HARBOR SEAL (*PHOCA VITULINA*, LINNAEUS) ABUNDANCE AND FISH MIGRATION IN THE SAINT JOHN HARBOUR

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ABSTRACT - Harbor seal (*Phoca vitulina* Linnaeus) abundance and distribution were examined in the Saint John Harbour, Saint John, New Brunswick, Canada, from May–August of 1999 and 2000. Seal counts in the water were made with respect to tide, time of day, season, and weather. Maximum seal counts per week were compared to peaks in fish runs of alewife (*Alosa pseudoharengus* Wilson) and Atlantic salmon (*Salmo salar* Linnaeus). Significantly greater numbers of seals were observed at high tide and with lower temperatures. Seal abundance peaked in early May and coincided directly with the presence of alewife. Seal numbers were not found to be significantly related to adult Atlantic salmon migration through the harbor.

INTRODUCTION

Harbor seals (*Phoca vitulina* Linnaeus) are opportunistic predators that adjust their feeding patterns to take advantage of locally and seasonally abundant prey (Olesiuk 1993, Payne and Selzer 1989). Seal movements coincide with fish movements in some areas but are not correlated with fish in others (Allen et al. 1984, Brown and Mate 1983, Renouf et al. 1981). Colbourne and Terhune (1991) found no relationship between seal haul-out locations and herring (*Clupea harengus* Linnaeus) movements in the Bay of Fundy. Recent anecdotal reports suggest that large numbers of seals raid gillnet fisheries in the Saint John Harbour, Saint John, New Brunswick, Canada. Local fishers of the Saint John Harbor are concerned about seal predation on commercial fish species such as alewife/gaspereau *(Alosa pseudoharengus* Wilson) and American shad (*Alosa sapidissima* Wilson) that migrate upstream through the harbor in April/May.

Adult Atlantic salmon (*Salmo salar* Linnaeus) travel upriver during June–October and the smolts travel out to the Bay of Fundy during April/May (D. Sutherland, pers. comm.). Seal predation upon Atlantic salmon is of concern because the Atlantic salmon is an endangered species (COSEWIC 2001).

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In the Bay of Fundy, Canada, harbor seals haul out in the greatest numbers when low tide is in the afternoon (Pauli and Terhune 1987a). Other factors associated with an increased number of seals hauled out are warmer air temperatures, low cloud coverage, low precipitation, high waves offshore, little surf splash, and no human disturbances (Pauli and Terhune 1987b, Sullivan 1980). Seals move between haul-out areas on a daily basis. The absence of seals for 2–3 day periods at a haul-out site near Saint John, NB, suggests that they may use more than one site but seals do not always haul out every day (Pauli and Terhune 1987b, Terhune and Almon 1983). Although most studies have been conducted at haul-out sites, seals spend the majority of their time in the water (Thompson et al. 1998).

Our goal was to determine if seal numbers increase during the alewife and Atlantic salmon runs. We also examined the influence of tide, time of day, season, and weather conditions on seal numbers in the harbor.

METHODS

Seals were observed while they were in the water in the Saint John Harbor (45°15'20"–16'30" N, 66°03'45"–05'40" W). Saint John, New Brunswick, is an industrial city, population 75,000, situated along the north coast of the Bay of Fundy.

1999

Observations were made from 8 different locations, sites 2, 4, 6, 8,10, 11, 12, and 14 (Fig. 1) from May 5 to August 31. All sites were on the North side of the Harbor with the exception of site 12. Reversing Falls is between sites 11 and 14. Observation sites were selected using a random numbers table. Counts were made of harbor seals that were at the surface using 7 x 50 binoculars. Counts were the maximum number of seals observed within a three-minute duration, separated by a three-minute interval, for one hour per site. Individual seals would not be counted twice during a three-minute observation period because counts were of the maximum number of seals which could be seen at once. Therefore, all counts were a minimum number of seals present in the area. Approximately 5 one-hour sessions were conducted per day, five days a week. Observations were made between dawn and dusk on an opportunistic basis.

2000

The methods for 2000 were similar to those of 1999. However, sites were selected to view the largest number of seals possible rather than selected randomly as in 1999. Seals were observed from sites 2, 4, 6, and 7 (Fig. 1) from April 1 to May 17. Site 4 was used exclusively from May

17 to August 30 because it was found to have the most seals. Site 4 included the area from the Harbour Bridge to a 1 km viewing distance downstream. The water downstream from the Harbour Bridge was deep and fast moving on the west side of the harbor, and slow and shallow with large rocks exposed at low tide on the east side close to the Harbour Bridge. The full width of the harbor had no rocky shallow areas about 300 m downstream from the Harbour Bridge.

The observation session was chosen at a time of tide that would allow the greatest numbers of seals to be observed. From April 1 until May 4 observations were made 2 h before high tide for 4 h. From May 5–22, seals were observed from high tide for 4 h. From May 23, until the end of the study period, the viewing time was determined by the previous day's maximum count because this method was most effective in ensuring that daily peaks in seal numbers would be observed. The number of minutes after high tide that the maximum count of the day was recorded was used as the mid-point for the next day's 4 h observation period. A four-hour session was recorded during optimal tidal time

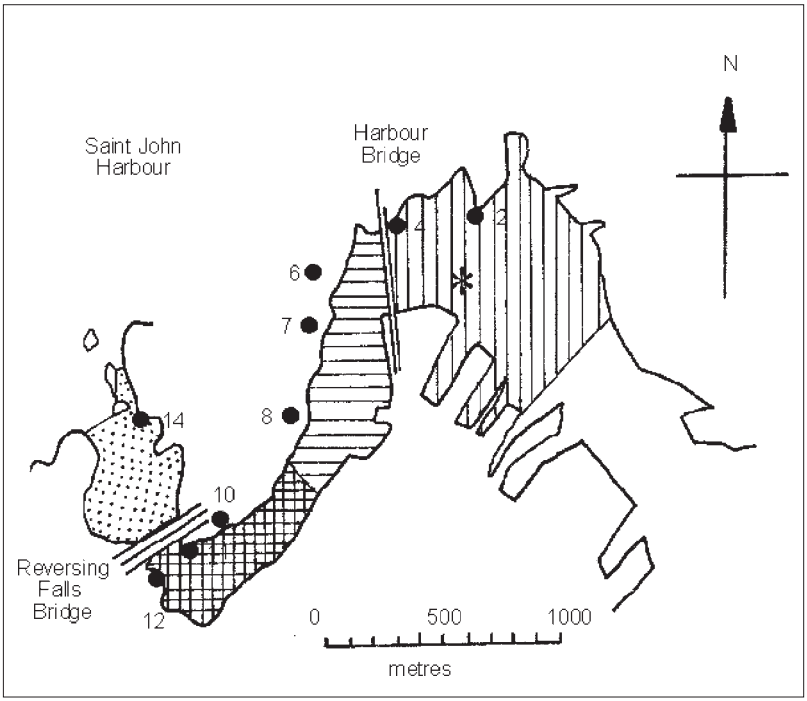

Figure 1: Map of the Saint John Harbor, New Brunswick. Numbers represent observation sites. The symbol * marks the location where large numbers of seals would congregate. Surface area of the observation areas varied and were approximately as follows: a ' 577000 m^2 (vertical stripes), b ' 222,000 m^2 (horizontal stripes), c ' 148,000 m^2 (checked), and d ' 155,000 m^2 (dots).

for approximately 10 days at a time, then there were 4 days without observation due to optimal tidal time being before dawn or after dusk.

Meteorological and tidal effects on seal numbers

A number of weather conditions, time to high tide, and time of day were recorded at each three-minute seal count. A MANOVA test was used to determine the effects on seal counts of 8 independent categorical variables: wind, temperature, cloud, rain, time to high tide, time of day, month, and site (SPSS™ 1990). Wind was categorized as either no wind, slight breeze, windy, or extremely windy. Temperature was grouped as either 0–9 °C, 10–19 °C, or 20–29 °C. Cloud was categorized as no clouds, less than 50% cloud coverage, more than 50% cloud coverage, or 100% overcast. Rain was grouped as no rain, slight drizzle, or rain. Counts were discontinued if rain became heavy because visibility would be poor. Time to high tide and time of day were grouped into 2 hour periods (i.e., 0 to 120 minutes to high tide, or 8:00–9:59 for time). Observation sites were grouped into 4 areas (Fig. 1, a (2, 4), b (6, 7, 8), c (10, 11, 12), and d (14). Only the fifth count per hour was selected (random number table) for analysis to ensure that counts were independent. A significance level of $p < 0.05$ was used.

Seal and fish movements

Data on alewife and shad commercial fishery landings from the Saint John Harbor area were obtained from the Department of Fisheries and Oceans (DFO). Atlantic salmon numbers were obtained from the Mactaquac Fish Culture Station. These counts were made at the Mactaquac dam on the Saint John River approximately 150 km upriver from the Saint John Harbour. Non-linear regression was used to determine if seal numbers increased when alewife landings or Atlantic salmon numbers increased. Statistica™ version 3.1 was used for data analysis (StatSoft 1992).

RESULTS

Observation days

A total of 3,610, three-minute observations were made on 65 days between May 5 and August 31, 1999. The greatest number of seals seen at one time in 1999 was 34 on May 12. Observations could not be made on approximately 10 days due to excessive rain or fog.

A total of 2,920, three-minute observations were collected on 75 days between April 1 and August 30, 2000. The greatest number of seals seen at one time in 2000 was 55 on May 1. Four hours of observations were made on each observation day except for 8 days when the last hour of observation was not collected due to adverse viewing conditions such as thick fog or darkness.

There was an eight-day period from July 1–7 in 1999 when observation was not conducted. In 2000, observation was not conducted from June 5–9 (5 d), June 20–27 (8 d), July 4–10 (6 d), and July 20–26 (7 d) and observations were only made on 3 days in April (April 1, 15, and 21). Fifty-five percent of all days were sampled between May 5 and August 31, 1999, and 51% of all days were sampled between April 1 and August 30, 2000.

Meteorological and tidal effects on seal numbers

The greatest number of seals present in the harbor occurred at high tide or just after high tide. Seals would enter the harbor a couple of hours before high tide and move upstream with the current, often passing over the Reversing Falls sill into the area adjacent to site 14. When the water direction changed the seals would begin to move downstream with the current. At high tide seals would be spread throughout the harbor, but as the current changed and moved seaward, seals moved out of the upper areas while the seals from the lower areas would remain. This resulted in a concentration of seals in sites 2 and 4. Therefore the best time and place to see the largest number of seals in the harbor would be at sites 2 and 4, below the Harbour Bridge, approximately 4 hours after high tide. Seals observed from sites 2 and 4 were most often located in deeper water in a boating channel (Fig. 1). Aggregations of seals were often observed in the deep channel where it began to widen. Seals were observed spread out in the water 300 m and more downstream from the Harbour Bridge or in the deep water just downstream from the Harbour Bridge (Fig. 1). Seals did not appear to favor any area of the water in any of the other sites.

Cloud cover, rain, and time of day did not have significant effects on seal numbers (Table 1). Significantly greater numbers of seals were observed when temperatures were cooler (Table 1). Significantly lower numbers of seals were observed at low tide (Table 1). Seal numbers were greatest in late April, and still high in May but were much lower in

Table 1. Meteorological and temporal effects on harbor seal numbers in the Saint John Harbor in 1999 and 2000. A MANOVA with a significance level of $p < 0.05$ was used.

Conditions	F-value	df	P-value
Wind speed	4.653	3	0.003
Temperature	35.295	2	0.000
Cloud cover	0.865	3	0.459
Rain	1.849	2	0.158
Time of day	1.884	6	0.081
Month	18.168	4	0.000
Time of tide	9.863	6	0.000
Location	6.177	3	0.000

June, July, and August (Fig. 2). Significantly greater numbers of seals were observed in sites 2/4 than 6/7/8 while sites 10/11/12 had the lowest numbers of seals observed. Wind was found to have a significant effect on seal numbers (Table 1), however, the greatest number of seals was observed with extremely strong winds, followed by a slight breeze and then no wind, and the lowest numbers of seals were observed on windy days. The seal count data were not normally distributed and could not be normalized with log transformation, therefore this must be taken into consideration when interpreting the results.

Seal and fish movements

There was a significant difference in seal numbers associated with the month of the year (Table 1). In 1999, there was a large peak in seal numbers (maximum 34) during the second week of May when the shad and alewife were in the harbor and a low dip during the second week of June and after the end of the of the alewife run. A second, but smaller, peak in seal numbers (maximum 17) during the first week of August coincided with the adult Atlantic salmon upstream migration. In 2000, a large peak in seal numbers (maximum 55) occurred at the end of April and beginning of May and then numbers dropped and remained relatively constant all summer (Fig. 2). Alewife catches peaked at the

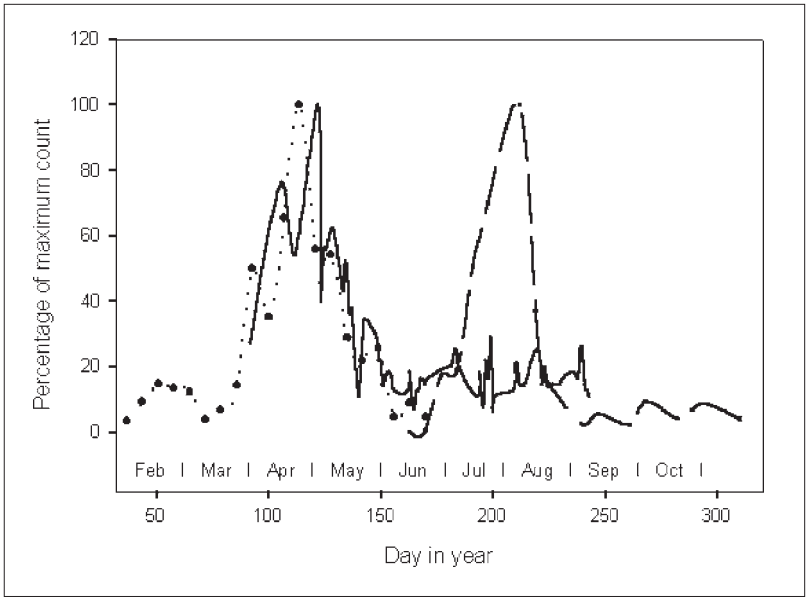

Figure 2. Relative harbor seal (solid line), alewife (dotted line) and Atlantic salmon (dashed line) maximum weekly numbers in the Saint John Harbor with respect to season, in 2000. Actual numbers for highest count (100% on graph) were 55 seals, 9,119 kg of alewife, and 801 salmon. Shad numbers peaked in May and catches were 3,269 kg in May and 515 kg in June.

end of April (Fig. 2). A significant relation between maximum seal counts (per week) and alewife landings (by week) was found in 1999 ($R(x,y) = 0.797$, $n = 6$, $p = 0.029$) and 2000 ($R(x,y) = 0.604$, $n = 10$, $p = 0.032$). Reports of shad catches were not detailed enough to be used for analysis because they were totaled by the month. However, the alewife run is much larger than shad (13.4 x greater catches) and therefore likely plays a greater role in influencing seal behaviour. There were no significant relationships between seal and adult Atlantic salmon numbers in 1999 ($R(x,y) = 0.423$, $n = 11$, $p = 0.098$) or 2000 ($R(x,y) = 0.020$, $n = 10$, $p = 0.478$).

There are no data available on the numbers or timing of the seaward migration of Atlantic salmon smolts or the outward migration of alewife. A seal was observed eating an adult Atlantic salmon on 24 June 1999 and 13 July 2000.

DISCUSSION

The seal counts were occasionally hampered by poor viewing conditions and incomplete sampling during both summers. Aside from the April 2000 counts (when only three days were sampled), the periods when no observations were made were spread throughout the study period and it is unlikely that any significant seasonal trends in seal numbers were missed. Under optimal viewing conditions it is likely that virtually all of the seals present would have been counted. The major increases in seal numbers in May of both years were not attributable to any possible biases in the data collection.

Meteorological and tidal effects on seal numbers

The greatest fluctuation in seal numbers occurred with seasonal changes and can be correlated with the availability of food sources. Within a daily period seal numbers also fluctuate; tidal period appears to be the most important factor controlling seal numbers in the harbour. The tide heights in the Bay of Fundy exceed 6–8 m and seals only haul out when the tide is falling (Pauli and Terhune 1987a). Pauli and Terhune (1987a, b) found that greater numbers of seals hauled out at the Shag rocks (haul-out area), just outside of the Saint John Harbour, were associated with low tide, afternoons, less wind, warmer temperatures, low cloud cover, and low precipitation. Therefore with reverse conditions from those favorable for haul out, fewer seals would haul out, leaving more seals in the water (feeding area). Greater numbers of seals were observed at high tide and with lower temperatures; however, the other meteorological conditions appear to be less important in determining the number of seals to enter the harbour. The significant difference in seal numbers due to wind had no discernable pattern and may have been simply due to sample variability.

The distribution of seals within the harbour is influenced by the tide. Most of the seals enter the harbor from the Bay of Fundy and must travel through the lower sites to get to the upper sites. Therefore almost all of the seals would have to be in the lower sites at some point but they may not all travel into the upper sites. Also the water at the upper sites (the Reversing Falls) moves faster than the lower sites so swimming in the lower sites would require less energy. At low tide, the water in the upper sites moves so fast that seals could not stay in the area, so any counts at low tide at these upper sites would have been 0 counts.

Seal and fish movements

High seal numbers and alewife landings coincided in both 1999 and 2000. This suggests that seals are congregating in the harbor during alewife migrations. Previous studies of seal movements in the Bay of Fundy suggest that seals do not follow herring (Colbourne and Terhune 1991). However, their study recorded numbers of seals on nearby haul-out sites and did not account for their daily movements during their feeding period. It is not surprising that a predator would make local movements to take advantage of a seasonally abundant food source (Brown and Mate 1983).

The Atlantic salmon counts were obtained farther upstream and thus there would have been a time lag between the time these fish were in the harbor and when they were counted. Both observations of seals eating adult salmon were made during the same time period that salmon numbers peaked at Mactaquac. In 2000, the Atlantic salmon numbers showed a definite peak that was not reflected by an increase (then, earlier or later) in the number of harbor seals in the harbor. There were no statistically significant correlations found between seal numbers and Atlantic salmon numbers in 1999 or 2000, therefore it is unlikely that the seals are congregating to specifically target salmon in the Saint John Harbor. Whether the seals are following the fish or not is of particular concern for salmon populations because the seals may be able to eat a large proportion of this migrating fish population because of its small size (i.e., 3,574 individuals recorded in 2000).

In the Northwest Atlantic only a small percentage of harbor seal diet is of Atlantic salmon. However, even if the Atlantic salmon only makes up a small percentage of the seal's diet, high seal abundance could seriously affect the salmon population (Cairns and Reddin 2000). Atlantic salmon may form a greater percentage of the harbor seal diet for those animals that are in the Saint John Harbour during salmon migration. If seals are congregating during salmon migrations, seal control measures may be necessary to protect salmon populations.

In conclusion, meteorological and tidal conditions play an important role in seal numbers; seals were found to be in greatest numbers in the harbor during high tide and with lower temperatures. Harbor seals were found to congregate in the Saint John Harbour during the runs of alewife but not Atlantic salmon.

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