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# Logistic fates of Atlantic salmon (*Salmo salar*) at sea

by

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## Abstract

The possible fates of migrating Atlantic salmon are listed. The potential for these listings to provide clear signals in surviving cohorts concerning marine mortality and distribution are discussed.

## Résumé

Les possibilités des saumons de l'Atlantique en migration sont présentés et l'on traite de leur utilisation possible pour obtenir des indices clairs de la mortalité en mer et de la distribution chez les cohortes survivantes.

**Introduction**

The recent downturn in returns of Atlantic salmon to rivers of North America has resulted in an increased examination of factors which could have contributed to that apparent downturn. The conditions of the marine habitat have been correlated with returns to North America (Reddin and Friedland 1993 ) and to specific areas of the Maritimes Region (Harvie and Amiro 1996).

Existing forecasts of returns of Atlantic salmon to rivers of the Maritimes Region for 1997 overestimated both the 1SW and MSW components of actual returns (Amiro et al. 1998). Recent increases in marine habitat for salmon have not resulted in consistent increases in recruitment indicating other operands need to be explored.

Examination of possible causes of loss of returns to North American rivers in 1997 would follow a series of logic trees which would apply to the survival or mortality of Atlantic salmon during the marine migration phase of their life cycle. The purpose of this paper is to describe those logic trees for the possible fates of Atlantic salmon at sea.

# Fates of Atlantic salmon at sea

The fates of Atlantic salmon during the marine migration phase of their life cycle include a multitude of possibilities, foremost among them is survival or death.

## *Survivors*

Survivors return to their natal river in a number of possible conditions, either healthy or unhealthy, and if unhealthy, in a variety of possible states: poor condition, diseased, and if diseased, the disease could be in an active or dormant condition (Table 1). These same possible fates affect both hatchery and wild fish. An additional factor related to the difference in survival rates of the hatchery and wild fish would impact upon the ultimate fate of hatchery fish. Hatchery smolts have been demonstrated to return to rivers at a rate which is lower than noted for wild smolts (Amiro 1998).

Evidence to support the likelihood of fish having experienced the life histories described either exists, and is evident by changes in length frequency distributions, or in return rates; or can be found by examining returning fish for general condition, for diseases or disease resistance (Table 1).

## *Mortalities*

Atlantic salmon may die at sea of natural causes or from fishing. Atlantic salmon which die of natural causes are not available for examination so evidence regarding their fate is circumstantial. Natural mortalities would encompass being preyed upon or wasting (Table 2), where wasting includes condition loss due to disease or a lack of availability of food but not being preyed upon.

### *Wasting*

The probability associated with the loss of fish at sea can be estimated from the number of smolts which exit North American rivers and the number which return. Estimating what proportion disappear from the population as a result of wasting is virtually impossible from the data currently available because the cause of mortality assumes that the fish die and are not recovered. However, the likelihood of fish being lost due to wasting could be examined by looking for diseased or resistant fish which survive to return to rivers. Fish captured at sea could also be examined for evidence of disease. If fish which are in poor condition, diseased, or resistant are not found, then it follows that all mortalities at sea due to wasting have "dropped out" and would not be seen. Given that sick or weak fish are not found, this scenario presupposes that the mortalities caused by wasting could only occur as an all-or-nothing response.

*Preyed upon*

Mortalities at sea which occur as a result of predation would effectively remove the organism from the population and leave no evidence. Proof of a predator consuming salmon could be found in stomach content analysis of the predator. However, some fish would survive attack by a predator and return to a natal stream. Evidence for missed attacks would be available through examination of fish at monitoring stations. Within the proportion of fish which are killed by a predator, there are various states, healthy or unhealthy, and within the unhealthy category, diseased or resistant, and so on. One would expect that the probability of a fish being consumed by a predator is related to the condition or size of the fish being pursued so that the probability of consumption by a predator would follow a hierarchy as follows: active diseased > poor condition > healthy (Table 3). Assuming a predator is actively removing a reasonably large proportion of the population, the likelihood of seeing diseased or poor condition fish at monitoring stations is greatly reduced.

Predation may occur at differential rates depending on the size of the fish. Anecdotal evidence of the incidence of scars (possible unsuccessful attacks) on salmon at fish counting facilities indicates that the rate is much higher on large salmon than on grilse. Although the incidence of possible attacks (scars) is not documented, the survival rate of fish wounded by a predator may be size dependent.

*Fishing-induced mortality*

Mortalities attributed to fishing would presumably not be selective according to the condition of the fish unless some means of escape from fishing gear could occur related to condition (e.g., fish which are enmeshed in a net and manage to struggle free). Thus the probability of a fish being caught would be uniform across the condition range of the population of fishes within a particular area. Obviously different migration paths for stocks of salmon would result in different probabilities of capture related to fishing effort by area and so on, but again, that difference in probability of capture would be unrelated to condition.

Sampling and analyses of fish taken in fishing gear at sea may provide insight into the hypotheses that predators or wasting are having a significant impact on survival of salmon during a particular time or location of their marine migration.

## Temporal and spatial distribution of salmon at sea

The distribution of Atlantic salmon in the ocean during their migration has been described by Ritter (1989). The size, timing, and location of the various life stages of salmon from the Gulf of St. Lawrence, the Atlantic coast of the Maritimes and the outer and inner Bay of Fundy rivers has been determined largely through tagging programs (Table 4). The information from those tag returns can place the salmon at the most probable location and time and thus allow comparison with environmental or predator and prey data to look for coincidental and possibly deterministic forces.

## Literature Cited

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Table 1. Potential status of Atlantic salmon (hatchery and wild) that survive the marine migration phase of their life cycle.

| Survivor origin | General health | Condition | Disease status | Potential status based on history | Data or approach to determine likelihood |
|---|---|---|---|---|---|
| Wild or hatchery | Healthy | | | Condition good. Numbers dependant on growth and survival; frequency distributions of lengths are normally distributed. | Length frequency distributions |
| | Unhealthy | Poor condition | | Condition poor. Numbers probably lower than normal. | Return rates; condition factors |
| | | Diseased | Active | Condition poor. Active disease present. Numbers probably low. | Return rates; disease testing |
| Possible behavior or condition offset for all hatchery fish outcomes | | | Resistant | Condition variable. Numbers probably low. | Returns rates; disease testing; Antigen or stress test positive for recent exposure. |

Table 2. Potential status of Atlantic salmon (hatchery and wild) that succomb to predators, disease, or wasting, during the marine migration phase of their life cycle.

| Origin | Ultimate fate | Cause of mortality | History: Size | History: General health | History: Condition | History: Disease status | Likelihood of fish succumbing based on history |
|---|---|---|---|---|---|---|---|
| Wild or hatchery at sea stages | Survivors | See Table 1. | | | | | |
| | Mortalities | Fished | | Healthy | | | Likelihood can be estimated |
| | | | | Unhealthy | Poor condition | Active | |
| | | | | | Diseased | Resistant | |
| | | Preyed upon | Large fish | Healthy | | | Lower probability of capture. |
| | | | | Unhealthy | Poor condition | | High probability of capture. |
| | | | | | Diseased | Active | High probability of capture |
| | | | Small fish | Healthy | | | Lower probability of capture. |
| | | | | Unhealthy | Poor condition | | High probability of capture. |
| | | | | | Diseased | Active | High probability of capture |
| | | Wasted and decayed | | Unhealthy | Poor condition | | Undetectable and low probability of discovery |

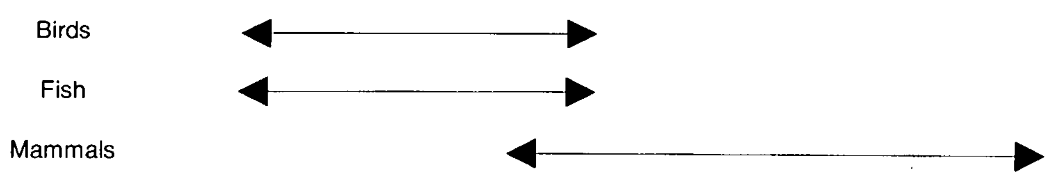
Table 3. Probability of capture of Atlantic salmon by a predator associated with the origin and potential status of the salmon during the marine migration phase of their life history.

| Predator type | Atlantic salmon: Origins | Size | General health | Condition | Disease status | Probability of capture by predator |
|---|---|---|---|---|---|---|
| Preyed upon by: (1) avian species (2) mammals (3) fish | Wild or hatchery | Larger | | | | Lower |
| | | | Healthy | | | Lower |
| | | | Unhealthy | Poor condition | | High |
| | | | | Diseased | Active | High |
| | | | | | Resistant | Lower |
| | | Smaller | | | | Higher |
| | | | Healthy | | | Lower |
| | | | Unhealthy | Poor condition | | High |
| | | | | Diseased | Active | High |
| | | | | | Resistant | Lower |

Table 4. Temporal and spatial distribution of possible outcomes for Atlantic salmon during their migration from freshwater and throughout the marine migration phase of their life cycle.

| | | Probable location from tag recoveries | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Life | | Post smolt | | | | | | | | |
| Source | strategy | Smolt | Early | Late | Win1 | Spr.1 | Sum1 | Win2 | Spr.2 | Sum2 | Returns |
| NNS | 1SW | Estu | GulfSL | E_Nfld | SLabS | E_Nfld | CB | na | na | na | |
| | 2SW | Estu | GulfSL | E_Nfld | SLabS | SLabS | Grnld | Grnld | LabS | NSCst | |
| Atl NS | 1SW | Estu | NSCst | S_Nfld | SLabS | E_Nfld | NSCst | na | na | na | |
| | 2SW | Estu | NSCst | S_Nfld | SLabS | SLabS | Grnld | Grnld | LabS | NSCst | |
| IBF | 1SW | Estu | iBoF | WBoF | ? | WBoF | Estu | na | na | na | |
| | 2SW | Estu | iBoF | WBoF | ? | WBoF | Estu | ? | ? | Estu | |
| SBF | 1SW | Estu | NSCst | S_Nfld | SLabS | E_Nfld | ONScst | na | na | na | |
| | 2SW | Estu | NSCst | S_Nfld | SLabS | SLabS | Grnld | Grnld | LabS | ONSCst | |
| Size at age (cm) | Min | 12 | 15 | 25 | 25 | 30 | 45 | 50 | 50 | 60 | |
| | Max | 20 | 35 | 45 | 45 | 50 | 60 | 60 | 70 | 80 | |

Predator size preference




Explanation of abbreviations:

| | |
|---|---|
| Atl NS | Atlantic Nova Scotia |
| CB | Cape Breton |
| E_Nfld | Eastern Newfoundland |
| Estu | Estuary |
| Grnld | Greenland |
| GulfSL | Gulf of St. Lawrence |
| IBF | Inner Bay of Fundy |
| iBoF | Inner Bay of Fundy |
| LabS | Labrador south |
| NNS | Northern Nova Scotia |
| NSCst | Nova Scotia coast |
| ONSCst | Off Nova Scotia coast |
| S_Nfld | Southern Newfoundland |
| SBF | Southern Bay of Fundy |
| SLabS | Southern Labrador Sea |
| WBoF | Western Bay of Fundy |