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Abstract approved: Redacted for Privacy
R. L. Goulding

A study of the host range and distribution of ticks and chiggers (Acari) was undertaken in two contrasting forested areas of western Oregon. Acarines were sampled from host mammals which were trapped along line transects laid out in both areas, each consisting of 18 stations 50 feet apart. Hosts were captured alive and the ticks and chiggers removed. Hosts were marked and then released to make recapture possible. The deer mouse was the most common host recaptured in either sampling area. *Ixodes angustus* Neumann proved to be the most common tick in the coastal sampling site (Neptune State Park). *Ixodes soricis* Gregson was less abundant in this area and *I. pacificus* Cooley and Kohls was absent. Immature stages of *I. pacificus* were found in moderate numbers in the valley sampling site (William L. Finley National Wildlife Refuge) in the summer and fall.

The chiggers *Euschöngastia oregonensis* (Ewing), *Comatacarus americana* (Ewing), and *Chatia setosa* Brennan were most common in the Neptune study area, while *Neotrombicula cavicola* Ewing was most abundant in the William L. Finley study area.

Good evidence is supplied by host records in this study that *I. angustus* most commonly infests nest building mammals. Lack of records from larger animals or from the "flag" illustrates its absence on vegetation and soil litter, or duff.

Ixodes soricis was found on shrews and the shrew-mole in this study. None was collected from other moles although heavy parasitization by immatures of *I. angustus* on these hosts was recorded.

I. pacificus is the only central western Oregon species of this genus that climbs vegetation or that feeds on larger animals including man. Immatures of *I. pacificus* were collected from small mammal and lizard hosts in the Finley study area in summer and fall. Mean number of immature ticks per host was higher for lizards than for small mammals indicating the importance of these hosts for the maintenance of tick populations.

The chigger *C. americana* was found mostly on shrews and moles in both sampling areas. *E. oregonensis* commonly attached around the eyelids on deer mice, but on other parts of the body on shrews. *N. harperi* and *N. cavicola* were not found on deer mice in this study and most of the chiggers were found in the ear canals of voles or chipmunks.

A negative correlation factor was used to measure the degree of compatibility between different parasites on a single host. The negative binomial distribution adequately described the pattern of distribution of *I. angustus* and *E. oregonensis* in both study areas.

The species of trombiculids identified during the course of this study may be segregated into two ecological groups: (1) soil litter forms, and (2) burrow-inhabiting forms. *Ch. setosa*, *C. americana*, and *E. oregonensis* probably occur in burrows while *N. harperi* and *N. cavicola* inhabit soil litter. *N. harperi* was found only in summer months and is probably affected by phenology.

A Study of Ticks (Acarina:Ixodidae) and Chiggers (Trombiculidae) from Two Areas in Western Oregon

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I would like to thank Mr. Richard S. Rogers, Supervisor of the William L. Finley National Wildlife Refuge, for his cooperation in allowing me to use a portion of the refuge as a study area. Dr. Robert M. Storm and Mr. Chris Maser verified identifications of vole and shrew hosts collected by the author and Mrs. LaRea Johnston confirmed plant material from the study areas.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A STUDY OF TICKS (ACARINA: IXODIDAE) AND CHIGGERS (TROMBICULIDAE) FROM TWO AREAS IN WESTERN OREGON

INTRODUCTION AND LITERATURE REVIEW

Little is known of the distribution and host-parasite interactions of ectoparasites affecting birds and mammals in the Pacific Northwest. Foremost among these groups are representatives of the acarine families Ixodidae (hard ticks) and Trombiculidae (chiggers).

Host specificity in many species of chiggers is thought to be a matter of the suitability of the host as a source of food and the availability of the host depends on the particular "niche" of the mite (Wharton, 1957; Nutting, 1968). For example, chiggers found only in soil accumulations in trees, such as _Euschöngastia indica_ in southeast Asia (Wharton and Fuller, 1952), feed only on animals that climb trees. _Trombicula aplodontiae_ Brennan has been collected in the Pacific Northwest only from the mountain beaver, _Aplodontia rufa_ (Brennan and Wharton, 1946), a mammal found nowhere else in North America. The lack of records of this mite on other hosts may suggest restriction to burrow situations which only the mountain beaver and a few other mammals occupy. In other words the apparent host specificity of _T. aplodontiae_ for the mountain beaver may be an "ecological specificity" for a burrow situation in a Pacific rain forest.

In certain species of ticks, host specificity is well developed

(Arthur, 1961), but with many of those ticks found in western Oregon, Washington, and western British Columbia their absence in the drier regions east of the Cascade and Coast mountain ranges suggests that ecological specificity is the general rule.

The dragging of a flannel cloth over low growing vegetation is of value in sampling those species of ticks that climb vegetation in search of a host. Ticks that are commonly sampled on vegetation in this manner, such as Dermacentor variabilus and Amblyomma americanum, have seasonal periods of activity (Hair and Howell, 1970; Sonenshine and Levy, 1971). Dermacentor variabilus adults in Virginia reached maximum activity in June (Sonenshine, Atwood and Lamb, 1966) and then numbers diminished later in the summer. Bimodal periods of activity were noted for larvae and nymphs suggesting the presence of two populations. Seasonal activity has been studied in human pest chiggers (Jenkins, 1948), and Wharton and Fuller (1950) report that some larvae are prevalent on hosts in the summer while others (Jameson, 1972) are found on hosts during wet winter periods.

Sonenshine et al. (1966) showed a positive correlation in distribution of D. variabilus with vegetation types and found the tick more common in low, woody-deciduous habitats than in evergreen or herb-grass situations. Semtner, Howell and Hair (1971) found higher numbers of A. americanum in the immediate vicinity of the ecotone in eastern Oklahoma and in general tick populations decreased with an increase in distance from the ecotone. Studies in which numbers of ticks have been contrasted in two different areas have been recently reported in Virginia (Sonenshine and Levy, 1971; Sonenshine and Stout, 1971), and in Oklahoma Semtner, Barker and Hair (1971) studied the lone star tick, *Amblyomma americanum*, in four different ecological habitats.

The object of this study was to compare ticks and chiggers in two contrasting forested areas within the range of the species in order to reveal possible differences in (1) species of parasite, (2) seasonal occurrence of different species or their relative abundance showing one or more peaks of activity, and (3) host relationships.

METHODS

Description of the Study Areas

Neptune State Park

This study area is located four miles south of Yachats, Oregon, in northwestern Lane County. The area (elevation 80-150 feet) is bounded by the Pacific Ocean to the west, Cummins Creek to the south, and Cape Perpetua to the north. The site is predominated by a dense overstory of Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) approximately 150-200 years old. Climate is typical of the "fog belt" (see discussion on climate, p. 55) and the soil probably is Astoria silty clay or clay loam.

William L. Finley National Wildlife Refuge

This area is located 16 miles south of Corvallis, Oregon (Benton County), just north of Bellfountain. The trapping site is near Gray Creek on the southwestern edge of the refuge in secondary growth (50-year-old timber) at about 350 feet elevation. Douglas-fir (*Pseudotsuga menziesii*) and white Oregon oak (*Quercus garryana*) are the predominant species of plants. Soil type is Grande Ronde silty clay loam.

Other plants found in both areas are listed in Table 1.

Table 1. List of plants found to occur in the Neptune State Park and William L. Finley study areas.

		Neptune	Finley
Overstory vegetation			
Picea sitchensis	Sitka spruce	X	-
Tsuga heterophylla	western hemlock	X	-
Pseudotsuga menziesii	Douglas-fir	-	X
Quercus garryana	white Oregon oak	-	X
Alnus rubra	red alder	-	X
Intermediate growth			
Berberis aquifolium	Oregon grape	X	X
Abies grandis	grand fir	-	X
Alnus rubra	red alder	X	-
Symphoricarpus albus	snowberry	-	X
Rubus spectabilus	salmonberry	X	X
Rubus parviflorus	thimbleberry	X	X
Acer circinatum	vine maple	-	X
Ground cover			
Gaultheria shallon	salal	X	X
Polystichum munitum	western sword fern	X	X
Vaccinium ovatum	evergreen huckleberry	X	-
Maianthemum dilatum	false lily-of-the-valley	X	-
Marah oreganus	wild cucumber	X	X
Pteridium aquilinum	western bracken fern	X	X
Rhus diversiloba	poison oak	-	X
Rubus ursinus var. *macropetalus*	wild blackberry	-	X
Rubus laciniatus	evergreen blackberry	-	X
Holodiscus discolor	ocean spray	X	X

Mammals that occur in both areas are listed in Table 2.

Mammals such as the oppossum, western gray squirrel, and dusky footed wood rat occur throughout the Willamette Valley basin, but have not extended their range to the coast. Reptiles known to occur in the refuge include the gopher snake (*Pituophis catenifer*), common garter snake (*Thamnophis sirtalis*), rubber boa (*Charina bottae*), western fence lizard (*Sceloporus occidentalis*), and the Oregon alligator lizard (*Gerrhonotus multicarinatus*). The same species probably range to the coast with the exception of the Oregon alligator lizard, which is replaced on the coast with the northern alligator lizard (*G. coeruleus*).

Other mammals examined in western Oregon which probably occur in both areas but were not sampled include red fox (*Vulpes fulva*), gray fox (*Urocyon cinereoargenteus*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), long tail weasel (*Mustela frenata*), and short tail weasel (*M. erminea*). The black bear (*Ursus americanus*) and Roosevelt elk (*Cervus canadensis*) are known to occur on the coast but were not encountered in the study area.

Sampling Procedure

Line transects were set out in each area consisting of three Sherman box (enclosed on all sides; H. B. Sherman, DeLand, Florida) or #0 Havahart live traps (mesh on sides and open at both ends; from

Table 2. List of mammals known to occur in the Neptune and William L. Finley study areas.

		Neptune	Finley
Carnivores			
Spilogale putorius	spotted skunk	X	-[a]
Mephitis mephitis	striped skunk	-	X
Procyon lotor	raccoon	X	X
Didelphis marsupialis	oppossum	-	X
Ungulates			
Odocoileus hemionus	black tail deer	X	X
Lagomorphs			
Sylvilagus bachmani	brush rabbit	X	X
Rodents			
Sciurus griseus	western gray squirrel	-	X
Tamiasciurus douglasi	Douglas squirrel	X	X
Glaucomys sabrinus	northern flying squirrel	X	?[a]
Eutamius townsendi	Townsends chipmunk	X	X
Citellus beecheyi	California ground squirrel	X	X
Zapus trinotatus	Pacific jumping mouse	X	X
Peromyscus maniculatus	deer mouse	X	X
Neotoma cinerea	bushy tailed wood rat	X	-
Neotoma fuscipes	dusky footed wood rat	-	X
Clethrionomys occidentalis	California red-back mouse	X	X
Phenacomys longicaudus	tree phenacomys	X	-
Arborimus (P.) albipes	white footed vole	X	?
Microtus oregoni	Oregon vole	?	X
Microtus montanus[b]	Montane vole	-	X
Microtus townsendi	Townsend vole	-	X
Insectivores			
Neurotrichus gibbsii	Gibb's shrew mole	X	X
Scapanus townsendi	Townsend mole	X	X
Thomomys bulbivorous	giant pocket gopher	-	X
Sorex vagrans	vagrant shrew	-	X
Sorex trowbridgi	Trowbridge shrew	X	X
Sorex bendirei	marsh shrew	X	X
Sorex pacificus or S. vagrans yaquinae[c]	Pacific shrew	X	?

Allcock Manufacturing Company, Ossining, New York) at stations 50 feet apart. Seventeen stations covering 850 feet were marked off in each habitat. Small mammals were captured alive, ear-tagged, and then released for possible capture at a later date. This was done in both areas for five consecutive days each month from July 1969 to June 1970. Traps were checked daily between 9:00 and 11:00 a.m.

Small mammals such as deer mice and voles were anesthetized with ethyl ether in plastic bags to facilitate handling, while squirrels and chipmunks were injected intraperitoneally with a 4% solution of sodium pentobarbitol (1 ml/5 lb body weight). Age and sex were the criteria used to estimate weight of mammals according to the weight-age relationships listed in Burt and Grossenheider (1964). Larger sized Havahart traps were used for skunks and oppossums, and "out of sight" mole traps for talpids. Skunks required special handling. The live trap was covered with a plastic bag and a burlap sack placed over the opening of the trap. The skunk was coaxed into the burlap sack where it was anesthetized with sodium pentobarbitol as above. When over-anesthetization occurred the mammal was revived with an equal injection of a counteractant, 3% mikedimide.

Ectoparasites were located and removed from live hosts with a dissecting microscope in the field. Dead hosts were kept in plastic bags under refrigeration until they could be examined more closely in the laboratory. Due to overexposure, mammals often died in the field traps, particularly when they were recaptured on several consecutive days. Detergent washing was used to recover parasites present in the fur (Lipovsky, 1951). The nasal turbinates were flushed with a syringe or wash bottle (Yunker, 1961) and the washings examined for nasal chiggers. In hosts that were not retained for study skins, the nares were opened with scissors and turbinates examined under the dissection microscope.

When dead hosts were allowed to cool overnight under refrigeration and then allowed to warm to room temperature, attached ticks and chiggers often detached and were removed with a detergent wash. Carcasses were shaken up in a gallon jar with Labtone (sudless detergent from VanWaters and Rogers, Portland, Oregon), and the washings filtered through a Büchner funnel using no. 4 Whatman filter paper to retain the parasites. Live material often was secured in this manner for rearing.

A "flag" made of flannel cloth (24 x 32 inches) attached to a round pole was used to sample ticks that climb vegetation. <u>Ixodes pacificus</u> was collected by the flag with ease in the Tillamook burn area (personal communication, R. Gresbrink) and in the Ashland-Medford areas (personal communication, C. M. Clifford) during the moist spring months.

Dry ice on a flannel cloth (Garcia, 1965) or in a burrow trap (Miles, 1968) has been useful in collecting those species of ticks that respond to carbon dioxide. Success with *Ornithodoros parkeri*, an argasid tick, in California using the burrow trap suggested that it might be a useful sampling device for species of *Ixodes* ticks in Oregon that may inhabit burrows.

Large herbivores were not examined in the study areas because of the difficulty in trapping them. Deer and elk were examined at check stations during the regular hunting seasons in October and November.

Preservation and Slide Mounts

Adult and nymphal ticks were preserved in 80% ethyl alcohol and stored in stoppered glass vials. Larval ticks and larval trombiculid mites (chiggers) were preserved in ethyl alcohol and then mounted in Hoyer's mounting medium. Slides were ringed with a waterproofing sealant material, "Zut" (Bennett Paint Company, Salt Lake City, Utah), since the Hoyer's mounting medium often deteriorates if not sealed. A Zeiss phase contrast microscope with oil immersion lens was used for identification of larvae.

Rearing

Engorged female ticks recovered from hosts for egg laying were stored in 10-gram vials in a rearing jar consisting of a normal desiccator jar containing a solution of 10% "roccal" (Lapine Scientific

Company, Berkeley, California) fungicide to prevent mold from covering the insides of the vessel. A few drops also were placed on a strip of filter paper in the vials. Humidity in the jar was estimated to be 100% and the jar was maintained in a room ranging in temperature from 78-81^{o}F. Larval ticks hatching from eggs were then compared with larvae collected in the field to insure correct identification.

Data Analysis

Host-parasite data were analyzed using conversational programs supplied by the OS-3 computer. The Statistical Instruction Programming System (SIPS) provided a complex of statistical tests allowing rapid manipulation of data. A program developed by Strand and Nagel (personal communication) was used to test the fit of negative binomial distributions described in Southwood (1968).

RESULTS

Enumeration of Hosts

Analysis of total numbers of deer mice (Figure 1) by the "calendar of catches" method (from Petrusewicz and MacFadyen, 1970) demonstrated a definite winter peak in the Finley study area (FSA) reaching a maximum of 18 individuals in January and then declining with a smaller peak in April (Figure 2). In the Neptune study area (NSA), the highest number (17) occurred in late August and a series of peaks occurred from September to January followed by smaller peaks in the spring months. Seasonal changes in numbers of deer mice in FSA are consistent with results of Sadleir (1970) in western British Columbia, and Hooven (1958) in the Tillamook burn area of northwestern Oregon. In both studies a fall rise in numbers took place followed by a steady decline over the winter, and populations of *Peromyscus* seem to exhibit relatively constant low numbers (Terman, 1968).

The decline in numbers of deer mice collected in this study from September to December in NSA may not reflect actual conditions since predators (spotted skunks) overturned large numbers of live traps on several occasions. Throughout the trapping period, timber slugs (*Ariolimax columbianus*) were found in the traps in NSA. The slugs reached maximum abundance in traps during the spring months

Tag	July					August						Sept.				Oct.				
no.	21	22	25	26	27	23	24	27	28	29	30	20	21	22	23	24	25	26	27	28
252A♂	4	-	5																	
253I ♀	5	-	8	8	6	7														
255A♀	8																			
256A♂	8	8	8																	
259A♂		2																		
258I ♂		2	2	6	3	6														
260A♂		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	4	5	
261A♂		5	-	10	4															
262A♀		8	-	-	-	-	-	-	-	8										
263A♀		8																		
264A♀			3	-	1	-	4	-	-	4										
265A♂				11	11	10	9	9	8	10	10									
266 I♀				11	11	10														
267A♂					10															
268A♂					10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
275I ♂						7	8	8												
276A♂						5														
277A♂							9	7	8	8	8	10	10							
278A♀							5	-	-	-	5									
279A♀								5												
280A♂								3	1	2										
283A♀								7	-	-	-	-	2							
284A♀									10											
285A♂										3	-	2	-	3	4					
286A♀										7										
287A♀											8	9								
288I ♂												1	-	-	-	3	-	1		

(Continued on next page)

Figure 1. (Continued)

Tag no.	July 21	22	25	26	27	August 23	24	27	28	29	30	Sept. 20	21	22	23	Oct. 24	25	26	27	28
289I ♂												2								
290I ♂												3 --	3							
291A♂												4 --	----	5 --	6					
292A♀												5								
293I ♀												7 --	7							
294A♀												7 --	8							
295A♂												8 --	8							
296A♂												8 --	6							
298A♀													10 --	10						
300I ♂													10 --	----	----	10 --	----	----	----	----
304I ♀														10						
330A♀																	3 --	4 --	----	4
Caught	4	7	5	5	8	6	5	6	5	7	4	12	9	4	2	2				
Total	4	9	8	8	10	10	8	11	10	11	8	15	14	8	6	4				

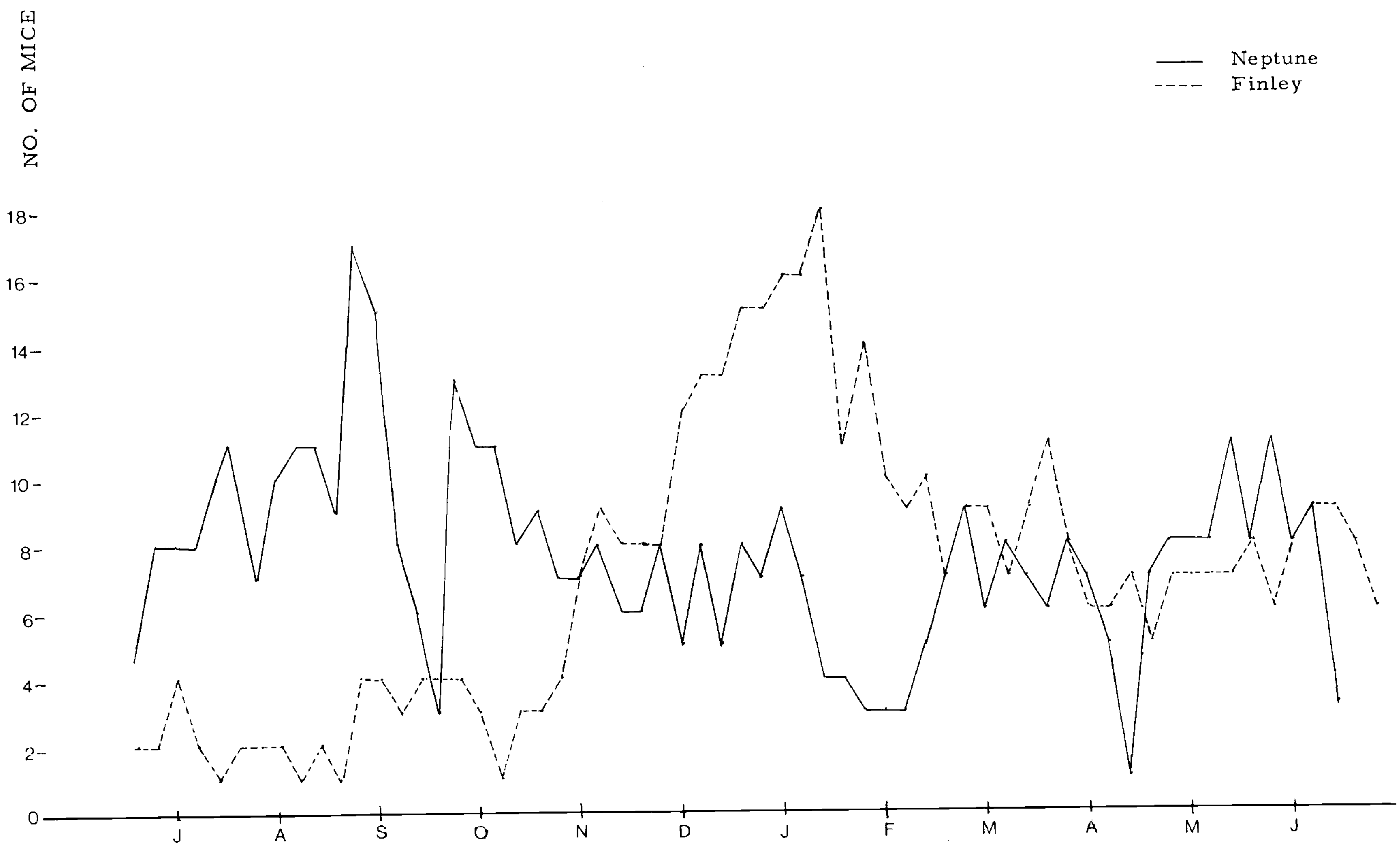


Figure 2. Total catch of deer mice from the "Calendar of catches" method in the Neptune and Finley study areas from July 1969 to June 1970.

and were possibly attracted by the decaying organic material supplied by fecal pellets of previously trapped mice.

This study was undertaken in heavily forested regions for the purpose of avoiding areas which livestock might inhabit during some period of the year. A number of cattle were released in FSA during the summer months, but they were removed in early fall before *Ixodes pacificus* activity is known to occur on vegetation; thus, the cattle were eliminated as possible hosts for the tick.

Ticks

Ixodes pacificus Cooley and Kohls

Ixodes pacificus was not found in NSA but 28 larvae and 5 nymphs were collected from rodents during the summer months in FSA. A total of 11 larvae and 14 nymphs were recovered during the same period from 3 lizards examined in a brushy field adjacent to the line transect. Mean number of ticks per small mammal host was less than mean number of ticks per lizard in FSA (Table 3), as eight lizards accounted for 40% of total immature ticks collected.

Figure 3 shows a summer peak of activity of immature ticks from early June to September with one nymph being collected in November.

The examination of deer at game commission check stations has revealed that deer are probably the most important hosts for the

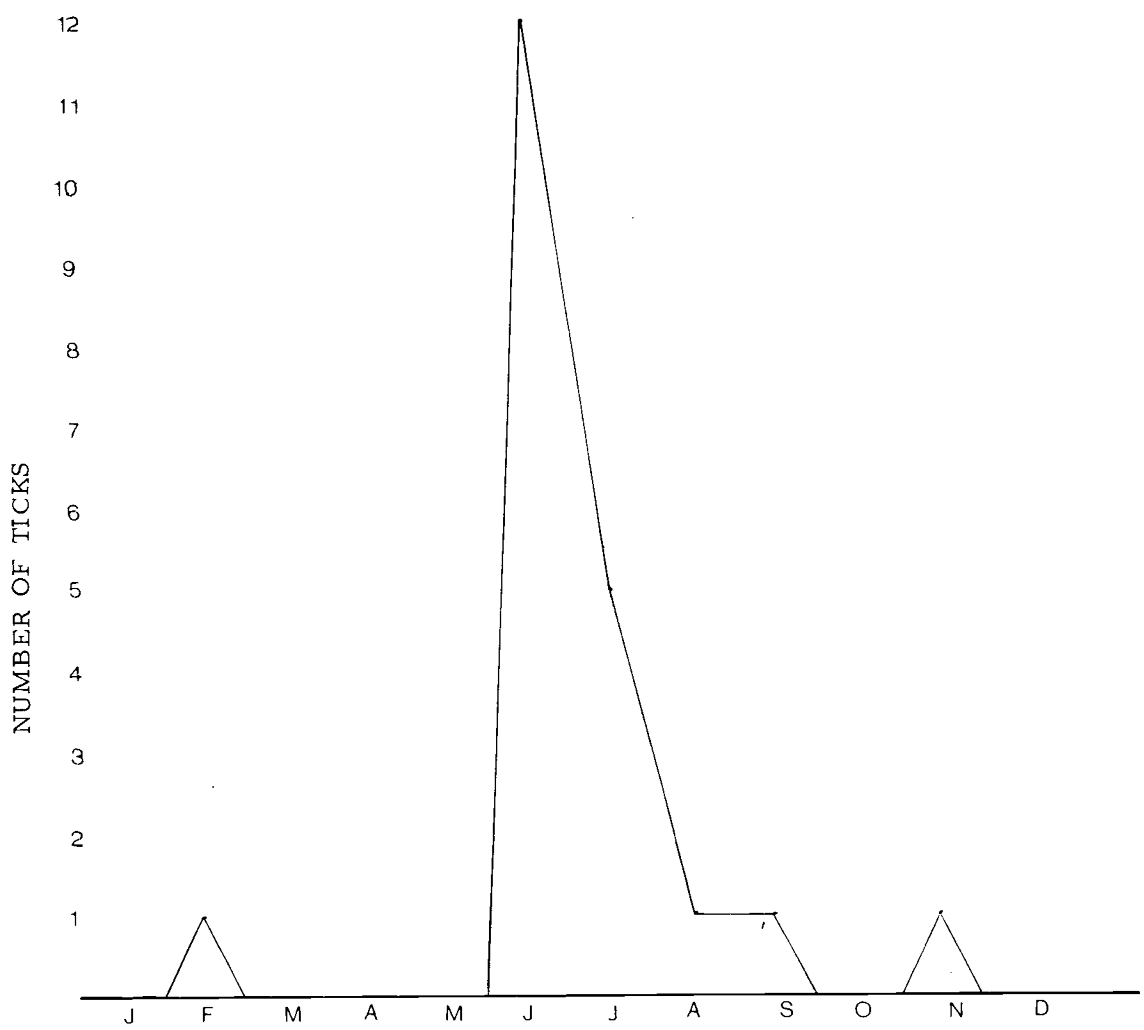


Figure 3. Activity of immature Ixodes pacificus from host data in the Finley study area from July 1969 to June 1970.

Table 3. Hosts of immature Ixodes pacificus in the William L. Finley study area.

Host	No. examined	L[a]	N	F	Total	Mean
Alligator lizard[b]	6	10	10	0	20	3.3
W. fence lizard	2	1	4	0	5	2.5
Deer mouse	236	17	2	2	21	0.08
Vagrant shrew	39	8	1	0	9	0.23
Wood rat (dusky)	11	2	1	1	4	0.36
Chipmunk	2	1	1	0	2	1.00
Total	296	39	19	3	61	

[a]L = larvae; N = nymph; F = female

[b]Alligator lizard = Oregon alligator lizard; Wood rat = Dusky footed wood rat; Chipmunk = Townsend's chipmunk

adults of I. pacificus. A total of 72 ticks (17 male, 55 female) were collected from the axilla, inside of the thigh, and inguen of 27 deer examined.

Ixodes angustus Neumann

A total of 463 I. angustus were collected in NSA (Table 4), consisting of 82 nymphs and 381 larvae. Most of the larvae were collected between May and September (367 of 381), but a few were encountered throughout the year with lowest numbers found in the winter and spring months from November to May. The nymphs were common during the same period (54) and smaller numbers were found from December to March. A total of 71 ticks were collected in FSA, consisting of 39 larvae, 24 nymphs, and 8 females. Most of the larvae

Table 4. Seasonal occurrence of Ixodes angustus in two contrasting areas of western Oregon.

Month	No. hosts examined	L[a]	N	A	Total ticks
		Neptune			
July	30	146	12	0	158
Aug	42	83	14	0	97
Sept	33	25	13	0	38
Oct	38	7	11	0	18
Nov	35	2	5	0	7
Dec	27	2	1	0	3
Jan	27	0	1	0	1
Feb	11	1	0	0	1
Mar	29	1	8	0	9
Apr	23	1	2	0	3
May	31	70	11	0	81
June	38	32	4	0	47
Total	364	381	82	0	463
		Finley			
July	13	1	1	0	2
Aug	13	14	1	0	15
Sept	32	1	1	2	4
Oct	22	2	11	4	17
Nov	35	0	1	0	1
Dec	47	0	0	1	1
Jan	42	0	0	0	0
Feb	34	2	2	0	4
Mar	36	2	5	0	7
Apr	21	2	0	0	2
May	20	10	1	0	11
June	36	5	1	1	7
Total	351	39	24	8	71

[a] L = larvae; N = nymph; A = adult

(31) were collected from May to August. No ticks were found from November to January. Nymphs were found (19) from October to April and of the 8 females collected, 1 was collected in June, 2 in September, 4 in October, and 1 in December. No females were collected from January to June. Males are rarely found on hosts, but one male was collected in copulation while the female was feeding on a long tailed vole (Microtus longicaudus) south of Burnt Woods.

The deer mouse was the most important host (Table 5) for I. angustus in both study areas. A total of 336 ticks were collected from 284 deer mice examined in NSA (71. 64%), while 77 ticks were found on Trowbridge shrews (16. 41%) and 36 ticks were found on chipmunks (7. 67%). A total of 42 ticks were collected from 236 deer mice in the FSA (58. 33%) while 18 ticks were collected from vagrant shrews (25. 0%) and 10 from the Trowbridge shrew (13. 88%). The vagrant shrew, considered by Burt and Grossenheider (1964) to be an inhabitant of fields and marshy areas, was not found in NSA.

Ixodes angustus larvae were attached mainly to the ear pinna (20), the tail (6), and feet and ankles (3) of shrews, and on the ear pinna (8) of deer mice in FSA. Nymphs were most common on the ear pinna (21) and the adults were generally attached to the head around the base of the ears. Larvae were mostly attached to the ear pinna (137) of deer mice and shrews in NSA, while the remainder were attached to the tail or ankles and feet. Nymphs were mostly found on the ear pinna (59) of mice.

Table 5. Hosts of Ixodes angustus in two areas of western Oregon.

Host	No. examined	% of total	L[a]	N	F	Total	% of total
		Neptune					
Flying squirrel	4	1.11	2	5	1	8	1.70
Douglas squirrel	2	0.55	2	1	2	5	1.06
Townsend chipmunk	5	1.39	24	11	1	36	7.67
Dusky footed wood rat	-						
Bushy tail wood rat	2	0.55		1		1	0.21
Deer mouse	284	79.32	279	57		336	71.64
Vagrant shrew	-						
Trowbridge shrew	50	13.96	76	1		77	16.41
Pacific shrew	11	3.07	6			6	1.27
Total	358		389	76	4	469	
		Finley					
Flying squirrel	-						
Douglas squirrel	1	0.31					
Townsend chipmunk	2	0.62					
Dusky footed wood rat	11	3.41		1	1	2	2.77
Bushy tail wood rat	-						
Deer mouse	236	73.29	11	23	8	42	58.33
Vagrant shrew	39	12.11	17	1		18	25.0
Trowbridge shrew	31	9.62	10			10	13.88
Pacific shrew	0						
Total	320		38	25	9	72	

[a]L = larvae; N = nymph; F = female

No significant difference was revealed by the Wilcoxon-rank test (Snedecor and Cochran, 1967) between the number of hosts examined in NSA (364) compared to 351 examined in FSA.

Nests of numerous hosts were examined to locate the male of *I. angustus* (Table 6).

Table 6. *Ixodes angustus* from nests of mammals examined in the Willamette Valley.

Host	No. nests examined	F[a]	M	N	L	Total	% of Total
Vagrant shrew	5		1			1	2.94
Townsend mole	1		1			1	2.94
Townsend vole	4	1	6	4		11	32.35
Montane vole	5		6	3	2	11	32.35
Deer mouse	4			1		1	2.94
Red tree mouse	3	3	6			9	26.47
Dusky footed wood rat	1			2		2	5.88
Total	23	4	20	10	2	36	

[a]F = female; M = male; N = nymph; L = larvae

The presence of 20 males from 23 nests examined indicates the nest as the habitat of *I. angustus* when it is not parasitic.

Ixodes soricis Gregson

Ixodes soricis was found only on shrews and on the shrew-mole in this study.

A total of 48 ticks (Table 7) infested 62 hosts in the NSA, of which 45 ticks were larvae, 1 a nymph, and 2 were female. The

Table 7. Hosts of *Ixodes soricis* in two areas of western Oregon.

Host	No. examined	% of Total	L[a]	N	F	Total	% of Total
		Neptune					
Trowbridge shrew	50	80.64	40	1	1	42	87.50
Marsh shrew	1	1.61			1	1	2.08
Pacific shrew	11	17.74	5			5	10.41
Vagrant shrew	0						
Gibb's shrew mole	0						
Total	62		45	1	2	48	
		Finley					
Trowbridge shrew	31	42.46	6		1	7	15.90
Marsh shrew	0						
Pacific shrew	0						
Vagrant shrew	39	53.42	29	3	4	36	81.81
Gibb's shrew mole	3	4.10		1		1	2.27
Total	73		35	4	5	44	

[a] L = larva; N = nymph; F = female

Trowbridge shrew accounted for 42 ticks (87.5% of total), the Pacific shrew 5 (10.41%), and only 1 tick was found on one marsh shrew examined.

Total number of ticks found in FSA was 44 from 73 hosts examined, of which 35 ticks were larvae, 4 were nymphs, and 5 female. No males of I. soricis were found on hosts. The vagrant shrew accounted for 36 of the 44 ticks (81.8%), 7 ticks were found on the Trowbridge shrew (15.94%), and 1 tick was found on a Gibb's shrew-mole (2.27%). The vagrant shrew and Gibb's shrew-mole were not collected in NSA even though both mammals are distributed along the coast (Ingles, 1965). The marsh and Pacific shrews were not collected in FSA.

A unimodal peak of abundance was noticed with larvae in both areas (Figure 4) active from March and April to August. Nymphs and females were active between September and April. Female ticks in FSA were attached to the head of the shrew, although one unengorged female was feeding on the tail of a Trowbridge shrew. Larvae were attached to the tail (13), the hind legs (1), and one was found on the ear pinna. Nymphs were found on the ear (1), neck (1), snout (1), and right hind ankle of the host.

Larvae in NSA were attached to the tail (12), legs, ankles and feet (5), and the ears (4). One nymph was attached to a hind leg. No females were collected. The site of attachment could not be ascertained

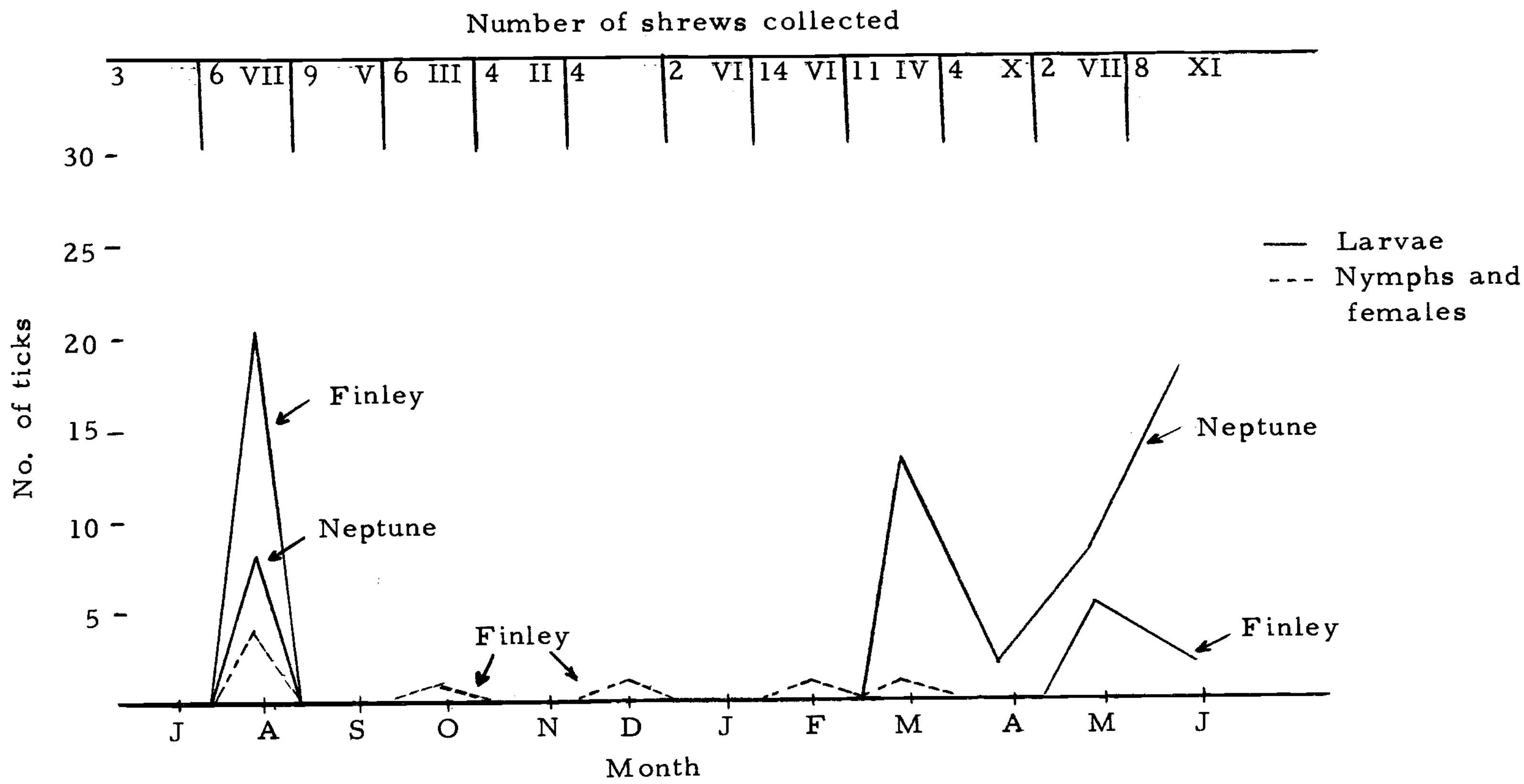


Figure 4. Population composition of Ixodes soricis in the Finley and Neptune study areas from July 1969 to June 1970.
Arabic numbers = Finley; Roman numerals - Neptune

for all 92 ticks recovered, since some were found crawling on the dead hosts. In the field it was impossible to distinguish the larvae of *I. soricis* from the larvae of the closely related species *I. angustus*, which occurred commonly on insectivores.

Chiggers

Comatacarus americana (Ewing)

Comatacarus americana was the second most abundant species collected in western Oregon. A total of 168 mites were removed from 352 hosts examined in NSA (Table 8). Insectivores constituted the most common host for this mite. Ninety chiggers (53. 5%) were found attached to Trowbridge shrews, 74 chiggers on Pacific shrews (44. 0%), and 2 on deer mice (1. 19%).

One mite collected from a spotted skunk was not considered to be significant since skunks are common predators of insectivores and rodents in this area. The most important host for *C. americana* in FSA was the vagrant shrew (53 mites, or 76. 81%). No mites were found on the 31 Trowbridge shrews examined. The 16 mites collected from montane voles (23. 18%) suggest the presence of chiggers in open areas where this vole is more common. The mean number of mites per host was highest on the Trowbridge shrew (6. 72) in NSA and on the montane vole (5. 33) in FSA.

Table 8. Hosts of Comatacarus americana in two areas of western Oregon.

Host	No. examined	% of Hosts	Mites	Mean	% of Total
		Neptune			
Trowbridge shrew	50	14.2	90	1.80	53.5
Vagrant shrew	0				
Marsh shrew	1	0.28			
Pacific shrew	11	3.12	74	6.72	44.0
Gibb's shrew mole	0				
Deer mouse	284	80.68	2	0.00	1.19
California red-back mouse	2	0.56	1	0.50	0.59
Spotted skunk	4	1.13	1	0.25	0.59
Montane vole	0				
Total	352		168		
		Finley			
Trowbridge shrew	31	9.87	0		
Vagrant shrew	39	12.42	53	1.35	76.81
Marsh shrew	0				
Pacific shrew	0				
Gibb's shrew mole	3	0.95	0		
Deer mouse	236	75.15	0		
California red-back mouse	2	0.63	0		
Spotted skunk	0				
Montane vole	3	0.95	16	5.33	23.18
Total	314		69		

The mites were attached in or around the ear canal of shrews and none was feeding on the external ear. Highest infestations per host in NSA were 26 and 20 mites respectively on Pacific shrews, while in FSA 18 mites were found attached to the ear of one vagrant shrew.

Chigger activity was greatest from February to April in FSA (Figure 5), while greatest activity in NSA was evident in June with a smaller peak in March suggesting a bimodal period of abundance.

Chatia setosa Brennan

Chatia setosa was the least abundant chigger encountered during this study. Of a total of 42 mites collected, 41 specimens were found in NSA but only one mite was collected in FSA.

The deer mouse was the most common host for *Ch. setosa*, with 28 chiggers (70.0%) found on 14 mice. Four mites were attached to two Townsend chipmunks and eight mites were recovered from a California red-back mouse (20.0%). Chiggers were attached mainly to the eyelids of deer mice (14) but they also attached to the vibrissae and external ear. One mite was attached to the rear leg and another in front of the anus.

The greatest activity of *Ch. setosa* was noted in late summer and fall as 9 mites were collected in August, 8 in September, and 4 in October. No chiggers were noted in January, February, and April through July.

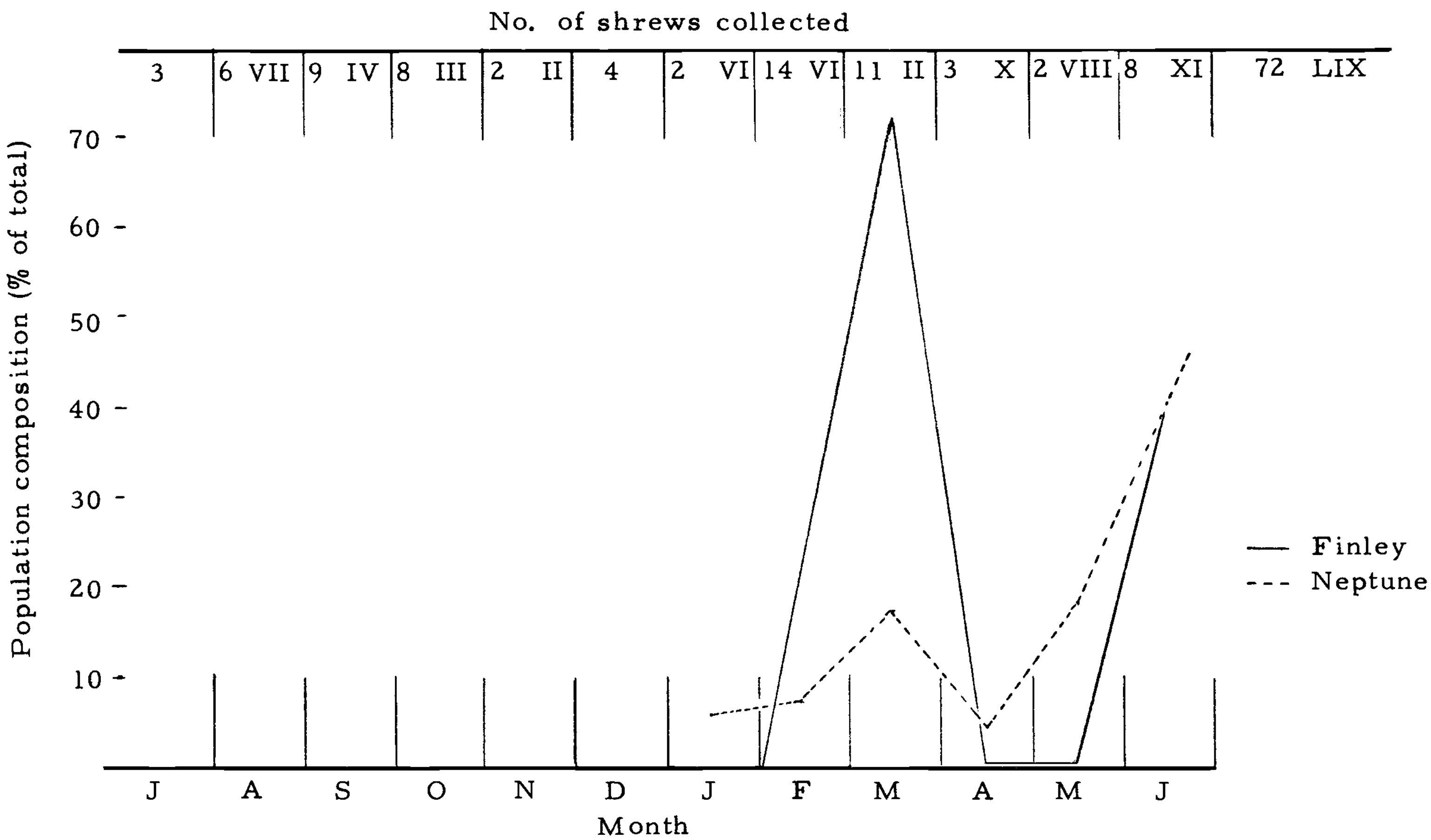


Figure 5. The population of Comatacarus americana in two areas of western Oregon from July 1969 - June 1970.
Arabic numbers = Finley; Roman numerals = Neptune

Euschöngastia oregonensis (Ewing)

Euschöngastia oregonensis was the most abundant chigger collected. A total of 261 mites (Table 9) were collected in NSA as compared to 100 in FSA. The deer mouse was the most common host in the coastal study. A total of 242 mites were found on deer mice in NSA (92. 72%) and 19 mites were feeding on chipmunks (7. 85%). The mean number of chiggers per host was higher for chipmunks (6. 33) than for the deer mouse (0. 85).

A total of 83 mites were found on vagrant shrews (83. 0%) in FSA, 8 from deer mice (8. 0%) and 4 from Trowbridge shrews. The mean number of mites per host was higher for vagrant shrews (2. 12) than for deer mice (0. 033) in this area.

Moderate numbers of E. oregonensis were collected in NSA throughout the year. The largest numbers of mites collected per month were 44 in August (Table 10) and 61 in September, and lowest numbers occurred in May (2) and June (3). Largest numbers of mites collected in FSA were 49 in August and 22 in October, while small numbers of mites were found in the winter and spring from November through May.

E. oregonensis attached to the vicinity of the eyes (37. 6%) generally on the lids and 17. 25% were attached to the ear pinna in NSA. Only 8. 0% of the mites in FSA were found on deer mice; 3

Table 9. Hosts of Euschöngastia oregonensis in two areas of western Oregon.

Host	No. examined	% of Hosts	Mites	Mean	% of Total
		Neptune			
Townsends chipmunk	3	0.88	19	6.33	7.85
Deer mouse	284	83.77	242	0.85	92.72
California red-back mouse	2	0.58			
Oregon vole	0				
Vagrant shrew	0				
Trowbridge shrew	50	14.74			
Total	339		261		
		Finley			
Townsends chipmunk	2	0.63	1	0.50	1.00
Deer mouse	236	74.94	8	3.38	8.00
California red-back mouse	2	0.63	3	1.50	3.00
Oregon vole	5	1.58	1	0.20	1.00
Vagrant shrew	39	12.38	83	2.12	83.00
Trowbridge shrew	31	9.84	4	0.12	4.00
Total	315		100		

Table 10. Seasonal occurrence of chiggers in two contrasting areas of western Oregon.

Month	No. hosts examined	*Euschöngastia oregonensis*	*Neotrombicula harperi*	*Neotrombicula cavicola*	Total mites
		Neptune			
July	30	15	100	0	115
Aug	42	44	40	0	84
Sept	33	61	40	0	101
Oct	38	30	0	0	30
Nov	35	26	0	0	26
Dec	27	30	0	20	50
Jan	27	16	0	0	16
Feb	11	9	0	8	17
Mar	29	13	0	8	21
Apr	23	0	0	0	0
May	31	2	0	0	2
June	38	3	0	0	3
Total	364	249	180	36	465
% of total		53.5	37.7	7.7	
		Finley			
July	13	12	39	19	70
Aug	13	49	13	0	62
Sept	32	4	1	1	6
Oct	22	22	0	0	22
Nov	35	0	0	6	6
Dec	47	1	0	5	6
Jan	42	5	0	0	5
Feb	34	1	0	12	13
Mar	36	1	0	15	16
Apr	21	0	0	0	0
May	20	1	0	0	1
June	36	12	92	0	104
Total	351	108	145	58	311
% of total		34.7	46.6	18.6	

chiggers were found around the eyes, 1 was in the ear, and 4 were on the vibrissae. On shrews, 4 mites were found on the snout, 4 on ears, 1 around the eye, but the majority (52) were attached on the venter near the genitals. Highest infestation on one host in NSA was 10 mites from one deer mouse. In FSA, 28 mites were found on the venter and snout of a vagrant shrew.

Neotrombicula harperi Ewing

A total of 347 *N. harperi* was collected in this study, of which 196 chiggers were found in NSA and 133 in FSA (Table 11). The chipmunk was the chief host parasitized in NSA; 163 chiggers (or 83.0%) followed by 19 mites collected from bushy tail wood rats (9.7%) and 14 from the Pacific shrew (7.1%). The mean number of mites per host was highest for chipmunks (32.6) and lowest for bushy tail wood rats (9.6). No chiggers were collected from deer mice in either study area and only one specimen was collected from this host during this study.

The most common host for *N. harperi* in FSA was the montane vole (81 mites, 61.0%), but all chiggers were attached to one individual and only three hosts were examined. Mites were also removed from the California red-back mouse (37; 27.8%), the chipmunk (8; 6.02%), and the vagrant shrew (5; 3.7%). Mean number of mites per host was generally higher for this chigger than for species formerly

Table 11. Hosts of <u>Neotrombicula harperi</u> and <u>N. cavicola</u> in two areas of western Oregon.

Host	No. examined	% of Hosts	N. harperi no.	N. harperi mean	N. cavicola no.	N. cavicola mean	Total mites	% of Total
			Neptune					
Deer mouse	284	93.42	0					
Townsend chipmunk	5	1.64	163	32.6	8	1.60	171	73.70
Montane vole	0							
Oregon vole	0							
California red-back mouse	2	0.65	0		20[a]	10.0	20	8.62
Dusky footed wood rat	0							
Bushy tailed wood rat	2	0.65	19	9.5	8	4.0	27	11.63
Pacific shrew	11	3.61	14				14	6.03
Vagrant shrew	0							
Total	304		196		36		232	
			Finley					
Deer mouse	236	79.19	0		3	0.12	3	1.68
Townsend chipmunk	2	0.67	8	4.0	0		8	4.49
Montane vole	3	1.00	81[a]	27.0	10	3.33	91	51.12
Oregon vole	5	1.67	2	0.40	2	0.40	4	2.24
California red-back mouse	2	0.67	37	18.5	18	9.00	55	30.89
Dusky footed wood rat	11				10	0.90	10	5.61
Bushy tailed wood rat	0							
Pacific shrew	0							
Vagrant shrew	39	13.08	5	0.12	2	0.05	7	3.93
Total	298		133		45		178	

[a]From one individual

discussed, as the mean for montane voles was 27.0, California red-back mouse 18.6, and the chipmunk 4.0.

Mites always were found attached in the ear conch of hosts. *N. harperi* was collected in late summer and early fall in NSA and from June to August in FSA. No mites were collected from October through May.

Neotrombicula cavicola Ewing

A total of 94 *N. cavicola* was collected in this study. The mite was more common in FSA (45) as compared to 36 mites collected in NSA (Table 11). A total of 20 mites were found on one California red-back mouse (mean of 10), 8 mites were removed from 5 chipmunks (mean of 1.6) and 3 chiggers were found on 2 bushy tail wood rats (mean of 4.0).

The California red-back mouse was the most highly infested host in FSA (18 mites; mean of 9.0) while 10 mites were found on 3 montane voles (mean of 3.3) and 10 were removed from 11 dusky footed wood rats (0.90).

A total of 48 mites were found in FSA (Table 10) from July to March and no mites were found from April to June. The 36 mites found in NSA occurred in December, February, and March. Other records of *N. cavicola* in Oregon show collections in February, March, May, September, and December, which suggests an absence of the chigger in the summer.

DISCUSSION

Relationship to Habitat

Ixodes pacificus was not collected in NSA where lizards are probably not present and climax timber does not support nourishing food plants for deer. Lizards have been reported (Arthur and Snow, 1968) as hosts for immature ticks and in this study the western swift, Oregon alligator, and northern alligator lizard were the most important. Habitat of lizards is generally improved when man purposely "clearcuts" climax timber. This activity provides clearings and open spaces that supply lizards with litter for concealment and at the same time allows food plants readily fed upon by deer to thrive. Records from the flag over several seasons in western Oregon (Gresbrink, 1971) indicate that adult activity is most pronounced from March to June. The presence of larvae in samples of oak litter from the forest floor in May, the absence of this species in nests of mammals, and the absence of immature ticks on lizards and small mammal hosts before June and after October indicates that larvae and nymphs thrive in the upper soil layers of the forest floor and do not inhabit nests or burrows.

Ixodes angustus is probably the most common ixodid in western Oregon. No ticks of this species were collected on a flag in either study area or in sweeping vegetation, suggesting that the species does not find its host on vegetation in a manner similar to *I. pacificus*.

The lack of records of male ticks on hosts, the failure of males to feed on mice in this study, and the presence of males as well as other stages of this tick in nests indicate that the non-parasitic portions of the life cycle are spent in burrows or nests rather than in duff or litter.

The few number of female ticks collected on hosts in this study cannot be explained. The deer mouse was the chief host parasitized but literature records infer that squirrels are important hosts. The silver gray and the Douglas squirrel are probably important hosts in FSA, whereas the Douglas and flying squirrels may be more important in the NSA where western silver gray squirrels are absent. The Townsend mole, common to both areas, was heavily parasitized with larvae and nymphs of *I. angustus*, but not with adults.

Ixodes soricis, called the shrew tick by Spencer (1963), has been found on shrews almost without exception as this species appears to be one of the most host-specific ixodids found in the Pacific Northwest. A report by Gregson (1952) of three females feeding on a gopher, *Thomomys talpoides*, and a report of a tick biting man (Spencer, 1963) are the only literature records available of the tick feeding on a non-soricine. *I. soricis* was found in this study on four species of shrews and one species of shrew-mole (Table 7). The two nymphs collected from Gibb's shrew-mole is considered a new host record. This insectivore, considered by Ingles (1967) to be a true mole in the family Talpidae, may be an accidental host for this tick but the insectivore is elusive and not frequently collected. Only three individuals were captured in FSA and none in NSA, even though the mammal is thought to be present. This mole inhabits surface runways similar to other talpids, but *Neurotrichus gibbsi* forages over the surface of the ground as well. *Ixodes soricis* was not found infesting the Townsend mole, a common insectivore found in both areas that resides in subterranean passageways and is found on the surface of the ground only when young moles leave the nest (Pederson, 1963).

The lack of males found on hosts in this study and the paucity of records of males in the literature leads one to believe that males are probably inhabitants of the shrew nest and this tick as well as *I. angustus* is a nest-inhabitor when it is not parasitic.

The deer mouse was the most common host for the chigger, *E. oregonensis*, in NSA but shrews were more heavily parasitized in FSA, and in California, Jameson and Brennan (1957) reported 98 mites from a total of 1 shrew-mole, 3 northern water shrews (*S. palustris*), 28 Trowbridge shrews, and 1 montane vole. No chiggers were found on deer mice. Further evidence is then provided that the mite is not host specific but feeds on various mammalian hosts that enter the area. The feeding of *E. oregonensis* on shrews in FSA where deer mice are common cannot be explained.

Loomis (1956) found that orange to red chiggers found on the surface of the ground in Kansas had a wider host range than pale chiggers found more closely associated with mammals in tree holes or burrow situations. In Malaya, Nadchatram (1970) correlated color of trombiculid mites with their habitat and on this basis separated them into several ecological groups (7). In group I, he placed orange to red chiggers found on the ground surface and ones probably affected by fluctuating environmental conditions. The chiggers in group II were white to yellow and found in ground burrows of terrestial animals. Another group of white, orange, or red chiggers was arboreal; one group of orange chiggers was bird-infesting; one lived in bat caves and tree holes where they fed on bats; one was hypodermal in frogs or endoparasitic in amphibious sea snakes; and one, which contained only two species, was found infesting scorpions and millipedes in ground holes or under dead logs. As yet there is no evidence for arboreal chiggers in Oregon and none has been found on bats, but these hosts have not been extensively examined. However, three specimens of an intradermal species, Euschöngastia velata (Brennan and Yunker, 1966), found on a vole and bushy tail wood rat in Montana, were taken from a deer mouse south of Burnt Woods, Oregon. E. velata was not found in FSA or NSA. With the exception of this intradermal species the chiggers found in this study could be most appropriately categorized in ecological groups I and II.

Nadchatram felt that chiggers in groups III to VII showed closer relationship with host animals and were more host specific than those in groups I and II, which show ecological specificity. The restricted habitat of white and yellow chiggers reduces and almost eliminates their opportunity for feeding on man and most chiggers that are man-infesting probably occur in ecological group I. Nadchatram further suggested that species of chiggers that exhibited a variation in color from white to orange may live in different areas; white forms in underground burrows and orange on the surface of the ground. Color in chiggers is not thought to be cuticular since the pigment soon is dissolved in ethyl alcohol preservative. It is believed to be dependent on the food taken in by nymphs and adults as Hyland (1951) observed red larvae of *Eutrombicula splendens* collected from a garter snake in the field but second generation larvae fed on gravid mosquito ovaries were pale yellow. Nadchatram (1970) found that *Leptotrombidium diliense* fed on eggs of *Culex* were dark grey and another batch from the same population feeding on collembolan eggs were bright orange.

Chiggers always found to be white in this study included *Comatacarus americana*, *Chatia setosa*, and *Euschöngastia oregonensis*. Crossley (1960) described a nymph of *C. americana* as yellow with red eyes. The color of nymphs in *E. oregonensis* is unknown. Even though free living mites were not recovered from burrow and nest situations in this study, the lack of records from non-burrowing animals such as herbivores, some canines, and man, and the occurrence of the mites throughout the year suggest that the mites are probably nidicolous and burrow dwellers.

In a study of the genus *Neotrombicula* by Brennan and Wharton (1950), only *N. cavicola* was found to be white in life while other species were orange to red. Gould (1956) noticed color variation from white-orange to red in *N. cavicola* from California and similar observations were made in this study. All specimens of *N. dinehartae* collected from garter snakes (Clifford *et al.*, 1970) and lizards in southwestern Oregon have been red, as well as all specimens of *N. harperi* collected in this study.

Even though most of the hosts parasitized by *N. harperi* in this study were burrow inhabitors, this is partially due to collecting techniques inasmuch as rodents and insectivores were more easily trapped than were carnivores. The 8 mites collected from an opossum, 1 from a brush rabbit, 10 from a red fox, and 3 from the spotted skunk (Figure 6) provide greater evidence that the mite lives on top of the ground surface. There are no records from herbivores or man.

Neotrombicula cavicola parasitized more host species than any other chigger species in this study (16), which would be expected if it lives in burrow situations (white strain) as well as on the surface of the ground (orange or red strain). Mites found living in both habitats would tend to be found on more host species, as there would be greater

	a	b	c	d	e	f
No. host species	11	7	14	15	12	16
No. host records	47	32	79	25	63	46
Man					1	
Dog					1	
Horse					5	
Deer					1(4)[g]	
Red fox				1		
Grey fox					1	
Oppossum				1		
Spotted skunk	1			1		
Coyote			1			1
California ground squirrel				1	8[g]	1
Douglas squirrel		6[g]	1[g]		2[g]	
Townsend vole		1				2
Montane vole	1		1[g]	1		3
Long tail vole			2[g]			1
Oregon vole	1	8		2		14
White footed vole			1			
California red-back mouse	1	2	3	1		4
Townsend chipmunk		1	4	6	1[g]	2
Bushy tail wood rat	1[g]	3[g]	1	2	3[g]	1
Dusky footed wood rat						5
Deer mouse	2	11	49	1	1(22)[g]	4
Pinon mouse					14[g]	1
Brush rabbit			1	1	3[g]	
Short tail weasel						1
Pacific jumping mouse				2		
Vagrant shrew	12		8	3		1
Marsh shrew	1					
Trowbridge shrew	19		3			
Pacific shrew	6		1[g]	1		
Townsend mole	2		3	1		3
Giant pocket gopher						2

likelihood of mite-host interaction. Neotrombicula harperi fed on 15 host species and E. oregonensis on 14, but the large number of records of the latter species infers that the mite is more common in mature forested situations and N. harperi may be more common in field habitats. Chatia setosa was found on 7 different host species (Figure 6) and Comatacarus americana was found on 11 species.

Compatibility

In order to evaluate the interrelationships of species of ectoparasites on a single host species, an index of compatibility was calculated (Allred, 1971) for the two study areas in western Oregon based on a negative correlation factor according to the following:

$$\frac{\text{Expected rate - Actual rate}}{\text{Expected rate}} = \text{Negative correlation factor}$$

when the expected rate equals the sum of two or more rates of infestation (expressed in percent). On the Trowbridge shrew for example, three species of tick and two species of chigger may be found feeding on the pinna or conch of the ear. Ixodes soricis was found on 2.56% of the Trowbridge shrews examined in FSA and I. angustus was found on 9.67% of these hosts. Both species of ticks would be expected to occur on 12.23%, but they were only found together on 3.2%. The difference between the actual (3.2%) and the expected (12.23%) is 9.03% according to the above formula which, when divided by 12.23% (the expected rate of infestation, gives a correlation factor of 73.6.

Allred (1971) found that parasites such as lice have a high correlation factor near 100 so that a higher correlation factor could be used to measure the host specificity of the parasite. On the other hand, parasites having low correlation factors were less host specific and found on several host groups. In this study, ectoparasites that feed on a number of different host groups such as Ixodes pacificus and I. angustus would tend to have a high actual rate of infestation between hosts which would result in a lower negative correlation factor.

The lowest value of 32.7 in this study (Table 12) for I. pacificus and I. angustus is consistent with the low degree of host specificity that these tick species maintain while the value of 94.4 for I. soricis and I. angustus reflects the high degree of host specificity of I. soricis for shrews. Consortism was more pronounced in FSA where numbers of most parasites were lower than in NSA. Consortism between N. harperi and N. cavicola was found only in NSA, while consortism between I. angustus and I. soricis occurred both in NSA and FSA.

The correlation factor of 92.6 for C. americana and E. oregonensis (Table 12) on vagrant shrews is consistent with host records of these mites feeding only on burrow inhabiting mammals, while the

Table 12. Negative correlation factors listing consortium of ectoparasites in the William L. Finley study area.

Ectoparasite association[a]	Deer mouse	Vagrant shrew	Trowbridge shrew	Bushy tail wood rat
pacificus-angustus	88.91	32.7		
angustus-soricis		94.4	73.6 73.0(N)[b]	
americana-oregonensis	83.0	92.6		
harperi-cavicola				66.6(N)[b]

[a] pacificus = I. pacificus; angustus = I. angustus; soricis = I. soricis; americana = C. americana; oregonensis = E. oregonensis; harperi = N. harperi; cavicola = N. cavicola

[b] (N) = Neptune study area

lower value (66.6) for N. harperi and N. cavicola is consistent with our knowledge of these chiggers feeding on a wider range of host species.

In many cases with deer mice C. americana and E. oregonensis did not compete for feeding sites since C. americana was found in the conch of the ear and E. oregonensis attached around the eyes. On hosts other than deer mice, E. oregonensis fed on other parts of the body such as on or in the middle ear of shrews. N. harperi and N. cavicola were not found parasitizing deer mice in this study despite the broad range of feeding habits possessed by the two species. N. harperi and N. cavicola were found feeding on vagrant shrews in FSA but both species of mites were not found on the same individual at the same time. The same is true with the California red-back mouse and the Townsend chipmunk as the high infestation rates (71.4 for N. harperi in the NSA, Table 13) suggests that if more hosts of these two species were examined a greater interaction of ectoparasites would have been observed. The seven Townsend chipmunks and two California red-back mice collected over the 12-month period probably underestimate the actual population level of these hosts in the area.

Distribution in the Habitat

Crofton (1971a) discussed parasitic situations in which the negative binomial distribution can arise such as (1) a result of a series of exposures to infection in which the exposure is random but the chances of infection differs at each exposure, or (2) as a result of infective stages not being randomly distributed as in cases where infective stages arise from masses of eggs where there is departure from randomness, (3) as a result of variation in age, rate of development and genetic constitution as well as individual habits which alter the chances of individuals becoming infected or (4) with chances of infection of individual hosts changing with time.

In order to describe the distribution of ticks and chiggers on hosts in this study, three values of k of the negative binomial were calculated from a computer program using the following three methods from Southwood (1968).

Table 13. Parasite infestations (%) on common hosts in two forested areas.

	Total no. hosts		*Ixodes pacificus*			*Ixodes angustus*				*Ixodes soricis*			
			N	F		N		F		N		F	
	N[a]	F[a]	with ticks	with ticks	%	with ticks	%	with ticks	%	with ticks	%	with ticks	%
Deer mouse	284	236	0	10	4.23	101	35.56	26	11.01	0	0.0	0	0.0
Vagrant shrew	0	39	0	6	15.38	0	0.0	9	23.07	0	0.0	9	23.07
Trowbridge shrew	50	31	0	1	3.22	12	24.0	3	9.67	14	28.0	1	2.56
California redback mouse	2	3	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Bushy tail wood rat	2	0	0	0	0.0	1	50.0	0	0.0	0	0.0	0	0.0
Dusky footed wood rat	0	11	0	3	27.27	0	0.0	2	18.18	0	0.0	0	0.0
Townsend chipmunk	7	2	0	1	50.0	7	100.0	0	0.0	0	0.0	0	0.0

	Comatacarus americana				*Euschongastia oregonensis*				*Neotrombicula harperi*				*Neotrombicula cavicola*			
	N		F		N		F		N		F		N		F	
	with mites	%	with mites	%	with mites	%	with mites	%	with mites	%	with mites	%	with mites	%	with mites	%
Deer mouse	1	0.35	1	0.42	73	25.70	5	2.11	0	0.0	0	0.0	0	0.0	0	0.0
Vagrant shrew	0	0.0	16	41.02	0	0.0	11	28.20	0	0.0	3	7.69	0	0.0	1	2.56
Trowbridge shrew	20	40.0	0	0.0	0	0.0	3	9.67	0	0.0	0	0.0	0	0.0	0	0.0
California red-back mouse	1	50.0	0	0.0	1	50.0	3	100.0	0	0.0	1	33.3	1	50.0	3	100.0
Bushy tail wood rat	0	0.0	0	0.0	0	0.0	0	0.0	2	100.0	0	0.0	1	50.0	0	0.0
Dusky footed wood rat	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	27.27
Townsend chipmunk	0	0.0	0	0.0	3	42.85	1	50.0	5	71.42	1	50.0	2	28.57	0	0.0

[a]N = Neptune study area; F = Finley study area

(1) $$k1 = \frac{\bar{x}^2}{(s^2 - \bar{x})}$$

(2) $$\ln\left(\frac{N}{f_0}\right) = k2 \ln\left(1 + \frac{\bar{x}}{k2}\right)$$

(3) $$N \ln\left(\frac{1 + \bar{x}}{k3}\right) = \Sigma\left(\frac{Ax}{kx + x}\right)$$

where

$\bar{x}$ = mean number of organisms per sample

s^2 = variance

f_0 = frequency of the zero class

N = total number of samples

Ax = the sum of all frequencies of sampling units containing more than x individuals

When a moderate degree of clumping exists, formula (1) is not thought to be as reliable (Southwood, 1968), whereas formula (2) is efficient with populations having very small means or it has been used to study large populations having extensive clumping. When the value of k has been found by trial and error in equations (2) and (3) by substituting values in either side until both are equal, the agreement between the negative binomial series as a model and the actual distribution can be tested by calculating the expected frequencies of each value and comparing these by a chi-square with the actual values.

The expected values are calculated by:

$$Px = \frac{\Gamma(k + x)}{x!\,\Gamma(k)} \times \left(\frac{\bar{x}}{\bar{x} + k}\right)^x \times \left(\frac{k}{k + \bar{x}}\right)^k$$

where

Px = the sample containing x animals, and the values of x! and $\Gamma(k)$ are found in tables of factorials and log gamma functions respectively. χ^2 has three fewer degrees of freedom than the number of comparisons that are made between expected and actual frequencies; those with small expectations are pooled.

Negative binomial distributions in this study are fitted to data of Ixodes angustus ticks (Table 14) and to chigger data (Tables 15 and 16). In all cases, the mean is much lower than the variance, automatically eliminating a Poisson series from adequately describing the data. Because the closest fit was obtained with method (2) from Southwood, values from other methods have not been included here.

The calculated chi-square values at eight degrees of freedom (Table 14) did not exceed the tabular chi-square value of 17.5 at the .025 level of probability, so we assume no significant difference and the data follow the negative binomial distribution. No significant difference was obtained with E. oregonensis from deer mice (Table 16) or of data of chiggers lumped from all hosts (Table 15). The values of k contrast greatly from one area to another, but in either area are the values of k high or low enough to suggest that the parasites are dispersed in a random manner. The value of k (.3193) in Table 15 for chigger data in NSA is higher than the value of .0456 obtained from data in FSA, suggesting that chiggers in the Neptune

Table 14. Negative binomial distributions fitted to data of Ixodes angustus in two areas of western Oregon.

No. of ticks	Finley average no. hosts	Finley frequency expected	Neptune average no. hosts	Neptune frequency expected
0	17.86	17.86	11.86	11.85
1	2.06	2.05	3.06	3.69
2	1.20	0.84	2.46	2.11
3	0.33	0.42	1.80	1.39
4	0.06	0.23	0.73	0.98
5	0.00	0.14	0.40	0.71
6	0.00	0.08	0.53	0.53
7	0.00	0.05	0.20	0.40
8	0.00	0.09	0.20	0.31
9	0.00	-	0.46	0.24
10+	0.26	-	1.46	0.93
No. hosts (H)	21.77		23.17	
No. ticks (T)	8.38		44.36	
Mean (T/H)	0.38		1.87	
Variance	1.65		8.83	
Chi-square		0.906		1.964
Degrees of freedom		6		8
k value		.1637		.3737

Table 15. Negative binomial distributions fitted to data of chiggers in two areas of western Oregon.

No. of chiggers	Finley		Neptune	
	average no. hosts	frequency expected	average no. hosts	frequency expected
0	19.73	19.730	12.13	12.141
1	0.86	0.823	2.86	3.378
2	0.26	0.392	1.80	1.941
3	0.13	0.244	1.00	1.307
4	0.13	0.169	1.13	0.945
5	0.20	0.125	0.73	0.711
6	0.00	0.096	0.53	0.549
7	0.00	0.075	0.46	0.432
8	0.00	0.060	0.33	0.344
9	0.13	0.336	0.33	0.277
10+	0.60	-	2.06	1.332
No. hosts (H)	22.06		23.36	
No. mites (C)	10.52		50.33	
Mean (C/H)	0.477		1.939	
Variance	3.609		10.15	
Chi-square		0.8446		0.6182
Degrees of freedom		7		8
k value		.0456		.3193

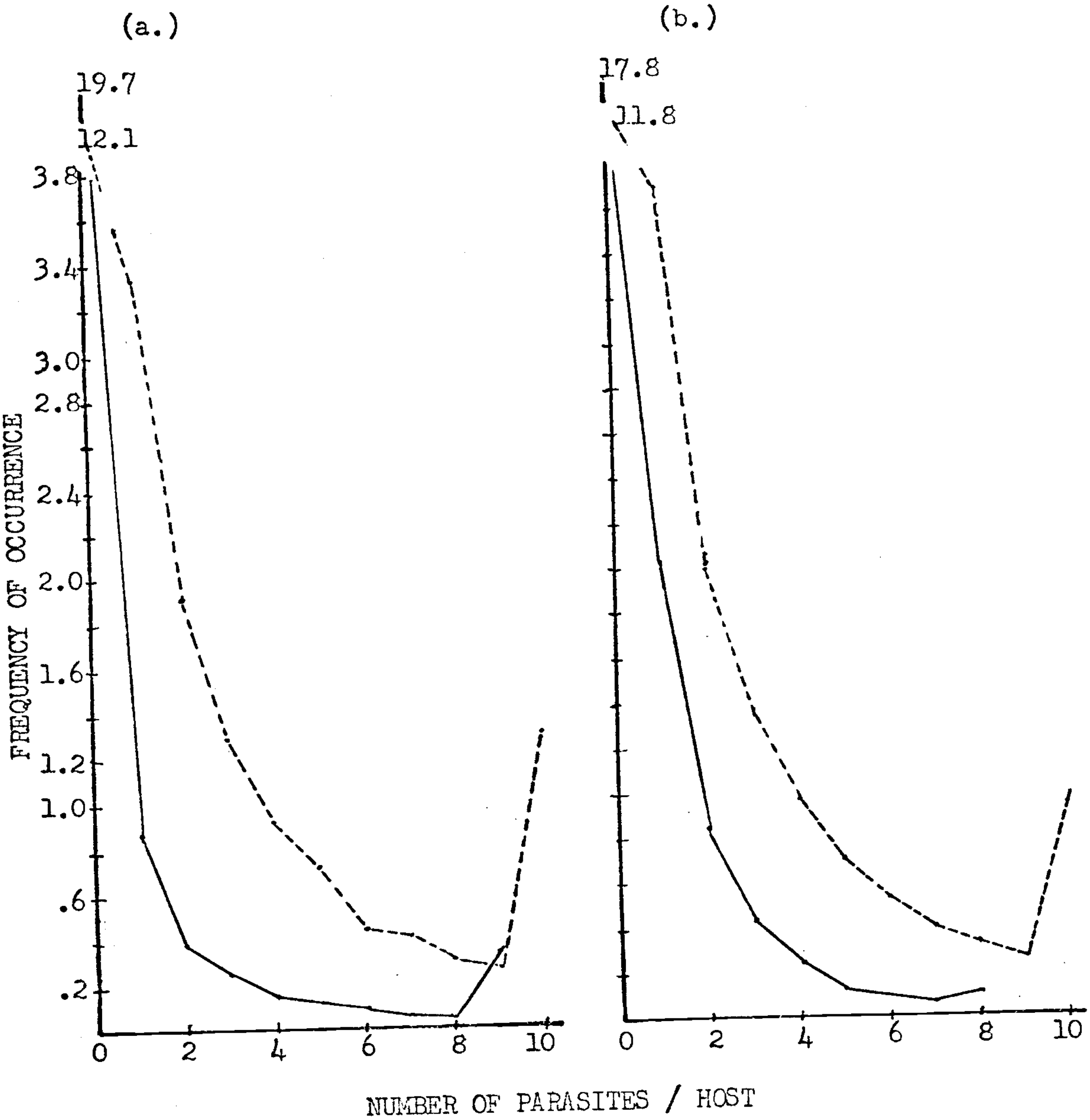
Table 16. Negative binomial distributions fitted to data of Euschöngastia oregonensis in the Neptune study area.

No. of chiggers	Station 8		All stations	
	no. deer mice	frequency expected	average no. deer mice	frequency expected
0	14	14.010	11.066	11.069
1	3	5.325	2.266	2.683
2	5	3.286	1.533	1.478
3	1	2.287	0.733	0.967
4	3	1.683	0.866	0.682
5	0	1.277	0.533	0.502
6	2	0.990	0.266	0.380
7	0	0.779	0.400	0.293
8	2	0.619	0.266	0.229
9	0	0.496	0.200	0.181
10+	3	2.244	1.133	0.793
No. hosts (H)	33		19.262	
No. mites (C)	76		33.247	
Mean (C/H)	2.60		1.729	
Variance	11.12		8.775	
Chi-square		10.5798		0.40049
Degrees of freedom		8		8
k value		.4450		.2818

study area were more randomly distributed than those in FSA. A great difference in k values also took place between number of I. angustus ticks in FSA and NSA (Table 14).

With a deterministic model of host-parasite relationships using the negative binomial distribution, Crofton (1971b) found that when the infecting organism has a distribution of $k > 1$, a pathogenic effect exists which produces an equilibrium between host and parasite populations. Parasitism in this case would exert a highly significant and more or less continuous population control which could be observed in an epizootic or disease situation. The distribution of the parasites in this study were overdispersed ($k < 1$) according to the negative binomial (.0456 and .1637 in FSA; .2819, .3193, .3737, and .4450 in NSA), indicating that pathogenicity did not exert a significant role in population control. The death of hosts in this study was due to factors other than those of parasitism.

Frequency distributions in this study show that the zero class was the largest as the majority of hosts were not parasitized either by chiggers (19.7 in FSA, 12.1 in NSA; Figure 7a) or by ticks (17.8 in FSA, 11.8 in NSA; Figure 7b). Frequency of infestation of chiggers and Ixodes angustus ticks per host was higher in NSA than in FSA. There were only a small number of hosts that had more than ten parasites although one montane vole in FSA (Table 11) had 81 N. harperi.



——— = Finley

----- = Neptune

Figure 7 Frequency distributions represented by the fitted negative binomial in two areas of western Oregon (a.) chiggers (b.) Ixodes angustus ticks.

Environmental Influences

It was hypothesized that climatic conditions influence distribution of parasites. Therefore, two habitats were chosen to represent extremes of climatic differences. Elevations were kept similar.

The climate of Oregon from the Pacific Ocean to the summit of the Cascade Range is considered to be greatly influenced by prevailing westerly winds from the ocean. This maritime effect is most pronounced along the immediate coast line and as the distance from the ocean increases the climate is influenced by differences in altitude, mountain barriers, and local topography (Ruth, 1954). The distinguishing features of prolonged cloudiness, a long frost-free season, equable temperatures, and abundant rainfall on the coast gradually diminish going eastward, where at the same latitude in eastern Oregon extremes exist of cold winters and hot summers.

Annual precipitation in excess of 100 inches per year is commonplace in the Cape Perpetua area of the Siuslaw National Forest. The average rainfall annually is between 75-80 inches as compared to an average annual rainfall of 40 inches on the floor of the mid-Willamette Valley (Bates and Calhoun, 1971). As the marine-conditioned air masses move continually inland and ascend the west slopes of the Cascades to 5,000 feet and above, increasing amounts of precipitation occur with the elevation increase. Most of the precipitation in the valley and coastal areas occurs during the winter, with about 70% of the rainfall occurring from November through March and only 5% occurring in the summer months. Measurable amounts of snowfall occur only three or four times a year.

Temperature differences were less marked than those of precipitation. In July, the greatest range in mean temperature was less than 30°F in the mid-Willamette Valley and less than 17°F on the coast at Newport or Cascade Head. The temperature and rainfall data so far discussed were taken from local weather stations; Newport and Cascade Head north of Lincoln City, and Hyslop crop science farm six miles northeast of Corvallis. The latter station is 22 miles northeast of the Finley refuge while the Neptune station is 29 miles north of Neptune State Park. Temperature and precipitation in the habitats may have differed from measurements made at these stations and greatest differences probably existed at ground level (Geiger, 1957). A "fog belt" exists in the coastal area which influences the amount of rainfall reaching the ground. In the cover of a forest canopy a rain gauge will not collect appreciable water during periods of light rain as foliage probably absorbs this moisture and any excess evaporates before it reaches the ground. Rain gauges not under the cover of a canopy collect considerable precipitation during this time. In times of summer fog, precipitation collects on tree crowns and drips to the ground while rain gauges in the open collect no precipitation. Fog-drip in the Cascade Head Experimental Forest accounted for 26% more precipitation than noted in open areas and the excess moisture is thought to provide additional moisture during the growing season when rainfall is minimal.

No linear relationship was apparent in scatter diagrams when temperature and precipitation was compared with the number of hosts or the number of parasites in either study area. Some linearity occurred when number of parasites was compared with the number of hosts. This was to be expected since the more common species of ticks and chiggers in climax forests were not found in litter of the forest floor but in nest and burrow situations beneath the upper soil layers. Temperatures of nests and burrows were not recorded in this study partly because of the necessity of completely disrupting the habitat in order to locate the nest. According to the literature, Kennerly (1964) found a high relative humidity from 89-95% in burrows of the pocket gopher in Texas, and Stark (1963) reported relative humidities of 64-96%. Air of sealed pocket gopher burrows approached saturation even when soil moisture was low, so that moisture in soil moves by capillary action toward the burrow wall and then evaporates. Stark (1963) suggested that nests in burrows have a temperature similar to that of surrounding soil and during winter there is an insulative value in this situation.

The deer mouse, considered a non-hibernating burrow inhabitor, was found to live in a microclimate of stable burrow temperatures, particularly under forest cover (Hayward, 1965). Burrow temperatures were the most stable under the cover of snow due to the insulative influence. Johnson (1970) measured burrow temperatures made by the mountain beaver, Aplodontia rufa, in Benton County and found daily variation in temperature of less than four degrees C (7°F), and an annual range in mean temperature from 2-14°C (35-57°F). He also found less variation in maximum and minimum temperatures at 6 cm above the surface of the ground in a study area having a tree canopy than in open areas where solar radiation and wind currents are factors. Yunker and Guirgis (1969) proved in Egypt that ectoparasites in burrows were not influenced by external environmental factors and similar results have been shown in a study of the dusky footed wood rat nest in California (Furman, 1968).

Variation between maximum and minimum air temperatures measured at the Newport weather station in this study was relatively low (17°F) throughout the year and under a forest canopy where solar radiation is almost absent, variation should be even less. Soil temperatures are always cooler under vegetation than they are under bare ground and the amount of temperature difference probably is correlated with the amount of plant material acting as a heat insulating layer. Wilkinson (1967) in Canada noted that Dermacentor andersoni was often found in clearings where lack of tree cover allowed the sun to warm the soil above air temperature. If this is true, temperatures and relative humidities in the burrows underneath forest canopies would also be very stable so that fluctuating environmental conditions would not appreciably affect the microhabitat of a burrow or nest. In thinly clad non-hibernating mammals such as the deer mouse, the burrow may offer the insulating covering lacking in the coat of hair. The same stable habitat offers an insulative barrier for ectoparasites such as Ixodes angustus, I. soricis, C. americana, E. oregonensis, and Ch. setosa. The relative uniformity of a microhabitat characteristic of a burrow or nest may partly account for the wide distribution of I. angustus in northern North America (Cooley and Kohls, 1945). It does not account for the distribution of the shrew tick, I. soricis (Gregson and Kohls, 1952; Gregson, 1956). The shrew tick which feeds only on soricines must have a highly developed discernment for shrews and seemingly is restricted to shrews and their nests; whereas, I. angustus does not have a strict host preference. This may be one factor that enables I. angustus to exist over large areas of the continent.

The presence of larger populations of burrow inhabiting ticks and chiggers in the coastal area as compared to lower numbers in FSA might be attributed to a more stable microenvironment in burrows as represented by NSA on the coast. The availability of ground water (U.S. Geology Survey, 1968) and the average discharge of water from rivers is much greater in the Willamette Valley than on the coast.

This results in a fluctuating water table so that in periods of heavy rainfall from November to April the water table in the Finley habitat is near the surface of the ground requiring nest building mammals to construct their homes near the soil surface (Figure 8). During drier periods between June and October the upper layers of the soil increase in temperature and nests are constructed deeper. The water table in NSA is well below the ground surface so that ground water would rarely affect the nests or burrows and reconstruction of nesting sites would be less.

The paucity of Ixodes pacificus in 150-200-year-old climax forests as represented by NSA, and its presence in 50-60-year-old forests represented by FSA, strongly demonstrated that vegetation is one of the factors in delimiting the population of this tick. It is known that species of ticks that climb vegetation are affected by the seasons and evidence to this point reveals that I. pacificus is affected by phenology (Figure 9). Immature stages of the tick do feed commonly on lizards, and in colder months of the year lizards hibernate in burrow situations. Of 15 lizards examined in March and April, only one nymph was found, inferring that ticks do not feed on lizards while the latter are hibernating in burrows. The lack of ticks collected on a flag in climax forests as compared to larger numbers collected on warm spring days in logged over areas (Tillamook Burn) and in open forested regions of southwestern Oregon provides greater

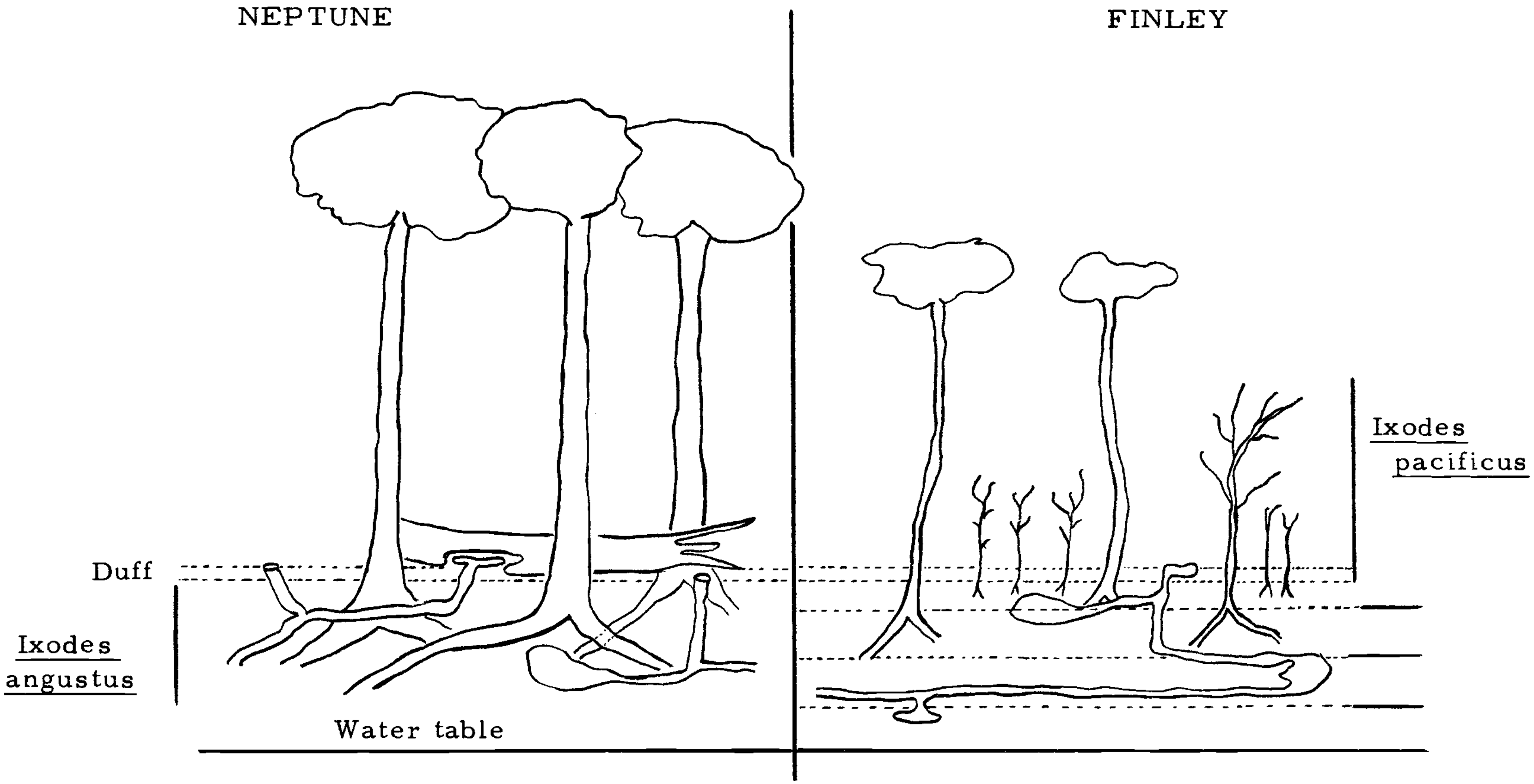


Figure 8. The habitat of Ixodes angustus and I. pacificus in two areas of western Oregon.

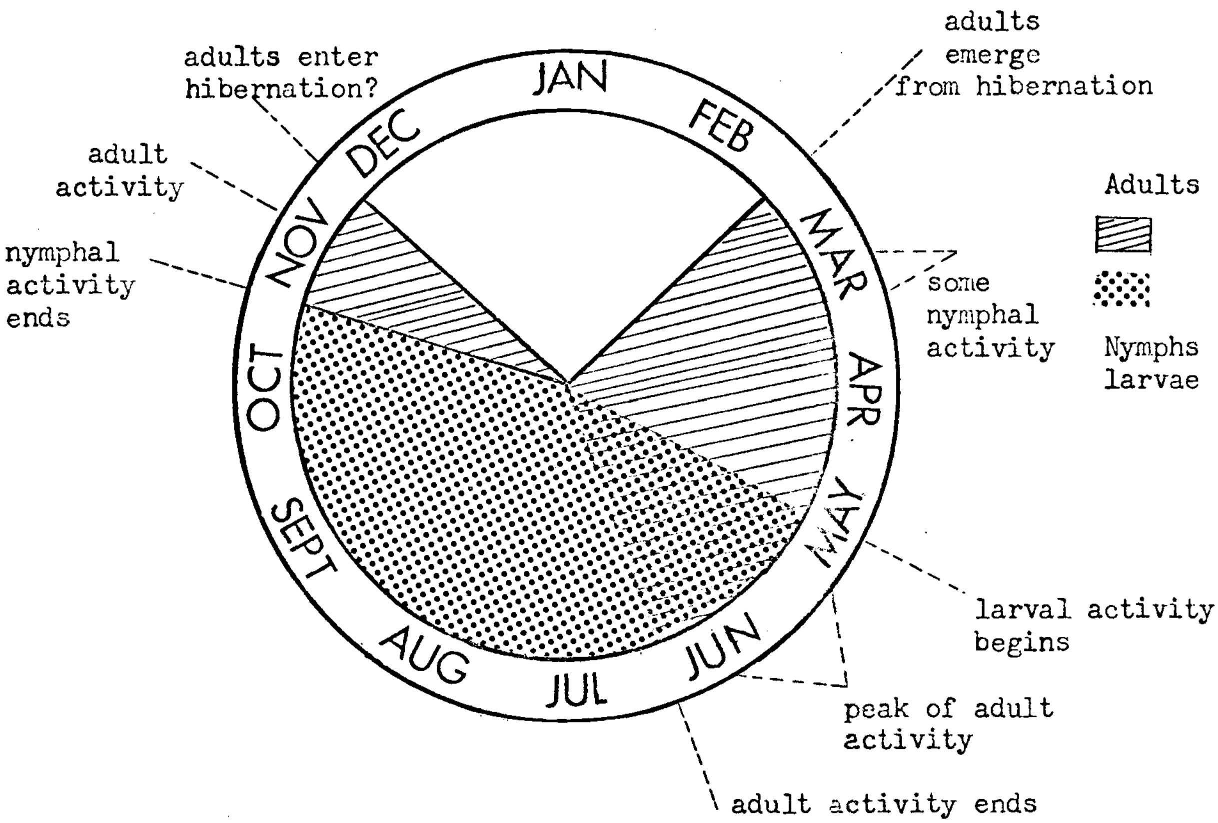


Figure 9 Seasonal activity of the Pacific tick, Ixodes pacificus in western Oregon.

evidence that tick abundance in the latter regions is determined by a combination of the following factors: (1) presence of an important host of immatures such as the lizard which is not found in forests under heavy canopy, (2) ecotone or brushy situations providing necessary browse for hosts of the adult tick (deer). Deer probably do not feed under climax timber but prefer plants growing in open areas such as trailing blackberry, red alder, vine maple, and salal (Brown, 1961). (3) Amount of solar radiation that affects the soil, and (4) type of soil. Solar radiation in a climax forest is minimal and peak abundance of Ixodes pacificus in May and June in more open areas may be due to an increase in solar radiation that warms upper soil layers.

SUMMARY

A total of 211 small mammal hosts were examined in the Neptune study area (NSA). The most common animals trapped were the deer mouse (137) and the Trowbridge shrew (50). In the William L. Finley study area (FSA) of a total of 252 hosts the most common animals taken were deer mice (112), vagrant shrew (82), and the Trowbridge shrew (31). A total of 137 deer mice were recaptured in NSA as compared to 133 deer mice and 11 wood rats in FSA. Deer mice were most abundant from December through February in FSA and from August through October in NSA.

Immature stages of Ixodes pacificus (40 larvae, 19 nymphs) were collected from hosts in the secondary growth Douglas-fir - Oregon oak woodland in FSA, but no ticks were found in the climax forest of Sitka spruce - western hemlock in NSA. The absence of the Pacific tick in climax forests characterized by a tree canopy of 90% or better, the greater number of immature stages feeding on lizards and the adults on deer, provides greater evidence that the tick prefers an "ecotone" type of habitat where deer and lizards are more abundant. Temperatures near the ground beneath a tree canopy in NSA would not tend to fluctuate as widely as temperatures near the ground in clearings or open areas receiving greater amounts of solar radiation. Collections made throughout the year based on the flag in areas where

the tick is known to be abundant, have shown that ticks are absent on vegetation during cold winter periods and during the hot dry summer season between July and October. Greatest activity occurs from March to June when precipitation is heaviest. Temperatures during this period are in general warmer than in December and January, but cooler than in July and August. The microhabitat in surface runways, or under boards, provides adequate moisture for survival of nymphs and larvae that would soon desiccate on vegetation during this period.

Ixodes angustus was more common in NSA (469) than in FSA (72). The deer mouse was the most important host infested in both areas; 71. 6% of total ticks in NSA, 58. 3% in FSA. The host pattern of the tick feeding on nest-building mammals, the abundance of male ticks in nests, and presence of larvae on hosts throughout the year, and the absence of records of this species from larger animals or from a flag strongly implies that *I. angustus* is a nest and burrow inhabitor and the tick is not appreciably affected by changes in phenology.

The higher numbers of *I. angustus* found in NSA may be indicative of a more stable microenvironment that normally does not exist in the Willamette Valley. The rise in the water table during the winter months requires nest building mammals to build their homes near the surface of the ground. Conversely, when the water table recedes in the summer, nesting occurs at greater depths.

Ixodes soricis was found equally as abundant in both study areas feeding on several species of shrews. Records are new from the marsh and Pacific shrews. The shrew mole also appears to be a host for this tick, even though other species of moles were not found to be parasitized.

Comatacarus americana was the second most abundant species of chigger collected. The 168 mites found in NSA and the 69 chiggers in FSA were found commonly on insectivores. The marsh shrew, Oregon, and montane vole are new hosts.

Chatia setosa was the least abundant chigger collected; 41 mites from the NSA and only one from FSA. The most abundant chigger, Euschöngastia oregonensis, was more common in NSA (261) as opposed to FSA (100). New hosts include the California red-back mouse, Pacific phenacomys, vagrant shrew, brush rabbit, and bushy tail wood rat.

The chipmunk was the chief host for Neotrombicula harperi with 196 mites found in NSA and 133 mites from FSA. N. cavicola was more common in FSA (58) as compared to 36 in NSA. New hosts were montane vole, vagrant shrew, and California ground squirrel.

Compatibility was greater in FSA than in NSA for different species of ectoparasites on the same host. High correlation values were found with parasites having strong host specificity (i. e., I. soricis and insectivores). Lower values were calculated for ectoparasites that feed on a wide number of host species.

The negative binomial distribution adequately described the dispersion of populations of I. angustus and E. oregonensis in both study areas. Values of k less than one indicated that pathogenicity did not exert a significant role in the host population.

The chiggers E. oregonensis, C. americana, and Ch. setosa probably occupy subsurface runways, as there is no evidence that they live in litter of the soil or duff. The burrow or runway supplies a stable microenvironment and abundance or activity is not affected by fluctuating environmental conditions. Arthropods that live in soil duff or litter are more affected by fluctuating climatic conditions. Definite seasonal activity was observed for N. harperi, a chigger active in litter mainly in the summer seasons.

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APPENDICES

APPENDIX A

THE PERCENT OF HOSTS INFESTED BY SEVERAL PARASITES IN TWO STUDY AREAS IN WESTERN OREGON.

	Deer mouse		Vagrant shrew		Trowbridge shrew		California red-back mouse		Bushy tail wood rat		Dusky footed wood rat		Townsend chipmunk	
	N[a]	F[a]	N	F	N	F	N	F	N	F	N	F	N	F
I. pacificus	0.00	4.23	0.00	15.38	0.00	3.22	0.00	0.00	0.00	0.00	0.00	27.27	0.00	50.00
I. angustus	35.56	11.01	0.00	23.07	2.40	9.67	0.00	0.00	5.00	0.00	0.00	18.18	100.0	0.00
I. soricis	0.00	0.00	0.00	23.07	28.0	2.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. americana	0.35	0.42	0.00	41.02	40.0	0.00	50.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E. oregonensis	25.70	2.11	0.00	28.20	0.00	9.67	50.0	100.0	0.00	0.00	0.00	0.00	42.85	50.0
N. harperi	0.00	0.00	0.00	7.69	0.00	0.00	0.00	33.3	100.0	0.00	0.00	0.00	71.42	50.0
N. cavicola	0.00	0.00	0.00	2.56	0.00	0.00	50.0	100.0	50.0	0.00	0.00	27.27	28.57	0.00

[a]N = Neptune study area; F = W. L. Finley study area

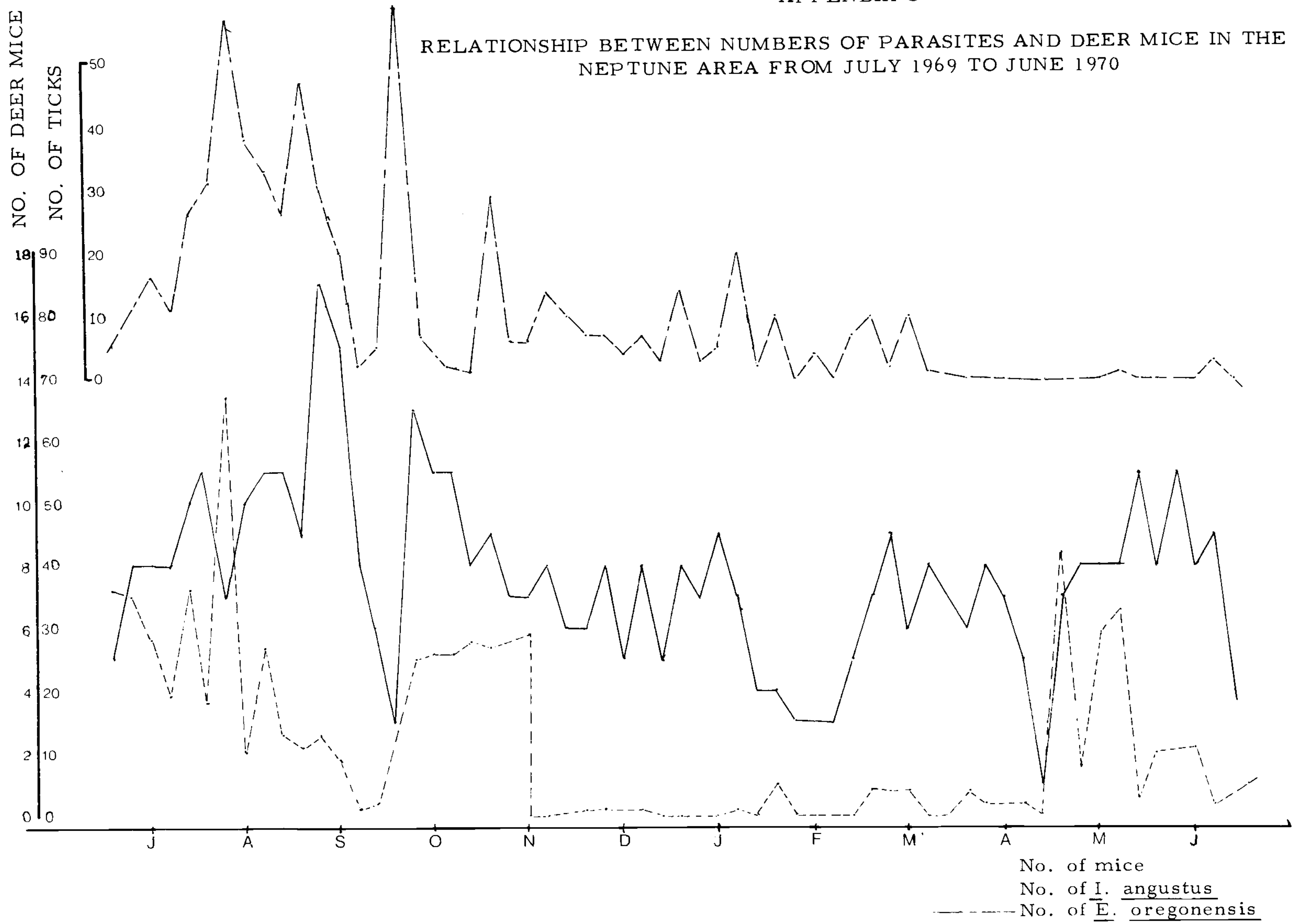
APPENDIX B

WEATHER SUMMARY FOR CORVALLIS, OREGON, AND THE COASTAL AREA

	Corvallis temp. (^{o}F)		Newport temp. (^{o}F)		Precipitation (inches)		
	Ave. max. 1936-52	Ave. min. 1936-52	Ave. max. 1931-65	Ave. min. 1931-65	Corvallis 10-yr mean	Newport 10-yr mean	Cape Perpetua 1969-70
Jan	45.8	32.8	50.0	38.2	6.85	12.03	21.60
Feb	51.9	35.0	51.9	38.8	5.05	9.18	9.55
Mar	56.5	37.5	53.2	39.4	5.17	8.83	4.94
Apr	63.6	41.4	56.4	42.0	2.42	5.16	7.29
May	70.0	46.1	59.6	45.4	2.24	3.69	3.01
June	74.9	50.3	62.6	48.8	0.98	2.03	1.42
July	82.2	52.8	64.2	50.4	0.26	0.62	0.23
Aug	80.8	51.7	64.7	50.6	0.40	1.31	0.53
Sept	74.9	47.3	64.1	48.6	1.01	2.22	2.88
Oct	64.1	42.7	60.7	46.2	3.02	6.06	3.10
Nov	52.5	37.2	54.8	42.1	6.44	10.54	7.06
Dec	47.3	35.1	50.6	39.4	5.91	10.05	13.77
					39.75	71.72	75.38

APPENDIX C

RELATIONSHIP BETWEEN NUMBERS OF PARASITES AND DEER MICE IN THE NEPTUNE AREA FROM JULY 1969 TO JUNE 1970



APPENDIX D

RELATIONSHIP BETWEEN NUMBERS OF IXODES ANGUSTUS AND DEER MICE IN THE FINLEY AREA FROM JULY 1969 TO JUNE 1970