1949

Contribution on the life history of the water shrew (Sorex palustris navigator Baird)

Clinton Harper Conaway
The University of Montana

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A CONTRIBUTION ON THE
LIFE HISTORY OF THE
WATER SHREW
(Sorex palustris navigator BAIRD)

by

C. H. Conaway
Department of Zoology
Montana State University
Missoula, Montana

B. A., Purdue University, West Lafayette, Indiana, 1947

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Montana State University
1949

Approved:

Chairman of Examining Committee

Dean of the Graduate School
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INTRODUCTION

This thesis, based upon a combination of field and laboratory studies, is the result of an attempt to gain a more complete understanding of the life history of the water shrew (*Sorex palustris navigator*). Published literature relating to this species is largely confined to taxonomic or distributional considerations. Only a few incidental observations concerning the habits of this small semi-aquatic insectivore are recorded.

In the autumn of 1947 preliminary collection of specimens was begun. Subsequently it was indicated that sufficient material might be obtained to make a life history study possible. In February of 1948 a more detailed approach to the problem was initiated. This report is based upon that material collected between September 1947 and January 1949.

All specimens collected were obtained in Montana west of the Continental Divide. This region is entirely within the range of the subspecies *Sorex palustris navigator* as defined by Jackson (1928).

During the course of the study I have received invaluable assistance from many persons, only a few of whom I can mention here. Foremost among these was Dr. Philip L. Wright, under whose direction the study was carried out and who gave counsel and assistance in all phases of this work. Dr. Ludvig G. Browman gave advice and help on numerous problems throughout the study. Mr. G. M. Kohls and Mr. M. L. Kuns identified the parasites. Specimens were contributed by Dr. F. B. Brunson, Charles D. Haynes, Kenneth Riersgard, Alan Sexton, and Ronald Clothier. Also I am indebted to Dr. LeRoy Harvey for aid in identifi-
cation of plants. My wife spent many hours in the field and laboratory aiding me in every way possible. The sketches and graphs were also done by her.
METHODS

Specimens were collected by the use of back breaker mouse traps baited with peanut butter to which sufficient anise oil had been added to give a pronounced odor. Animals were ordinarily brought into the laboratory and autopsied within a few hours after being removed from the traps. When this was not possible such work was done in the field. In all instances an attempt to obtain uniformity of conditions and material was made. Thus frozen specimens were allowed to thaw and those that were wet were dried before autopsy proceedings were begun.

Animals were weighed and measured, then examined for ectoparasites. Following this the animal was skinned. The reproductive tract was removed from the body and preserved in Mossman's modification of Formalin, Alcohol, and Acetic Acid fixitive (Guyer, 1936). The stomach and intestines were removed and preserved in 10% Formalin. After a cursory examination of the skinned carcass for parasites or abnormalities, the head was removed and the remainder discarded. The skin was examined for skin glands, pigmentation, and molt, after which it was prepared as a study skin.

Special techniques will be elaborated in detail under the appropriate sections relating to their application.
HABITAT

In reference to the habitat of *Sorex palustris*, Jackson (1928) states it is "seldom found at any great distance from water, which may be a lake or pond, a brook or merely a pothole in a swamp bog or forest." Borell and Ellis (1934) remark that the water shrew prefers "slow moving streams with logs and drift" while Grinnell and Storer (1924) and Long (1940) state it is found along swift streams.

The general range of this species is usually considered as the Canadian and Hudsonian zones (Dalquest, 1948). In western Montana the Canadian zone is a heavily timbered region, characterized by such tree species as Douglas fir \(^1\) (*Pseudotsuga taxifolia*), grand fir (*Abies grandis*), western tamarack (*Larix occidentalis*) and lodge pole pine (*Pinus contorta*). Altitudinally, this zone usually lies between 4000 and 6000 feet, although there is much local variation. Above the Canadian lies the Hudsonian or timberline zone. Here the dominant trees are dwarfed white pine (*Pinus albicaulis*) and alpine fir (*Abies lasiocarpa*). A detailed discussion of the life zones in Glacier Park is given by Bailey (1918). While the water shrew ordinarily occurs at rather high elevations it has been recorded as low as 300 feet in western Washington along fast cold streams descending from nearby mountains (Jackson, 1928).

During the present study I have taken 49 specimens and 13 specimens were taken by other persons. For 10 of the contributed specimens it has been possible for me to see the exact location of capture and for 2 the approximate location. These specimens were all obtained at elevations between 3100 feet and 6950 feet. All but a few were trapped along rapid

---

\(^1\) Common and scientific plant names are according to Kelsey and Dayton (1942).
streams. However, relatively few traps were set in other habitats since
the objective of trapping was primarily to secure specimens. Accordingly
trapping was conducted in those habitats where the most success was had.
As the study continued trapping techniques became more refined and habitats
were carefully selected.

It became apparent as specimens were secured that optimum results
were obtained in rather limited habitats. These regions were along fast,
cold mountain streams whose banks offered favorable cover. Such banks
were composed of large stones, boulders and tree roots forming many
crevices and overhanging ledges. (Figures 11 & 12). Many specimens
were secured where streams flowed beneath such banks in the crevices or
where small springs entered a larger stream under similar conditions.
During the latter part of the study trapping was largely confined to
streams presenting these physical characteristics.

Vegetation along such habitat was typically Canadian in composition
(Cary 1917). Mosses and liverworts occurred on the rocks near the water.
Near the edge of the stream such plants as: green pyrola (Pyrola chlorantha),
sidebell pyrola (P. secunda), red baneberry (Actaea rubra), and bearberry
(Arctostaphylos uva-ursi) frequently occurred. The chief tree species
along good habitats was Douglas fir (Pseudotsuga taxifolia). Grand fir
(Abies grandis) and Pacific yew (Taxus brevifolia) was present also in
some habitats.

When setting traps the method employed was to wade in the stream
setting traps beneath the banks within a few inches of the water's edge.
By working from the stream it was possible to select and trap in optimum
sites which were not accessible from the bank. Traps were attached to a
stable object by means of a two or three foot length of #28 copper wire to prevent their loss should they fall into the stream. Ordinarily traps were placed 10 to 100 feet apart, depending on the available sites. All traps were numbered and the numbers recorded to facilitate recovery. Considerable care was executed in placing the traps, thus three or four hours were required to set 30 to 40 traps. In most instances traps were set during an afternoon and recovered the next morning.

As has been previously indicated trapping was of a specialized nature and thus the results obtained cannot be considered as a random sample. However, a listing of the various categories of habitats and the numbers of individuals obtained is at least indicative of some habitats of water shrews. Table I indicates the habitats of 61 shrews for which positive data are possessed (excluding the one specimen for which no habitat data are available) and the number of individuals caught in each type.

**TABLE I**

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Number</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial stone walls</td>
<td>14</td>
<td>22.9</td>
</tr>
<tr>
<td>Log bridge abutments and retaining walls</td>
<td>6</td>
<td>9.8</td>
</tr>
<tr>
<td>Overhanging banks and crevices</td>
<td>27</td>
<td>44.3</td>
</tr>
<tr>
<td>Brush and logs at water's edge</td>
<td>6</td>
<td>9.8</td>
</tr>
<tr>
<td>Edge of dams and log jams</td>
<td>3</td>
<td>4.9</td>
</tr>
<tr>
<td>Water cress near bank</td>
<td>3</td>
<td>4.9</td>
</tr>
<tr>
<td>Stream in meadow</td>
<td>2</td>
<td>3.3</td>
</tr>
</tbody>
</table>

The artificial stone walls listed in Table I were located along the water's edge either as foundations of abandoned mine buildings or along the Rattlesnake River near Missoula where they had been constructed to
prevent overflow. (Figure 13). Water either flowed along the bases of such structures or higher, varying with the stream conditions. The next category is essentially the same except that these structures were of log and loose rock. (Figure 14). Overhanging banks and crevices are those natural situations previously described. Brush and logs include such sites as windfalls and other debris along the stream's edge. The 3 specimens taken at the edges of dams and log jams were all trapped where small flows of water seeped through these barriers. Three specimens were taken in traps placed on a mat of water cress (Rorippa nasturtium-aquaticum) in shallow water just a few inches from a rocky bank. Of the two specimens secured in meadow conditions, one was obtained at 3200 feet in elevation, about 30 feet from the mouth of a small stream only a few inches wide, which flowed through a grass meadow before entering the Rattlesnake River. The second specimen in this category was taken at an elevation of 6000 feet in a run of Microtus richardsoni, along a small stream flowing through a subalpine meadow. Only a few hundred feet from this meadow the stream descended rapidly through an area closely resembling that which has been described above as optimum trapping habitat.

Since early in the trapping it was indicated that greater success was had if the traps were set very close to the water, all traps were placed within a few inches of water. The greatest distance any specimen was taken from water was 7 inches. Rand (1944) records having taken one 10 feet from the water's edge but most other records indicate specimens were taken nearer to water. Hall (1946) obtained success in trapping water shrews by using a modification of Stirtons (1944) method for trapping Rhomys. A barrier was placed across a stream and a trap placed in a depression
in the center of the barrier. This method has not been used in this study since it seemed that specimens could be obtained readily by trapping along the banks.
AGE DETERMINATION

In order to understand the reproductive cycle and other phases of the life history of the water shrew it is necessary to have a method of approximating the age of the specimens obtained. Workers in the past have used a variety of criteria to determine age within several species of shrews which have been studied. Pearson (1945) has adequately reviewed these various methods and concluded that such criteria as body weight, reproductive condition, scars on tail, and body length are not sufficiently accurate to use as criteria for determining age. Working with Blarina, he developed a system for determining age based upon toothwear and the assumption that such attrition will be relatively constant throughout the animal's life. Toothwear had previously been used by some workers as an index to age in Insectivora although their methods were somewhat crude. Jackson (1928) divided shrews into four age categories based on the amount of toothwear. Hamilton (1940) working with *Sorex fumeus* likewise used toothwear as an index of age, along with other criteria such as the body weight and amount of hair on the tail. In Parascalops, Eadie (1939) found that the moles collected in March and April could be classified into four well-defined groups based upon toothwear. He considered these to be representative of 1, 2, 3 and 4 year old age classes.

Pearson (1945) arbitrarily selected 7 representative specimens of Blarina chosen to show graded degrees of wear from very slight to extreme wear. These were assigned numbers from 1 to 7 according to the extent of wear and all other skulls were compared with this series as a standard. Each skull compared was assigned a number corresponding to that of the
standard with which it was most similar. The toothwear numbers were then plotted against the months of the year in which they were collected. When this was done a regression was obtained and it was apparent that two groups existed during the summer. That group showing a small amount of toothwear was considered to be the juvenile population, while the other group was considered to be the adult population, i.e., those having survived one winter.

Since Pearson's technique of comparison is rather subjective and further, since the results obtained by this technique show a range so wide that in some instances it is impossible to determine in which age group his specimens belong, it was decided to use a different technique for determining toothwear in this study. The method employed was to obtain a standard series of measurements of the length of a number of representative teeth in each specimen. (Figure 5). The individual measurements were then totaled to obtain a toothwear number for each specimen.

For each specimen the following measurements were taken:

A. Right and left maxillary tooth rows.
   1 p.m. - Distance from base of cingulum to tip of metacone
   2 m. - Distance from base of cingulum to tip of metacone
   3 m. - Distance from base of cingulum to tip of metacone

B. Right and left mandibular tooth rows.
   1 i. - Distance from base of cingulum to apex
   2 c. - Distance from cingulum to tip of protoconid
   3 m. - Distance from cingulum to tip of protoconid
   4 m. - Distance from cingulum to tip of protoconid
All measurements were taken with a dissecting microscope and filar micrometer at a magnification of 23 diameters. To measure the maxillary teeth the skull was mounted upon a block and fixed in such a position as to obtain a buccal view of the tooth row in a plane horizontal to the stage of the microscope. When one side had been measured the skull was then turned with the other tooth row upon a similar position and measured. The mandibles were separated and placed on the stage of the microscope and a lateral buccal view thus obtained. An attempt was made to standardize the measuring techniques by using uniform methods.

The 14 individual measurements were then added and the total plotted directly in occular units (Figure 1). Conversion from occular units to micra (one occular unit = 3.5 micra) was not computed since for the purpose of determining comparative figures this would be superfluous.

Although an attempt was made to standardize the technique, some variation would be expected. To determine the extent of this variation three skulls were each measured ten times and the standard deviation of each computed. The results of this were as follows: For sample 1, the mean of ten trials was 4217 with a standard deviation of 23.7; for sample 2, the mean was 4525 and the standard deviation, 31.6, and for sample 3, the mean was 4945 and the standard deviation, 24.6. It may be seen from Figure 1 that slight variations in measurements as indicated by standard deviations of this magnitude would probably not result in confusion between the two age classes of shrews recognizable during the summer.

Figure 1 represents the toothwear numbers plotted against the months in which the specimens were obtained. It may be seen that a very definite
**Figure 1. Tooth-Wear in the Water Shrew**

- **Males**
  - □ No sperm in testes
  - ■ Sperm in testes

- **Females**
  - △ Not pregnant
  - ▲ Pregnant, lactating, and/or corpora lutea
trend in toothwear exists with the highest numbers occurring in June and the lowest in August. The nature of this trend supports the hypothesis that toothwear is relatively constant through the course of the animal's life and that it is feasible to determine age by a method based upon toothwear. If it is assumed that this is so, it becomes apparent that in the population studied, the first young (those animals with a minimum of toothwear) occurred in June and that the oldest specimens obtained were in their second summer.

Even though a well defined trend exists it will be noted that considerable spread occurs. This would be anticipated due to the variables involved. As has been previously pointed out, there was some variation in repeated measurements of the same skull and some error of measurement would be expected. In addition, individual variation in tooth length within animals of the same age would be expected. Some variation might be attributed to sexual differences. Differential rates of toothwear undoubtedly account for considerable variation. As is indicated in Figure 1 and will be discussed later, the breeding season is protracted over a considerable period of time. This means that animals trapped on the same date may differ in age by several months even though they were born during the same breeding season.

In the following sections animals will be classed as old or young, based upon their toothwear numbers. "Old" will arbitrarily be used to designate animals after January 1 of their first winter, while "young" will refer to animals not yet having reached January 1 of their first winter. The term "mature" will refer to sexual maturity and "immature" to sexual immaturity.
WEIGHTS AND MEASUREMENTS

Although the weight of an individual shrew would be expected to vary considerably within short periods of time as Pearson (1945) has shown in Blaring, certain well defined trends can be seen in the body weights of both sexes of water shrews. An increase in the body weight of males occurs concomitantly with the onset of sexual activity. A similar increase associated with sexual activity has been reported in other members of the genus Sorex. In Sorex fumeus this occurs in March (Hamilton, 1940). In Sorex araneus, in mid-March (Brambell 1935) and early in April in Sorex minutus (Brambell and Hall 1937).

Figure 2 indicates the body weights of all male specimens, their testicular condition, and the date of capture. In Table 2, the male animals obtained during November, December and January are recorded with their body weights, testis weights and testis condition shown.

<table>
<thead>
<tr>
<th>Date</th>
<th>Body weight</th>
<th>Testis weight</th>
<th>Testis condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov. 7, 1948</td>
<td>8.6 gm.</td>
<td>2.2 mg.</td>
<td>inactive</td>
</tr>
<tr>
<td>Nov. 14, 1948</td>
<td>8.9 gm.</td>
<td>1.6 mg.</td>
<td>inactive</td>
</tr>
<tr>
<td>Dec. 5, 1948</td>
<td>10.6 gm.</td>
<td>10.8 mg.</td>
<td>many mitoses</td>
</tr>
<tr>
<td>Dec. 6, 1947</td>
<td>12.0 gm.</td>
<td>64.8 mg.</td>
<td>spermatids</td>
</tr>
<tr>
<td>Jan. 4, 1948</td>
<td>12.0 gm.</td>
<td>30.4 mg.</td>
<td>many mitoses</td>
</tr>
<tr>
<td>Jan. 24, 1948</td>
<td>13.2 gm.</td>
<td>68.8 mg.</td>
<td>spermatids</td>
</tr>
<tr>
<td>Jan. 24, 1948</td>
<td>13.4 gm.</td>
<td>132.2 mg.</td>
<td>sperm</td>
</tr>
<tr>
<td>Jan. 24, 1948</td>
<td>17.4 gm.</td>
<td>170.8 mg.</td>
<td>sperm</td>
</tr>
<tr>
<td>Jan. 24, 1948</td>
<td>13.9 gm.</td>
<td>95.8 mg.</td>
<td>spermatids</td>
</tr>
</tbody>
</table>

From examination of these data it may be seen that the increase of body weight is closely associated with the increase of testicular weights and activity. The mean body weight of the 8 males whose testes contained sperm
Figure 2. Body Weights of Male Water Shrews

Old Males

- No sperm in testes
- Sperm in testes

Young Males

- No sperm in testes
was 15.03 ± .63 grams, while the mean body weight of the 14 males whose testes were inactive was 9.6 ± .39 grams. When these two groups were subjected to a "t" test (Fisher 1933) the difference in weight between them was found to be highly significant. The results of this "t" test are shown in Table 3.

### Table 3

**Analysis of Weights and Measurements by the "t" Test**

<table>
<thead>
<tr>
<th>Characters and Classes Compared</th>
<th>Value of N</th>
<th>Calculated &quot;t&quot;</th>
<th>&quot;t&quot; for P of .01</th>
<th>&quot;t&quot; for P of .05</th>
<th>&quot;t&quot; for P of .10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wts. of Immature and Mature Males</td>
<td>22</td>
<td>7.182</td>
<td>2.845</td>
<td>2.086</td>
<td>1.725</td>
</tr>
<tr>
<td>Wts. of Immature and Mature Females</td>
<td>22</td>
<td>6.405</td>
<td>2.845</td>
<td>2.086</td>
<td>1.725</td>
</tr>
<tr>
<td>Wts. of Mature Males and Mature Females</td>
<td>19</td>
<td>2.035</td>
<td>2.898</td>
<td>2.110</td>
<td>1.740</td>
</tr>
<tr>
<td>Wts. of Immature Males and Immature Females</td>
<td>26</td>
<td>1.095</td>
<td>2.797</td>
<td>2.064</td>
<td>1.711</td>
</tr>
<tr>
<td>Total Lengths of Males and Females</td>
<td>42</td>
<td>1.034</td>
<td>2.704</td>
<td>2.021</td>
<td>1.697</td>
</tr>
<tr>
<td>Tail Lengths of Males and Females</td>
<td>42</td>
<td>0.052</td>
<td>2.704</td>
<td>2.021</td>
<td>1.697</td>
</tr>
<tr>
<td>Hind Foot Lengths of Males and Females</td>
<td>42</td>
<td>0.270</td>
<td>2.704</td>
<td>2.021</td>
<td>1.697</td>
</tr>
</tbody>
</table>

When the calculated "t" is larger than the "t" for a probability of .01 a highly significant difference between the averages of the groups compared is indicated. Thus in this instance the calculated "t" is 7.182 while the "t" for a probability of .01 is 2.845. This means that in less than once out of a 100 cases would these different means exist in such samples drawn from the same population. Therefore it may be said that two populations are involved and a difference between them exists.
An increase of weight is likewise apparent in the female specimens at the time of the onset of reproductive activity. It will be noted in Figure 3 that apparently two well defined groups exist during the summer and these might be interpreted as the old and young animals. However, the female indicated by the symbol ▲ is a pregnant young animal. Breeding in young females will be discussed later in the consideration of reproduction, but here it should be noted that if this individual's age had been judged on the basis of weight, it probably would have been classed as an old animal. The mean body weight of 11 sexually mature females, either pregnant or lactating or whose ovaries had large follicles, was $13.2 \pm 0.53$ grams while the mean weights of 12 reproductively inactive animals was $9.70 \pm 0.32$ grams. A "t" test of the means of these two groups showed a highly significant difference (Table 3). In a comparison of the weights of sexually mature females with sexually mature males by a "t" test, $t$ was found to be between 0.05 and 0.10. When the two sexes of immature animals were likewise compared $t$ was greater than 0.10.

For a comparison of body measurements of the two sexes those young specimens taken in their first summer before October were eliminated since some of them were obviously not fully grown. The shortest animal obtained during the summer was a female weighing 8.5 grams and measuring as follows: total length 133 mm., tail length 66 mm., hind foot 19.5 mm. Of 21 females taken after October 1 the mean measurements were as follows: total length 149.62 ± 1.35 mm., tail 72.28 ± 0.56 mm., hind foot 19.95 ± 0.05 mm. Twenty-one males taken during the same period yielded the following measurements: total length 151.52 ± 0.93 mm., tail 73.14 ± 0.65 mm., hind foot 20.62 ± 0.17 mm.
FIGURE 3. BODY WEIGHTS OF FEMALE WATER SHREWS

- Old Females
- Young Females

- Not pregnant
- Pregnant
- Lactating and/or corpora lutea
When the standard measurements of these two groups of animals were compared by a "t" test no significant difference was indicated, F. being greater than .10 in all cases (Table 3). Thus it would seem that there is probably little, if any, difference in total length, tail length or hind foot length between sexes.
REPRODUCTION

The reproductive cycle of the male and female were studied by analysis of reproductive tracts from wild-caught specimens. The entire tract of both sexes was removed at autopsy and preserved in A.F.A. after noting the gross appearance. In addition, mammary tissue from mature females was preserved. After fixing, the tissues were stored in 70% alcohol.

Before histological technique was begun upon the male tissues, the testes were weighed. Testes were prepared for weighing by removing the epididymides and as much connective tissue as possible from the tunica albuginea. The weight of each pair of testes was obtained by removing them from the alcohol, rolling them about on paper toweling for a few seconds, then placing them in a capsule which had just previously been weighed. The capsule and testes were then weighed and the weight of the testes obtained by subtracting the weight of the capsule from the weight of testes and capsule combined. All weights were taken on a Roller Smith precision spring balance. Several sources of error are apparent in this method of weighing. In order to obtain some comprehension of the magnitude of variation which could be expected, one pair of testes was weighed repeatedly during several days. After each weighing these testes were returned to alcohol for not less than one hour before another weight was obtained. The mean for 12 weights of one pair of mature testes was 112.4 mg., with a standard deviation of .83. The mean for 12 weights of one pair of immature testes was 1.06 mg. with the standard deviation being .09.

Histological preparations were made of the gonads of both sexes. Sections of one testis and the tail of an epididymis were prepared from each male specimen. The ovaries of the females were removed and serially
sectioned. When corpora lutea were found the entire uterus was serially sectioned if embryos were not visible macroscopically. Mammary tissue from many of the reproductively active specimens was also sectioned. The dioxan method was used for all material and sections were cut at 10 micra then stained with Erhlich's Hematoxylin and Eosin.

The male cycle. The male reproductive cycle seems fairly well defined by the material available in this study. A total of 33 male specimens was studied, representing material collected in all months of the year except April.

From Figure 1 it may be seen that all males taken during the summer and autumn which were classified as young according to their toothwear, had inactive testes while those taken in the same period and classified as old were in active spermatogenesis. In Figure 4 the testicular weights and spermatogenic states are indicated.

Between May, when the first young male was taken, and November all young animals present an essentially uniform condition. The testicular weights during this period varied from 0.4 mg. to 4.0 mg. for both testes. Microscopically the testes were similar, the seminiferous tubules were solid with only spermatogonia and sertoli cells being present.

A specimen taken December 5, 1948 shows the first indication of beginning sexual activity. The testes of this individual weighed 10.8 mg. and many mitoses were apparent in the seminiferous tubules. Another specimen taken December 6, 1947 whose testes weighed 64.8 mg. showed many spermatids in the seminiferous tubules. No sperm were present in either the testes or epididymides of the specimen. The data from these and additional specimens taken during January which are in various stages of spermatogenic activity are summarized in Table 2.
FIGURE 4. SEMI-LOGARITHMIC PLOTTING OF TESTICULAR WEIGHTS OF MALE WATER SHREWS

- □ No sperm
- ■ Sperm
All old specimens taken after the beginning of February possessed testes weighing above 110 mg. with both testes and epididymides containing sperm. No evidence of testicular regression was found in any of the material. Two old specimens taken during mid-August are in active spermatogenesis with no indication of regression. Since no old specimens were taken after this date it cannot be determined whether regression occurs and if so at what period of the year. In *Sorex araneus*, Brambell (1935) found no positive evidence of regression. Likewise Hamilton (1940) in the study of *Sorex fumeus* found no indication of regression in the males, his last male specimen being taken in early September. However, Pearson (1944) obtained specimens of *Blarina* late in the autumn in which the testes were regressing.

The general pattern of the male reproductive cycle in *Sorex palustris* is similar to that of other Soricidae as indicated from published studies. The most striking peculiarity is in the season of onset of spermatogenesis. As previously shown, the first activity was noted early in December and all specimens taken after the beginning of February were fully active. In *Sorex araneus* sperm appears in the testes in the second half of March (Brambell, 1935), while in *Sorex minutus* the earliest appearance was recorded on March 31 (Brambell and Hall, 1927). For *Sorex fumeus* the time is given as the latter part of March (Hamilton, 1940). *Blarina brevicauda* first showed testicular growth in late January and sperm appeared by the end of February (Pearson, 1944).

Considerable individual variation in testicular condition was found in water shrews taken the same day and in the same area. Also, although the first evidence of testicular activity was seen in early December, a
specimen secured in late January was not yet producing sperm. These facts, together with the number of specimens showing intermediate stages of development during the period of rising testicular activity, are suggestive that development occurs rather slowly with considerable individual variation. Hamilton (1940) indicates that in Sorex fumeus this process is very abrupt and uniform since in mid-March animals were inactive while by early April all specimens were mature.

Reproduction in the female. For convenience of discussion, the female reproductive tracts have been divided into two categories based upon ovarian activity. The first category designated as "inactive" is characterized by small ovaries largely composed of interstitial cells and a few primary follicles. This group includes most young females taken during the summer and autumn. Into the second or "active" group have been placed those animals having large ovaries with numerous maturing follicles, Graffian follicles, or corpora lutea. The descriptive term, "maturing follicles" is used to designate those follicles advanced beyond the primary stage but in which antra had not yet formed. Graffian follicles are those in which antra had formed.

In addition to the 27 female specimens collected during the period September 1, 1947 to January 1, 1949, data are included on the reproductive tracts of 8 females taken during February and March of 1949. Of these 35 females available for study, 23 have been considered active. Because of the inadequate number of specimens available, many details of the female reproductive cycle cannot be understood. However, since so little is known of the reproductive cycle in the water shrew it seems advisable to present those data which are available with the hope that further collection may lead to a greater understanding of details.
With the exception of two young females taken in June all of the young specimens obtained during the summer and autumn were reproductively quiescent. These reproductive tracts were inconspicuous and difficult to locate at autopsy. The ovaries were small and composed chiefly of interstitial cells with a few primary follicles. (Figure 15). This is in contrast to the situation in Blarina in which Pearson (1944) found the ovary at this stage to be composed of primary, small and medium sized follicles, and the bulk of the ovary at all times to consist largely of follicular elements with very few interstitial cells. The uteri of these inactive specimens are thin walled with inconspicuous uterine glands.

The earliest indication of ovarian activity is encountered in a specimen taken January 24, 1948. The ovaries of this individual were large and contained numerous maturing follicles. Subsequent to this date all old specimens secured were found to be reproductively active. Figure 29 shows the appearance of a pre-ovulatory ovary. In Table 4 the condition of these animals and the two young active specimens previously mentioned is summarized. When corpora lutea or embryo numbers are given the number before the parentheses indicates the total found in both sides of the tract. The first number within the parentheses is the number found on the right side of the tract and the second number is that found on the left.

The first pregnant animal was obtained February 24, 1948. This specimen contained six implanted embryos in the neural crest stage. (Figure 16). Since the distribution of corpora varies from that of the embryos, (Table 4) transfer of the blastocysts between uterine horns must have occurred across the superior end of the cervix. As in Sorex araneus (Brambell 1935) and Blarina (Pearson 1944) the ovary of the water shrew is encapsulated thus precluding any other manner of transfer.
## Table 4

**Reproductive Condition of "Active" Female Water Shrews**

<table>
<thead>
<tr>
<th>Date</th>
<th>Elevation</th>
<th>Ovarian Condition</th>
<th>Uterus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old mature females.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan. 4, 1948</td>
<td>3250</td>
<td>few maturing follicles</td>
<td>small, thin walled glands undeveloped</td>
</tr>
<tr>
<td>Jan. 24, 1948</td>
<td>3250</td>
<td>many maturing follicles</td>
<td>large glands, well developed</td>
</tr>
<tr>
<td>Feb. 15, 1948</td>
<td>3550</td>
<td>few maturing follicles</td>
<td>moderate development of uterus and glands</td>
</tr>
<tr>
<td>Feb. 15, 1948</td>
<td>3750</td>
<td>Graafian follicles</td>
<td>uterus large, glands well developed</td>
</tr>
<tr>
<td>Feb. 24, 1948</td>
<td>3250</td>
<td>6 (1 &amp; 5) corpora lutea</td>
<td>6 (3 &amp; 3) implanted embryos</td>
</tr>
<tr>
<td>Feb. 26, 1949</td>
<td>3250</td>
<td>Graafian follicles</td>
<td>large, glands well developed</td>
</tr>
<tr>
<td>Feb. 26, 1949</td>
<td>3250</td>
<td>Graafian follicles</td>
<td>large, glands well developed</td>
</tr>
<tr>
<td>Feb. 26, 1949</td>
<td>3250</td>
<td>Graafian follicles</td>
<td>large, glands well developed</td>
</tr>
<tr>
<td>Feb. 29, 1949</td>
<td>3900</td>
<td>Corpora lutea 6 (2 &amp; 4)</td>
<td>unimplanted blastocysts 5 (4 &amp; 1), degenerating ovum 1 (0 &amp; 1)</td>
</tr>
<tr>
<td>Mar. 7, 1949</td>
<td>3250</td>
<td>maturing follicles</td>
<td>large, glands well developed</td>
</tr>
<tr>
<td>Mar. 7, 1948</td>
<td>4200</td>
<td>maturing follicles</td>
<td>uterus and glands moderately developed</td>
</tr>
<tr>
<td>Mar. 13, 1949</td>
<td>3400</td>
<td>highly vascular, Graafian follicles</td>
<td>large, sperm in oviduct</td>
</tr>
<tr>
<td>Mar. 19, 1949</td>
<td>3400</td>
<td>2 sets of corpora lutea, old 5 (3 &amp; 2), new 6 (5 &amp; 1)</td>
<td>resorbing implanted embryos 5 (2 &amp; 3) embryos pronuclei stage 6 (5 &amp; 1)</td>
</tr>
<tr>
<td>Mar. 20, 1949</td>
<td>3300</td>
<td>maturing follicles</td>
<td>uterus moderately developed</td>
</tr>
</tbody>
</table>
# TABLE 4 (continued)

**REPRODUCTIVE CONDITION OF "ACTIVE" FEMALE WATER SHREWS**

<table>
<thead>
<tr>
<th>Date</th>
<th>Elevation</th>
<th>Ovarian condition</th>
<th>Uterus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Old mature females.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar. 20, 1949</td>
<td>3300</td>
<td>Graafian follicles</td>
<td>large, sperm in oviduct</td>
</tr>
<tr>
<td>Mar. 20, 1948</td>
<td>4050</td>
<td>corpora lutea 11 (6 &amp; 5)</td>
<td>unimplanted blastocysts 5 (4 &amp; 1)</td>
</tr>
<tr>
<td>Mar. 21, 1948</td>
<td>4050</td>
<td>maturing follicles</td>
<td>moderately developed</td>
</tr>
<tr>
<td>June 25, 1948</td>
<td>4650</td>
<td>corpora lutea 12 (7 &amp; 5)</td>
<td>fetuses 6 (3 &amp; 3)</td>
</tr>
<tr>
<td>July 13, 1948</td>
<td>3300</td>
<td>corpora lutea 9 (5 &amp; 4)</td>
<td>no embryos resorption debris ?</td>
</tr>
<tr>
<td>July 27, 1948</td>
<td>3300</td>
<td>old corpora lutea 11 (5 &amp; 6) new corpora lutea 6 (1 &amp; 5)</td>
<td>unimplanted blastocysts 5 (0 &amp; 5)</td>
</tr>
<tr>
<td>Aug. 13, 1948</td>
<td>6000</td>
<td>corpora lutea 12 (8 &amp; 4)</td>
<td>no embryos resorption debris ?</td>
</tr>
<tr>
<td><strong>Young mature females.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 18, 1948</td>
<td>6950</td>
<td>many maturing follicles</td>
<td>medium development</td>
</tr>
<tr>
<td>June 25, 1948</td>
<td>4650</td>
<td>corpora lutea 4 (1 &amp; 3)</td>
<td>unimplanted blastocysts 1 (0 &amp; 1)</td>
</tr>
</tbody>
</table>
A second pregnant animal was taken February 29, 1948. This animal had 6 corpora in the ovaries and 5 unimplanted blastocysts were seen in the uterine lumina. (Figure 17). In addition a degenerating ovum was found. (Figure 18). Degeneration was sufficiently advanced so that it was impossible to determine whether or not this ovum had been fertilized. On March 20, 1948 a third pregnant animal was obtained in which 11 corpora were present and five unimplanted embryos were found in the uterus. (Figures 30 and 31). The uterine glands were not well developed and the uterus was thin walled. These observations in addition to the weak development of mammary tissue are interpreted to indicate that this animal was probably in its first pregnancy. A second animal taken the following day was not yet pregnant. Unlike in Sorex araneus (Brambell 1935) there is no fibrous connective tissue stratum between the mucosa and muscularis of the nonparous uterus which disappears during the first pregnancy. No other clearly demarcated difference has been found between the parous and nonparous uterus, thus it is difficult to say with certainty that these specimens had not previously bred.

A specimen which was taken June 25, 1948 had 6 near term fetuses. The mammary glands were highly developed and contained milk as determined by histological examination. An animal with five unimplanted blastocysts of small size (Figure 19), was taken July 27, 1948. In this specimen two distinct kinds of corpora lutea were found, one set being large with cells of large size while the other set was small and degenerating. (Figure 20). Unfortunately in this critical specimen no mammary tissue was preserved and neither was the gross appearance of the gland recorded. The two sets of corpora may be interpreted to indicate: (1) pregnancy following a post
partum heat; (2) the persistence of corpora from an earlier pregnancy; (3) or corpora resulting from a previous spontaneous ovulation not resulting in pregnancy. Brambell (1935) determined that in Sorex araneus the corpus of pregnancy disappears approximately at parturition and he found no regressing corpora persisting after the 2 cell stage of a pregnancy following post partum heat.

From the series of pregnant animals available it was possible to determine the appearance of corpora lutea during various stages of pregnancy. (Figures 21-24). Corpora in the two specimens with implanted embryos appear more compact than those from animals having unimplanted embryos. This appearance is caused by the smaller size of the luteal cells within the corpora of implanted specimens as well as the grossly smaller size of the corpora.

The reproductive tracts of two specimens are difficult to analyze with any degree of certainty. These two, as listed in Table 4, are specimens in which relatively fresh corpora lutea were found but no embryos were recovered in the uterus. The corpora of both of these tracts appeared to be similar to those of preimplantation specimens. In both of these specimens the mammary glands were actively lactating. Thus the animals seem to be lactating animals which had recently ovulated but were not pregnant. It is possible that these animals contained unimplanted embryos which were lost in the histological preparation of their uteri, but this seems improbable since blastocysts were recovered from other specimens prepared in the same manner. Corpora may have resulted from spontaneous ovulation. However, in all Soricidae, in which ovulation has been studied, it has been found that ovulation occurs only upon stimulus of copulation.
Pearson (1944) demonstrated that with Blarina repeated copulation was necessary to induce ovulation. That this situation obtains in the water shrew is suggested by the several specimens having sperm in the reproductive tract but which had not ovulated. The corpora may indicate pseudo-pregnancy although this seems improbable. Perhaps the most probable explanation is that fertilization occurred followed by resorption of the embryos. Debris in the uterine lumina resembling debris of resorption was found in the uteri of both specimens.

An animal taken March 19, 1949 presents a most interesting condition. When autopsied, this animal appeared to be pregnant since 5 small swellings in the normal antimesometrial position were seen in the uterus. However, after the uterus was sectioned the embryos were found to be resorbing. (Figure 25). Characteristic implantation modifications of the uterine wall were seen in sections through the sites but the embryos were degenerating. Resorption debris and embryonic cells occurred in the lumen of the uterus and only a few embryonic cells (remnants of the trophoblast) were applied to the uterus in these areas. The ovaries of this specimen contained two sets of corpora, one set of 5 of same age (Figure 26) and a second set of 6 obviously very recent containing a central cavity. (Figure 21). In the oviducts a second set of embryos were found, all of which are in the pronucleus stage. (Figure 27). Thus the specimen had one set of resorbing implanted embryos and a second set of unimplanted embryos in the pronucli stage.

In the mink, *Mustela vison*, which ovulates only by stimulation of copulation, it has been demonstrated that following the first ovulation a second series of copulations will induce a second group of ovulations.
(Hanson, 1947). This will occur only if the second series of copulation follows the previous by more than 6 days. Under these circumstances usually the first group of embryos is lost before implantation and the second group is retained. The second set of matings and ovulations seems to be possible because of an inactive stage of the corpora lutea which occurs prior to implantation. In the water shrew no such inactive stage of the corpora is seen and in this instance implantation had occurred. It would seem that this represents an atypical situation in the water shrew, the mechanics of which are not apparent from this study.

From the study of reproduction in the adult female, only a few conclusions seem warrantable. It is apparent that the breeding season extends over a considerable period of time since pregnant animals were taken between February and July. Also since all old females taken from the end of March until mid-August were either pregnant or lactating, it seems probable that several litters are produced during the course of the breeding season. In the present study, each of two specimens with normal implanted embryos contained 6 embryos. In 12 records from various sources, (Long, 1940; Grinnell and Storer, 1924; Borell and Ellis, 1934; Jackson, 1920; Hall, 1946; Warren, 1942) from 5 to 8 embryos have been recorded with 6 being the most common number.

The material from young females presents two sharply contrasting conditions. The majority of the specimens had ovaries which were completely inactive as previously described. However, two young females taken in June indicate reproductive activity. The first of these is a specimen taken June 18, 1948. This was a very small individual weighing 8.5 grams and measuring only 133 millimeters in total length. The toothwear number is
5325, one of the highest recorded. All of these facts indicate this specimen was quite young, yet both ovaries and uterus were active, (Figure 28) being comparable to old specimens taken in late January and February. The ovaries contained many maturing follicles and the uterus was well developed with prominent glands.

The second specimen, taken June 25, 1948 was pregnant. Four corpora were found in the ovaries and one unimplanted blastocyst was recovered from the uterus. This embryo is in a late cleavage stage. (Figure 29). Mammary tissue was abundant but microscopically differentiation of the lobule-alveolar system was found to be in an early stage. From this and from the appearance of the uterus it was concluded that the animal was in its first pregnancy.

The remainder of the young specimens taken throughout the summer and autumn were reproductively inactive. It is unfortunate that only one July and one August specimen was available, both of which were very young and showed no activity. With the collection of additional spring and summer young, the significance of breeding in young females can be more accurately determined. Brambell (1935) found Sorex araneus to be non-breeders. However, since his method of age determination was based upon weight there would seem to be some doubt as to the validity of this conclusion. In Blarina, Pearson (1944) found evidence of breeding in the early born young females. It would seem that this might also be the situation in the water shrew. However, at the present time it is impossible to determine the prevalence of breeding in the young females.
FOOD HABITS

The stomach contents of 59 water shrews were analyzed in an effort to obtain some knowledge of the food habits of the species. The contents of these stomachs were chiefly a mass of finely divided food particles and fragments of chitin. All stomachs examined contained some material, the amount varying considerably in individual stomachs.

To prepare the stomach contents for study each stomach was removed from the formalin in which it was preserved, opened, and the contents placed in a vial. Dioxan was added to the vial and this mixture was vigorously agitated to separate all particles. After the particles were dehydrated, the dioxan was decanted away and the stomach contents mounted in Canada balsam. The particles were then examined under a binocular microscope of magnifications of 9, 18, and 27 powers.

Since the material was in a finely divided and fragmented condition it seemed impossible to obtain any reliable quantitative data. Therefore, all material which could be identified in each stomach was listed and the number of stomachs in which each class of food appeared computed to obtain the frequency of occurrence. Insect remains could be recognized by wings, fragments of appendages, tracheal tubes and fragments of exoskeleton. However recognition of the order of insects represented was in many cases impossible. A reference collection of common aquatic insects was prepared and used for study and comparison in an effort to identify the remains of aquatic forms. Identification of aquatic insects was based upon the occurrence of characteristic gills and appendages.

The results of the analysis of stomach contents are tabulated in Table 5. Undoubtedly certain classes of food items were completely or
frequently overlooked. The results do, however, provide at least an indication of some foods of the water shrew.

**TABLE 5**

**ANALYSIS OF 59 STOMACHS**

<table>
<thead>
<tr>
<th>Food Class</th>
<th>Number of Stomachs</th>
<th>Percentage of Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insect</td>
<td>58</td>
<td>98.3</td>
</tr>
<tr>
<td>Tipulidae larvae</td>
<td>5</td>
<td>8.5</td>
</tr>
<tr>
<td>Aquatic insects</td>
<td>28</td>
<td>47.4</td>
</tr>
<tr>
<td>Flecoptera larvae</td>
<td>6</td>
<td>11.7</td>
</tr>
<tr>
<td>Trichoptera larvae</td>
<td>19</td>
<td>32.2</td>
</tr>
<tr>
<td>Ephemerida larvae</td>
<td>10</td>
<td>16.9</td>
</tr>
<tr>
<td>Simuliidae larvae</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>Chironomidae larvae</td>
<td>3</td>
<td>5.1</td>
</tr>
<tr>
<td>Arachnida</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>5</td>
<td>8.5</td>
</tr>
<tr>
<td>Sorex hair</td>
<td>3</td>
<td>5.1</td>
</tr>
<tr>
<td>Fish scales</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>Vegetable matter</td>
<td>15</td>
<td>25.4</td>
</tr>
</tbody>
</table>
It is apparent that the water shrew is primarily insectivorous. The high frequency with which aquatic organisms are encountered (47% of the stomachs) is of interest since it is indicative that a considerable portion of the food is obtained in the water. This would seem to be expected in a form which is highly specialized for aquatic existence as is the water shrew, but Hamilton (1930) in a study of 13 stomachs of *Sorex palustris albibarbis* found aquatic organisms in only 3 stomachs and concluded that food was obtained largely from land. By bulk he found these stomachs to contain 78% insect material, 4.4% planaria, 3.1% plant and 13% undetermined.

Mammalian hair and skin appeared in only 3 stomachs and in each case this was the remains of shrews. In one instance the specimen containing shrew hair was taken about ten feet from a second partially eaten water shrew. In the other two stomachs there was no evidence to indicate the species of shrew from which the hair came. Small fish scales occurred in one stomach, whether or not this represented carrion could not be determined.

Although vegetable material was found in 15 stomachs it made up a very small proportion of the contents in each instance. It seems probable that much of this may have been ingested inadvertently during the course of feeding on other material.

From the study of food habits as shown by stomach contents it appears that insects are quantitatively the most important food of the water shrew. It is also apparent that larvae of aquatic insects are taken very frequently. Experiments with a captive water shrew demonstrated that the animal was capable of taking small fish in an aquarium with ease. Under these artificial conditions, however, the fish were probably more easily taken than under natural conditions. One account of a water shrew capturing a small
fish under natural conditions has been published (Lampman, 1947). Therefore it would seem that while the water shrew may occasionally take small fish they do not constitute an important food source.
PARASITES

The water shrew is remarkably free from parasites. Ectoparasites were found on but a small percentage of the 62 specimens examined. Only a few parasites were found upon those animals which were infested (Table 6). A single flea was obtained on each of two different water shrews. These fleas have been identified by Mr. G. M. Kohls as *Nearctopsylla hyrtaci* and are the first United States record of the flea which had previously been recorded from various hosts in British Columbia (Kohls-in press). Several species of mites were also found as indicated in Table 6. In no instance was any detrimental effect resulting from parasitism by ectoparasites apparent.

Final determination of three of the four forms of endoparasites collected has as yet not been completed. The most frequently encountered endoparasites were Nematodes of the genus *Capillaria* occurring in the urinary bladder and the stomach. The form from the urinary bladder has been identified as *Capillaria incrassata*, while the species of the stomach *Capillaria* has not been determined. In addition, a Nematode of the genus *Porrocecum*, similar to *Porrocecum incapsulatum* which commonly occurs in *Blarina brevicauda*, was found in the subcutaneous fascia of several specimens. A large number of plerocerci of the genus *Ictrathyridium* were found in the abdominal and pleural cavities of one specimen. As with the ectoparasites, there was no visible deleterious effect produced by any of the endoparasites.

In Table 6 the parasites are listed with their percentage of occurrence in the 62 specimens examined, previously recorded hosts, and the identifying authority. Since no parasites of the water shrew have previously been recorded, all parasites listed are new host records. Ectoparasites were sent
### TABLE 6

**PARASITES OF THE WATER SHREW**

<table>
<thead>
<tr>
<th>Parasite</th>
<th>Percentage of 62 shrews infested</th>
<th>Previously recorded hosts</th>
<th>Identifying authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flea</td>
<td>3.2</td>
<td>Sorex obscurus</td>
<td>G. M. Kohls</td>
</tr>
<tr>
<td><em>Nearctopsylla hyrtaci</em></td>
<td></td>
<td>Mustela vison</td>
<td></td>
</tr>
<tr>
<td>Kite</td>
<td>3.2</td>
<td>Sorex sp.</td>
<td>E. W. Jameson</td>
</tr>
<tr>
<td><em>Hirstionyesus sp.</em></td>
<td></td>
<td>Blarina</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cryptotis</td>
<td></td>
</tr>
<tr>
<td>Mite</td>
<td>1.6</td>
<td>?</td>
<td>H. L. Keegan</td>
</tr>
<tr>
<td><em>Euhaemogamasus</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>liponyssoides</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mite</td>
<td>1.6</td>
<td>?</td>
<td>H. L. Keegan</td>
</tr>
<tr>
<td><em>Euhaemogamus nidi</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nematode</td>
<td>43.5</td>
<td>Sorex araneus</td>
<td>M. L. Kuns</td>
</tr>
<tr>
<td><em>Capillaria incrassata</em></td>
<td></td>
<td>Sorex vagrans</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sorex cinereus</td>
<td></td>
</tr>
<tr>
<td>Nematode</td>
<td>29.0</td>
<td>?</td>
<td>M. L. Kuns</td>
</tr>
<tr>
<td><em>Capillaria sp.</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nematode</td>
<td>6.4</td>
<td>Blarina brevicauda</td>
<td>M. L. Kuns</td>
</tr>
<tr>
<td><em>Porrocareum sp.</em></td>
<td></td>
<td>Sorex vagrans</td>
<td></td>
</tr>
<tr>
<td>Cestode plerocerci</td>
<td>1.6</td>
<td>Crocidura mucina</td>
<td>M. L. Kuns</td>
</tr>
<tr>
<td><em>Tetrathyridium sp.</em></td>
<td></td>
<td>Desmana mosehata</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Talpa euroraca</td>
<td></td>
</tr>
</tbody>
</table>
to Mr. G. M. Kohls of the U. S. Public Health Service and through his efforts final identification was obtained by various authorities. Mr. M. L. Kuns of Purdue University is examining the endoparasites.
DERMAL GLANDS

Sexually active male water shrews possess dermal glands located in the skin on each side of the body midway between the fore and hind legs. Only the sexually active males have such glands. This seems to be a unique situation since in all other species of Soricidae in which skin glands have been noted, they occur in both sexes, although they may be less prominent in the females (Pearson 1946). Side glands were not visible in sexually immature male water shrews. They were first noted in specimen collected December 6, 1947, whose testes weighed 64.8 mg. However, in a male collected December 5, 1948 whose testes weighed 10.8 mg. the glands could not be detected. In those animals obtained during January 1948 which had testes weighing less than 100 mg., side glands were observable but not prominent. In all animals in full spermatogenesis the glands were very prominent both externally and internally on the skin. When the glands became fully developed, short white hair grew from them, thus producing an oval patch of white hair on the animal's sides, approximately 6 mm. long. This hair was oily in appearance and matted together. The pronounced odor of the water shrew seemed to be produced at least in part in the region of these glands. Cotton rubbed across the oily hair covering the glands smelled strongly, while, when rubbed across hair in other regions, it had no odor. Pearson (1946) concluded that the odor of Blarina was also produced by the dermal glands..........................
MOLTS

The molts of the water shrew have been briefly discussed by Jackson (1928). He describes two molts, one occurring in the spring and the other in the early autumn or late summer. From the limited number of spring specimens available to him he concluded that the spring molt occurred in May or June. The fall molt usually occurred in August or September, according to his description.

Since in the present study spring specimens were available it was possible to follow the spring molt more closely. The summer pelage is more brown in color than the winter pelage and thus the two pelages may be distinguished. The spring molt begins on the rostrum of the animal and progresses posteriorly, the flanks and base of the tail being the last region to acquire summer pelage.

In Table 7 an attempt has been made to summarize the molt condition of specimens obtained during the winter and spring. From these data it is apparent that considerable variation occurs in the time when the molt begins, as a specimen taken February 12, showed the beginning of the molt, while individuals which had not yet begun to molt were taken on April 2. The large number of specimens obtained in the same stage of molt (that is, summer pelage on the rostrum only) is suggestive that the onset of the molt may be rather slow, this stage persisting for a considerable period of time. With the collection of additional spring specimens the terminal phases of this molt should become more clearly understood. Molt on the venter is difficult to distinguish since the two pelages are very similar in that region.

In discussing the autumnal molt, two groups of animals must be considered. These are the young of the year and the old animals. Only two
<table>
<thead>
<tr>
<th>Period</th>
<th>No. of Specimens</th>
<th>Condition of Molt in Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 1-15</td>
<td>2</td>
<td>2 complete winter pelage</td>
</tr>
<tr>
<td>January 16-31</td>
<td>4</td>
<td>4 complete winter pelage</td>
</tr>
<tr>
<td>February 1-15</td>
<td>3</td>
<td>3 summer pelage on rostrum</td>
</tr>
<tr>
<td>February 16-28</td>
<td>8</td>
<td>3 summer pelage on rostrum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 entire head in summer pelage</td>
</tr>
<tr>
<td>March 1-15</td>
<td>4</td>
<td>2 summer pelage on rostrum</td>
</tr>
<tr>
<td>March 16-31</td>
<td>12</td>
<td>3 summer on rostrum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 head and shoulders molted</td>
</tr>
<tr>
<td>April 1-15</td>
<td>5</td>
<td>1 head in summer pelage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 rostrum in summer pelage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 complete winter pelage</td>
</tr>
<tr>
<td>April 16-30</td>
<td>1</td>
<td>1 head in summer pelage</td>
</tr>
<tr>
<td>May 1-15</td>
<td>1</td>
<td>1 all summer pelage except flanks which were in winter pelage</td>
</tr>
<tr>
<td>May 16-31</td>
<td>1</td>
<td>1 all summer pelage except flanks which were in winter pelage</td>
</tr>
<tr>
<td>June 1-15</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>June 16-30</td>
<td>2</td>
<td>2 in summer pelage</td>
</tr>
</tbody>
</table>
young animals are available which show the autumnal molt. The first of these is a specimen captured August 17 which is in complete winter pelage with the exception of a 12 mm. wide band of summer pelage extending across the head just anterior to the ears. The rostrum of this animal is in winter pelage. The second specimen showing molt is a captive animal which died in early September. A small patch of winter hair is apparent on each flank while the remainder of the body is in summer pelage. Other specimens taken August 17 and August 19 are in complete summer pelage as are all young taken earlier. Specimens captured September 18 and September 19 are in complete winter pelage.

The molt in old animals is visible in five specimens. A specimen secured July 6 is in complete summer pelage. Two specimens taken July 13 and 16, respectively, each have small patches of winter hair on the rostrum with the remainder of the body in summer pelage. A specimen secured July 28 has the sides and rostrum molted to winter with the remainder of the body in summer pelage. Two specimens collected on August 14 have winter hair on the flanks and back and on the rostrum with the remainder of the body summer fur. These are the last old animals obtained.

It would seem that the molt to winter pelage occurs in both old and young animals chiefly during late July and August. This apparently represents the first molt that young animals undergo. The growth of new hair begins on or near the flanks and spreads anteriorly from this center. A separate center develops upon the nose. The last area to molt is thus the region of the head between the ears.

In a study of molting in *Sorex vegrane* Dalquest (1944) found that the spring molt occurred between March and May with a high degree of individual
variability as to the time when it began. This molt was first evident between the shoulders and spread from that area over the body. The autumn molt occurred in October, beginning on the rump and later a second center developed on the nose as in the water shrew. An anomalous molt during mid-summer during which the summer pelage was replaced by a new summer pelage, was noted in three specimens.

The molts of the water shrew are very similar to those of *Sorex vagrans*. However in the water shrew, the spring molt begins on the rostrum rather than on the shoulders. Considerable irregularity as to the time of occurrence of this molt in both species is apparent. The mode of progression of the autumn molt is similar in both *Sorex vagrans* and *Sorex palustris* although the months of occurrence differ. In the water shrew no indication of an anomalous mid-summer molt was seen.
The water shrew appears to be a rather secretive animal, remaining under the cover of overhanging banks and debris much of the time. As has previously been discussed, the majority of specimens were secured from traps placed in such situations. During the study I have seen only four individuals alive. Three of these were along the water's edge under cover of overhanging banks and were observed for only a few seconds before they disappeared from sight. The fourth animal was seen running along the bank of a small stream. It plunged into the water between tree roots, then disappeared from sight. A few seconds later it reappeared, coming out of the water on to the bank at my feet. It started to run along the edge of the bank when it was captured alive by hand.

In habitat where the water shrew was abundant ordinarily no indication of its presence was noted. I have seen tracks on the snow only on one occasion although many specimens have been taken under conditions which would have made tracks inevitable had the shrews been active upon the surface of the snow. During the winter the habits of the water shrew seem to be as in other seasons, with the majority of the activity confined to banks of streams. In the region where the shrews were collected during the winter, streams do not freeze solid although shelf ice forms along the banks or over the entire stream. When water levels drop a space remains between the bottom of the shelf ice and the water's surface. Many winter specimens were secured along stream banks under such shelf ice.

In one instance four feces were found upon a small rock exposed above water several inches from the edge of an overhanging bank. These feces appeared to be those of a water shrew, so several traps were place beneath
the bank. The next day a specimen was obtained at this site, lending support to the belief that the feces were those of a water shrew. This instance and the one occurrence of tracks are the only occasion upon which any "sign" of the water shrew was found.

The specimen which was captured alive was maintained in captivity between July 12, 1948 and early September 1948, when it died of undetermined causes. This animal was a young male. During the period it remained in captivity it was housed in a ten gallon aquarium. One to two inches of water was kept in the aquarium with rocks and bark placed in one end to provide a dry area for the shrew. Water was changed five or six times daily, fresh cold spring water being used to refill the aquarium since it was apparent that the shrew became highly agitated whenever the temperature in the aquarium became warm. A small piece of dry cotton was kept on the rocks. This was utilized by the shrew and it spent much of the time concealed in the cotton although no attempt to construct a definite nest was noted.

The animal was active intermittently during the day and night, but only for short periods. After a period of activity it would retreat to the cotton presumably to sleep before becoming active again. While moving about it would often simply stop and fall asleep in a crouched position. On several occasions when this happened it was seen to fall from a rock into the water. Davis (1939) states that the water shrew is nocturnal. However the behavior of the captive specimen, the observation of other individuals during the day, and also the fact that five specimens were known to have been trapped during the day indicates the water shrew is active both during the day and the night.
The behavior of the water shrew in the water and the manner in which it swims has been described by Jackson (1928) and by Svihla (1934) who maintained a specimen in captivity for several weeks. Further elaboration of this seems needless since my observations concur with these descriptions.

Sight seems to be poorly developed while smell and probably tactile senses are important. When small minnows were placed in the water the shrew would rush about on the rocks, stopping frequently to elevate the nose as if scenting. (Figure 10) It would then plunge into the water and swim beneath the surface. If the fish were not moving the shrew apparently experienced difficulty in locating them and it would frequently bump into them seemingly by accident. However, if the fish were swimming the shrew had little difficulty in finding and following them. This is suggestive that tactile senses might be important under such circumstances.

Svihla (1934) found that his captive animal was unable to capture minnows even after touching them. The specimen I maintained in captivity caught small minnows up to 6 cm. in length. When 8 or 10 such minnows were placed in the aquarium the shrew would capture one in the water and bring it to the rocks. The shrew, using its incisors, would bite the fish through the head to kill it. Usually the first minnow would be eaten immediately. However after that the shrew would continue to catch and kill the fish until none were left. Each one caught would frequently be brought to the same place where it would be killed and deposited, thus a number of minnows would be piled together.

The remarkable resistance of water shrew hair to wetting is well known. Frequently though, after several minutes of activity in the water the hair would begin to wet. When this occurred the animal would dry its fur by
rapidly and thoroughly working over its body with the hind feet. (Figures 6 and 7). During this process fine droplets of water would be thrown off. The process would last for 10–30 seconds after which the hair was dry. The marginal vibrissae of the feet, which are well developed in this species, seemed to facilitate this operations, functioning almost as a comb.

The captive specimen was fed largely fish, although it ate mice, insects, and any meat offered. It was not seen to eat any vegetable material. During several 24 hour periods an excess of food was placed in the aquarium to determine the quantity which was eaten. For four consecutive days the average food consumption was 10.3 grams of meat or fish for each 24 hour period; 5.1 grams were consumed between 8:30 a.m. and 8:30 p.m. and 5.2 grams between 8:30 p.m. and 8:30 a.m. The body weight of this specimen was probably about 10 grams. Food consumption of various species of shrews has been recorded and it is well known that daily food intake of some species is greater than their body weight. Thus in a 24 hour period, the Turkestan desert shrew (Diplopesodon pulchellum) weighing 10 grams consumed 10–17 grams of food (Heptner, 1939) a 5 gram Cryptotis floridana consumed 5.5 grams of food (Springer, 1937) and a captive Sorex cinereus consumed 3.3 times its own weight (Blossom 1932). Svihla (1934) records that his captive Sorex palustris ate "a dead Microtus, a dead Zapus, each of which weighed more than the shrew, besides several snails, all within 24 hours."
SUMMARY

This study was based upon 62 water shrews taken in Montana, west of the Continental Divide. These specimens were collected with back breaker mouse traps, baited with a mixture of peanut butter and anise oil. The majority of specimens were secured along streams in the Canadian zone at elevations of 3100 to 6950 feet. All specimens were taken very close to the edges of streams and most frequently in traps placed beneath overhanging banks and within a few inches of the water.

A system of age determination based upon measurements of individual teeth to determine toothwear was developed. Application of this method indicated that no specimens in the sample had lived beyond the end of the summer following the one in which they were born. Thus the maximum age of any specimen obtained would not be in excess of 18 months. The standard measurements are given for each sex of the water shrew and when these were analyzed by a "t" test, no significant differences between the sexes were found.

Male water shrews were not sexually active during the breeding season in which they were born. The following December and January the onset of spermatogenesis began, at which time an increase in body weight was apparent. All males born the previous year taken between January and August were in active spermatogenesis. Reproductively active females were taken between February and August. Some young females, probably those produced early in the breeding season, bred during that same breeding season. The majority of breeding females, however, are those born the preceding season. Several litters are probably produced each year with the average number of young per litter being six.
The food of the water shrew is largely insects and 47% of the stomachs examined contained larvae of aquatic insects. This would indicate that much of the water shrews' food comes from aquatic sources. Eight species of parasites of the water shrew were found, all of which are new host records. Dermal glands were found in only sexually active males.

Two annual molts occur, one during the spring between February and May and one in the autumn during July and August.

A specimen was maintained in captivity for seven weeks. This animal was capable of capturing small minnows in the water. The average food consumption of the captive was 10.3 grams of food during a 24 hour period.
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Figure 5

Individual tooth measurements taken on each shrew skull to obtain toothwear number. Red lines joining bars indicate line of measurement. 15X.
Figures 6 & 7

Sketches showing use of hind foot to aid in drying fur. Approximately natural size.

Figure 8

Characteristic pose and use of fore feet to clean vibrissae. Approximately natural size.

Figure 9

Method of eating small fish. Approximately natural size.

Figure 10

Pose frequently assumed when attempting to locate food or source of disturbance. Approximately natural size.
Figure 11

Natural habitat of the water shrew, Rattlesnake River, 4 miles north of Missoula, Montana, April 20, 1949. Specimen CHC No. 177 was obtained April 16, 1949 in a trap placed along the water's edge at the site indicated by arrow.

Figure 12

Natural habitat, Rattlesnake River, 4 miles north of Missoula, Montana, April 20, 1949. Specimen CHC No. 178 was taken April 16, 1949 in a trap placed beneath tree roots, at site indicated by arrow.
Figure 13

Typical artificial stone wall habitat along Rattlesnake River, Greenough Park, Missoula, Montana, February 27, 1949. Specimen CHC No. 147 was taken the preceding day in a trap set in the crevice indicated by arrow.

Figure 14

Log retaining wall, Rattlesnake River, Greenough Park, Missoula, Montana, February 27, 1949. Specimen CHC No. 148 was taken the same date in a trap placed under lower log on a small stone. Arrow indicates site.
Figure 15

Ovary of young female. CHC No. 134 taken September 18, 1948. The small size and dense appearance are characteristic of late summer and autumn young females. Only early stages of follicular development are seen. Small interstitial cells are abundant. 66X.

Figure 16

Section through uterus and embryo of M.S.U. No. 680 taken February 24, 1948. This animal contained six embryos in the neural crest stage. Embryo in Figure 16 has been cut in cross section and the neural crest is visible. 66X.

Figure 17

Unimplanted blastocyst from M.S.U. No. 685 taken February 29, 1948. Five blastocysts were found in similar stages of development. 167X.

Figure 18

Degenerating ovum from uterus of M.S.U. No. 685 (Figure 17). In addition to the blastocysts the single ovum degenerating and apparently unfertilized was found. Note degenerative changes of cytoplasm and zona pellucida. 167X.

Figure 19

Blastocyst from CHC No. 110 taken July 28, 1948. 167X.

Figure 20

Ovary of CHC No. 110 taken July 28, 1948. Two sets of corpora lutea are visible. Two relatively fresh corpora, characterized by large size and large cells, are seen at the left while three old degenerating corpora of small size are indicated by arrows. 66X.
Figure 21

Ovary of CHC No. 152 taken March 19, 1949. The ovaries of this specimen contained two sets of corpora lutea. Degenerating, implanted embryos and unimplanted embryos in the pronucleus stage were found. In the figure a very recent corpus luteum is visible. Note antrum. 66X.

Figure 22

Ovary of M.S.U. No. 743 trapped June 25, 1948. This specimen was a pregnant young female containing an unimplanted blastocyst. Two corpora are visible in the section shown. No antra are seen as in Figure 21, but the corpora have large cells and are highly vascular. 66X.

Figure 23

Ovary of M.S.U. No. 680 taken February 24, 1948. The specimen contained six embryos in the neural crest stage. A decrease in cell size and vascularity of the corpus shown is apparent when compared with Figure 22. 66X.

Figure 24

Ovary of M.S.U. No. 740 taken June 25, 1948. This specimen contained six near-term fetuses. Three corpora are seen in the figure. Note avascularity and reduced cell size. 66X.

Figure 25

Resorbing embryo in the uterus of CHC No. 152 (See description of Figure 21 for data). Resorption debris is seen in the uterine lumen and several large embryonic cells (indicated by arrow) are still visible at the implantation site. 66X.
Figure 26

Degenerating corpora in the ovary of CHC No. 152 (See description of Figure 21 for data). 66X.

Figure 27

Ovary of young female. M.S.U. No. 735 taken June 19, 1948. Maturing follicles are apparent. Compare with inactive ovary from young female taken in autumn. 66X.

Figure 28

Blastocyst from young female. M.S.U. No. 743 trapped June 25, 1948. Corpora were found in the ovaries of this specimen and the one blastocyst figured was seen in the uterus. 66X.

Figure 29

Pre-ovulatory ovary from CHC No. 150 taken March 13, 1949. Sperm was present in the oviducts and within the ovarian capsule. Note vascularity of the follicles. 66X.

Figure 30

Blastocyst in uterus of M.S.U. No. 688 trapped March 20, 1948. Five blastocysts were found in the uterus. Note inner cell mass. 167X.

Figure 31

Blastocyst in uterus of M.S.U. No. 688. This blastocyst represents an earlier developmental stage than that shown in Figure 30. Note large size of cells. 167X.