Estimated nutrient content of diets commonly fed to pet birds

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The owners of 135 pet birds were surveyed by questionnaire to determine their birds' weekly food consumption. The birds were divided into six food groups on the basis of the amounts of seeds, formulated products and human food they consumed. The formulated products and seeds were analysed for their nutrient content by two independent laboratories, the nutrient content of the human foods was obtained from a standard nutrition reference, and each bird's nutrient intake was estimated. The dietary content of individual nutrients was then compared with the estimated maintenance requirements for pet birds. Birds consuming less than approximately 50 per cent of their diets as formulated products had inadequate intakes of vitamins A and D_3, and calcium. Diets high in human food were low in protein, energy, vitamins and minerals. Diets high in seed were excessive in fat and deficient in vitamins A and D_3, and calcium.

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DESPITE the popularity of psittacine and passerine birds as pets, little is known about their nutritional requirements. There have been few studies of the feeding habits of the birds in the wild, and only recently have investigators begun to study the nutritional needs of the birds in captivity (Axelson 1986, Drepper and others 1988, Earle and Clarke 1991, Harrison 1991, Kamphues and Meyer 1991, Taylor 1991, Ullrey 1991, Ullrey and others 1991, Nott 1992, Nott and Taylor 1993a, b, Brue 1994, Kollias 1995, Wrobel and others 1995, Kamphues and others 1996, Rosskopf and Woerpel 1996, Roudybush 1997). Because of the lack of adequate data, the dietary recommendations for pet birds have been extrapolated from nutritional studies of domestic poultry (Snyder and Terry 1986, Quesenberry and others 1991, Taylor 1991, Underwood and others 1991, National Research Council 1994). However, the nutritional requirements of poultry have generally been calculated to minimise cost while maximising the production of meat and eggs, aims that do not apply to pet psittacine and passerine birds (Nott and Taylor 1993a, Rosskopf and Woerpel 1996). In addition, although pet birds are in many respects anatomically and physiologically similar to poultry, the differences in structure and function among Galliformes, Psittaciformes and Passeriformes are likely to result in differences in their nutritional needs (Roudybush 1986); differences in age, physiological and reproductive state, activity level and health will also affect their nutritional requirements (Lowenstine 1986, Grau and others 1989, Dorrestein and others 1991, La Bonde 1992, Nott 1992, Nott and Taylor 1993b, Wrobel and others 1995, Rabehl and others 1996).

Traditionally, seeds have been the staple diet of most psittacine and passerine pets (Bauck 1992, Nott and Taylor 1993a). However, seeds are lacking or are limited in their content of many nutrients, including vitamins A and D_3, several of the B vitamins, and several minerals (Pitts 1983, Dorrestein and others 1987, Rosskopf and Woerpel 1990, Harrison 1991, Ullrey and Allen 1991, Kamphues and others 1993, Rosskopf and Woerpel 1996, Smith and Roudybush 1997). Seeds also have a low ratio of calcium to phosphorus (Hochleithner 1989, Ullrey 1991, Underwood and others 1991). This excess of phosphorus relative to calcium is important in growing and egg-laying birds which require high concentrations of calcium for skeletal development and eggshell production (Quesenberry and others 1991, Nott 1992, Nott and Taylor 1993a). Finally, most seed-based diets are high in fat and may lead to obesity, particularly in sedentary birds (Rosskopf and Woerpel 1990, Hagen 1992, Murphy 1992, Macwhirter 1994).

Because of the nutrient deficiencies and excess fat of seed-based diets, several pelleted and extruded diets have been developed commercially for pet psittacine and passerine birds (Ullrey 1991, Roudybush 1996). These commercial diets have been formulated on the basis of the dietary requirements of poultry, and from the limited information available about the nutritional requirements of pet birds (Brue 1994), and they aim to provide the birds with a complete and optimally balanced diet which will reduce diseases associated with malnutrition (Rosskopf and Woerpel 1996); anecdotal reports suggest that the use of these formulated diets does reduce the prevalence of nutritionally based disease. However, no published studies have directly compared the ability of seed-based diets and commercially available formulated products to meet the nutritional requirements of pet birds. The aim of this study was to compare to what extent commercial diets, seeds, or a combination of commercial diets and seeds and/or human food satisfy the currently recommended nutritional requirements of pet psittacine and passerine birds.

MATERIALS AND METHODS

The owners of 135 pet birds were surveyed by questionnaire to determine their birds' food consumption during one week. The owners were identified sequentially between July 1996 and May 1997, as they brought their birds to the Animal Medical Center in New York City for a routine health examination. Only owners keeping their birds one to a cage were included in the survey.

The questionnaire was prepared according to established techniques used by human dieticians (Burke 1947, Young and others 1953, Beal 1967, Krause and Mahan 1984, Zeman and Ney 1988, Pennington 1994). It asked specific questions about the quantity of food consumed (in teaspoons, tablespoons, cups, or individual pieces or slices of foods such as potato chips, bread, cookies and nuts) and the preparation (cooked versus raw) of 106 named human foods, plus mixed bird seeds and nine commercially formulated products. The owners were asked to estimate visually the amount of food their birds consumed during the week, and not the amount of food they were offered. Information about the birds, including their bodyweight, environment and egg-laying history, was also obtained.

The percentages of seeds, human food and formulated product that each bird ingested was calculated from the amounts of the various foods their owners estimated they had consumed. Any named food other than seeds or a formulated product was defined as human food. The birds were then divided into six food groups, according to the amounts of seeds, human food and formulated products their diets were calculated to contain (Table 1). Groups 3 and 4 contained only nine and five birds, respectively.

TABLE 1: Numbers and species of pet birds fed the six food groups classified on the basis of the amounts of seeds, formulated products and table foods consumed

Group	Diet	Number of birds	Species
1	1-25 per cent formulated products	36	African grey, eclectus, Jardine, budgerigar, cockatiel, green-winged macaw, severe macaw, Amazon, grey-cheeked parakeet, Senegal, cockatoo, noble macaw, pionus, ring neck parakeet
2	25-50 per cent formulated products	18	Pionus, cockatoo, green-winged macaw, Amazon, blue and gold macaw, lovebird, Senegal, African grey, conure, cockatiel, budgerigar
3	50-75 per cent formulated products	9	Cockatoo, conure, African grey, green-winged macaw, cockatiel, pionus
4	75-100 per cent formulated products	5	Cockatiel, lory, Amazon, cockatoo
5	100 per cent seeds	14	Lovebird, budgerigar, cockatiel, finch
6	Seeds and human food only	53	Grey-cheeked parakeet, Hans macaw, scarlet macaw, African grey, Amazon, pionus, Quaker, budgerigar, lovebird, parrotlet, eclectus, cockatiel, green-winged macaw, conure, canary
	Total	135	

The results of the survey were analysed by a computer program (Animal Nutritionist 2.5; N² and Durango Software) and the estimated weekly intake of the individual nutrients was determined for each bird. Mixed seeds and nine popular formulated diets (Table 2) were analysed for their nutrient content by two independent laboratories. Fat-soluble vitamins were estimated by high pressure liquid chromatography (Anresco Laboratories) and a basic proximate analysis was made (Northeast Dairy Herd Association), and the data were added to the computer database. The nutrient content of the human foods not present in the database was obtained from a standard nutrition reference (Pennington 1994). The dietary content of the individual nutrients consumed by each bird was then compared (per kilocalorie of metabolisable energy) with the published, estimated, maintenance dietary requirements for pet psittacine and passerine birds (Brue 1994) (Table 3).

The data were analysed statistically by means of a software program (SAS 6.12; SAS Institute). Fisher's exact test was used to compare categorical variables across the food groups, and the Kruskal-Wallis test was used to compare ordinal variables. A value of $P \leq 0 \cdot 05$ was considered significant for these two tests. The Mann-Whitney test was used to make post hoc pairwise multiple comparisons and, in this case, a value of $P \leq 0 \cdot 01$ was considered significant, to decrease the possibility of chance significant comparisons.

TABLE 3: Predicted deficiencies or excesses of the major nutrients consumed by birds fed the different food groups, calculated by comparison with the recommended nutrient allowances given in Table 2

Group	Deficiency	Excess
1	Protein, energy, vitamin A, Vitamin D_3, calcium, phosphorus	Fat
2	Protein, energy, vitamin D_3 calcium phosphorus	Fat
3	Vitamin D_3, calcium	Fat, energy
4		Fat, energy
5	Protein, vitamin A, vitamin D_3 calcium, phosphorus	Fat, energy
6	Protein, energy, vitamin A, vitamin D_3, calcium	Fat

TABLE 2: Recommended nutrient allowances for pet bird diets*

Nutrient	Recommended allowance for maintenance As fed	Per kcal ME
Protein	12·0%	40 mg
Fat	4·0%	13 mg
ME	3000 kcal/kg	
Vitamin A	5000 iu/kg	1·67 iu
Vitamin D_3	1000 iu/kg	0·33 iu
Vitamin E	20·0 iu/kg	$6 \cdot 67 \times 10^{-3}$ iu
Calcium	0·50%	1·67 mg
Phosphorus total (approximately)	0·40%	1·33 mg

* Adapted with permission from Brue (1994)
ME Metabolisable energy

RESULTS

The mean age of 118 of the 135 birds was 4·9 years (median 4·0 years, range two months to 30 years). The mean bodyweight of the 135 birds was 265·6 g (median 124·0 g, range 15 to 1294 g). A total of 26 different genus or species groups were represented; groups for which there were five or more individuals included cockatiel (25), budgerigar (20), African grey parrot (18), Amazon parrot (14), cockatoo (10), macaw (10) and lovebird (seven). The sex of 78 birds had been determined by blood sexing or sexually dimorphic characteristics; 34 (43·6 per cent) were female and 44 (56·4 per cent) were male. Ninety-five of the 135 birds (70 per cent) were housed strictly indoors, 16 (12 per cent) went outdoors more than 10 times a year, and 24 (18 per cent) went outdoors less than 10 times a year. Only 11 of the birds (8·1 per cent) had laid eggs.

The birds were distributed unevenly among the food groups, with the largest numbers of birds consuming either less than 25 per cent formulated products or a combination of seeds and human food only (Table 1). When the median individual nutrient content of food groups was compared with published estimated maintenance dietary requirements, many discrepancies were found (Table 4). There were also significant differences in individual nutrients between the food groups, although the small size of groups 3 and 4 made statistical comparisons inappropriate. Eighty per cent of the birds consumed less crude protein than recommended for maintenance (Brue 1994), and only the birds in group 3 apparently consumed sufficient or more than their mainte-

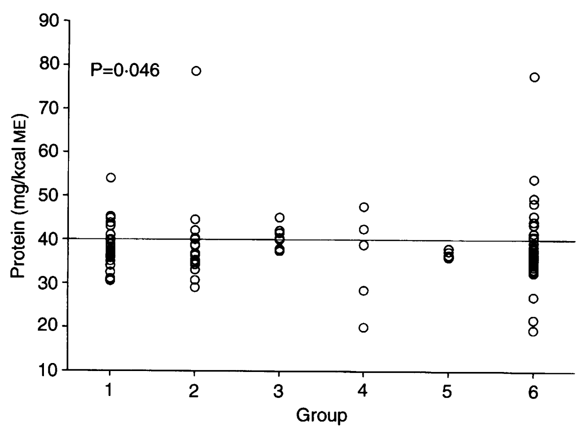

FIG 1: Scatter plot depicting dietary protein in each food group. Protein intake in an individual bird is represented by an open circle. The solid line marks the recommended allowance for maintenance for protein (Brue 1994). The P value refers to the results of a Kruskal-Wallis test. ME Metabolisable energy

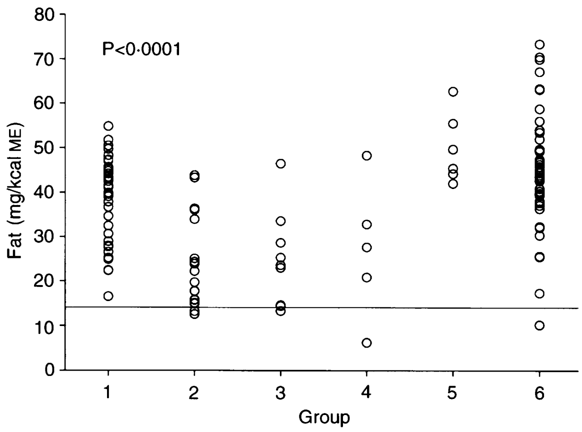

FIG 2: Scatter plot depicting dietary fat in each food group. Fat intake in an individual bird is represented by an open circle. The solid line marks the recommended allowance for maintenance for fat (Brue 1994). The P value refers to the results of a Kruskal-Wallis test. ME Metabolisable energy

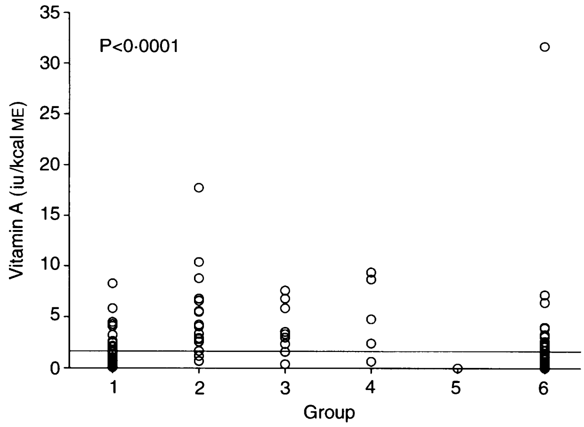

FIG 3: Scatter plot depicting dietary vitamin A in each food group. Vitamin A intake in an individual bird is represented by an open circle. The solid line marks the recommended allowance for maintenance for vitamin A (Brue 1994). The P value refers to the results of a Kruskal-Wallis test. ME Metabolisable energy

nance requirements. The median concentrations of protein varied significantly between the food groups (P=0·046) (Fig 1).

In contrast, only three of the birds consumed less fat than recommended for maintenance (Brue 1994); 104 of the birds (77·0 per cent) consumed at least twice their maintenance requirements, and 80 (59·2 per cent) consumed at least three times their maintenance requirements of fat. The birds in groups 2, 3 and 4 consumed approximately one-and-a-half times their maintenance recommendation, and the birds in groups 1 and 5 consumed approximately three times their maintenance recommendation. The median concentrations of fat also varied significantly between the food groups (P<0·0001) (Fig 2); the birds in group 5 consumed significantly higher concentrations of fat than the birds in the other food groups (P<0·01 for all comparisons), and the birds in groups 1 and 6 consumed significantly higher concentrations of fat than the birds in groups 2 and 3 (P<0·01).

Eighty of the birds (59·3 per cent) consumed fewer kilocalories of metabolisable energy per kilogram of diet (energy density) than recommended for maintenance (Brue 1994). The median energy density varied significantly between the groups (P=0·0001), with only the birds in groups 3, 4 and 5 consuming a diet with an adequate energy density. The birds in group 5 consumed a diet with a significantly higher energy density than the birds in the other groups (P<0·01 for all comparisons).

Seventy-eight of the birds (57·8 per cent) consumed less vitamin A than recommended for maintenance (Brue 1994). Two birds consumed more than 10 times their maintenance requirements by eating large amounts of beta-carotene-rich vegetables and fruits. Both the formulated products and human food were potential sources of preformed vitamin A or its precursors, but birds ingesting up to 25 per cent of their diets as formulated products (group 1) and birds ingesting human food plus seeds only (group 6) consumed less vitamin A from all sources than their maintenance recommendations.

The diets of the birds in group 5 contained negligible amounts of vitamin A, and the median concentrations of vitamin A varied significantly between the groups (P<0·0001) (Fig 3). The birds in group 5 consumed a diet with a significantly lower concentration of vitamin A than the birds in all the other food groups (P<0·0002 for all comparisons). Birds whose diets contained 25 to 50 per cent formulated products (group 2) consumed diets with significantly higher concentrations of vitamin A than birds whose diets contained large amounts of human food (groups 1 and 6, P<0·01 for both comparisons).

One hundred and thirty-three of the birds (98·5 per cent) consumed less vitamin D_3 than recommended for maintenance (Brue 1994), and none of them ingested potentially toxic quantities of the vitamin. The median dietary concentrations of vitamin D_3 varied significantly between the groups (P<0·0001) (Fig 4), with the birds ingesting large amounts of human food consuming the lowest dietary concentrations of vitamin D_3. Birds ingesting large amounts of human food or seeds (groups 1, 5 and 6) consumed significantly less vitamin D_3 than birds ingesting 1 to 50 per cent of their diets as formulated products (groups 2 and 3, P<0·01 for all comparisons).

Only 29 of the birds (21·4 per cent) consumed less vitamin E than recommended for maintenance (Brue 1994). The diets high in human food and seeds were lowest in vitamin E, and the diets high in formulated products were highest in vitamin E. The median dietary concentrations of vitamin E varied significantly between the groups (P<0·0001) (Fig 5). Birds ingesting large amounts of human food and seeds (groups 1, 5 and 6) consumed significantly lower levels of vitamin E than the birds in groups 2 and 3 (P<0·01 for all comparisons).

TABLE 4: Median estimated nutrient intake according to food group

Group	Protein (mg/kcal ME)	Fat (mg/kcal ME)	Energy density (kcal/kg diet)	Vitamin A (iu/kcal ME)	Vitamin D_3 (iu/kcal ME)	Vitamin E (iu/kcal ME)	Calcium (mg/kcal ME)	Phosphorus (mg/kcal ME)
1	36·5	39·7	2046·2	1·47	0·12	0·012	0·61	0·96
2	36·6	20·9	2093·5	3·70	0·12	0·020	0·94	1·00
3	40·0	23·5	3271·7	3·31	0·22	0·024	1·26	1·04
4	38·8	27·6	3463·0	4·78	0·17	0·006	0·97	0·82
5	36·4	49·6	4554·0	0	0·14	0·012	0·42	1·01
6	36·0	44·9	2549·3	0·88	0·12	0·009	0·38	0·94
P value	0·46	<0·0001	0·0001	<0·0001	<0·0001	<0·0001	<0·0001	0·0001

ME Metabolisable energy

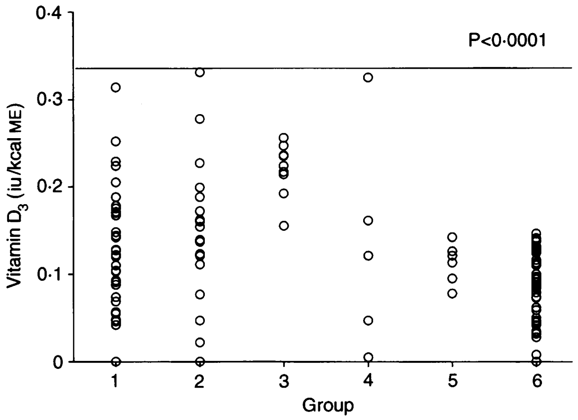

FIG 4: Scatter plot depicting dietary vitamin D_3 in each food group. Vitamin D_3 intake in an individual bird is represented by an open circle. The solid line marks the recommended allowance for maintenance for vitamin D_3 (Brue 1994). The P value refers to the results of a Kruskal-Wallis test. ME Metabolisable energy

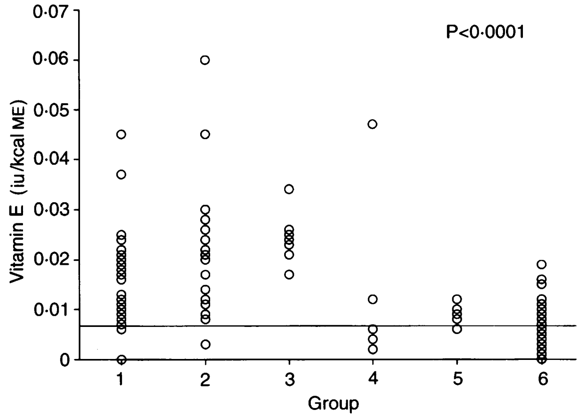

FIG 5: Scatter plot depicting dietary vitamin E in each food group. Vitamin E intake in an individual bird is represented by an open circle. The solid line marks the recommended allowance for maintenance for vitamin E (Brue 1994). The P value refers to the results of a Kruskal-Wallis test. ME Metabolisable energy

One hundred and twenty-nine of the birds (95·6 per cent) consumed diets containing less calcium than recommended for maintenance, and 125 (92·6 per cent) consumed diets with less phosphorus than recommended for maintenance (Brue 1994). Only the birds in group 3 consumed calcium and phosphorus at levels close to the maintenance recommendations. The median concentrations of both dietary calcium and dietary phosphorus varied significantly between the groups ($P<0·0001$) (Figs 6, 7). The birds in groups 2 and 3 consumed significantly higher levels of calcium than the birds in groups 1, 5 and 6 ($P<0·01$ for all comparisons). The birds in groups 2, 3 and 5 consumed significantly higher levels of phosphorus than the birds in group 6 ($P<0·01$ for all comparisons).

The dietary ratios of calcium:phosphorus also varied significantly between the food groups ($P=0·0001$). Only 12 of the birds (8·9 per cent) consumed a diet with a calcium: phosphorus ratio between 1·25:1 and 2:1, and 112 birds (83 per cent) consumed a diet with a calcium:phosphorus ratio of less than 1. Only birds consuming more than 75 per cent of their diets as a formulated products had dietary calcium:phosphorus ratios consistently between 1·25:1 and 2:1.

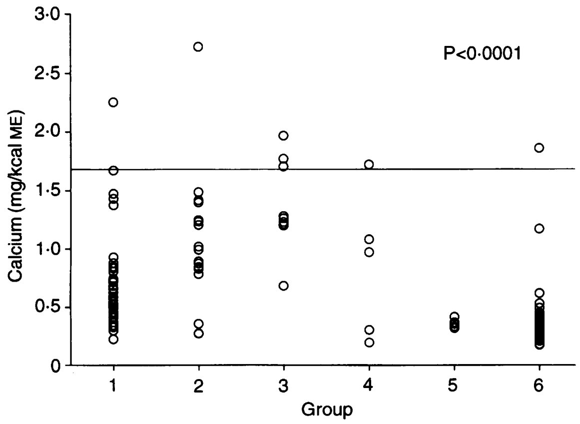

FIG 6: Scatter plot depicting dietary calcium in each food group. Calcium intake in an individual bird is represented by an open circle. The solid line marks the recommended allowance for maintenance for calcium (Brue 1994). The P value refers to the results of a Kruskal-Wallis test. ME Metabolisable energy

DISCUSSION

The results of this study suggest that the optimal diet for pet birds is high in a complete and balanced formulated product, with little human food and a limited amount of seed, supporting the manufacturers' claims that formulated products provide a more complete and balanced diet for birds than human food and seed. However, not all formulated products are necessarily of comparable quality. Diets high in human food lack many nutrients, or may not provide some nutrients (such as vitamin D) in an available form. Feeding a large proportion of human food apparently reduces the birds' overall intakes of dietary protein and available vitamins and minerals. The birds which consumed less than 50 per cent of their diets as formulated products were at risk of becoming deficient in several nutrients, including vitamins A and D_3, and calcium, even when usable precursor forms of these nutrients (such as beta-carotene) were included.

The birds consuming high-seed diets were likely to consume excess fat; the data also suggest that these diets are complete and balanced only if they are properly supplemented with calcium and vitamins A and D_3 In addition, although the total protein content of seeds may appear to be almost sufficient, they are generally deficient in several amino acids, including tryptophan, methionine, arginine and lysine (Macwhirter 1994). Furthermore, any deficiency may be made worse by the high fat content of most seeds, because birds on a high-fat, seed-based diet may consume less food to fulfill their caloric requirements than birds not eating much seed. As a result, their intakes of other nutrients may not meet their requirements.

It was not possible to measure the birds intake of vitamins and minerals from supplements, because although many

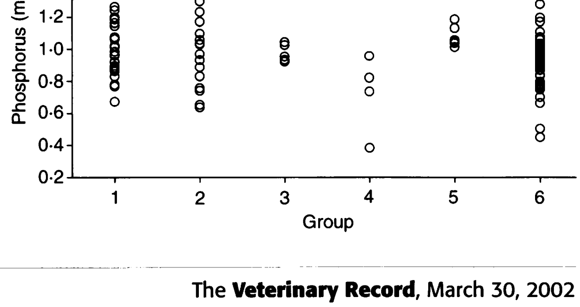

FIG 7: Scatter plot depicting dietary phosphorus in each food group. Phosphorus intake in an individual bird is represented by an open circle. The solid line marks the recommended allowance for maintenance for phosphorus (Brue 1994). The P value refers to the results of a Kruskal-Wallis test. ME Metabolisable energy

owners recorded feeding their birds vitamin and mineral supplements, most of them could not recall either the names of the supplements or the amounts consumed. Thus, although the potential for vitamin and mineral deficiencies may not have been as serious as the results suggest, the data strongly support the routine use of good quality supplements for pet birds consuming primarily seeds and human food. One exception may be vitamin E. Most of the birds appeared to consume adequate amounts of vitamin E, and clinical disease associated with vitamin E deficiency has rarely been reported in pet birds. However, the vitamin E requirements of pet birds may be greater than that established for poultry. Pet birds consuming high-fat diets could require more vitamin E, because vitamin E is an antioxidant that helps to prevent fat becoming rancid and fatty acids from breaking down (Macwhirter 1994). Deficiencies in other dietary antioxidants, for example selenium, may also affect pet birds' vitamin E requirements.

This study surveyed a large number of birds, and included independent, unbiased analyses of the formulated products and seeds, even though they may have been affected by sampling errors or variations in the manufacturing processes when single assays were used. The questionnaire used the 24-hour recall and food frequency techniques used in human studies, and although both have limitations, many human studies have established that reliable information can be obtained from them (Burke 1947, Young and others 1953, Beal 1967, Krause and Mahan 1984, Zeman and Ney 1988, Pennington 1994). For the 24-hour recall, subjects are asked to recall everything eaten within the previous 24 hours; its potential disadvantages include an inability to recall all the food items consumed, inaccurate estimations of portion size, and an atypical food intake during the 24-hour period studied. The food frequency questionnaire overcomes some of the weaknesses of the 24-hour recall by asking subjects to estimate how many times per day, per week, or per month they eat particular foods. Extending the period of study results in more representative data, and the use of a detailed list of possible foods consumed makes it less likely that any items will be overlooked (Krause and Mahan 1984). An obvious shortcoming of this study, inherent in both the 24-hour recall and food frequency techniques, was that the calculation of each bird's nutrient intake was based on the owner's visual estimation of their pet's food consumption during a week, rather than on controlled measurements. Although the owners were asked to recall what their birds actually ate, not what they were offered, this type of questioning has a potential for inaccuracy. Nevertheless, even the qualitative data gathered provide valuable information about what pet birds eat and the nutrient deficiencies they are most likely to suffer.

Several additional factors limit the conclusions that may safely be drawn from the data. First, the birds were distributed unevenly among the six groups, making statistical analyses inappropriate in some cases; group 3 contained only nine birds, and group 4 contained only five of the 135 birds. Secondly, the analyses and references (Pennington 1994) used to estimate the birds' nutrient intakes lacked data for many nutrients, and it was impossible either to estimate the intake of these nutrients, or to make recommendations regarding them. Finally, the actual nutrient requirements of psittacine and passerine birds are not known (Drepper and others 1988, Earle and Clarke 1991, Harrison 1991, Kamphues and Meyer 1991, Ullrey and others 1991, Nott and Taylor 1993a, Brue 1994, Kollias 1995, Wrobel and others 1995, Kamphues and others 1996, Rosskopf and Woerpel 1996, Roudybush 1997). Although there are likely to be differences between the dietary requirements of psittacine and passerine birds and between different species, too little is known about them to make order- or species-specific nutrient recommendations. The published nutritional requirements for psittacine and passerine birds bring them together under the broader grouping 'companion birds' (Brue 1994). The recommended intakes of specific nutrients for these companion species have been extrapolated from poultry, and the requirements for pet birds undoubtedly vary because of species differences and differences in body structure and function (Lowenstine 1986, Roudybush 1986, Snyder and Terry 1986, Dorrestein and others 1991, Quesenberry and others 1991, Underwood and others 1991, La Bonde 1992, National Research Council 1994, Rabehl and others 1996). Until order- and species-specific nutrient requirements have been established, nutritional recommendations can only be made for 'companion birds' as a whole.

Research is needed to improve the diets fed to companion birds. The nutrient requirements of psittacine and passerine birds need to be established, together with the differences due to variations in age, sex, physiological state and species. More complete data are needed on the nutrient content of the foods birds consume, especially formulated products. Finally, long-term studies of the health and longevity of individual birds fed different diets are needed to establish potential correlations between diet and disease.

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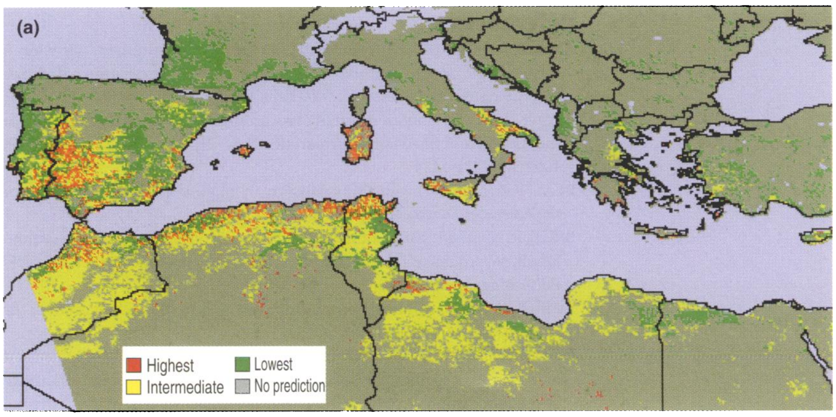
Correction

Prediction of areas around the Mediterranean at risk of bluetongue by modelling the distribution of its vector using satellite imaging (*VR*, November 24, 2001, pp 639-643)

As a result of a production error, the colour-coded key to the map Fig 1a on p 641 of this article, indicating the abundance of *Culicoides imicola* around the Mediterranean, was wrongly labelled. Red should indicate highest, and yellow intermediate. The map should have appeared as follows:



The error is regretted.