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BREEDING OF THE SALT MARSH SHREW

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Salt marsh shrews (*Sorex vagrans halicoetes*) are common inhabitants of some of the San Francisco Bay salt marshes in California. Their numbers in favorable marshes form perhaps 10 per cent of the mammalian fauna present, the rest of which is chiefly composed of *Microtus californicus, Rattus norvegicus, Mus musculus,* and *Reithrodontomys raviventris,* all of which are more abundant than shrews. There is no study yet reported on the biology of salt marsh shrews, and indeed little on the species *S. vagrans* throughout its range. Comparative material in this paper has been drawn mainly from Clothier (1955), Hamilton (1940, 1944, 1949), Jameson (1955), Blossom (1932), and Dehnel (1952); only the first of these deals with *Sorex vagrans.*

Field work was done from 1949 to 1955, although the major part of this time was spent on studies other than this one. Trapping was undertaken on all San Francisco Bay marshes inhabited by *S. v. halicoetes;* observations on nesting activity were carried out on San Pablo marsh, Richmond, Contra Costa County; a collection of owl pellets was also made at this locality. Observations on captive shrews were made at the Museum of Vertebrate Zoology (Rudd, 1953).

The environment.—The San Francisco Bay salt marshes are in an area of Mediterranean climate. Temperatures average perhaps 55° F. through the year, minima of 28° to 30° and maxima rarely of 90° to 100° occurring. Rainfall averages 18 to 25 inches a year and falls in the period from November to April. Thus, there is a long summer dry season. However, because of the summer high tides, dryness may reach critical levels for salt marsh shrews only in September and October.

The lower parts of salt marshes, 3 to 6 feet above sea level, are grown to extensive pure stands of cordgrass (*Spartina foliosa*); this part of the marsh is covered at least once a day by tidewater. Higher ground, 5 to 9 feet above sea level, is covered by the *Salicornia* association, characterized by pickleweed (*Salicornia ambigua*) and saltgrass (*Distichlis spicata*), and on especially raised areas there is gumplant (*Grindelia cuneifolia*). A full discussion of the relationship of plant distribution to tide levels may be found in Hinde (1954).

Habitat.—*Sorex vagrans halicoetes* frequents those parts of salt marshes that offer dense cover, an abundance of invertebrate animals as food, suitable nesting

and resting sites, and fairly continuous ground moisture. The shrew metropolis is found on the medium high marsh, about 6 to 8 feet above sea level, and it extends to lower marsh areas not regularly flooded by tidewater. Suitable areas within this expanse of marsh characteristically have an abundance of stranded driftwood and other detritus scattered in *Salicornia*, which ordinarily reaches one to two feet in height. Under these pieces of wood, moisture is retained fairly well into the autumnal dry period, and amphipods, isopods and other invertebrates are common in most seasons of the year. Nesting and resting cover for shrews is provided by the same driftwood and plant material. The latter includes the living *Salicornia*, but equally important is the dead material left by tidewater; most of this is *Spartina* duff. The higher marsh, 8 to 9 feet in elevation, being dry and with minimal cover, has few or no shrews and the lower *Spartina* zone, subject to daily floods and without heavy cover, is devoid of them.

Numbers.—No census of shrews on San Pablo Marsh was taken. However, a variation in relative numbers was noted in the period from 1951 to 1955, based on the number of active nests found. Shrews were abundant in 1952 and 1955, moderately abundant in 1951 and 1954, and scarce in 1953. The number of nests found with young was: 1951, 1; 1952, 11; 1953, 0; 1954, 4; 1955, 10. In 1953 Johnston was watching carefully for nesting activity and found but three nests, all empty, in the course of the entire year. Little additional information on fluctuation in numbers was obtained from an examination of 387 pellets of the short-eared owl (*Asio flammeus*); this owl is found on the marsh from late August to April. In 1951-52, 6.1 per cent of the items in pellets were shrews; in 1952-53, 2.6 per cent; in 1953-54, 1.0 per cent; and in 1954-55, 1.3 per cent.

Nests.—Two kinds of nest are made by salt marsh shrews. One is used for housing litters and is made presumably by females; the other, which we call the resting nest, is probably made and used by both sexes.

The breeding nest is made of dead plant matter. Fragmented leaves and stems of *Spartina* are used preferably. *Distichlis* and *Salicornia* are also used. Grasses otherwise appear infrequently and mammal hair (*Rattus norvegicus*) was noted once as a cup lining. Small pieces of paper occur in almost all fresh nests and form the topmost part of the cup, which almost always is domed. As the young grow the cup enlarges, the dome is obliterated, and the paper lost.

The walls of the nest are concentrically arranged around the cavity. The construction is substantial but since the nests are damp and placed on a wet substrate they are not as coherent as they would be were they dry. Runways enter the cavity of the cup from the sides and from beneath, through the peripheral duff; the cup is thus not open to view until the young are two to three weeks old. Clothier (1955:218) describes a nest of *S. vagrans* in Montana as merely a ball of dried grass with no definite nest cavity, placed in a hollow log.

The breeding nest is of variable size due partly to the shape of the plank or cover under which it is placed. The mass may be from 8 to 24 cm. by from 6 to 12 cm., and 4 to 6 cm. in depth. Cups of fresh nests measure 3 × 3 cm. to 4 × 4 cm. and 2 to 3 cm. in depth. The dome of the nest is placed frequently in a cavity in the underside of the covering structure. Such concavities are rarely found but usually show evidence of use by shrews. One such cavity in a large woodblock was occupied almost continually since observation began in 1951; four nests with young have been found under it, including one of the two found in September. Resting nests are smaller, 2 or 3 by 3 or 4 cm., and are shallow cups only. They are placed under a cover but in all cases are elevated above the soil surface in the depressed *Salicornia*. Adult shrews have been found in these nests occasionally.

BREEDING BEHAVIOR

The breeding season.—Figure 1 shows the dates and frequency of occurrence of parturition in salt marsh shrews. The histogram was constructed on 20 records of trapped pregnant shrews and on 19 records of nests found with young in them. A certain number of days was added to the date of capture of the pregnant females in accordance with their state of pregnancy to get an assumed date of parturition; a certain number of days was subtracted from the date young were found, in accordance with their age, to get assumed dates of parturition. This is a convenient way in which to express these data, but it should be noted that they are from several years and the cycles unquestionably vary from one year to another. The principal season for births extends from the last of February to the first of June; the modal date for parturition in the spring is April 25, and more than half of all litters are born in April. Subsequent to early June there is a three-month gap in our records of breeding; there is a small amount of breeding in middle and late September.

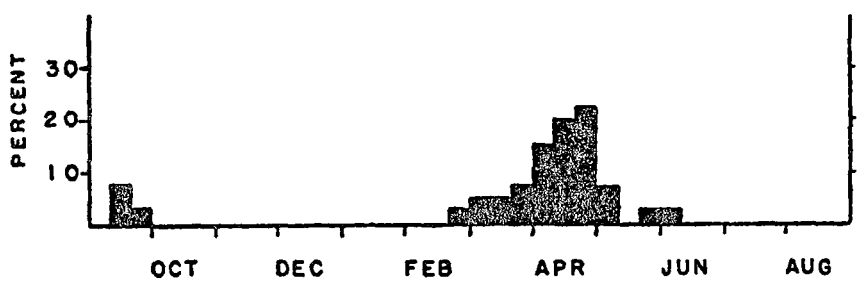

FIG. 1.—Breeding season of salt marsh shrews as shown by frequency of parturition. Vertical columns represent ten-day periods with the 5th, 15th, and 25th of each month as medians. $N = 39$.

There may not be a complete cessation of breeding in the summer months; animals capable of breeding are not common in the population at this time. Postpartum mating and double litters probably occur in the salt marsh shrew; Clothier (1955:218) found this to be true of *S. vagrans* in Montana, and it

has been established for *Blarina* and S. *fumeus* in New York (Hamilton, 1949: 259), in S. *trowbridgei* in the Sierra Nevada of California (Jameson, 1955:345), and in captive S. *araneus* (Dehnel, 1952). However, it may be that the only occurrence of double litters in salt marsh shrews is that represented (Fig. 1) by the small number of births in late May and June.

Probably it is mainly the young of the year that breed in the fall, for it is about this time that young shrews appear to be nearly adult in linear size and in behavior, and adults are almost completely absent from the population then. There is no indication of breeding activity in the winter.

Litter size.—Gestation in the salt marsh shrew lasts about 20 days. Figure 1 can thus be taken to represent the seasonal occurrence of first dates of pregnancy in the population if 20 days are subtracted from the dates in it. Average litter size is 5.16 young; numbers of young are distributed as follows:

Size of litter	2	3	4	5	6	7	8	9
Number of occurrences	1	5	6	11	11	2	2	1

The average size of litters *in utero* is 5.55 and in the nests 4.74. The discrepancy of 0.81 young probably represents combined mortality due to resorption, birth trauma, and postnatal inviability of various kinds occurring within about the first week of life which is the time, on the average, when our records on young in nests begin. Litters totally resorbed or killed after birth are not included in our records giving the mean of 4.74; thus, this is a figure for surviving litters. Mortality from the time of conception to the age of about 7 days postpartum therefore is not less than 15 per cent.

Clothier (1955:218) found mean litter size *in utero* to be 6.4, with a range of 2 to 9, in S. *vagrans* in Montana. It is possible that the higher mean count in Montana indicates that S. *vagrans* varies in litter size in a manner parallel to the geographic variation in clutch-size of many birds (see, for example, Lack, 1947). Such variation commonly is associated with increases in altitude, latitude and continental climate (Lack, *op. cit.*; Johnston, 1954), but the proximate factors are not yet known.

The female begins to wean the young at about 16 days, and this process is completed by about the 25th day. The young stay in the nest to perhaps the 5th week. This group situation is not truly social, for members of one family only are involved in it. The major activity of young in these groups while in the nest is huddling together, apparently to conserve body heat; nonsibling young are intolerant of one another, at least in captivity (Rudd, 1953:119). It is not known if the familial bond extends to activities outside the nest; individuals doubtless leave periodically to forage, however.

DEVELOPMENT OF THE YOUNG

The growth curve of young salt marsh shrews shown in the diagram (Fig. 2) depends on aging the individuals at the time of capture. Three basic categories were used: one week, unfurred, eyes closed; two weeks, fur dorsally, eyes open, teeth not erupted; and three weeks, heavy pelage, teeth erupted. Within each of these categories individuals were assorted as follows: category

1, younger if body red in color, older if pink and a slight gray cast of growing hairs apparent; category 2, younger if pelage thin and eyes closed, older if pelage thicker and eyes clearly open; category 3, younger if teeth not fully erupted, older if clearly erupted. The ages of individuals plotted in Figure 2 are derived from estimated deviations from weekly ages according to these criteria.

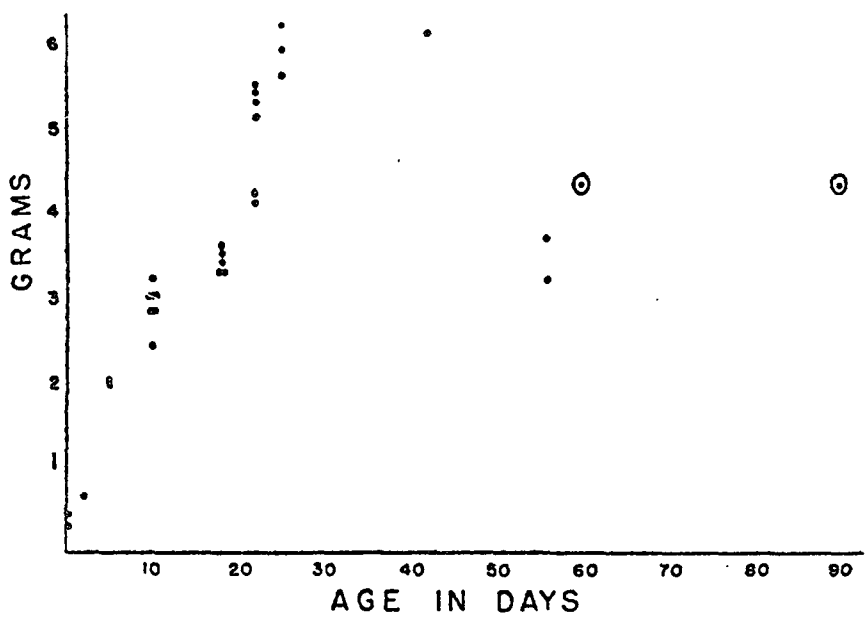

FIG. 2.—Weights of young salt marsh shrews. Encircled readings represent mean weights of thirteen individuals apiece; see text for details.

The first three and last three individual weights are of animals born and kept in captivity; these are indicated by triangles. The encircled dots placed at 60 and 90 days represent mean weights of juvenile animals captured on marshes by traps; 13 individuals of both sexes are involved in each mean reading. These animals are not precisely 60 and 90 days old, but they were taken in July and August, respectively; on the basis of our curve on incidence of birth (Fig. 1) we have assumed that the majority captured in each of those two months were two and three months old, respectively.

At birth *S. vagrans halicoetes* weighs about 0.5 gram. A similar birth weight datum for *S. cinereus* is 0.1 gram (Blossom, 1932) and for *Cryptotis parva*, 0.32 gram (Hamilton, 1944:6). After birth, weight gain is rapid and apparently constant to the age of one month, at which time shrews reach 5 to 6 grams. After this time a drop to a relatively constant weight of between 4 and 5 grams occurs, and this weight is maintained until December and January (Rudd,

1955:335), at which time increases coincident with the onset of breeding activity are noted to a maximum of 8.4 grams in males and 7.7 grams in females.

The most important fact to be seen in the diagram on weight gains (Fig. 2) is that shrews one month of age are heavier than shrews two and three months old. This specific type of weight relationship to age has not before been clearly demonstrated in *Sorex*. However, Figure 1 of Hamilton (1940:486) on *S. fumeus* shows a decline in weight of juvenile animals in the period from June through July when one-month old animals are fairly common in the population of young. Additionally, Brambell (1935:9;55) found that *S. araneus* is heavier one or two months after birth than in the following winter and early spring. Among other mammals nothing similar is found, to our knowledge; *Microtus pennsylvanicus* (Hamilton, 1937:503), probably typical of rodents generally, shows a steep but smooth curve leveling off at about 80 days to a relatively constant value.

The cause for this drop in weight after 30 days may lie in the fact that a shrew family stays together until the young are about one month old; until this time they live a semi-social existence, have little or no aggressive interactions, and they conserve heat by huddling in a ball. Subsequent to this time the young disperse through the population and expend much energy in the course of becoming independent.

Mortality of young.—The young in 15 of the nests found were observed until they were about three weeks old. These 15 litters included 61 individuals (1 to 6 young per litter) of which 35 were still alive after three weeks. Survival from near birth until just after weaning was about 55 to 60 per cent. Since mortality around the time of birth is about 15 per cent, less than half the salt marsh shrews conceived live to the age of 21 days.

Causes of death to shrews in the nest are difficult to find. One known cause is drowning due to high tidewater; four, or 17 per cent, of the dead young died this way. Doubtless another cause is death of the attendant mother shrew. Possibly 10 (39 per cent) of the deaths were due to this; the proximate causes of death would be starvation, cold and exposure. No cause can be indicated for the remaining deaths. Predation by *Rattus norvegicus* is a possibility, but we have no evidence. Avian predators do not take young shrews before their dispersal from the family group; indeed predatory birds are unimportant as a large-scale mortality agent to adult salt marsh shrews.

There is no evidence of a differential survival due to size of the litter. The mean litter size of those observed is about 4 individuals. The survival rate in litters of 2, 3 and 4 was 56 per cent; in litters of 5 and 6 it was 57 per cent.

SUMMARY

Sorex vagrans halicoetes on San Francisco Bay salt marshes in California lives mainly in the *Salicornia* zone and finds foraging, breeding, and resting sites under stranded driftwood. The season for births runs from late February to early June; a small amount of breeding occurs in September. Mean litter size *in utero* is 5.55 and in nests 1 to 2 weeks old it is 4.74; mortality to the age

of about one week in surviving litters is thus at least 15 per cent of total implantations. Young shrews gain weight rapidly, reaching 5 to 6 grams at about 30 days of age; following dispersal from the nest, weights decline and 2- and 3-month old shrews weigh about 1 gram less. Survival of young from shortly after birth to 3 weeks is 55 to 60 per cent; litter size has no influence on mortality.

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