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Effect of Tidal Flooding on Mortality of Juvenile Muskrats

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ABSTRACT: The effect of tidal flooding on survival of juvenile muskrats (*Ondatra zibethicus*) was investigated in a brackish marsh in Louisiana by examining 50 muskrat lodges each month from July 1984 to June 1985 and tidal data over a 19-yr period. Tide levels increased at a rate of 1.58 cm yr^{-1} during the 19-yr period prior to the study, and during the study nest chambers in muskrat lodges were flooded on 43 d. Seventy-seven captured litters averaged 2.2 ± 0.3 young per litter. Older litters were less common than younger litters, but the number of young per litter did not differ among 5-d age classes, suggesting that mortality factors usually affected entire litters. The frequency of tidal flooding prior to opening of lodges each month was associated negatively with the number of litters and number of young per litter. If marsh subsidence and sea level rise continue, tidal flooding will become more prevalent and litter mortality will likely increase.

Introduction

The muskrat (*Ondatra zibethicus*) is a major furbearer in Louisiana. Highest populations occur in brackish marshes (O'Neil 1949; Palmisano 1972; Linscombe and Kinler 1985) that encompass 10,000 km^2 of the state's coastal region (Chabreck and Linscombe 1982). Although these marshes provide important habitat for muskrats, the future status of this habitat is uncertain (Fruge 1982). Gagliano et al. (1981) reported that coastal marshes in Louisiana were being lost at a rate of 100 km^2 yr^{-1} as a result of erosion, subsidence, and sea level rise, and that the annual rate of loss was increasing. Net sea level rise, which includes marsh subsidence, sea level rise, and marsh accretion (Boesch et al. 1983), was estimated to be 4.5–5.0 mm yr^{-1} in southwestern Louisiana (Baumann and DeLaune 1981; Hatton et al. 1983).

Bellrose and Brown (1941) and Donohoe (1966) reported that muskrats in Illinois and Ohio were more abundant in areas with stable water levels than in areas with fluctuating water levels. Donohoe (1966) attributed the lower muskrat population to increased mortality because of flooding. If sea level continues to rise along the Louisiana coast, marsh inundation will increase and mortality of muskrats, especially juveniles, may increase. The objective of this study was to evaluate the effect of tidal flooding on muskrat mortality.

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Methods

The study was conducted on a 200-ha section of brackish marsh along the south-central Louisiana coast between Vermilion Bay and the Intracoastal Waterway (Kinler 1986). Topographic elevation (mean sea level = 0.00 m) was transferred from a permanent U.S. Coast and Geodetic Survey benchmark to temporary benchmarks located within the study area.

Tidal characteristics of the study area were determined from tidal data collected by the U.S. Army Corps of Engineers at Luke's Landing, 45 km southeast of the study area. Daily high-tide data were available only for 1981–1985. However, 0800-h readings of tide levels were available for a longer period and were used to assess tidal trends before 1985 with a 19-yr series as recommended by the U.S. Coast and Geodetic Survey (Hicks 1967). Mean 0800-h tide levels were compared among months and years, and a simple linear re-

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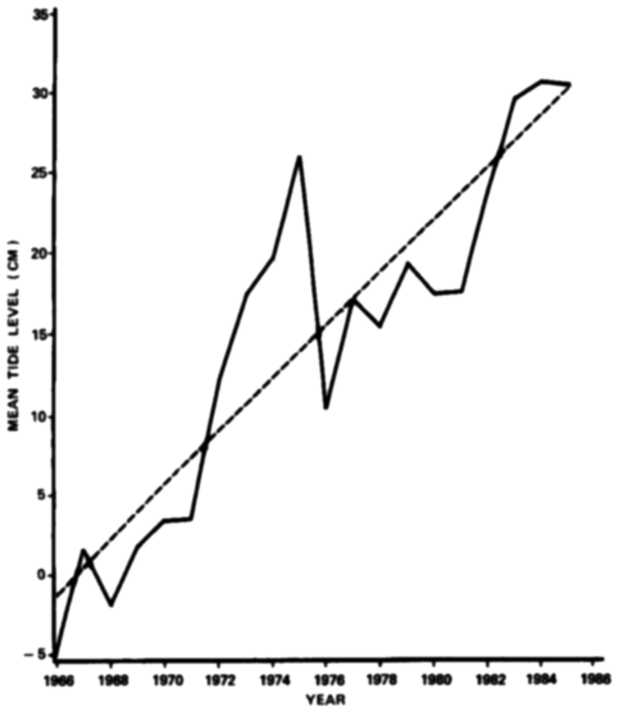

Fig. 1. Mean annual level (cm) of daily tide readings at 0800 h and predicted water level rise as estimated by a simple linear regression, Luke's Landing, Louisiana, 1966–1984.

gression was used to estimate the rate of water level rise during the 19-yr series.

Nest-chamber elevations and age-class distribution of young muskrats were determined by examining 50 different muskrat lodges each month from July 1984 through June 1985. Lodges were examined only if fresh droppings, vegetation, or mud indicated that the lodge was active. Nest chambers were exposed by removing top layers of lodge vegetation. Although some young muskrats may be killed by partial flooding of lodges, we assumed that tidal flooding would not be detrimental until the highest nest chamber was completely inundated. The elevation of the ceiling of the highest nest chamber was determined by extending a level line from the chamber ceiling of the lodge to a nearby temporary benchmark.

As each lodge was opened, nest chambers, tunnels, and lodge entrances were examined for muskrat litters as described by Smith (1938), Errington (1939), and Sather (1958). Tail length, total length, and weight of each muskrat were measured and used to determine the age of each captured litter as described by Errington (1939), Dorney and Rusch (1953), and LaBoulenge (1977).

Nest chamber elevations were compared among months using analysis of variance (SAS Institute, Inc. 1982). The relationships between the frequency of tidal flooding and monthly variation in the number of litters and number of young per litter were determined using linear regression. Frequency of tidal flooding was quantified as the number of days in the 24-d period before the examination of lodges each month that tide levels exceeded the mean elevation of the ceilings of the highest nest chambers. A 24-d period was chosen because it represented the maximum time that a litter could have been exposed to flooding (maximum age of litters analyzed was 24 d).

A chi-square goodness-of-fit test was used to determine if the monthly proportion of lodges with litters during our study (observed) differed significantly from the monthly proportion of lodges with litters as reported by O'Neil (1949) (expected). Mean number of young per litter was compared among 5-d age groups and among months using a general linear model (SAS Institute, Inc. 1982). A weighted analysis of variance (SAS Institute, Inc. 1982) was used to test for a difference between litter sizes as estimated by this study and by O'Neil's (1949) study.

Results and Discussion

An assessment of long-term (1966–1984) tide readings indicated that 0800-h tide levels varied considerably from year to year (Fig. 1). Varying amounts of rainfall, activity of tropical storms, and influx of spring freshwater from the Mississippi River may contribute to annual tidal variations. The 19-yr tidal series indicated a general increase in tide levels that was calculated to be 1.58 cm yr^{-1} ($r^2 = 0.79$, 18 d.f., $p = 0.0001$). This estimate falls within the range of water level increase for other areas in Louisiana as reported by Byrne et al. (1976) for the Barataria Basin (0.85–1.76 cm yr^{-1}) and by Byrne (1977) for the Vermilion Basin (0.88–3.26 cm yr^{-1}).

The mean (± SE) elevation of nest chambers was 0.83 ± 0.01 m. Chamber elevations differed among months ($F = 48.19$, 11 and 588 d.f., $p = 0.0001$) and ranged from 0.74 ± 0.01 m in August to 0.92 ± 0.01 m in October. The frequency of tidal flooding (range: 0–9 d) was correlated positively with nest-chamber elevation ($r = 0.64$, 11 d.f., $p = 0.0242$). Apparently, muskrats reacted to flooding by constructing additional nest chambers at higher elevations within lodges; however, we were unable to determine the extent to which construction of higher nest chambers reduced mortality. For example, on September 21, 1984 an attempt to sample lodges was prohibited by a rising storm tide approximately 0.30 m above the marsh (elevation = 0.90 m). We sampled lodges one week later, and the mean nest-chamber elevation ($\bar{x} = 0.85$ m) was higher than those in the first 2 months of sampling (July: $\bar{x} = 0.79$ m, August: $\bar{x} = 0.74$ m). In September, nest chambers within individual lodges differed as much as 0.18 m in elevation.

Our observations indicated that muskrats at 4 d of age floated temporarily but could not climb or swim. At that age, young muskrats probably could not escape if rising water flooded the nest chamber and would drown unless assisted by adult muskrats. Errington (1937, 1960) reported that young litters were often abandoned when burrows and lodges became flooded. Muskrats 5–9 d old climbed along vegetation but were poor swimmers; animals 10–14 d old swam and dove fairly well. Errington (1963) noted that eye-opening commonly occurred between 14 d and 16 d, and even before eye-opening young muskrats may leave a disturbed lodge and head across surrounding open water; however, their survival is unlikely unless they are assisted by an adult.

Young muskrats, 1–24 d old, may not survive even if they reach the top of a flooded lodge. O'Neil (1949) speculated that young muskrats forced to exit from a lodge would be unable to locate subsurface entrances to return to the lodge interior. Errington (1937) and Bellrose and Low (1943) reported that starvation or exposure (rather than drowning) often was the cause of death of young muskrats stranded by high water. If water level exceeds the top of the lodge, the young muskrat's only chance for survival lies in its opportunity to take refuge on floating lodges, vegetation, logs, or rafts of debris (Bellrose and Low 1943; Lynch et al. 1947). Based on observations in this study, the likelihood that muskrats $\leq$24 d old would be able to survive complete lodge inundation is remote.

We found 77 litters that ranged in age from 1–24 d. Older litters (n = 25, age 13–24 d) were less common than younger litters (n = 52, age 1–12 d), but the number of young per litter did not differ among 5-d age groups ($F = 1.12$, 4 and 72 d.f., $p = 0.3538$). Number of young per litter ranged from 1 to 5 and averaged 2.2 $\pm$ 0.3. Number of young per litter and number of litters each month were associated positively ($r = 0.65$, 11 d.f., $p = 0.0152$) and may have been influenced by the same factors.

The mean number of young per litter in our study ($\bar{x} = 2.2$) was different from that found by O'Neil (1949, $\bar{x} = 3.5$, $F = 40.90$, 1 and 21 d.f., $p = 0.0001$). Also, the proportion of lodges with litters ($\bar{x} = 12.8\%$) differed from that reported by O'Neil (1949, $\bar{x} = 30.7\%$, $\chi^2 = 96.54$, 11 d.f., $p < 0.005$). A net sea level rise of 0.18–0.21 m has occurred since O'Neil's (1949) study (Boesch et al. 1983) and may have accounted for the differences between the two studies.

The frequency of nest-chamber flooding during the 24-d period before the monthly examination of lodges was associated negatively with the number of litters ($p = 0.0195$) and number of young per litter ($p = 0.0095$, Fig. 2). Tidal flooding of nest chambers accounted for 44% of the variation in the number of litters and 51% of the variation in the number of young per litter. Tide levels that reached the mean elevation of the ceiling of nest chambers did not inundate nest chambers in all lodges (nest-chamber elevations varied as much as 0.18 m in September) and young in all lodges were not lost. However, we believe that in many lodges all young died when nest chambers were flooded.

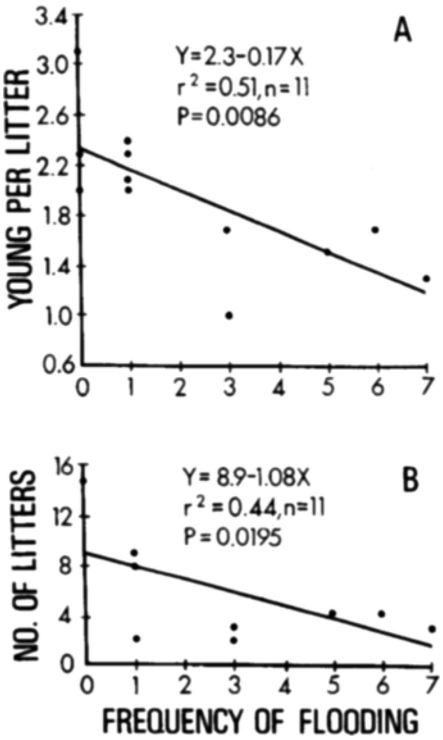

Fig. 2. The relationship of number of litters and number of young per litter to the frequency (days) of tidal flooding of muskrat lodges in the 24-d period before the monthly examination of 50 lodges.

Conclusions

During the 12-month study period, high tides exceeded the mean ceiling elevation of nest chambers in muskrat lodges on 43 d, and lodge flooding occurred every month except July. Muskrat litters were present in lodges every month, and the number of litters and number of young per litter were associated negatively with the frequency of nest chamber flooding prior to lodge opening each month.

Daily tidal readings during the 19-yr period prior to the study indicated a gradual rise in sea level of 1.58 cm yr^{-1}. This trend was similar to the findings of other studies of sea level along the Louisiana coast. Net sea level rise in the area is currently dominated by land subsidence (Boesch et al. 1983), and marsh accretion is unable to equal sea level rise in most areas. Increased tidal flooding of coastal marshes from additional rises in sea level could further increase mortality of juvenile muskrats along the Louisiana coast.

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