FATTY ACID COMPOSITION OF ADIPOSE TISSUE AS AN INDICATOR OF DIET: A PRELIMINARY ASSESSMENT

RUSSELL F. REIDINGER, JR., U.S. Fish and Wildlife Service, % Monell Chemical Senses Center, 3500 Market St., Philadelphia, PA 19104
JOHN N. LABOWS, Monell Chemical Senses Center, 3500 Market St., Philadelphia, PA 19104
DAVID P. FELLOWS, U.S. Fish and Wildlife Service, Wildlife Damage Research Station, Hilo, HI 96720
J. RUSSELL MASON, Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104

Abstract: In one experiment, male Norway rats (*Rattus norvegicus*) were provided diets in which oil composition varied systematically from 20% corn oil (and no coconut oil) to 20% coconut oil (and no corn oil). After 5 weeks, samples of adipose tissue (N = four rats/diet) were analyzed for fatty acids. Oleic and linoleic acids (combined) made up the greatest proportion of fatty acids in the samples ($\bar{x}$ = 53.5%), whereas palmitoleic ($\bar{x}$ = 3.1%) and stearic acids ($\bar{x}$ = 3.2%) were relatively least abundant. Lauric and myristic acids, more of which are found in coconut oil than in corn oil, were strongly (r^2 = 0.83 and 0.88, respectively) and directly associated with percentage of dietary coconut oil. In a second experiment, three black rats (*R. rattus*) were maintained on a diet of macadamia nuts for 28 days, and another three were collected in a macadamia grove. Three mongoose (*Herpestes auropunctatus*) were fed rats for 38 days that had been collected in a macadamia grove, and three were fed rats collected in a sugarcane field. All animals except the latter three mongoose (r^2 = 0.49) had proportions of fatty acids that were strongly associated (r^2 = 0.84–0.99) with the proportions of fatty acids in the oil of macadamia nuts. The data support the hypothesis that analyses of fatty acids could provide reliable information on the dietary histories of vertebrates in selected agroecosystems and might supplement existing methods, such as radiotelemetry and analyses of stomach contents, as a tool for identifying vertebrate pests and their food-web associates.

J. WILDL. MANAGE. 49(1):170–177

Mosby et al. (1974) suggested that, in situations where fat constitutes a large portion of the diet, fatty acid composition of body fat might be used to provide information on the dietary histories of animals. Such a tool might be a useful complement to existing methods (which now include stomach content analyses, marking foods, and direct field observation [Korschgen 1971]) for studying food habits of wildlife and, perhaps, their food-web associates in certain ecosystems. In support of this notion is considerable literature indicating that diet can influence the fatty acid composition of adipose and other tissues in animals (e.g., Hilditch and Williams 1964). For example, Garton et al. (1952) reported that a domestic pig fed from weaning on a diet consisting of 50% whale oil had backfat whose fatty acid composition reflected in part that of whale oil. In general, relations between diet and body fat of livestock are sufficiently understood to allow the use of diet to upgrade the composition of fat before marketing animals (Masoro 1968:25).

Evidence also suggests that relationships exist between diet and composition of body fat in rodents. Fatty acids in the adipose tissue reflected diets when various strains of laboratory rats (*R. norvegicus*) were fed corn oil (Longenecker 1939*a*), coconut oil (Longenecker 1939*b*), odd-chain fatty acids (Bernardini et al. 1976), or branched-chain fatty acids (Smith et al. 1978). Mosby et al. (1974) reported that composition of fatty acids in the body fat of Polynesian rats (*R. exulans*) was similar to that found in coconut oil. The rats were collected on the Tokelau Islands where coconuts constitute a major portion of their diets (Mosby et al. 1973).

However, factors other than diet can also influence the fatty acid composition of adipose tissue (e.g., Masoro 1968:25). Fatty acids can be subjected to various biochemical transformations that alter overall composition of deposited fats. Mosby et al. (1974), for example, noted a lower ratio of lauric:myristic acids in adipose tissue of *R. exulans* than occurs in coconut oil, possibly due to an elongation of lauric acid to myristic acid by enzymes known to be present in the rat. Fatty acid composition also differs among species, probably as influenced by diet. Hilditch and Williams (1964:93) characterized the body fat of land mammals as having about 30% (molar) palmitic acid, and the body fat of ruminants, including domestic goats, deer (*Cervus elaphus*), camels, (*Camelus* spp.), and hippopotamuses (*Hippopotamus amphibius*), as "stearic rich" (p. 99). Stearic acid generally

constituted over 10% of the fatty acids in the body fats of these animals when they were fed fat-free diets. Physical microenvironment apparently can also influence fatty acid composition of body fat. For example, Mac Grath et al. (1968) showed that fatty acid composition of the backfat of pigs can be influenced by ambient temperature.

Lipids might provide information on the diets of wildlife in at least three ways: (1) if strongly associated, proportions of one or more fatty acids in body fat might be used to estimate the proportion of dietary fat; (2) if strongly associated, proportions of fatty acids in body fat might be used as a qualitative reflection of dietary fatty acids; and (3) in some instances, presence in body fat might reflect an unusual or unique lipid in the diet. To further explore the first two possibilities, we conducted two experiments.

We thank P. A. Smith-Barbaro for providing the rats and preparing their diets for the first experiment; B. J. Dawson, F. W. Taylor, and M. L. Barth for assisting with the chemical analyses of the samples of adipose tissue; and C. A. Kornet and G. K. Beauchamp for critical comments.

MATERIALS AND METHODS

Experiment 1

Male Norway rats (ARS Sprague-Dawley®, Madison, Wis.), about 6 weeks old, were housed individually in hanging wire cages in a room with a 12-hour light:dark cycle and an ambient temperature of 20–23 C. Rats were fed a diet high in carbohydrates (5% corn oil) for a week before being randomly assigned to six groups (A–F), then provided diets whose oil composition varied in the following manner (w/w): Group A, 5% corn oil; Group B, 20% corn oil; Group C, 15% corn oil and 5% coconut oil; Group D, 10% corn oil and 10% coconut oil; Group E, 5% corn oil and 15% coconut oil; and Group F, 20% coconut oil. Except for Group A, oils made up 20% of the diet for each group, but the groups differed systematically in the proportion of corn oil:coconut oil in the diet. Other features of the diet were described by Smith-Barbaro et al. (1980, 1981). Salt concentration also varied within diet groups, but its level appeared unimportant as a factor affecting fatty acid composition of the rats, and these subgroups were combined for our study. Rats were allowed free access to the diets and water for 5 weeks, after which they were killed. Four rats from each group were selected at random, a sample (ca. 1 g) of body fat (i.e., adipose tissue) was taken from the dorsal surface of each, and the sample was frozen until analyzed for fatty acids.

Chemical analyses involved extracting the lipids from tissue, converting them to their methyl esters, and separating and quantifying the esters by gas chromatography (Morrison and Smith 1964). The extracted tissue samples were methanolyzed with boron trifluoride/methanol. A Perkin-Elmer 3920B gas chromatograph (reference to trade names does not imply endorsement of a product by the U.S. Government) equipped with either a 3.0-m × 2-mm glass column packed with 3% 6P 2100 DOH (Supelco, Inc.) or 2.4-m × 2-mm glass column packed with 5% Silar-10C was used for separation of fatty acid methyl esters. Quantification of peak areas was accomplished with a Spectra-Physics 4100 Computing Integrator. Identities of the esters were confirmed by comparing their retention times on both columns with known samples and by determining their mass spectra. To assess the reliability of the method, we conducted duplicate to quadruplicate analyses for 65% of the samples. Means of these samples rather than individual values were used in the statistical analyses.

Results from the chemical analyses were assessed by using a mixed, two-factor analysis of variance with groups (six levels, between) as one factor and fatty acids (six levels, within) as the other (Linton and Gallo 1975). Significant differences among means were separated by using the post hoc Bonferroni t statistic (Games 1971, Bailey 1977). In addition, family regression analyses and correlations (Hewlett-Packard 9815 statistical program) were conducted to determine which fatty acids were most closely associated with diet.

Experiment 2

Animals included six adult black rats and six adult mongoose collected on the island of Hawaii. The three female rats assigned to Group A had been captured in a forested area. They were housed individually and maintained on a diet of macadamia nuts for 28 days before sacrifice. The two females and a male assigned to Group B were captured in a macadamia grove and killed immediately. The mongoose (females) were collected adjacent to a slaughter-

house near Keaau. Three, assigned to Group C, were fed rats for 38 days that had been collected in a macadamia grove. The other three, assigned to Group D, were also fed rats for 38 days, but these rats had been trapped adjacent to a sugarcane plantation where macadamia nuts were unavailable. Mongoose were killed immediately after the last feeding, and subdermal fat samples from all of the animals were taken and analyzed for fatty acid composition as described for Experiment 1. We assessed results using a mixed, two-factor analysis of variance in which groups (four levels, between) were one factor and fatty acids (seven levels, within) were the other. In addition, we conducted family regression analyses and made simple linear correlations between group mean levels of fatty acids in the body fat and the fatty acid composition of macadamia nuts (as determined from a sample of nuts, shells removed, using the chemical method described above).

RESULTS

Experiment 1

Oleic and linoleic acids were not separated by the analytical procedure for all samples, so these acids were combined in the statistical analyses. Relative amounts of fatty acids varied within subjects ($F_{5,90} = 8{,}764$, $P < 0.01$), as did the interaction of the relative amounts of fatty acids and diet ($F_{25,90} = 26.7$, $P < 0.01$). Overall, oleic and linoleic acids (combined) composed the greatest proportion ($P < 0.05$) of fatty acids in the fat samples from rats on all diets ($\bar{x} = 53.5\%$), whereas palmitoleic ($\bar{x} = 3.1\%$) and stearic acids ($\bar{x} = 3.2\%$) were least abundant (Table 1).

Relative amounts of lauric and myristic acids appeared more affected by diet than did the amounts of other fatty acids (Table 1). In adipose tissue of rats fed diets containing 20% oil, those given no coconut oil (Group B) had relatively small amounts of lauric and myristic acids ($\bar{x}_s = 0.1$ and 0.7%, respectively), whereas those given 20% coconut oil (Group F) had relatively greater amounts of these acids ($\bar{x}_s = 34.8$ and 13.8%, respectively). In contrast, mean levels of palmitic acid varied only from 14.2 to 20.1%, and palmitoleic and stearic acids from 1.4 to 3.6%. Mean proportions of oleic and linoleic acids (combined) also varied considerably (from 30.8 to 80.1%), but only two levels of the diet (0 and 5% coconut oil) differed significantly

Table 1. Mean composition of fatty acids in adipose tissue of rats fed diets containing varied amounts of corn oil and coconut oil. Each fatty acid is expressed as a mean percentage of total fatty acids. N = four samples/group. Within columns (excluding overall means, Groups A–F) and across the row for overall means (Groups A–F), means without the same capital letters are different ($P < 0.05$).

Diet			Fatty acid											
	Percent corn oil	Percent coconut oil	Lauric		Myristic		Palmitic		Palmitoleic		Stearic		Oleic + linoleic	
			$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
A	5	0	0.9	0.5 A	2.4	0.5 A	29.4	4.3 A	7.5	0.4 A	5.1	1.6 A	54.7	3.7 A
B	20	0	0.1	0.1 A	0.7	0.3 A	14.2	0.8 A	1.4	0.3 B	3.6	0.1 A	80.1	1.1 B
C	15	5	12.2	3.4 AB	6.2	1.5 AB	20.1	3.2 A	2.2	0.7 B	3.5	0.9 A	56.3	9.1 AB
D	10	10	14.3	1.6 B	7.6	0.3 B	17.6	0.7 A	1.9	0.1 B	3.2	0.2 A	55.4	1.1 A
E	5	15	26.1	4.0 BC	10.6	0.3 B	14.6	0.2 A	2.1	0.7 B	2.6	0.3 A	44.0	3.7 A
F	0	20	34.8	3.0 C	13.8	0.7 C	15.1	0.7 A	3.6	0.8 B	1.4	0.3 A	30.8	3.0 A
A–F	—	—	14.7	2.8 AB	6.9	1.0 A	18.5	1.4 B	3.1	0.5 C	3.2	0.4 C	53.5	3.5 D

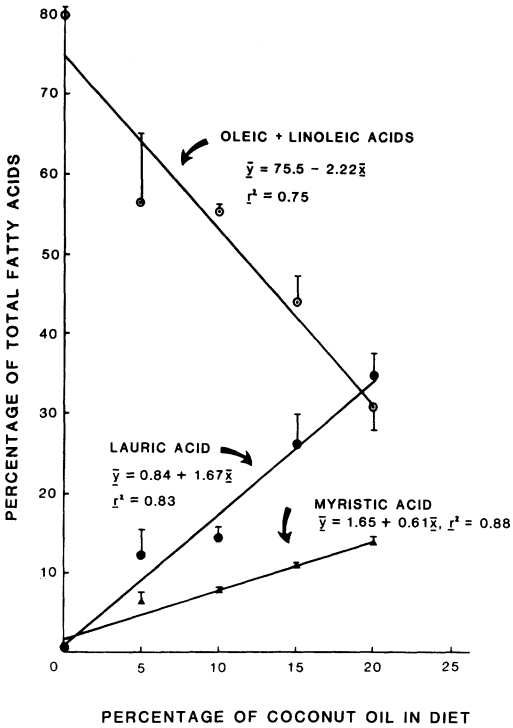

Fig. 1. Relationship between dietary coconut oil (%) and presence (% of total) of selected fatty acids in the body fats of male *Rattus norvegicus*, laboratory strain. Rats were assigned for 5 weeks to five groups whose diets differed in oil composition. Simple linear correlations are indicated by solid lines. Fatty acids illustrated include myristic acid (▲), lauric acid (●), and oleic + linoleic acids (⊙). N = four samples of body fat (rats) per group, points are means, and capped vertical lines represent standard errors.

from the others. Rats fed a diet containing only corn oil (5%) tended to have greater proportions of palmitic, palmitoleic, and stearic acids in their body fat.

For rats given a diet containing 20% oil, relative amounts of lauric acid and myristic acid in the adipose tissue were strongly ($r^2 = 0.83$ and 0.88, respectively) and directly associated with the percentage of coconut oil in the diet, whereas oleic and linoleic acid (combined) were strongly ($r^2 = 0.75$) and inversely associated with percentage of coconut oil in the diet (Fig. 1). Strengths of association were weak ($r^2 \leq 0.44$) for the other fatty acids. Overall, the associations appeared to best fit a linear model, and the strength of association was not improved (i.e., $r^2 = 0.88$) by trivariate analysis in which lauric acid and myristic acid were treated as independent variables.

Because both coconut and corn oil varied systematically in diets containing 20% oil, amounts of lauric acid and myristic acid in the body fat were also strongly but inversely associated with percentage of corn oil in the diet, whereas oleic and linoleic acids (combined) were strongly and directly associated. However, when Group A rats (5% corn oil only) were included in the regression analyses, strengths of association were weakened (from r^2 of 0.83 to 0.42 for lauric acid; from r^2 of 0.88 to 0.48 for myristic acid; and from r^2 of 0.75 to 0.66 for oleic + linoleic acids).

Experiment 2

As in Experiment 1, relative amounts of fatty acids differed within subjects ($F_{6,48} = 2{,}494$, $P < 0.01$), as did the interaction of group and amount of fatty acids ($F_{18,48} = 101.1$, $P < 0.01$). Overall, oleic acid made up the greatest proportion ($P < 0.05$) of fatty acids in the samples ($\bar{x} = 44.4\%$), whereas lauric acid ($\bar{x} = 3.0\%$) and myristic acid ($\bar{x} = 2.2\%$) were relatively least abundant (Table 2). Lauric and stearic acids were present in greater ($P < 0.05$) proportions (and myristic, palmitic, and linoleic acids tended to be) in the body fat of mongoose (Groups C and D) than in that of black rats (Groups A and B; Table 2). This trend was stronger for mongoose fed rats from a sugarcane field (Group D) than for those fed rats from a macadamia grove (Group C). Conversely, mongoose tended to have lower proportions of palmitoleic and oleic acids than the rats, particularly those that had been fed rats from sugarcane fields (Group D).

Oils in the pooled sample of macadamia nuts (shells removed) included the following acids: myristic, 1.2%; palmitic, 9.2%; palmitoleic, 24.0%; stearic, 1.4%; oleic, 56.8%; and linoleic, 5.6%. In separate regression analyses between fatty acid content of the macadamia nuts and adipose tissue, strengths of association were strong for three of the groups: Group A (rats fed macadamia nuts in the laboratory), $r^2 = 0.98$; Group B (rats collected in macadamia groves), $r^2 = 0.99$; and Group C (mongoose fed rats from macadamia groves), $r^2 = 0.84$. The strength of association was weak ($r^2 = 0.49$), however, for Group D (mongoose fed rats from sugarcane fields). Further, the slopes of the correlations for simple linear regressions were similar for Groups A and B ($ms = 0.84$ and 0.87, respectively), but less similar for Group C ($m = 0.63$) and Group D ($m = 0.34$).

Table 2. Mean composition of fatty acids in adipose tissue of rats and mongoose according to their known or presumed diet (described below). Relative presence of each fatty acid is expressed as a percentage of total fatty acids. N = three samples/group. Within columns (excluding overall means, Groups A–D) and across the row for overall means (Groups A–D), means without same capital letters are different ($P < 0.05$).

			Fatty acid											
			Lauric		Myristic		Palmitic		Palmitoleic		Stearic		Oleic		Linoleic	
Group	Animal	Diet	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
A	Black rat	Macadamia	0.5	0.5 A	1.0	0.2 A	8.7	0.8 A	16.3	1.6 A	5.0	1.0 A	50.4	1.2 A	5.7	1.20 A
B	Black rat	Unknown[a]	0.0	0.0 A	0.9	0.1 A	10.5	0.2 AB	19.4	0.5 A	4.7	0.2 A	51.6	2.7 A	8.4	3.7 AB
C	Mongoose	Rats from macadamia grove	2.9	0.3 B	2.3	0.5 AB	13.6	1.1 B	8.0	1.3 B	9.9	0.5 B	43.9	1.1 A	10.0	1.8 AB
D	Mongoose	Rats from sugarcane field	8.5	1.4 D	4.4	0.9 B	21.4	1.0 D	3.6	0.3 B	11.4	1.2 B	31.6	3.1 B	11.9	0.7 B
A–D	—	—	3.0	1.1 A	2.2	0.5 A	13.6	1.5 B	11.8	2.0 BD	7.7	1.0 D	44.4	2.6 E	9.0	1.14 BD

[a] Rats were collected in a macadamia grove.

DISCUSSION

Experiment 1

Rats fed a low-fat diet (Group A, 5% corn) had proportions of fatty acids in their adipose tissue similar to that reported for mammals fed fat-free diets (Hilditch and Williams 1964). Other researchers reported that oleic acid constituted about 47–65% of the fatty acids in adipose tissue in mammals; Group A rats in Experiment 1 had adipose tissue consisting of about 55% oleic and linoleic acid. Similarly, palmitic acid made up about 22–30% of the fatty acids in mammals fed fat-free diets (Hilditch and Williams 1964), and palmitic acid made up about 29% of the fatty acids in adipose tissue of rats in Group A. Rats fed diets with 20% fat (Groups B–F, mean of 10% coconut and 10% corn oil), however, had greater proportions of lauric acid ($\bar{x}$ = 17.5%) and myristic acid ($\bar{x}$ = 7.8%) than reported for mammals on a fat-free diet (Hilditch and Williams 1964), but less palmitic acid. We therefore believe that the diet of these rats affected the fatty acid composition of their adipose tissue. This conclusion is further supported by the fact that lauric and myristic acids combined make up about 60–65% of the fatty acids in coconut oil (e.g., Eckey 1954:316, Weiss 1970:35), and also because the relative amounts of lauric and myristic acids in the adipose tissue of the rats were strongly associated with the proportions of coconut oil in their diet (Fig. 1). Our results were consistent with the earlier findings of Mosby et al. (1974) involving *R. exulans* from the Tokelau Islands, and therefore support the common contention that diet influences the fatty acid composition of body fat in mammals.

Our results also support the idea that analyses of adipose tissue might provide parametric information on long-term diets of rodents in some agroecosystems. Under our methodology, and using laboratory strains of *R. norvegicus*, proportions of lauric and myristic acids appeared to be the best predictors of proportions of coconut oil in the diet. We suggest that these acids were directly related to the proportion of dietary coconut oil, rather than indirectly to corn oil content, because (1), as described earlier, lauric and myristic acids are the major fatty acids in coconut oil, and (2) inclusion of data from Group A (5% corn oil only) in the regression analyses resulted in weakened associations (i.e., had the fatty acids been related to corn

oil, addition of these data should have strengthened the associations). Additional studies with wild rodents will be required to evaluate the strength of such associations under actual field conditions; however, our results indicate that these studies are warranted.

The ratio of lauric acid:myristic acid varied among the rats given coconut oil (Groups C–F). We advance the possibility that transformation of lauric acid to myristic acid occurred (as postulated by Mosby et al. [1974] for *R. exulans*), but that the influence of such transformation on relative proportions of the fatty acids deposited in the adipose tissue was also affected by the amount of coconut oil in the diet. Our Group F rats (given 20% coconut oil) had a mean ratio of lauric acid:myristic acid equal to that found in coconut oil (2.52), whereas rats given 5–10% coconut oil (Groups C and D) had lowered mean ratios (1.97 and 1.88, respectively).

Experiment 2

In contrast to the results with rats fed 20% coconut oil in Experiment 1, where lauric acid and myristic acid constituted a mean of 24.3% of the fatty acids in adipose tissues (Table 1), lauric acid and myristic acids averaged only 1.5% of the fatty acids in adipose tissue of *R. rattus* fed macadamia nuts in the laboratory (Group A, Table 2) and less than 1.0% in specimens collected in macadamia groves. Although we cannot ignore influencing factors such as possible genetic differences between *R. rattus* and laboratory strains of *R. norvegicus*, the dissimilar results between experiments probably relate to the high proportions (ca. 75%) of lauric acids and myristic acids in coconut oil vs. their low content (ca. 1.2%) in macadamia nut. We therefore conclude that diet played a major role in the observed differences. Possible effects of sex on fatty acid composition were not evaluated, because females comprised all but one of the study specimens. However, the one male sampled had a fatty acid composition similar to that of the two female black rats that were also collected in a macadamia grove.

Our results are consistent with the hypothesis that proportions of fatty acids in the adipose tissue can be used as indicators of dietary history. Proportions of fatty acids in the adipose tissue of *R. rattus* fed macadamia nuts in the laboratory (Group A) were strongly associated ($r^2 = 0.98$) with the proportions of fatty acids in the oil of macadamia nuts. A strong association ($r^2 = 0.99$) also occurred between the proportions of fatty acids in the adipose tissue of *R. rattus* collected in macadamia groves and those in the oil of macadamia nuts. We suggest that the association indicated that macadamia nuts were part of the diet of the rats. The suggestion is consistent with findings by J. K. Crier (unpubl. data) that stomachs of *R. rattus* collected in macadamia groves sometimes contained fragments of macadamia nuts. Further, our results also support the premise that analyses of proportions of fatty acid compositions in the adipose tissue could be helpful in identifying food-web associations in a particular agroecosystem. Mongoose fed rats from macadamia groves had a fatty acid composition that was strongly associated ($r^2 = 0.84$) with the proportions of fatty acids in macadamia nuts, whereas mongoose fed rats from sugarcane fields had a much weaker association ($r^2 = 0.49$). The differences in proportions of lauric, palmitoleic, and stearic acid (Table 2) between *R. rattus* fed macadamia nuts or collected in a macadamia grove (Groups A and B) and mongoose fed rats from that area (Group C) cannot be readily explained, however.

MANAGEMENT IMPLICATIONS

We believe that our approach might provide useful information for wildlife managers studying the dietary habits of animals in certain situations, as illustrated by two specific examples. Several rodents occur within the coconut agroecosystem of the Philippine Islands; the species composition varies with respect to island and location (Fiedler et al. 1982). Rat damage to coconuts can be so severe that dramatic increases in nut production (e.g., 2.5 times pretreatment levels, cost:benefit of 1/24 [Reidinger and Libay 1980]) can occur with effective rodent control programs. However, studies involving radiotelemetry (Sultan 1978) and marked baits (Reidinger and Libay 1980) have indicated that a relatively small portion of the rodents within the agroecosystem actually cause damage. By analyzing fatty acid composition of rodents collected at various strata within the coconut grove (e.g., ground level, palm trunks, tree fronds) in relation to rats fed diets with known levels of coconut, it might be possible to further describe the distribution of rats that are actually causing damage. Such information could lead to further refinements in placement

of baits, thereby improving cost-effectiveness and reducing the hazards to nontarget animals.

A second example concerns the use of fatty acid analyses to provide information on food-web associates in macadamia groves on the Hawaiian Islands. Again, rodents damage maturing nuts and are considered a major economic pest. As indicated by our findings in Experiment 2, in which mongoose were fed rats from macadamia groves, it might be possible to use analyses of fatty acid composition of body fat to better elucidate predator–prey relationships within a macadamia grove. Such information would be useful for assessing the potential hazard to predators, particularly the endangered Hawaiian hawk (*Buteo solitarius*), where rats are controlled by rodenticides, or in determining the source of pesticide exposure in contaminated specimens. We collected animals within a macadamia grove on Hawaii to analyze their adipose tissues for proportions of fatty acids as described in Experiments 1 and 2. Four cardinals (*Cardinalis cardinalis*) had proportions of fatty acids that were strongly associated (r^2_s = 0.85–0.99) with those in the oil of macadamia nuts, as did one barn owl (*Tyto alba*; $r^2 = 0.84$) and one spotted dove (*Streptopelia chinensis*; $r^2 = 0.74$). Compared with macadamia oil, however, a Polynesian rat sampled had a higher proportion of lauric acid (0 vs. 14.6%, respectively), myristic acid (1.2 vs. 5.4%, respectively), and palmitic acid (9.2 vs. 17.2%, respectively), but less palmitoleic acid (24.0 vs. 9.4%, respectively) and oleic acid (51.8 vs. 37.2%, respectively). Proportions of fatty acids in the adipose of this rat were not correlated with those of macadamia oil ($r^2 = 0.10$), consistent with the observation that this species occurs in macadamia orchards but, unlike *R. norvegicus* and *R. rattus*, seldom feeds on nuts (J. K. Crier, unpubl. data). We feel that the data for cardinals are particularly noteworthy because these birds are known to feed on macadamia nuts that are germinating or damaged during harvesting (D. P. F. Fellows, unpubl. data).

Although our techniques were designed explicitly to test for common, free fatty acids, modifications could be made to assay specific triglycerides or other fatty substances that might be unique to a given animal. As an example, sheep wool is known to contain unusual branched-chain fatty acids (Altman and Ditmer 1964:378–379, Hilditch and Williams 1964: 110), and Meriwether and Johnson (1980) have shown that considerable amounts ($\bar{x}$ = 43–80%) of the hair of certain prey are digested by coyotes (*Canis latrans*). Hence, the presence of selected branched-chain fatty acids in coyote body fat perhaps would indicate which animals actually preyed on sheep. Reliable information on the proportion and distribution of pest coyotes would be invaluable in developing strategies for their control.

LITERATURE CITED

ALTMAN, P. L., AND D. S. DITTMER. 1964. Biology data book. Fed. Assoc. Soc. Exp. Biol., Washington, D.C. 633pp.

BAILEY, B. J. R. 1977. Tables of the Bonferroni *t* statistic. J. Am. Stat. Assoc. 72:469–478.

BERNARDINI, M. P., ET AL. 1976. Effect of feeding odd-chain fatty acids on litter size and composition of rat tissues. Nutr. Rep. Int. 14:405–413.

ECKEY, E. W. 1954. Vegetable fats and oils. Reinhold Publ. Corp., New York, N.Y. 836pp.

FIEDLER, L. A., M. W. FALL, AND R. F. REIDINGER, JR. 1982. Development and evaluation of methods to reduce rat damage to coconut in the Philippines. Proc. Vertebr. Pest Conf. 10:73–79.

GAMES, P. A. 1971. Multiple comparisons of means. Am. Educ. Res. J. 8:531–565.

GARTON, G. A., T. P. HILDITCH, AND M. L. MEARA. 1952. The composition of the depot fats of a pig fed on a diet rich in whale oil. Biochem. J. 50:517–524.

HILDITCH, T. P., AND P. N. WILLIAMS. 1964. The chemical constitution of natural fats. 4th ed. John Wiley & Sons, London, U.K. 745pp.

KORSCHGEN, L. J. 1971. Procedures for food-habits analyses. Pages 223–250 *in* R. H. Giles, Jr., ed. Wildlife management techniques. The Wildl. Soc., Washington, D.C.

LINTON, M., AND P. S. GALLO, JR. 1975. The practical statistician. Simplified handbook of statistics. Brooks/Cole Publ. Co., Monterey, Calif. 384pp.

LONGENECKER, H. E. 1939*a*. Deposition and utilization of fatty acids. II. The nonpreferential utilization and slow replacement of depot fat consisting mainly of oleic and linoleic acids; and a fatty acid analysis of corn oil. J. Biol. Chem. 129:13–22.

———. 1939*b*. Deposition and utilization of fatty acids of low molecular weight; and a fatty acid analysis of coconut oil. J. Biol. Chem. 130:167–177.

MAC GRATH, W. S., JR., G. W. VANDER NOOT, R. L. GILBREATH, AND H. FISHER. 1968. Influence of environmental temperature and dietary fat on backfat composition of swine. J. Nutr. 96: 461–466.

MASORO, E. J. 1968. Physiological chemistry of lipids in mammals. W. B. Saunders Co., Philadelphia, Pa. 302pp.

MERIWETHER, D., AND M. K. JOHNSON. 1980. Mammalian prey digestibility by coyotes. J. Mammal. 61:774–775.

MORRISON, W. R., AND L. M. SMITH. 1964. Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride-methanol. J. Lipid Res. 5:600–608.

MOSBY, J. M., K. WODZICKI, AND F. B. SHORLAND. 1974. Fatty acid composition of the depot fats of the Polynesian rat, *Rattus exulans*, Tokelau Islands. N.Z. J. Zool. 1:67–70.

———, ———, AND H. R. THOMPSON. 1973. Food of the kimoa (*Rattus exulans*) in the Tokelau Islands and other habitats in the Pacific. N.Z. J. Sci. 16:799–810.

REIDINGER, R. F., JR., AND J. L. LIBAY. 1980. Crown-baiting in coconut trees with anticoagulant rodenticides to reduce rat damage. Pages 211–222 *in* Biotrop (Bogor, Indonesia) Spec. Publ. 12.

SMITH, A., A. K. LOUGH, AND C. R. A. EARL. 1978. Fatty acid composition of tissue lipids of rats given branched-chain fatty acids. Proc. Nutr. Soc. 37:76A (Abstr.).

SMITH-BARBARO, P., H. FISHER, M. R. QUINN, AND D. M. HEGSTED. 1980. The effect of varying polyunsaturated to saturated fat ratios on salt induced hypertension in rats. Nutr. Rep. Int. 22: 759–770.

———, M. R. QUINN, H. FISHER, AND D. M. HEGSTED. 1981. The effect of dietary fat and salt on blood pressure, renal and aortic prostaglandins. Nutr. Res. 1:277–287.

SULTAN, Z. M. 1978. Behavioral studies of rats in relation to coconut damage. M.S. Thesis, Univ. Philippines at Los Banos Coll., Laguna. 45pp.

WEISS, T. J. 1970. Food oils and their uses. The Avi Publ. Co., Inc., Westport, Conn. 224pp.

Received 12 December 1983.
Accepted 17 April 1984.

KIDNEY WEIGHT VARIATION AND THE KIDNEY FAT INDEX: AN EVALUATION[1]

DIRK VAN VUREN,[2] The Nature Conservancy, 735 State Street, Santa Barbara, CA 93101
BRUCE E. COBLENTZ, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331

J. WILDL. MANAGE. 49(1):177–179

Riney (1955) proposed the kidney fat index (KFI) as a measure of physical condition for animals. KFI is calculated by dividing the weight of a standardized portion of perirenal fat by kidney weight and then multiplying by 100. The method is fast and easy, and it has been adopted as an indicator of condition for a variety of ungulates (Dauphine 1975).

KFI is based on the assumption that amount of perirenal fat is a reliable indicator of total body fat. Kidney weight is included in the index to permit comparison of KFI's among animals of different size; the underlying assumption, that kidney weight is proportional to body weight, has not been substantiated. Moreover, kidney weight may fluctuate seasonally and not necessarily as a function of body weight (Batcheler and Clarke 1970, Dauphine 1975, Mitchell et al. 1976, Anderson 1981). Judgments about the effect of kidney weight variation on KFI are inconsistent; Mitchell et al. (1976) and Finger et al. (1981) considered the effect insignificant, whereas Batcheler and Clarke (1970) and Dauphine (1975) argued that variation in kidney weight substantially altered interseasonal comparisons of KFI.

We report data on kidney weights, body weights, and KFI from a population of feral sheep (*Ovis aries*) on Santa Cruz Island (SCI), California. Our purpose was to evaluate proportionality of kidney weight and body weight during 1 month, determine the effect of seasonal variation in kidney weight on KFI, and consider alternatives for improving validity of the index.

METHODS

Sheep were shot on SCI during November 1979 and March and June 1980. One kidney with associated perirenal fat was collected from each sheep and weighed fresh; fat was trimmed before weighing, following the method of Riney (1955). In addition, sheep were weighed in June. Linear regression was used to evaluate the relationship between kidney weight and body weight for all sheep shot in June ($N = 47$); a high linear correlation and a $\hat{Y}$-intercept of zero would indicate proportionality. Mean kidney weight and KFI of adult (>1 year) ewes only

[1] Oregon State Univ. Agric. Exp. Stn. Tech. Rep. No. 7056.

[2] Present address: Department of Systematics and Ecology, University of Kansas, Lawrence, KS 66045.