**FILE S1**

**Life table simulations for Atlantic salmon**

We used simulations to test the biological plausibility of our life table estimates of age specific survivorship, related to assumptions about the biology of the mature male parr. Specifically, we evaluated the consequences of the incidence of parr maturity and their relative survival for the sex and age composition of anadromous fish, by simultaneously varying the former two parameters (from 0 to 0.99). Under the assumption of no difference in ocean survival between the sexes, we compared the sex composition of simulated anadromous age groups with empirical values for each river, to obtain an indication of realistic parameter ranges for subsequent analyses.

**Simulation results**

Survivorship and age structure were strongly influenced by the incidence of male parr maturation and relative survival ($s_{rel}$). Simulation results (Figure S1) show, not surprisingly, that increases in both the incidence of mature parr maturation and their relative mortality (reduced $s_{rel}$) lead to reductions in the expected relative number of anadromous males in the model. For rivers such as Northeast River (Placentia), with a strong anadromous sex bias (90% female), the range of plausible parameter combinations is much narrower (Figure S1 a,b) than for rivers such as Sandhill (Figure A.1e,f), where the observed anadromous sex ratio is close to one (i.e. 50% of anadromous fish are female). The mortality costs associated with parr maturation may therefore be substantial. For example, for Gander River, with an anadromous sex ratio of 75% females (Figure S1 c,d), typical for many Newfoundland rivers, our simulations suggest that parr maturation incurs a reduction in subsequent survival of at least 40%. However, at this lower extreme all male parr are assumed to mature, which seems incompatible with empirical observations, suggesting that the mortality associated with parr maturation may often be higher. Based on these results, we used a value of $s_{rel}=0.35$ for most subsequent life table analyses, along with male parr maturation rates that result in an age structure compatible with empirical observations. An exception is Northeast River (Placentia), where the extreme sex ratio in anadromous fish (>90% female) necessitates assuming a higher mortality associated with parr maturation ($s_{rel}=0.25$). Simulations suggest that a wider range of parameter combinations of parr survival and maturation are plausible for Sandhill River (Figure S1 e,f), although mature parr maturation incidence is less than 10% for a wide range of $s_{rel}$. In summary, we used simulations to select biologically realistic values for mature parr incidence and survival, which were subsequently used to calculate survivorship values. These life table analyses yielded estimates of generation time ($G$) and correction factor $C$, used in the genetic estimation of $N_e$.

Resulting estimates of $G$ range from 4.5 yrs [Northeast River (Placentia)] to 6.7 yrs (Sandhill River).

**Discussion**

Despite the comparative wealth of ecological and demographic data available for Newfoundland Atlantic salmon, our life table analyses required a number of important assumptions. Empirical estimates of (high) mature parr incidence (Pepper 1976; Dalley et al. 1983; Myers 1984; Myers et al. 1986) and their survival relative to non-maturing parr (Myers 1984; Hutchings and Myers 1994) were only available for a number of Newfoundland rivers. However, high parr maturation rates may generally be expected, given that the study rivers are predominantly lacustrine systems, facilitating high growth rates and productivity (O’Connell and Ash 1993). Uncertainty regarding survival at the freshwater stages (both absolute and relative between mature and non-mature male parr) thus likely has a larger impact on our results. The most critical assumptions in our analyses were 1) resident (non-anadromous) life history phenotypes do not constitute a major component of populations, 2) freshwater survival (for immature parr) is independent of age, and 3) previous maturation as parr does not reduce ocean survival of male smolts.
Resident (non-anadromous) Atlantic salmon are common in many Newfoundland river systems (Power 1958; Scott and Crossman 1964; Andrews 1966; Leggett and Power 1969, see Hutchings 2002 for a review). These are fish that never migrate out to sea and complete their entire life cycle in freshwater. In some instances, they have been reported to be genetically distinct from anadromous forms (Birt et al. 1991; Verspoor and Cole 2005), though they can spawn in the same locations (Hutchings 1986) and no behavioral mechanisms appear to isolate the forms from interbreeding (Hutchings and Myers 1985). In an extensive study conducted on Newfoundland systems, Adams (2007) attributed genetic differentiation between the two life history forms mainly to geographic separation, detecting little genetic differences where they co-occur. Like male parr maturation, they can therefore be considered as one of several life history strategies present in a salmon population (Hutchings and Myers 1985; Hutchings 1986). Hence we cannot rule out bias in our life table analyses in populations where non-anadromous salmon are very common, such as Terra Nova River (Andrews 1966), made more accessible to anadromous fish in the past century only (Burgeois et al. 2002). This river is characterized by very high genetic diversity and large estimates of $N_e$, which appear incompatible with what is known about the current size of the anadromous runs (O’Connell et al. 2006b). Based upon the limited information on the reproductive biology and age structure of non-anadromous fish (Scott and Crossman 1964; Leggett and Power 1969), we may have underestimated age-specific survival and iteroparity, but perhaps overestimated fecundity. Large non-anadromous population components likely result in more even age distribution of projected reproduction ($p_k$), with a reduction in genetic fluctuations among cohorts that is larger than accounted for by the cohort model. This would imply that $N_e$ estimates based on the cohort model may be biased upwards for river systems with (unaccounted for) large components of non-anadromous salmon. Though the presence of non-anadromous life history phenotypes may generally enhance population stability, there is thus some uncertainty that this presence would also result in larger (and more stable) effective population sizes.

Secondly, freshwater survival in Atlantic salmon is likely not constant over time, with high mortality occurring from egg deposition to initiation of foraging by fry (reviewed by Hutchings and Jones 1998). However, the survivorship of relevance for $N_e$ is that among the reproducing year classes (Nunney 1993) and we therefore ignored this initial stage in our life table analyses. Although the assumed annual survival rate corresponds to locally relevant empirical estimates (Evans et al. 1984), a more important consideration is whether this survival increases with age. An underestimation of freshwater survival during and after the male parr maturation ages implies that we may have overestimated the incidence of parr maturation and/or underestimated their relative survival. Although this has consequences for the age composition of adults, our simulations suggest that $N_e$ estimation is more strongly influenced by assumptions about the age distribution of reproductive output. Furthermore, analyses of brown trout populations in lake systems in Sweden (Jorde and Ryman 1996; Palm et al. 2003) suggest a relative insensitivity of annual survival rate to age (i.e. type II survivorship curve). Therefore, our findings with regards to $N_e$ may be comparatively robust to uncertainty about (relative) freshwater survival.

We further assumed that smolts that previously matured have similar ocean survival to that of non-mature fish, whereas some work suggests this may instead be reduced (Berglund et al. 1992 but see Skilbrei 1990). We therefore implicitly linked parr maturation with the sex bias in anadromous runs, ubiquitous in Newfoundland (Davis and Farwell 1975; Chadwick et al. 1978; O’Connell et al. 2006a). Fleming (1998) argued that increased ocean mortality, together with sex differences in (anadromous) age-at-maturity, form a better explanation for anadromous sex bias, although decreased freshwater survival was acknowledged to affect this bias. However, smolt runs in Newfoundland already display a strong bias towards females (Davis and Farwell 1975; Dalley 1978; Chadwick et al. 1978; Chadwick 1981; Dalley et al. 1983; Myers 1984; Hutchings 1986). Furthermore, anecdotal observations suggest there may be no sex difference in ocean survival for smolts in Newfoundland (Chadwick et al. 1978). Since our life table analyses explicitly corrected for sex differences related to anadromy, a link between parr maturation and sex bias in anadromous runs may therefore indeed exist in Newfoundland.
Finally, several lines of indirect evidence provide support for our life table analyses. Firstly, under the assumption that genetic drift is the predominant cause of temporal genetic fluctuations, allele frequency change ($F$) will depend on the time separating the two cohorts considered (Jorde and Ryman 1995). Low values of $F$ are especially expected between cohorts that are born exactly one generation apart (Jorde and Ryman 1996, see also Waples and Teel 1990). A comparison of these values for the study rivers (results not shown) suggests that a generation time of roughly five years (as commonly derived from life table analyses) seems usually appropriate. Secondly, numerical estimates of relative parr abundance, based on these life tables, yielded numbers comparable to empirical observations. A quantification, based on the assumed survival and maturation schedules, suggests a range of 120-220 mature male parr may be present for each anadromous female in a river. These estimates are comparable to a value of 167 reported by L'Abée-Lund (1989) for a Norwegian river with similar (high) incidence of male parr maturation. These numbers are much lower (80-135 mature male parr per anadromous female), had we assumed zero survival of male parr after maturation. Despite some uncertainty remaining in life table analyses, the parameter estimates derived from them may thus provide a reasonable basis for estimating $N_e$.

References not included in main publication


Scott, W.B. and E.J. Grossman (1964) Fishes occurring in the fresh waters of insular Newfoundland. Department of Fisheries, Queens Printer, Ottawa.

FIGURE S1.—Life table simulations for three different rivers, evaluating the consequences of mature parr incidence and mortality for anadromous sex ratios, compared to actual observed values in the specific rivers (intersecting plane). Graphs on the right illustrate the range of combinations of relative survival (s_rel mature parr) and maturation incidence (% mature parr) for which simulations resulted in anadromous sex ratios similar to the average of empirical values observed in the annual runs in each river.