Atlantic Salmon and Climate Variation in the North Atlantic

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The largest component of natural mortality affecting Atlantic salmon populations in the marine environment occurs during the first year at sea. The juveniles are referred to as post-smolts during this period, which begins after their migration to the ocean and continues up until the first winter. The stock complexes for Europe and North America appear to have different climate-controlling mechanisms reflecting theorized differences in post-smolt distribution and ecology.

The nursery zone for European post-smolts is located in the open ocean whereas North American post-smolts appear to utilize inshore habitats. Holm et al. (2000) described the distribution of European post-smolts from surface trawling operations in the Northeast Atlantic. The nursery is confined to a region within the Norwegian Sea, the northern extent of which would appear to be defined by current transport. In North America, post-smolts can be found in high numbers in the Labrador Sea during the fall of the year (Reddin and Short 1991). However, during the earlier part of the post-smolt period, i.e. through the spring and summer months, fish are also found in the Gulf of St. Lawrence, the coast of Nova Scotia, and elsewhere (Dutil and Coutu 1988; Ritter 1989; Friedland et al. 1999). Furthermore, North American stocks may not physically mix for many months after entering the ocean whereas it appears European stocks are concentrated in a single, albeit large, ocean area (Friedland and Reddin 2000).

If in some years the North American post-smolt nursery is distributed along the coast, it would function in fundamentally different ways than the European post-smolt nursery, thus affecting the climate response of the respective stock complexes. Predation losses for the North American stocks may be the result of more avian and mammalian predators emanating from specific rookery locations on the coast (Montevecchi et al. 1988); whereas European fish would be expected to face growth-mediated predation pressure associated with the dynamics of an oceanic ecosystem (Sogard 1997). Growth data provides a practical test for this idea. Inter-annual post-smolt growth variation for Scottish and Norwegian stocks correlated with survival supports the idea that mortality of these stocks is controlled by their growth (Friedland et al. 2000). However, similar growth signatures for North American stocks are uncorrelated with survival (Friedland and Haas 1996). It is important to qualify this observation by stating that the survival differences among stocks can, at times, be attributed to growth regardless of the pattern of inter-annual growth variation (Friedland et al. 1996).

A fundamentally different response to climate forcing due to the nature of the post-smolt nursery may be what is reflected in our current state of knowledge concerning climate forcing and recruitment of Atlantic salmon. From analyses of sea surface temperature distribution, spring thermal conditions have emerged as an important forcing in the recruitment of European salmon stocks. The relationship was first quantified for trends in the entire stock complex, i.e. for all sea age fish, using time series subjected to temporal averaging (Friedland et al. 1993). Subsequently, when examined for a distinct set of stocks from the centre of the European range using a time step of one month, the relationship became much clearer (Friedland et al. 1998a). However, similar relationships have not emerged in respect to the North American stock complex.

To date, the only evidence of climate forcing related to North American stocks is the relationship between 2SW salmon and winter thermal habitat in the Northwest Atlantic (Friedland et al. 1993). However, it is not clear if this relationship is related to survival given the season of the climate effect; instead, it has been suggested that this relationship may be related to maturity (Friedland et al. 1998b). It would appear that European salmon stocks in the Northeast Atlantic are responding to broad-scale climate forcing, such as temperature and factors likely to co-vary with temperature, much like other pelagic species. The response would appear to be related to the distribution of the post-smolt nursery. North American salmon stocks in the Northwest Atlantic do not appear to have a pelagically distributed nursery and climate forcing has not been detected either because researchers are not examining the correct variables, or other non-climate factors, such as predator abundance, are more important.

Age at maturation has important consequences on the total complement of eggs deposited during spawning. While age at maturity has a strong genetic component (Gjerde 1984), environment can also play a significant role (Saunders et al. 1983). Climate may be acting on this process in a number of different ways. Conditions that affect the growth of fish may determine whether an individual is physiologically ready to return to the river to spawn.

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There is evidence that growth at various times during the post-smolt year may be important to achieving maturity (Scarnecchia et al. 1989, 1991; Gudjonsson 1995; Duston and Saunders 1999), suggesting that hypotheses regarding genetic and temporally fixed mechanisms lack the plasticity realized by wild stocks (Thorpe 1986). Alternatively, some investigators have suggested that climate variations that extend migrations beyond a reasonable return distance contribute to a variable proportion of grilse in the return (Martin and Mitchell 1985). Some animals on migration routes away from home rivers are actually approaching maturation and likely regress when they fail to find their home rivers (Friedland et al. 1998b).

The unprecedented decline in Atlantic salmon abundance over the past few decades raises concerns over the future impact of climate change. With climate at the core of many of the factors contributing to the decline of stocks, the effects of further shifts, beyond the reactive norms to which salmon populations have adapted, now pose the threat of range shift for the species. If these climate changes are being accelerated by anthropogenic factors, the speed at which the changes occur may be beyond the time-scales salmon need to develop requisite survival adaptations, thus posing the threat of widespread extinctions.

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