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Ondatra zibethicus.

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Ondatra zibethicus (Linnaeus, 1758)

Muskrat

Castor moschatus Linnaeus, 1758:59. Type locality eastern Canada.

Castor zibethicus Linnaeus, 1766:79. Type locality eastern Canada.

Ondatra americana Tiedemann, 1808:481. Renaming of *C. zibethicus* Linnaeus.

Fiber zibethicus-albus Sabine (*in* Franklin) 1823:660. Type locality Cumberland House [Saskatchewan, Canada].

Fiber osoyoosensis Lord, 1863:97. Type locality Lake Osoyoos [British Columbia], Canada.

Fiber macrodon Merriam, 1897:143. Type locality Lake Drummond, Dismal Swamp [Norfolk County], Virginia.

Fiber spatulatus Osgood, 1900:36. Type locality Lake Marsh, Northwest Territory, Canada.

Fiber occipitalis Elliot, 1903:162. Type locality Florence [Lane County], Oregon.

F[iber] niger Brass, 1911:604. Type locality in New Jersey or Delaware.

CONTEXT AND CONTENT. Order Rodentia, Suborder Myomorpha, Family Muridae, Subfamily Microtinae, Genus *Ondatra*. We follow Pietsch (1970) in considering the Newfoundland muskrat a subspecies of *O. zibethicus*. There are 16 subspecies of *O. zibethicus* as follows:

O. z. zibethicus (Linnaeus, 1758:59), see above (*maculosus* Richardson, *moschatus* Linnaeus, *niger* Fitzinger, *nigra* Richardson, *varius* Fitzinger, are synonyms).

O. z. albus (Sabine *in* Franklin, 1823:660), see above (*hudsonius* Preble a synonym).

O. z. osoyoosensis (Lord, 1863), see above.

O. z. pallidus (Mearns, 1890:280). Type locality Fort Verde [Yavapai County], Arizona.

O. z. rivalicius (Bangs, 1895:542). Type locality Burbridge [Plaquemines Parish], Louisiana.

O. z. macrodon (Merriam, 1897:143), see above (*niger* Brass a synonym).

O. z. aquilonius (Bangs, 1899:11). Type locality Rigoulette, Hamilton Inlet, Labrador.

O. z. spatulatus (Osgood, 1900:36), see above.

O. z. ripensis (Bailey, 1902:119). Type locality Pecos River at Carlsbad (Eddy) [Eddy County], New Mexico.

O. z. obscurus (Bangs, 1894:133). Type locality Codroy, Newfoundland.

O. z. occipitalis (Elliot, 1903:162), see above.

O. z. mergens (Hollister, 1910*a*:1). Type locality Fallon [Churchill County], Nevada.

O. z. zalophus (Hollister, 1910*a*:1). Type locality Becharof Lake, Alaska.

O. z. cinnamominus (Hollister, 1910*b*:125). Type locality Wakeeney, Trego County, Kansas.

O. z. bernardi Goldman, 1932:93. Type locality 4 mi. S. Gadsden, Yuma County, Arizona.

O. z. goldmani Huey, 1938:409. Type locality Saint George, Washington County, Utah.

DIAGNOSIS. The muskrat is the largest microtine. It is chunky in appearance and has a large, blunt head, relatively small eyes, and short, rounded ears that barely protrude from the fur (Fig. 1). The partially webbed hind feet are broad and fimbriated; the forefeet are much smaller. Tail is nearly as long as the head and body, flattened laterally, scaley and with a sparse fringe of hair on ventral keel. The skull is vole-like although more massive. The anterior margin of the cranium is abruptly constricted. The interorbital region has a median ridge. Upper incisors protrude slightly beyond the nasals. Incisive foramina are long and narrow. Posterior margin of palate has a spine; palatal bridges absent. The incisors are rootless and without grooves; the molars are rooted. First lower molar has six triangles, first of which is not closed; anterior loop bilobed. Third lower molar has three outer salient angles (modified from Hall and Kelson, 1959; Godin, 1977). The skull is illustrated in Fig. 2.

GENERAL CHARACTERS. Descriptions are found in Hall (1955), Hall and Kelson (1959), and Hollister (1911). The ventral pelage is somewhat lighter than the remainder of the fur. Pelage color varies from white and silver through tan, reddish brown and black; generally dark brown. The tail and feet usually are dark brown or black in color. The dental formula is i 1/1, c 0/0, p 0/0, m 3/3, total 16.

There is no sexual dimorphism in external or cranial measurements. Average ranges of external measurements (in mm) of adult muskrats are: total length, 456 to 553; length of tail, 200 to 254; length of hind foot, 65 to 78; length of ear from notch, 20 to 21 (Hall, 1955). The weight of adults ranges from about 700 g to over 1,800 g (Walker et al., 1975); neonates weigh only about 21 g (Hall, 1955). Additional data on weights and measurements are given in Hollister (1911) and Dozier (1945, 1950). The range of mean cranial measurements (in mm) of adults are as follows (Hollister, 1911): basal length, 53.6 to 65.1; zygomatic breadth, 34.6 to 44.0; length of nasals, 7.7 to 10.1; length of maxillary tooth row, 14.5 to 17.7. Additional data on cranial measurements are given in Hall (1955), Hall and Kelson (1959), Paradiso (1969), Ruprecht (1974) and Youngman (1975). Boyce (1978) discussed the effects of climatic variability on the body size and cranial variation in North American muskrat populations.

DISTRIBUTION. In North America (Fig. 3), muskrats occur from near the Arctic Circle in the Yukon and Northwest

FIGURE 1. Photograph of *Ondatra zibethicus* courtesy of (Leonard Lee Rue III).

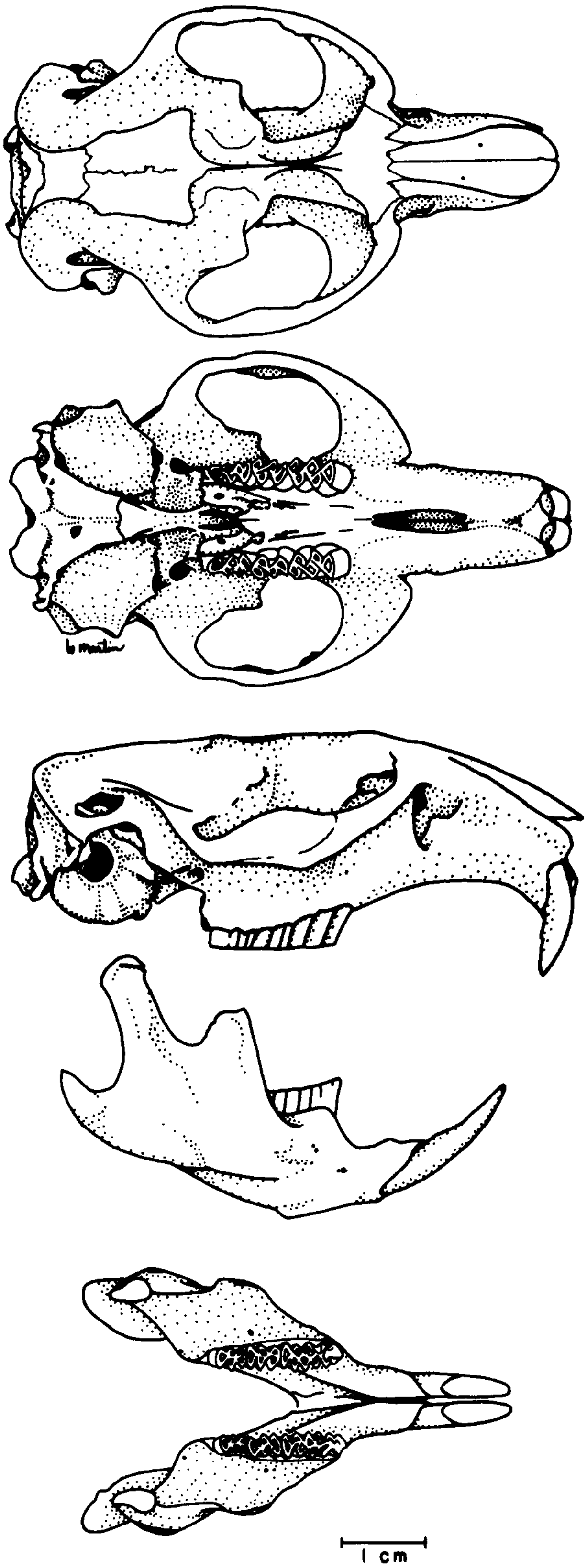

FIGURE 2. Skull and mandible of *Ondatra zibethicus macrodon.* From top: dorsal, ventral, and lateral views of cranium; lateral and dorsal views of mandible. Drawn by Wilma Martin. Appalachian Environmental Laboratory #AEL-600.

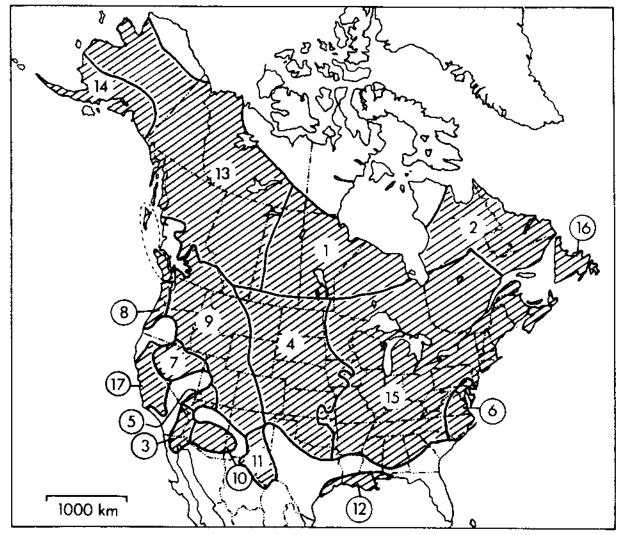

FIGURE 3. Distribution of *Ondatra zibethicus* in North America: 1, *O. z. albus*; 2, *O. z. aquilonius*; 3, *O. z. bernardi*; 4, *O. z. cinnamominus*; 5, *O. z. goldmani*; 6, *O. z. macrodon*; 7, *O. z. mergens*; 8, *O. z. occipitalis*; 9, *O. z. osoyoosensis*; 10, *O. z. pallidus*; 11, *O. z. ripensis*; 12, *O. z. rivalicus*; 13, *O. z. spatulatus*; 14, *O. z. zalophus*; 15, *O. z. zibethicus*; 16, *O. z. obscurus*; and 17, introduced *O. zibethicus* (adapted from Anderson 1972; Banfield, 1974; Hall and Kelson, 1959; Yocom and Eley, 1972).

Territories to as far south as the Gulf of Mexico; and from the Aleutian Islands east to Labrador and southward along the Atlantic coast to North Carolina. An insular subspecies (*O. z. obscurus*) occurs in Newfoundland (Hall and Kelson, 1959; Walker et al., 1975).

Muskrats have been widely introduced into many areas of North America, Europe and South America (Hall and Kelson, 1959; Troostwijk, 1976). Many of these introductions have resulted in the establishment of viable populations. The primary sources of these introduced populations were fur farms. Areas which now have viable populations of muskrats include western Europe, Scandanavia, Japan, and Russia (Fig. 4) (Danell, 1978; DeVos et al., 1956; Troostwijk, 1976). In North America, introductions have been made in areas of California as well as islands off the coast of British Columbia (Newsom, 1937; Storer, 1937; Yocom, 1970; Yocom and Eley, 1972). The muskrat has also been reported as introduced into the mainland and islands at the southern tip of South America (Pine et al., 1973).

FOSSIL RECORD. McMullen (1978) recovered late Pleistocene specimens on *Ondatra zibethicus* from the Duck Creek local fauna of Kansas and believed the material to be of Illinoian age. Other Pleistocene specimens of *Ondatra* have been taken in Florida (Gillette, 1976), Ohio (Mills, 1975), and West Virginia (Guilday and Hamilton, 1978). Mills (1975) reported muskrat remains found with ground sloth (*Megalonyx*) remains which were radiocarbon dated at 12,190 years B.P. Nelson and Semken (1970) reported that the muskrat (*Ondatra* sp.) is a common element in late Kansas and post-Kansas deposits, and that their remains are valuable stratigraphic tools for deposits of glacial age. Shultz et al. (1972) reported that chronoclines are present for muskrat lineages. The Recent subfossil record of the muskrat is also well documented (Guilday and Bender, 1958; Guilday and Parmalee, 1965; Parmalee, 1962).

FORM AND FUNCTION. The pelage of adult muskrats consists of a layer of soft, dense underfur, interspersed with longer, coarse guard hairs. The annual molt usually begins in the summer months, with the pelage reaching its minimum density during August. In the early fall, the hair growth is renewed until a prime winter coat is developed. The characteristic luster of the winter pelage is due to a significant increase in the number of dark, glossy guard hairs (Linde, 1963). The underfur is considered to be waterproof under normal conditions (Errington, 1963). A layer of air trapped in the nonwettable fur enhances the muskrat's buoyancy and insulation. Johansen (1962) found the volume of

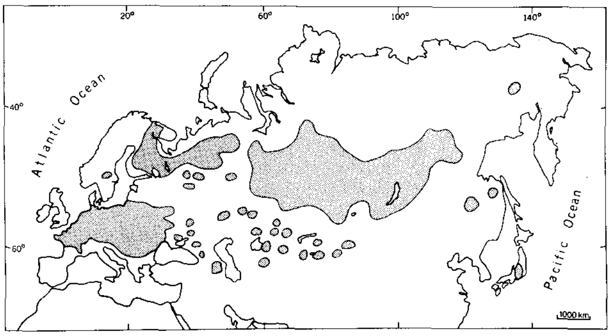

FIGURE 4. Distribution of introduced *Ondatra zibethicus* in Eurasia (adapted from DeVos et al., 1956; Pietsch, 1970).

trapped air to average 21.5% of the animal's total dry volume. The common name of the muskrat is derived from the conspicuous odor of secretions from paired perineal musk glands found beneath the skin at the ventral base of the tail. Both sexes possess functional glands. During the breeding season, scent is deposited around defecation sites, houses and dens, and along trails (Errington, 1963). Females generally have three pair of mammae, one pectoral and two inguinal (Godin, 1977), although as many as four or five pairs have been noted (Linde, 1963; Svihla and Svihla, 1931). The uterus is duplex with both cervical canals distinctly separated (Kanagawa and Hafez, 1973).

The muskrat's large, unrooted incisor teeth are well suited for gnawing as well as transporting materials through an aquatic environment. A valvular mouth, with lips that close behind the incisors, allows the animal to gnaw while submerged (Godin, 1977). The small forefeet are used for digging and the manipulation of foodstuffs or construction materials. The hindfeet are relatively large and modified for swimming. They are partially webbed and have fringes of stiff hairs lining the toes. The ankle joints are capable of strong lateral movements (Ferrigno, 1967).

Muskrats can swim at a rate of 1½–5 km/h and can swim backwards (Peterson, 1950). They can stay submerged for up to 20 min (Errington, 1961). The normal diving bracycardia is thought to be affected by water temperature stimuli (Thornton et al., 1978). Fairbanks and Kilgore (1978) found post-dive oxygen consumption to be similar for both unrestrained and restrained dives; however, recovery time was longer after restrained dives. The muskrat's long, laterally flattened tail is used in a rudder-like manner during swimming. It may also serve in thermoregulation by functioning as a heat sink during periods of exercise and high ambient temperatures (Johansen, 1962). Wika and Pasche (1976) emphasized that heat loss via the tail is proportional to temperature gradients between the tail and the environment, and the potential for heat dissipation is highest in cold water. MacArthur (1979) found that body cooling was retarded in adults in the winter and juveniles in the summer by periodic removal from the water. Muskrats apparently avoided hypothermia during under-ice travel by raising their abdominal temperature (maximum 1.2°C) prior to entering the water.

Adrenal glands are at minimum relative weights during the fall and winter, and increase in weight during the summer months. The enlargement is thought to be related to reproductive activity (Schacher and Pelton, 1976). Thyroid weights also were found to increase during the spring and summer and decrease in the winter (Akhmetov, 1977; Beer and Meyer, 1951). Aleksiuk and Frohlinger (1971) suggested that hypoxic winter conditions cause a compensatory increase in muskrat heart and lung weights, as well as increased hematocrit and hemoglobin counts.

The gestation period of the muskrat varies between 25 and 30 days (Erickson, 1963; McLeod and Bondar, 1952). Differences in recorded gestation lengths may be due to variation in implantation time (Beer, 1950).

The mean litter size varies from about four to eight; most investigators record a mean of six or seven. Schacher and Pelton (1975) summarized litter data from various studies of muskrats over North America. They suggested the existence of a latitudinal gradient in litter size, with more northern populations producing larger litters (see also Becker, 1973; Danell, 1978; Mathiak, 1966). O'Neil (1949) reported that female muskrats of Louisiana marshes usually produced five to six litters per year. A general pattern of two or occasionally three litters per season is common in the more northern regions of Maine (Gashwiler, 1950), southern Quebec (Stewart and Bider, 1974), West Germany (Becker, 1973), and in northern France (Vincent and Quéré, 1972*a*). In some areas fourth litters are reported, but only infrequently (Olsen, 1959; Vincent and Quéré, 1972*a*). Neal (1968) found that muskrats living in poorer quality habitats tended to have fewer litters and smaller litter sizes.

Geographic and climatological conditions are major determinants of the initiation and duration of the breeding season (Errington, 1963). Muskrats inhabitating more southerly latitudes of the United States breed throughout the year, with peak reproductive activity occurring in the winter (O'Neil, 1949; Svihla and Svihla, 1931). In more northern latitudes, reproductive activities are confined to spring and summer, with the first litters usually born in late April (Mathiak, 1966; Steward and Bider, 1974) or early May (Beer, 1959; McLeod and Bondar, 1952). Peak production of first litters occurred in May for muskrats in Wisconsin (Mathiak, 1966), southeastern Idaho (Reeves and Williams, 1956), southern Quebec (Steward and Bider, 1974), and northern Sweden (Danell, 1978). In Nebraska, Sather (1958) found the first peak production period in late April or early May. Subsequent litters can be born at monthly intervals due to an immediate postpartum estrus (Olsen, 1959). The time of the last litter of the season can vary annually within the same population (Mathiak, 1966). He found that in Wisconsin, few litters are born from September to November. Muskrats in Maryland produce most of their litters prior to the end of September (Smith, 1938).

Neonates are blind, almost hairless, pink or grey in coloration, and have a rounded tail. However, they are fairly hardy when exposed to near 0°C temperatures (Errington, 1963). The young are covered with soft fur, become active and able to swim within fourteen days. Incisors break through the gum line after 6 or 7 days and eyes open between 14 and 16 days (Erickson, 1963; Sather, 1958). Young are weaned at 4 weeks. Weight and length curves for kits from birth to 30 and 50 days of age were established by Errington (1939) and Erickson (1963), respectively. The tail becomes laterally compressed during the second month (Errington, 1963). Dorney and Rusch (1953) found a slower body growth rate (after 8 weeks of age) for females than for males. In northern France, Vincent and Quéré (1972*a*) reported that young-of-the-year are adult-size when winter arrives; young born near the end of the breeding season grow at a faster rate than those born at the beginning of the season. Longevity in muskrats is considered to be 3 or 4 years (Godin, 1977).

Most muskrats first become sexually active the spring after their birth; however, precocial breeding by immature animals has been recorded by several investigators. Errington (1961) reported a 1.5% rate of precocial breeding in parts of Iowa. In Wisconsin, Mathiak (1966) also found precocial breeding, but he felt that it was too insignificant to effect population growth.

Spermatogenesis usually begins in early spring and lasts into late autumn (Errington, 1963; Forbes, 1942). In Tennessee, however, Schacher and Pelton (1975) found sperm in some males throughout the year. The vaginal orifice is sealed from birth and opens just before breeding activity begins in the spring (Baumgartner and Bellrose, 1943). The length of the estrous cycle averages between 3 and 6 days (McLeod and Bondar, 1952).

Beer and Truax (1950) compiled data from over 89,000 muskrats from all age classes and from various localities. They found an overall sex ratio of 55% males. In a similar review, Troostwijk (1976) reported a sex ratio favoring males in all age groups. Schacher and Pelton (1976) suggested that there is a seasonal trapping bias producing unbalanced sex ratios. More females were collected in the summer months of their study, possibly reflecting a shift in activity and not a true sex ratio.

Errington (1961) found age ratios of 12 to 15 young per adult female not uncommon on productive Iowa marshes. Beer and Truax (1950) found a ratio of 7 young per adult female in Wisconsin. There are large yearly variations in age ratios (Mathiak, 1966). Methods to determine age and sex of muskrats may be found in Chieh et al., 1974; Le Boulengé, 1977; and Taber, 1971.

ECOLOGY. Depending on the environment, muskrats construct either conical houses or dig burrows into banks. "Pushups" are another type of construction made by muskrats over icecracks (MacArthur and Aleksiuk, 1979). Le Boulengé (1972) reviewed the early literature on muskrat dwellings. Their ability to construct either type of dwelling enables them to occupy most aquatic habitats throughout the United States and Europe (Danell, 1978); including creeks, lakes, marshes, and ponds (Errington, 1963). Man-made areas such as strip mine ponds (Arata, 1959), and farm ponds (Earhart, 1969) are also used. House construction usually begins on a firm substrate and uses the dominant emergent plants in the area (Danell, 1978). Houses are built above water level with several underwater tunnels or "leads" as the only entrances. One or more nest chambers lined with fresh plant material are usually found in the center of the house (Errington, 1963). Water depth, soil texture, and amount of aquatic vegetation influence muskrats in their selection of sites for house construction (Danell, 1978). Soil type and slope of the bank determine the permanence and complexity of a burrow (Beshears and Haugen, 1953; Earhart, 1969). Muskrats construct two types of houses: a main dwelling and a feeding house (Dozier, 1948*a*; Sather, 1958). Feeding houses are generally much smaller than main dwellings. MacArthur and Aleksiuk (1979) noted that external and nest chamber dimensions, wall thickness, and floor-to-wall distance were significantly larger in winter dwellings than in summer dwellings. Muskrats begin building houses during the ice-free period. Peak building activity occurs between late May and early June and again during the early part of October (Danell, 1978). Muskrat houses in a Maryland marsh remained intact for approximately 5 months before collapsing (Nicholson and Davis, 1957). Boyce (1978) discussed the affects of extreme water level fluctuations on muskrat populations.

Darchen (1964) found that temperatures inside muskrat houses were higher than ambient air temperature and surrounding water temperature. Temperatures inside breeding burrows are higher and more stable than those found in feeding burrows in winter (Earhart, 1969). When several muskrats "huddle" in a house, temperatures increase, enhancing survival during the winter months (MacArthur and Aleksuik, 1979).

Numerous vertebrates and invertebrates use muskrat houses as nesting places (Buckley and Hicks, 1962; Judd, 1970; Kiviat, 1978; Newsom et al., 1976). We found heavy infestations of the tick, *Dermacentor variabilis*, in muskrat houses in Maryland (unpubl. data). Nutria (*Myocastor coypus*) use the tops of muskrat houses as defecation and feeding sites (Harris, 1956). Muskrat houses have been used to estimate population densities (see review by Palmisano, 1972).

The burrowing activities of muskrats cause extensive damage to river banks and agricultural areas, and programs are often initiated to control or eliminate them (Troostwijk, 1976). Burrowing activities caused leakage in many small impoundments in Maryland, New York, and Pennsylvania (Erickson, 1966). Control procedures include trapping, gassing, poisoning, shooting, and manipulating water levels. "Rip-rapping" banks with crushed stone provided the most effective means of minimizing muskrat damage (Erickson, 1966).

Muskrats may have a detrimental impact on vegetation because of feeding and house construction (see Sipple, 1978, for references). Danell (1978) found that as the density of the muskrat population increased, stands of horsetail (*Equisetum fluviatile* L.) decreased, forming large pools of open water. Pelikán et al. (1970) found that a muskrat population of 28 to 55 animals per ha reduced stands of cattail (*Typha latifolia*) by 5 to 10%. "Eat-out" is a term frequently used to describe the decimation of aquatic vegetation by high densities of muskrats (see Danell, 1978, for references).

Muskrats are primarily herbivorous; however, animal matter may occasionally be consumed (Errington, 1963). Muskrats feed on aquatic vegetation that grows in the vicinity of their dwellings; thus food habits vary according to the plant species available (Bellrose, 1950; Danell, 1978). Stand density, water levels, and phenological stage of plant growth are factors that influence the degree of plant utilization (Takos, 1947). The roots and basal portion of various hydrophytes make up the most important portions of the muskrat diet in North America and Europe (see Dannell, 1978; and Willner et al., 1975, for review). Animal matter consumed includes crayfish (*Cambarus* sp.), fish, molluscs (for example *Unio* sp. and *Anodonata* sp.), and turtles. These are usually eaten during times of food shortages or when a particular animal species is abundant (Errington, 1963; Marcström, 1964; O'Neil, 1949). Characteristic signs of muskrat feeding activity include food platforms and feeding shelters (Dozier, 1948*a*). Caching of food in dwellings occurs occasionally (Earhart, 1969; Errington, 1963).

Man is the major cause of muskrat mortality (Errington, 1963). Since 1971, the muskrat pelt harvest and value has continued to increase (Deems and Pursley, 1978). Methods of trapping and handling muskrats are discussed by Errington (1961). Smith and Jordan (1976) presented a muskrat harvest yield curve and noted that the harvest rate should not exceed 80% of a population.

Raccoons (*Procyon lotor*) and mink (*Mustela vison*) may feed on muskrats caught in steel traps, on carrion left by trappers, or on diseased animals (Errington, 1963). Mink and raccoon predation increased upon muskrats that were exposed to environmental crisis or disease epidemics (Errington, 1967). Harris (1951) suggested that raccoons actually may be in search of small rodents, such as rice rats (*Oryzomys palustris*), rather than the muskrats occupying the dwelling. Muskrat kits from a Wisconsin marsh were important to the diet of raccoons during the summer while adult muskrats were important in the spring and fall months (Dorney, 1954). Other North American mammalian predators that feed occasionally on muskrats were summarized by Errington (1963). In Europe, the red fox (*Vulpes vulpes*), polecat (*Putorius putorius*), mink, and stoat (*Mustela erminea*) are predators of muskrats (Danell, 1978; Troostwijk, 1976; Zlobin, 1973). Wild dog populations (*Canis domesticus*) also prey on muskrats (Errington, 1963). Muskrats constitute only a small portion of the diet of avian predators. Muskrat hair and bones have been found in nests and/or pellets of bald eagles (*Haliaeetus leucocephalus*) (Dunstan and Harper, 1975), great horned owls (*Bubo virginianus*) (Errington, 1963), ferruginous hawks (*Buteo regalis*) (Lokemoen and Duebbert, 1976) and other hawks (Smith, 1938).

Diagnosed diseases of muskrat include adiaspiromycosis (Otcenásek et al., 1974); epizootic chlamydiosis (Spalatin et al., 1971); hemorrhagic disease (Errington's disease) (Errington, 1963); leptospirosis (Al Saadi and Post, 1976; Paul et al., 1972); pseudotuberculosis (Langford, 1972); ringworm disease (Dozier, 1943; Errington, 1963); salmonellosis (Armstrong, 1942); tularemia (Errington, 1963); Tyzzer's Disease (Chalmers and MacNeill, 1977; Karstad et al., 1971; Wobeser et al., 1978); and yellow fat disease (Debbie, 1968). Pathological symptoms and etiology of hemorrhagic disease are discussed in Lord et al. (1956*a*, 1956*b*). In western Siberia, Korsh et al. (1975) observed that the tick, *Ixodes apronophorus*, played a significant role in the transmission of tularemia and Omsk hemorrhagic fever. A water vole (*Arvicola* sp.) acted as the main carrier to muskrat populations.

The endo- and ectoparasites of the muskrat were summarized by Beckett and Gallicchio (1967), Gash and Hanna (1972) and Meyer and Reilly (1950). McKenzie and Welsh (1979) noted that the list of parasites reported from North American literature includes 36 trematodes, 19 nematodes, 13 cestodes, 2 acanthocephalans, and 17 acarina. The most frequently cited species of endoparasite included: the trematodes, *Echinostoma revolutum*, *Plagiorchis proximus*, and *Quinqueserialis quinqueserialis;* the nematode, *Trichuris opaca*; and the cestodes, *Hymenolepis* spp. and *Taenia taeniaeformis*. Knight (1951*a*) noted a greater incidence of infection of trematodes in muskrats collected from the northern region of North America than those collected from the southern region.

Several studies have shown that the number and kinds of parasites that infect muskrats vary with habitat and geographical location (Abram, 1969; Rice and Heck, 1975). Anderson and Beaudoin (1966) and MacKinnon and Burt (1978) found that muskrats occupying streams were infected by a greater diversity of species and intensity of parasites in comparison to muskrats inhabiting other types of aquatic habitats. In the Netherlands, Troostwijk (1976) noted that parasites generally did not affect the weight or the general body condition of the muskrat but did have a marked effect on their reproduction. He observed that pregnant muskrats infected with the tapeworm, *Taenia taeniaeformis*, produced fewer young than those not infected.

The dominant ectoparasites are the mites and ticks (Acarina). Good (1973) found heavy infestations of the tick, *Ixodes muris*, in muskrats from New York primarily during the summer months. Bell and Chalgren (1943) identified the mite, *Ichoronyssuc spiniger*, from muskrats collected from the eastern part of the United States. In British Columbia, Knight (1951*b*) identified five mites, *Laelaps multispinosus*, *Dermacerus validus*, *Listrophorus americanus*, *Eutrombicula harperi*, and *E. radfordia*, from muskrats. Shuteev (1977) recovered the mite, *Hirstionyssus isabellinus*, and the flea, *Ceratophyllus rectangulatus*, from muskrats collected in Russia. Sather (1958) observed that nestling young were parasitized by mites particularly along the ventral side. He noted that severe infestation caused skin rashes but were not fatal.

Muskrat home range sizes are relatively small (see MacArthur, 1978, for references). The majority of locations of 11 radio-collared muskrats were within 15 m of their primary dwelling lodge. Most foraging activity occurred within a 5 to 10 m radius of a lodge or push-up. Stewart and Bider (1977) correlated muskrat activity and movements with selected meteorological variables and found that regardless of weather, muskrats displayed two peak periods of increased activity, between 1600 and 1700 h and between 2200 and 2300 h. On rainy days, activity began much earlier (1100–1200 h) than on days with no rain (1400–1500 h).

Movements were also influenced by rainfall; muskrats moved a greater distance on days with rain than on days with no rain.

Dispersal in muskrat populations usually occurs in the spring, between March and April. Spring movement may be initiated by snow and ice conditions (Erickson, 1963), air temperature (Sprugel, 1951), endocrinological changes (Beer and Meyer, 1951) or a combination of any of these. Muskrats actively disperse to establish breeding territories or colonize vacant territories (Errington, 1940, 1963). Between 30 and 40% of marked populations show evidence of migratory movements (Aldous, 1946; Erickson, 1963). More males than females dispersed to new territories (Erickson, 1963). Danell (1978) found that dispersal rate in Sweden was 3.2 ± .03 km/year. Movements of muskrats also are influenced by population density (Shanks and Arthur, 1952) and sex and age composition (Beer and Meyer, 1951; Sather, 1958; Takos, 1944). Neal (1968) observed that larger home ranges were characteristic of declining populations occupying poor habitat. Vincent and Quéré (1972*b*) found that "family" groups stayed within exclusive home ranges. Errington (1963) discussed forced movements caused by flood waters, drought conditions and intraspecific strife.

Erickson (1963) found that regardless of obstacles, most displaced muskrats returned to their home range. Mallach (1972) found that of muskrats released 500 to 2,000 m away, 57% returned; 3,000 m away, 31% returned; and 4,000 m, 15% returned to the original home range.

Main competitors of the muskrat include nutria (*Myocastor coypus*) (Evans, 1970), Norway rats (*Rattus norvegicus*), and water voles (*Arvicola terrestris*) (Le Boulengé, 1972). Other possible competitors in Europe are discussed by Danell (1978) and Troostwijk (1976). Muskrat populations occupying marshes along the eastern shore of Maryland consume large quantities of stems in July and August and roots in winter (Willner et al., 1975). Similar feeding habits were found for nutria (Willner et al., 1979). Thus, there may be competition for food resources on Maryland marshes.

Muskrat populations generally follow a 10-year cycle (Elton and Nicholson, 1942). Butler (1962) compared fur harvest records from Saskatchewan between 1915 and 1960 to muskrat population densities and found a 6-year cycle, whereas McLeod (1948, 1950) noted a 5-year cycle for muskrats in Manitoba. Errington (1963) discussed the cyclic pattern of muskrats as it related to their reproduction, disease, and behavior.

Bulmer (1974) noted that an increase in muskrat population was followed by an increase in mink population a year later; an increase in mink was followed by a decrease in muskrats a year later. Danell (1978) suggested that a vole-fox-muskrat cycle may exist in Sweden.

In a study that analyzed muskrat liver, kidney, and bone tissues for heavy metal accumulation, Everett and Anthony (1976) concluded that muskrats are useful indicators of pollution in aquatic environments. McEwan et al. (1974) studied the effects of crude oil on the energy metabolism of captive muskrats and found that it is unlikely that muskrats exposed to even moderate quantities of crude oil would survive in the wild.

BEHAVIOR. Muskrats are most aggressive prior to and during the breeding season. Dominance hierarchies are established through fighting. Low ranking muskrats retreat from the area, and are more vulnerable to cannibalization and predation (Steiniger, 1976). When the muskrats are at the peak of reproductive activity they also exhibit the highest degree of territoriality (Beer and Meyer, 1951).

Increases in the amount of fighting and subsequent movements occur during the fall when subadults prepare to expand their territory. Akkermann (1975) found that muskrats in Germany marked territories up to 5,500 m^2 in size. Both males and females actively defended territories. Errington (1963) found that females were more aggressive than males in defending their breeding territory, often killing any intruder. Competition between muskrats for breeding sites is intense (Earhart, 1969). Optimum burrow sites were occupied by the larger or older members of the population.

Svihla and Svihla (1931) observed that prior to mating, captive muskrats released scent from the anal glands along the sides of the pen. Muskrats mate while partially submerged. Young are born inside nest chambers of houses, or in nests of coots (*Fulica americana*) or diving ducks (Errington, 1963). Young are cared for by the mother until weaned. Males only care for young in the event of the females death (Errington, 1963). Errington (1963) described the sexual relations between muskrats as "loose monogamy."

O'Neil (1949) and Svihla and Svihla (1931) found captive muskrats were primarily nocturnal. Muskrats are active during the day as well (Stewart and Bider, 1977). MacArthur (1979) found that body temperatures decreased substantially while muskrats were swimming or diving in winter and increased while muskrats were feeding, grooming, or resting on a feeding platform in summer or in feeding shelters in winter.

Muskrats emit three different vocal sounds: a squeak, a high pitched n-n-n-n-, and a chattering produced by their incisors. Walker et al. (1975) noted a "whining-growl" emitted from disturbed animals. Muskrats do not emit sounds while swimming underwater (Komarov, 1976).

GENETICS. The diploid number of chromosomes is 54. One pair of autosomes is submetacentric, the remainder are acrocentrics. Of these, at least one pair has satellites. The sex chromosomes also are acrocentric (Makino, 1953; Hsu and Benirschke, 1971). Dozier (1948*b*) described variations in pelt color, ranging from white to black, and their associated genotypes.

Shows et al. (1969) examined the electrophoretic patterns of erythrocyte and tissue lactate dehydrogenase (LDH) from 26 species of rodents, including the muskrat. Erythrocytes from most mammalian species contain both A and B polypeptide chains (Bauer and Pattie, 1968); however, the LDH phenotype of muskrats possessed only A subunits. Shows et al. (1969) suggested that a regulator gene suppresses the expression of the B gene in the erythrocytes of muskrats and other myomorphs. The amino acid sequence of muskrat pancreatic ribonuclease was determined by Van Dijk et al. (1976). Muskrat ribonuclease contained no carbohydrate. Genaux et al. (1976) electrophoretically determined the composition of the tryptic peptides of muskrat hemoglobin for both the α and β chains.

REMARKS. The muskrat is the most valuable semi-aquatic furbearing mammal in North America. The value of individual pelts often runs as high as six dollars, with total industry incomes in the millions of dollars. Because of the value of the muskrat as a furbearer they have been intensively managed. The two most widely used management techniques are (1) marsh burning to promote growth of food plants, and (2) ditching to open up water areas and provide burrowing sites. See Giles (1978) for complete review of current management practices for muskrat. A bibliography of references on muskrats was prepared by Hoffman (1967, 1972, 1973).

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