mode or most likely value, the 95% probability interval (PI) and the method on how this prior probability distribution has been obtained. These priors will be updated when fitting the Beverton-Holt stock-recruit function to the available stock-recruit data (Section 5.3.9).

		Smolt production capacity (thousand)		Method of
		Mode	95% PI	estimation
Assessment unit 1				
1	Tornionjoki	690	246-6819	1
2	Simojoki	39	15-384	1
3	Kalixälven	240	143-2779	1
4	Råneälven	26	10-294	1
Total assessment unit 1		1598	589-8255	
Assessment unit 2				
5	Piteälven	30	7-369	4
6	Åbyälven	6	3-119	1
7	Byskeälven	75	31-879	1
8	Rickleån	3	1.0-31	1
9	Sävarån	2	0.6-30	1
10	Ume/Vindelälven	95	86-1330	3
11	Öreälven	5	4-160	1
12	Lögdeälven	17	7-289	1
Total assessment unit 2		492	238-2221	
Assessment unit 3				
13	Ljungan	2	0.8-27	1
Total assessment unit 3		2	0.8-27	
Assessment unit 4				
14	Emån	15	11-21.	4
15	Mörrumsån	90	66-128	4
Total assessment unit 4		105	79-145	
Assessment unit 5				
16	Pärnu	3,5	2.2-6.2	2
17	Salaca	30	26-35	4
18	Vitrupe	4	2.6-7.2	4
19	Peterupe	5	3.2-9.	4
20	Gauja	28	18-51	4
21	Daugava	10	6.-18	4
22	Irbe	4	2.6-7.2	4
23	Venta	15	10.-27	4
24	Saka	8	5.-14	4
25	Uzava	4	2.6-7.2	4
26	Barta	4	2.6-7.2	4
27	Nemunas river basin	150	96-269	4
Total assessment unit 5		291	218-395	

Method of estimation of smolt production capacity

1 Bayesian modelling of expert knowledge (Uusitalo et al. 2005)

2 Accessible linear stream length and production capacity per area

3 Bayesian hierarchical stock-recruit analysis of Atlantic salmon stocks (Michielsens and McAllister 2004)

4 Expert opinion with associated uncertainty

Table 5.3.5.1 Prior probability distributions for the wild smolt production (* 1000) in different Baltic salmon rivers. The prior distributions are described in terms of their mode (i.e. most likely value), the 95% probability interval (PI) and the method on how these prior probability distribution have been obtained. These priors will be updated in Section 5.3.9.

	Wild smolt production (thousand)																								Method of estimation
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Assessment unit 1																									
1 Tornionjoki	61	73	64	74	80	80	124	198	128	99	88	120	202	606	819	617	610	634	635	691	746	1063	1221	1532	1,3,4
95%PI	38-117	46-129	36-128	48-124	55-130	50-145	84-196	133-319	81-234	67-153	57-144	85-185	151-278	456-830	638-1109	509-768	470-851	492-871	492-833	527-981	569-1020	835-1455	953-1627	1160-2385	
2 Simojoki	2	2	9	10	8	13	9	9	2	1	2	7	11	40	53	52	50	35	26	35	33	39	22	25	1,3,4
95%PI	1-4	0-3	5-20	5-20	4-15	7-26	5-18	5-20	1-3	0-3	1-5	4-15	6-20	26-72	35-86	35-84	34-84	22-58	17-40	23-55	22-47	26-62	11-52	12-92	
3 Kalixälven	98	65	60	57	98	79	133	79	77	76	50	85	188	279	287	280	241	313	448	396	573	426	532	567	1,4
95%PI	45-1011	29-585	23-455	21-297	37-622	32-414	55-753	29-451	31-430	27-421	19-265	35-466	65-1299	119-1400	118-1405	121-1367	103-1127	131-1553	191-2424	171-1937	247-2800	182-2043	225-2613	248-3339	
4 Råneälven	4	3	4	2	2	3	3	3	1	1	2	5	8	14	16	11	9	15	21	17	25	27	22	22	1,4
95%PI	1-443	1-252	0-281	0-153	0-135	0-99	0-73	0-59	0-24	0-17	0-18	1-37	2-65	4-95	6-106	3-89	3-67	5-99	7-146	6-133	10-156	11-165	9-144	10-193	
Total assessment unit 1	164	146	147	154	197	189	284	317	229	189	152	231	416	997	1249	1014	974	1052	1174	1208	1438	1641	1902	2333	
95%PI	110-1080	100-664	94-532	101-395	125-716	122-520	187-892	214-700	147-586	123-534	100-368	157-606	272-1528	726-2081	931-2333	769-2075	723-1851	770-2276	833-3117	859-2719	997-3651	1212-3234	1394-3947	1679-5173	
Assessment unit 2																									
5 Piteälven	0	0	1	1	1	1	1	1	3	3	5	6	4	5	18	12	7	9	7	21	29	26	18	18	5
95%PI	0-7	0-6	0-2	0-2	0-2	0-2	0-2	0-2	1-7	1-7	2-12	3-14	2-10	2-12	9-43	6-28	3-17	4-21	4-18	13-37	16-66	13-52	9-36	9-36	
6 Åbyälven	1	1	1	1	1	2	3	4	2	2	3	4	3	6	9	6	4	4	3	2	8	12	8	8	1,4
95%PI	0-25	0-21	0-16	0-13	0-22	0-22	0-47	1-44	0-20	0-23	0-32	1-35	0-28	1-50	2-60	1-45	1-32	1-33	0-25	0-22	2-59	4-80	2-61	2-61	
7 Byskeälven	12	10	9	8	10	12	30	15	16	16	17	30	41	58	66	50	45	46	64	76	99	83	74	77	1,4
95%PI	4-116	3-85	2-77	2-55	2-75	3-72	11-186	4-103	6-102	6-98	6-102	11-186	16-265	25-298	29-336	22-272	18-224	18-241	26-359	34-364	44-519	37-404	34-360	33-470	
8 Rickleån	0.06	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.02	0.03	0.09	0.12	0.15	0.09	0.14	0.04	0.18	0.09	0.09	0.09	1
95%PI	0-16	0-9	0-6	0-3	0-2	0-1	0-1	0-1	0-3	0-2	0-3	0-3	0-4	0-4	0-7	0-8	0-9	0-7	0-7	0-5	0-10	0-7	0-7	0-8	
9 Sävarån	0.8	0.4	0.3	0.5	0.3	0.7	0.5	0.3	0.3	0.2	0.2	0.9	0.7	1.0	1.1	1.0	1.4	1.5	3.8	3.0	3.2	4.6	3.0	3.3	1,3,4
95%PI	0-29	0-21	0-17	0-11	0-10	0-9	0-8	0-6	0-6	0-5	0-6	0-11	0-10	0-11	0-12	0-13	0-14	0-14	2-5	2-3	2-4	3-6	0-17	0-20	
10 Ume/Vindelälven	14	5	9	10	16	8	8	10	8	3	6	9	31	85	35	72	90	48	72	52	64	87	64	46	1,4
95%PI	4-173	2-248	2-280	3-229	5-157	2-162	2-208	2-112	2-67	0-41	1-59	2-74	6-371	24-795	14-359	31-586	36-801	16-357	26-494	20-372	25-450	35-557	26-416	16-350	
11 Öreälven	0.6	0.2	0.2	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	1.1	0.9	0.8	1.5	0.9	0.9	0.6	1,4
95%PI	0-56	0-32	0-24	0-18	0-14	0-15	0-13	0-12	0-11	0-12	0-12	0-16	0-18	0-22	0-21	0-26	0-32	0-39	0-33	0-34	0-44	0-39	0-35	0-37	
12 Lögdeälven	0.6	0.4	0.3	0.3	0.2	0.3	0.7	0.4	0.4	0.7	0.5	1.3	1.7	2.1	3.3	2.5	2.0	2.7	3.8	5.2	5.3	4.8	3.7	3.6	1,4
95%PI	0-21	0-13	0-11	0-9	0-7	0-8	0-13	0-11	0-9	0-13	0-12	0-21	0-23	0-26	0-34	0-31	0-28	0-29	0-36	1-45	1-46	1-42	0-36	0-38	
Total assessment unit 2	55	33	36	33	46	36	71	51	45	39	49	73	122	207	183	202	185	159	204	216	291	295	225	250	
95%PI	29-319	22-356	19-317	18-274	22-233	19-214	33-374	23-249	22-196	19-173	25-205	38-321	59-685	105-1196	101-769	106-893	108-1055	81-667	107-980	117-870	166-1126	163-1114	132-1011	134-646	
Assessment unit 3																									
13 Lungan	0.16	0.11	0.16	0.29	0.41	0.20	0.20	0.16	0.04	0.08	0.24	0.28	0.43	0.72	0.62	0.42	0.25	0.18	0.23	0.19	0.54	0.29	0.15	0.33	1,4
95%PI	0-17	0-14	0-11	0-12	0-14	0-10	0-12	0-9	0-6	0-8	0-14	0-11	0-17	0-21	0-18	0-14	0-9	0-9	0-9	0-7	0-18	0-12	0-10	0-16	
Total assessment unit 3	0.16	0.11	0.16	0.29	0.41	0.20	0.20	0.16	0.04	0.08	0.24	0.28	0.43	0.72	0.62	0.42	0.25	0.18	0.23	0.19	0.54	0.29	0.15	0.33	
95%PI	0-17	0-14	0-11	0-12	0-14	0-10	0-12	0-9	0-6	0-8	0-14	0-11	0-17	0-21	0-18	0-14	0-9	0-9	0-9	0-7	0-18	0-12	0-10	0-16	

	Wild smolt production (thousand)																								Method of estimation
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Assessment unit 4																									
14 Emån			5	5	5	15	5	5	3	3	4	4	4	5	3	3	3	3	3	3	1	2	3	3	4
95% PI			3.6-7	3.6-7	3.6-7	11-22	3.6-7	3.3-7	2.2-4	1.8-3.7	2.9-6	2.5-5	2.9-6	3.6-7	2.2-4	2.2-4	2.2-4	1.8-3.7	2.3-4	2.3-4	0.4-1.4	1-3.5	1.5-5.4	1.5-5.4	
15 Mörrumsån			120	120	120	100	90	60	30	35	60	60	76	98	70	68	55	76	50	65	87	38	44	44	4
95% PI			86-178	86-180	86-180	72-150	64-135	43-90	22-45	25-52	43-90	43-90	54-114	70-147	50-105	49-102	39-82	54-113	40-66	47-79	64-99	29-47	35-53	35-53	
Total assessment unit 4			125	125	125	116	95	65	33	38	64	64	80	103	73	71	58	78	53	68	62	40	48	48	
95% PI			91-185	91-185	91-185	86-165	69-140	47-95	24-48	28-55	47-94	46-93	58-118	75-152	53-108	51-104	42-85	57-116	42-69	50-83	44-91	32-50	39-60	39-60	
Assessment unit 5																									
16 Pärnu											3	2	1	0.1	0.1	0.1	0	0	0	0	0	0			3,4
95% PI											1.3-16	0.9-11	0.4-5	0-0.5	0-0.5	0-0.5	0-0	0-0	0-0	0-0	0-0	0-0			
17 Salaca							22	15	15	20	20	29	27	19	29	27	25	10	27	30	17	25			2
95% PI							15-36	10-25	10-25	14-33	14-33	20-48	18-44	13-31	20-48	18-44	17-41	7-16	18-44	20-49	12-29	17-41			
18 Vitrupe															2	2	2	2	2	1	1	1			5
95% PI															1.1-5	1.1-5	1.1-5	1.1-5	1.1-5	0.6-2.3	0.6-2.3	0.6-2.3			
19 Peterupe															2	2	2	2	2	2	1	1			2,5
95% PI															1.1-5	1.1-5	1.1-5	1.1-5	1.1-5	1.1-5	0.6-2.3	0.6-2.3			
20 Gauja								13	13	14	14	13	13	13	12	12	12	10	10	10	10	10			2,5
95% PI								9-22	9-22	9-23	9-23	9-22	9-22	9-22	8-20	10-25	10-25	7-17	7-17	7-17	7-17	7-17			
21 Daugava															2	2	2	2	2	2	1	1			5,6
95% PI															1.1-5	1.1-5	1.1-5	1.1-5	1.1-5	1.1-5	0.6-2.3	0.6-2.3			
22 Irbe															5	5	5	4	5	2	2	2			5
95% PI															2.8-12	2.8-12	2.8-12	2.2-9	2.8-12	1.1-5	1.1-5	1.1-5			
23 Venta															10	10	10	10	10	10	8	8			2,5
95% PI															6-18	6-18	6-18	6-18	6-18	6-18	5-15	5-15			
24 Saka															2	2	2	2	2	2	2	2			5
95% PI															1.3-3.6	1.3-3.6	1.3-3.6	1.3-3.6	1.3-3.6	1.3-3.6	1.3-3.6	1.3-3.6			
25 Uzava															2	2	2	2	2	2	1	1			5
95% PI															1.1-5	1.1-5	1.1-5	1.1-5	1.1-5	1.1-5	0.6-2.3	0.6-2.3			
26 Barta															2	2	2	2	2	2	1	1			5
95% PI															1.1-5	1.1-5	1.1-5	1.1-5	1.1-5	1.1-5	0.6-2.3	0.6-2.3			
27 Nemunas river basin							10	10	10	10	10	10	2	7	6	4	2	5	7	6	14	15			3,4
95% PI							8.2-12.2	8.2-12.3	8.2-12.4	8.2-12.5	8.2-12.6	8.2-12.7	1.8-2.7	5.8-8.6	5.0-7.4	3.3-5	1.8-2.7	4.2-6	5.8-8.6	5.0-7.4	9-23	10-25			
Total assessment unit 5															87	87	78	61	80	78	65	76			
95% PI															71.6-108	71.4-109	64.2-98	51-74	66.4-100	64.8-98	54.7-78	61-96			

Method of estimation of prior pdf of current smolt production

1. Bayesian linear regression model (see section 6.3.5)
2. Sampling of smolts and estimate of total smolt run size.
3. Estimate of smolt run from parr production by relation developed in the same river.
4. Estimate of smolt run from parr production by relation developed in another river.
5. Inference of smolt production from data derived from similar rivers in the region.
6. Estimate infered from stocking of reared salmon in the river

Table 5.3.6.1 Median values and coefficients of variation of the estimated M74 mortality for different Atlantic salmon stocks (1985–2008).

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Simojoki	2	1	1	2	1	1	38	60	53	66	51	62	7	42	28	27	18	1	1	1	3	13	8	7
cv	1.04	1.14	1.14	1.09	1.19	1.12	0.19	0.15	0.17	0.09	0.17	0.12	0.32	0.12	0.21	0.23	0.25	0.57	0.63	0.96	0.59	0.31	0.45	0.96
Tornionjoki									78	54			8	39	23	26	27	0	1	1	4	5	14	7
cv									0.06	0.10			0.41	0.21	0.22	0.23	0.28	0.81	1.09	1.51	0.61	0.53	0.48	0.96
Kemijoki																						22	17	7
cv																						0.30	0.38	0.97
Luleälven								49	59	46	34	38	12	5	23	15	15	5	1	2	0	9	15	8
cv								0.16	0.06	0.13	0.20	0.15	0.34	0.22	0.15	0.16	0.26	0.52	0.46	0.47	0.69	0.25	0.17	0.31
Skellelteälven								35	46	51	33	56	5	4	28	10	10	3	2	0	1	2	10	1
cv								0.23	0.11	0.14	0.22	0.16	0.45	0.55	0.20	0.33	0.37	0.61	0.58	1.62	0.90	0.65	0.38	1.06
Ume/Vindel älven	21	11	13	10	8	16	34	64	78	66	46	57	11	13	35	30	19	5	4	2	0	3	10	3
cv	0.40	0.42	0.42	0.43	0.51	0.41	0.19	0.16	0.07	0.13	0.20	0.15	0.37	0.35	0.18	0.18	0.29	0.55	0.49	0.75	1.32	0.56	0.38	0.63
Angermanälven								42	69	49	31	47	7	4	19	15	13	6	3	2	1	13	21	12
cv								0.17	0.07	0.15	0.21	0.17	0.37	0.49	0.19	0.20	0.29	0.53	0.43	0.60	0.64	0.28	0.20	0.34
Indalsälven	3	4	5	4	2	4	6	38	65	53	28	48	7	1	14	15	4	3	1	0	1	9	12	13
cv	0.47	0.42	0.42	0.42	0.53	0.44	0.27	0.17	0.06	0.13	0.21	0.15	0.36	0.56	0.21	0.20	0.41	0.55	0.56	1.63	0.64	0.29	0.24	0.31
Ljungan								52	77	42	37	26	9	9	19	12	6	6	2					
cv								0.21	0.13	0.23	0.24	0.29	0.47	0.52	0.33	0.52	0.69	0.59	1.05					
Ljusnan	1	1	0	1	0	0	13	29	67	48	37	53	7	7	28	18	23	5	4	0	1	12	11	7
cv	1.05	1.12	1.12	1.10	1.18	1.09	0.26	0.21	0.07	0.14	0.20	0.15	0.37	0.34	0.21	0.19	0.27	0.55	0.43	1.60	1.25	0.30	0.32	0.42
Dalälven	15	5	5	11	6	5	17	65	76	42	37	43	12	13	23	19	17	5	4	2	2	9	13	6
cv	0.39	0.57	0.49	0.41	0.50	0.58	0.25	0.16	0.07	0.15	0.23	0.16	0.35	0.25	0.20	0.18	0.29	0.53	0.42	0.56	0.51	0.27	0.24	0.41
Mörrumsån	25	25	33	25	30	37	47	46	79	54	41	42	7											
cv	0.38	0.39	0.38	0.38	0.37	0.38	0.17	0.19	0.07	0.21	0.24	0.22	0.47											
Unsampled stock	7	6	6	7	5	6	24	46	68	51	36	46	9	11	24	19	15	3	3	1	2	10	14	7
cv	0.93	1.02	1.01	0.97	1.07	0.98	0.55	0.36	0.22	0.28	0.39	0.32	0.66	0.80	0.49	0.57	0.61	0.83	1.03	1.52	1.21	0.71	0.68	0.96

Table 5.3.7.1 Mean and CV for the posterior probability distribution of the steepness for the Beverton-Holt stock-recruit function for Atlantic salmon. The posterior predictive distribution for an unsampled Atlantic salmon stock is used as a prior probability distribution for any unsampled Atlantic salmon stock in the Baltic Sea area.

	Posterior distributions	
Stock	mean	CV
Little Codroy river	0.79	0.13
Margaree river	0.66	0.19
Pollett river	0.74	0.14
Trinite river	0.79	0.13
Western Arm Brook	0.64	0.23
river Bush	0.70	0.19
river Ellidaar	0.72	0.19
river Oir	0.70	0.19
river Bec-Scie	0.67	0.19
Unknown Atlantic salmon river	0.71	0.20

Table 5.3.9.1 Posterior probability distributions for the steepness and alpha and beta parameters of the Beverton-Holt stock-recruit relationship for different Baltic salmon stocks. The posterior distributions are described in terms of their mean and CV (%).

		Steepness		Alpha parameter		Beta parameter	
		Mean	cv	Mean	cv	Mean	cv
Assessment unit 1							
1	Tornionjoki	0.67	14	47	26	0.001	24
2	Simojoki	0.44	24	211	32	0.012	35
3	Kalixälven	0.82	10	22	42	0.001	38
4	Råneälven	0.68	16	49	47	0.017	53
Assessment unit 2							
5	Piteälven	0.81	9	19	39	0.038	26
6	Åbyälven	0.72	17	40	64	0.064	42
7	Byskeälven	0.77	13	26	54	0.007	35
8	Rickleån	0.63	19	68	46	0.230	147
9	Sävarån	0.65	18	61	49	0.131	56
10	Ume/Vindelälven	0.90	6	8	48	0.005	36
11	Öreälven	0.63	17	62	40	0.051	72
12	Lögdeälven	0.68	16	47	45	0.043	62
Assessment unit 3							
13	Ljungan	0.66	23	64	79	0.436	63
Assessment unit 4							
14	Emån	0.34	21	392	17	0.033	37
15	Mörrumsån	0.45	26	175	40	0.008	31
Assessment unit 5							
16	Pärnu	0.24	10	3373	31	0.05	58
17	Salaca	0.51	28	86	58	0.02	25
18	Vitrupe	0.49	27	105	59	0.18	35
19	Peterupe	0.48	27	117	54	0.15	38
20	Gauja	0.45	27	137	46	0.03	42
21	Daugava	0.43	26	149	43	0.07	41
22	Irbe	0.49	30	90	64	0.13	28
23	Venta	0.51	27	96	62	0.05	32
24	Saka	0.44	26	146	44	0.09	42
25	Uzava	0.49	27	106	58	0.18	36
26	Batra	0.49	27	106	58	0.18	35
27	Nemunas river basin	0.36	22	276	26	0.00	42

Table 5.3.9.2 Posterior probability distributions for the smolt production capacity (*1000) in different Baltic salmon rivers. The posterior distributions are described in terms of their mode or most likely value, the 95% probability interval (PI), the method on how the posterior probability distribution has been obtained. These estimates serve as reference points to evaluate the status of the stock This table also shows the mode as estimated by last year's stock assessment and how much the estimated mode has changed compared to last year.

		Smolt production capacity (thousand)				Method of estimation	Last year´s Mode	% change
		Mode	Median	Mean	95% PI			
Assessment unit 1								
1	Tornionjoki	1318	1427	1506	962-2541	1	1160	14%
2	Simojoki	45	55	60	28-131	1	40	14%
3	Kalixälven	812	968	1099	551-2292	1	1003	-19%
4	Råneälven	29	57	75	25-206	1	35	-16%
	Total assessment unit 1	2468	2615	2740	1824-4195		2457	1%
Assessment unit 2								
5	Piteälven	22	25	26	16-45	1	22	-1%
6	Åbyälven	13	15	17	7-33	1	14	-9%
7	Byskeälven	121	143	159	82-330	1	123	-2%
8	Rickleån	6	10	10	0-28	1	9	-35%
9	Sävarån	6	8	9	3-19	1	3	92%
10	Ume/Vindelälven	158	189	207	94-429	1	110	43%
11	Öreälven	16	20	21	5-44	1	14	15%
12	Lögdeälven	15	23	31	8-97	1	17	-12%
	Total assessment unit 2	429	458	480	308-774		425	1%
Assessment unit 3								
13	Ljungan	1	2	3	0-14	1	1	-14%
	Total assessment unit 3	1	2	3	0-14		1	-14%
Assessment unit 4								
14	Emån	14	15	15	10-20	1	15	-2%
15	Mörrumsån	80	83	84	62-115	1	82	-2%
	Total assessment unit 4	96	98	100	'77-131		98	-2%
Assessment unit 5								
16	Pärnu	3,5	3,7	3,9	2-6	2	3,5	0%
17	Salaca	30	30	30	25-35	3	30	0%
18	Vitrupe	4	4	4	2-6	3	4	0%
19	Peterupe	5	5	5	3-8	3	5	0%
20	Gauja	24	26	27	15-44	3	24	0%
21	Daugava	9	10	10	5-17	3	9	0%
22	Irbe	5	5	5	3-7	3	5	0%
23	Venta	14	15	16	10-24	3	15	-4%
24	Saka	7	8	8	4-13	3	7	0%
25	Uzava	4	4	4	2-6	3	4	0%
26	Barta	4	4	4	2-6	3	4	0%
27	Nemunas river	148	159	165	94-271	3	153	-3%
	Total assessment unit 5	268	275	284	213-393		275	0%
Total assessment units		**3379**	**3499**	**3607**	2613-5131		**3451**	-2%

Table 5.3.9.3 Salmon smolt production in Baltic rivers with natural reproduction of salmon grouped by assessment units. Most probable number (x 1000) of smolts from natural reproduction with the associated uncertainty (95% Probability interval).

Assessment unit, sub-division, country	Category	Reprod. area (ha, mode)	Potential (*1000)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Pred 2009	Pred 2010	Method of estimation	
																			Pot. prod.	Pres. prod.
Gulf of Bothnia, Sub-div. 30-31:																				
Finland																				
Simojoki	wild	254	45	3	5	7	10	23	44	46	49	39	32	36	34	41	38	34	1	1
95% PI		218-299	28-131	1-4	3-8	4-12	6-16	16-38	32-61	34-65	37-71	28-56	23-45	27-49	26-46	30-56	25-60	22-59		
Finland/Sweden																				
Tornionjoki;Torneälven	wild	4997	1317.6	98	70	126	218	533	698	618	626	628	644	770	818	1056	1184	1001	1	1
95% PI		3877-6695	962-2541	72-148	50-106	94-172	168-282	425-690	552-873	522-763	497-826	503-812	522-812	596-1007	644-1058	837-1376	949-1518	655-1753		
Sweden																				
Kalixälven	wild	2570	812	102	77	166	337	530	611	539	467	511	632	685	713	725	755	740	1	1
95% PI		2062-3295	551-2292	56-226	40-185	91-327	209-635	363-1086	398-1361	341-1197	292-946	318-1099	411-1460	447-1546	448-1782	449-1785	459-1939	428-2021		
Råneälven	wild	384	29	5	4	10	14	19	25	24	18	20	23	28	30	36	36	33	1	1
95% PI		325-462	25-206	1-20	1-15	4-29	7-36	10-47	14-54	13-50	9-41	10-42	13-54	16-61	17-67	20-78	19-81	17-77		
Assessment unit 1, total			**2468**	**222**	**168**	**324**	**597**	**1152**	**1419**	**1278**	**1201**	**1246**	**1392**	**1573**	**1674**	**1948**	**2102**	**1940**		
95% PI			1824-4195	159-353	118-274	231-486	443-887	931-1700	1127-2133	1018-1890	955-1672	989-1825	1104-2190	1228-2446	1271-2729	1542-3009	1660-3269	1402-3263		
Piteälven	wild	425	22	3	3	4	5	6	15	15	12	14	13	19	22	23	20	21	1	1
95% PI		359-511	16-45	1-6	2-6	2-8	3-9	3-11	10-23	9-23	7-20	9-22	8-22	13-27	14-37	16-37	14-31	12-39		
Åbyälven	wild	84	13	3	3	5	7	9	11	11	9	9	9	9	11	12	12	11	1	1
95% PI		67-108	7-33	1-10	1-9	2-11	3-14	5-18	6-22	6-21	5-18	4-18	4-18	5-19	6-25	7-26	6-26	6-24		
Byskeälven	wild	560	121	28	20	44	65	79	97	96	82	92	98	112	111	117	116	112	1	1
95% PI		473-673	82-330	15-74	9-61	25-94	35-136	46-160	58-182	59-173	51-163	57-179	61-192	70-222	71-224	71-254	71-254	68-257		
Rickleån	wild	15	6	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.3	0.3	0.3	0.5	0.8	0.9	0.8	1	1
95% PI		9.2-29	0-28	0-0	0-0	0-0	0-0	0-0	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-2	0-3	0-3		
Sävarån	wild	21	6	1	1	2	2	2	3	3	3	3	4	3	3	4	4	4	1	1
95% PI		13-40	3-19	0-4	0-2	0-4	1-4	0-4	1-5	1-5	1-5	1-5	2-4	2-3	2-4	3-6	2-8	2-8		
Ume/Vindelälven	wild	1242	158	17	17	24	56	75	96	86	83	75	95	129	136	145	145	145	1	1
95% PI		917-1778	94-429	7-52	8-48	13-65	30-132	40-173	56-203	46-187	44-191	39-168	51-211	77-289	80-299	84-340	82-320	76-342		
Öreälven	wild	105	16	0.6	0.4	0.9	1.1	1	2	2	2	2	2	3	4	5	5	5	1	1
95% PI		84-135	5-44	0-2	0-1	0-2	0-3	0-4	0-6	1-6	0-5	0-6	1-7	1-8	1-10	2-14	2-14	2-16		
Lögdeälven	wild	104	15	1	1	2	3	4	6	6	5	5	6	8	10	11	12	11	1	1
95% PI		82-136	8-97	0-5	0-4	0-6	1-8	1-10	3-14	3-14	2-12	2-12	3-14	4-17	5-20	6-25	6-27	5-26		
Assessment unit 2, total			**429**	**66**	**55**	**93**	**154**	**194**	**248**	**237**	**216**	**220**	**252**	**307**	**322**	**352**	**350**	**348**		
95% PI			308-774	42-118	35-99	64-150	104-249	140-308	180-378	175-358	153-335	158-334	183-384	226-467	236-509	259-574	240-548	244-584		
Ljungan	mixed	17	1	0.57	0.41	0.86	1.05	1.18	1.34	1.08	1.07	0.98	1.04	1.17	1.25	1.33	1.31	1.20	1	1
95% PI		9.8-37	0-14	0-2	0-2	0-2	1-3	1-3	1-4	1-3	0-3	0-3	1-3	1-3	1-4	1-4	1-4	1-4		
Assessment unit 3, total			1	0.57	0.41	0.86	1.05	1.18	1.34	1.08	1.07	0.98	1.04	1.17	1.25	1.33	1.31	1.20		
95% PI			0-14	0-2	0-2	0-2	1-3	1-3	1-4	1-3	0-3	0-3	1-3	1-3	1-4	1-4	1-4	1-4		
Total Gulf of B., Sub-divs.30-31			**2980**	**297**	**229**	**426**	**769**	**1366**	**1693**	**1538**	**1439**	**1490**	**1664**	**1920**	**2038**	**2346**	**2496**	**2341**		
95% PI			2266-4759	228-425	170-338	329-600	601-1073	1123-189	1379-239	1248-216	1163-191	1206-206	1355-2470	1543-2769	1603-3070	1888-3370	2001-3623	1764-3644		
Assessment unit, sub-division, country	**Category**	**Reprod. area (ha, mode)**	**Potential (*1000)**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**Pred 2009**	**Pred 2010**	**Method of estimation**	
																			Pot. prod.	**Pres. prod.**
Sweden																				
Emån	wild	21.7	14	2	4	3	4	5	3	3	3	3	3	3	1.5	2.4	2.7	1.7	1	1
95% PI			10-20	1-3	2-4	2-4	2-5	3-6	2-4	2-3	2-3	1-3	2-4	2-4	0-2	1-3	2-4	1-3		
Mörrumsån	wild	44	80	36	61	62	75	88	66	62	53	68	57	65	83	42	46	50	1	1
95% PI			62-115	26-51	47-82	48-83	58-102	68-119	50-92	47-86	40-73	52-93	43-76	50-88	70-100	35-51	39-53	30-93		

Table 5.3.9.3 continued.

Assessment unit 4, total			**96**	**39**	**65**	**66**	**79**	**93**	**70**	**65**	**56**	**70**	**60**	**68**	**84**	**45**	**48**	**52**		
95% PI			77-131	29-54	51-87	52-87	62-106	73-125	53-95	50-89	44-75	56-96	47-80	53-91	72-102	38-54	43-56	33-94		
Estonia																				
Pärnu	wild	3	3.5		4.4	0.7	0.3	0.07	0.2	0.2	0.01	0.01	0.006	0.01	0.012	0.0011	0.0007	0.0007	2	3, 4
95% PI			2-6		2-14	0-2	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0		
Latvia																				
Salaca	wild	47	30	22	23	32	26	20	28	27	24	15	27	25	27	27	25	28	3	2
95% PI			25-35	14-35	15-36	21-52	17-42	13-31	20-39	19-40	17-35	10-23	19-38	13-51	15-58	14-54	13-49	16-59		
Vitrupe	wild	5	4						2	2	2	3	3	3	3	3	3	3	3	5
95% PI			2-6						1-4	1-4	1-4	1-4	1-4	1-6	1-7	1-7	1-7	1-7		
Peterupe	wild	5	5						3	2	2	3	3	3	3	3	3	3	3	2, 5
95% PI			3-8						1-4	1-4	1-4	1-4	1-4	1-6	1-7	1-7	1-8	1-8		
Gauja	mixed	50	24	15	15	15	14	13	13	13	11	12	13	13	15	15	15	17	3	2, 5
95% PI			15-44	9-24	10-23	9-24	9-22	8-20	9-19	9-19	8-17	8-17	8-18	5-31	7-37	7-35	7-37	7-39		
Daugava***	mixed	20	9						2	2	2	3	3	3	4	4	4	4	3	5, 6
95% PI			5-17						1-4	1-4	1-4	1-4	1-5	1-8	1-10	1-11	1-11	1-12		
Irbe	wild	10	5						5	5	5	5	5	5	5	5	5	5	3	5
95% PI			3-7						3-9	3-9	3-8	3-8	3-9	2-10	2-11	2-11	2-11	2-11		
Venta	mixed	30	14						11	11	10	11	12	11	12	12	13	13	3	2, 5
95% PI			10-24						7-17	7-17	6-16	7-17	7-18	5-24	6-27	6-28	6-28	6-30		
Saka	wild	20	7						2	2	2	2	2	3	3	3	3	4	3	5
95% PI			4-13						1-3	1-3	1-3	1-3	1-4	1-7	1-9	1-9	1-9	1-10		
Uzava	wild	5	4						2	2	2	3	3	3	3	3	3	3	3	5
95% PI			2-6						1-4	1-4	1-3	1-4	1-4	1-6	1-7	1-7	1-7	1-7		
Barta	wild	10	4						2	2	2	3	3	3	3	3	3	3	3	5
95% PI			2-6						1-4	1-4	1-4	1-4	1-4	1-6	1-7	1-7	1-7	1-7		
Lithuania																				
Nemunas river basin	wild		148	10	10	10	2	7	6	4	2	5	7	4	4	3	6	7	3	3, 4
95% PI			94-271	8-12	7-11	7-11	1-2	6-9	5-7	3-5	1-2	3-5	5-8	1-14	1-14	1-10	2-18	2-27		
Assessment unit 5, total			268						**82**	**78**	**70**	**66**	**84**	**84**	**96**	**95**	**97**	**107**		
95% PI			213-393						70-98	66-95	58-84	55-80	71-99	50-133	58-149	58-145	58-147	65-166		
Total Main B., Sub-divs. 22-29			**378**						**153**	**145**	**128**	**138**	**145**	**154**	**181**	**140**	**146**	**162**		
95% PI			298-494						131-181	124-171	109-152	117-165	125-169	118-210	142-239	106-193	111-200	120-233		
Gulf of B.+Main B., Sub-divs. 22-31			**3539**						**1861**	**1706**	**1580**	**1646**	**1841**	**2100**	**2262**	**2518**	**2682**	**2544**		
95% PI			2496-5428						1475-2424	1336-2258	1270-2023	1294-2167	1416-2498	1626-2820	1699-3167	1935-3418	2052-3662	1831-3785		

+ = Low and uncertain production (not added into
++ = Same method over time series; only the extension backwards
*** = Tributaries
**** = Only Latvian part, Lithuanian part of the river needs to be added
n/a No data available.

Methods of estimating production

Potential production
1. Bayesian stock-recruit a
2. Accessible linear strea
3. Expert opinion with as

Present production
1. Bayesian full life history model (section 6.3.9)
2. Sampling of smolts and estimate of total smolt run size.
3. Estimate of smolt run from parr production by relation developed in the same river.
4. Estimate of smolt run from parr production by relation developed in another river.
5. Inference of smolt production from data derived from similar rivers in the region.
6. Count of spawners.
7. Estimate inferred from stocking of reared fish in the river.
8. Salmon catch, exploitation and survival estimate.

Reared smolts
*=Release river not specified

Table 5.3.9.4 Overview of the status of the Gulf of Bothnia and Main Basin stocks in terms of their probability to reach 50 and 75% of the smolt production capacity by 2010. Stocks are considered very likely to reach this objective in case the probability is more than 90%. They are likely to reach the objective in case the probability is between 70 and 90% and unlikely in case the probability is less than 30%. When the probability of reaching the objective lies between 30 and 70%, it is considered uncertain if they will reach the objective in 2010.

	Prob to reach 50%				Prob to reach 75%			
	V.likely	Likely	Uncert.	Unlikely	V.likely	Likely	Uncert.	Unlikely
Unit 1								
Tornionjoki	X						X	
Simojoki		X					X	
Kalixälven	X					X		
Råneälven		X					X	
Unit 2								
Piteälven	X					X		
Åbyälven	X						X	
Byskeälven	X					X		
Rickleån				X				X
Sävarån			X				X	
Ume/Vindelälven	X					X		
Öreälven				X				X
Lögdeälven			X				X	
Unit 3								
Ljungan		X					X	
Unit 4								
Emån				X				X
Mörrumsån		X					X	
Unit 5								
Pärnu				X				X
Salaca	X					X		
Vitrupe	X					X		
Peterupe		X					X	
Gauja		X					X	
Daugava			X					X
Irbe	X					X		
Venta	X					X		
Saka			X				X	
Uzava	X					X		
Barta	X					X		
Nemunas				X				X

Table 5.4.2.1a Key assumptions underlying the stock projections.

Scenario	Effort*
1	Minimum effort
2	Mode effort
3	Max effort
4	Whole range of effort

Scenario	Post-smolt survival**
a	Low *(2005 median, i.e. 13.6%)*
b	Medium *(2004-2007 median, i.e. 15.6%)*
c	High *(historical median, i.e. 25.2%)*

Survival from M74***
Historical median, i.e. 90%

* Scenarios 1–3 assume min, max or mode effort given in Table 4.2.1for whole projection period. Scenario 4 assumes the whole range of effort given in Table 4.2.1.

** Scenarios a–c presents the median of post-smolt survival to which the Mps is expected to return.

*** For M74 it is assumed only one survival scenario to which it is expected to return.

Table 5.4.3.1 Total catch and total number of spawners in 2010 (in thousands). Total reported commercial catch and its share between longlines and trapnets.

Effort scenario	Catch total in 2010 (x % of TAC 2009)			Reported median catch in 2010		Spawners total 2010	
	median	95%PI	reported commercial	OLL	CTN	median	95%PI
1	248	(161,375)	167 (51%)	92	75	203	(111,323)
2	360	(234,545)	243 (75%)	139	104	170	(95,273)
3	521	(340,790)	352 (108%)	208	144	128	(72,205)
4	368	(236,559)	248 (76%)	141	107	168	(93,269)

Table 5.4.3.2 Probability to meet 50% and 75% of PSPC by 2015 with effort scenarios and by 2018 with post-smolt survival scenarios.

a) Probability to meet 50% or 75% of the carrying capacity by 2015.

Effort	Tornionjoki		Simojoki		Kalixälven		Råneälven		Piteälven		Åbyälven		Byskeälven		Rickleån		Sävarån		Ume/Vindelälven		Öreälven		Lögdeälven		Ljungan		Mörrumsån		Emån	
	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75
1	1.0	0.9	0.9	0.6	1.0	0.9	1.0	0.8	1.0	0.9	1.0	0.9	1.0	0.9	0.5	0.3	1.0	0.7	1.0	0.9	0.8	0.5	1.0	0.8	0.9	0.8	0.9	0.6	0.0	0.0
2	1.0	0.8	0.8	0.4	1.0	0.9	1.0	0.8	1.0	0.9	1.0	0.9	1.0	0.9	0.5	0.3	0.9	0.7	1.0	0.9	0.8	0.5	0.9	0.7	0.9	0.7	0.9	0.6	0.0	0.0
3	1.0	0.7	0.6	0.2	1.0	0.8	0.9	0.6	1.0	0.9	1.0	0.8	1.0	0.9	0.4	0.2	0.9	0.6	1.0	0.9	0.7	0.3	0.9	0.6	0.9	0.6	0.8	0.4	0.0	0.0
4	1.0	0.8	0.8	0.4	1.0	0.9	1.0	0.7	1.0	0.9	1.0	0.9	1.0	0.9	0.5	0.3	0.9	0.7	1.0	0.9	0.8	0.5	0.9	0.7	0.9	0.7	0.9	0.5	0.0	0.0

b) Probability to meet 50% or 75% of the carrying capacity by 2018.

Survival	Tornionjoki		Simojoki		Kalixälven		Råneälven		Piteälven		Åbyälven		Byskeälven		Rickleån		Sävarån		Ume/Vindelälven		Öreälven		Lögdeälven		Ljungan		Mörrumsån		Emån	
	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75	50	75
a	1.0	0.8	0.6	0.3	1.0	0.9	0.9	0.7	1.0	0.9	1.0	0.8	1.0	0.9	0.5	0.3	0.9	0.7	1.0	0.9	0.8	0.4	0.9	0.7	0.9	0.7	0.9	0.7	0.0	0.0
b	1.0	0.8	0.6	0.3	1.0	0.9	0.9	0.7	1.0	0.9	1.0	0.8	1.0	0.9	0.5	0.3	0.9	0.6	1.0	0.9	0.8	0.4	0.9	0.7	0.9	0.7	0.9	0.7	0.0	0.0
c	1.0	0.8	0.7	0.3	1.0	0.9	0.9	0.7	1.0	0.9	1.0	0.9	1.0	0.9	0.5	0.3	0.9	0.7	1.0	0.9	0.8	0.5	0.9	0.7	0.9	0.7	1.0	0.8	0.1	0.0

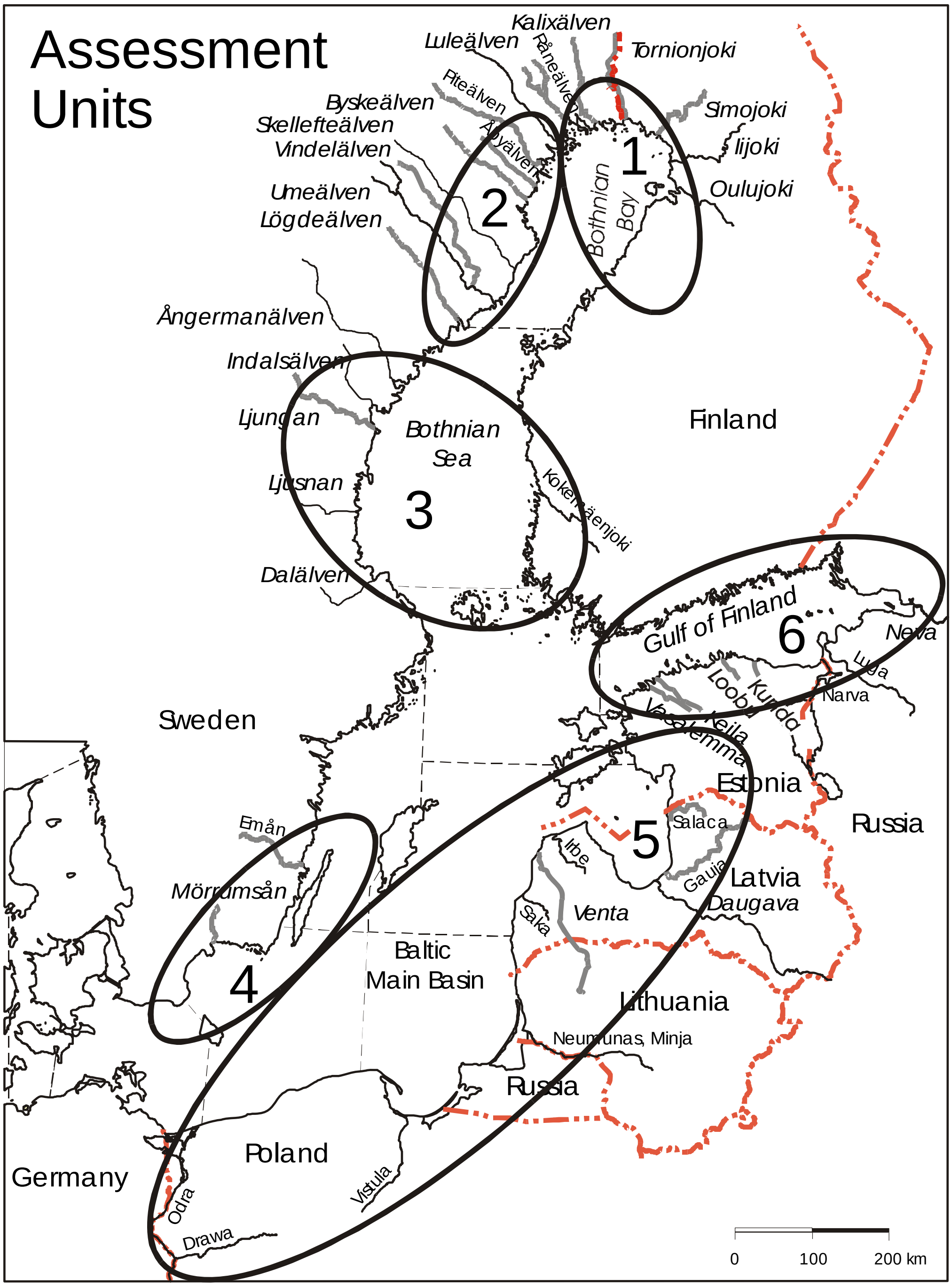


Figure 5.3.1.1 Grouping of salmon stocks in 6 assessment units in the Baltic Sea. The genetic variability between stocks of an assessment unit is smaller than the genetic variability between stocks of different units. In addition, the stocks of a particular unit exhibit similar migration patterns. Section 5.3.1 of the report describes exactly which rivers belong to which assessment unit.

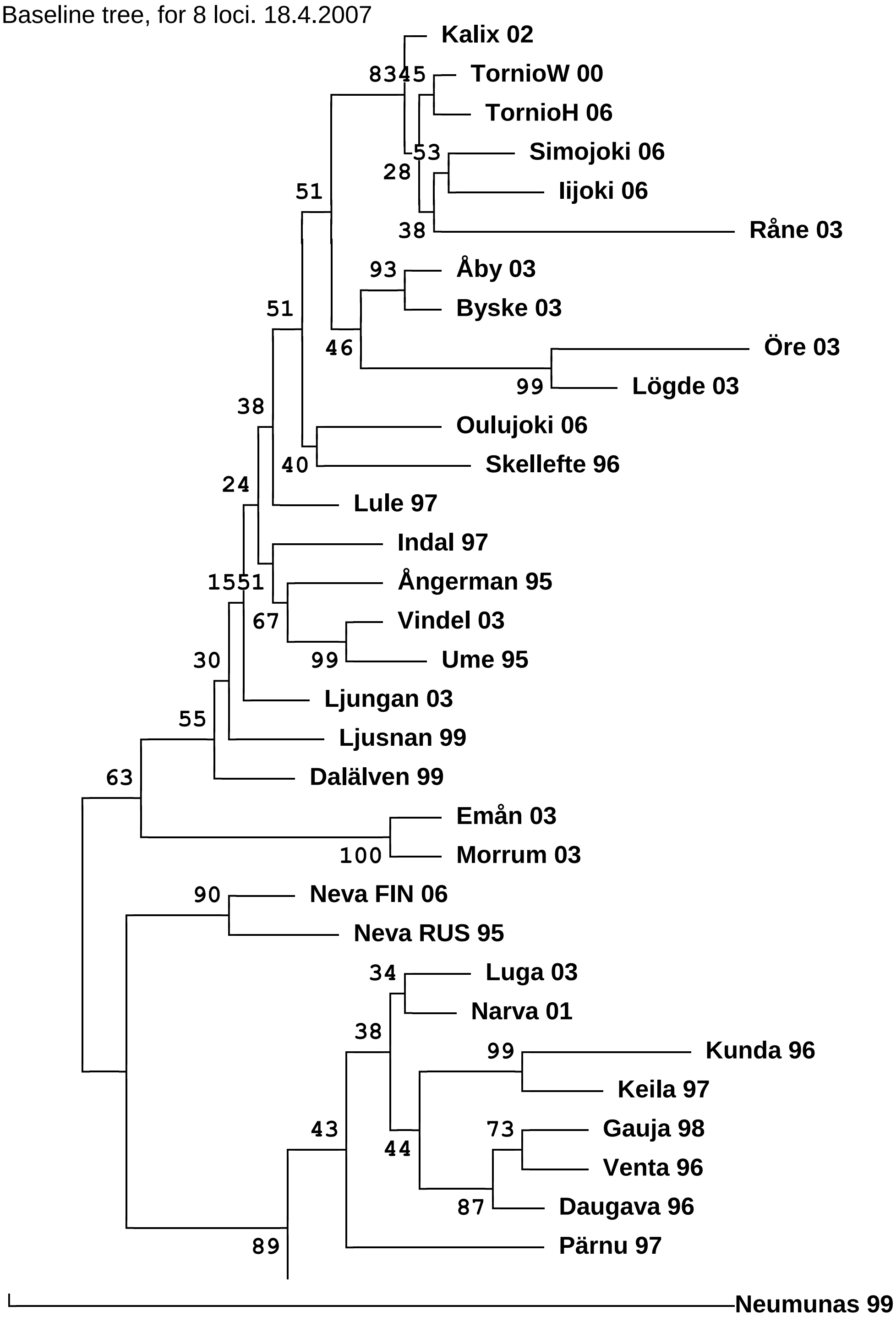
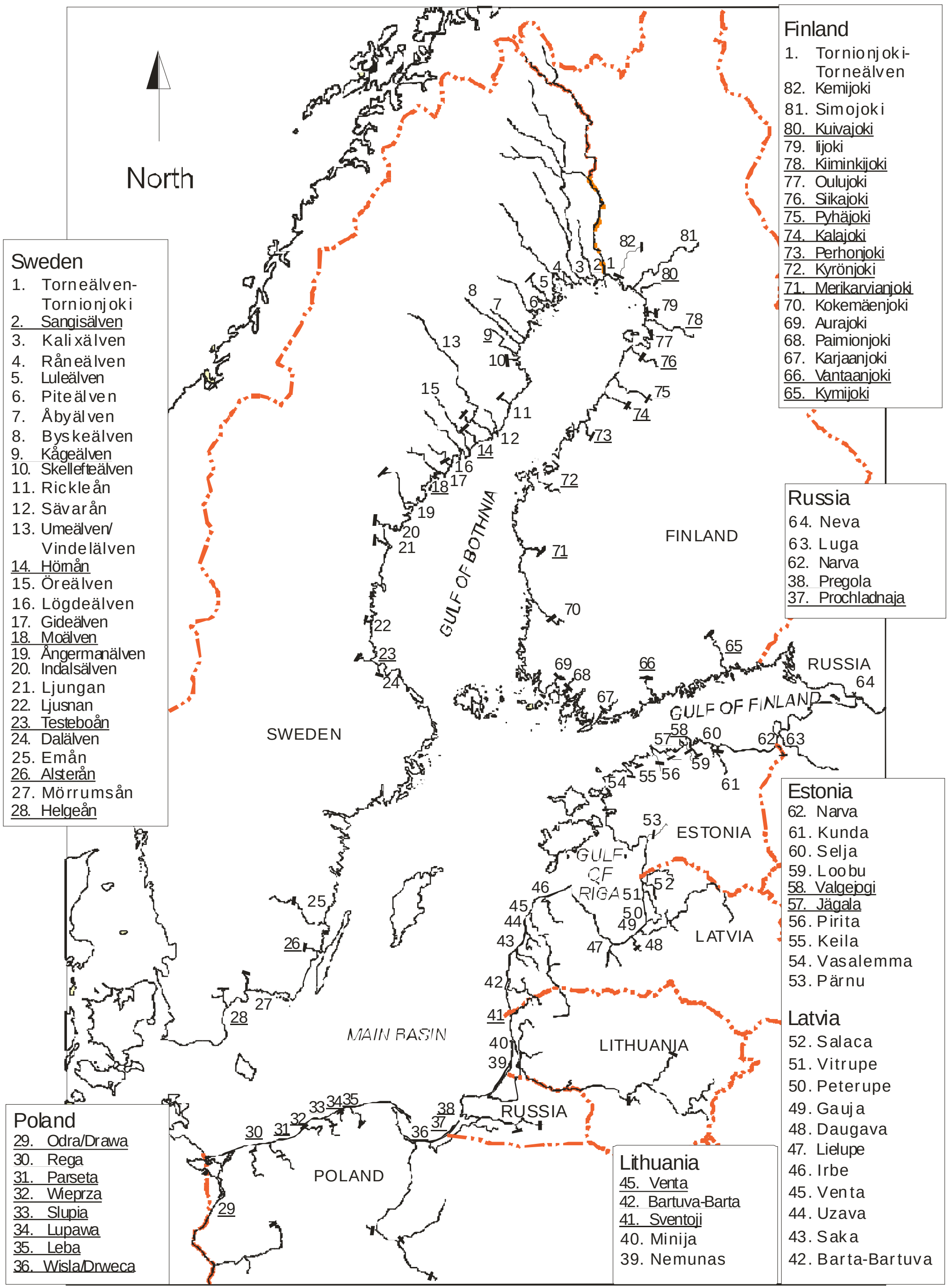
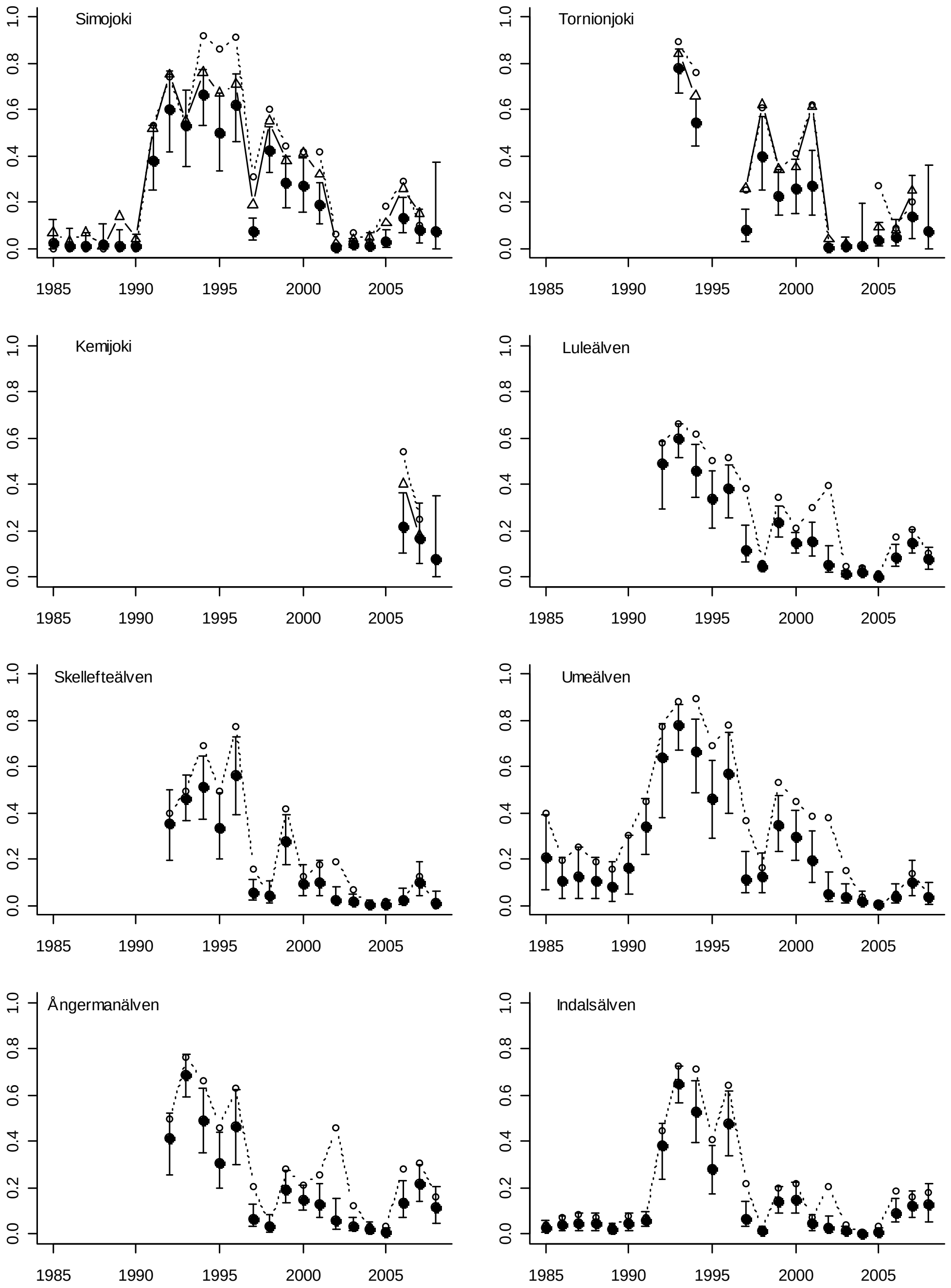


Figure 5.3.1.2 Baseline data for the genetic stock proportion estimation of catches. Genetic distances between baseline stocks. Percent support from 1000 bootstrap replication are given for the grouping of the branches. Sampling years are indicated after each population name.



River names with a slash (/) show main river/tributary. River names with hyphen (-) show names in different countries.

Figure 5.3.1.3 Baltic salmon rivers divided into three categories. Only lower parts of rivers with current salmon production or potential for production of wild salmon are shown. The presence of dams, which prevents access to areas, is indicated by lines across rivers. Notation: river name in bold = river with wild smolt production; river name underlined = river with potential for establishment of wild salmon; normal font = river with releases, no natural reproduction.


Simojoki
Tornionjoki
Kemijoki
Luleälven
Skellefteälven
Umeälven
Ångermanälven
Indalsälven
0.0
0.2
0.4
0.6
0.8
1.0
1985
1990
1995
2000
2005

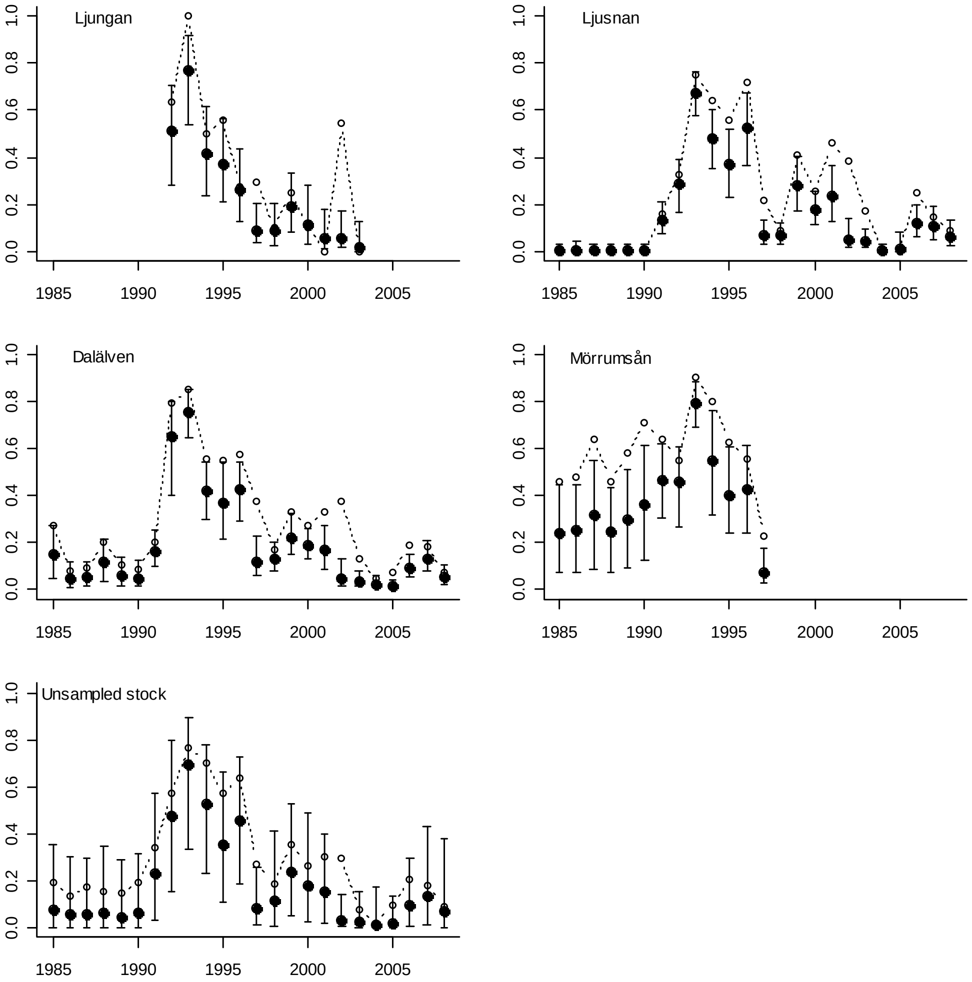


Figure 5.3.6.1 M74 mortality among Atlantic salmon stocks within the Baltic Sea. Solid circles and whiskers represent the medians and 95% probability intervals of the estimated M74 mortality. Open circles represent the proportion of females with offspring affected by M74 and triangles the total average yolk-sac-fry mortalities among offspring.

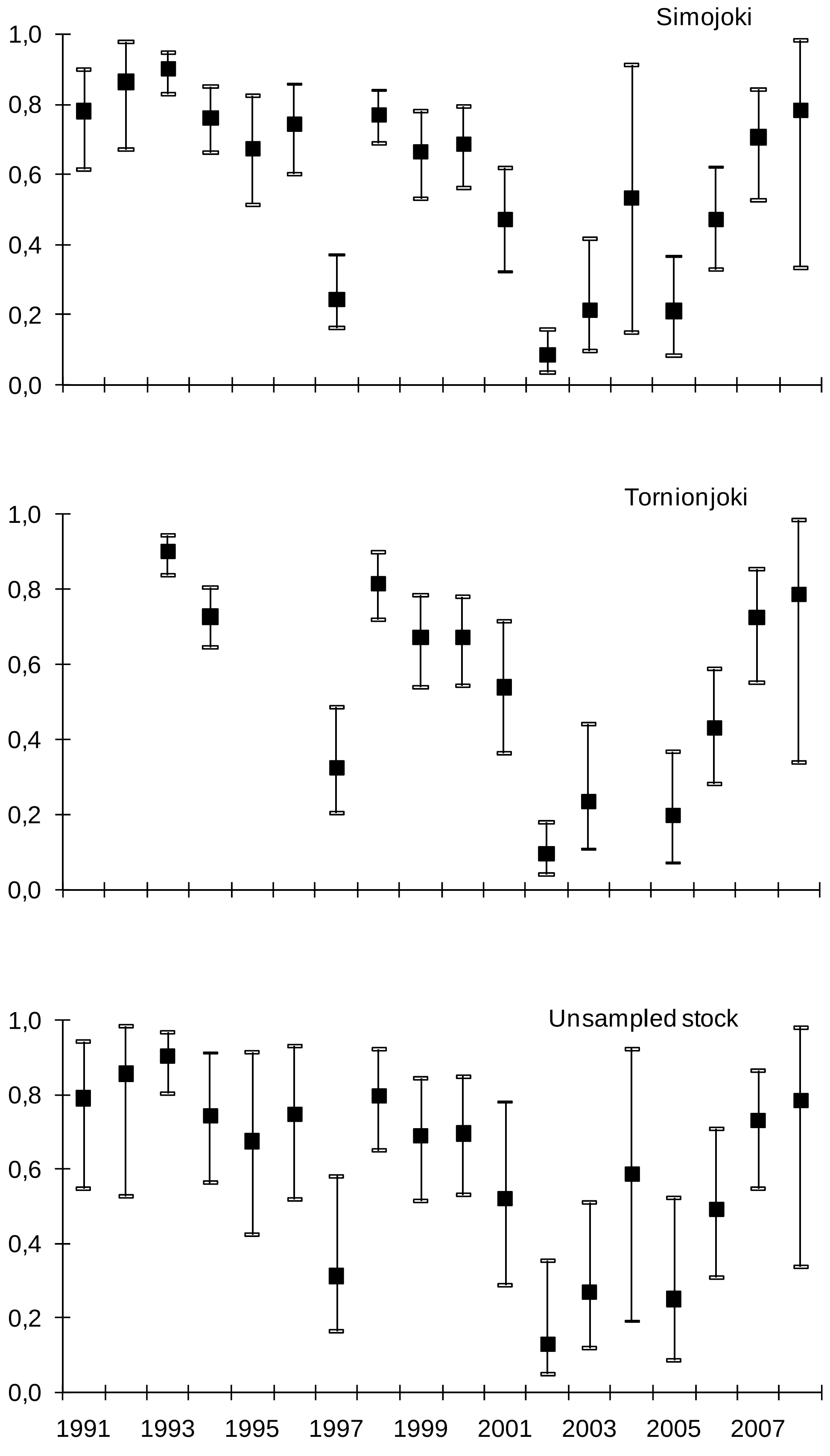
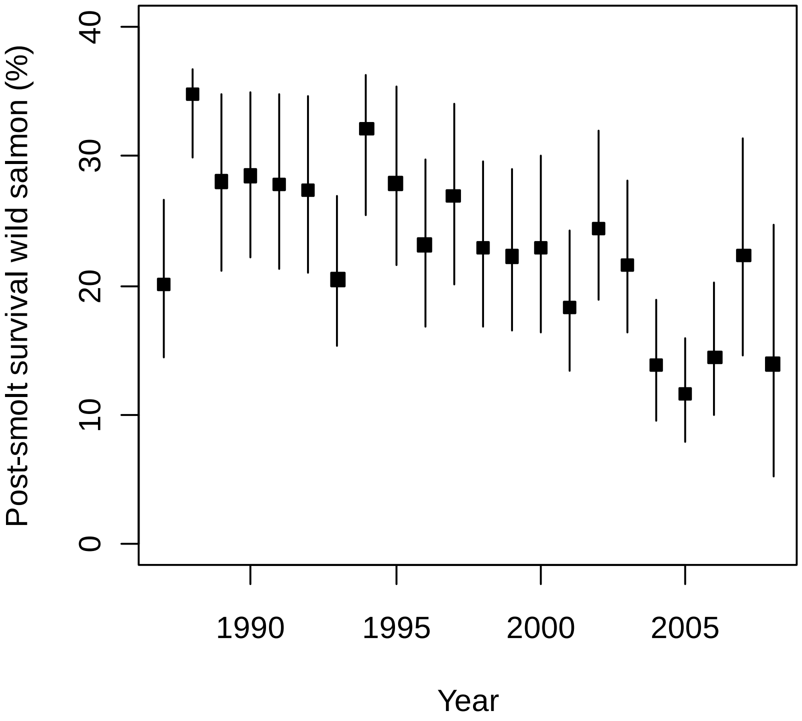


Figure 5.3.6.2 Estimated proportion of M74-affected offspring that die.



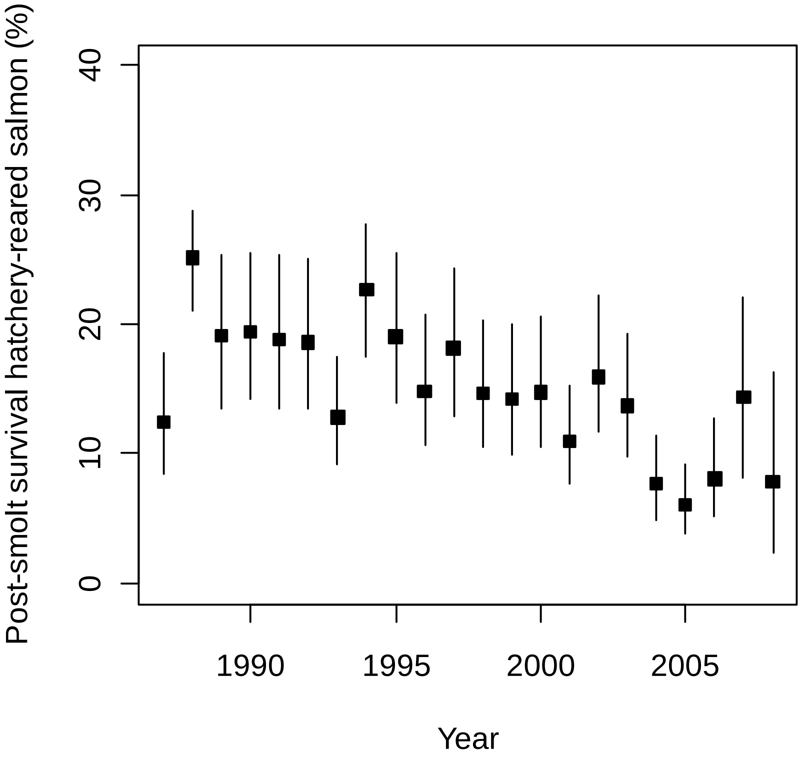


Figure 5.3.9.1 Post-smolt survival for wild and hatchery-reared salmon.

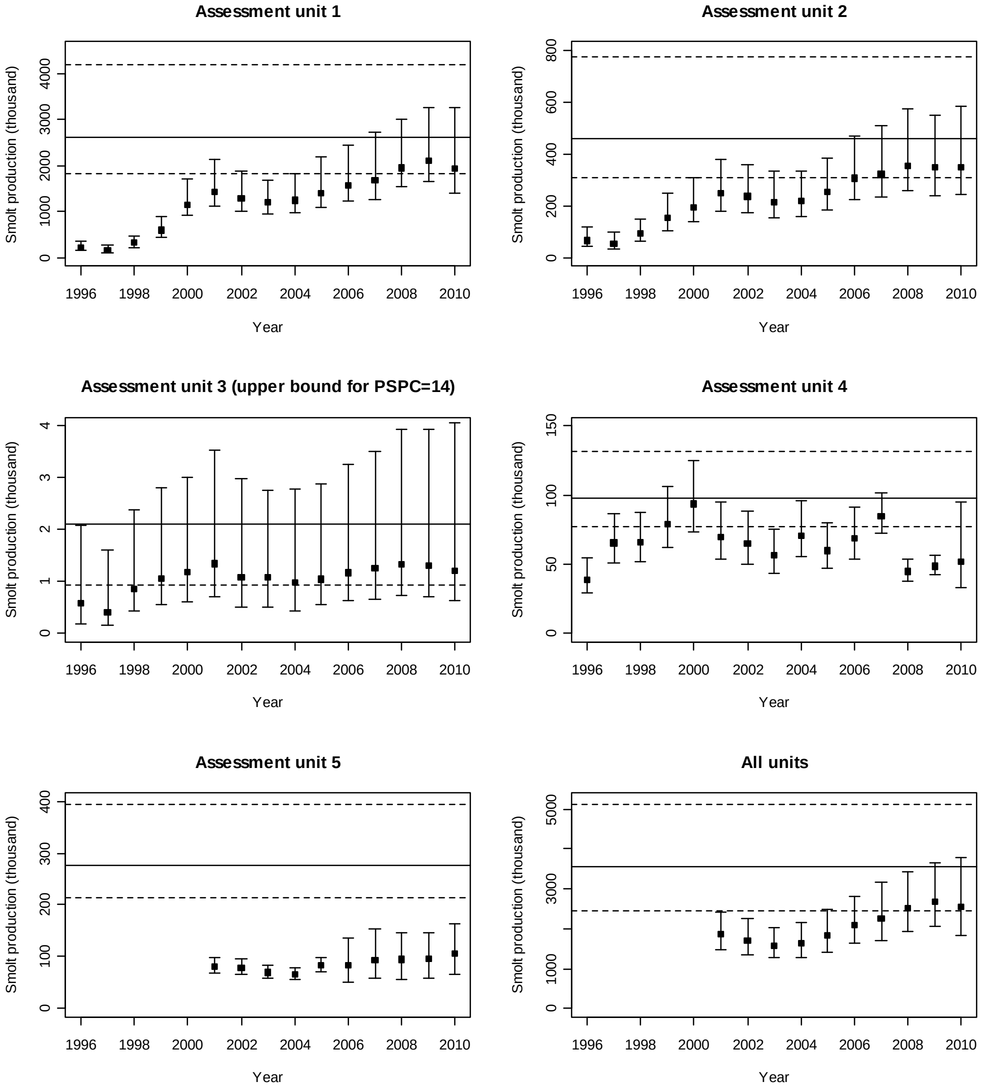
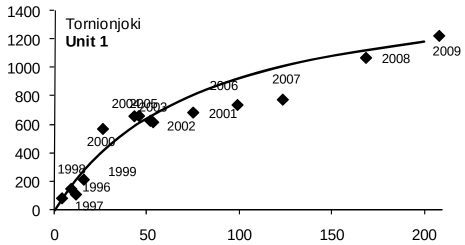
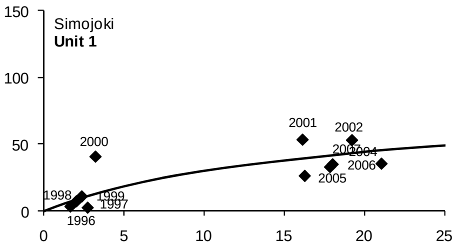
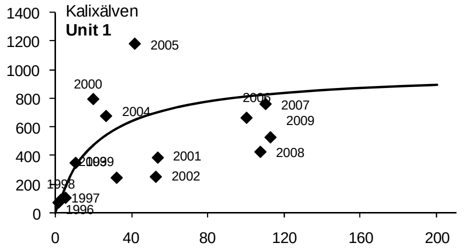
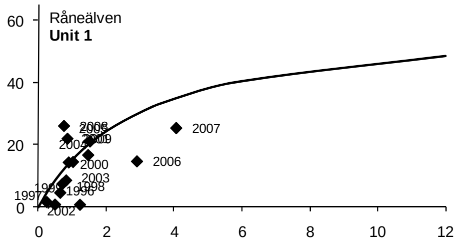


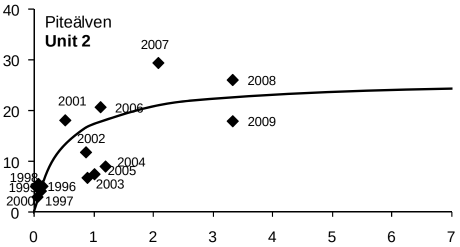
Figure 5.3.9.2 Posterior probability distribution (median and 95% PI) of the total smolt production within assessment units 1–5 and in total. Vertical lines show the median (solid line) and 95% PI (dashed lines) for potential smolt production capacity (PSPC).

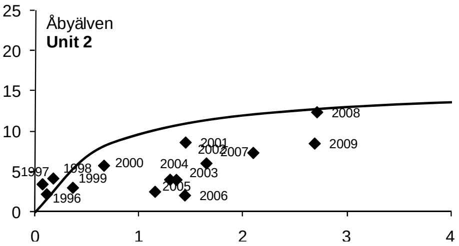

Tornionjoki
Unit 1
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
2009
2008
2007
2006
2005
2003
2001
2002
2000
1999
1998
1996
1997


Simojoki
Unit 1
150
100
50
0
0
5
10
15
20
25
2001
2002
2000
2004
2006
2005
1998
1999
1997
1996


Kalixälven
Unit 1
1400
1200
1000
800
600
400
200
0
0
40
80
120
160
200
2005
2000
2004
2006
2007
2009
2008
2001
2002
1999
1998
1997
1996


Råneälven
Unit 1
60
40
20
0
0
2
4
6
8
10
12
2007
2006
2008
2005
2009
2004
2000
2003
1998
1999
1996
1997
2002


Piteälven
Unit 2
40
30
20
10
0
0
1
2
3
4
5
6
7
2007
2008
2009
2001
2006
2002
2004
2005
2003
1998
1999
1996
2000
1997


Åbyälven
Unit 2
25
20
15
10
5
0
0
1
2
3
4
2008
2009
2001
2002
2007
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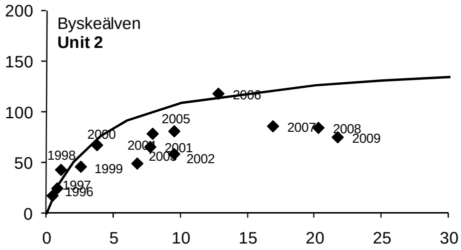
2006
1997
1998
1999
1996


Byskeälven
Unit 2
200
150
100
50
0
0
5
10
15
20
25
30
2006
2005
2007
2008
2009
2000
2004
2001
2003
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1998
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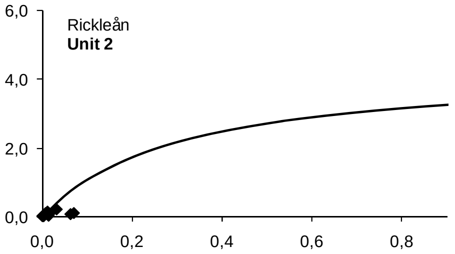
1997
1996


Rickleån
Unit 2
6,0
4,0
2,0
0,0
0,0
0,2
0,4
0,6
0,8

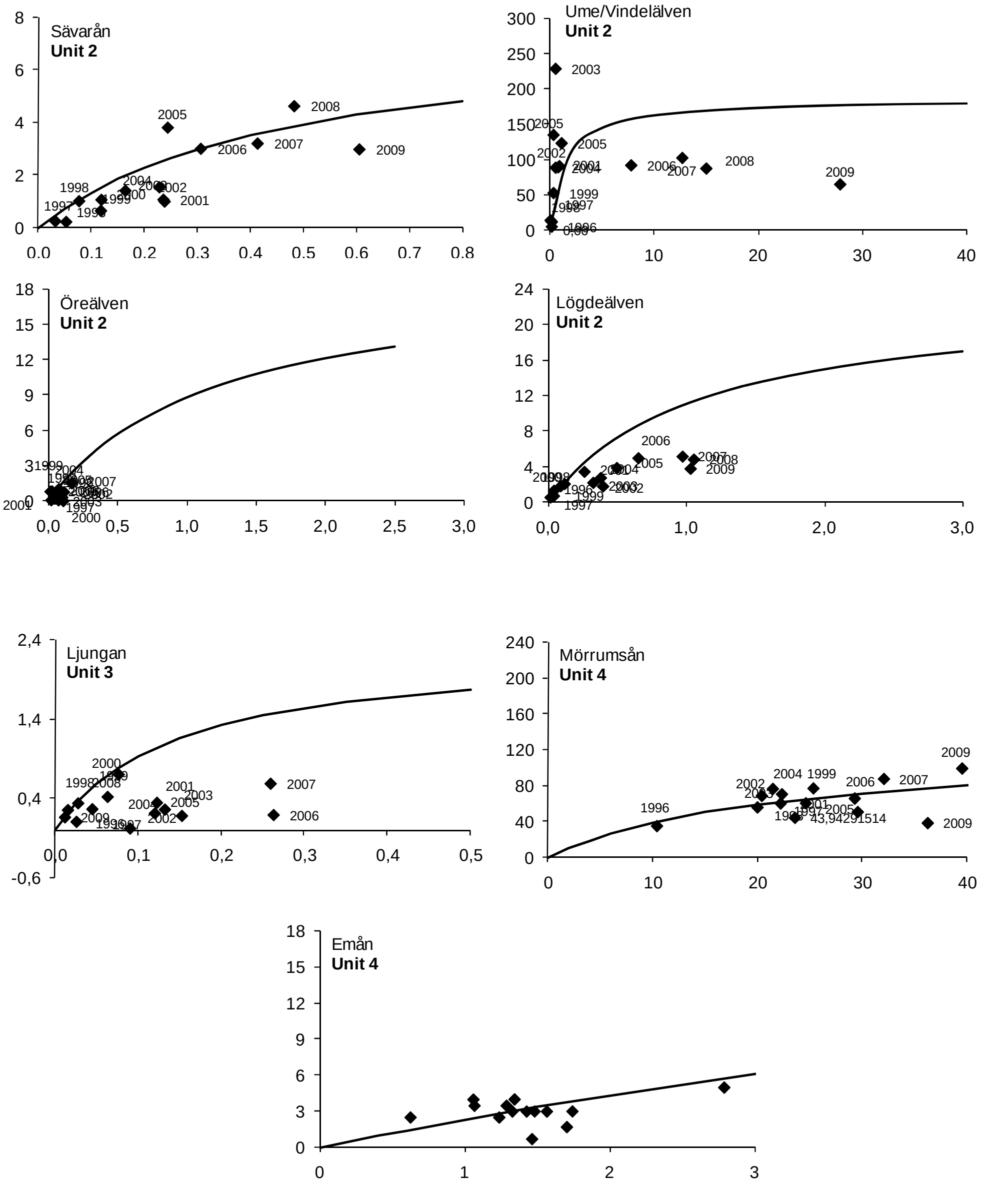


Figure 5.3.9.3 These graphs shows the median of the resulting distribution for egg abundance (million), plotted against the median smolt abundance (thousand) for stocks of assessment units 1, 2, 3 and 4. These stock-recruit data have been obtained by combining the smolt abundance estimates obtained by the hierarchical linear regression analysis of parr density data with estimtes of the natural and fishing mortality at sea. The graph also indicates the estimated median stock-recruit relationships as estimated by the full life history model.

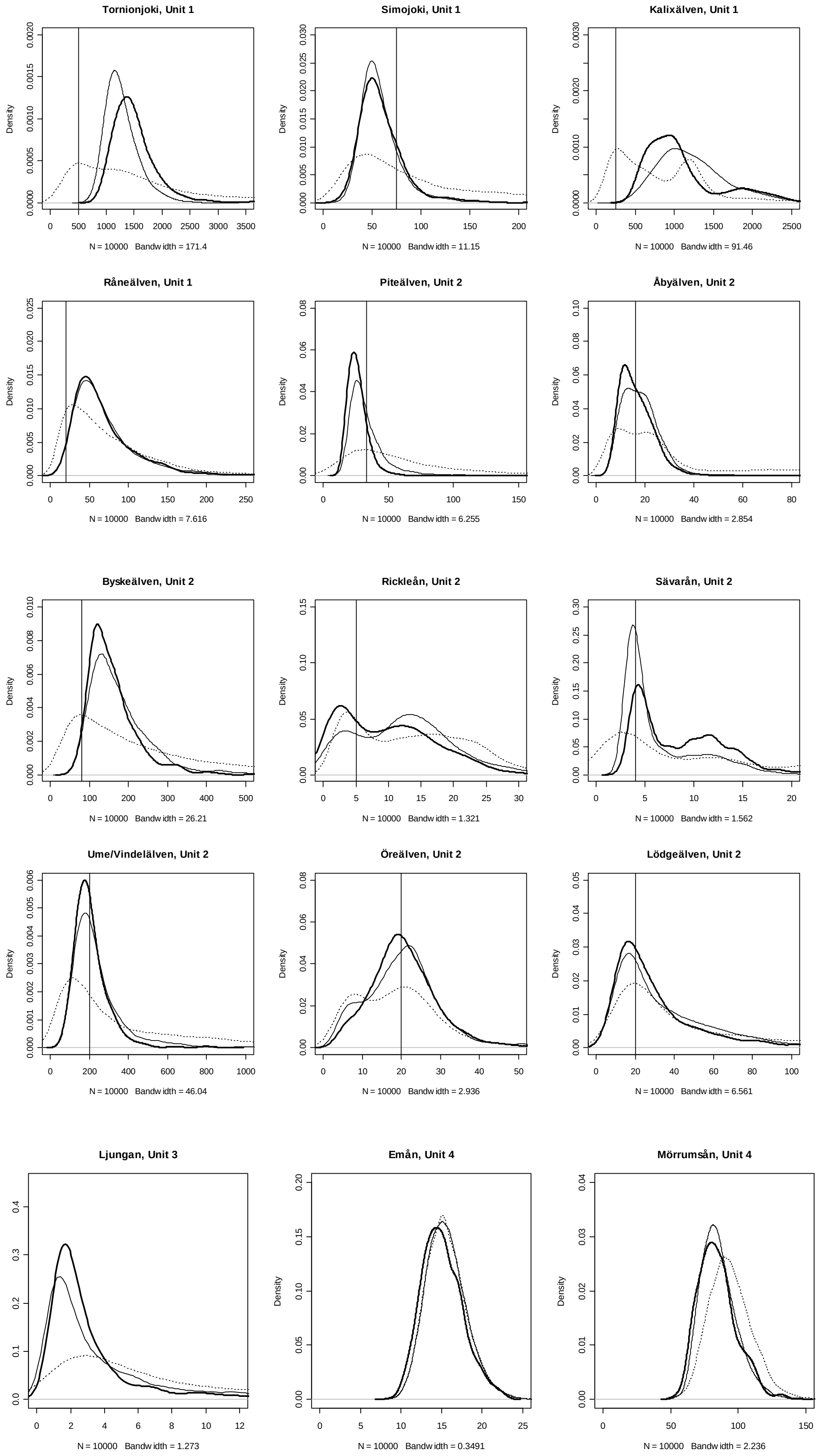


Figure 5.3.9.4 Old point estimates (vertical line), prior probability distributions (dotted line) and posterior probability distributions of the smolt production capacity obtained in the assessment of 2008 (thin line) and 2009 (bold line).

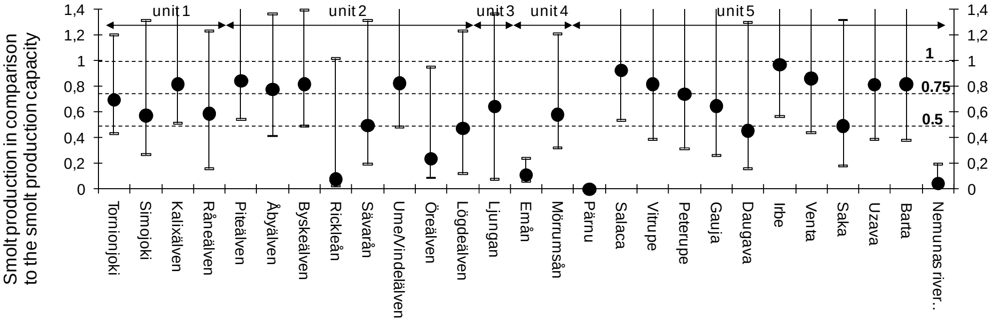


Figure 5.3.9.5 Smolt production in 2010 in comparison to the natural smolt production capacity for the Gulf of Bothnia and Main Basin stocsk (mode and 95% probability interval).

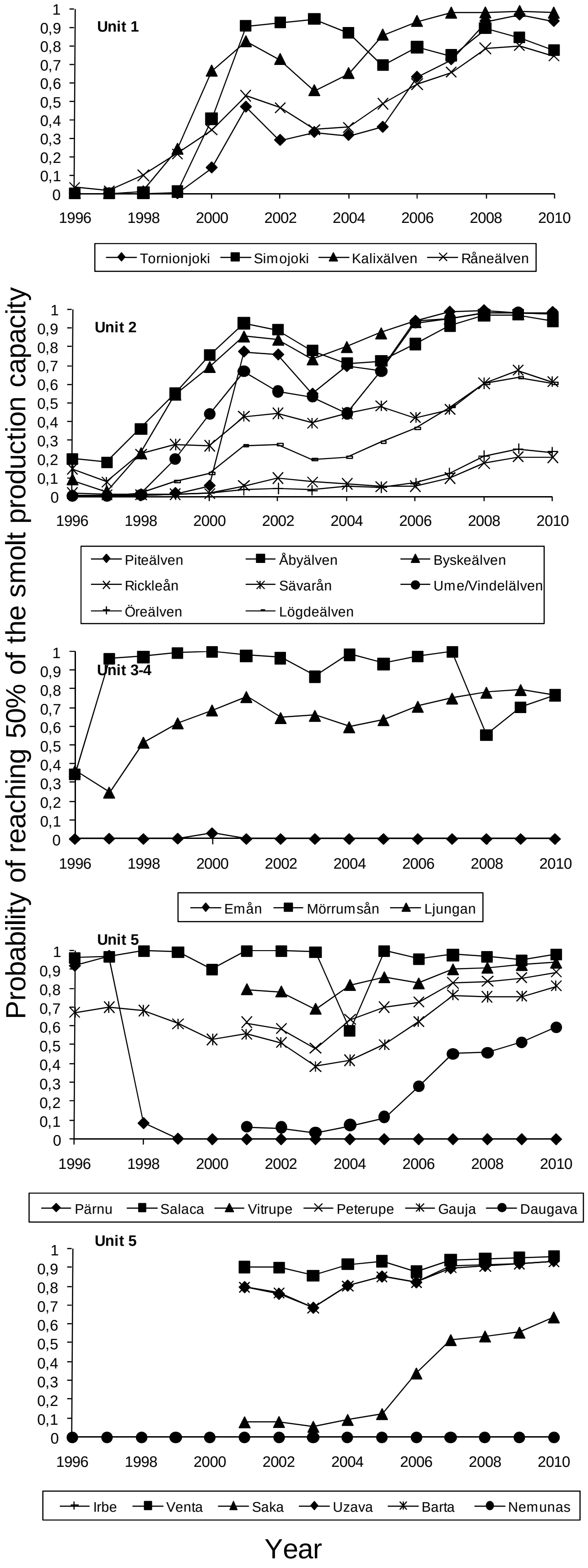


Figure 5.3.9.6 Probability of reaching 50% of the smolt production capacity for different stocks of the Gulf of Bothnia and Main Basin.

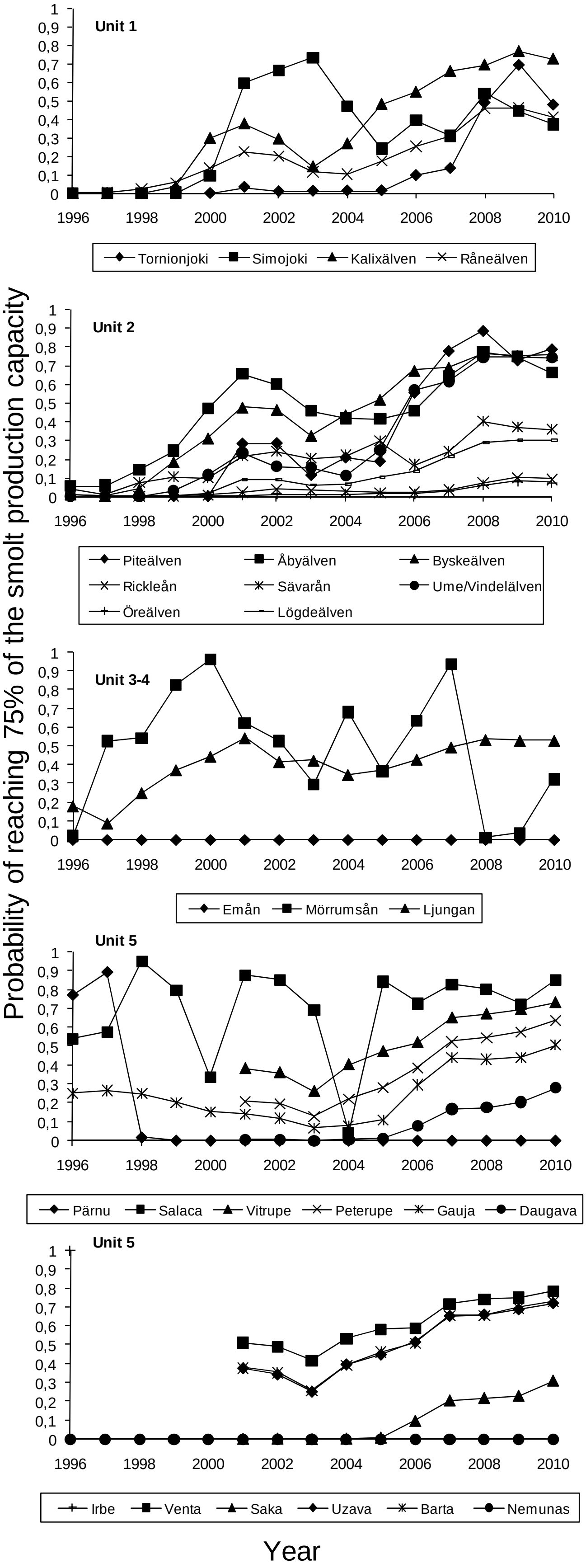


Figure 5.3.9.7 Probability of reaching 75% of the smolt production capacity for different stocks of the Gulf of Bothnia and Main Basin.

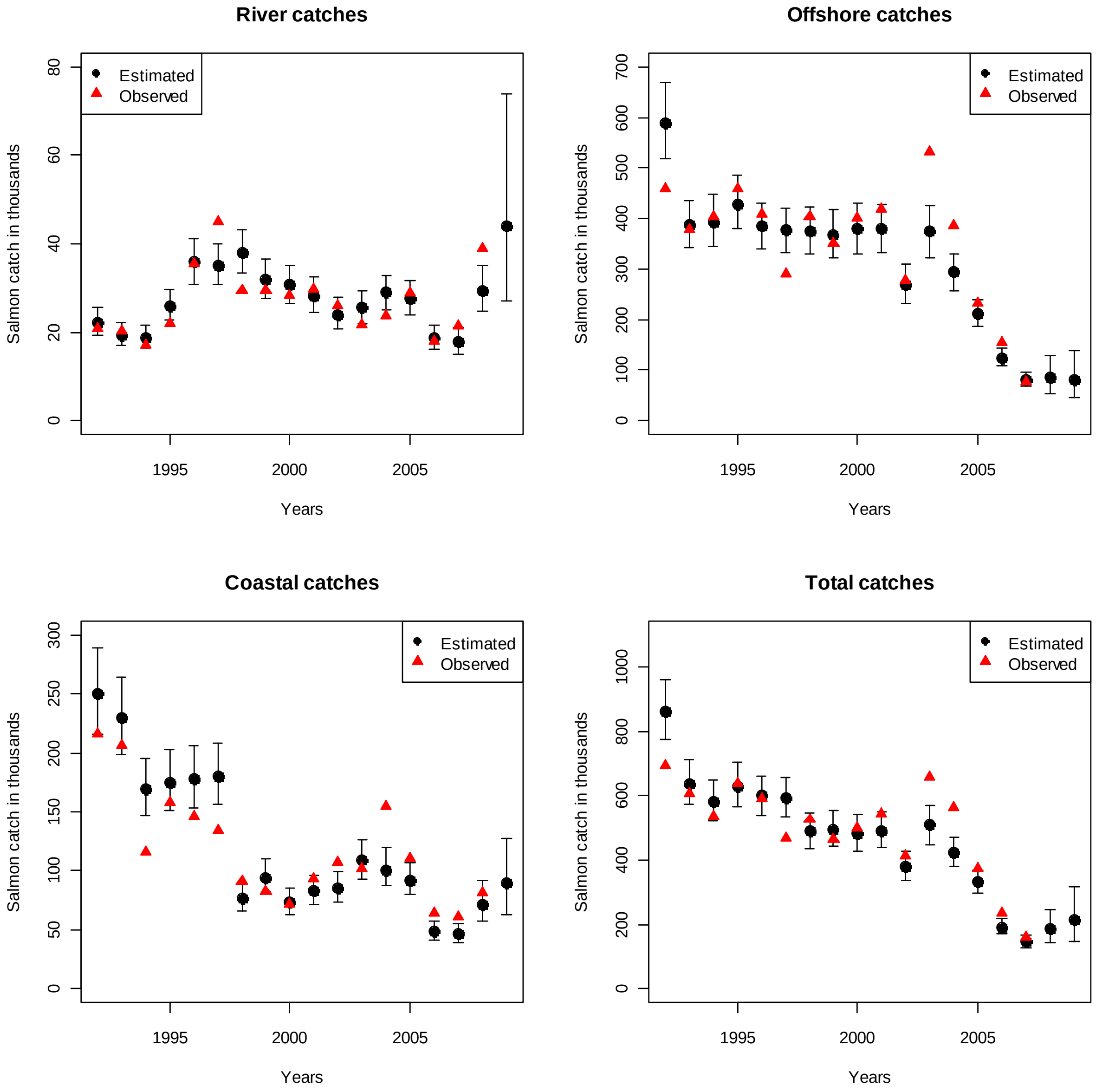


Figure 5.3.9.8 Estimated posterior distributions of catches in comparison to corresponding observed catches.

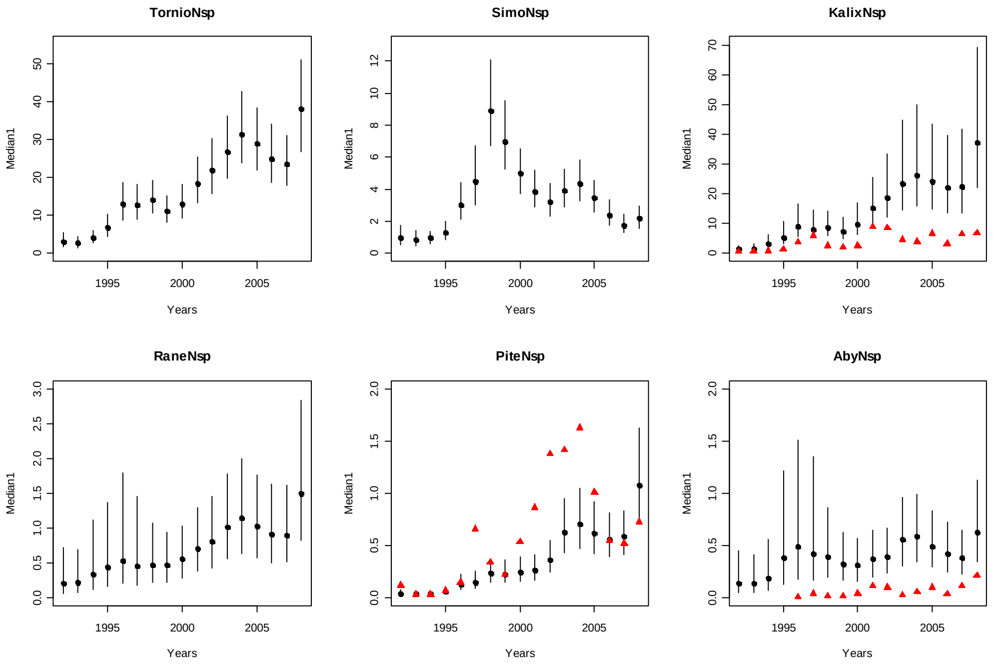


Figure 5.3.9.9.a Estimated posterior distributions of the amount of spawners in each river versus observed numbers of spawners in fish ladder counters.

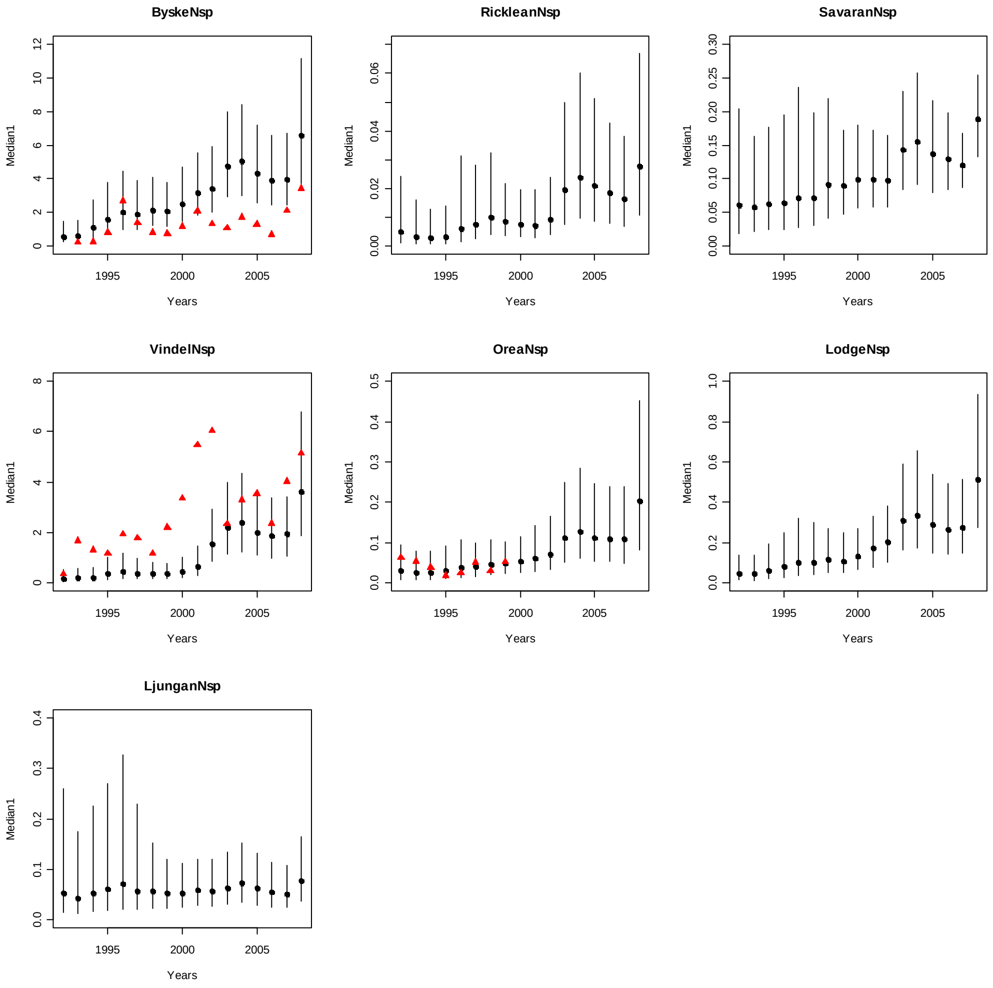


Figure 5.3.9.9.b Estimated posterior distributions of the amount of spawners in each river versus observed numbers of spawners in fish ladder counters.

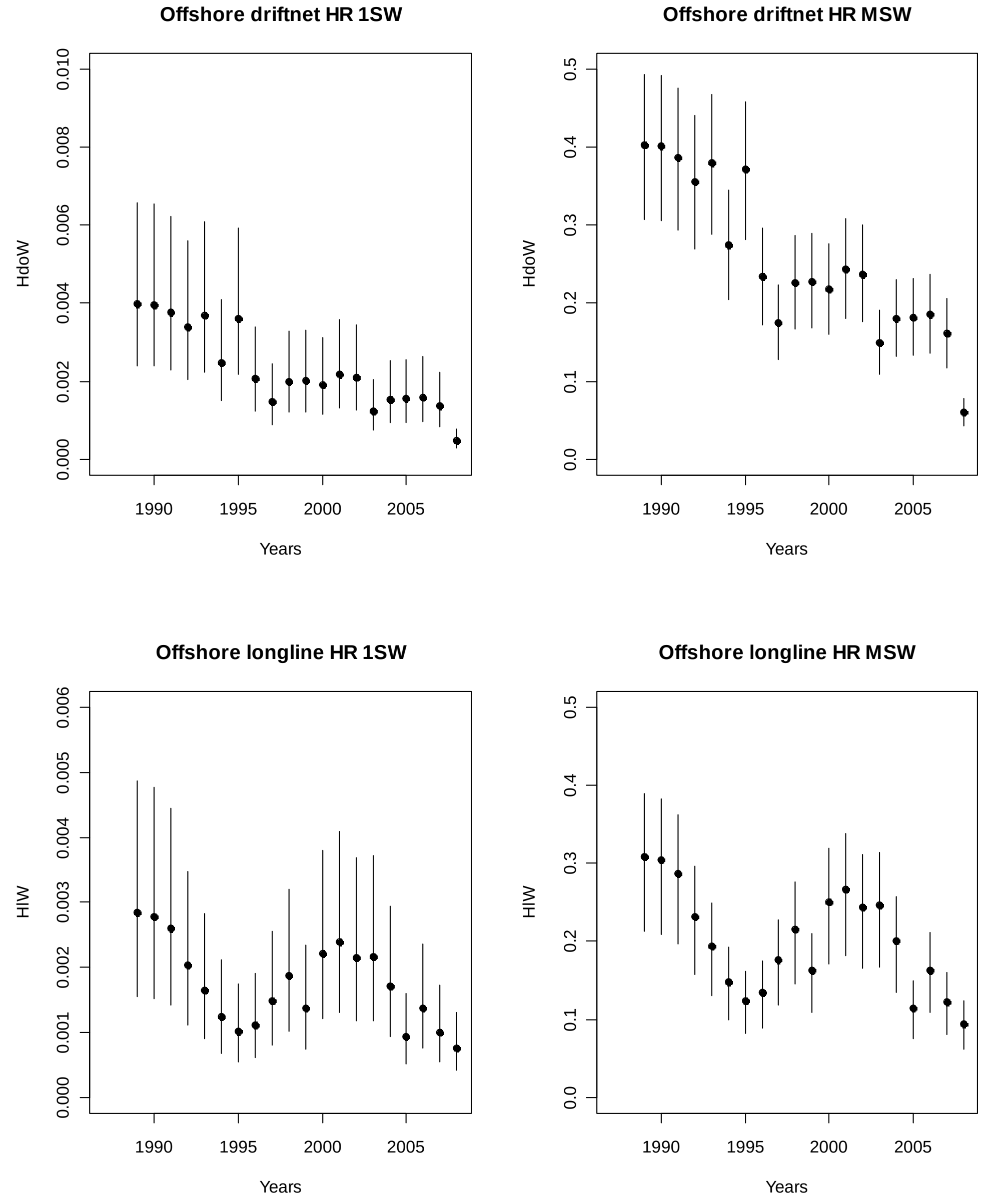


Figure 5.3.9.10.a Estimated posterior distributions of the harvest rates in offshore driftnet and offshore longline fisheries separately for one-sea-winter and multi-sea-winter salmon. Note that driftnet harvest rate in 2008 is not zero since it contains fishing effort from second half of 2007 due to computational reasons.

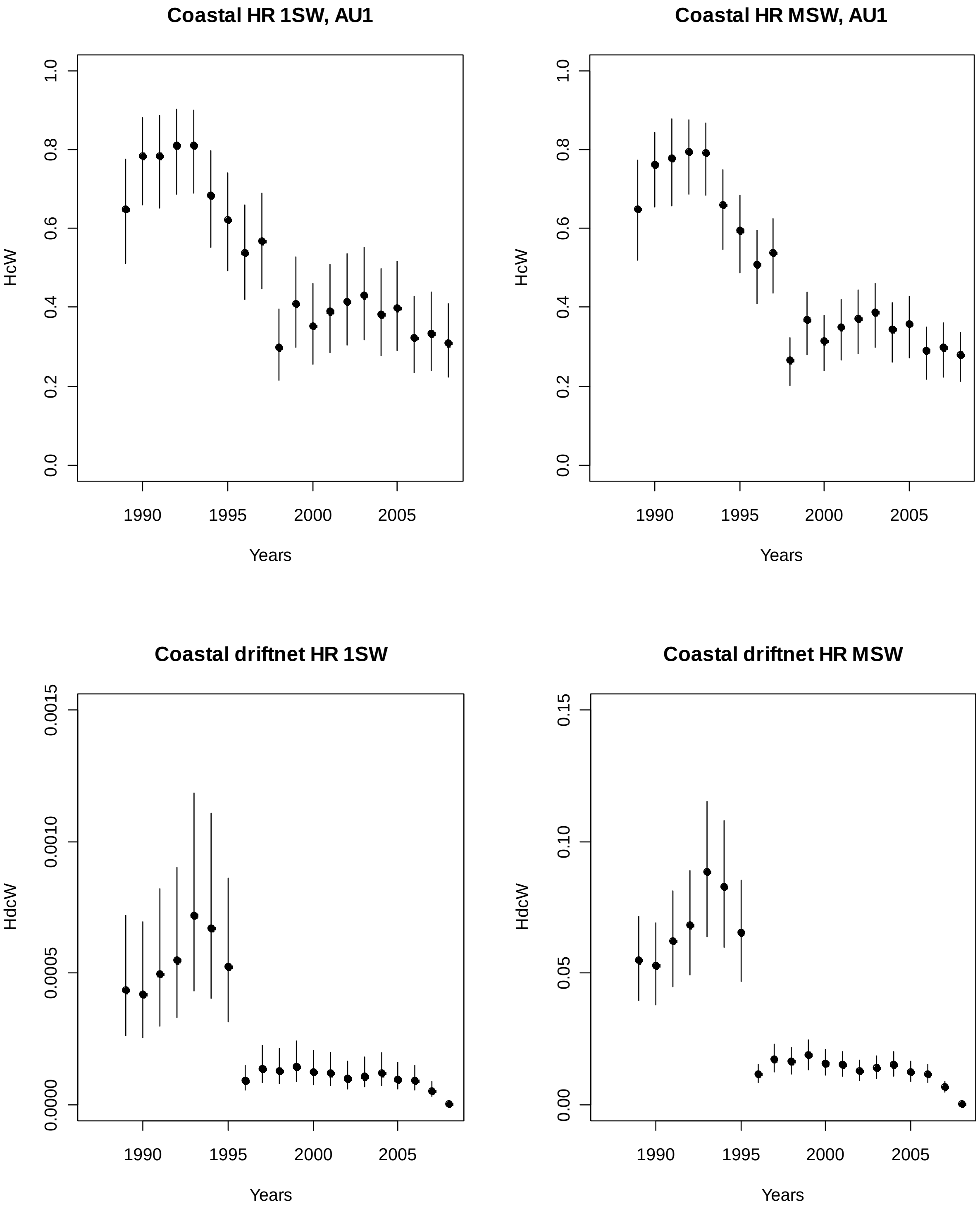


Figure 5.3.9.10.b Estimated posterior distributions of the harvest rates in other coastal fisheries than driftnetting in AU 1 and coastal driftnetting (all AU's together) separately for one-sea-winter and multi-sea-winter salmon.

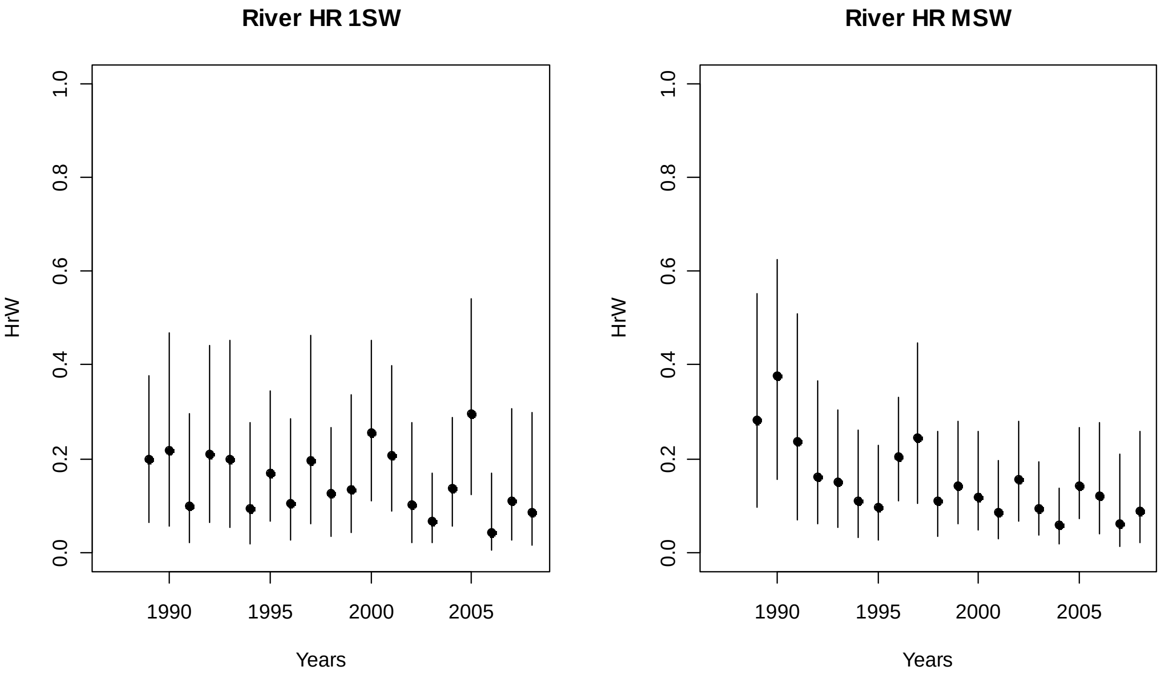


Figure 5.3.9.10.c Estimated posterior distributions of the harvest rates in river fishery separately for one-sea-winter and multi-sea-winter salmon.

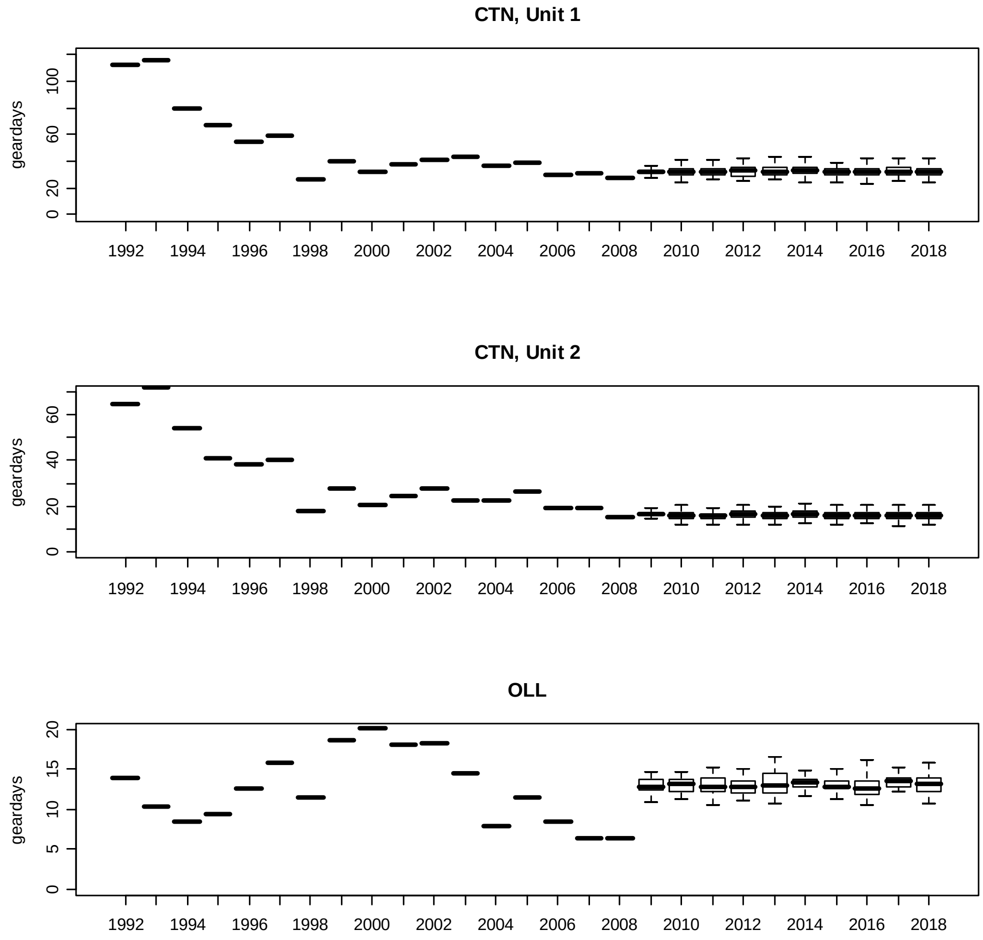


Figure 5.4.2.1.a Illustration of fishing effort for coastal trapnets (CTN) per assessment units and for offshore longlines (OLL) in historical years (1992–2008) and in future years (2009–2018) based on expert opinions (Table 4.5.1).

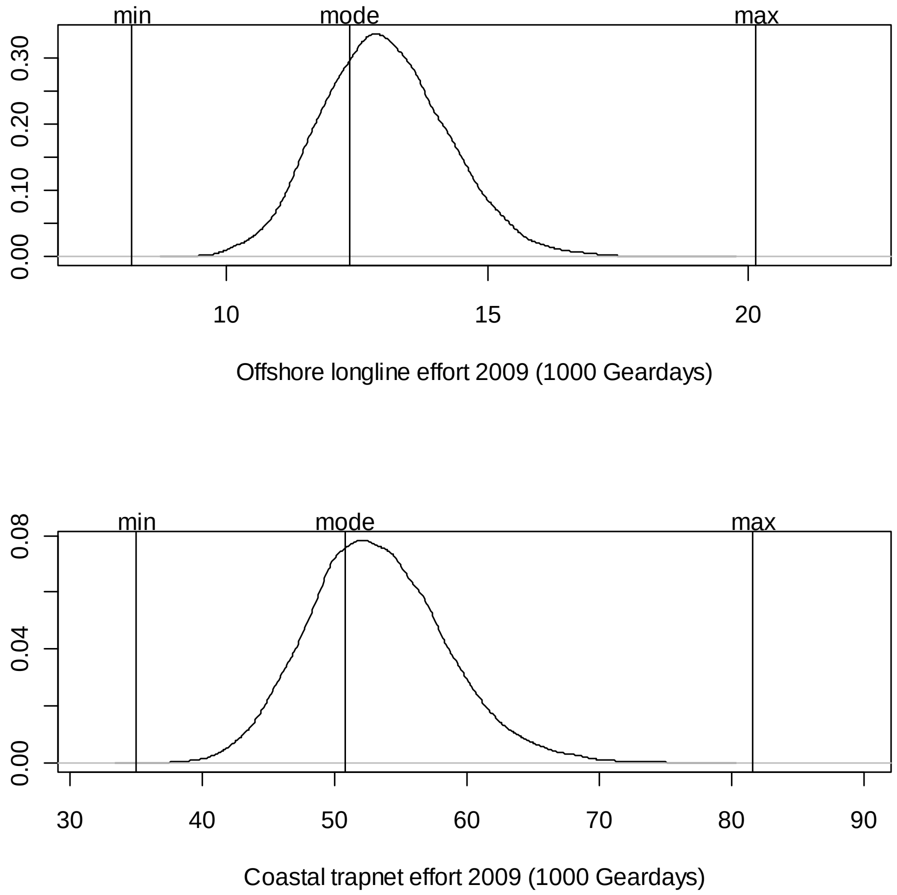


Figure 5.4.2.1.b Effort estimates combined from country specific effort distributions.

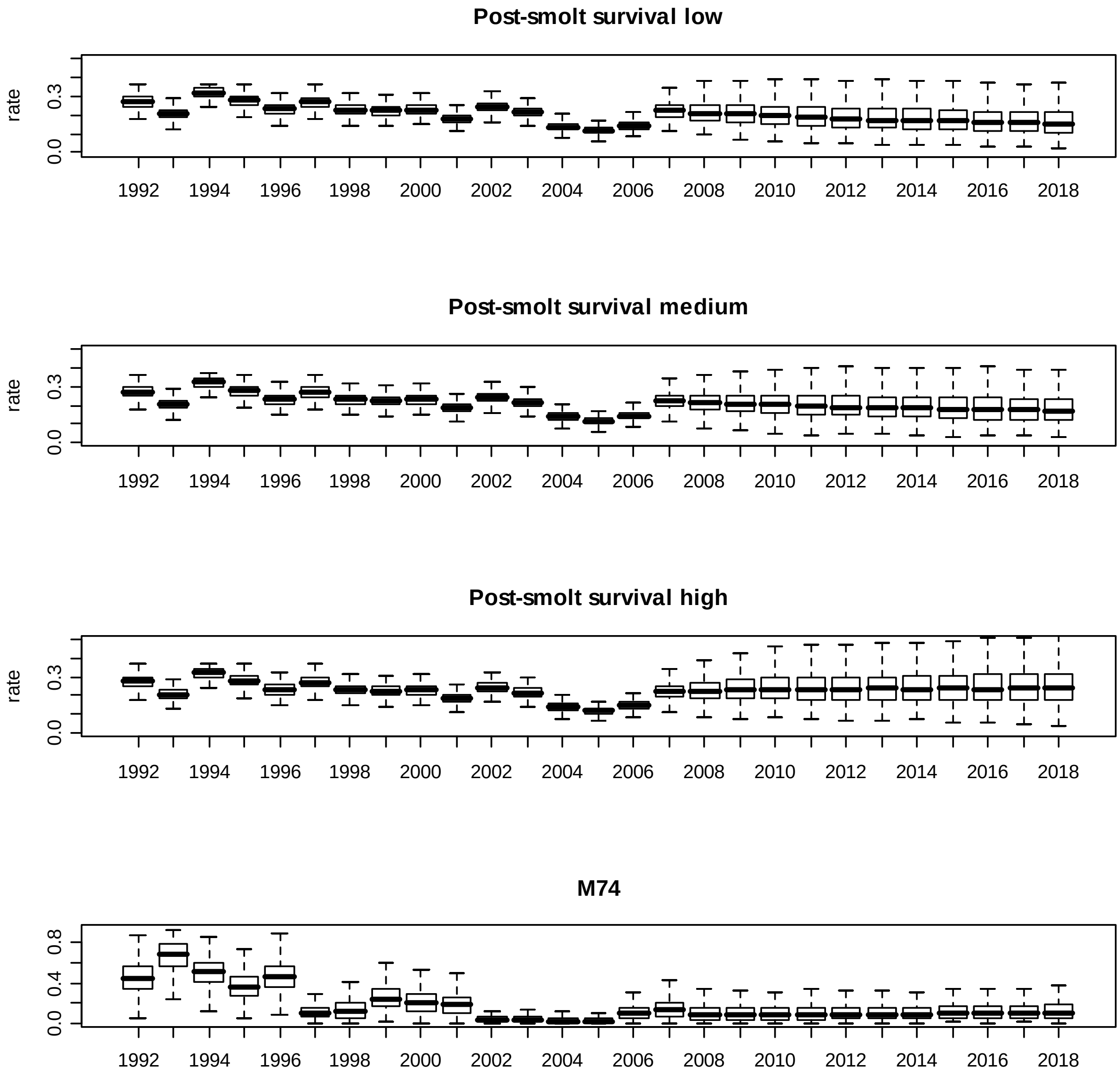


Figure 5.4.2.2 Box plot illustration of post-smolt survival rates of the three sceranios and scenario for M74.

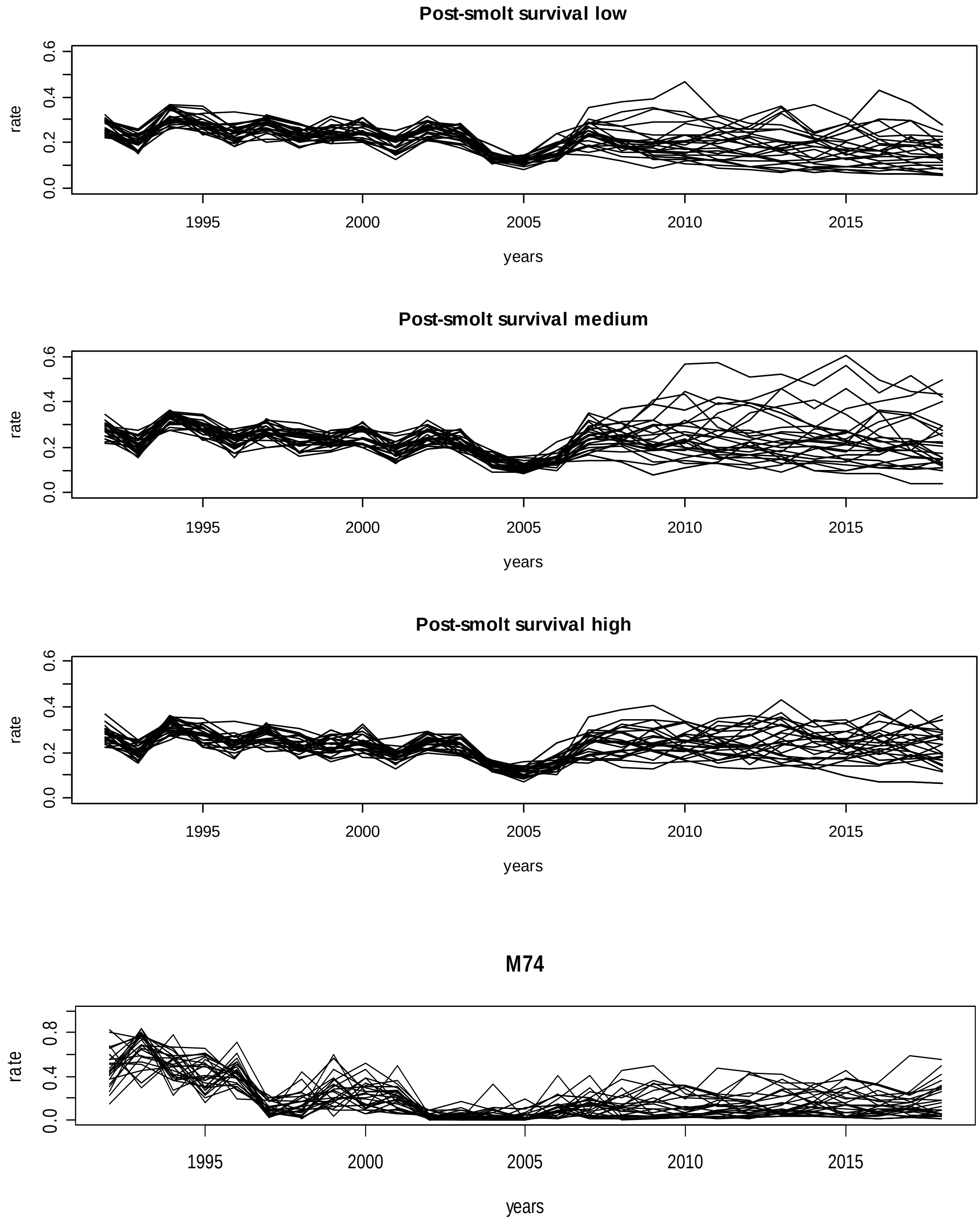


Figure 5.4.2.3. Trajectories of post-smolt survival rates of the three sceranios and the trajectories of the M74 scenario.

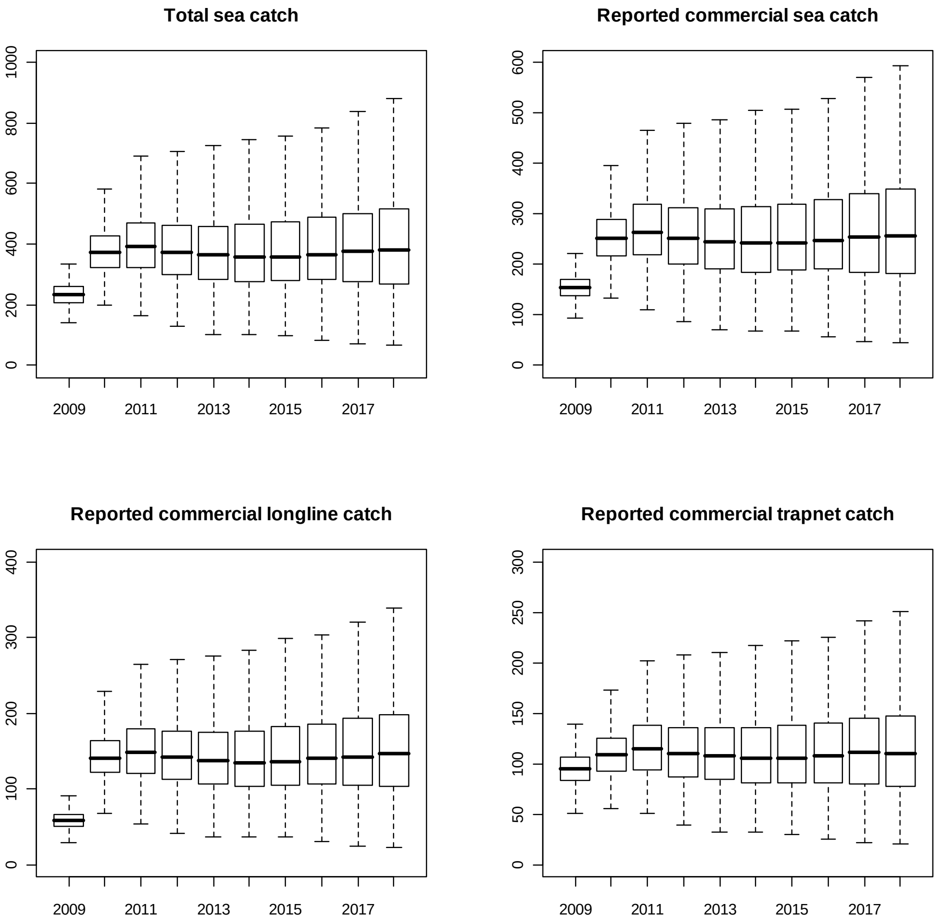


Figure 5.4.3.1. Total catch and total reported commercial catch estimates with effort scenario 4 (whole range of effort) and post-smolt scenario b (medium survival).

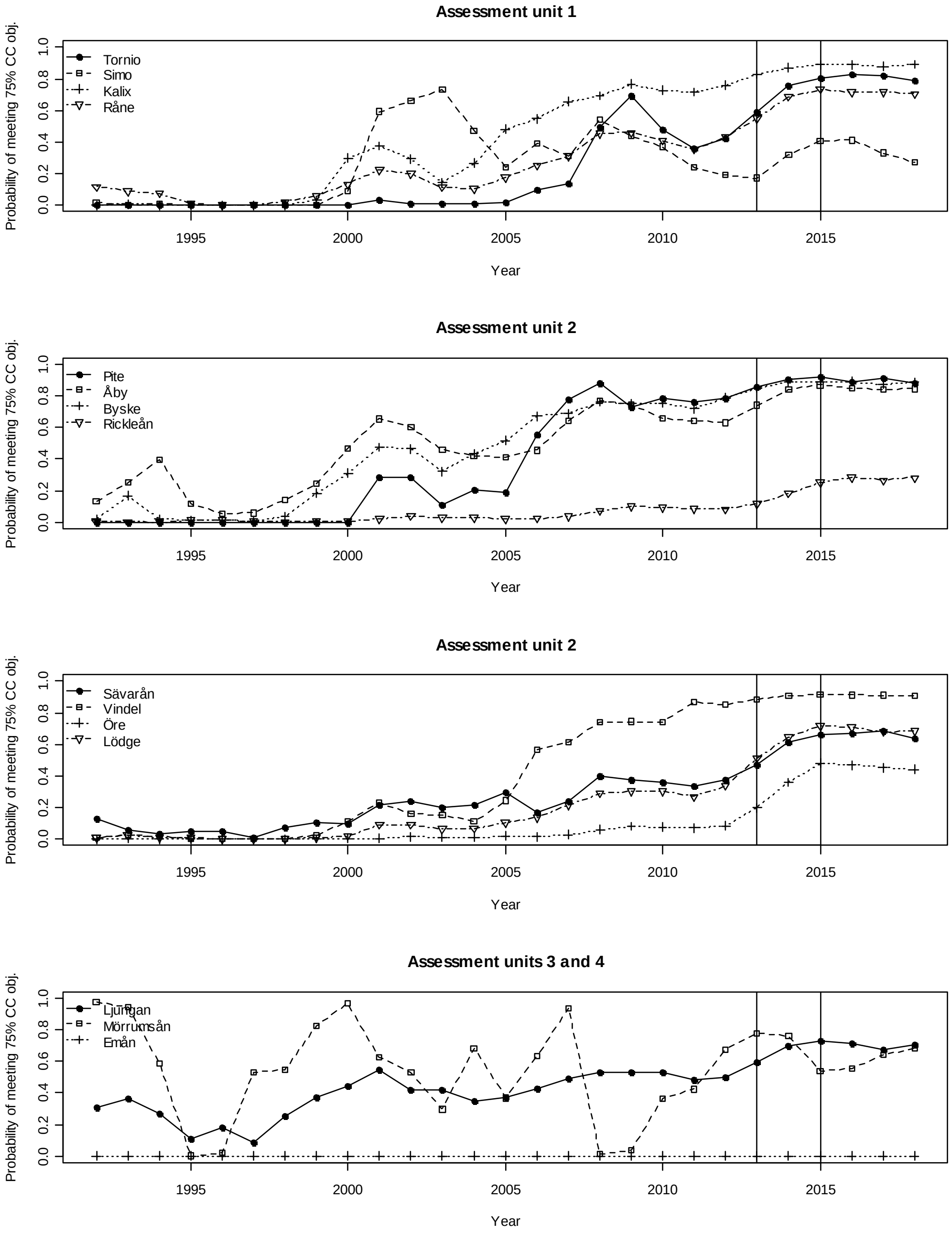


Figure 5.4.3.2.a The probability of meeting an objective of 75% of carrying capacity for each river and each year with whole range effort scenario (4). Fishing in 2010 affects mostly years 2013–2015.

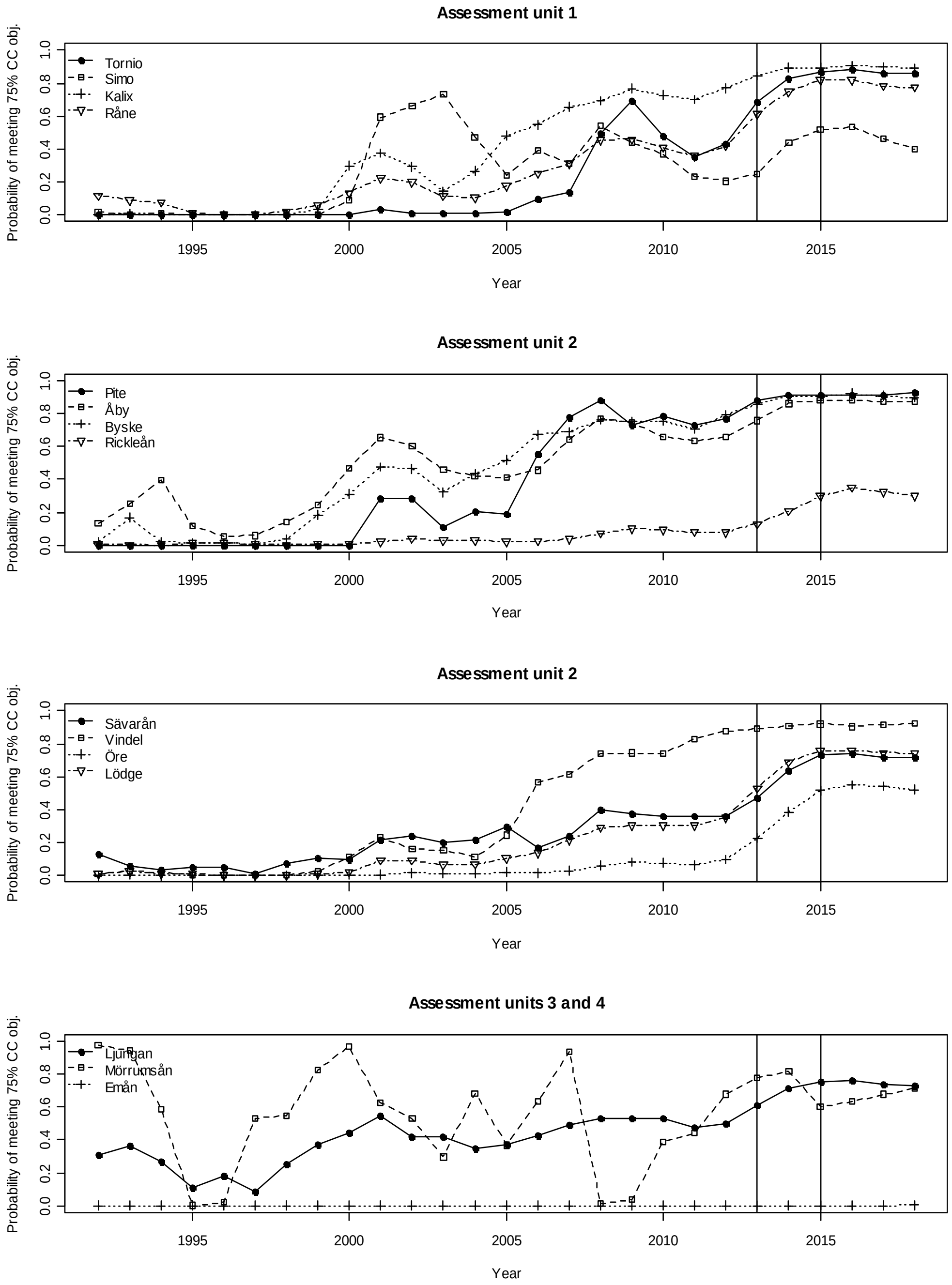


Figure 5.4.3.2.b The probability of meeting an objective of 75% of carrying capacity for each river and each year with minimum effort scenario (1). Fishing in 2010 affects mostly years 2013–2015.

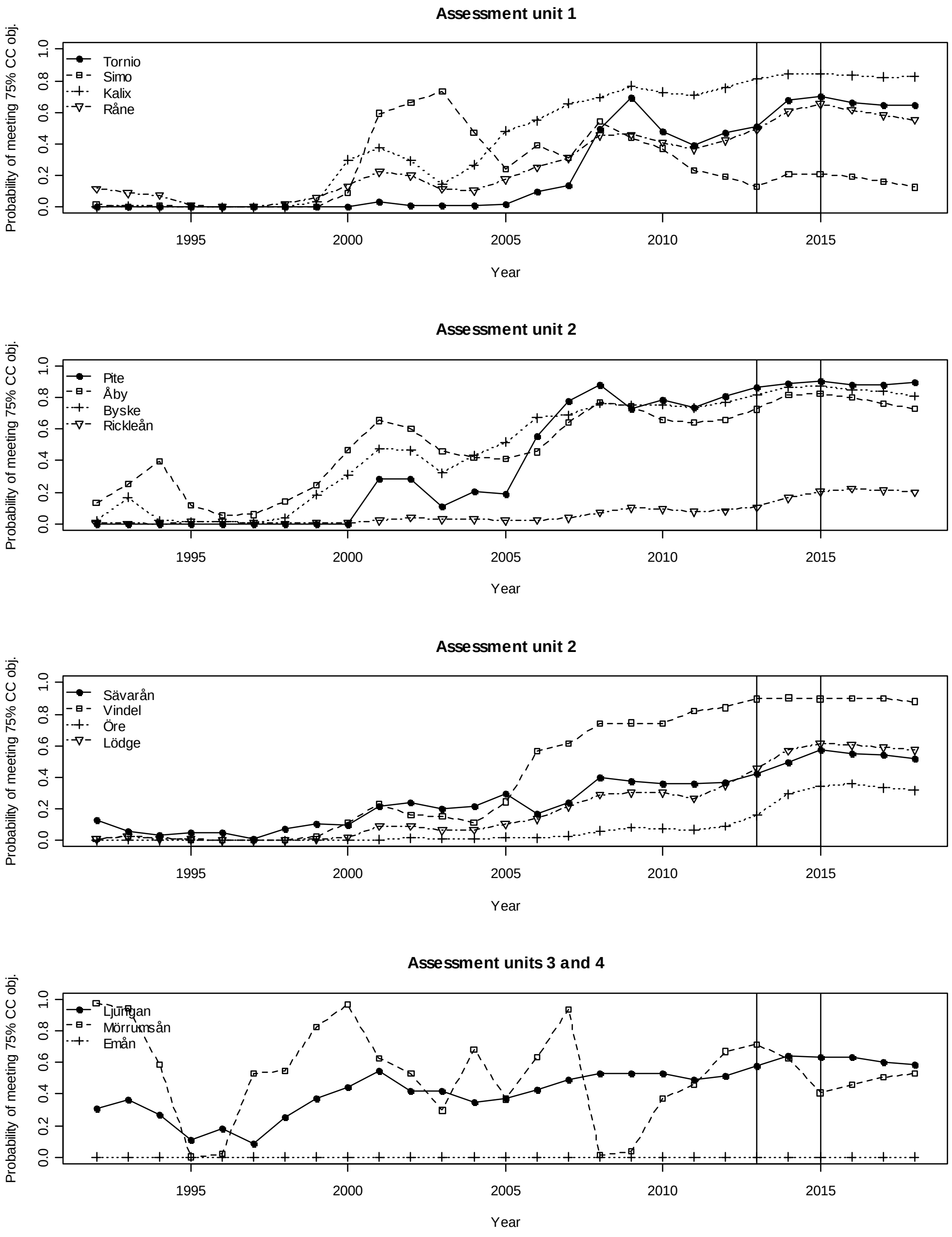


Figure 5.4.3.2.c The probability of meeting an objective of 75% of carrying capacity for each river and each year with maximum effort scenario (3). Fishing in 2010 affects mostly years 2013–2015.

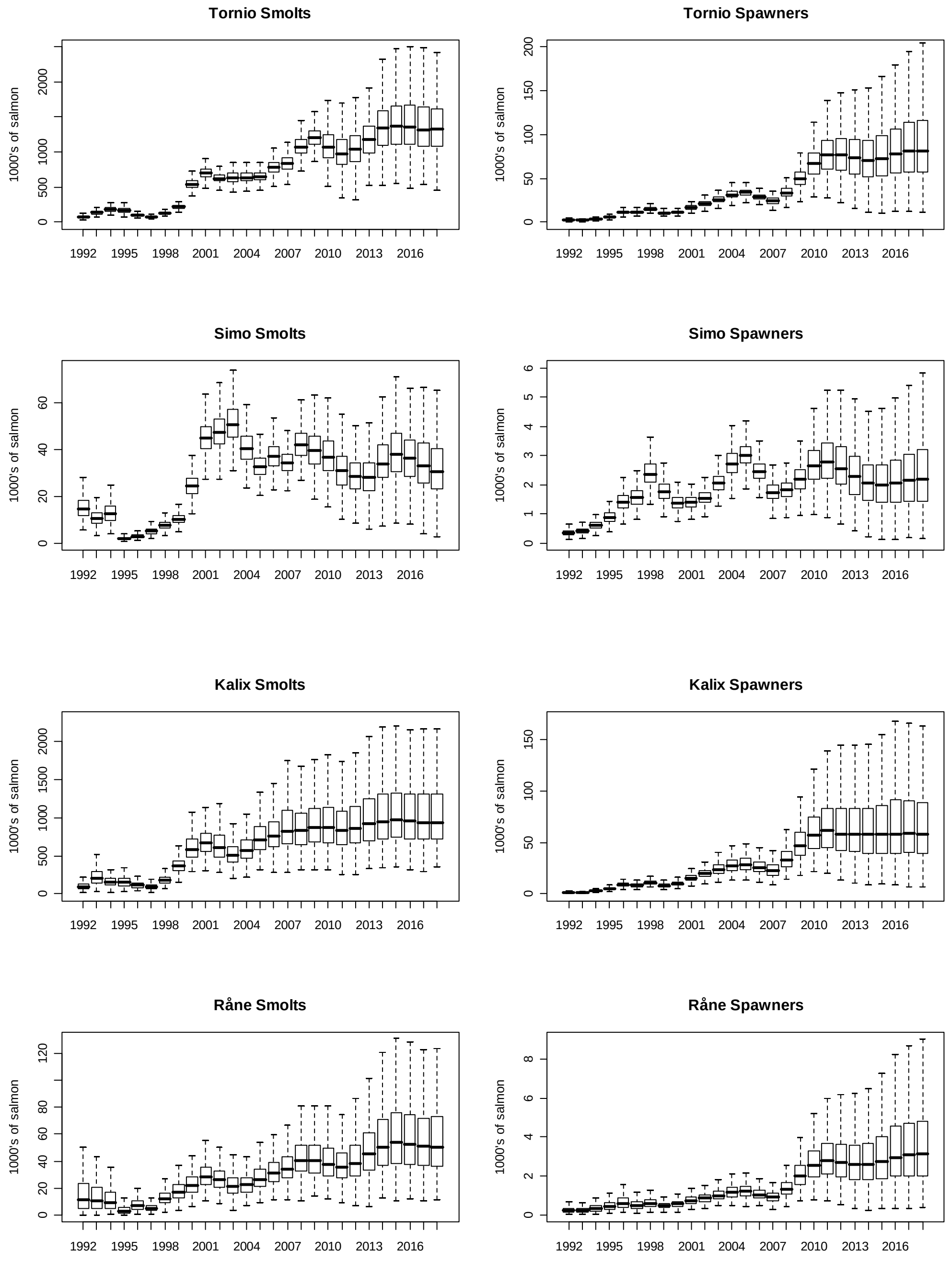


Figure 5.4.3.3 a) Uncertainty and expected values regarding smolt and spawner abundance for rivers Tornionjoki, Simojoki, Kalixälven and Råneälven. Whole range of effort and medium post-smolt survival is assumed for this scenario.

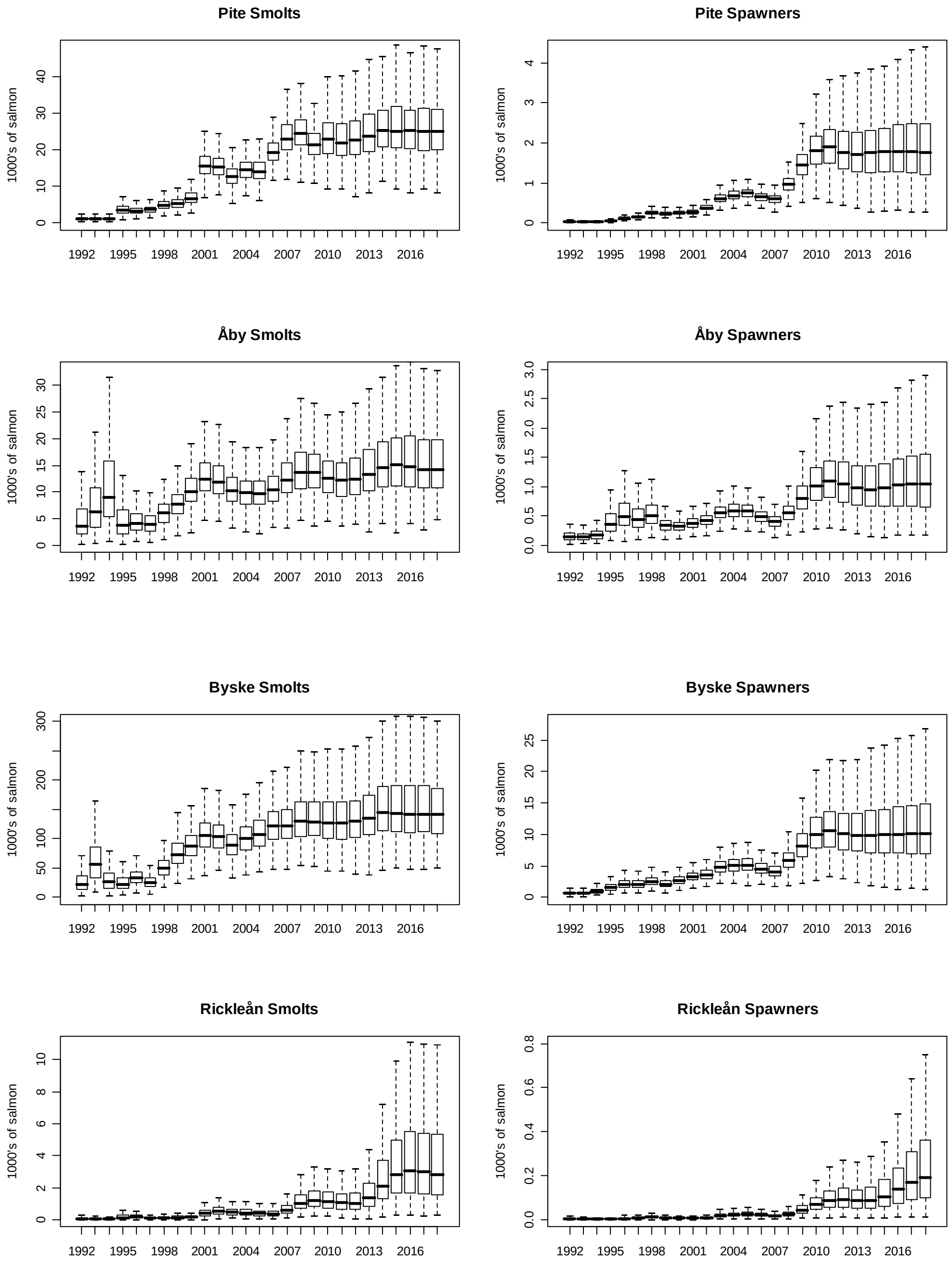


Figure 5.4.3.3.b) Uncertainty and expected values regarding smolt and spawner abundance for rivers Piteälven, Åbyälven Byskeälven and Rickleån. Whole range of effort and medium post-smolt survival is assumed for this scenario.

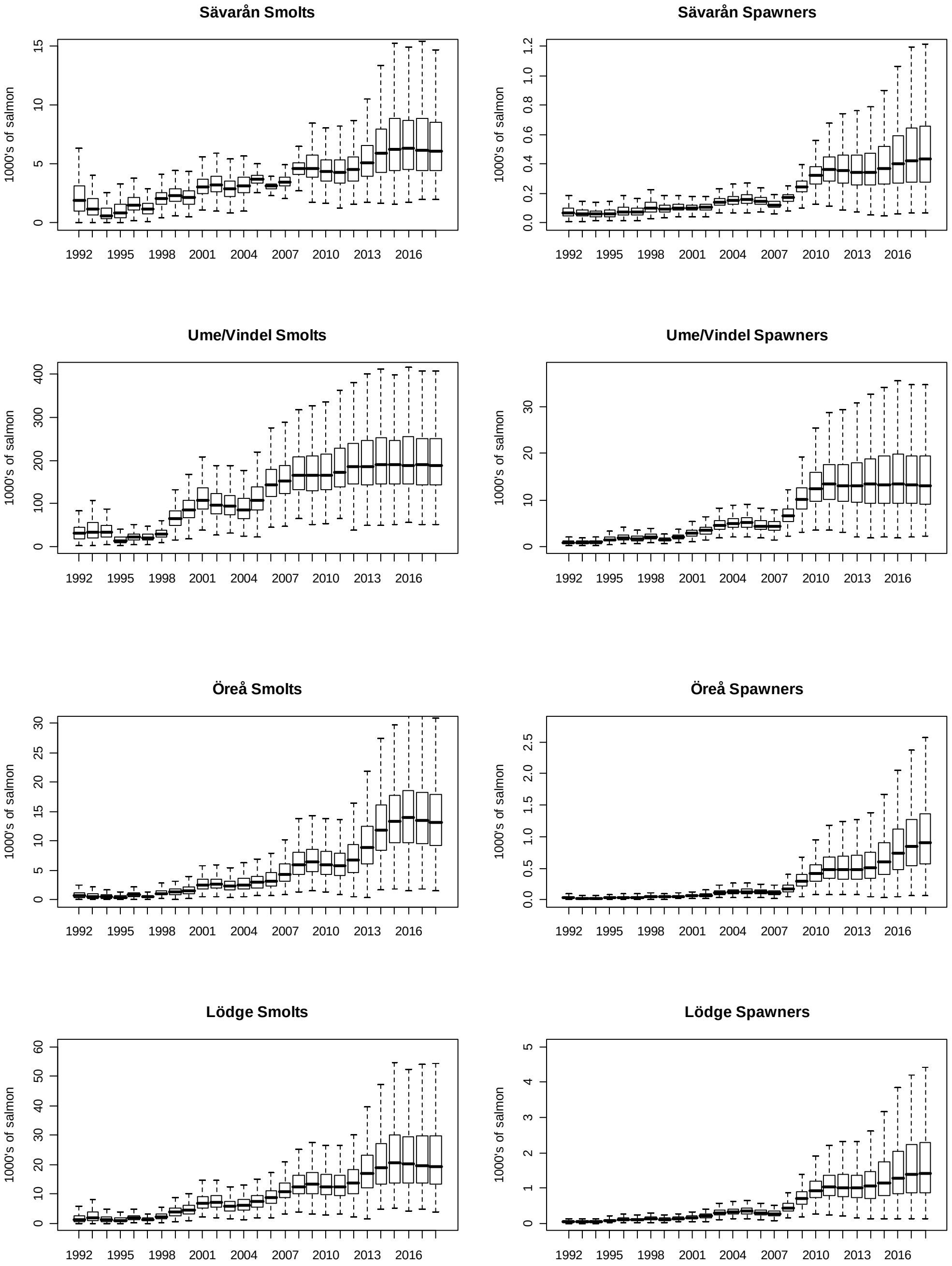


Figure 5.4.3.3.c) Uncertainty and expected values regarding smolt and spawner abundance for rivers Sävarån, Ume/Vindelälven, Öreälven and Lögdeälven. Whole range of effort and medium post-smolt survival is assumed for this scenario.

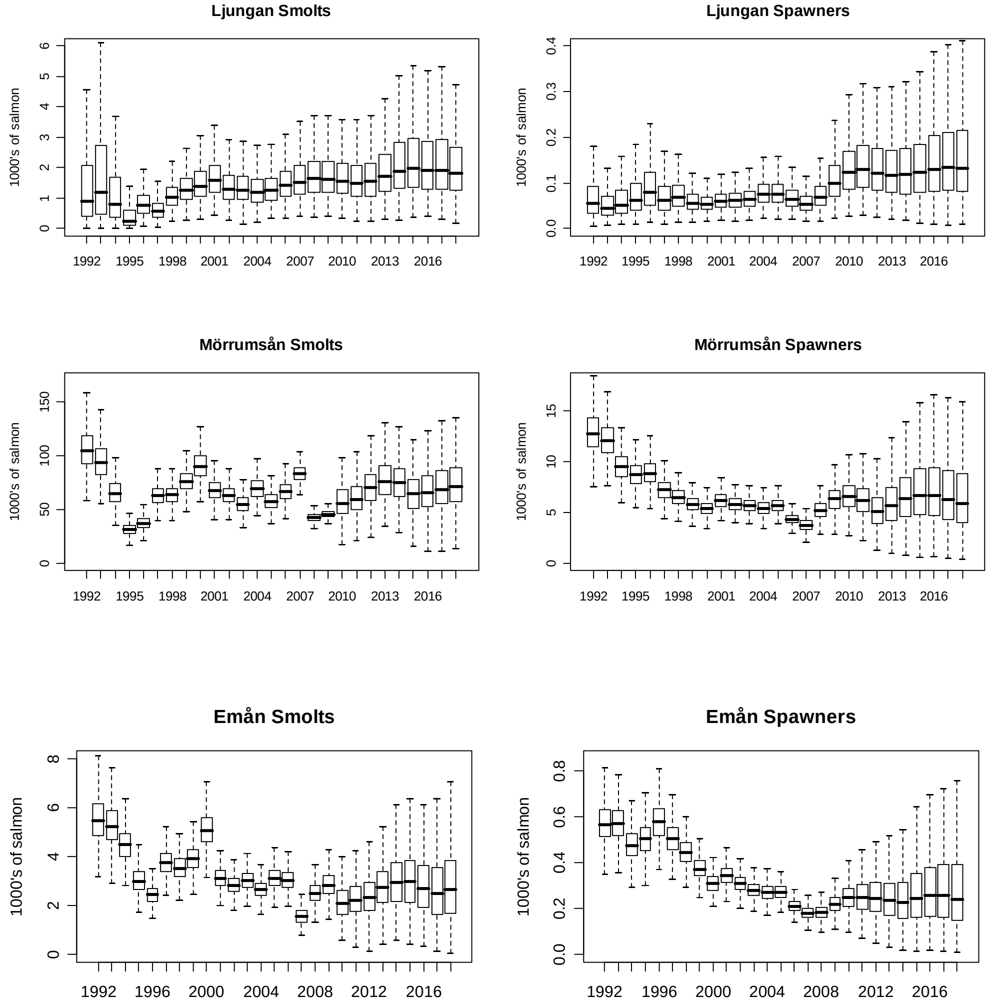
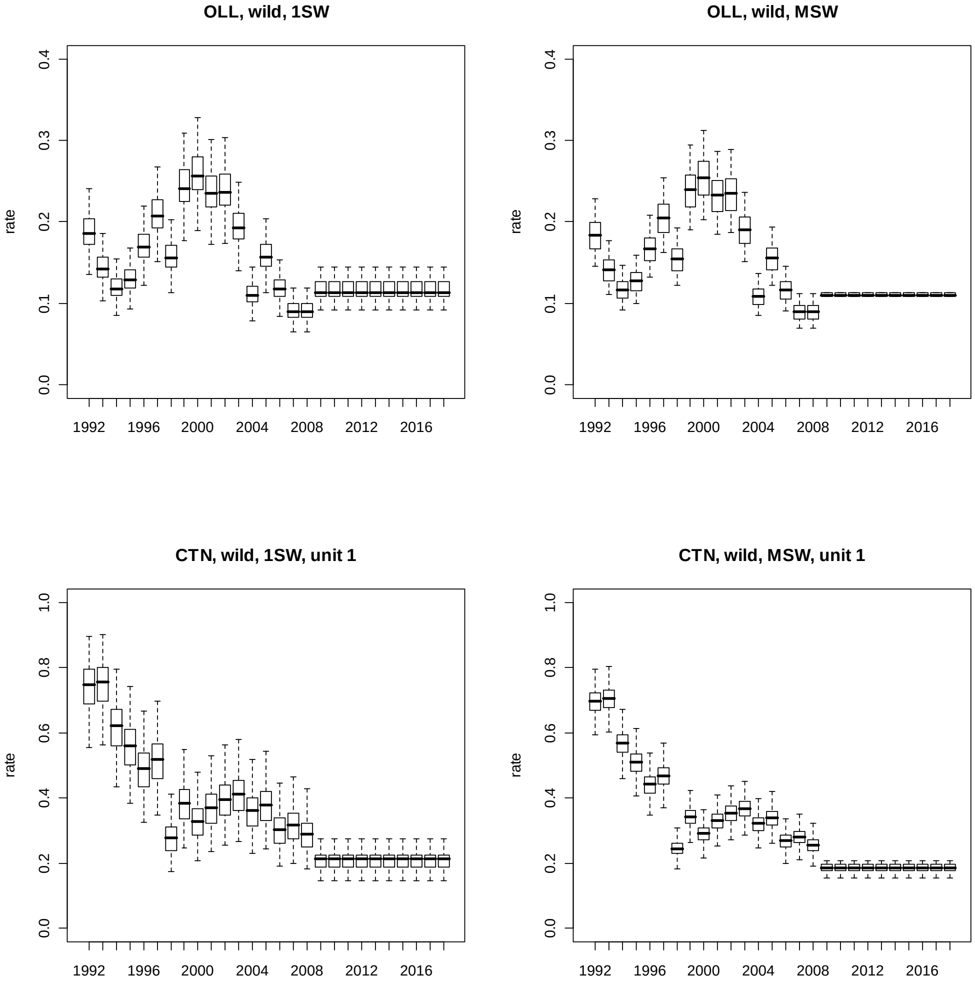
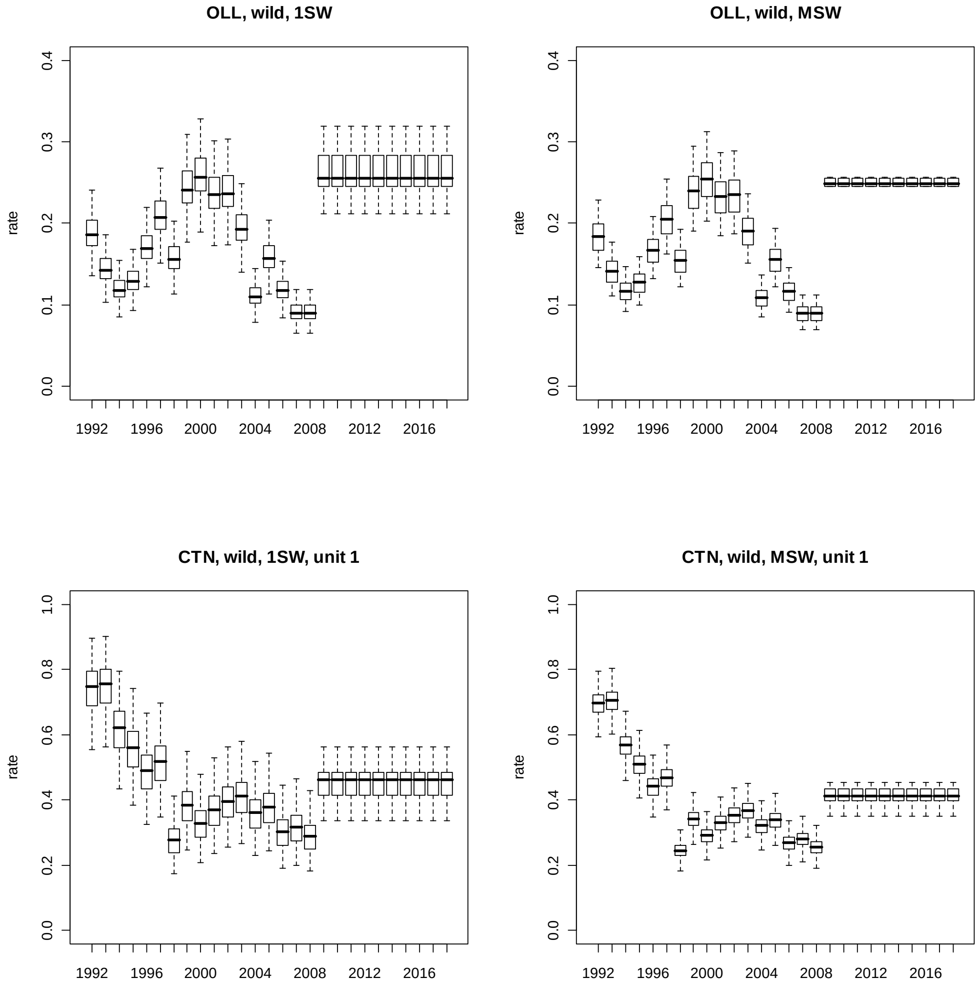


Figure 5.4.3.3.d) Uncertainty and expected values regarding smolt and spawner abundance for rivers Ljungan, Mörrumsån and Emån. Whole range of effort and medium post-smolt survival is assumed for this scenario.



F 5.4.3.4 a Harvest rates for offshore longline and coastal trapnet (assessment unit 1) with minimum effort scenario.



F 5.4.3.4 b Harvest rates for offshore longline and coastal trapnet (assessment unit 1) with maximum effort scenario.