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This study involved the use of the two-choice preference test to determine the taste reactions of buck and doe Columbian black-tailed deer (Odocoileus hemionus columbianus) to ascending concentrations of water extracts of Douglas fir, red alder, cascara, western hemlock and bitterbrush; to an ethanol extract of Douglas fir, and to the organic acids - citric, malic, quinic, and succinic. Also, the water extracts of Douglas fir and western hemlock, the Douglas fir ethanol extract, and acetic and malic acids were tested in the presence of butyric acid. Responses to Douglas fir and western hemlock water extracts and the Douglas fir ethanol extract were also determined while in the presence of an odorous extract of fish, PF Extract (Fraction G).

Animals were separated by sex, and penned in groups of two or three animals per pen. All groups were fed pelleted alfalfa hay and pelleted concentrate, ad libitum.

Each response was determined by expressing the intake of the test solution at a given concentration as a percent of the total fluid intake for two, 24-hour periods. Responses were plotted graphically by sex and compared to threshold values for intake. In preliminary tests with water, a 95% confidence interval was established from a theoretical mean intake of 50%. The upper confidence level was 56% intake, with the lower level being 44% intake. Thus, intake of test fluid from 44% to 56% intake was described as the nondiscrimination zone. The preference threshold was set at 80% intake, and the rejection threshold at 20% intake.

The sensitivity levels (the point at which discrimination first occurred) of the bucks for the water extracts were (ml extract/100 ml water): Douglas fir, 0.63; red alder, 0.05; cascara, 0.0125; western hemlock, 0.48; and bitterbrush, 0.025. The sensitivity for the ethanol extract of Douglas fir was 0.14. All sensitivity responses were preference reactions. The sensitivity levels of the does for the water extracts were (ml/100 ml): Douglas fir, 0.05; red alder, 0.05; cascara, 2.24; western hemlock, 0.20; and bitterbrush, 0.025. The sensitivity for the ethanol extract of Douglas fir was 0.10. All sensitivity responses were preference reactions except the response to red alder extract.

The preference threshold (test fluid 80% or more of total fluid intake) was crossed by the bucks in response to the water extracts

of Douglas fir at 1.52 ml/100 ml, western hemlock at 1.48 ml/100 ml, and bitterbrush at 0.34 ml/100 ml. The preference threshold was crossed by the does in response to the water extracts of Douglas fir at 2.94 ml/100 ml and western hemlock at 1.52 ml/100 ml. The does exhibited the only 20% rejection response to the browse extracts, with the ethanol extract of Douglas fir prompting rejection at 2.96 ml/100 ml.

The sensitivity level of the bucks for citric acid was 0.072 ml/100 ml; for malic acid 0.004 ml/100 ml; for quinic acid 0.434 ml/100 ml; and for succinic acid 0.00063 ml/100 ml. All sensitivity responses were preference reactions except the response to quinic acid. The sensitivity levels exhibited by the does were all rejections at levels of 0.0016 ml/100 ml for citric and succinic acids and 0.00063 ml/100 ml for malic and quinic acids.

The preference threshold was exhibited by the bucks in response to malic acid at 0.01 ml/100 ml. The responses of the bucks crossed the rejection threshold at 2.50 ml/100 ml for citric acid and 0.442 ml/100 ml for succinic acid. Responses of the does that first crossed the rejection threshold were prompted by citric acid at 0.504 ml/100 ml, malic acid at 0.120 ml/100 ml, quinic acid at 0.395 ml/100 ml, and succinic acid at 0.060 ml/100 ml.

The presence of butyric acid in cotton patches at the top of the fluid containers had no influence on the taste response of the bucks to the test solutions. Also, butyric acid had no influence on the taste

responses of the does to test solutions of acetic acid and Douglas fir water extract, but resulted in an increase ($P < 0.05$) in the intake of malic acid and a decrease ($P < 0.05$) in the intake of western hemlock extract and Douglas fir ethanol extract.

The presence of PF Extract (Fraction G) did not influence the taste response of the bucks to western hemlock extract, but resulted in a decreased response to test solutions of both Douglas fir extracts. PF Extract had no influence on the response of the does to the test solutions.

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INTRODUCTION

Man's continued population growth, development of land, use of natural resources, and growing recreational demands may dictate that the management of the Columbian black-tailed deer (Odocoileus hemionus columbianus) will have to be expanded and intensified. The study of taste responses and their relationships to palatability and preference may offer means of initiating managerial policies to meet the growing demands of the human population for stabilized deer numbers and to combat problems that presently exist in deer herd management.

Taste reactions of deer, whether they are preferences or rejections, may aid in determining the nutritional requirements of deer. A more complete knowledge of these requirements would be advantageous in formulating a nutritionally adequate and acceptable emergency winter ration for black-tailed deer. An increasingly serious problem is the involvement of black-tails in tree plantation damage (in particular Douglas fir) and damage to agricultural crops and residential shrubbery. Specific information on the involvement of taste in the deer's sensory mechanism can be used in combating these problems. These responses and/or further analysis of these responses could be utilized

by employing positive or negative taste stimulants in the development of effective deer repellents or attractants. Taste responses can also help determine why preferences are shown for some browse species and not for others. Determination of browse preferences of deer is another component that is necessary for assessment of the range and its wild and domestic animal carrying capacity. Knowledge of browse preferences also will offer criteria for selection of strains of trees that are less preferred by deer and, therefore, less susceptible to browse damage. The involvement of taste in management could result in minimized crop damage and maximum sustained production in many phases of wildland and game management.

The purpose of this study was to determine taste reactions in Columbian black-tailed deer to extracts of browse species and to organic acids common to many plants. The study also determined the effect of noxious odors on these taste responses and the differences in taste responses attributable to sex. The work was prompted by a lack of knowledge concerning taste responses and the mechanisms of determining browse preferences of deer.

LITERATURE REVIEW

The literature of subjects pertaining to taste in both domestic animals and deer has been recently reviewed by Crawford (1970), Goatcher (1969, 1970), and Goatcher and Church (1970e). Subjects considered in those reviews were: the four classifications for taste, existence of water and alkaline tastes, intraorganic and environmental factors influencing taste, species and individual taste differences, taste modifiers, interactions of tastes, taste thresholds, methods of determining taste responses, mechanisms of sensory evaluation of foods, and repellents and attractants for deer. This literature review will introduce new subject areas and, where appropriate, summarize and expand the previous reviews.

Classification of Taste

Attempts to classify the sense of taste of animals generally have been centered around the four primary groups that man has categorized for his taste sensations. These four groups— sweet, sour, bitter, and salty— were first described in man by Fick (as cited by Bekesy, 1964b), and subsequently used by many authors (Bekesy, 1964a, b, 1965; Bell, 1959; Beidler, 1963; Blair and FitzSimons, 1970; Crawford, 1970; Goatcher, 1969, 1970; Goatcher and Church, 1969, 1970e; Goatcher, Church and Crawford, 1970). Goatcher (1969) and Kare

(1970) gave a general description of the chemicals involved in these different taste groups.

Use of the four primary taste groups involves the assumption that animals have a sense of taste similar to man, although it is known that animals can have sensory mechanisms that exceed the ability of those of man (Kare, 1966). Some workers do not feel the use of these four groups is appropriate. Kare and Halpern (1961) stated that taste results from combined stimulations and there are no corresponding, rigidly specific taste cells. Other objections arise from studies showing high intraspecies and interspecies variation in taste responses (Kare and Ficken, 1963). Kare (1970) states that, with animals, it is appropriate to divide taste responses into dimensions of pleasant, unpleasant, and indifferent. Yet, the four primary classifications have been widely used and, as stated by Goatcher (1969), offer a means of comparing different investigations.

Further classifications of tastes have also been proposed. These are water; alkaline; bitter, warm, sweet; and sour, cold, salty. Work regarding the water response has been reviewed by Amerine, Pangborn, and Roessler (1965). The action of the alkaline taste was described by Liljestrand and Zotterman (1956). Bekesy (1964a) stated that the tongue is sensitive not only to the four primary tastes, but also to heat and cold. This work showed an interaction between warm, bitter, sweet, and cold, sour, salty, forming two clearly separate

groups of stimuli with some common quality. There was no interaction between members of the two groups.

Sensory Interaction and Physiological Characteristics

The animal body contains a multitude of chemoreceptors which are involved in the perception of chemical stimuli in the environment. These chemical senses can be divided into three classes: (1) olfaction, (2) taste, and (3) common chemical sense, or sensitivity to nonspecific stimulants such as irritants (Kare, 1970).

Interactions with Other Senses

Interactions may occur within a given sense as well as between senses. The sense of taste may receive reinforcement from smell or other senses. Heat and touch receptors may aid the taste sense in determining the qualities of ingested food (Bell, 1959). Arnold (1966), while experimenting with sheep, noted significant differences in the relative acceptability of plant species when taste, smell and touch were impaired. These changes were either an increase or a decrease in intake, but had no overall effect on animal productivity. The impairment of taste alone also resulted in some variation, either an increase or decrease in intake. It has been shown that, when children are blindfolded, they can no longer judge the flavor of a popsickel correctly (Beilder, 1966). Heady (1964) stated that the preference for plants by

domestic animals is influenced by the external form of the plants. It is evident, as pointed out by Goatcher, Church, and Crawford (1970), that there is an interrelationship between taste, touch and odor in determining food preferences.

The relation of odor to taste is an area of much speculation. Human experience shows that, when a person is hungry, an odor may be pleasant and associated with a good taste, but when satiated the same odor may cause an indifferent reaction. An odor recognized as a single stimulus, may be a complex of odors, none of which can be successfully, singularly classified (Lettvin and Gesteland, 1965). Both electrophysiological (Moulton and Tucker, 1964) and behavior studies (Stone, 1964) have been used to determine olfactory responses. However, the sense of smell, for the most part, has not been investigated in conjunction with taste. Sagarin (1954), in defining odor, stated that it "... is distinct from seeing, hearing, tasting or feeling..."

Classification of odors was first developed by Linnaeus (Harper, 1966). Schutz and Pilgrim (1957) identified nine odor factors by associating the factors with standard chemicals. Included in these factors were butyric acid used to identify rancid smells. Amoore and Venstrom (1965) used seven classes of odor when describing the correlation between molecular shape and odor quality. A history of odor classifications and descriptions was presented by Harper, Smith and Land (1968). Various authors described, among the classifications,

the indoloid group which resembles decomposing mammalian flesh or rotting fish.

The sensitivity of an individual to an odor stimulus is variable. The review of Amerine et al. (1965) stated that there is an increase in odor sensitivity in humans during the morning, and a decrease after each meal. Moncrieff (1951) found that the sense of smell fatigues rapidly, and that fatigue for one odor has little effect on perception of dissimilar odors, but interferes with the perception of similar odors. When two olfactory stimuli are presented at the same time, any one of five results may happen. There may be a blending of the odors; one may be perceived first and then the other; the odors may be experienced simultaneously but separately; one odor may mask the other; or one odor may neutralize the other (Bartley, 1958).

Associative Learning

Taste responses may also be influenced by previous conditioning techniques, as shown by Pavlov's dog. Further Russian work has shown that a calf can be conditioned to pick up its leg in response to the taste of a test solution (Kare, 1966). Studies conducted with chicks by Capretta (1969) indicated that the conditions of feeding prior to experimental work influenced the chicks' preferences in the direction of the first food consumed. Heady (1964) indicated that a similar response probably exists in freely grazing animals. Moulton (1969) suggested

that learning factors associated with taste are involved with neurological relations of the systems. The taste and visceral nerve receptors meet at one region of the brain, while auditory, visual, and cutaneous receptors meet at another region. Therefore, a more positive association should occur between taste and visceral sensations than between taste and cutaneous sensations.

Physiological Characteristics

The taste organs of mammals are located in the mucosa of the oral and pharyngeal cavities, with the maximum concentration being in the mucosa of the tongue. These organs, or taste buds, which contain numerous receptor cells each, are located on the papillae. The distribution of taste buds varies greatly among mammalian species. The cow has large numbers of taste buds on the front and back of the tongue, but relatively few in the middle. The taste buds in the chicken which has few total buds, are located on the base of the tongue and on the floor of the pharynx (Kare, 1970). Iggo and Leek (1965) reported that in the sheep the distribution of taste receptor cells responsive to the salt taste is in the anterior two-thirds of the tongue, while those responsive to bitter, sour, and sweet tastes are located in the posterior one-third of the tongue.

The sensory fibers for mammalian taste receptor cells travel in three nerves. Receptors located on the anterior two-thirds of the

tongue receive fibers from the chorda tympani branch of the VII cranial nerve (facial). Fibers from the IX cranial nerve (glosso-pharyngeal) innervate the posterior one-third of the tongue. The X cranial nerve (vagus) provides fibers to taste receptors in the pharynx and larynx (Bell, 1959; Kare, 1970; Pfaffman, Fisher and Frank, 1965). In addition to the nerves innervating the receptor cells of the tongue and pharynx, some workers have described free nerve endings between or close to the taste receptors (Moulton, 1969). All taste responses pass to the medulla and thence to the thalmus and cerebral cortex (Kare, 1970).

Taste stimuli, in initiating a response, must first mix with the salvia coating the tongue. Contact is then made with the microvilli, which extend from each taste receptor cell, and the chemicals are absorbed on specific sites on the microvilli (Beidler, 1963, 1965b, 1966). Some workers (Dastoli and Price, 1966; Moulton, 1969) feel that a specific receptor molecule, which may be a protein, might be involved in binding the stimulating chemical to the receptor cells. Using this approach, Dastoli and Price isolated a protein from bovine taste buds which forms complexes with sugars and saccharines. After contact of the stimulus with the microvilli, a shift in the electrical potential across the cell membrane occurs, and results in the propagation of an action potential. The magnitude of the voltage change is

proportional to the number of microvilli receptor sites stimulated (Beidler, 1966).

Taste receptor cells are continually degenerating and being replaced by new cells. As the old cells die, they are leaving nerve fiber branches which innervate the newly forming taste cell. The specificity of the nerve would, then, induce the same properties in the new cell as found in the old cell (Beidler, 1963; Moulton, 1969).

Environmental and Internal Factors Which May Influence the Taste Response

A number of factors, both environmental and internal, may affect the type and magnitude of the taste response in animals. Many of these factors have been reviewed and discussed by Crawford (1970), Goatcher (1969, 1970) and Goatcher and Church (1970c, e). Some of the factors reviewed and pertinent sources are listed in the following table.

Factor Influencing Taste	References
Age	Cicala and McMichael (1964) Cooper, Bilash, and Zubek (1959) Glanville, Kaplan, and Fisher (1964)
Disease conditions	Henkin (1967)
Diurnal variations	Conrad (1966) Goetzl, Ahokns, and Payne (1950)

Factor Influencing Taste	Reference
Environmental temperature	Bekesy (1964a; 1965) Kare (1970) Sato (1963) Yamashita and Sato (1965) Yamashita, Yamada, and Sato (1964)
Hydrogen ion concentration	Beidler (1965a) Furest and Kare (1962)
Nutrient deficiencies or imbalances	Bernard and Halpern (1968) Harper (1967) Jacobs (1962) Richter (1942) Smith and Duffy (1957) Tepperman (1961)
Sex	Glanville, Kaplan and Fisher (1964) Wade and Zucker (1969)
Visual and positional cues	Pick and Kare (1962) Young (1948)

Other related factors, such as odor, body hydration, diet, and relative availability of desired foodstuffs, also influence the taste response in animals.

Certain compounds are capable of modifying the normal taste sensations. Such compounds are potassium gymnemate, which causes the ability to taste sweetness to disappear for a short period of time; gymnemic acid, which reduces the bitter taste sensation; Miracle Fruit, which causes sour tasting compounds to taste sweet; and monosodium glutamate and disodium inosinate, which are flavor enhancers (Beidler, 1966; Goatcher, 1970).

Goatcher and Church (1970e) pointed out that taste responses to pure stimulants allow the prediction of ingestive responses when animals are exposed to foods containing high levels of such stimulants. However, in many situations the food presented contains appreciable amounts of several taste stimulants. The combination of stimulants can result in an interaction of the tastes. Reports of these interactions have been made by Hironaka and Bailey (1968) on the effect of sugar on salt consumption by ruminants; Tepperman (1961) on the level of carbohydrate, fat, or protein in the diet on the taste reaction; Kamen et al. (1961) on the interactions of suprathreshold taste stimuli, and Fabian and Blum (1943) on the taste interactions of some basic food constituents.

Species and Individual Differences in Taste Responses

Taste in higher animals functions in different ways, among which are control of ingestive behavior, reinforcement in learning situations, and the onset of specific appetites (Goatcher and Church, 1970e). In considering the involvement of taste in these responses for different species, it would be erroneous to assume that all animals would react similarly to a given stimulus. Both electrophysiological and behavioral testing techniques have shown large variations between similar animals (Kare and Ficken, 1963).

Species differences in taste responses have been shown for the cat, rabbit, and rat in responses to sugars and salts (Pfaffman, 1953); for calves, pigs and rats to saccharin (Kare and Ficken, 1963); for man, rats, cattle, chickens, and dogs to saccharin and sucrose as described by Kare (1966); for sheep to sugars, saccharin, ethanol, salts, acids, quinine, urea, and sodium hydroxide (Goatcher and Church, 1970a, b); for pygmy goats, normal goats, sheep and cattle to sucrose, sodium chloride, acetic acid and quine hydrochloride (Goatcher and Church, 1970c, d), and for pygmy goats, normal goats, sheep, cattle, and black-tailed deer to sucrose, sodium chloride, acetic acid, and quine hydrochloride (Goatcher, Church, and Crawford, 1970; Church, 1971).

Within species, individual taste response differences have been observed. Kare (1969) reported that, in many animal taste experiments, a minority of animals would contradict the taste behavior shown by the majority of the same species. Pigs from the same litter, when tested with saccharin solutions, showed rejection and indifference, but the majority showed a strong preference. The response of individual quail to one chloride was no indication of how the bird would respond to another chloride. Individual differences in the response of chickens, both preference and rejection, to ammonium, calcium, and ferric chloride were also found (Ficken and Kare, 1961).

Species and intraspecies differences in taste responses may be related to a number of physiological or environmental factors. Among these factors are: blood glucose levels (Kare and Ficken, 1963); distribution in the number of receptors responding to one chemical stimulus (Beidler, 1963); genetic variation (Fischer, 1967; Kare, 1966); postingestive processes (Goatcher, Church, and Crawford, 1970; Pfaffmann, Fisher and Frank, 1965); the number of taste buds (Kare, 1966); ecological advantages (Kare, 1969), and evolutionary adaptation (Maller, 1967).

Experimentation has shown that there is a difference in the taste response of wild and domestic animals. Maller and Kare (1965) found that both wild and domestic rats show a preference for lactose and xylose, but the wild rats limited their energy intake by consuming smaller quantities of the solutions. Jungle fowl also showed the tendency to regulate their caloric intake, regardless of a bitter stimulus which caused rejection by domestic fowl. The apparent ability of the wild animal to discriminate foodstuffs, despite a desirable or undesirable taste, so as to regulate its nutritive intake, indicates a protective mechanism. The reduced ability of the domestic animal to exhibit this protective mechanism probably results from the housing of animals, grazing restrictions, and the limiting of free movement (Bell, 1959). These limitations have altered the anatomical and physiological characteristics of domestic animals (Kare, 1969).

Browse Preferences of Deer

Preferences, in regard to feeding patterns, are measured by the relative selection by an animal of a feed from a choice of foods (Heady, 1964). Preference is, then, a behavioral pattern dependent upon palatability, which is affected by the stimulation of sight, smell, touch, and taste as sensed by the animal (Church, 1971).

The relation of palatability and preference responses of deer to taste has received little or no attention in previous work. However, considerable work has been done to determine the browse preferences of deer. Knowledge of the chemical composition of these foods may provide a means of determining which chemicals initiate a taste reaction.

Methods used in studying deer browse preferences are: (1) determining the extent to which the vegetation on the feeding site is used, (2) animal feeding observations, (3) feeding experiments, and (4) analysis of the stomach contents (Brown, 1961; Crawford, 1970). Each method has limitations which should be recognized. Classification of deer browse preferences by vegetation use may be subject to error because the same browse may be used by other animals such as rabbits, rodents, and birds. Feeding observations are limited by the area that can be observed, animal movement, and the inability to observe the animal during its total feeding period (Cowan, 1945).

Feeding experiments probably are most advantageous in allowing observation and control of the animal, but may be limited in the ability to duplicate the combination of browse species naturally utilized. Stomach analysis can be limiting because of the difficulty of plant species identification, the necessity to obtain stomach samples on a yearly basis (Brown, 1961), and the relative digestion rates of the different species.

Much of the work that has been done to determine the preferences of deer for various plant species has been by observing the use of vegetation. Shafer (1965) described several methods to determine the use of the vegetation. One technique is the twig-length method, in which an estimate of the average normal length of twigs is compared with the average length left after browsing; the deer use is expressed as a percentage of normal twig length. The twig-count method expresses browse preference according to the number of twigs of each species browsed in an established plot. Other methods utilized include density measurements, weight estimations, the clip-and-weigh method, and comparing vegetative growth inside an exclosure to the growth of the same species exposed to browsing outside the exclosure.

Browse Preferences

Pogge (1967) utilized the twig-count procedure to determine that the sprouts and tops of American elm were the browse preferred by

white-tailed deer (Odocoileus virginianus) in northwestern Pennsylvania. The exclosure method was used by Webb (1959) in determining the summer browse preference of Adirondack white-tailed deer to be elderberry and dogwood. In studies determining the preference of mule deer (Odocoileus hemionus) for bitterbrush, Hubbard and Dunaway (1958) used the twig-length method, while Hagen (1953) estimated by observation the relative degree of plant utilization. Observations of vegetation use have been made to determine the preferences of black-tailed deer for Douglas fir, red alder, cascara, red huckleberry, and trailing blackberry (Crouch, 1964, 1966, 1968; Miller, 1968). The preferences of black-tailed deer for redwood and Douglas fir have been studied by the use of exclosures (Browning and Lauppe, 1964).

Feeding observations of deer have been made by a number of workers. Nixon, McClain, and Russell (1970), using field observations of Ohio white-tailed deer, found that the important foods were agricultural crops, not woody browse species. Einarsen (1946) listed preferred browse of Oregon black-tailed deer to be red alder and cascara. Cowan (1945) observed black-tails on Vancouver Island, British Columbia, and found highly preferred species to be red alder in the summer and Douglas fir in the winter, with little use of western hemlock. Observations of black-tail feeding habits in the Tillamook Burn in Oregon made by Miller (1968, 1970), found preferred browse species to be red huckleberry, salal, red alder, trailing blackberry

and, in the winter, Douglas fir. Brown (1961) used semitame animals while studying the black-tail of western Washington. These animals were allowed to roam freely, with observations of browse preferences made for a year. Trailing blackberry was preferred most; other species of high preferences were salal, red alder, red huckleberry, cascara, western hemlock, and Douglas fir, in that order.

Feeding experiments with deer to determine preferences for natural browse species have been few in number, probably because of the difficulty and expense of maintaining a deer herd. Ullrey et al. (1967, 1968) fed white-tailed deer white cedar, balsam fir, and jack pine. Consumption was ten times greater by the deer fed cedar than those fed balsam fir. Cedar consumption was four times greater than the consumption of jack pine. Bissel et al. (1955), Dietz (1965) and Dietz, Udall and Yeager (1962a, b) found bitterbrush to be preferred to other natural foods when fed to mule deer. Brown (1961), studying black-tailed deer, fed five browse species. He found that red huckleberry was the most highly preferred, followed by western red cedar, salal, willow and cascara.

Analysis of rumen contents is done by washing the material over a small mesh screen, separating individual identifiable particles, and expressing the amount of each species as percent volume of the total identified material (Brown, 1961), or as percent weight of the total material (Nixon et al., 1970). Preferred browse species found in

black-tailed deer rumens by Brown (1961) were trailing blackberry, 36.9%; salal, 10.8%; red alder, 5.1%; western hemlock, 4.2%; Douglas fir, 3.3%; and red huckleberry, 3.1%. The percent occurrence of a species did not always correspond to it being a high percent of the identifiable material, indicating seasonal use of some species. Mitchell (1964) found preferred species of the black-tail to be Douglas fir, salal and red alder, respectively.

All of these observations may be subject to variation due to such factors as abundance of the preferred species and associated species, the parts of the plants eaten, the geographic location in regard to soil type and agricultural crops, and the maturity of the browse species.

Browse Preferences Related to Nutrient Content

Arnold (1966) pointed out that "The variability in acceptability of strains of species suggests seasonal changes in plant chemical constiuents that elicit responses to taste and smell." The browse preferences of deer change with the variations in the chemical, or nutrient, contents of the browse.

Of the nutrients, crude protein levels show the best correlation with browse preferences. Bissel and Strong (1955) found that crude protein levels in browse species are highest in spring and summer, but in bitterbrush, a highly preferred fall and winter mule deer browse,

the crude protein content is highest in the fall and winter. Studies by Dietz (1965), Dietz et al. (1962b) and Smith (1952) indicate the same findings. Brown (1961) and Einarsen (1946) found crude protein content of western Washington and Oregon browse species to correlate generally with the preferences determined for black-tailed deer. The conifers—Douglas fir, western hemlock, and western red cedar—which are used as winter browse were consistently constant in crude protein. The preferred deciduous browse species—trailing blackberry, red alder, cascara, red huckleberry, and salal—were higher in crude protein in the spring and early summer than the conifers, but in the fall protein levels were lower than those of the coniferous species. These trends in crude protein contents correspond to leaf growth and fall, and to established deer preferences.

Investigations of other nutrient components also indicate that preference is associated with high total nutrient content. The total available carbohydrates in bitterbrush were found to follow the same trend as found for protein (McConnell and Garrison, 1966). Gastler, Moxon, and McKean (1951) found that palatable species had higher total sugars than did non-palatable species. Browse with a high moisture content, which usually has less lignin, is more palatable than species of lower water content (Tew, 1970). Studies by Dietz (1965) and Short, Dietz and Remmenga (1966) indicate that the rise in crude fiber, which occurs with leaf fall, restricts energy and dry

matter digestibility by deer. The effect of essential oils isolated from Douglas fir needles upon deer rumen microbial activity has been reported by Oh, Jones and Longhurst (1968) and Oh et al. (1967). These volatile compounds showed an inhibitory effect on the rumen microorganims only at high concentrations. Low levels increased rumen microbial activity. These relationships of nutrient levels in browse to preferred browse species may offer insight into the preferences and taste responses exhibited by deer. Also, they offer a potential for aiding the manager in evaluating the deer supporting capacity of the range (Ullrey et al. 1970).

Deer Damage

A major problem in many areas is the damage caused by deer to agricultural or forestry crops. This problem may occur with the migratory mule deer in the western mountain states, the sedentary white-tail of the eastern states, or the black-tail of the Pacific coast region.

Damage by deer to agricultural crops continues to increase as more land is developed for agricultural purposes. Brown (1961) stated that the State of Washington paid $10, 180. 00 for black-tail deer damage to crops and gardens for the period from July, 1957 to June, 1959. Damage was sustained by raspberries, cranberries, fruit trees, grains, legumes, and flowers and gardens in residential areas.

Extensive crop damage caused by white-tailed deer in Maryland included such species as soybeans, corn, buckwheat, truck crops, and Christmas trees. Damage is done also to fruit trees by bucks rubbing the bark off with their antlers (Flyger and Thoerig, 1962). Similar reports of white-tailed deer damage in Ohio (Nixon et al., 1970) and in Illinois (Klimstra and Thomas, 1964) have been made. Garthwarte (1968) reported damage done by roe deer in Britain to corn, root crops and roses. Deer may also consume or damage the forage necessary to sustain range livestock operations (Buechner, 1944; McMahan, 1964).

Deer browsing of conifers, in particular Douglas fir, represents a financial loss to the timber industry. Browsing of the central leaders of young trees results in the growth of lateral leaders, delays growth, gives the tree a dwarfed appearance, and may lower the quality of the timber at maturity (Oh et al., 1967). Leopold (1950) stated that, "At times excessive numbers of deer consume tree reproduction along with brush species, a fact which may delay formation of a forest canopy or favor reforestation with undesirable species which happen to be unpalatable to deer." The severity of the browsing damage by deer to Douglas fir seedlings appears to be related to the amount of preferred browse species growing in the same area (Roy, 1960). Logging of mature Douglas fir forests benefits the black-tailed deer. Lawrence (1958) stated that in the first ten years following logging there was a ten fold increase in the deer population.

Establishment of new stands of seedlings immediately after logging will minimize damage, because the fir will be growing before the deer population is large enough to cause severe damage (Cowan, 1945). Weather conditions will also influence the extent of conifer damage. Douglas fir seedlings become preferred browse when other preferred foods such as trailing blackberry and salal become unavailable because of snow cover. Crouch (1964) found that, after browsing of Douglas fir began, browsing continued until growth of other species began in the spring. The seedling may be preferred over other species in the early spring during bud growth. Work by Browning and Lauppe (1964) found growth of fir seedlings, exposed to browsing by black-tailed deer, averaged an increase of 166% over a four-year period. Those trees inside the exclosure averaged a 410% increase in growth over the same period. Similar observations have been made by Hines and Smith (1962) and Roy (1960). Further observations made by Browning and Lauppe indicate that a young tree must reach three to four feet to escape deer damage. The protected trees reached this height in four years, while the growth rate of the browsed trees indicated it would take thirteen years to reach the same height.

Deer Repellents and Attractants

Suggestions to prevent crop and tree damage by deer have included elimination of the deer, modification of planting practices, and the

use of repellents or attractants. Each alternative probably would be objectionable to some segment of society, but as Taber and Dasmann (1958) said, "We have to learn the ways of deer, not only that we may understand and appreciate them more, but that we may encourage them where we want more of them and discourage them where we want fewer."

The development of a repellent would discourage the deer where they are not wanted, but would not harm the deer. A repellent could be either unpleasant to the taste or smell, or both. The use of tankage (Carpenter, 1966) or bloodmeal-bonemeal mixture (Ives, 1960) placed in small bags and hung on trees has been reported to be effective for a two to three month period. Laukhart (1940) used creosote as a crop repellent, but reported that the deer soon became accustomed to it. Two repellents, ZAC (zinc dimethyl-dithio-carbonate cyclohexylamine complex) and TMTD (tetramethylthiuramdisulfide) have been reported effective against white-tail deer browsing of ponderosa pine, and mule deer and white-tail deer browsing of chokecherry and aspen (Dietz and Tigner, 1968; Heidman, 1963). The use of attractants, which would necessarily have a positive effect on sight, smell, touch, or taste, exists as a means of reducing deer damage problems. Dasmann and Hubbard (1967) found a mixture of molasses and salt sprayed on brush effective in increasing the plant's palatability to deer. Other possible attractants would be feeding commercial feeds

in areas of conifer seedlings subjected to heavy browsing, and the planting of other naturally highly preferred species in close proximity to preferred, commercially valuable species.

PART I

Methods

The study was conducted during the spring and summer of 1970 at Oregon State University. Three black-tailed does and three bucks approximately one year old were used for the taste experiments with water extracts of Douglas fir (Pseudotsuga menziesii) and red alder (Alnus rubra). Six does and two bucks were used for trials with water extracts of cascara (Rhamnus purshiana), western hemlock (Tsuga heterophylla), bitterbrush (Purshia tridentata), and for an ethanol extract of Douglas fir.

The deer were separated by sex and confined in pens consisting of two parts; a 9 x 12' roofed portion with a concrete floor inside a barn opening to a 9 x 48' concrete slab outside portion. All animals were fed concentrate and alfalfa pellets, ad libitum.

The taste testing procedure used was the two-choice preference test used by Crawford (1970) for deer and by Goatcher and Church (1970a, b, c, d) for sheep, goats, and cattle. Fluid was provided for each group in two containers, one filled to weight with tap water and the other filled with tap water plus the plant extract. Each concentration was tested for two 24-hour periods with the position of the containers being reversed after the first 24-hour period. The amount of test fluid consumed was expressed as the percent of the total fluid

consumed from both containers for the 48-hour period. Preference and rejection thresholds and a nondiscrimination zone were found by establishing a 95% confidence interval around a theoretical mean intake of 50%. This determined the normal variation in consumption of water from both containers. The nondiscrimination zone was from 44% to 56% with an intake of 57% being the lower threshold of preference, and an intake of 43% being the upper threshold of rejection. When the test solution comprised 20% of the total fluid intake, it was considered the rejection threshold. Conversely, when consumption of the test fluid was 80% of the total, it was considered the preference threshold. Figure 1 (adapted from Goatcher and Church, 1970a) shows the relationship between the thresholds. For each extract tested the mean responses of the deer for each concentration were plotted graphically by sex, with preference and rejection thresholds interpolated from the graph. Variations in sex response to each extract were determined by the use of the paired "Student's t-distribution."

Twigs of Douglas fir, cascara, and red alder used for the study of extracts were collected in December, 1969, in the Cedar Creek area of the Tillamook Burn, Oregon. Twigs and new growth used for the ethanol extraction of Douglas fir and water extraction of western hemlock were collected in July, 1970. Material for the bitterbrush extraction was collected east of the Cascade Mountains, Oregon, in July, 1970. The Douglas fir, cascara, and red alder tissue obtained

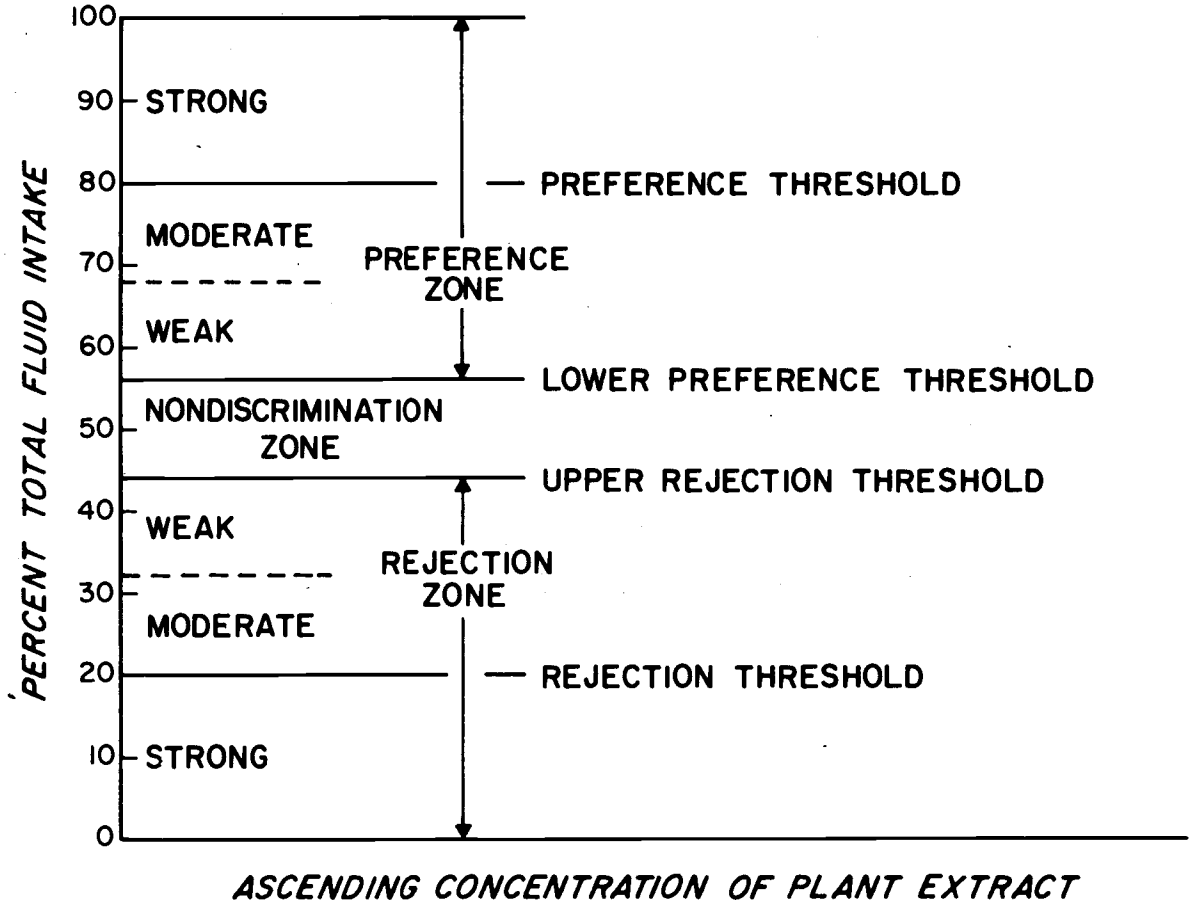

Figure 1. A schematic presentation of the relationships between deer taste thresholds and taste responses to plant extracts.

in 1969 was collected from plants that were being actively browsed by deer. The Douglas fir tissue collected in the summer of 1970 was from the same trees as the earlier collection, but was obtained at a time when the deer were not browsing the trees. Similarly, the western hemlock and bitterbrush plants were not being browsed at the time of collection.

The method of cold water extraction was similar to that used by Smart et al. (1961). Ground fresh tissue (1300 g) was blended with distilled water (3000 ml); solids were separated from the liquid by squeezing through two layers of cheese cloth. The extract was allowed to settle for two days under refrigeration and the clear liquid drawn off the top of the solids. The sediment was then centrifuged (5000 rpm) and the supernatant added to the clear extract. The ethanol extract of Douglas fir was obtained by blending 1300 g of tissue with 3000 ml of 70% ethanol. The solids and liquid were separated by the same means as the cold water extracts.

Results

Six browse extracts were studied—five by extracting with cold water and one by extracting with ethanol. Table 1 presents the responses of bucks and does that correspond to the preference threshold, rejection threshold, 80% preference threshold, 20% rejection threshold, and the zone of nondiscrimination. The preference

Table 1. Taste responses of buck and doe deer to extracts tested.

Bucks

Extract	Pre[a]	Rej[b]	80% Pre[c]	20% Rej[d]	N-D[e]
Water extracts			Concentration (ml/100 ml)		
Douglas fir	0.63		1.52-2.62		0.05-0.63
Red alder	0.05				0.56-1.60
Cascara	0.0125				0.07-3.20
W hemlock	0.48		1.48-1.62		0.025-0.48
Bitterbrush	0.025		0.34-1.33		
Ethanol extract					
Douglas fir	0.14				0.05-0.14

Does

Extract	Pre	Rej	80% Pre	20% Rej	N-D
Water extracts			Concentration (ml/100 ml)		
Douglas fir	0.05		2.94-3.20		
Red alder		0.05			0.078-1.60
Cascara	2.24				0.0125-2.24
W hemlock	0.20		1.52-3.20		0.025-0.20
Bitterbrush	0.025				
Ethanol extract					
Douglas fir	0.10	0.74		2.96-3.20	0.40-0.74

[a]Preference threshold-concentration at which preference was first shown (57% intake)

[b]Rejection threshold-concentration at which rejection was first shown (43% intake)

[c]80% preference threshold

[d]20% rejection threshold

[e]Zone of nondiscrimination

threshold or the rejection threshold is also the sensitivity level, depending on which was exhibited at the lowest concentration.

Figures 2 and 3 present the responses of the bucks to all concentrations of each extract tested. For all extracts the response of the bucks was never in the zone of rejection. All concentrations of each extract were either preferred or there was no discrimination between the extract solution and the water. Three water extracts— Douglas fir, western hemlock, and bitterbrush— were preferred by the bucks at the 80% level. The bitterbrush extract was highly preferred over the widest concentration range, with intakes of 85.07% and 84.98% at 0.40 ml/100 ml and 0.80 ml/100 ml, respectively. Bitterbrush was the only extract preferred by the bucks at all concentrations. The Douglas fir ethanol extract was preferred at a lower concentration than the water extract of Douglas fir. The bucks failed to discriminate between water and the solution with the ethanol extract at 3.20 ml/100 ml (57.46% intake), but highly preferred the water extract at the same concentration (78.16% intake). Response of the bucks to red alder extract showed some variation, but all responses indicated a weak preference or no discrimination. Cascara extract was tested at concentrations of from 0.0125 to 3.20 ml/100 ml. Highest preference (77.20% was shown at the lowest concentration, with a generally decreasing preference with increasing concentration. At concentrations from 0.025-3.20 ml/100 ml, western hemlock prompted

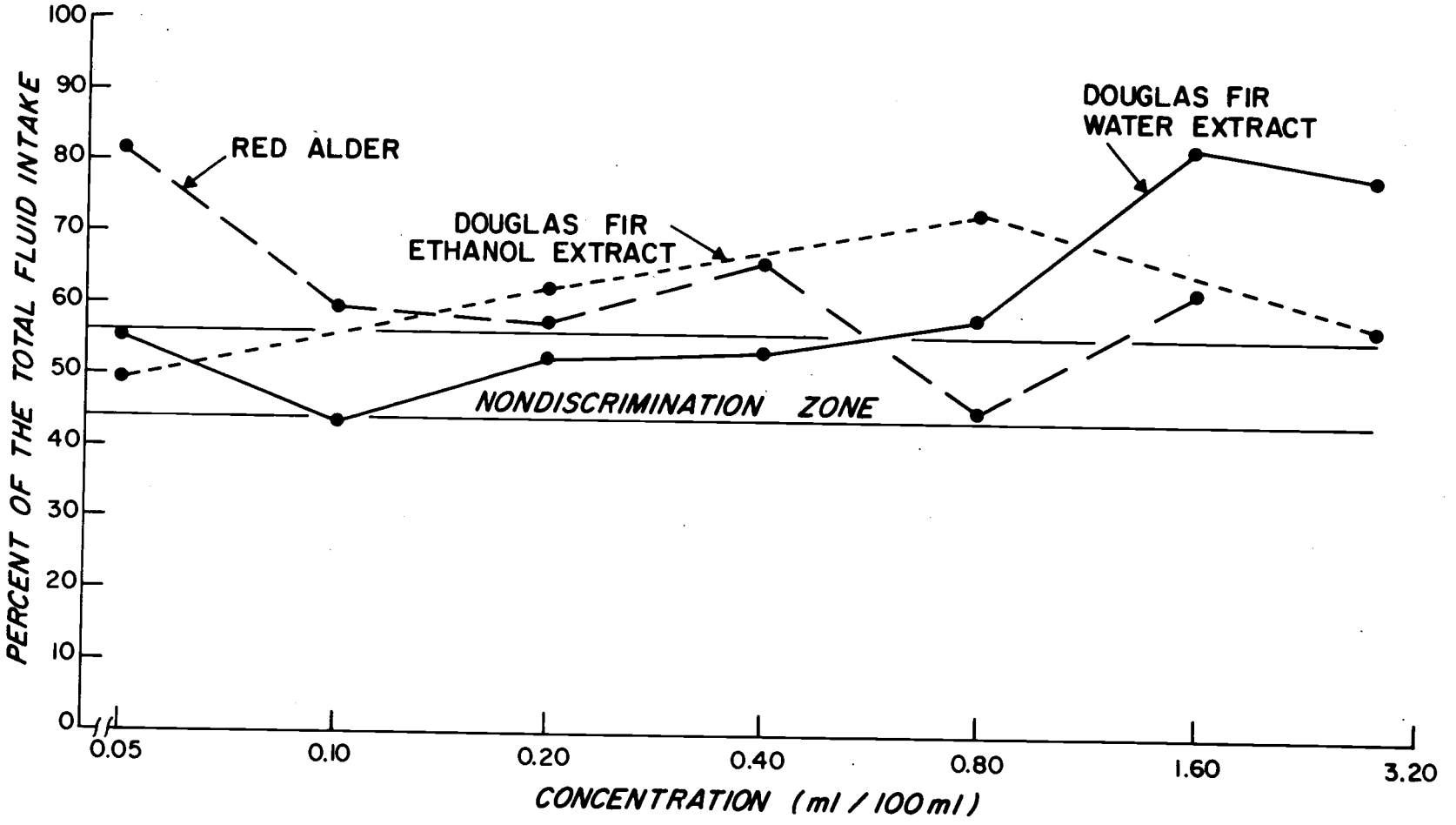

Figure 2. Taste responses of buck deer to ascending concentrations of Douglas fir water and ethanol extracts and to red alder water extract.

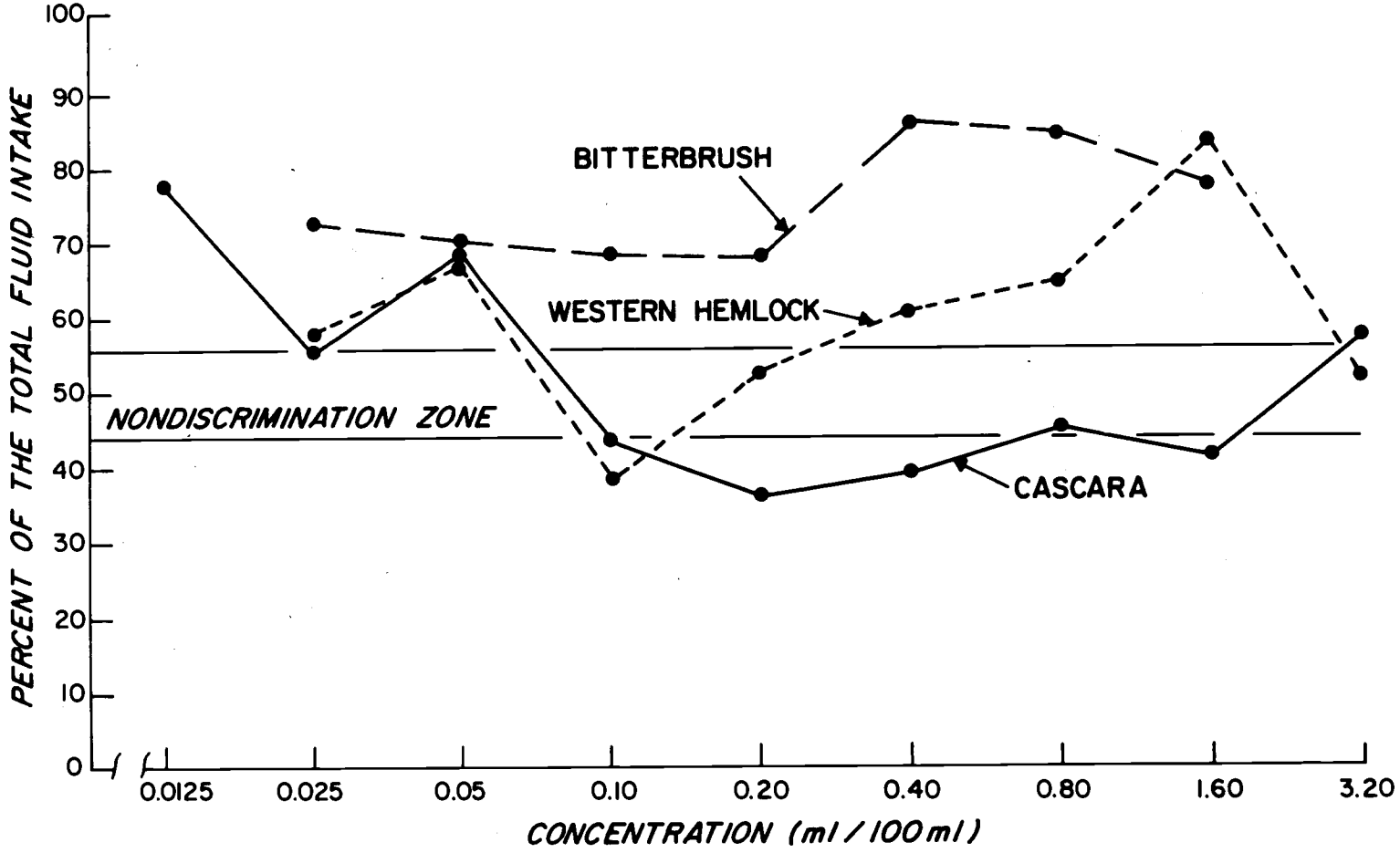

Figure 3. Taste responses of buck deer to ascending concentrations of cascara, western hemlock and bitterbrush water extracts.

four discriminatory responses, with only the concentration of 1.60 ml/100 ml resulting in a strong preference (83.69%).

Responses of the does, illustrated in Figures 4 and 5, showed that two water extracts of western hemlock and Douglas fir evoked an 80% preference response, with the high intake of 84.70% at 3.20 ml/100 ml prompted by the fir. The Douglas fir water extract, tested at concentrations from 0.05-3.20 ml/100 ml, showed a preference response at all test levels. The ethanol extract of Douglas fir tested over the same concentration range exhibited a weak preference at only one concentration (63.29% at 0.20 ml/100 ml). The ethanol extract elicited the only 20% rejection response (18.13% at 3.20 ml/100ml). Bitterbrush extract was preferred by the does at all concentrations tested (0.025-1.60 ml/100 ml). At concentrations from 0.05-1.60 ml/100 ml, red alder extract prompted nondiscriminatory or weak rejection responses. The only substantial discrimination with respect to cascara extract occurred at the 3.20 ml/100 ml level. The reaction was strongly positive (83.84% intake). The lower concentrations of western hemlock extract (0.025-0.80 ml/100 ml) prompted nondiscriminatory or weak preference responses from the does. Concentrations of 1.60 and 3.20 ml/100 ml induced strong preference responses of 82.96% and 80.06%, respectively.

The mean responses of the deer to all extracts are presented in Figures 6 and 7. Water extracts of Douglas fir and western hemlock

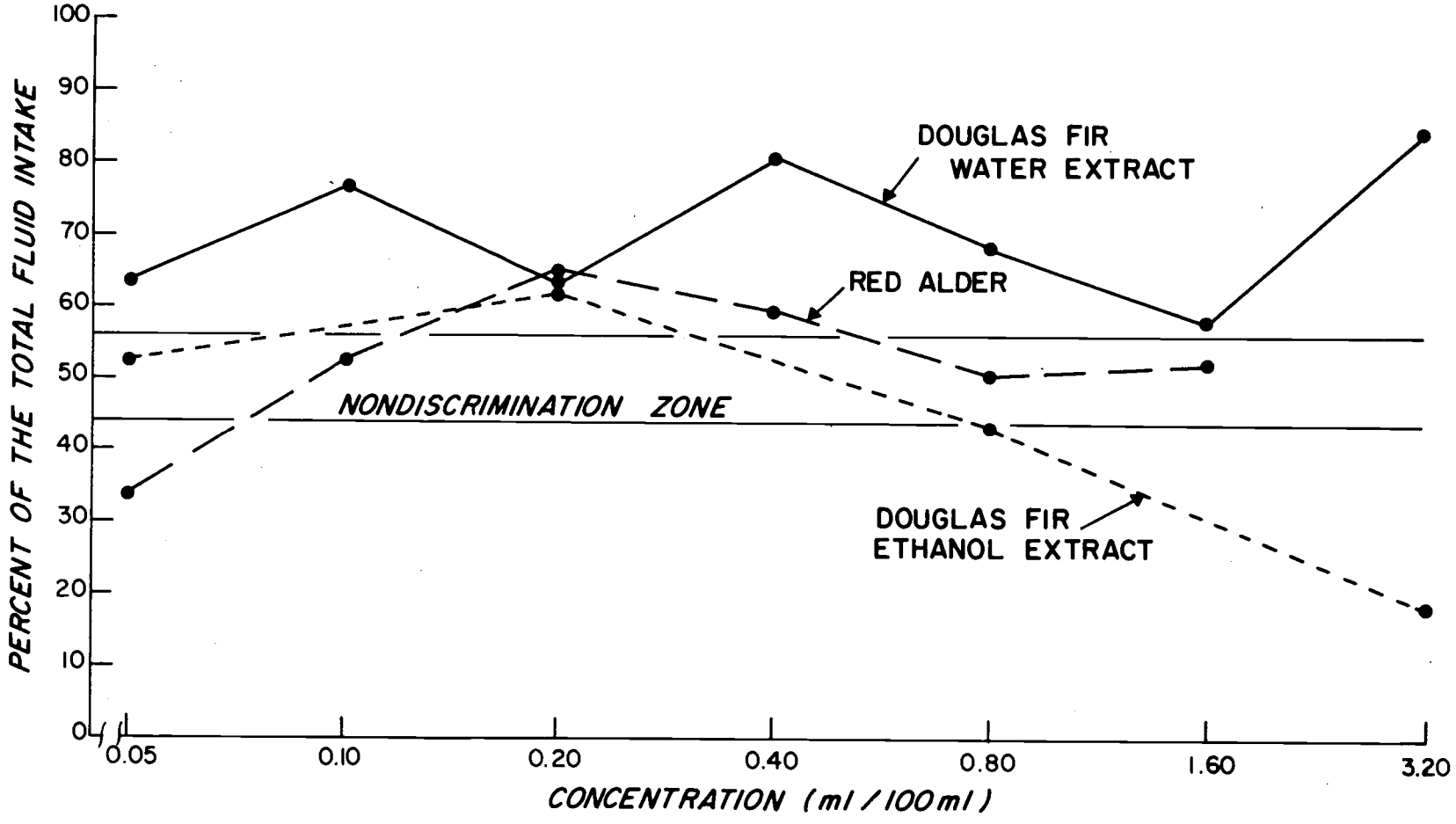

Figure 4. Taste responses of doe deer to ascending concentrations of Douglas fir water and ethanol extracts and to red alder water extract.

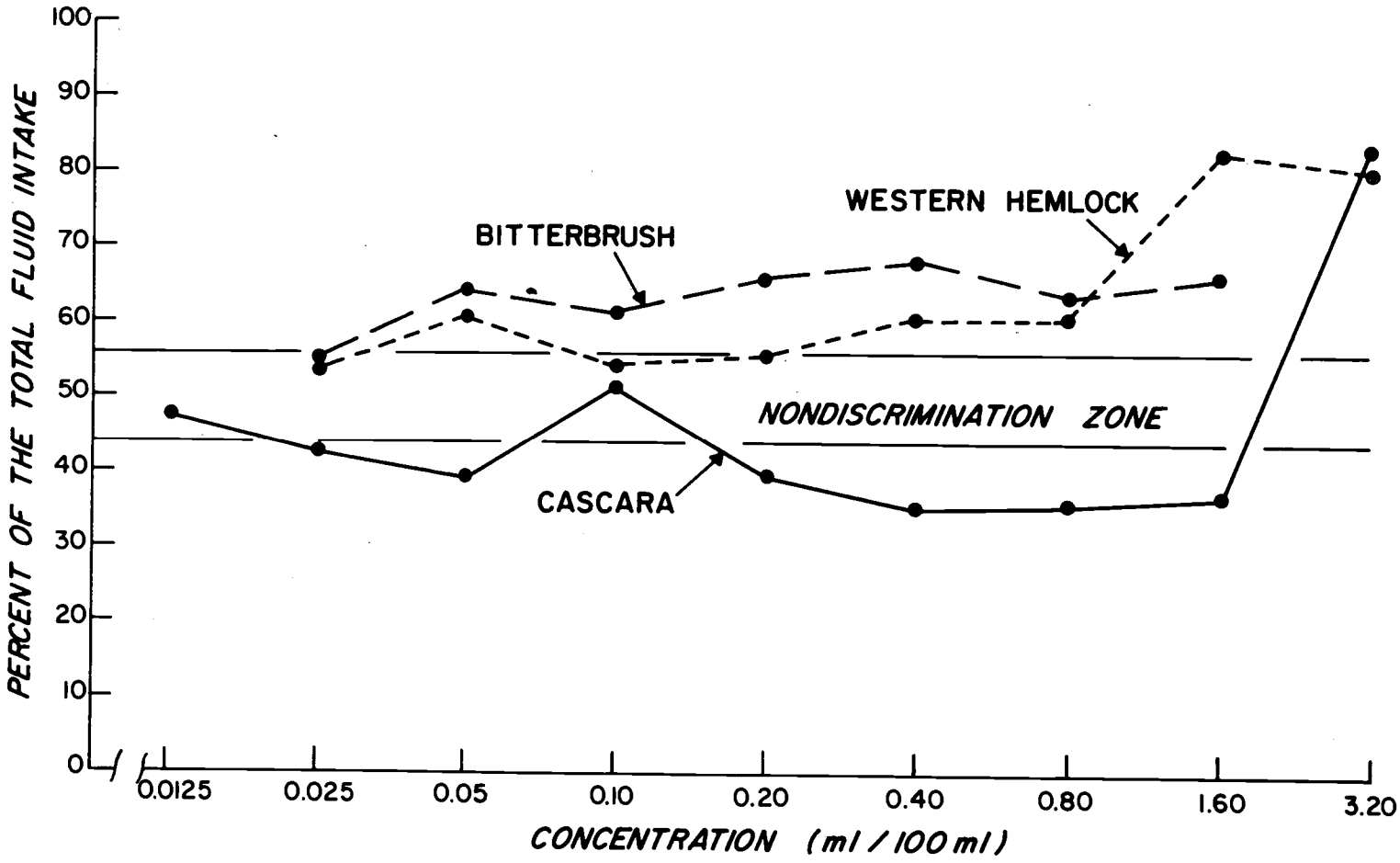

Figure 5. Taste responses of doe deer to ascending concentrations of cascara, western hemlock and bitterbrush water extracts.

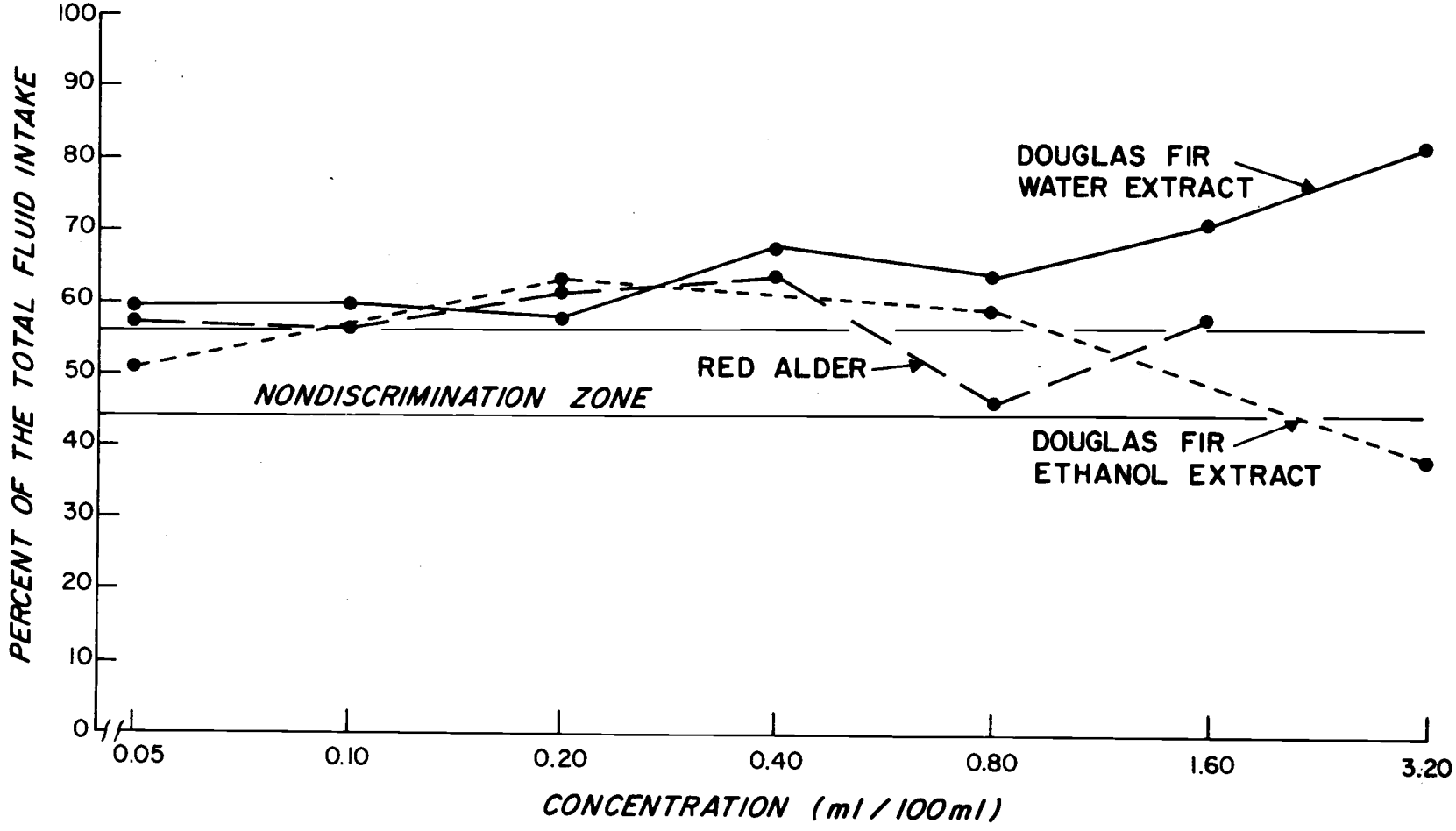

Figure 6. Mean taste responses of buck and doe deer to ascending concentrations of Douglas fir water and ethanol extracts to red alder water extract.

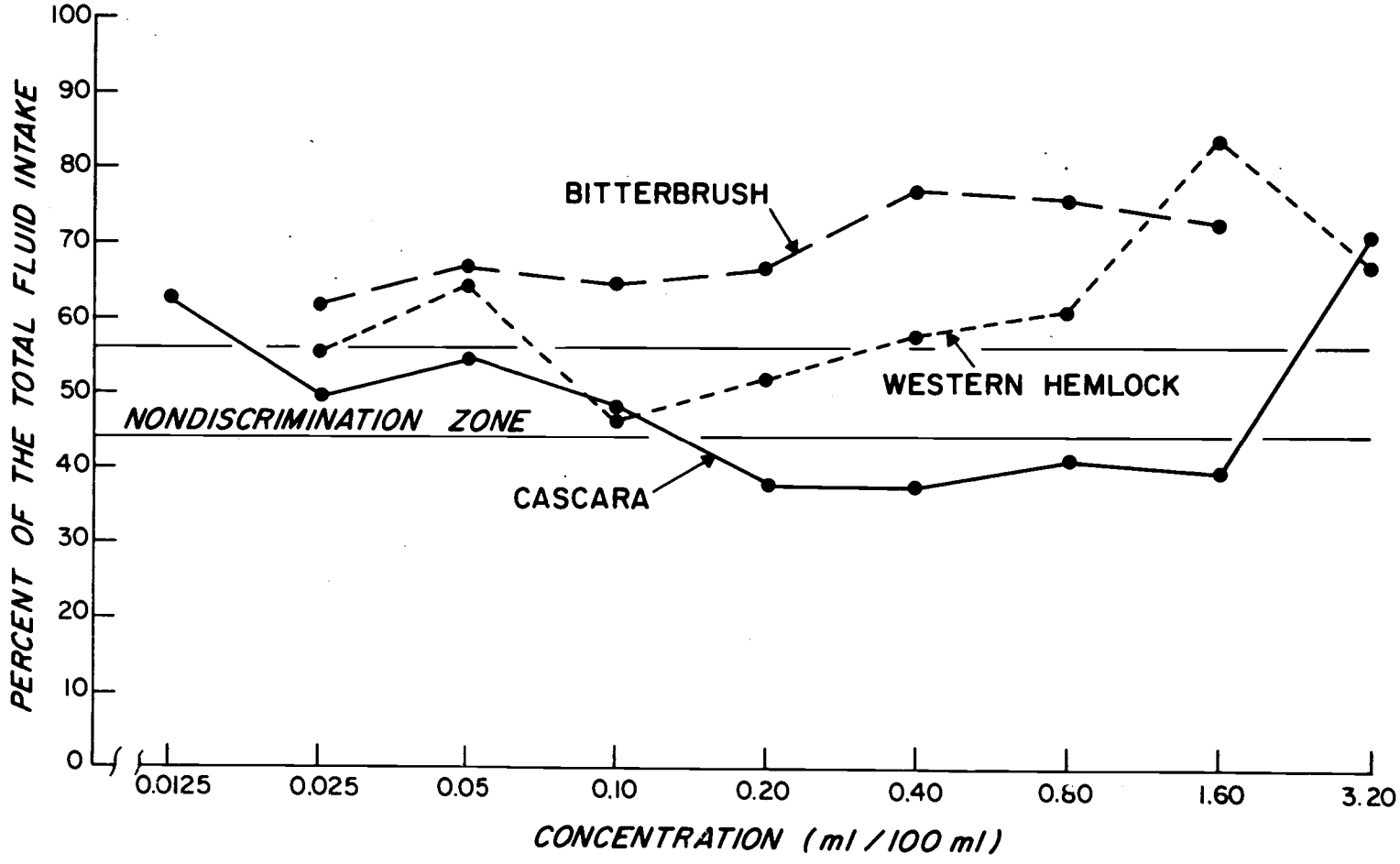

Figure 7. Mean taste responses of buck and doe deer to ascending concentrations of cascara, western hemlock, and bitterbrush water extracts.

initiated 80% preferences, from 2.99 to 3.20 ml/100 ml and from 1.48 to 1.84 ml/100 ml, respectively. The highest levels of intake were 81.43% at 3.20 ml/100 ml for the fir, and 83.33% at 1.60 ml/100 ml for the hemlock. A mean 20% rejection level was not attained with any extract. Bitterbrush and Douglas fir water extracts were preferred at all concentrations tested. The response to red alder extract was a weak preference from 0.05-0.60 ml/100 ml, with no discrimination shown from 0.60-1.60 ml/100 ml. Reactions to all concentrations of cascara extract were variable with a low of 37.46% intake at 0.40 ml/100 ml and a high of 70.67% intake at 3.20 ml/100 ml, both weak responses. Douglas fir ethanol extract evoked a very weak preference response from 0.12 to 1.04 ml/100 ml and a weak rejection from 2.40 to 3.20 ml/100 ml.

Responses to water extracts of Douglas fir obtained from tissue collected in the winter of 1969 and the summer of 1970 showed little variation. At the concentration of 3.2 ml/100 ml, the extract from the tissue collected in the winter of 1969 prompted an intake of 78.16% for the bucks, and 84.70% for the does. Responses to the extract from tissue from the same trees collected in the summer of 1970 were an intake of 81.73% for the bucks, and 80.52% for the does.

A greater preference for all concentrations of bitterbrush tested was exhibited by the bucks when compared to the does ($P < 0.05$). Bucks also showed a greater preference for the ethanol extract of

Douglas fir ($P < 0.20$). There was no significant sex difference ($P > 0.05$ or > 0.20) in taste responses shown for water extracts Douglas fir, red alder, cascara, and western hemlock.

Levels of pH for all concentrations of all water extracts tested were between 6.0 and 7.0, with one exception. The pH at the concentration of 3.20 ml/100 ml for the water extract of Douglas fir was 4.6. The pH of the Douglas fir ethanol extract ranged from 6.0 at 0.05 ml/100 ml to 4.1 at 3.20 ml/100 ml.

Discussion

Data obtained in this study indicated that the taste sensitivity of the deer was greatest for the bitterbrush extract. The next most effective stimulating substance was the water extract of Douglas fir at a concentration of twice that necessary to cause a preference reaction to the bitterbrush solution. Concentrations of the red alder extract and the ethanol extract of Douglas fir necessary to prompt a preference sensitivity reaction were four times greater than the bitterbrush extract. Similar responses for western hemlock and cascara were 16 and 96 times greater, respectively.

The highest average intake for all concentrations that were tested for an extract was prompted by the bitterbrush solutions, with an intake of 69.16%. The lowest average solution intake was 48.08%, initiated by the cascara extract. The average intake was a function of

the maximum intake obtained and of the number of test concentrations that did not result in a discriminatory response.

Of the natural browse species tested in this study, the taste responses indicated that Douglas fir was the most highly preferred. However, other studies using feeding observations, stomach content analysis, and observation of vegetation use (Brown, 1961; Crouch, 1966; Mitchell, 1964) found red alder and western hemlock to be more highly preferred than Douglas fir. Most browse preference determinations, these taste studies included, found cascara to be utilized, but not highly preferred. The differences between the taste sensitivities found in this study and the browse preference rankings of other studies may have resulted from such factors as difficulty in observing deer while feeding, vegetation use by other animals, difficulty in identifying browse in rumen contents due to relative digestion and passage rates, and because the two-choice preference test did not allow the deer access to all plant extract solutions at the same time.

Bitterbrush, the most highly preferred extract, is an unnatural browse species for black-tailed deer, but is a species highly preferred by mule deer (Dietz et al., 1962b). The fact that the bitterbrush extract was the most highly preferred species indicates that the preference for browse is not highly heritable, but depends on innovation of sensory mechanisms. In this study the deer had no previous exposure to

browse, so previous learning experiences which could affect preference (Heady, 1964) would have had no effect on the taste responses.

Analysis of the water extracts of Douglas fir, red alder, and cascara done by the Forestry Sciences Laboratory, Olympia, Washington, indicated that the total sugar content on a fresh weight basis was 3.69%, 3.00%, and 2.35%, respectively. The preference for these three extracts (from more to less preferred) corresponds to the decreasing levels of total sugars in the extracts. Using total sugars as a classification for sweetness, these reactions would be expected, as Crawford (1970) found black-tailed deer showed a high preference sensitivity for sweet (glucose and sucrose) taste stimulants.

Other chemical constituents of browse extracts may cause them to be more or less preferred than the intact plant, depending upon composition changes due to extracting. Water extraction results in a fiber content less than that found for fresh browse tissue. A reduction in fiber would increase the relative proportion of the other plant components, which may be positive or negative taste stimulants. Depending on the method of extraction, preference for a given plant may also vary. Jones and Barnes (1967) stated that extraction with ethanol removes more of the organic acids from plants than does water extraction. However, pH measurements for equal concentrations of the two Douglas fir extracts found the acidic content of the ethanol extract to be greatest. At a concentration of 3.2 ml/100 ml, results

clearly showed the water extract (pH, 4.6) to be highly preferred (intake of 81.43%), while the ethanol extract (pH, 4.1) was rejected (intake of 37.80%). These responses indicate that the pH differences resulting from the different extraction methods may be involved in eliciting a taste reaction.

Crawford (1970) observed a sex difference in taste responses, with bucks showing a definite preference for bitter compounds (quinine sulfate and quinine monohydrochloride) while does exhibited rejection or a nondiscriminatory response. The reaction to the bitterbrush extract in this study was similar, and would seem to indicate that the extract contained a compound, or compounds, which evoke a bitter taste sensation.

Taste responses of deer to extracts of fresh browse tissue do not correspond to observational studies of preference. However, controlled studies such as these offer a means of determining why preferences are shown, and can help elucidate such factors as sex differences and chemical constituents involved in preference responses.

PART II

Methods

The study was conducted from October, 1970 to February, 1971, at Oregon State University. Six black-tailed does and two bucks were used for taste trials with citric acid. Four does and four bucks were used for trials with malic, quinic, and succinic acids. All chemicals used were reagent grade. The taste testing procedure and analysis of results were the same as that used for the study with browse extracts.

Results

The taste responses to four organic acids were studied. Citric and malic acids were tested at concentrations from 0.00063 to 2.50 ml/100 ml. Quinic and succinic acids were tested at concentrations from 0.00063 to 0.63 ml/100 ml. All test concentrations were at increments of four times the preceding concentration. Separate responses were determined for the bucks and does. Table 2 presents the responses of the bucks and does that correspond to the preference threshold, 80% preference threshold, 20% rejection threshold and the zone of nondiscrimination. The responses of the deer to all concentrations for each acid tested are presented in Figure 8 for the bucks, in Figure 9 for the does, and the mean response in Figure 10. The responses versus the pH for all concentrations of each acid are shown for the

Table 2. Taste response of buck and doe deer to organic acids.

Acid	Pre[a]	Rej[b]	80% Pre[c]	20% Rej[d]	N-D[e]
			Bucks		
			Concentration (ml/100 ml)		
Citric	0.072	1.690		2.50	0.00063-0.072
Malic	0.004	2.064	0.01-0.348		0.00063-0.004
Quinic		0.434			0.00063-0.434
Succinic	0.00063	0.144		0.442-0.63	0.096-0.144
			Does		
Acid	Pre	Rej	80% Pre	20% Rej	N-D
			Concentration (ml/100 ml)		
Citric		0.0016		0.504-2.50	0.00063-0.0016
Malic		0.00063		0.120-2.50	
Quinic		0.00063		0.395-0.63	
Succinic		0.0016		0.060-0.63	0.00063-0.0016

[a]Preference threshold-concentration at which preference was first shown (57% intake)

[b]Rejection threshold-concentration at which rejection was first shown (43% intake)

[c]80% preference threshold

[d]20% rejection threshold

[e]Zone of nondiscrimination

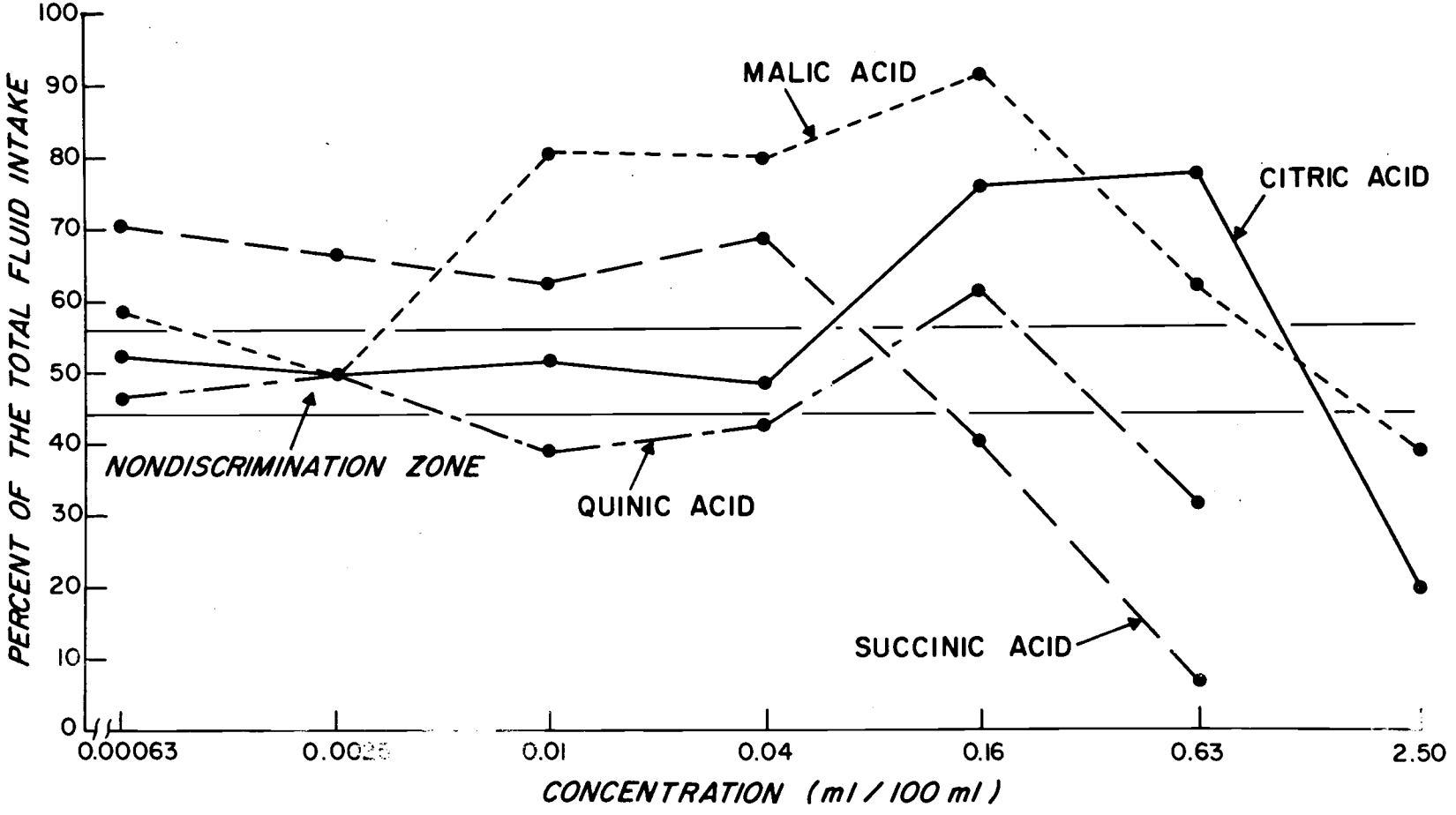

Figure 8. Taste responses of buck deer to ascending concentrations of organic acid solutions.

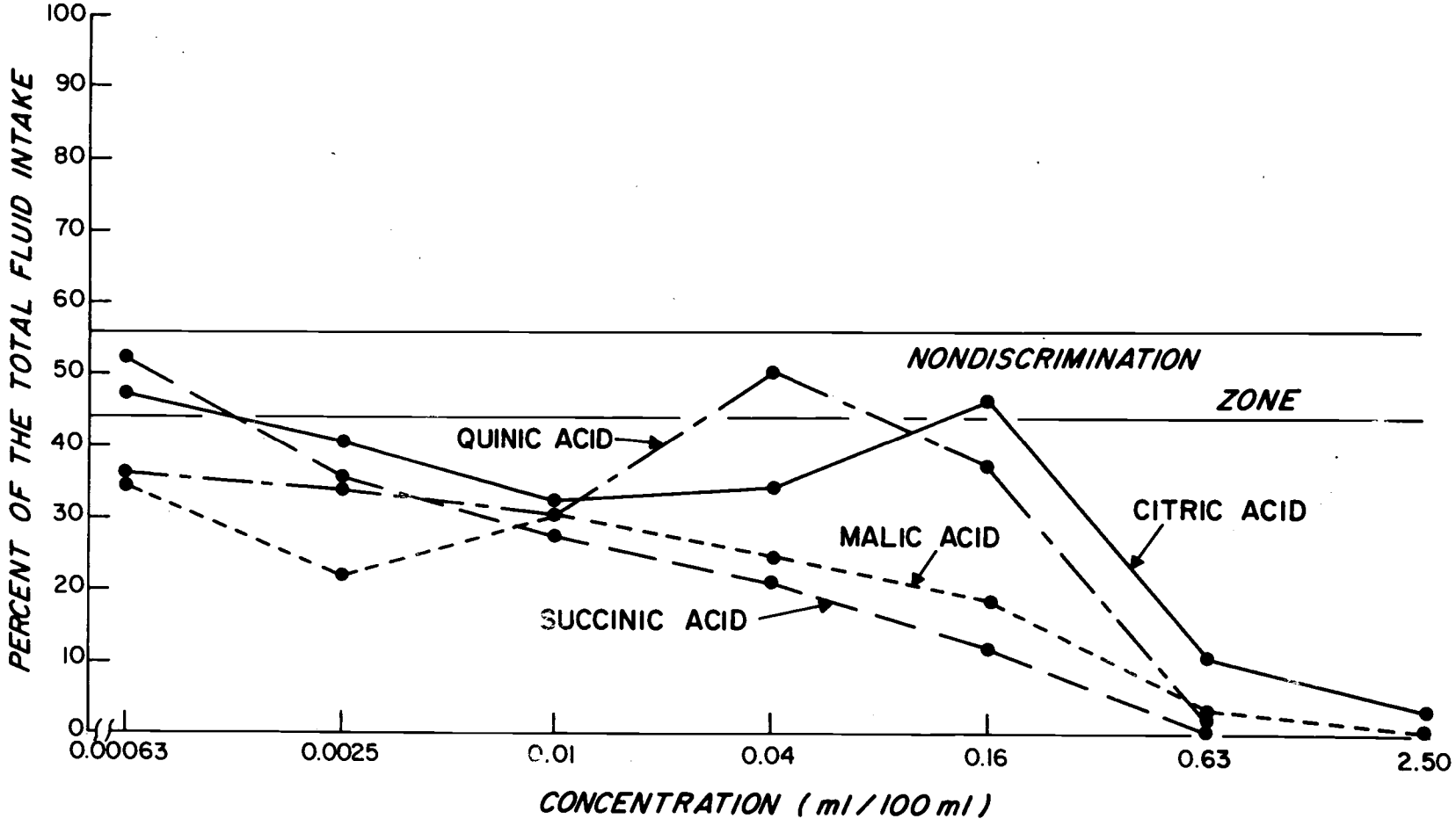

Figure 9. Taste responses of doe deer to ascending concentrations of organic acid solutions.

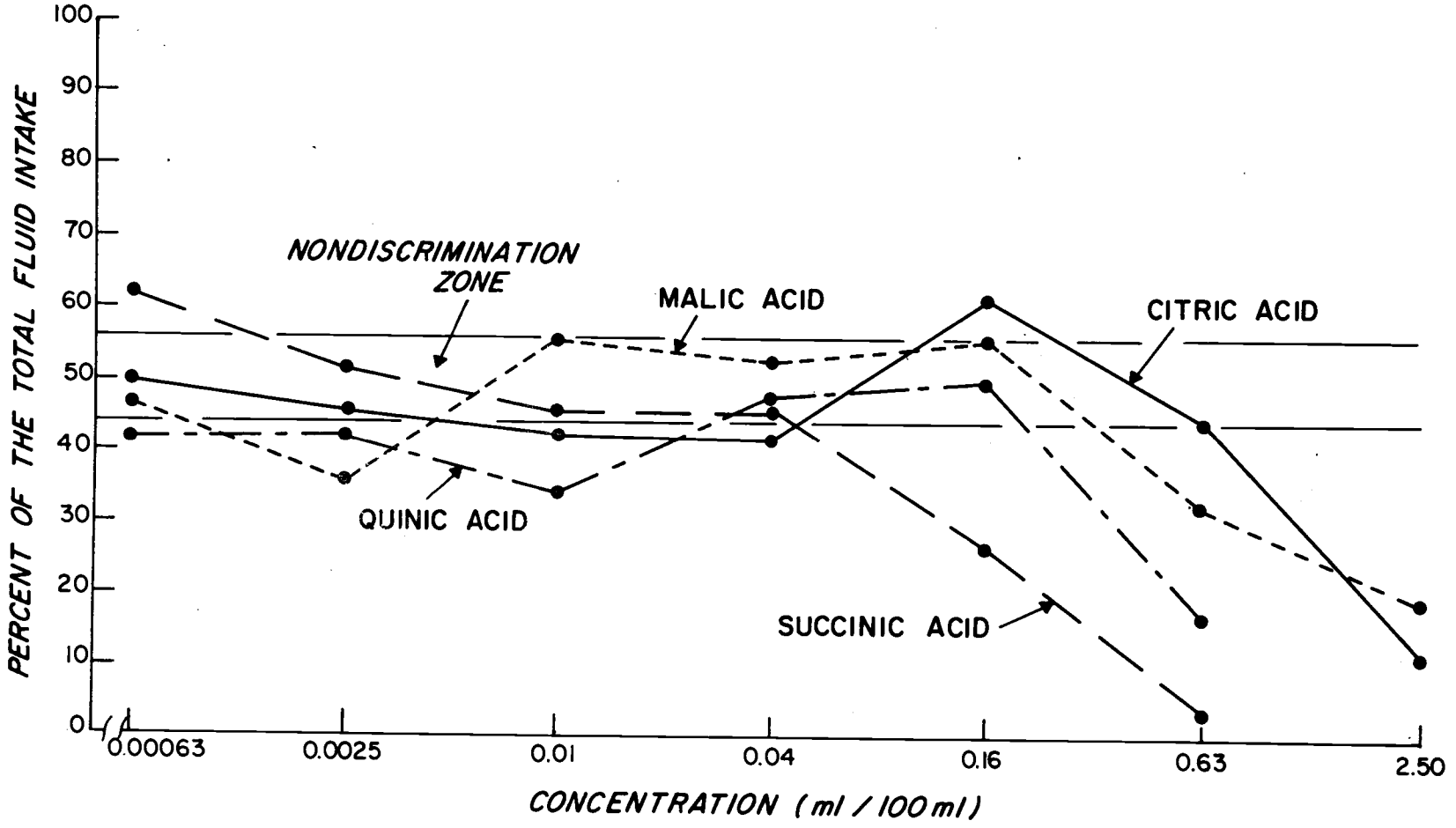

Figure 10. Mean taste responses of buck and doe deer to ascending concentrations of organic acid solutions.

bucks in Figure 11, for the does in Figure 12, and the mean response in Figure 13.

Citric Acid

The sensitivity response of the bucks to citric acid was one of preference. The 80% preference level was not attained, but a moderate preference (77.97% intake) was prompted at the concentration of 0.63 ml/100 ml (pH, 2.5). The 20% rejection level was reached at the highest concentration tested (pH, 2.2) with an intake of 19.94%.

Does showed no preference for citric acid. Rejection sensitivity was shown at 0.0016 ml/100 ml (pH, 6.7) with the 20% rejection level reached at 0.504 ml/100 ml (pH, 2.6). Definite rejection was exhibited at all higher concentrations with a low intake of 3.13% at 2.50ml/100 ml (pH, 2.2).

The mean response was generally nondiscriminatory from 0.00063 ml/100 ml (pH, 6.8) to 0.63 ml/100 ml (pH, 2.5). A weak preference of 61.10% intake was shown at 0.16 ml/100 ml (pH, 4.6), and a weak rejection intake of 41.53% was exhibited at the level of 0.04 ml/100 ml (pH, 6.3). A strong mean rejection (11.54% intake) was prompted by a concentration of 2.50 ml/100 ml (pH, 2.2).

Malic Acid

The bucks exhibited preference sensitivity to malic acid at a

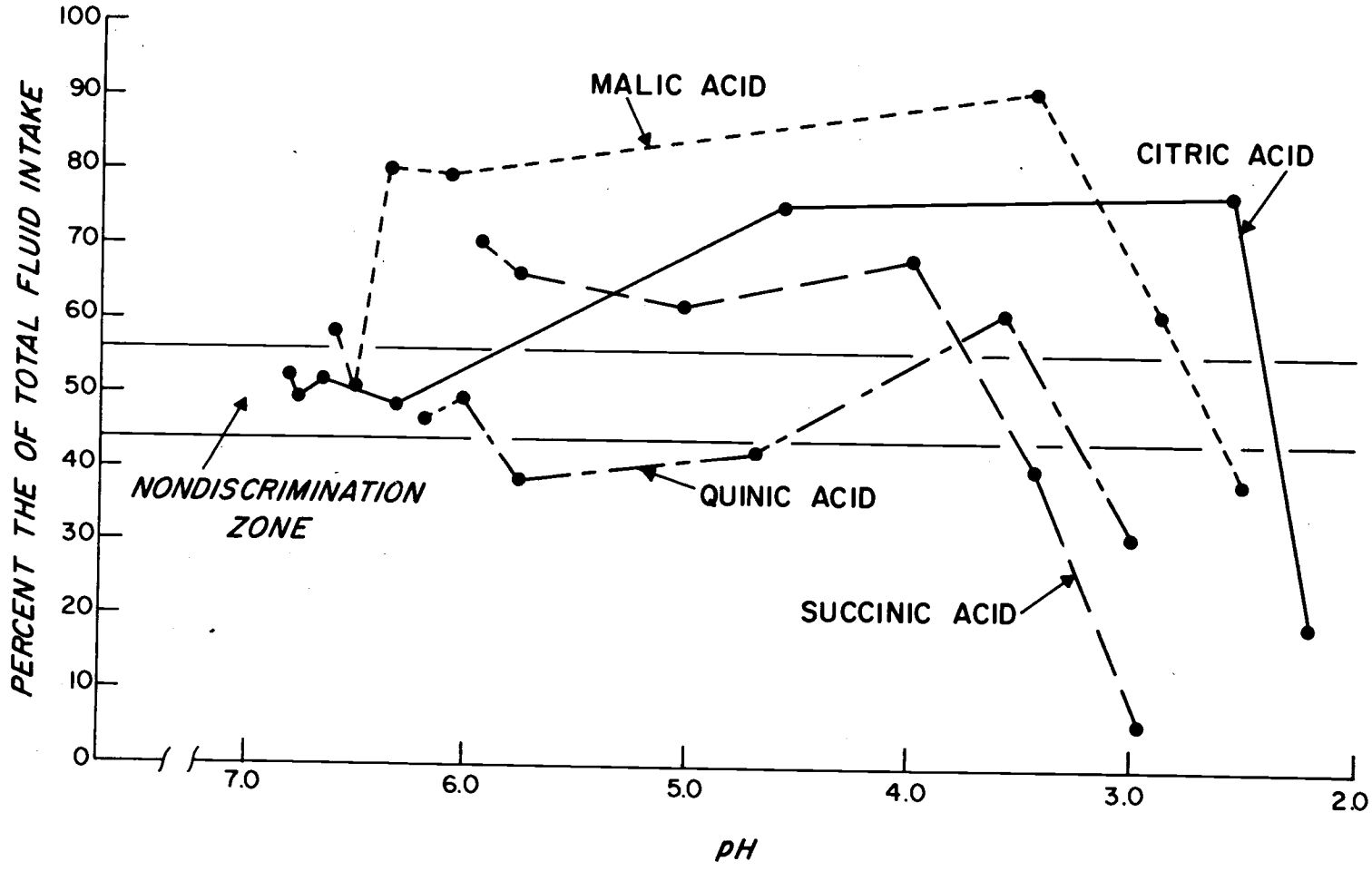

Figure 11. Taste responses of buck deer to descending pH of organic acid solutions.

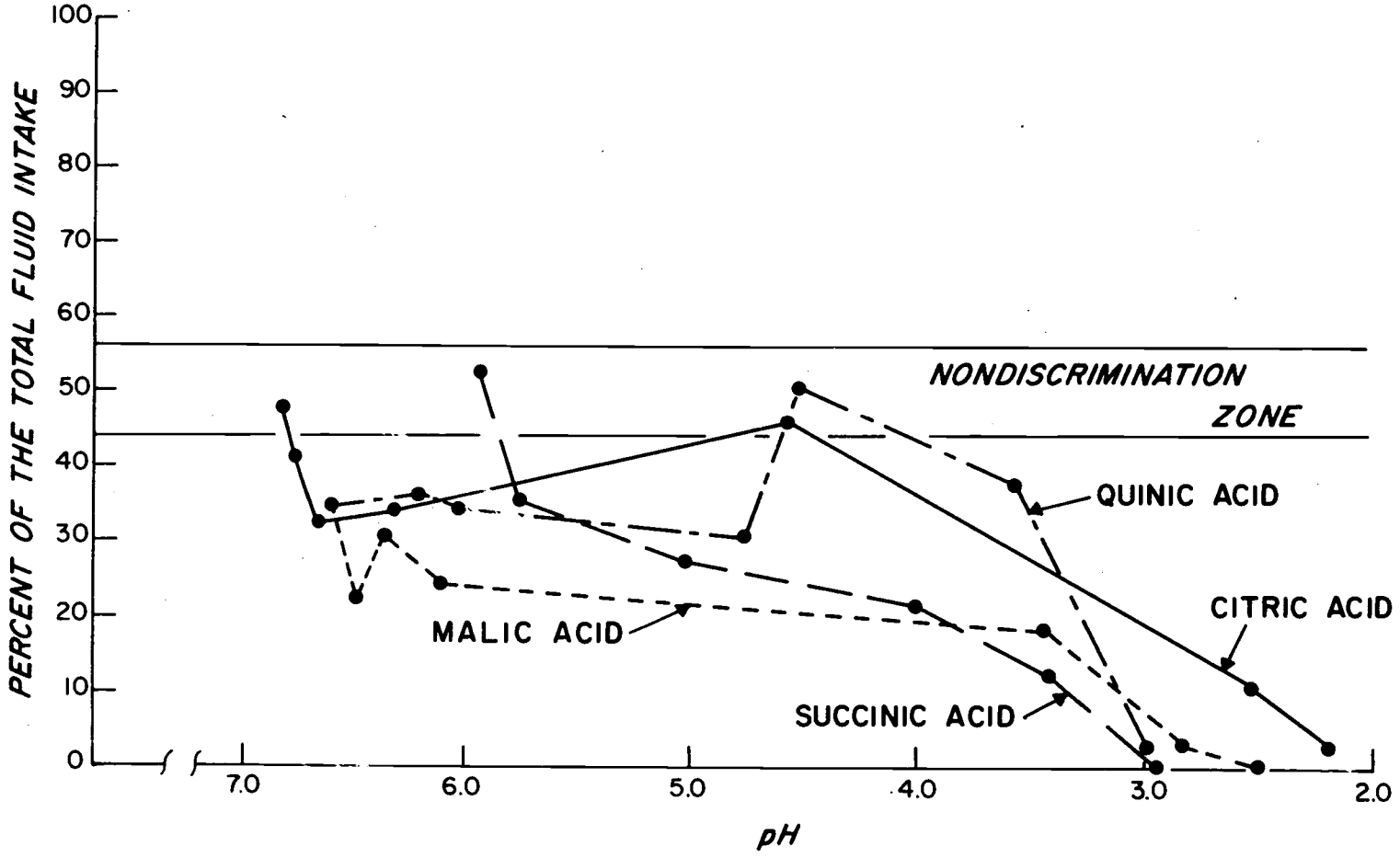

Figure 12. Taste responses of doe deer to descending pH of organic acid solutions.

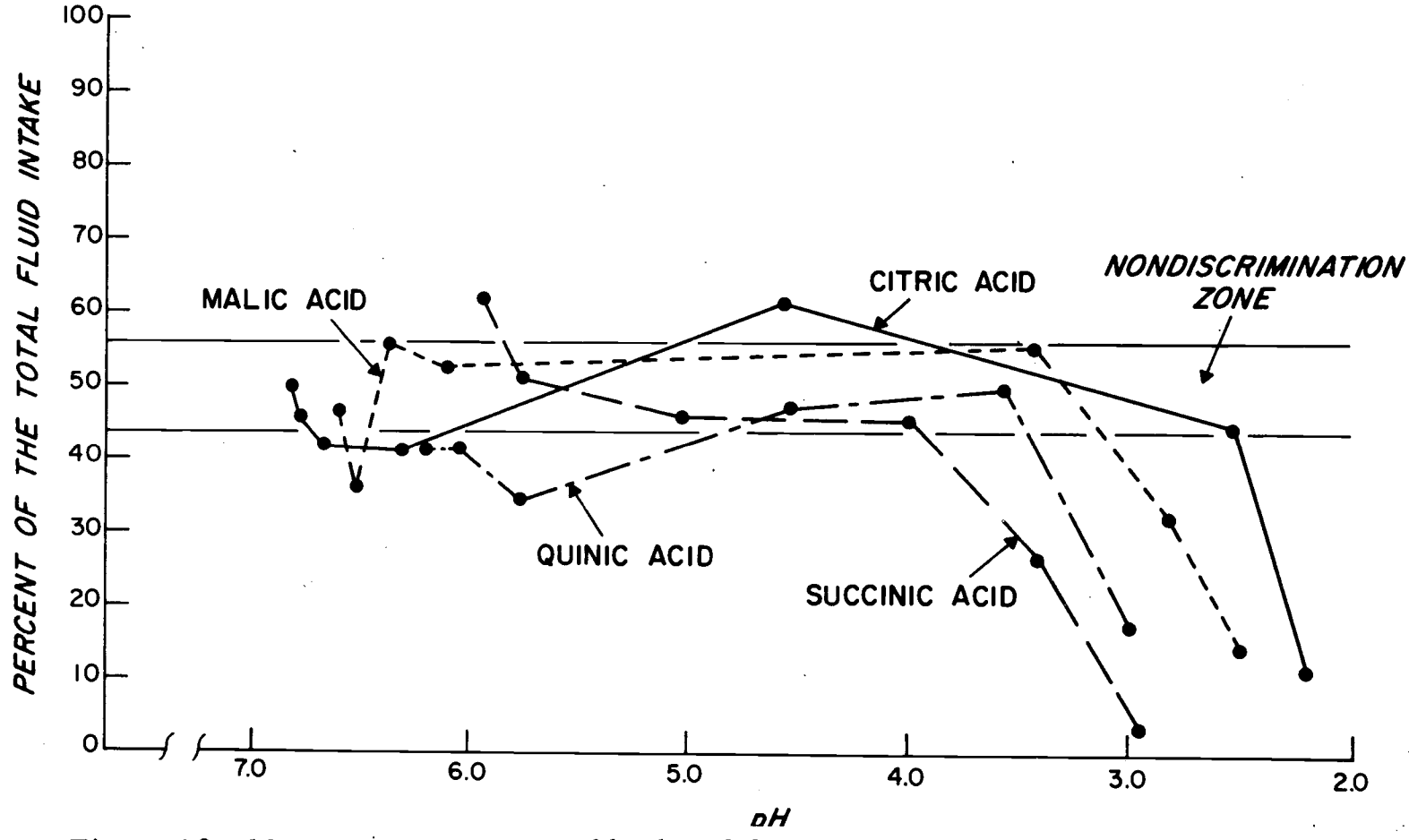

Figure 13. Mean taste responses of buck and doe deer to descending pH of organic acid solutions.

level of 0. 004 ml/100 ml (pH, 6. 5). The acid solutions were preferred at the 80% level with high intakes of 91. 10% and 92. 92% at concentrations of 0. 16 ml/100 ml (pH, 3. 4) and 0. 63 ml/100 ml (pH, 2. 8), respectively. The acid was preferred by the bucks over a wide concentration range from 0. 004 ml/100 ml (pH, 6. 5) to 1. 064 ml/100 ml (pH, 2. 7). Rejection at 2. 50 ml/100 ml (pH, 2. 5) was only slight with an intake of 38. 47%. The 20% rejection level was not prompted by any concentration tested.

The responses of the does to malic acid were all within the zone of rejection. An intake of 34. 66% showed a weak rejection at the lowest concentration (0. 00063 ml/100 ml, pH, 6. 6). Concentrations from 0. 0025 (pH, 6. 5) to 0. 04 ml/100 ml (pH, 6. 1) caused responses of moderate rejection, with intakes of 22. 10% and 24. 82%, respectively. Reaction to the concentrations of 0. 16 (pH, 3. 4) and 0. 63 ml/100 ml (pH, 2. 8) was that of strong rejection, with intakes of 18. 43% and 3. 38%, respectively. Response of the does to the test level of 2. 50 ml/100 ml (pH, 2. 5) was one of complete rejection (0. 00% of the intake).

The mean response of the bucks and does was generally nondiscriminatory from 0. 00063 (pH, 6. 6) to 0. 397 ml/100 ml (pH, 3. 1). Responses then commenced to decline rapidly to a strong rejection of 19. 24% at 2. 50 ml/100 ml (pH, 2. 5).

Quinic Acid

Quinic acid solutions did not evoke a significant preference response from the bucks. Only weak preference was shown at the concentration of 0. 15 ml/100 ml (pH, 3. 6) with an intake of 61. 35%. Weak rejection responses of 38. 63%, 42. 82%, and 31. 82% of the intake at concentrations of 0. 01 (pH, 5. 8), 0. 04 (pH, 4. 5) and 0. 63 ml/100 ml (pH, 3. 0) was exhibited. The remaining concentrations tested prompted nondiscriminatory responses.

The does rejected quinic acid solutions at all concentrations tested, with the exception of an indifferent response at 0. 04 ml/100 ml (pH, 4. 5, intake of 50. 49%). All rejection responses were that of weak rejection except at the highest concentration tested (0. 63 ml/ 100 ml, pH, 3. 0) which prompted an intake of 2. 18%.

A weak rejection mean response occurred from 0. 00063 ml/ 100 ml (pH, 6. 2, intake of 41. 04%) to 0. 033 ml/100 ml (pH, 4. 8). A nondiscriminatory response was then exhibited to a concentration of 0. 250 ml/100 ml (pH, 3. 5) with the remaining responses being rejections. The lowest percent consumption was at the highest level offered; 0. 63 ml/100 ml (pH, 3. 0, intake of 17. 00%), with the 20% rejection level at 0. 582 ml/100 ml (pH, 3. 1).

Succinic Acid

Bucks preferred succinic acid solutions from 0.00063 (pH, 5.9) to 0.110 ml/100 ml (pH, 3.7). The 80% preference threshold was not attained, but a high consumption of 70.18% was reached at the acid level of 0.00063 ml/100 ml (pH, 5.9). The concentration of 0.16 ml/100 ml (pH, 3.4) initiated a weak rejection (40.40% intake). The highest level tested (0.63 ml/100 ml, pH 3.0) exceeded the 20% rejection level with an intake of 6.51%.

The does were indifferent to the succinic acid solutions at the initial concentration tested. The reaction to the rest of the concentrations tested was a rejection response. The responses were a weak rejection at 0.0025 ml/100 ml (pH, 5.8), moderate rejection at 0.01 (pH, 5.0) and 0.04 ml/100 ml (pH, 4.0), and strong rejection at 0.16 (pH, 3.4, 12.54% intake) and 0.63 ml/100 ml (pH, 3.0, 0.00% intake).

The initial mean response was of weak preference (61.58% intake). A nondiscriminatory response prevailed from 0.0016 (pH, 5.9) to 0.048 ml/100 ml (pH, 4.0). The 20% mean rejection level was from 0.286 ml/100 ml (pH, 3.3) to the highest concentration tested, 0.63 ml/100 ml (pH, 3.0, intake of 3.26%).

Sex Differences

Comparison of sex responses showed that two of the acids,

malic and succinic, were more highly preferred by the bucks at all concentrations tested than they were by the does ($P < 0.05$). The bucks also showed a higher percent consumption of citric and quinic acids when compared to the does ($P < 0.20$).

Discussion

As determined by the lowest concentration of acid discriminated, the sensitivity of the deer was in the order: succinic > quinic > malic > citric. All mean discriminatory responses were rejections with the lowest percent consumption obtained with succinic acid solutions, followed in order by citric, quinic, and malic acids. The concentration necessary to prompt the low response to succinic acid was equal to the low response concentration of quinic acid, but was one-fourth the concentration necessary to evoke the low response to citric and malic acid solutions.

From these data and the data reported by Crawford (1970), the sensitivities of black-tailed deer for the sour acid taste were: acetic > succinic > butyric > hydrochloric > quinic > malic > citric, with only the sensitivity to acetic acid being one of preference. Sensitivities based on molar concentration were : acetic (0.0011 M) > succinic (0.0041 M) > butyric (0.0100 M) > quinic (0.0130 M) > hydrochloric (0.0258 M) > malic (0.0295 M) > citric (0.0301 M). On the molar concentration basis, acetic acid was preferred at 3.6% of the

concentration required to cause rejection of citric acid. On the same basis succinic acid was rejected at 13.6%, butyric 33.0%, quinic 43.2%, hydrochloric 85.7%, and malic acid 98.0%. If pH is used as the criteria the sensitivity series would be as follows: butyric (6.4), acetic (6.3), succinic (4.0), quinic (3.5), malic (3.1), citric (2.5), and hydrochloric (2.4). Results with deer indicate that pH is secondary to smell in evoking taste sensitivity, as the volatile acids, acetic and butyric, caused sensitivity at higher pH levels than did the rest of the acids. The response to the non-volatile acids would seem to be more dependent on pH, although the organic acids evoked a taste sensation at a higher pH than did the mineral acid.

Crawford (1970) did not find a sex difference in the response of black-tailed deer to the sour taste of acids. However, in this study, if the responses of each sex are considered, there is considerable difference in the reaction to citric, malic, and succinic acids with less variation in the responses to quinic acid. The discriminatory responses of the bucks were preferences except the response to quinic acid. The sensitivity of the bucks was in the order: succinic > malic > citric > quinic. All discriminatory responses exhibited by the does were rejections, with the sensitivity in the order: malic=quinic > succinic=citric. The does exhibited sensitivity at a lower concentration to all acids, except succinic, than did the bucks. If the mean percent consumption for all concentrations tested of each acid is considered, the response of

the bucks was always greater than that of the does. The mean consumption of citric acid by the bucks was 53. 77% versus 30. 66% for the does; for malic acid 65. 76% versus 19. 06%; for succinic 52. 69% versus 24. 96%; and for quinic 45. 02% versus 31. 82%. These variations in sex response would not have been a reaction to nutritional or environmental factors, as such conditions were the same for both the bucks and the does. No clear explanation is available for the sex difference, but such reactions may be in response to physiological variables such as hormone levels. As these organic acids are high in many plant species, the variation in sex reaction to the solutions may be an indication of differing preferences to foods utilized by deer.

The non-volatile organic acids used in this study are known to exist in a variety of plants. Citric, malic, and quinic acids exist in a number of fruits and vegetables, as well as existing with small amounts of succinic acid in grasses. Relatively high quantities of these acids in ryegrass and other species were reported by Hirst and Ramstad (1957) and Jones and Barnes (1967). Cowlishaw and Alder (1960) found a positive correlation between the preference of cattle and sheep for grasses and the content of citric and quinic acids in the grasses. No correlation was found between preference and the content of malic and succinic acids. It would seem, if these acids can be correlated with preference in domestic ruminants, then a similar preference may occur in wild ruminants. In contrast, Arnold (1970) reported that the

addition of malic or quinic acid to the diet decreased the amount of voluntary food intake, indicating a negative taste response. The data obtained in this study substantiates the rejection response to these acids.

Citric, malic, and succinic acids are important metabolites of the ruminant animal. They are intermediates in the reduction of oxygen and the generation of ATP in the tricarboxylic acid cycle. In the ruminant, volatile fatty acids (VFA) serve as the major energy source upon entry into the TCA cycle. If the VFA levels in the rumen were low and other sources of energy were limited, test solutions of organic acids may evoke a preference response, as a reaction to fulfill the energy requirement. The diet the deer received in this study was considered nutritionally adequate, and therefore, would not be energy deficient. As the mean reactions were all rejections, the taste sensitivities to all concentrations of citric, malic, and succinic acids were not in response to nutritional need, but were an aversion to the stimuli. It has been shown that quinic acid can be converted to shikimic acid, which is an intermediate in the formation of aromatic amino acids (White, Handler, and Smith, 1968). As the ruminant has the ability, through microbial synthesis, to provide amino acids, ingestion of quinic acid solutions would not be for the purpose of satisfying a nutritional inadequacy. Therefore, the rejection responses to

quinic acid in this study would be a response to an unpleasant taste caused by the acid.

The taste responses exhibited toward organic acid solutions may describe not only the variability between sexes, but may be indicative of a response that would be generated by plants containing relatively high proportions of organic acids or similar compounds. However, if this generalization is to be made, several interrelated factors must be considered. Rejection or preference for a plant based upon organic acid content would necessarily change with increasing maturity of the plant because the total acid content and digestibility of the plant decreases (Ely et al., 1953). Past learning experience (Pfaffman et al. 1965), age, presence of disease and genetic constitution (Goatcher and Church, 1970e) may also alter discrimination to the stimulus.

The ability to relate taste responses obtained with pure acid solutions to plant preference or non-preference may suffer from lack of knowledge about the effect of other gustatory stimuli, both nutrient and non-nutrient, on the palatability and ensuing preference or rejection of a foodstuff. Yet, these taste responses exhibited by black-tailed deer may offer insight into determining the mechanisms and complex of stimuli involved in the taste response.

PART III

Methods

This study was conducted to provide data on the influence of the odor of taste solutions on the taste responses exhibited toward the solutions. The study was conducted with four black-tailed does and four bucks during February, March and April of 1971. Selected concentrations of compounds known to prompt a definite discriminatory taste response were tested in the presence of materials that emit offensive odors. The taste stimuli were presented as a two-choice preference test with the test solutions in one container and tap water in the other container. A measured amount of the odorous materials was placed on two patches of cotton, approximately 1" x 1" x $\frac{1}{2}$", that were taped on the front and back inside surface of each container. Each cotton patch was attached $1\frac{1}{2}$-2" above the liquid in the container. All patches and test solutions were replaced after every 24-hour period.

In the first section of the study the effect of the presence of butyric acid on the taste response of the deer to discriminatory concentrations of acetic acid, malic acid, Douglas fir-water extract, Douglas fir-ethanol extract, and western hemlock-water extract was determined. The second phase of the study consisted of testing the influence of PF Extract (Fraction G) on the response to the water and

ethanol extracts of Douglas fir and the water extract of western hemlock. The PF Extract is a candidate deer repellent supplied for the study by the Forestry Sciences Laboratory, Olympia, Washington. The material is extracted from fish, and as yet the chemical composition is not known.

Comparison was made between the percent consumption of the test solutions in the presence of butyric acid, or PF Extract, and the intake of the test solutions obtained in a previous taste study that was not influenced by extraneous odors. The intake during the presence of butyric acid versus the intake during the presence of PF Extract was also compared. Significance of the results was tested by the use of the "Student's" t-distribution.

Results and Discussion

In this study it was necessary to make three assumptions in order to classify the effect of odor on the taste response. First, it was necessary to assume that the concentrations of butyric acid (3 ml/cotton patch) or PF Extract (0.5 g/cotton patch) were sufficient to mask any odor that may have been elicited by the acids or plant extracts. The concentrations used were judged to be highly offensive to human smell, and were easily accomodated by the absorbant material. Secondly, if the odor of the butyric acid or the PF Extract had no influence, the taste response would be the same as that exhibited

toward the test solutions when not in the presence of the odoriferous materials. Third, if an odor of a test material existed as a positive effect, the response to exposure of the test solution with an odor camouflaging agent would be less than that shown for the material when not in the presence of the odor camouflaging agent; or, if an odor of a test material existed as a negative effect, and the odor of the butyric acid or PF Extract was not offensive to the deer, then the response would have been more than normal.

The results of the trials with butyric acid as the odor camouflaging agent are presented in Table 3. Acetic acid, a volatile compound which emits a strong odor (that found in vinegar), was tested at a concentration found by Crawford (1970) to be highly preferred by black-tailed deer. The effect of the butyric acid was to decrease the strong preference for acetic acid solutions to a response of weak preference. As the presence of butyric acid caused a slight, but nonsignificant decrease, it would appear that the odor emanated by acetic acid was a weak positive stimulus to the taste response. This appears to substantiate work reported by Crawford in which he felt that smell of the volatile acids was involved in prompting taste sensitivity.

Malic acid was tested at a concentration (0. 16 ml/100 ml) previously found to be highly preferred by the bucks and strongly rejected by the does. When the containers of the test solution and water were offered in the presence of butyric acid, the opposite response was

Table 3. Comparison of the response to test material and to test material in the presence of butyric acid.

Test material	Conc (ml/100 ml)	Percent Total Consumption		
		Bucks	Does	Average
Acids				
Acetic	0.08	76.00[af]	85.00[af]	80.50
Acetic + Butyric	0.08	68.38	65.17	66.78
Malic	0.16	91.65[d]	18.43	55.04
Malic + Butyric	0.16	36.36[f]	75.66[b]	56.01
Water extracts				
Douglas fir	3.20	78.16	84.70[c]	81.43
Douglas fir + butyric	3.20	83.62	77.99	80.81
W hemlock	1.60	83.69	82.96[b]	83.33
W hemlock + butyric	1.60	90.88[c]	62.54	76.71
Ethanol extract				
Douglas fir	0.80	73.00[e]	43.10[b]	58.05
Douglas fir + butyric	0.80	76.47[d]	6.53	41.50

[a] Crawford, J. C. 1970

[b] Value significantly greater ($P < 0.05$) than corresponding value for the same sex

[c] Value significantly greater ($P < 0.20$) than corresponding value for the same sex

[d] Significant preference ($P < 0.05$) exhibited by the bucks compared to the does

[e] Significant preference ($P < 0.20$) exhibited by the bucks compared to the does

[f] Unknown or insufficient data for analysis

obtained. The does exhibited an increased response of 57.23 percentage points, and the response of the bucks decreased by 55.29 percentage points. Malic acid gives off only a faint odor in the concentrated form, so it would seem unlikely that such a highly diluted solution would emit an odor that would have been detected by the deer. If no detectable odor of the acid solutions existed, there should have been no difference in the response to the test solutions, with and without the presence of butyric acid. However, the validity of the responses to the malic acid solutions in the presence of butyric acid was limited by the number of significant observations. Of eight test observations made, only three resulted in fluid intake, due to rainy weather during which puddles of water gave the deer access to an alternate source of fluid.

Responses of the bucks to the water extract of Douglas fir in the presence of butyric acid were not significantly different from the taste responses exhibited when only the fir extract was present. Reaction of the does was a slight significant decrease ($P < 0.20$) of 6.71% of the total intake. The Douglas fir extract at the concentration of 3.2 ml/100 ml had a pleasant odor detectable by humans. However, as there was little change in the preference response, it would appear that the reactions to the test solutions were dependent mainly upon gustatory stimulation and not on the odor of the extract. Also, as stated by

Bartley (1958), there could have been a blending of the odors, with a single odor dominated by the fir being perceived.

The response of the bucks to the western hemlock extract in the presence of butyric acid was a slightly significant decrease ($P < 0.20$), when compared to the response prompted by the extract when the butyric acid was not present. As both responses, with and without butyric acid, of the bucks were ones of strong preference, the difference may have been the result of normal variation. Also, as any odor of the extract was considered masked by the butyric acid, the reaction of the bucks probably was due to taste stimulation, not odor. A significant decrease ($P < 0.05$) in the percent of the consumption of the western hemlock extract solutions was exhibited by the does when the solutions were presented with butyric acid. The decreased response of the does indicated that their response to the western hemlock extract was partially due to the odor of the test solution.

The presence of butyric acid had no influence on the response of the bucks to the ethanol extract of Douglas fir, but caused a highly significant decrease ($P < 0.05$) in the intake of the fir test solution by the does. The initial reaction of the does to the ethanol extract was one of weak rejection, but when the extract was presented in the presence of butyric acid the reaction was a strong rejection. The decreased response indicated that the initial reaction to the extract by the does was a positive response to the smell of the material, and that

the taste of the extract was offensive. These responses along with the decreased response of the does to the western hemlock extract indicated that there was a sex difference in the response to the odor of butyric acid. The review of Amerine et al. (1965) stated that a similar greater odor sensitivity exists in human females and in female rats. The responses also indicated that if the odor of the browse extracts was masked by another odor, the actual differences in taste responses due to sex are greater than the responses determined when the influence of odor is not masked.

The results of the trials with PF Extract as the odor camouflaging agent are presented in Table 4. The responses of the does to the water extracts of Douglas fir and western hemlock and to the ethanol extract of Douglas fir were not significantly different than the taste responses exhibited to the test solutions when not in the presence of the PF Extract. The reaction of the bucks to the influence of the extract on the western hemlock solutions was also one of nonsignificance. A significant decrease ($P < 0.05$) was shown by the bucks to the water extract of Douglas fir when the PF Extract was present. The response of the bucks to the ethanol extract of the fir was also less than their response to the extract when the PF Extract was not present.

The responses of the deer to the PF Extract indicated that there was a sex difference in the sensitivity to the putrid olfactory stimulus. As the reaction of the bucks was less for both extracts of Douglas fir,

Table 4. Comparison of the response to test material and to test material in the presence of PF Extract (Fraction G).

Test material	Conc (ml/100 ml)	Percent Total Consumption		
Water extracts		Bucks	Does	Average
Douglas fir	3.20	78.16[a]	84.70	81.43
Douglas fir + PF extract	3.20	6.48	75.72[c]	41.10
W hemlock	1.60	83.69	82.96	83.33
W hemlock + PF extract	1.60	77.12	86.29	81.70
Ethanol extract				
Douglas fir	0.80	73.00[b]	43.10	58.05
Douglas fir + PF extract	0.80	29.80	48.24	39.02

[a]Value significantly greater ($P < 0.05$) than corresponding value for the same sex

[b]Value significantly greater ($P < 0.20$) than corresponding value for the same sex

[c]Significant preference ($P < 0.05$) exhibited by the does compared to the corresponding value for the bucks

and was not different for the western hemlock extract, it appeared that the PF Extract was masking a hedonistic odor of the fir extracts that was partially responsible for the previously exhibited positive taste responses.

A comparison of the responses of the deer to the browse extract solutions in the presence of butyric acid and in the presence of PF Extract is presented in Table 5. No significant difference in the responses of the bucks and does to the two odor stimulants was noted, except for the decreased responses of the bucks to the Douglas fir extracts when in the presence of the PF Extract. These responses suggested that the PF Extract was perceived as a stronger negative stimulus by the bucks than the butyric acid, or that the PF Extract effectively masked the odor of the fir extracts and the butyric acid did not. The apparent strong olfactory stimulation by the PF Extract may have been due to the putrid nitrogenous compound, cadaverine (Harper et al., 1968). Cadaverine is formed by the decarboxylation of lysine (White et al., 1968), an amino acid that exists in relatively large quantities in fish.

Taste responses of black-tailed deer to organic acids and browse extracts may be influenced by noxious odors. The reactions to these odors vary with sex, the taste material, and the odorous material. However, knowledge of the response to these and other odors may further explain taste preferences, and may offer insight for the

Table 5. Comparison of the response to test material in the presence of butyric acid to test material in the presence of PF Extract (Fraction G).

Test material	Conc (ml/100 ml)	Percent Total Consumption		
Water extract		Bucks	Does	Average
Douglas fir + butyric	3.20	83.62[a]	77.99	80.81
Douglas fir + PF Extract	3.20	6.48	75.72	41.10
W hemlock + butyric	1.60	90.88	62.54	76.71
W hemlock + PF Extract	1.60	77.12	86.29	81.70
Ethanol extract				
Douglas fir + butyric	0.80	76.47[b]	6.53	41.50
Douglas fir + PF Extract	0.80	29.80	48.24	39.02

[a]Values significantly greater ($P < 0.05$) than corresponding values for the same sex

[b]Values significantly greater ($P < 0.20$) than corresponding values for the same sex

development of deer repellents to be used for protection of seedlings, crops, orchards, and residential shrubbery.

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APPENDIX

Table A-1. Mean percent intake of water from container "A" in two positions (two, 12-hours periods in each position), for six does and six bucks.

Group	Observation	Percent Intake from Container "A"
Pen 1-bucks	1	44.5
	2	49.3
Pen 2-bucks	3	53.0
	4	65.7
Pen 3-does	5	52.5
	6	45.0
Pen 4-does	7	60.5
	8	58.7
	Sum	429.2
	Mean	53.6[a]

Computed "t" = 1.36

"t" at 95% confidence level = 2.365

[a]Not significantly different from a theoretical mean of 50% at the 5% level of probability as determined by the use of a "t" test between the experimental mean and the theoretical mean.

95% confidence interval = mean $\pm$ standard error of the mean x $t_{.05}$ = 56.35 and 43.65

Table A-2. Comparison of sex differences for responses to all concentrations of test materials.

Test Materials		
Water extracts	Organic acids	Ethanol extract
Douglas fir[c]	Citric[b]	Douglas fir[b]
Red alder[c]	Malic[a]	
Cascara[c]	Quinic[b]	
Western hemlock[d]	Succinic[a]	
Bitterbrush[a]		

[a]Preference exhibited by the bucks compared to the does ($P < 0.05$)

[b]Preference exhibited by the bucks compared to the does ($P < 0.20$)

[c]No significant difference ($P > 0.40$)

[d]No significant difference ($P > 0.20$)

Table A-3. Taste responses of deer to ascending concentrations of Douglas fir water extract solutions: expressed as percent of total fluid intake.

Conc. ml/100 ml	pH	Bucks	Does	Grand Mean
0.05	6.61	55.23	63.67	59.45
0.10	6.50	43.09	76.61	59.85
0.20	6.46	52.64	63.27	57.96
0.40	6.30	53.62	80.87	67.25
0.80	6.18	58.15	68.43	63.29
1.60	6.07	82.78	58.43	70.60
3.20	4.58	78.16	84.70	81.43

Table A-4. Taste responses of deer to ascending concentrations of red alder extract solutions: expressed as percent of total fluid intake.

Conc. ml/100 ml	pH	Bucks	Does	Grand Mean
0.05	6.90	81.05	33.97	57.51
0.10	6.94	59.96	52.61	56.28
0.20	7.00	57.83	64.67	61.25
0.40	6.90	66.26	59.96	63.11
0.80	7.02	40.17	50.81	45.49
1.60	6.90	62.53	52.37	57.45

Table A-5. Taste responses of deer to ascending concentrations of cascara extract solutions: expressed as percent of total fluid intake.

Conc.		Bucks		Does				
ml/100 ml	pH	Grp. 4	Mean	Grp. 1	Grp. 2	Grp. 3	Mean	Grand Mean
0.0125	6.90	77.20	77.20	55.26	51.06	37.08	47.08	62.14
0.025	6.90	55.94	55.94	43.26	34.92	50.47	42.88	49.64
0.05	6.75	68.95	68.95	51.02	25.86	41.94	39.60	54.27
0.10	6.70	43.75	43.75	79.09	34.93	42.57	51.19	47.47
0.20	6.64	36.45	36.45	36.93	27.23	53.67	39.27	37.86
0.40	6.54	39.31	39.31	31.09	25.45	50.34	35.62	37.46
0.80	6.48	45.56	45.56	50.93	36.58	20.23	35.91	40.74
1.60	6.40	41.55	41.55	32.43	25.86	52.30	36.80	39.18
3.20	6.22	57.50	57.50	---[a]	---	83.84	83.84	70.67

[a]Missing data are concentrations that could not be tested because of a limited supply of extract.

Table A-6. Taste responses of deer to ascending concentrations of western hemlock extract solutions: expressed as percent of total fluid intake.

Conc.		Bucks		Does				
ml/100 ml	pH	Grp. 4	Mean	Grp. 1	Grp. 2	Grp. 3	Mean	Grand Mean
0.025	6.87	57.32	57.32	39.30	51.48	69.75	53.51	55.41
0.05	6.80	68.29	68.29	55.74	66.05	59.36	60.38	64.34
0.01	6.75	38.04	38.04	69.67	24.80	58.83	54.44	46.24
0.20	6.69	47.74	47.74	73.57	37.09	55.85	55.51	51.62
0.40	6.54	55.30	55.30	74.29	31.81	75.58	60.56	57.93
0.80	6.50	59.89	59.89	60.67	58.21	63.19	60.69	60.29
1.60	6.40	83.69	83.69	82.84	86.26	79.77	82.96	83.33
3.20	6.12	52.10	52.10	---[a]	---	80.06	80.06	66.08

[a]Missing data are concentrations that could not be tested because of a limited supply of extract.

Table A-7. Taste responses of deer to ascending concentrations of bitterbrush extract solutions: expressed as percent of total fluid intake.

Conc.		Bucks		Does				
ml/100 ml	pH	Grp. 4	Mean	Grp. 1	Grp. 2	Grp. 3	Mean	Grand Mean
0.025	6.42	72.49	72.49	54.15	---[a]	55.33	54.74	61.62
0.05	6.44	69.14	69.14	69.26	44.17	79.88	64.43	66.78
0.10	6.40	68.17	68.17	74.34	41.71	67.70	61.25	64.71
0.20	6.44	68.00	68.00	72.25	49.16	74.54	65.98	66.99
0.40	6.48	85.07	85.07	77.01	58.03	70.28	68.44	76.76
0.80	6.38	84.98	84.98	67.61	52.67	69.10	63.13	75.06
1.60	6.16	77.86	77.86	55.52	---[b]	77.58	66.55	72.20

[a] Missing data

[b] Missing data is a concentration that could not be tested because of a limited supply of extract.

Table A-8. Taste responses of deer to ascending concentrations of Douglas fir ethanol extract solutions: expressed as percent of total fluid intake.

Conc.		Bucks		Does				
ml/100 ml	pH	Grp. 4	Mean	Grp. 1	Grp. 2	Grp. 3	Mean	Grand Mean
0.05	6.10	49.65	49.65	52.20	25.18	79.40	52.20	50.93
0.20	5.94	62.18	62.18	60.55	54.08	75.25	63.29	62.74
0.80	5.50	73.00	73.00	41.85	48.01	39.48	43.10	58.05
3.20	4.10	57.46	57.46	29.88	10.33	14.19	18.13	37.80

Table A-9. Taste responses of deer to ascending concentrations of citric acid solutions: expressed as percent of total fluid intake.

Conc.		Bucks		Does				
ml/100 ml	pH	Grp. 4	Mean	Grp. 1	Grp. 2	Grp. 3	Mean	Grand Mean
0.00063	6.81	52.25	52.25	51.60	48.49	41.88	47.32	49.79
0.0025	6.78	49.57	49.57	23.77	58.62	39.56	40.64	45.11
0.01	6.66	51.90	51.90	19.06	40.95	36.89	32.30	42.10
0.04	6.31	48.69	48.69	6.75	65.53	30.84	34.37	41.53
0.16	4.58	75.93	75.93	4.47	75.34	58.45	46.09	61.01
0.63	2.52	77.97	77.97	12.62	14.81	4.88	10.76	44.36
2.50	2.20	19.94	19.94	---[a]	---	3.13	3.13	11.54

[a]Missing data are concentrations that could not be tested because of a limited supply of acid.

Table A-10. Taste responses of deer to ascending concentrations of malic acid solutions: expressed as percent of total fluid intake.

Conc.		Bucks			Does			
ml/100 ml	pH	Grp. 1	Grp. 4	Mean	Grp. 2	Grp. 3	Mean	Grand Mean
0.00063	6.60	48.89	72.92	58.57	---[a]	34.66	34.66	46.62
0.0025	6.51	56.22	43.48	49.85	0.00	33.15	22.10	35.98
0.01	6.38	66.07	94.91	80.09	27.77	32.37	30.07	55.08
0.04	6.10	91.10	68.40	79.75	5.00	44.65	24.82	52.28
0.16	3.44	92.92	90.38	91.65	0.00	36.87	18.43	55.04
0.63	2.82	71.84	52.10	61.97	0.00	6.75	3.38	32.22
2.50	2.50	26.94	50.00	38.47	---[a]	0.00	0.00	19.24

[a]Missing data

Table A-11. Taste responses of deer to ascending concentrations of quinic acid solutions: expressed as percent of total fluid intake.

Conc.		Bucks			Does			
ml/100 ml	pH	Grp. 1	Grp. 4	Mean	Grp. 2	Grp. 3	Mean	Grand Mean
0.00063	6.20	61.26	31.44	46.35	36.36	35.08	35.72	41.04
0.0025	6.04	54.04	44.12	49.13	26.84	42.54	34.69	41.91
0.01	5.78	32.98	44.27	38.62	21.54	38.60	30.07	34.35
0.04	4.52	58.19	27.46	42.82	15.06	85.92	50.49	46.65
0.16	3.58	82.12	40.58	61.35	21.21	54.32	37.76	49.56
0.63	3.00	56.07	7.58	31.82	0.00	4.35	2.18	17.00

Table A-12. Taste responses of deer to ascending concentrations of succinic acid solutions: expressed as percent of total fluid intake.

Conc.		Bucks			Does			
ml/100 ml	pH	Grp. 1	Grp. 4	Mean	Grp. 2	Grp. 3	Mean	Grand Mean
0.00063	5.94	66.54	75.07	70.81	60.60	44.12	52.36	61.58
0.0025	5.76	62.82	71.01	66.91	19.04	51.44	35.24	51.07
0.01	5.02	77.16	48.01	62.58	0.00	43.52	27.66	45.12
0.04	4.00	79.56	58.34	68.95	0.00	32.98	21.99	45.47
0.16	3.42	67.78	13.02	40.40	0.00	25.09	12.54	26.47
0.63	2.96	13.02	0.00	6.51	0.00	0.00	0.00	3.26

Table A-13. Composition of deer feed.[a]

Ingredient	Percent
Cottonseed meal	29.0
Ground oats	21.5
Soybean meal	14.0
Molasses	14.0
Ground wheat	13.0
Alfalfa meal	7.0
Tricalcium phosphate	0.7
Iodized salt	0.7
Vitamin A (325, 000 I U/g)	85 g/ton

[a]Fed ad libitum as 3/16" pellets along with alfalfa pellets containing 7% molasses

Table A-14. List of common and scientific names used in the text.

Common Name	Scientific Name
American elm	*Ulmus americana*
Aspen	*Populus tremuloides*
Balsam fir	*Abies balsamea*
Bitterbrush	*Purshia tridentata*
Cascara	*Rhamnus purshiana*
Chokecherry	*Prunus virginiana*
Coast redwood	*Sequoia sempervirens*
Dogwood	*Cornus sp.*
Douglas fir	*Pseudotsuga menziesii*
Elderberry	*Sambucus sp.*
Jack pine	*Pinus banksiana*
Ponderosa pine	*Pinus ponderosa*
Red alder	*Alnus rubra*
Red huckleberry	*Vaccinium parvifolium*
Salal	*Gaultheria shallon*
Trailing blackberry	*Rubus ursinus*
Western hemlock	*Tsuga heterophylla*
Western red cedar	*Thuja plicata*
White cedar	*Thuja occidentalis*
Willow	*Salix sp.*