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POPULATION DYNAMICS OF SACRAMENTO VALLEY MUSKRATS[1/]

by

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ABSTRACT

Muskrat (Ondatra zibethicus) populations were studied in agricultural canals of the Sacramento Valley, Yolo County, California, by live trapping and tagging during 1978 and 1979. Information on aspects of the dynamics of muskrat populations came from data collected on 898 muskrats.

Densities of 1.5 to 7.5 ($\bar{x}$ = 4.0) pairs/km, and linear home ranges sizes of 133 to 650 ($\bar{x}$ = 331) m of canal were observed. Density and home range sizes were inversely related, and home ranges of adjacent pairs did not overlap significantly. Movements of approximately 1.5 km were observed in two individuals; observed movements of the other 100 tagged muskrats were restricted to established home ranges.

The age structure of the winter muskrat population consisted of 24% adult and 76% sub-adults. An overall male to female ratio of 120:100 was seen. Sex ratios varied between age classes.

The observed breeding season began in mid-February, and ended by mid-October. However, evidence of mid-winter breeding also was seen. An average size of 19.3 young per adult female muskrat is produced annually in 3 to 4 litters averaging 5 to 6 young. Breeding was observed in 17.8% of female young-of-the-year muskrats resulting in an average productivity of 7.3 young in one or two litters.

A mortality rate of 72% occurs among young-of-the-year muskrats. High turnover rates are indicated by recapture data.

A census method involving plotting spring territories of breeding pairs is seen as applicable for canal populations.

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INTRODUCTION

The original distribution of the muskrat (Ondatra zibethicus) in California included inland freshwater marshes and streams of the Great Basin and along the Colorado River (Grinnell, Dixon, and Linsdale 1937). Muskrats were absent from the Central Valley until their introduction during the 1920's.

Muskrats were brought into parts of Northern California by trappers, for release into the wild, and for fur-farming (Storer 1938). Expanding populations found their way into the Sacramento River system and, aided by an extensive network of irrigation and drainage canals, spread throughout the valley (Seymour 1954). These canals, created by agricultural development, presently comprise the most important habitat for California muskrat populations.

This range expansion has allowed muskrats to become one of California's most valuable fur resources. From 40,000 to over 100,000 muskrats have been taken annually by licensed fur trappers over the last 25 years. This has provided a minimum income to trappers of $24,000, when prices were low in 1967-68 (Lee 1977) to over $246,000 during the 1976-77 season (California Department of Fish and Game 1979).

Extensive studies of muskrat populations in their native range have been reviewed by Errington (1963), with more recent findings being contributed by Mathiak (1966) and Stewart and Bider (1974). This accumulation of information shows considerable geographical and subspecific variation in the parameters of muskrat population characteristics. The varied and unknown origins of the Central California muskrat population, combined with the unique environmental conditions of the area, have made only very general estimates of Sacramento Valley muskrat population parameters possible.

Sacramento Valley muskrat populations have only been studied in reference to distribution and range extensions (Storer 1938, Twining and Hensley 1943, Seymour 1954) and muskrat-related damage (Belluomini 1978). The purpose of this study, done in 1978 and 1979, was to gather data on population characteristics of Sacramento Valley muskrats, and suggest a method for censusing muskrat populations. Specific objectives included measuring densities, home ranges and movements, population structure, reproductive rates, and mortality of muskrat populations in agricultural canals.

STUDY AREA

This study was conducted primarily on the Conway Ranch, located 8 km (5 miles) northeast of Davis in Yolo County, California (Figure 1). This area of approximately 7,890 ha (19,500 acres) of irrigated land is centrally located in the Sacramento Valley at an elevation of 6 to 9 m (20 to 30 ft). Monthly variation in temperature and precipitation (Figure 2) is characterized by hot dry summers and mild wet winters. The eastern half of the ranch is in the Yolo Bypass, an overflow basin of the Sacramento River. This half of the ranch did not flood appreciably during the winter of 1978-79.

Figure 1. The Conway Ranch Study Area, Yolo County, California

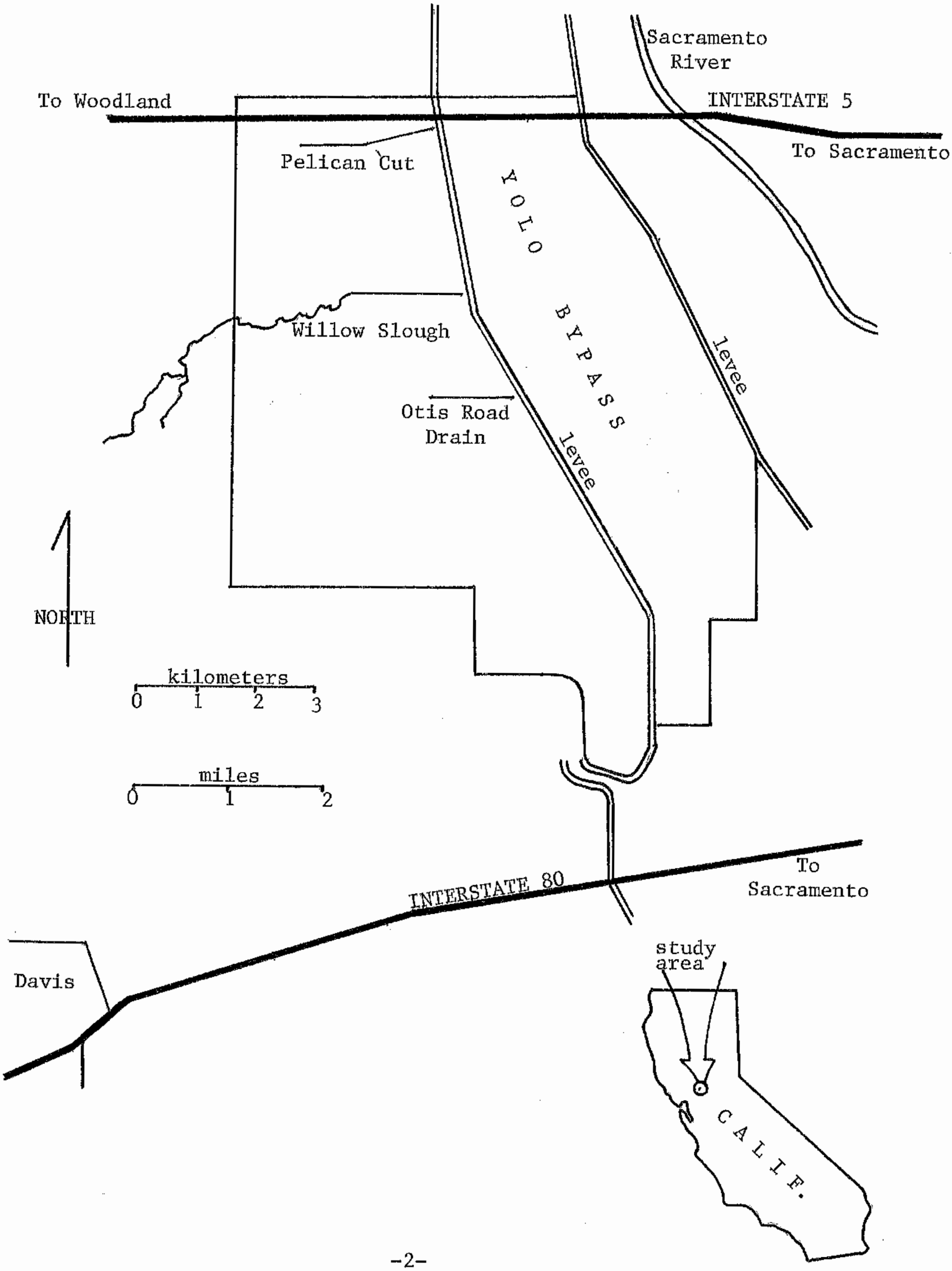
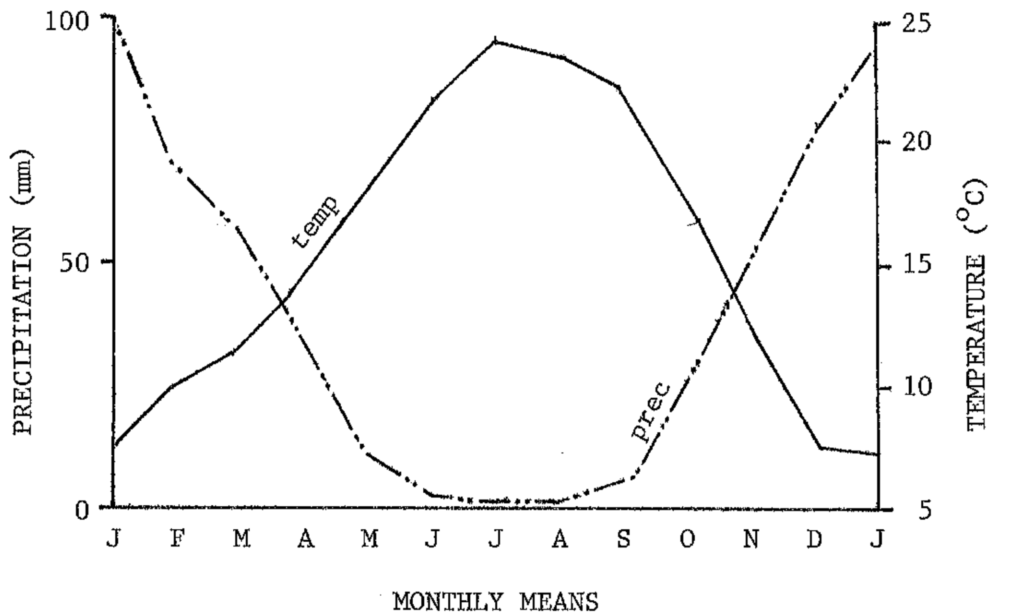


FIGURE 2. Climatalogical data from Sacramento, California, 12 miles southeast of the Conway Ranch Study Area



A variety of crops (rice, corn, sugar-beets) are irrigated during the dry summer months by an extensive system of canals. These canals, along with the natural slough in the area, are representative of Sacramento Valley muskrat habitat. The Conway Ranch contains approximately 80 km (50 miles) of canal with sufficient water and vegetation to support muskrat populations. Additional seasonal habitat exists in the form of flooded rice fields, supply canals, and areas flooded during the waterfowl season.

Noncultivated vegetation in the area is restricted by agricultural practices to canals, water courses, and their margins. Dominant plants associated with these areas are cat-tails (*Typha* spp.) and bulrushes (*Scirpus* spp.). A dense growth of water purslane (*Ludwigia* sp.) and knotweed (*Polygonum* sp.) was evident in some areas. Canal banks and levees are covered with a variety of vegetation including mustard (*Brassica* sp.), fennell (*Foeniculum* sp.), and several grasses (*Phalaris*, *Avena*, *Bromus*, *Polypogon*, *Hordeum*, *Cynodon*).

Three specific sub-areas were selected for study of density and home range size of muskrats. These areas were selected because muskrat "sign" indicated substantial populations. Other similar canals did not appear as productive.

Pelican Cut

The "Pelican Cut" is a large drainage canal containing substantial amounts of water when crops are being irrigated. During winter and early spring, parts of this ditch may consist of only a narrow channel of water between wide muddy banks. When irrigation starts in April, water levels rise approximately 1 m (3.3 ft), creating a water course 5 to 8 m (16 to 26 ft) in width. Length of canal sampled was 1.3 km (0.8 mile) long, set apart from other sections by culverts and road crossings.

Cat-tails and bulrushes, along with the previously mentioned grass species, grow along the banks of this canal. Crops associated with this area during the study included sugar-beets, corn and wheat.

Otis Road Drain

The "Otis Road Drain" is similar to the Pelican Cut in being a drainage canal and having similar vegetation. It, however, is more typical of the drains in the area, with water averaging only 1-2 m (3.3-6.6 ft) in width and approximately 0.5 m (1.7 ft) in depth. Length of canal sampled was 1.6 km (1 mile) and was set off from other sections by culverts and road crossings. Crops associated with this area included rice and sugar-beets.

Willow Slough

This natural waterway, although serving as an agricultural drain, differs considerably from the man-made canals common in this area. Areas of emergent cat-tail and bulrush growth up to 9 m (30 ft) wide border parts of this slough. Riparian vegetation, consisting of California blackberry (*Rubus ursinus*), willows (*Salix* spp.), cottonwoods (*Populus fremontii*), wild rose (*Rosa* sp.) valley oak (*Querius lobata*), buttonbush (*Cephalanthus occidentalis*), and various grasses and forbs, also borders this area. The section of slough studied was 0.8 km (0.5 mile) in length and 10 to 20 m (30-60 ft) in width. Its east end was demarcated by a road crossing and culvert, and its west end by the end of navigable waters where cat-tail and bulrush growth completely choked the waterway.

Additional data on reproductive rates of muskrats were collected from other areas in the Yolo Bypass approximately 8 km (5 miles) south of Davis. Unlike the situation on the Conway Ranch, muskrat habitat in this area mainly consists of marshes and natural watercourses. Vegetation consists almost completely of cat-tail and bulrush growth, with the latter being the dominant species.

METHODS

Spring and Summer Live Trapping

Estimates of population density and home range were obtained by live-trapping, examining, marking, releasing,and recapturing marked muskrats. Live-trapping was done extensively on the three previously described areas of the Conway Ranch during the spring and summer of 1978 and during the spring of 1979. Additional areas on the ranch were trapped on a limited basis during the summer of 1978.

Cage type traps, patterned after commercially available live traps, were constructed from welded wire fencing. Traps were placed on "floats" constructed of wood and styrofoam to eliminate problems associated with fluctuating water conditions. Trap densities of 12 to 75/km (20-120/mile) were tried, with 12/km (20/mile) adequate for sampling adult population densities.

Trapped muskrats were sexed, aged, measured (weight, tail length and tail height), marked, and released. Size and weight were used to determine age (sub-adult or adult) of spring and early summer caught muskrats. Mid- and late summer trapped muskrats were aged by examination of the external genitalia (Baumgartner and Bellrose 1943). No. 1 ear tags (National Tag and Band Co., 721 York Street, Newport, Ky., 41072) were attached to the right ear of captured muskrats. Additionally, size 18 aluminum butt-end leg bands (National Tag and Band Co.), normally used for bird banding, were clamped around the base of the tail of adult muskrats.

Home ranges were estimated by plotting recapture locations of tagged muskrats. Due to the linear nature of the canal type habitat, home ranges were expressed as a linear instead of two dimensional measurement.

1978-79 Fur-trapping Season

Data on sex and age structure, and reproductive and mortality rates were collected during the 1978-79 trapping season with the cooperation of the trapper working the Conway Ranch. Muskrats taken during the trapping season were captured in four types of traps. A "float set" was the most common method used. This set, consisting of two leg-hold traps placed on a floating wooden structure, accounted for approximately 8,000 trap nights (4,000 "set" nights). "Basket" or "cage" traps, wire cages set in underwater runways, accounted for approximately 950 trap nights. Conventional leg-hold and conibear "bank sets" accounted for approximately 750 trap nights. Several muskrats were collected by shooting with a 22-caliber rifle.

Trapping pressure on specific areas of the Conway Ranch is related to accessability. Deteriorating road conditions during winter limits the number of canals that can be trapped effectively. Only the Pelican Cut, of the three areas extensively live-trapped during the spring and summer of 1978, was worked during the 1978-79 trapping season.

Trapped muskrats were weighed, sexed, and aged by examination of external genitalia (Baumgartner and Bellrose 1943), and additional measurements were taken (overall length, hind foot length, tail length, and tail height). After skinning, carcasses were examined internally. Testis length or appearance of the uterus was noted as an aid in determining age (Errington 1939). Zygomatic breadth was recorded as another means by which age could be determined (Alexander 1951), as was the appearance of the first upper molar (Olsen 1959). Also pelts, when dry, were examined for age-differentiating characteristics (Applegate and Predmore 1947, Shanks 1948). Although some overlap of aging characteristics occurs between adults and sub-adults in winter trapped muskrats (Schofield 1955), one of the several aging techniques applied clearly distinguished age in almost all cases. Except for two young juveniles, all muskrats were classified as adults (individuals born during or prior to the 1977 breeding season) or sub-adults (individuals born during 1978). To determine any bias in age and sex structure estimates, due to trap selectivity, the type of trap each muskrat was captured in was noted. This allowed several estimates of population structure to be made, each corresponding to a different trap type.

Reproductive data were collected during this study by recording the presence of placental scars, embryos, and developed mammary tissue in female muskrats taken during the trapping season.

An indication of the mortality rate was obtained by recapturing muskrats tagged in 1978 during the 1978-79 trapping season and 1979 spring live trapping. An additional indication of the rate of mortality was shown by the comparison of reproductive potential and age structure data.

Several methods were considered in attempting to find a valid muskrat census technique. The use of various forms of sign (scats, diggings, cuttings, feed beds) often indicate the number of muskrats inhabiting an area. Although difficult to quantify, this method can reveal "high", "medium" or "low" population densities. A more quantitative method was applied involving plotting the foci of muskrat activity of established breeding pairs.

RESULTS

A total of 898 different muskrats was captured and examined during this study. Live trapping on the Conway Ranch during spring and summer of 1978 and spring of 1979 yeilded data on 113 muskrats through a total of 486 captures. Live trapping produced good information on adult populations only. Young-of-the-year were not taken readily in live traps. Data were collected from 788 muskrats, including three recaptures of tagged individuals, during the 1978-79 fur-trapping season. Of these, 657 came from the Conway Ranch, and 131 were from the Yolo Bypass area south of Davis.

Density

Muskrat densities, determined by spring and summer live trapping data (Table 1), were found to be 1.5-7.5 adult pairs/km (2.5-12 adult pairs/mile). An overall average density including both 1978 and 1979 data, of 4.0 ± 2.3 pairs/km ($\bar{x} \pm$S.D.) (6.4 ± 3.7 pairs/mile) was estimated. The Willow Slough study area had the highest population densities of 6.3-7.5 pairs /km (10-12 pairs/mile), with five pairs present in 1978 and six in 1979. The Otis Road Drain had densities of 2.5-3.1 pairs/km (4-5 pairs/mile) with five pairs in 1978 and four in 1979. Only the Pelican Cut showed a large variation in population density from year to year with four pairs present in 1978 (3.1 pairs/km; 4.9 pairs/mile) and two pairs in 1979 (1.5 pairs/km; 2.4 pairs/mile).

Home Range and Movements

Linear home ranges covering 133-650 m (0.08-0.40 mile) of slough or canal were estimated. Considering data from all three areas during 1978 and 1979, an average home range length of 331 m(S.D.$\pm$187 m)[0.20 miles (S.D.$\pm$0.11 mile)] was measured.

Mated pairs shared similar home ranges which overlapped little the home ranges of neighboring pairs. Occasionally, however, individuals (usually males) were captured within the home ranges of adjacent pairs. Substantial changes in home range size were seen only in the Pelican Cut, where home ranges covered approximately 325 m (0.2 mile) in 1978 and 650 m (0.4 mile) in 1979.

Table 1. Density and structure of muskrat populations live-trapped on the three Conway Ranch study areas during the spring and summer of 1978, and the spring of 1979.

	Pelican Cut	Otis Road Drain	Willow Slough	Total
Length (km)	1.3	1.6	0.8	3.7
1978				
No. individuals	24	15	32	71
Adults	11	9	11	31
males	6	5	6	17
females	5	3	5	24
Juveniles	13	6	21	40
males	3	3	9	15
females	10	3	12	24
Trapping Mortalities	8	3	12	23
% mortality	33.3	20.0	37.5	32.4
Estimated no. breeding pairs	4	5	5	14
Density (pairs/km)	3.1	3.1	6.3	3.8
Approximate Home Range Size (Linear m)	325	320	160	264
1979				
No. individuals	7	5	13	25
Adults	6	5	13	24
males	4	4	7	15
females	2	1	6	9
Juveniles	1	0	0	1
males	1	0	0	1
females	0	0	0	0
Trapping Mortalities	1	0	2	3
% mortality	14.3	0	15.4	12.5
Estimated no. breeding pairs	2	4	6	12
Density (pairs/km)	1.5	2.5	7.5	3.2
Approximate Home Range Size (linear m)	650	400	133	308

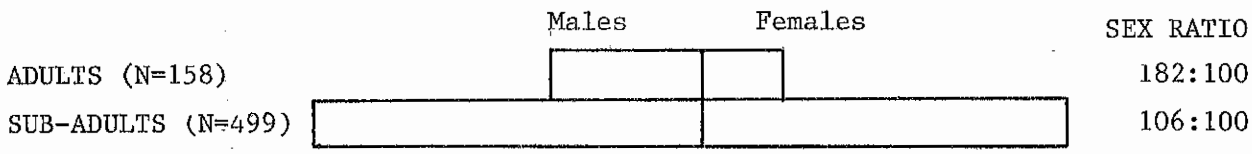
Extensive movements were recorded in the case of two muskrats which established territories in the Willow Slough study area during the spring of 1979. Both of these individuals were tagged as young-of-the-year in Aug. 1978, approximately 1.5 km (0.9 mile) from the borders of the home ranges they occupied during 1979.

Six additional individuals, three tagged as adults and three taged as young-of-the-year, were recaptured showing no appreciable movement from their location of tagging in 1978. Of these, three were retaken during the 1978-79 fur-trapping season, and three were recaptured during 1979 live trapping.

Population Structure

The age and sex structures of the winter population on the Conway Ranch, as indicated by the 657 muskrats taken during the 1978-79 fur-trapping season, are 24% adults and 76% subadults, and 120 males:100 females (Figure 3).

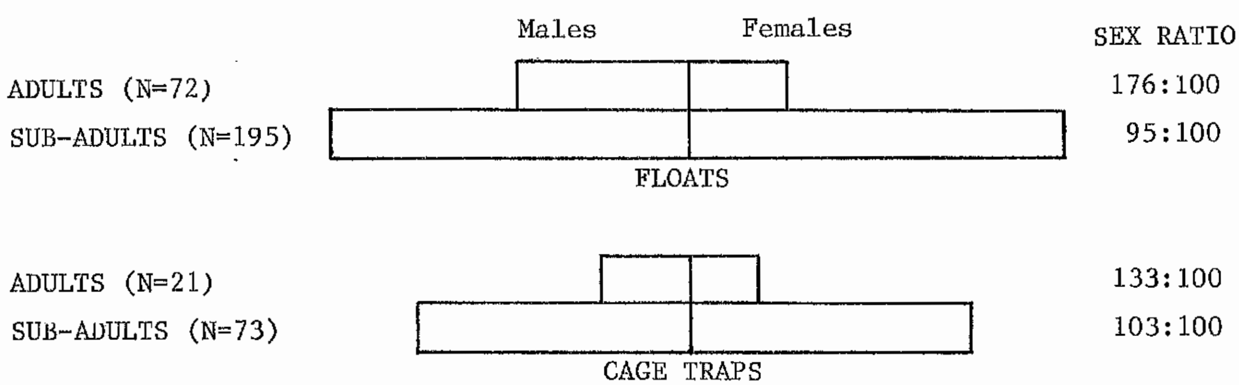
FIGURE 3. Age and sex composition of muskrats taken on the Conway Ranch during the 1978-79 trapping season.



Observed sex ratios differ between age classes. The sex ratio found in the sub-adult class, 106 males:100 females is not significantly different from 100:100 (x^2, p$>$.05), however, the adult sex ratio, 182 males:100 females differs significantly from 100:100 (p$<$.05), being imbalanced in favor of males.

From the last 393 muskrats trapped on the Conway Ranch, for which trap-type was noted, separate age and sex structure estimates were made. By comparing sex and age structures for "float-trapped" and "cage trapped" muskrats (Figure 4) trap selectivity can be estimated. Using cage traps, the indicated sex ratio of sub-adult and adult populations did not differ significantly from 100:100 (x^2, p$>$.05). Although approximately equal numbers of both sexes in the sub-adult class were caught in float sets, these same sets caught a significantly (p$<$.05) higher proportion of adult males than adult females (176:100). Although a difference exists in the age structure of muskrats taken in these two types of sets (floats: 30% adults, cages: 22% adults), the difference is not significant (x^2, p$>$.05) to indicate that trap-type biases the age of muskrats caught.

FIGURE 4. Comparison of sex and age composition of float-trapped and cage-trapped muskrats.



Reproduction

Breeding activity of Sacramento Valley muskrats occurs on almost a year-round basis with peak activity in the summer months, and a cessation of activity in mid-winter. Litters are born as early as mid-February as indicated by the presence of fresh placental scars in winter-trapped muskrats (Table 2).

Table 2. Occurrence of fresh placental scars in muskrats taken during the 1978-79 fur-trapping season (Conway Ranch and South Yolo Bypass data combined)

	Total Females Examined	No. with Fresh Scars	% with Fresh Scars
5 - 13 Feb	65	11	16.9
14 - 22 Feb	32	3	9.4
23 Feb - 3 Mar	31	8	25.8

The fall termination of breeding activity was not documented during this study. It was noted, however, that of the 147 female muskrats examined between 22 December 1978, when trapping started, and 23 January 1978, none contained embryos or fresh placental scars. An indication of mid-winter breeding was seen in the capture of two small (250-260 g) kits on 12 February 1979. Their age, as indicated by growth data (Mathiak 1966), was 25-28 days. This reflects a mid-January birth and mid-December conception. Other "small" individuals taken during the fur-trapping season weighed 500-600 g, indicating September or early October births, and a decrease in breeding activity after October.

Total reproductive capacity of Conway Ranch muskrats, as evidenced by the number of placental scars laid down during 1978 (Table 3), is 19.3 young produced annually by female adults, and 7.3 by reproductively active young of the year. A litter of 5-6 young was found to be the mean size as indicated by placental scar and embryo counts (Table 4). Placental scars indicating precocious breeding were found in 17.8% of young-of-the-year females taken during the 1978-79 fur-trapping season.

TABLE 3. Mean number of placental scars (laid down during 1978) found in the uteri of females examined during the 1978-79 fur-trapping season (20 Dec - 3 Mar: $\bar{x} \pm SD(N)$).

	Adults	Juveniles	Combined
Conway Ranch (n = 78)	$19.3 \pm 4.3(35)$	$7.3 \pm 3.4(43)$	$12.5 \pm 7.3(78)$
South Yolo Bypass (n = 13)	NO DATA	NO DATA	$13.9 \pm 7.6(13)$

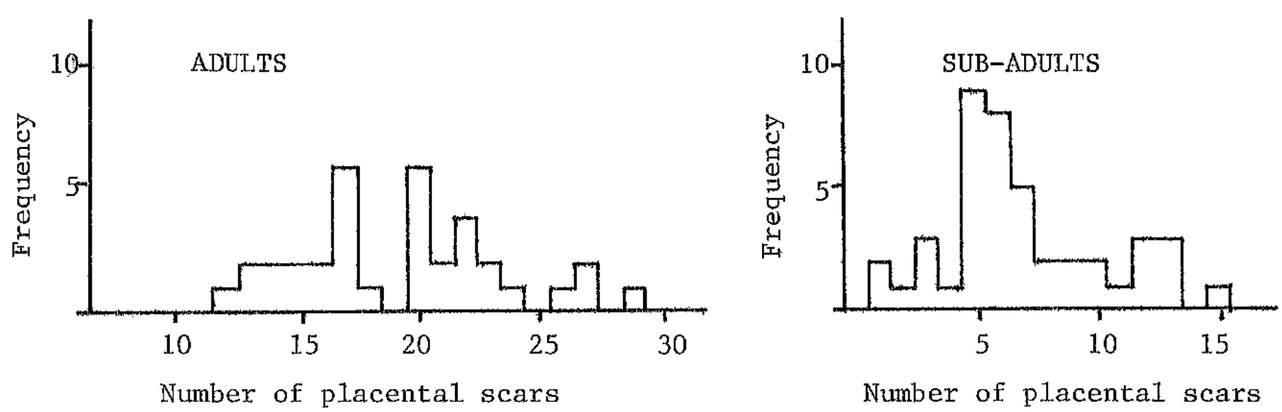
TABLE 4. Mean number of fresh placental scars (laid down during 1979) and embryos found per female uterus in muskrats taken during the 1978-79 fur-trapping season (20 DEC-3 MAR: $\bar{X} \pm SD$ (N)).

	Scars	Embryos
Conway Ranch	5.4 ± 1.2 (11)	5.4 ± 1.0 (5)
South Yolo Bypass	5.7 ± 1.4 (11)	6.1 ± 1.6 (16)
Total	5.5 ± 1.3 (22)	5.9 ± 1.3 (21)

The overall reproductive capacity of the predominantly ditch-dwelling muskrats of the Conway Ranch, as indicated by placental scar data (Table 3; 12.5 ± 7.3 scars/uterus adult and sub-adult data combined) does not differ significantly from similar data (13.9 ± 7.6 scars/uterus) taken from the predominantly marsh inhabiting muskrats of the South Yolo Bypass area (t-test, $p > .05$). Only combined data was available from south bypass muskrats because they were taken in late February or March, when aging is difficult. Similarly, litter sizes, as indicated by embryo and placental scar data (Table 4), did not differ significantly (t-test, $p > .05$) between these two areas.

The number of litters produced annually by a female Conway Ranch muskrat is indicated by the number of placental scars present. Data collected from muskrats taken during the 1978-79 fur-trapping season (Figure 5) indicates a possible 3-4 litters produced by adults and 1-2 by young-of-the-year.

FIGURE 5. Frequency of placental scar counts taken from Conway Ranch muskrats.



Mortality

A 72% mortality among young-of-the-year muskrats was determined by comparing reproductive potential and winter population structure. Adult female muskrats produce (directly, and through precocially breeding young) a potential of 31.8 young, based on placental scar data (19.3 young per adult female; 17.8% precocially breeding young females producing a mean of 7.3 young.) This compares with a winter population structure, based on fur-trapping catch of 56 adult females and 499 sub-adults, of 8.9 young per adult female.

High population turnover rates are indicated by recapture data. Of the 24 muskrats captured during the 1979 live trapping, five were recaptures. Only one was tagged as an adult during the 1978 live trapping, the others were tagged as young. Of the 66 tagged muskrats estimated to have survived into the fall of 1978, only three (4.5%) were recaptured during the 1978-79 fur-trapping season. No ear-tag loss was seen throughout the extended sampling during the summer of 1978. Tail banding was not successfull; no tail band stayed on for more than two weeks.

Although specific causes of mortality were not investigated during this study, intraspecific strife, as evidenced by numerous open cuts among winter-trapped muskrats, was seen as a possible major factor. Also it should be noted that a large number of muskrats were shot by ranch personnel.

Censusing Techniques

Estimates of densities (high, medium, low), made before the 1979 live trapping, corresponded well to observed densities. Willow Slough, which had an abundance of sign and was estimated to have high densities, had a density of 7.5 adult pairs/km (12 adult pairs/mile), as determined by live trapping. The Otis Road Drain, which had "moderate" amounts of sign, had 2.5 adult pairs/km (4.2 adult pairs/mile). The Pelican Cut, which had little obvious sign, had a density of 1.5 pairs/km (2.5 pairs/mile).

Plotting "foci of muskrat activity" to determine densities was not possible in all areas. In Willow Slough, where densities were high, signs of activity were continuous from territory to territory. This, combined with the irregularity of the shoreline, made identifying foci of activity impossible. In the Pelican Cut, fluctuating water levels made density estimation equally difficult. In the Otis Road Drain, however, there appeared to be four distinct locations where sign, mostly grass and cat-tail cuttings, were abundant. These locations corresponded to the four "breeding pairs" captured there during live trapping. These "foci of activity" became especially evident once litters were produced, and muskrat sign became more abundant in these localized areas.

DISCUSSION

Density

Trap mortality, which occurred during 1978 live-trapping, and to a lesser extent during 1979 live-trapping, created difficulties in determining densities. Muskrats that were eliminated eventually were replaced by individuals immigrating from adjacent areas. Estimated populations reflect the number of individuals present before trap-mortality, and may be lower than the number of muskrats captured. During 1979 live-trapping, the territory of a breeding pair was often indicated by the capture of one member of the pair, usually the male. During 1978, when live-trapping continued through the summer months, both individuals of any given pair were captured.

Muskrat densities found on the Conway Ranch (1.5 - 7.5 adult pairs/km) compare with densities found by Stewart and Bider (1974) of 2.6 pairs/km in their study of ditch dwelling muskrats in Southern Quebec. The Otis Road Drain, which is comparable to the "collection ditch" described and studied by Stewart and Bider, had similar densities of 2.5 to 3.1 pairs/km (4.0 to 5.0 pairs/mile). Dixon (1922), although not describing methods, estimated muskrat populations of adults and sub-adults in the canals and rivers of the Imperial Valley, Southern California, of 12.4 to 24.8/km (20 to 40/mile).

The relatively high population density (7.5 pairs/km) observed in Willow Slough is probably related to the highly suitable habitat provided by the marsh areas bordering this slough. These marshy borders, which are not found along the Pelican Cut or the Otis Road Drain, provide a considerable area of muskrat habitat per linear kilometer of waterway. Relatively stable water levels in Willow Slough add to its suitability as muskrat habitat by promoting growth of aquatic plants which serve as muskrat food, and limiting drought associated stress. In contrast, the water levels in the Pelican Cut fluctuate drastically and may account for year to year fluctuation in population density.

Home Range and Movements

As with density, the approximate home range size of muskrats inhabiting the Otis Road Drain (320-400 m) is very similar to the 446-536 m home ranges found by Stewart and Bider (1974). Muskrats in other areas had home ranges varying from 133 m in Willow Slough, where populations were high, to 650 m in the Pelican Cut, where populations were low in 1979. The increased home range size of muskrats inhabiting the Pelican Cut during 1979 is a result of a lower population density allowing larger exclusive home ranges. This inverse relationship between home range size and density has been noted by Errington (1963) during extensive studies of muskrat populations in Iowa.

The limited movements of muskrats observed during this study has been observed elsewhere by others (Errington 1963). However, Errington reported capturing individuals 3.6 to 5.2 km (2.25 to 3.25 miles) from their tagging sites, and in one extreme case recaptured an individual 33.6 km (21 miles) from its place of birth. Most of Erringtons 177 "returns" of marked animals (1539 total) showed no extensive movement.

Population Structure

Age structure of the muskrat population on the Conway Ranch (76.0% sub-adults, 24.0% adults) is almost identical to that found by Sooter (1946) in another introduced California population. He found 75.5% sub-adults at Tule Lake, Siskiyou County. Other studies by McCann (1944), Shanks (1948), and Beer and Truax (1950) similarly found populations of 72.6 to 79.0% sub-adults. Beer and Truax (1950), in summarizing data from 17 different Wisconsin marshes over a four year period, found variation in age structure of 65% - 89% sub-adults. They showed that as population densities increase the ratio of young to adults is reduced in the fall population (i.e. survival of young is inversly related to population densities). This relationship also was noted by Errington (1963).

Sex structure of the overall population of muskrats on the Conway ranch (120 males:100 females) agrees closely with data collected by Sooter (1946), at Tule Lake, California (122:100). Errington (1963), in summarizing data taken from 165,954 North American muskrats trapped for fur, came up with a similar figure of 122:100.

Differential sex ratios between age classes found during this study (sub-adults 106:100, adults 182:100) may be due to selectiveness of the trapping methods. It was suggested by Lay (1945), Heit (1949), Beer and Truax (1950), Alexander and Radway (1951), and Errington (1963) that the more frequent movements of male muskrats leads to higher trappability, creating an error in estimating sex structure from fur-trapping data. The difference in sex ratios of float-trapped (176:100) and cage-trapped (133:100) adult muskrats found during this study suggests selectiveness in float traps. Float-traps, which rely on the muskrats' habit of climbing on objects in the water, appear to be selective for adult males. Cage traps, which are set to take muskrats swimming along underwater runways apparently are not selective, and may more closely reflect the actual adult sex ratio.

Other studies (McCann 1944, Sooter, 1946, Beer and Truax, 1950) found sex ratios of adult populations that are approximately equal or slightly favor females, and sub-adult populations that favor males (120:100). These results, which differ considerably from the results found during this study, may be due to differing degrees of trap selectiveness. The trapping methods used in these other studies were not described.

Reproduction

The long breeding season found during this study is similar to that found by Dixon (1922) in Southern California. He found muskrats in the Imperial Valley breeding year-round, with most young born between 12 February and 30 October. Similarly, Svihla and Svihla (1931) found muskrats breeding year-round in Louisiana. Here, however, peak activity occurs during the winter months, November through April. In more northern latitudes shorter breeding seasons have been noted. In Manitoba, Canada, Mcleod and Bondar (1952) found that young seldom were born earlier than 18 May and rarely after August.

Although criticism has been expressed questioning the accuracy of placental scar counts as an indicator of reproductive rate (Davis and Emlen 1948), scar counts were used during this study. Errington (1963) used placental scar counts in studying muskrat populations in Iowa and found scar counts comparable to both embryo counts and data collected from litters examined in nests. Similarly, no significant difference (t-test, $p > .05$) was seen during this study between embryo counts and fresh placental scar counts as indicators of litter size.

A litter size of 5 or 6, determined for muskrats on the Conway Ranch is based on February embryo and placental scar data. Errington (1963) has shown that mean litter size varies throughout the breeding season (5.8-7.4) with larger litters being born later in the season. Litters born later in the season on the Conway Ranch then might be expected to average greater than 5 or 6. In other studies summarized by Errington (1963), litters have been observed consisting of 1 to twelve young with mean sizes of 3 to 8.

Breeding by young-of-the-year females (17.8%), as observed during this study, is more common than reported by Errington (1963) in Iowa. During 21 years of study he found breeding occured in only 1.5% of young females. However, he noted years of relatively high degrees of precocial breeding with as many as 6% of the sub-adult female showing placental scars. Mathiak (1966) found in naturally occurring Wisconsin populations even higher annual variation in the occurrence of precocial breeding with as many as 23% of sub-adult females breeding.

Production of more than one litter by young-of-the-year females observed during this study has not been reported in other North American studies. Errington (1963), in considering Hoffmann's (1952) data, suggested this occuring in German muskrat populations. The two litter sub-adult females observed during this study had some adult characteristics. They were possibly born during the winter of 1977-78, and were reproductively active early in 1978.

The average of 3 to 4 litters produced by adult muskrats on the Conway Ranch is related to the long breeding season. As with breeding season length, the reported number of litters produced per year varies with geographical area. Stevens (1953) reported muskrats in the Mackenzie Delta, Yukon Territory, producing only 1 or 2 litters. O'Neil (1949; cited by Errington 1963) reported 5 to 8 litters being common among muskrats in Louisiana's coastal marshes.

No association between litter size and breeding season length has been reported. In summarizing reported reproductive data, Errington (1963) discusses litter size data in relation to various subspecies, and breeding season length in relation to geographic location and climate.

Mortality

The apparent high mortality among young-of-the-year Conway Ranch muskrats, before or during their first winter, seems reasonable considering their high reproductive rates. A high trunover rate in the adult population is reflected in the low number of 1978 tagged adults recaptured during the 1978-79 fur-trapping and 1979 live-trapping. Most adult Conway Ranch muskrats apparently survive through only one breeding season.

Mathiak (1966), in a 10 year study of Wisconsin populations obtained similar, but more complete data reflecting mortality, turnover rates, and longevity. He estimated that "the average year class...dissappeared at a rate of 87% the first year, 11% the second year, and 2% the third year" and "muskrat populations had a complete turnover in two years".

Drought and flood are probably important mortality factors affecting valley populations. During the fall, after irrigation of crops is completed, many fields and canals are drained. This habitat, which probably provides an important outlet for the expanding population throughout the breeding season, is eliminated. These individuals then concentrate in the areas of permanent water. Intra-specific strife then becomes a direct mortality factor. Strife related injuries are most conspicuous during early spring when breeding territories are being established (Errington 1963).

During years of high precipitation, muskrats are often driven out of their burrows by high water. This is especially evident in the Yolo Bypass section of the Conway Ranch. Many muskrats can then be observed taking refuge above the rising water in trees or brush. Many probably die of exposure.

Errington (1963) has shown disease to be an important mortality factor among Iowa populations, often totally eliminating a population within a given area. Although not seen during this relatively short term study, disease is probably a potential mortality factor among valley populations.

Census Techniques

Many methods of estimating muskrat populations, as summarized by Sather (1958), have been proposed and used. The often used technique of counting the number of active muskrat houses in an area is not applicable to Sacramento Valley populations which are almost exclusively bank dwellers. The method used during this study of plotting spring territories (Errington 1963), is applicable to canal-dwelling muskrats which usually have well defined linear territories.

CONCLUSION

The large amount of irrigation canal habitat available to Sacramento Valley muskrats, and their inherently high reproductive rate, has made the muskrat one of California's most important fur resources. Barring changes in demand by the fur industry, muskrats will continue to be an important California fur resource. Changes in agricultural practices, however, may have a significant influence on the future of valley populations. The possible decreased use of earthen-banked ditches for irrigation purposes may eliminate populations dependent on this type of habitat. This and other changes which affect the amount of suitable muskrat habitat will be important factors shaping the future of Sacramento Valley populations.

In long term studies (Errington 1963) muskrat populations appear to be influenced by a "10 year cycle" of high and low densities. The exact details and causes of this "cycling" are not fully understood. Whether or not a 10 year cycle exists in Sacramento Valley populations is unknown.

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