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Title The Life History and Ecology of Townsend's Mole Scapanus townsendii (Bachman) in Tillamook County Oregon

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Townsend's mole, Scapanus townsendii (Bachman), was studied by live trapping, dead trapping, and observation from July 1961, to July 1963, in Tillamook County, Oregon. This study was initiated at the request of Tillamook County farmers to determine biological facts that would assist them in their efforts to control this small burrowing mammal.

The mole's diet consists of 72 percent earthworms and 28 percent roots. Seventy-nine percent of the stomachs examined contained from 200 to 4,000 milligrams of earthworms. One stomach contained 100 percent slugs and six stomachs contained traces of insect skeleton. Eighteen percent of the stomachs examined contained "root-balls."

Townsend's mole mates during February and March and the young are born during March and April. The average litter size is three, though litters of two are common. Prenatal litter size compares closely with nest litter size. Young moles weigh approximately five grams at birth and develop to sub-adult weight of 80 grams, $\pm$ five grams, in about 30 days, at which time they leave the nest. Adult males averaged 141.65 grams in weight and adult females 119.03 grams.

Forty-three nests containing young were located and examined. Three general forms of nest mounds were found. These were the fence post mound, the large single mound, and the aggregate mound.

Primary predators of this mole are domestic dogs and cats. Juvenile moles are killed by cattle stepping on the nests and sub-adults are killed by cars on roads during dispersal.

Two similar fields, differing in amount of fertilizer applied, were dead trapped to compare mole numbers. The smaller field, which received twice as much manure as the larger, produced 72 moles or 4.8 per acre. The larger field produced 52 moles or 2.6 per acre.

Four species of fleas, a single species of ticks, and mites of the suborder Mesostigmata were found on the Townsend mole.

THE LIFE HISTORY AND ECOLOGY OF TOWNSEND'S MOLE *SCAPANUS TOWNSENDII* (BACHMAN) IN TILLAMOOK COUNTY OREGON

by

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Thanks are due my wife, Audrey, as a competent laboratory technician she performed many exacting tests, which added to the strength of this paper.

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THE LIFE HISTORY AND ECOLOGY OF TOWNSEND'S MOLE *SCAPANUS TOWNSENDII* (BACHMAN) IN TILLAMOOK COUNTY OREGON

INTRODUCTION

This thesis presents the results of a two year field investigation of the life history and ecology of Townsend's mole, *Scapanus townsendii* (Bachman), in Tillamook County, Oregon. It began in July, 1961, and continued through June, 1963. Study phases included breeding and nesting habits, movements, food habits, growth, and reproductive potential. Incidental information has been gathered on parasites, mortality factors, hematology, and urology.

Moles have long been recognized in western Oregon as serious pests to farmers and home gardeners. The heaviest populations of moles in the state occur in the coastal counties, particularly Tillamook County, where soil conditions, fertility, and other factors are favorable. Damage to pastures and field crops in this important dairy area is due primarily to the many mounds of dirt pushed up by the extensive burrowing activities of these animals. These mounds cover desirable pasture grasses and legumes, make ideal seed-beds for weeds and undesirable grasses,

make pastures rough and uneven, slow harvesting operations, and frequently result in breakage of mowing and other harvesting equipment. Following the introduction of new and better types of farm equipment, particularly the "flail" type forage harvester, the mole problem was brought into sharp focus. Mounds of dirt picked up by these close cutting harvesters are pulverized and mixed into the silage, making it unpalatable to livestock and inhibiting proper curing. Mounds in hay fields make clean mowing impossible and result in considerable waste forage and equipment breakdowns.

Individual farmers have carried out successful control campaigns against moles in Tillamook County for many years. Community wide control programs have also been attempted from time to time, but usually have been terminated before any appreciable permanent results were obtained.

In 1959, members of the Nestucca Grange of Tillamook County asked the Pomona Grange and the Agriculture Planning Council for help on the mole problem. The council recommended that the Oregon State University Extension Service be requested to undertake an educational program in the county to demonstrate mole control methods and promote their use. The Extension Service began this program

in May, 1960, but after a short time found that many basic facts concerning the biology and habits of this burrowing mammal were unknown. To carry out an effective control program such facts were needed. In December, 1960, the Mole Control Advisory Committee, appointed by the Agriculture Planning Council to work with the Extension Service, submitted a formal request to the Oregon State University Agriculture Experiment Station to initiate a research program on the life history and ecology of the mole in Tillamook County. In July, 1961, the project was initiated and financed by the Experiment Station.

HISTORY

Five genera of moles in the family Talpidae are indigenous to North America. Scapanus and Neurotrichus are found only on the Pacific slope; Scalopus, Parascalops and Condylura only on the Atlantic slope. This family has been divided into five subfamilies of which two, Scalopinae and Condylurinae, occur in the new world. The two genera of moles found in Tillamook County, Scapanus and Neurotrichus, are classified in the subfamily Scalopinae.

No reference to American moles appears in the

literature until 1734, when Seba described and illustrated two mammals which he called "Talpa, Virginianus, niger" and "Talpa, rubra, Americana" (9, p. 22). Although it is doubtful as to which animals these names apply, his account clearly illustrates that moles were probably found in America at this time. The first definite knowledge of moles in America comes from Kalm who saw burrows near Philadelphia, Pennsylvania, and later captured one and noted its strength and ferocity (9, p. 22).

Linnaeus described two American moles in 1758, under the names Sorex cristatus and Sorex aquaticus, basing his work largely upon Kalm's work (9, p. 22). From this time on several papers and accounts of the mole appear in the literature. Interest centered on the odd habits, specialized anatomy, and unknown relationships of this animal.

The American Talpidae were confused by early zoologists until 1811, when Illiger based the genus Condylura upon Sorex cristatus (Linnaeus), and the genus Scalops upon Sorex aquaticus (Linnaeus)(9, p. 23). Following this came one of the first important treatments of a genus of American moles by Bachman. He revised the genus Scalops, including in it the genera now known as Scalopus,

Scapanus and Parascalops. The genus Scapanus was proposed by Pomel in 1848 to include Bachman's two species Scalops townsendii and Scalops breweri. The type of the genus Scapanus automatically became Scalops townsendii (Bachman) when True, in 1894, used Scalops breweri (Bachman) as the type for the genus Parascalops (9, p. 23).

In 1896, the distribution and taxonomic relationships of the American moles finally began to be understood. In this year True revised the American moles, recognizing eleven forms among eight species of five genera and describing one new species, Scapanus orarius (True).

The presence of moles in the Pacific Northwest was known to some of the early explorers, but Richardson was the first to accurately describe one. He described the mole now known as Scapanus townsendii, but referred his specimens to the common mole of the eastern United States. It was not until ten years later that this species was named when Bachman published his description, based upon two specimens (9, p. 24).

METHODS

In this study two principal methods were used to collect information. The first included dead trapping, live trapping and associated methods of specimen collection. Included in this category was the locating, digging, and collecting of nests and young during the breeding season. The second method used involved field observations. During this phase, data on the daily and seasonal activities, mortalities caused by accidents and predation, and other incidental facts were collected.

Trapping

Moles were dead trapped throughout Tillamook County (Fig. 1), but the bulk of this work was done within a five mile radius of the city of Tillamook. In this zone the farms are centrally located and more habitat is available to study within a short radius of travel (Fig. 2).

The principal type of dead trap employed was the scissors or "Out-O-Sight," although on occasion the diamond jaw or "Mole Choke" trap was used. The scissors trap (Fig. 3) proved to be very suitable for collecting specimens.

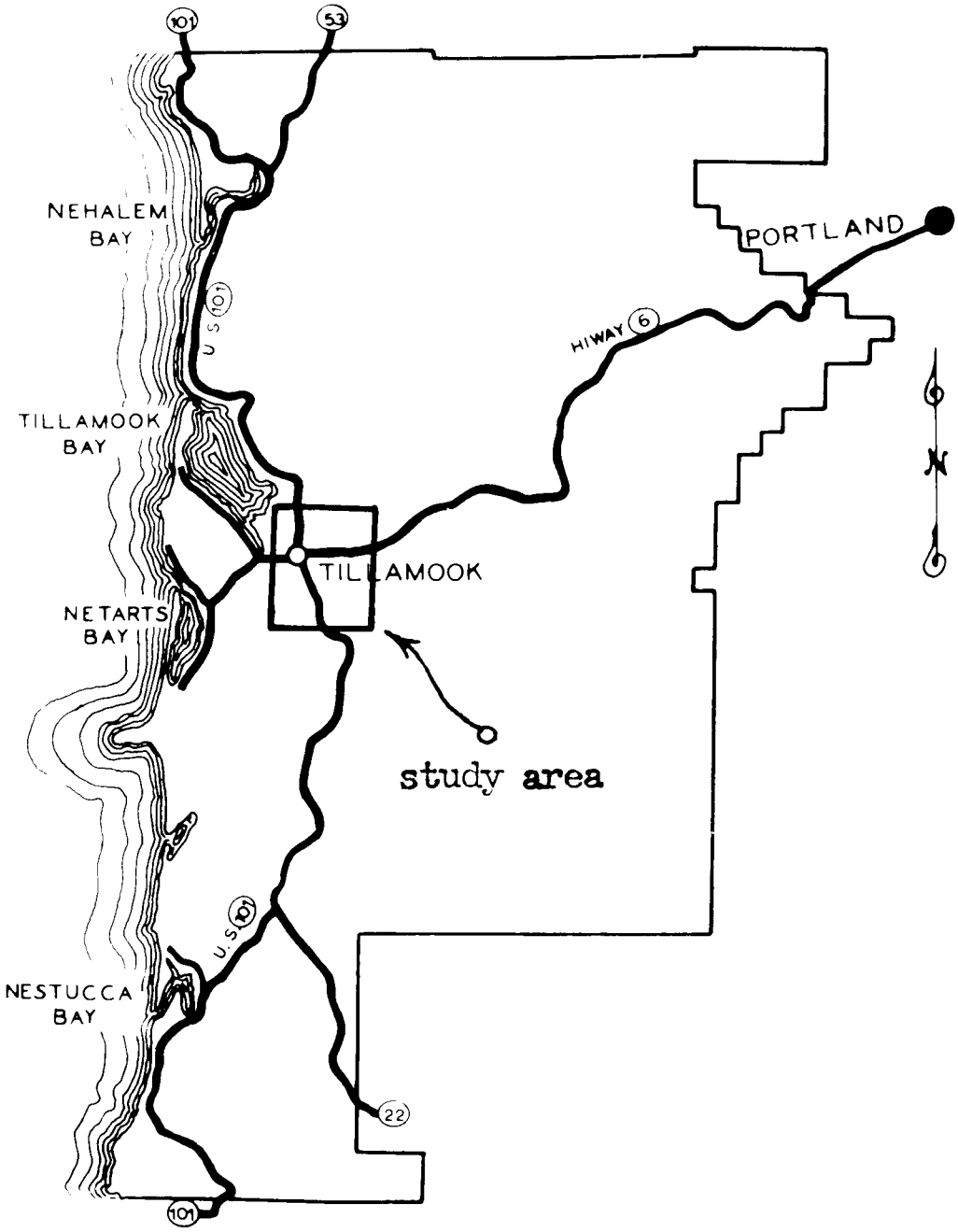

Figure 1. Map of Tillamook County with an inset indicating location of the primary study area.

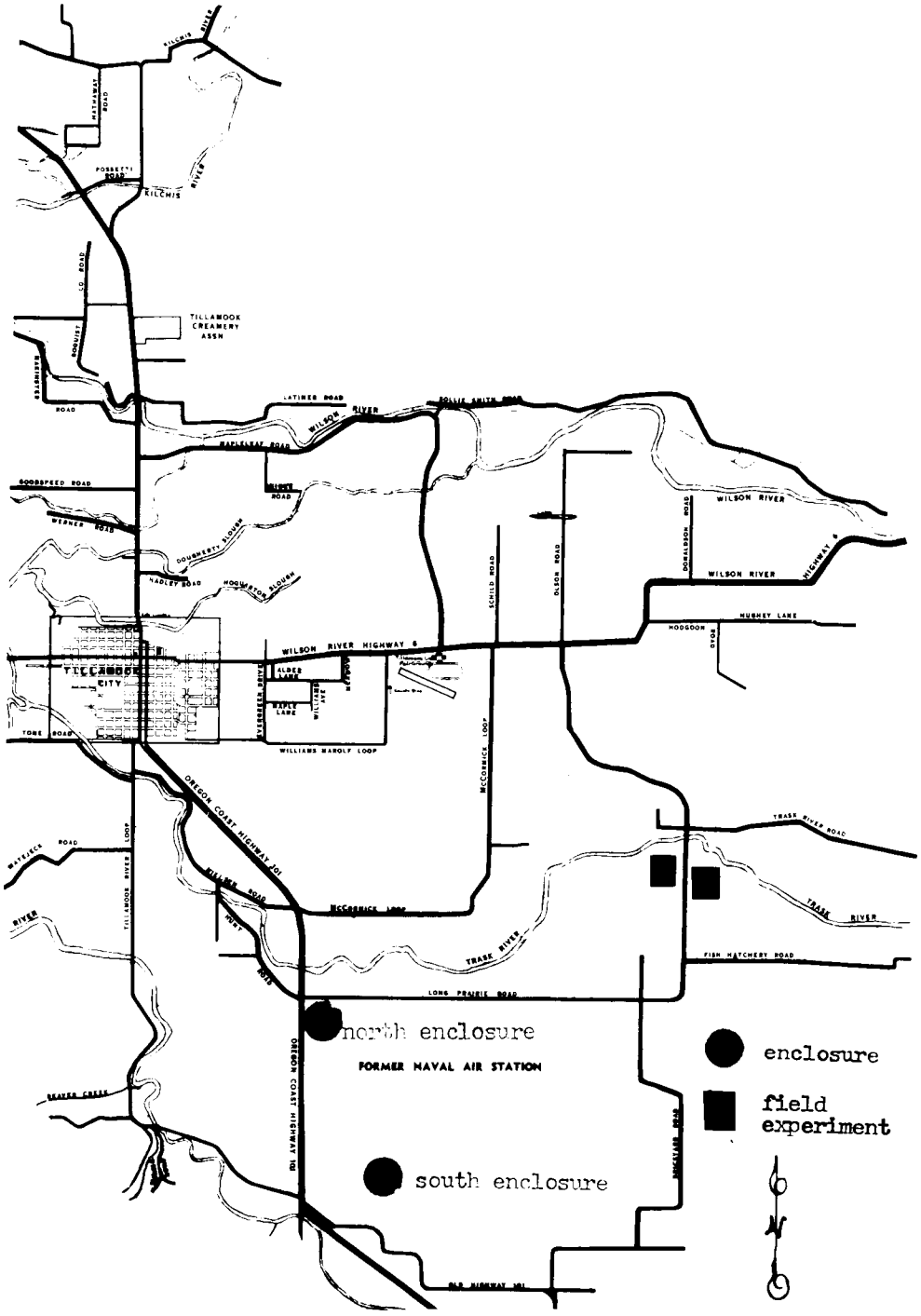

Figure 2. Enlarged map of the primary study area.

Figure 3. Cutaway view of a tunnel showing the scissors trap in place. A probe is also shown illustrating method of locating runway. Note the bridge of dirt under the trigger pan. (Photo by W. Q. Wick)

Live trapping was accomplished using a trap (Fig. 4) patterned after one designed by Moore (15, p. 223). The method of trap placement used in this study was different than that described by Moore (15, p. 224). Best results were obtained when the live trap was placed to form an integral part of the tunnel. When setting the live trap it was important to select a straight portion of tunnel at least three feet long. In almost every instance, a trap placed near a bend in the tunnel was avoided by the mole. Straight sections of a burrow system are easily located by probing between two mole hills with an iron rod or probe.

To place the live trap, a trap-length section of the straight runway is first removed. It is best to measure the length of the desired trap site before digging the hole. The length of the hole for the trap was often cut approximately an inch shorter than the trap thus making it necessary to force the trap into the hole, assuring a tight seal between both ends of the trap and the burrow system. Width of the trap site was not important as long as the trigger mechanism could function. Depth of the trap site was adjusted so that the artificial burrow within the trap and the natural burrow lined up to form a

Figure 4. A live trap in the set position.

continuous passage after the trap was in place.

After the trap site had been prepared, the trap was firmly packed with slightly moist soil obtained from nearby mole mounds. To make the artificial trap burrow, a short piece from an old shovel handle was pushed into this packed soil from either end toward the center. Care was taken not to make the artificial burrow go all the way through the trap, but to leave a firm plug of dirt in the center beneath the trigger. The mole discharged the trap while burrowing through this dirt plug to reopen his tunnel. Placing bait in the trap, as described by Moore (15, p. 24), was found to be unnecessary.

It required approximately 30 minutes to make a proper set. Traps properly placed in the tunnel systems readily caught moles, and on several occasions moles were caught within 10 minutes after a trap had been set. During rainy weather the trap hole often became filled with water, and the dirt within became mud. In this condition the trap would not function properly and resetting was necessary.

The live traps were checked at least every 12 hours as trapped animals would not survive much longer without food. It was noticed during the study that an animal

left in a live trap too long became "haunchy" in appearance when approaching starvation. The lower abdominal region, just anterior to the hips, of an animal in this condition became quite thin and sunken. Moles in this state seldom survived even when placed in the presence of a plentiful food supply. During the study this haunchy appearance was used as an indicator of condition, and any animal exhibiting it was considered to have a poor chance for survival.

Weights and Measurements

Standard mammalian measurements including total length, tail length, and length of hind foot were taken on all animals captured. Weights were taken to the nearest gram. Weights and measurements were recorded for 300 individual specimens to determine if any significant differences existed between the sexes. Although slight differences were found to exist in the external measurements, none were great enough to be of any help in sexing specimens. Males were found to average 214 millimeters (mm.) in total length, and females 203 mm. Body weights revealed the greatest differences between sexes (Fig. 5). Males averaged 141.65 grams, and females averaged 119.03 grams.

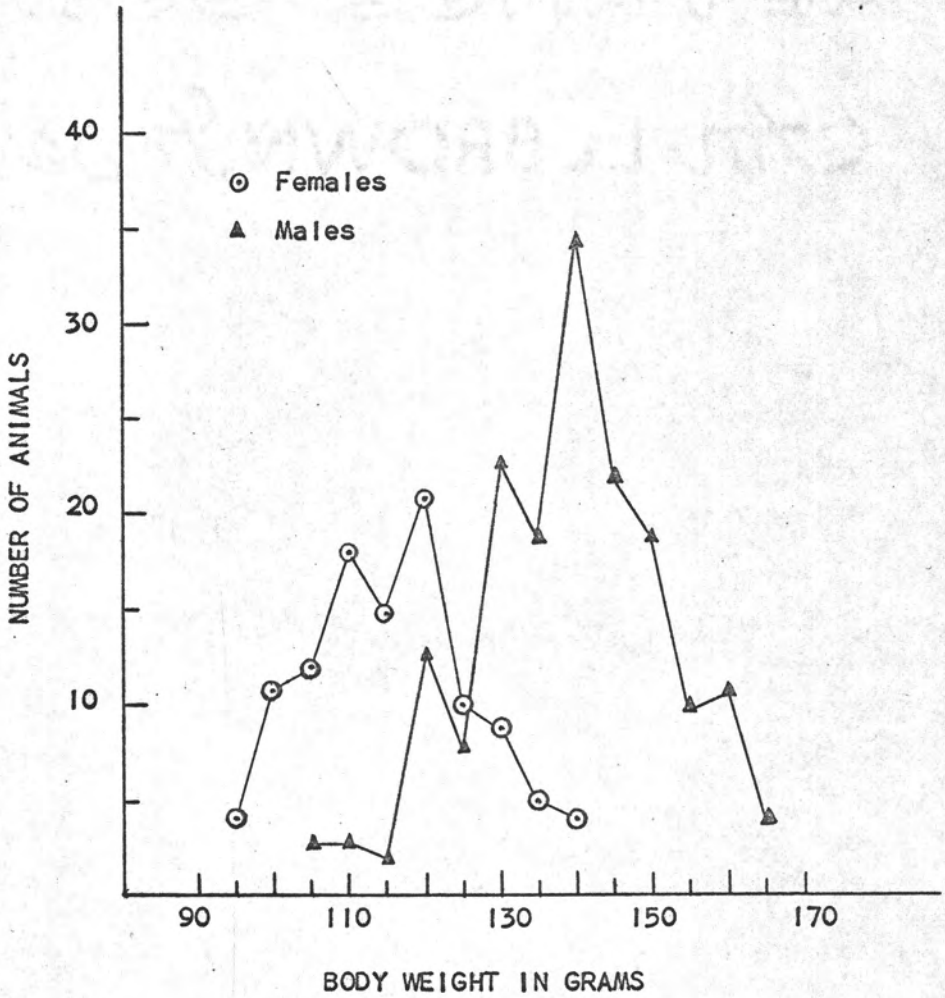

Figure 5. The difference between body weights of females and males

Testes measurements were recorded during the study to indicate breeding season and condition of the males. These organs were measured by removing them from dead trapped specimens, placing them on a plastic millimeter rule and interpreting the length directly.

Marking and Anesthetizing

Live trapped animals were toe-clipped for identification, using the hind toes for the tens place and the front toes as the units place. Toes were counted from left to right while holding the animal on its back and looking at the ventral surface in each case. Using this method, 100 animals could be marked without duplication by cutting only two toes, a front and a back. Toe clipping proved to be a satisfactory marking method, but "tail rings" offer a possible prospect for future tagging. Regular number four or five leg bands used for bird banding would probably be satisfactory. The mole's tail is actually of greater diameter in the middle than at either end, so a band attached around the tail near the body would probably not slip over the middle portion of the tail and fall off. Godfrey (6, p. 51) used monel-metal tail rings to mark moles and found them to be very successful.

Live trapped animals were difficult to work with because of their constant struggling. Ether was used and found to be suitable for anesthetizing moles. Animals were placed in a can, a piece of ether-saturated cotton added, and a tight fitting lid put into place. Within three or four minutes, depending upon the individual mole, the animal would cease scratching and could then be removed from the can in a completely relaxed state. In this condition the animal could easily be weighed, measured, and the ectoparasites collected. The mole was then placed on the ground, and within ten minutes the effects of the ether wore off and the animal could be returned to its burrow system. Moles handled in this manner showed no ill effects when later recaptured.

In another attempt to find a method to anesthetize them the drug xylecane was used. A one cubic centimeter syringe and a 25 gauge needle were used to inject the drug into the peritoneal cavity. Because of the variation in reaction for each individual (Table 1) this method was abandoned as a useful tool.

Table 1. Xylecane Experiment

Specimen No.	% Xylecane	Amount	Reaction
1.	1.00	.25cc	Death
2.	.01	.20cc	No effect
3.	.01	.40cc	No effect
4.	.01	.60cc	Death
5.	.02	.40cc	Docile
6.	.02	.20cc	Docile

ABUNDANCE

Mole populations in Tillamook County have probably increased as soil fertility and improvement practices have increased earthworms, their primary food supply. The fact that additional land, suitable for mole habitation, has been cleared, diked and drained is another factor that has contributed to an increase in their numbers.

> The farmer by bringing new land into cultivation, with the consequent improvement in soil fertility, attracts and thereby increases the numbers of animals dependent on soil fertility. Among the favored ones is the earthworm. The mole has increased in numbers with the abundance of its favorite food...the earthworm (11, p. 80-107).

Within Tillamook County numbers of moles vary considerably by area. This variation is apparently

proportional to the number of earthworms present, type of vegetation, amount of humus, drainage and soil type (Figs. 6 & 7). During this study a 15-acre field and a 20-acre field, which differed in fertilizer application rates, were found to have 4.8 and 2.6 moles per acre respectively. Both fields were located adjacent to the Trask River (Fig. 2) and contained a soil type of the Nehalem series. In so far as known each field received cow manure as the sole source of fertilizer. The smaller field received approximately twice as much as the larger. Moles were dead trapped from these fields until all visible surface activity ceased at which time the field was considered cleared. Seventy-two moles, 4.8 per acre, were trapped from the 15-acre field and 52 moles, 2.6 per acre, were removed from the 20-acre field (Figs. 8 & 9).

All moles trapped in these two fields were Townsend's mole except two Coast moles, *Scapanus orarius*, taken in the 15-acre field and one Coast mole taken in the 20-acre field. Several months later re-invasion occurred in the 15-acre field. The landowner resumed trapping to again control the moles, and 11 of the first 15 caught were *S. orarius*. In this particular field Coast moles apparently

Figure 6. The field segment to the right of center has received more cow manure and better care than the field segment to the left of center.

Figure 7. After the cattle were removed from this field in October, moles used the well established cattle trails.

Figure 8. Twenty acre experimental field before the entire population of moles was removed by dead trapping.

Figure 9. The same twenty acre experimental field after removal of the entire population of moles. This field contained 2.6 moles per acre.

reached a much higher population after the Townsend moles had been removed.

TUNNELS

Basically, the mole constructs four types of tunnels: a shallow tunnel, deep tunnel, surface tunnel, and a surface run. The most frequently encountered is the shallow tunnel, which averages six inches in depth. This tunnel services the immediate home range of the individual and is constantly being extended and repaired. In a field that has not been cultivated for many years an individual mole may occupy a burrow system hundreds of feet in length. Such a system is generally inhabited by a single individual. This is the type of tunnel that was most often trapped during this study.

The deep tunnel is less commonly encountered. It is used during dry periods of the year, or to pass under an obstruction such as a highway, building, or sidewalk. During the late summer months, moles are found less frequently in the shallow passages and have to be trapped in systems which are from 12 to 30 inches deep. Earthworm movements, in response to changes in soil moisture,

are probably responsible for the moles' descent to these lower levels.

In passing under obstructions, the deep tunnel may go down several feet. Many times during the study fields in which the moles had been controlled were re-invaded from adjoining, uncontrolled areas. These animals had either dug under or used already constructed deep tunnels which passed beneath paved roads, or similar obstructions. A few well placed traps in the field removed the intruders, but soon more mole hills appeared in the same place. Investigation disclosed that a single deep tunnel under the road barrier was serving as a community highway for the invading moles. A trap placed in this burrow and periodically checked, stopped further invasions. Several similar sites, located during this study produced 40 or more moles from a single trap.

The surface tunnel is most frequently found under boards, logs, or other objects lying flat upon the ground. The mole actually constructs just half a tunnel under such protected areas, the top of the passage being the overhead object itself. A pile of discarded lumber is a favorite place for the mole to build this form of tunnel. The mole probably constructs this

tunnel under such objects while searching for the many forms of insect life and earthworms which are frequently found in such environments.

The fourth type of tunnel, the surface run, was observed at all times of the year, but occurred most often in recently tilled fields. This form of passage is constructed when the mole "swims" forcefully through the upper three inches of loose soil. It is characterized by a continuous shallow ridge of soil and no mounds of dirt. Apparently this system is temporary and is used only once. I failed to catch any moles in this form of tunnel during extended trapping periods.

Many variations of these four basic tunnel systems exist. The most common is probably the fence line run way or "community highway." The fence line run exists as an old, well established tunnel network and is used by many individuals, apparently without conflict. Passages of this nature exist in almost every permanent fence line in Tillamook County and represent one of the routes by which moles are able to re-invade a controlled area so rapidly. Similar avenues of travel are often found under permanent main line water pipes, which feed sprinkler

systems, used for irrigation. Often these main lines extend across several paddocks and afford excellent pathways of ingress and egress. These permanent passages exist under such structures because they offer protection from agricultural machinery and the trampling action of cattle.

FOOD HABITS

The average diet of a Townsend's mole was found to be composed of 72 percent earthworms and 28 percent vegetable matter. The average stomach contained 3,581 milligrams of food. Of this, 2,580 milligrams were earthworms, and 1,000 milligrams were vegetable matter. The largest amount of vegetable matter found in any one stomach was 3,870 milligrams. The largest single amount of animal matter found in any one stomach was 9,700 milligrams. The largest single amount of total food found in a stomach was 9,850 milligrams.

Determination of the Townsend mole's food habits was accomplished by carefully examining the stomach contents of 200 dead trapped specimens taken at all times of the year. Each week, as dead trapped specimens were collected,

the stomachs were removed and individually preserved in a container of 10 percent formalin. These preserved stomachs were later weighed, examined, and individual food items identified.

The stomach was cut open, and the contents were washed through a number 40 mesh screen. This process eliminated the soil found in the stomachs, but retained all identifiable food materials. The contents were then removed from the screen, separated into vegetable and animal matter, and weighed on an analytical balance. All weights were taken as wet weights and noted in milligrams.

Animal Matter

With few exceptions, the predominant animal matter found in all stomachs was earthworm. The stomachs examined contained earthworms ranging in amounts from 200 milligrams to 9,700 milligrams with 79 percent of all stomachs examined containing between 200 milligrams and 4,000 milligrams of earthworms. One stomach examined contained 100 percent slugs and six stomachs examined contained traces of insect skeleton.

Vegetable Matter

Vegetation, composed solely of roots, was found throughout the year in the stomachs examined. The root matter was in the form of fleshy pieces five to ten millimeters long, and very white in color. Most of the roots were about the size of the largest half of a flat toothpick. Wight (18, p. 19-32) reported that only eight of the 306 Townsend mole stomachs he examined contained vegetation of a nature which had not been ingested by earthworms. I found that 81 percent of the stomachs examined contained between 200 milligrams and 1,800 milligrams of vegetable material. Twenty-five stomachs examined contained over 2,000 milligrams of vegetable matter, a sufficient amount to show that vegetation was not ingested incidentally as a portion of the earthworms' crop contents. Moore (13, p. 36-40) reported that 24 of 42 Townsend mole stomachs he examined contained vegetation in such amounts or form to indicate that it had not been ingested incidentally or as a portion of the earthworms' digestive tract.

> Townsend's mole also lives largely on earthworms and larval and adult insects, but it takes a considerably greater quantity of vegetable matter than does the Eastern mole. (17, p. 7)

Root Balls

During the stomach analysis, a curious mass of roots was found in 18 percent of the stomachs. This mass differed from the normal root content, in the moles' stomach, by being a solidified, dark brown mass. The normal roots found in a stomach are fleshy and very white in color. The size and shape of this "root ball" was very similar in each case, averaging ten millimeters long and five millimeters wide and closely resembling a red kidney bean in size and shape. Thirty-six of these root balls were found in the 200 stomachs examined.

Water

Under normal conditions, in Tillamook County, Townsend's mole appears to obtain enough moisture without recourse to surface water. After studying the mole's habits and running tests of the blood and urine (Tables 2 & 3), it is believed that free water is an unimportant part of this animal's diet. The percent of hemoglobin and the percent of packed red blood cells (hematocrit) indicates that the blood of this animal is slightly more concentrated than that of a man. The presence of albumin

Table 2. Hematology.

Specimen Number	Hemoglobin	WBC	Hematocrit	RBC	PMN	SL	Mono	Plate-lets
3	21.63	8,150	60	---	--	--	--	--
60	18.20	5,600	49	7.03	39	54	7	normal
76	17.60	7,900	48	6.23	25	74	1	normal
87	16.80	6,400	45	5.86	50	50	0	normal
88	17.60	4,200	48	6.01	70	30	0	normal
89	15.00	5,050	35	5.48	56	40	3	normal
93	11.60	2,750	40	---	--	--	--	--

Hemoglobin = Grams/100 cubic centimeters of blood
Hematocrit = Packed cell volume in percent
Normal = 150,000 to 300,000/cubic millimeter
RBC = Red blood cells in millions/cubic millimeter of blood
PMN* = Polymorphonuclearneutrophil/100 white cells
SL* = Small lymphs/100 white cells
MONO* = Monocyte/100 white cells
* White blood cells

Table 3. Urinalysis

Specimen Number	Reaction	Sugar*	Albumin**	Miscel-laneous
22	8.0	negative	3	Some triple phosphate and uric acid crys-als
40	8.0	negative	4	
42	6.5	negative	3	
56	6.5	negative	4	
62	8.0	negative	4	
97	6.5	negative	3	
137	7.0	1 plus	3	
138	6.5	trace	3	
140	7.0	trace	3	
199	7.0	2 plus	4	
200	6.0	trace	3	

*Robert's test
** Clinitest

in the urine, in amounts of three plus, also indicates that water is relatively unimportant in the daily diet.

It was found that moles kept in captivity and fed a diet of ground beef required drinking water. This may have been due in part to the high protein content of the beef. Captive moles, fed only earthworms, seemed to function normally without free water. This can probably be explained by the fact that earthworms, which form the bulk of the mole's natural food, are composed of more than 90 percent water.

REPRODUCTION

Nesting

During the breeding season a large underground cavity, approximately eight inches in diameter, is constructed to house the nest in which the young are born. The mole usually selects a site for this cavity where flooding can be avoided. In Tillamook County, the annual rainfall approaches 100 inches, and it is not uncommon for two inches of precipitation to occur within a 24-hour period. In addition, the rivers in this region often overflow during the winter months, flooding the adjacent lowlands.

> ...for it is in the breeding season that freshets are most common, and it is known that even heavy rains at this season drown some of the young in the nest (17,p.10).

Where possible, the mole constructs the nest cavity on elevated ground. The site selected may be several feet or just a few inches higher than the general contour of the surrounding land.

Well established fence lines were favorite nesting sites. Many of these fence lines in Tillamook County exhibit a ridge six to fourteen inches higher than the

surrounding land. This ridge is the result of many years of continuous grazing of the bordering paddocks. These higher fence line areas are well drained and provide protection from trampling by cattle.

As a second major nesting site, moles often used the slightly elevated areas in pastures. Little notice was given to these raised areas until the frequent appearance of "nest mounds" focused attention to them.

In one field examined, nine of the eleven nests discovered, were on slight undulations no more than a few inches higher than the general contour of the land.

The actual cavity, constructed to house the nest, is usually within eight inches of the surface, though some nests were located as deep as 20 inches below ground level. The cavity is spherical and has from one to several lateral tunnels entering it. All 43 nests I located during the study had at least three tunnels entering the cavity; one contained eleven.

Many of the nesting cavities contained a "bolt hole." This was a tunnel which exited the cavity from the bottom and dropped straight down for several inches. This escape tunnel then turned upward to re-enter one of the upper level burrows. The bolt hole probably serves as a

quick escape route and provides drainage for the nest cavity (11, p. 9).

Nest Mounds

During the construction of the nest cavity and adjoining tunnels the mole must remove a large amount of dirt. Some females deposit this in a large mole hill or "nest mound." Three general forms (Figs. 10, 11, & 12) were found: (1) a single large mound of dirt occurring at the base of a fence post; (2) several mounds occurring together to form a cluster of aggregate; or (3) a single large mound measuring thirty inches or more in diameter. Although nest mounds are commonly found during the breeding season in Tillamook County, they are not abundant. Apparently not all female moles construct them, but dispose of the dirt by a less conspicuous method. During the study locating these nest mounds proved to be of great value in finding the underground nests. In one fifteen-acre field eight nests were found in this manner.

Nests and Nest Building

After the cavity has been completed, the mole constructs a nest of two distinct parts, an inner core of

Figure 10. Fence post nest mound. (Photo by B. Carter)

Figure 11. Aggregate nest mound. (Photo by B. Carter)

Figure 12. Single nest mound.

dried vegetation and a surrounding layer of green vegetation. As most nests are located within pasture areas, the major nesting material used is grass. Three nests were located which were constructed of materials other than the predominant grass species. Two were built of moss, a common plant found in poorly managed pastures and along fencelines. The third was formed of dried alder, Alnus rubra, leaves.

The nest was often composed of grass plants with the root systems intact. I believe the mole gathers this material from burrow openings or shallow surface runs.

The green grass used to construct the outer portion of the nest is interwoven to form a shell approximately two inches thick. This shell forms the capsule for the inner sphere of dried grass in which the young are kept. The outer shell appears to be quite compact and solid with no visible entrance to the inner chamber. Additional fresh grass is added to the outer shell several times during the 30 days the young occupy the nest. During this period some nests observed had one-third of the outer nest replaced, and two had the entire outer portion rebuilt with fresh green grass. I believe this green vegetation contributes warmth to the young moles through a silage

action. This may explain why the new material is added.

The inner core, composed of finely shredded dry grass, is approximately four inches in diameter and here the young keep dry and warm during the wettest spring weather. Apparently some degree of sanitation is practiced as no accumulation of feces or other waste matter was found in any of the nests.

The nest and nest cavity can be constructed in a very short time. On March 12, 1962, a mound measuring 31 inches in diameter was found. It had not been there on March 8, and because of the season of the year and its large size it was suspected of being a nest site. On March 14, this mound was excavated, and a newly constructed nest found, but it contained no young. It was replaced in the cavity and covered with soil. By March 16, 48 hours later, a new mound measuring 26 inches in diameter had been built within 12 feet of the original site. Three days later this mound had been increased to 30 inches in diameter. On March 21, seven days after the first nest had been located the second was dug up and contained three young approximately four days old. This second nest and cavity had been constructed in about five days. None of the nest material from the first site was ever moved to the

second.

Nest Abandonment

Moles frequently abandoned their nest after an intrusion. Thirteen times during the study, nests were uncovered only to discover that the young had not been born. These nests were carefully replaced and re-checked at a later date. In only one instance did the female return to the disturbed site to have her litter. Abandonment of nests containing young also occurred. Young were removed from several nests, toe clipped, weighed and returned. Of these, two nests containing young were checked four times, two were checked twice, and one was checked only once before they were abandoned.

Reproductive Activity and Potential

The reproductive capacity of Townsend's mole is low. Sexual maturity is reached 10 months after birth, and most individuals are capable of breeding at that time. In 1962, only seven males and five females were trapped during the reproductive period that did not exhibit breeding condition. These few animals represented a small portion of the total breeding population.

In Tillamook County reproductive activity was first noted in November with the enlargement of the testes in the males. It ended when the last nestlings were found in April. By the end of November the testes of the males showed a definite increase in size and continued to increase until a peak was reached about January 15. During the peak of development the testes averaged 18 millimeters in length, a considerable increase over the three millimeter summer average. By the first of February the testes showed a decrease in size and reached their minimum by June (Fig. 13). During the summer months juvenile males were easily distinguished from adults by the undeveloped condition of the testes and seminiferous tubules. In juveniles the testes measured only one to two millimeters, and the seminiferous tubules were minute, pale white, and lacked convolutions. Adult males exhibited larger testes and the seminiferous tubules were convoluted. In juvenile females the uterus and uterine horns were pale, thread-like structures having little development or color. Adult females had a large, well developed, muscular uterus, pink in color.

The accessory organs associated with breeding showed an even greater change. By January the prostate gland

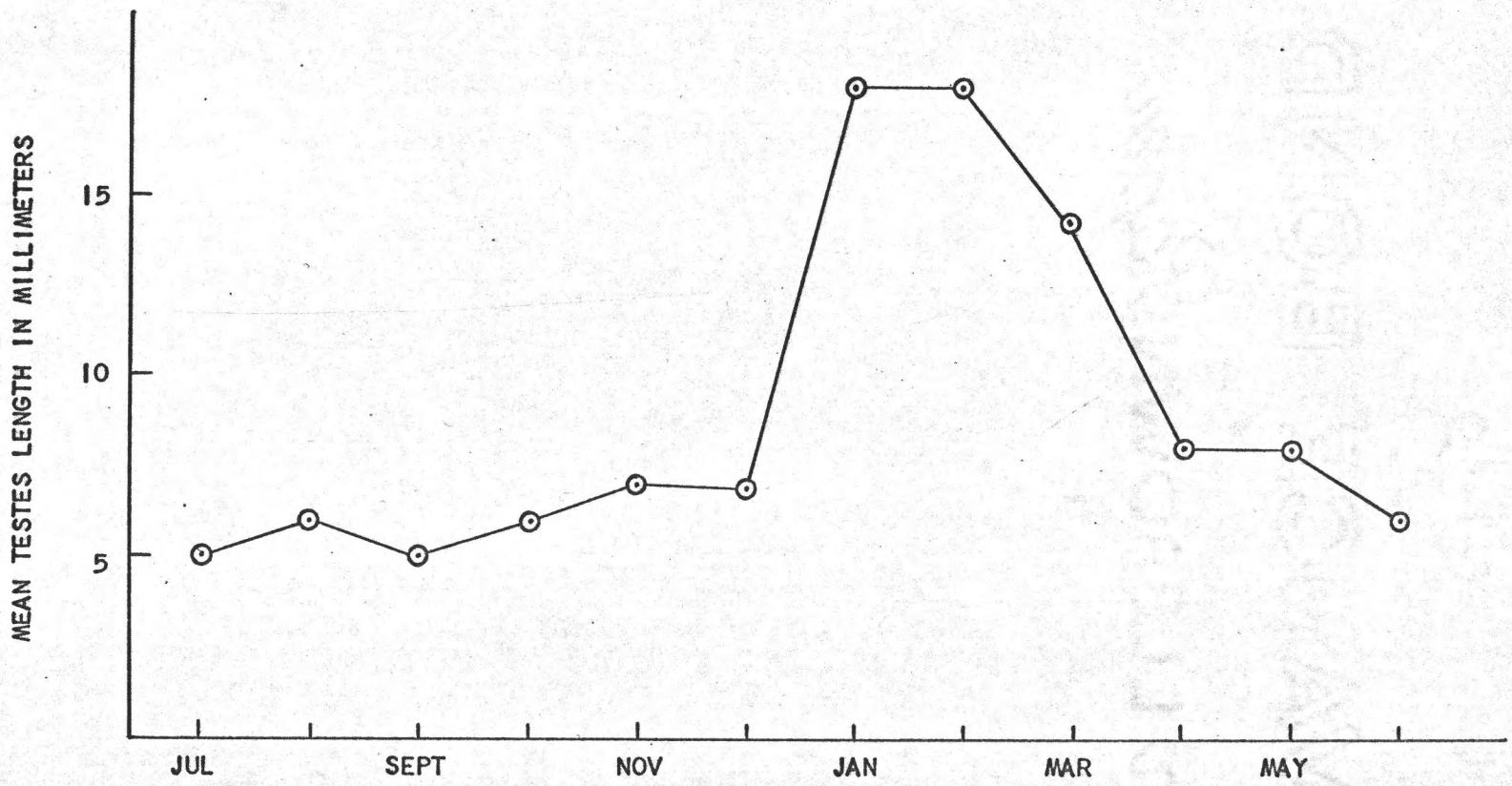

Figure 13. Testes size increase for a one year period

of the male increased many times from its obscure size at the beginning of breeding season.

A secondary sexual characteristic, associated with breeding moles, was also noted. Near the anal opening of both sexes are two glands, which increase slightly in size during the reproductive period and emit a strong odor. Although apparent in both sexes, the odor was more pungent in males than in females and was particularly noticeable in large males.

During the sexually quiescent months the males and females are very difficult to sex without internal dissection. The external genital opening of both sexes is nearly closed. In most individuals examined it was so small that a dissecting needle was used to locate the opening. During the reproductive period males were sexed by everting the penis, which was greatly enlarged at that time. Females were sexed by noting the enlarged vaginal orifice and the absence of a penis.

The majority of breeding apparently takes place in this species between the first of January and the first of February. During this study the first female, with an enlarged vaginal opening, was found on December 3. Most females showed this condition by January. On February 22

the first sign of embryos, small black spots in the enlarged uterine horns, was found in a trapped female. On March 8, the first well developed embryos were found. From this date on most females trapped contained visible embryos. Embryos removed from the uterus during various stages of development varied in weight from 130 milligrams to 6,480 milligrams (Table 4).

Young Townsend moles weigh about five grams at birth. Several nests were dug containing young with the umbilical cord still wet. These specimens averaged five grams in weight. The average litter size is three (Table 5). In 1962, 64 nests were collected of which 43 contained young in various stages of development. Eleven percent of the nests examined contained four young, 56 percent contained three, 30 percent had two and two percent contained one. This compared closely with the number of embryos found by examining uteri taken from trapped females (Table 6). No uteri were found with four embryos, 55 percent contained three, 39 percent contained two, and five percent contained one. No nests were discovered that contained more than four young.

Table 4. Prenatal Embryo Weights.

Date Female Captured	Number of Embryos per Uterus	Average Embryo Weight (Mgs.)
March 8	3	*
15	2	140
19	3	470
19	3	130
19	1	1370
19	2	*
19	3	*
21	2	2520
21	2	270
27	3	285
27	2	6480
28	3	270
28	2	765
30	3	*
30	3	860
30	2	*
April 2	3	4700
4	3	*

* Embryos too small to weigh.

Table 5. Nest Litter Size.

Number in Litter	Frequency of Occurrence	Percentage
4	5	12
3	24	56
2	13	30
1	1	2

Table 6. Uterine Litter Size.

Number in Litter	Frequency of Occurrence	Percentage
4	0	--
3	10	56
2	7	39
1	1	5

Development of Young

Development from birth to sub-adult is very rapid. Young moles spend approximately 30 days in the nest dependent upon the females' care. Young moles (Fig. 14) are born entirely helpless, much like young rats. They are pink, eyes are not distinguishable, teeth are absent and the claws are soft. The large paddle-like front feet are very pronounced even at birth. In four to ten days (Fig. 15) the young moles I observed lost their pink color and became pale gray. In about 15 to 20 days they weighed about 35 grams and fur was beginning to emerge. At 30 days of age the young had a sleek glossy coat of fur and weighed approximately 80 grams. Juvenile fur was softer, finer in texture, and lighter in color than

Figure 14. A mole nest containing three young 10-15 days old. (Photo by W.Q. Wick)

Figure 15. Two age classes of young moles. The small one is about five days old and the large one is 10-15 days old. (Photo by B. Carter)

that of the adult.

During this study three nests were opened, the young weighed, toe-clipped and returned. These nests were periodically reopened and the young weighed to determine growth rates. On April 20, 1962, a nest was found which contained two young moles (Table 7). These were toe-clipped number one and number three. Number one weighed 38 grams and number three 44 grams. Three days later, April 23, the nest was re-examined, and the young again weighed. Mole number one weighed 44 grams, a gain of six grams for the three-day period. Number three weighed 51 grams, a gain of seven grams. This litter was again examined on April 25, but the young had been abandoned and were dead.

On the same day, April 20, a second nest was found which contained two young just beginning to fur out (Table 7). They were toe-clipped number one and number two. The weight of number one at this time was 56 grams, and the weight of number two was 60 grams. Three days later, April 23, number one was found dead and number two weighed 66 grams, a gain of six grams. This nest was again re-opened on April 25 at which time number two weighed 70 grams. This same nest was re-opened for the

Table 7. Weight Development of Four Non-Captive Moles.

Nest No.	Date	Mole No.	Weight Gms.	Wt. Gain Gms.
1	April 20	1	56	--
		2	60	--
	April 23	1	dead	--
		2	66	6
	April 25	2	70	4
	April 30	2	84	14
2	April 20	1a	38	--
		3	44	--
	April 23	1a	44	6
		3	51	7
	April 25	(young moles were abandoned)		

fourth time on April 30. At this time number two weighed 84 grams. This nest was examined for the last time on May 2, but the young mole had left the nest. This particular nest had been successfully opened five times before the young dispersed.

On March 19, a nest was discovered which contained no young. It was removed from the ground, examined, and

replaced in the nest cavity. Four days later, March 23, the nest was re-opened and found to contain four young about three days old. On March 26, the nest was again removed from the nest cavity and the condition of the young noted. At this time, one young mole was found dead and three were in good condition. On April 20, the nest was re-checked, and the two remaining young moles were removed, weighed, and toe-clipped number three and four. The third young was never found, having probably escaped into the tunnel system during the nest digging operation. At this time number three weighed 76 grams, and number four weighed 70 grams. These two young moles were taken home and kept in the house in a cardboard box. Experimental feeding of a commercial meat-based, high protein, baby food was rejected by both animals. "Hi-Pro," a commercial baby formula was mixed with warm cow's milk and offered to them. They ate a small amount, but not enough to maintain body weight. On April 21, the young moles were offered warm cow's milk with no additives. When fed with an eye-dropper, they drank about nine cubic centimeters during a single feeding. After a feeding, they burrowed into the nest material, provided in the box, and became quiet for a period of about four hours.

Then they began scurrying about and another feeding of milk was necessary to quiet them. The eye-dropper proved to be a suitable feeding tool. The young moles drank from this instrument with no difficulty.

By April 24, number three weighed 77 grams, a gain of one gram. Number four weighed 66 grams, a loss of four grams. Both appeared to be thrifty and healthy (Table 8). By April 30, after 10 days in captivity, the two young refused to drink milk and scurried around in their box as if searching for a more desirable food. Two small earthworms were obtained and offered to them. They ate the worms immediately, apparently by instinct. The worms were grasped by an end ingested very rapidly by a combined chewing and swallowing action. The chewing action did not sever the worms into particles. Lean ground beef was next offered to the young moles, and they ate it readily. For the next days the moles were fed ground beef. When the moles were offered milk they refused it. By May 3, the moles were offered two tablespoons of ground beef twice a day. About half of this ration was eaten. During this time they were supplied with a small dish of water. When drinking the young moles crawled over the edge of the dish and submerged their snouts for several seconds.

Table 8. Weight Development of two Captive Moles.

Date	Mole No.	Weight Gms.	Weight Gain or Loss Gms.
April 20	3	76	--
	4	70	--
April 24	3	77	1
	4	66	4
April 30	3	88	11
	4	68	2
May 2*	3	86	-2
	4	60	-8
May 14	3	113	27
	4	82	22
May 16	3	118	5
	4	88	6
May 20	3	120	2
	4	83	-5
May 22	3	129	9
	4	74	-9
May 23	3	123	-6
	4	(succumbed)	
May 24	3	129	6
May 31	3	129	0
June 7	3	134	5
June 21	3	140	6
July 4	3	140	0
July 10**	3	142	2

Table 8. Continued

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* From April 20 to May 2, these moles were on a milk diet.

** Mole #3 attained a maximum weight of 142 gms. on July 10 and lived until October 15.

The drinking process was a lapping action with the mouth held open. While the animal was drinking, bubbles of air were expelled from the nostrils. After several seconds the mole removed his snout from the water and cleared his nostrils with a few short blowing snorts. This action was repeated four or five times before the mole satisfied his thirst.

On May 21, number four became ill, lost weight rapidly, and died on May 23. An autopsy revealed large areas of ruptured capillaries just beneath the skin.

Number three continued to thrive on the ground beef diet and gained to a peak weight of 142 grams on July 10. During the second week of October, it became ill and lost a considerable amount of weight. It refused any offered food and died within 48 hours.

Number four had been kept alive, in captivity, for 32 days and number three for 179 days. Both moles had been fed milk for the first 10 days and ground beef the remaining time. Water was the only addition to their diet.

PARASITES

Four species of fleas, *Corypsylla ornata*, *Nearctopsylla jordani*, *Epitedia jordani* and *Catallagia charlottensis*; a single species of tick, *Ixodes sp.* and mites of the suborder Mesostigmata were found on Townsend moles.[1]

Fleas were found to be most numerous from September to December, and mites were most numerous from May to July. On November 30, 1961, 113 fleas were found on four dead trapped moles. There were 99 of the species *C. ornata*, 70 females and 29 males; and 14 specimens of *N. jordani*, 10 females and 4 males.

On April 8, 1962, 79 fleas, *E. jordani*, were found in the pelage of a nestling mole approximately four weeks old. There were 62 females and 17 males.

All mites were classified in the suborder Mesostigmata and found to be most numerous during the nesting season. Seven fleas and 92 mites were removed from a litter of young moles approximately three weeks old.

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[1]Ectoparasites were identified by Edward Hansen, instructor of Fish and Game Management, Oregon State University.

MORTALITY

Predation

Most small mammals, both fossorial and terrestrial, are usually subject to predation by one or more predators. Unlike most fossorial animals, the mole infrequently appears beyond the safety of his burrow. This underground habit has discouraged most enemies of the mole.

House cats may kill more moles than any other predator. One dairyman reported that his cat captured five moles within a seven-day period.

Dogs were known to catch a few moles. On one occasion, a dog dug out a 12-foot section of tunnel and caught the mole. Another dog was observed to catch a mole by watching a mound where a mole was digging. As the dirt moved the dog pounced on the hill with his front feet and began digging rapidly. The mole was caught, thrown out upon the ground, and killed by the dog. Except for dogs and cats, no other predators were observed to kill moles.

Accidents

Several times during the study, nests were found

which had been destroyed by dairy cows. The odor from a buried nest, or the large nest mound may attract cattle to nest sites. In one instance, cows had pawed an eight inch depression over a nest, scattering the soil in a three foot radius. The nest was trampled and the three young moles were killed. In a similar instance, a pawed-over nest was found in a fence line. Cattle had pawed away half the nest mound and trampled a depression, but failed to kill the young. Another nest was located by examining one of these trampled areas. The nest with three live young was located 12 feet from the disturbed area.

During the month of June, young moles leave the safety of their parental burrows and disperse to adjacent habitat. Some of them travel over land and are killed. Fourteen road-killed moles were recorded during June 1962. All were juveniles except one, an adult male.

SUMMARY AND CONCLUSIONS

1. Townsend's mole, *Scapanus townsendii* (Bachman), was studied from July 1961 to September 1962, in Tillamook County, Oregon, to determine aspects of its life

history. This study was initiated, at the request of Tillamook County farmers, and financed by the Agriculture Experiment Station, Oregon State University.

2. Approximately 300 moles were weighed, examined, and measured during this study. Slight differences were found in the external measurements. Males averaged 214 millimeters in total length and females 203 millimeters. Body weights revealed the greatest differences between sexes with males averaging 141.65 grams and females 119.03 grams.

3. Toe-clipping proved to be a satisfactory method for marking live trapped moles during this study.

4. Ether was used successfully and without ill effects for anesthetizing moles. Xylecane was also tested, but proved to be unsatisfactory.

5. Numbers of moles varied with numbers of earthworms, types of vegetation, amount of humus in the soil, drainage, and soil type.

6. Moles constructed four basic tunnels; a shallow tunnel, deep tunnel, surface tunnel, and surface run. The shallow tunnel was most frequently encountered.

7. Community runways or "highways" were found under permanent fence lines, road beds, main irrigation lines,

and other similar structures.

8. Two hundred stomachs, taken from dead trapped moles, were examined for food content. The moles' diet consisted of 72 percent earthworms and 28 percent roots. Seventy-nine percent of the stomachs examined contained between 200 milligrams and 4,000 milligrams of earthworms. One stomach contained 100 percent slugs, and six contained traces of insect skeleton.

9. Moles mate during February and March, and the young are born during March and April. The average litter size is three. The prenatal size compared closely with nest litter size. Young moles weigh approximately five grams at birth and develop to a sub-adult weight of 80 grams, $\pm$ five grams, in about 30 days, at which time they leave the nest.

10. Three general types of nest mounds were found; the fence post nest mound, the aggregate nest mound, and the large single nest mound. Some nest mounds measured as much as 30 inches in diameter. Nests are usually within eight inches of the ground surface and composed of an outer layer of green grass and an inner layer of dry grass.

11. Ectoparasites found included four species of

fleas, one species of ticks, and mites. Fleas were most abundant in the fall, and mites were most abundant in the spring.

12. Dogs and cats are probably the most important predators of Townsend's mole. Trampling of the young by cattle and flooding kill some juveniles in the nest. Sub-adults are often killed on highways during dispersal.

BIBLIOGRAPHY

1. Arlton, A. V. An ecological study of the mole. Journal of Mammalogy 17:347-371. 1936.

2. Blair, Frank W. Some observed effects of stream-valley flooding on mammalian populations in Eastern Oklahoma. Journal of Mammalogy 20:304-306. 1939.

3. Conaway, C. H. The reproductive cycle of the Eastern Mole. Journal of Mammalogy 40:180-184. 1959.

4. Eadie, William Robert. The life history and ecology of the Hairy-Tailed Mole (Para scalops breweri Bachman). Ph.D. thesis. Ithaca, Cornell University, 1939. 80 numb. leaves.

5. Glendenning, R. Biology and control of the Coast Mole, Scapanus orarius orarius True, in British Columbia. Canadian Journal of Animal Science 39: 34-44. 1959.

6. Godfrey, Gillian and Peter Crowcroft. The life of the mole (Talpa europaea Linnaeus). London, Latimer, Trend and Co., Ltd., 1960. 152p.

7. Hisaw, Frederich L. Observations on the burrowing habits of moles (Scalopus aquaticus machrinoides). Journal of Mammalogy 4:79-88. 1923.

8. Hisaw, Frederich L. Feeding habits of moles. Journal of Mammalogy 4:9-20. 1923.

9. Jackson, Hartley H. T. A review of the American moles. Washington, U. S. Government Printing Office, 1915. 100p. (U. S. Dept. of Agriculture, Bureau of Biological Survey. North American Fauna no. 38)

10. Kruishtal, A. F. On the ecology and agricultural importance of the mole in the forest-steppe west of the Dneiper and the Palese of the Ukraine. Zoologicheskii Zhurnal 13:292-310. 1934. (In Russian. Translation by J. D. Jackson, 1947, for the Bureau of Animal Population, Oxford University, England. Trans. 213 F 1712 H)

11. MacDougall, R. Stewart. The mole, its life-history, habits, and economic importance. Transactions of the Highland Agriculture Society of Scotland 54: 80-107. 1942.

12. Milyutin, N. G. A note on the reproduction of the mole (Talpa europaea brauneri satun). Zoologicheskii Zhurnal 20:482-484. 1941. (In Russian. Translation by J. D. Jackson, 1947, for the Bureau of Animal Population, Oxford University, England. Trans 213 F 1712 H)

13. Moore, A. W. Food habits of Townsend and Coast Moles. Journal of Mammalogy 14:36-40. 1933.

14. Moore, A. W. Notes on the Townsend Mole. Journal of Mammalogy 20:499-501. 1939.

15. Moore, A. W. A live mole trap. Journal of Mammalogy 21:223-225. 1940.

16. Palmer, Fletcher G. Geographic variation in the mole Scapanus latimanus. Journal of Mammalogy 18: 280-314. 1937.

17. Silver, James and A. W. Moore. Mole control. Washington, U. S. Government Printing Office, 1941. 17p. (U. S. Dept. of Interior, Fish and Wildlife Service. Conservation Bulletin no. 16)

18. Wight, H. M. Food habits of the Townsend Mole, Scapanus townsendii (Bachman). Journal of Mammalogy 9:19-32. 1928.