MICRONESIAN KINGFISHER SPECIES SURVIVAL PLAN

HUSBANDRY MANUAL

Halcyon cinnamomina cinnamomina

First Edition

1997

Edited by

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CHAPTER 9

Diets for **MICRONESIAN KINGFISHER *Halcyon c. cinnamomina***

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Cite Reference:

Crissey, S. and B. Toddes (1997) Diets for Micronesian kingfisher *Halcycon c. cinnamomina*. In: *Micronesian Kingfisher Species Survival Plan Husbandry Manual*. B. Bahner, A. Baltz and E. Diebold Eds. American Association of Zoos and Aquariums

Due to the rapid decline of the Micronesian kingfisher on Guam, little information on their nutritional needs was gathered prior to the establishment of a captive population. Although it is essential to develop appropriate dietary guidelines which meet the nutritional needs of the Micronesian kingfisher, additional information on their natural feeding behavior can no longer be obtained now that the species is extinct in the wild. Therefore, the dietary guidelines presented here are based on a combination of sources: 1) published accounts of the feeding ecology of this species, 2) food preferences in captivity, 3) availability of food items in captivity and 4) known nutrient requirements of other avian species. Recommendations given here are subject to revision as we learn more about the nutritional needs and food preferences of these birds.

Part I: BACKGROUND

Feeding Ecology Data

Micronesian kingfishers have been observed to feed primarily on grasshoppers, skinks, annelids, insects, hermit crabs, other small crustaceans (Beck and Savidge 1990), and occasionally small mammals and young birds (Shelton 1986). During a 1985 nest survey, Sam Marshall observed that several species of skinks, green anoles and

geckos made up the main part of the diet of one pair which was raising chicks, although they also ate a variety of insects (Marshall personal communication with A. Baltz). Wild prey items were not analyzed for nutrient content nor is there information on feeding frequency, feeding preferences or seasonality of food sources. Some information may become available on the feeding ecology of a related kingfisher species if proposed field studies are funded.

Food Preference And Diet Intake

In contrast to the variety of food available in the wild, the variety items offered to animals in captivity are much more limited. Because of this limitation, captive animals cannot be relied upon to make nutritionally optimal choices of food. Among mammals it is often the case that poor nutritional choices are made in captivity (Oftedal and Allen 1996). There is no evidence that birds will behave differently, in this respect, than mammals. Thus, it is important to offer foods, which compliment each other nutritionally and assure an appropriate nutrient intake. Surveys of North American zoos holding Micronesian kingfishers were conducted by the nutrition advisors to the SSP in 1993, 1994 and 1996 to determine the types of food offered, food preferences, food consumption and nutrient content of the diet.

The first two nutrition surveys ('93,'94) demonstrated that many different food items were offered to captive kingfishers (Table 6). The '94 and '96 surveys allowed an evaluation of the intake of each food item offered in the diet (Table 7). In addition, the '94 survey identified nutrients that were potentially inadequate in the kingfisher diet and the '96 survey allowed an accurate quantification of the diet's nutrient density (Appendix K, Table 8)

TABLE 6: Micronesian Kingfisher Nutrition Survey results 1993, 1994. Participation, birds represented and number of items offered.

Year	Number of Institutions Surveyed	Number of Institutions Responding	Number of Birds Represented	Total Population	Number of Different Items Offered
1993	19	17	40	56	16
1994	14	13	42	51	12
1996	6	6	18	52	10

TABLE 7: Micronesian kingfisher Nutrition Survey 1994, 1996 significant intake results

Items offered	1994		1996	
	Intake rating	Offered by (# inst)	Intake rating	Offered by (# inst)
Mice (pink or fuzzy)	Good (>80% of offered)	13	Good (76.7 – 100 % of offered)	5
Insects (mealworms, crickets, waxworms)	Good (>80% of offered)	13	Good (>80% of offered)	6
Green anoles	Excellent (100%)	2	Excellent (100% of offered)	4
Complete foods (Dog food, Bird of Prey)	Poor (<40% of offered)	5	Poor (<40% of offered)	4
Vitamin and Mineral supplements	Unquantifiable	NA	Not surveyed	NA

Birds housed singly consumed about 12 g of food per bird/per day while pairs consumed between 20 and 38 g per day. Of major importance is the frequency of dietary items consumed by the kingfishers between the 1994 and

1996 surveys, indicating that the birds have a strong preference for whole food items (e.g., anoles, mice, insects, etc.) compared to the prepared commercial diets that were offered (e.g., dry dog food, Bird of Prey). The nutrient density of whole prey is highly variable (Appendix K), therefore, the nutrition advisors are very concerned about the actual nutrient intake of the Micronesian kingfisher.

A computer analysis of the 1994 survey intake results, using common data base values, showed that some of the diet items were inadequate in nutrients. Diets appeared high in energy, fat, protein, vitamin A and iron but low in vitamin E with some potential problems with the calcium to phosphorous ratio.

In order to more accurately determine the nutrient intake of the kingfishers, a more in-depth survey and intake study was performed in 1996. Food item consumption data were collected from six institutions. Each institution provided detailed diet consumption data for the birds in the institution's collection. The data collected included food items offered, remaining and consumed for 10 days quantified by weight. Each institution also submitted an appropriate number of food samples for chemical evaluation. Chemical evaluation was performed to ensure valid data existed for dry matter, protein, fat, energy, vitamins A, D, and E, carotenoids and minerals. Results from the analyses were entered in a nutritional diet assessment database and used to compute the nutrient content of the diet consumed (Table 8).

All Micronesian kingfishers received either fuzzy or pink mice. These comprised the largest contribution of total quantity in the diet with insects, as a group, following. The green anoles (*Anolis carolinensis*) that were offered were consumed at nearly 100%, suggesting that if they were offered at higher levels in the diet, the contribution to the diet may have been higher as well (Table 7). As expected, nutrient content of these items proved somewhat variable (Appendix K).

TABLE 8: Average dry matter, protein and kcal density of the diet consumed by Micronesian kingfishers (1996 survey results, computer analysis N2 computing).

Nutrient	**Range**
% Dry Matter	24 – 33%
% Protein (DM)	55 - 56%
Kcal /g (DM)	5.5 – 6.1

Protein

The protein content of the foods offered to the kingfishers ranged from 30–68% DM (Appendix K). The actual level of protein in the insects, after correction for the nitrogen contained in the chitin of the exoskeleton, will fall by approximately 10% (Allen 1989). Even after the insect portion of the diet is corrected for chitin, the level of protein in the diet will significantly exceed the target level of protein for the diet (Appendix L). This is not unusual in the diets of captive carnivores when the majority or entire diet is composed of foods derived from animal sources. Although we do not have an amino acid profile on the foods used in the kingfisher diet (except cat food), proteins from animal sources with known profiles contain a wide array of essential amino acids. Because the level of protein in the Micronesian kingfisher diet exceeds the requirements of both cats and poultry (NRC 1978, 1994), we believe this diet will meet the kingfisher's protein requirement.

Fats and Fatty Acids

Fat is important in the diet for energy, as a carrier for the fat soluble vitamins (A, D, E and K) and to supply fatty acids. The fatty acids, linoleic acid (18:2, n-6) and α-linolenic acid (18:3, n-3), are essential in the diet of birds because they cannot be produced endogenously. Although deficiencies of these fatty acids are not common, a deficiency of linoleic acid can result in decreased resistance to disease, impaired sperm production, and problems with embryo development. One percent linoleic acid in the diet, however, will alleviate these problems in poultry (NRC 1994). The dietary items used for the kingfisher (Appendix K) appear to contain enough fat for energy to support growth, reproduction and maintenance. The analysis of pink mice shows that, in general, mice are excellent sources of these fatty acids (Crissey et al., submitted).

Vitamins/Minerals

While each nutrient is important to the health and well-being of the animal, in this section we consider only those which appear to be related to the problems observed in the captive Micronesian kingfisher population as reported by the SSP participants.

Vitamin A

Vitamin A deficiencies in domestic poultry may lead to decreased growth, loss of appetite, weakness, staggering and ruffled feathers. In addition, susceptibility to infections may increase while egg production and hatchability can be reduced. Abnormal eye exudate and drying of the eyes have also been found (Machlin, 1984). Maximum tolerances for vitamin A in poultry are 10 to 30 times the requirement (NRC, 1994). Since Micronesian kingfishers naturally consume animal matter which may contain high levels of vitamin A, their tolerances may be slightly higher than that of poultry, although actual tolerance levels are unknown. Vitamin A levels in pink mice and green anoles exceeded domestic poultry requirements for growth by 9-18 times and 6-11 times, respectively, whereas insects provide less than 73% of the vitamin A level required by poultry (see Appendix K).

Vitamin E

The effects of Vitamin E can be related to the levels of other nutrients in the diet. When a diet high in polyunsaturated fatty acids is deficient in vitamin E, encephalomalacia (hemorrhage and necrosis of the cerebellum) occurs in domestic poultry. When selenium and vitamin E are both deficient, exudative diathesis (capillary permeability resulting in subcutaneous edema) occurs. Degeneration of the testis epithelium has also been reported as a symptom of vitamin E deficiency in chickens (Machlin 1984).

Vitamin E tolerance is 100 times the requirement for domestic poultry (NRC 1994). It should be noted that high dietary concentrations of vitamin A have been shown to depress vitamin E status in a number of mammals as well as chickens (Frigg & Broz 1984) indicating that nutrient interactions may significantly influence nutritional status. The mechanisms, while unknown, may be related to the fact that the antioxidant properties of vitamin E protect vitamin A from oxidation. Extrapolating to species other than domestic poultry may be difficult since there are differences in the response to vitamin E deficiency even among domestic poultry species (Machlin 1984). Vitamin E appeared moderate to low in adult mice, pink mice and insects and almost undetectable to moderate in green anoles

(Appendix K). Green anoles stored for >6 months by the standard method (Appendix M) may lead to some degradation of Vitamin E although this was not tested directly.

Carotenoids

Although it was once thought that carotenoids served only as a precursor to vitamin A, more recent studies suggest that carotenoids, particularly β-carotene, may influence immunity and reproduction (Chew 1987, Simpson and Chichester 1981). Carotenoids also play a well-known role in bird pigmentation (Brush 1981). In domestic poultry, lutein, zeaxanthin and some β-carotene contribute to the yellow color of skin and egg yolk (NRC 1994). In the laying hen, 50% of the body's zeaxanthin is found in the ovary (NRC 1994). In the diet of the Micronesian kingfisher, carotenoids including Lutein + zeaxanthin, β-cryptoxanthin, and β-carotene, were much greater in green anoles compared to the other food items (Appendix K). Carotenoids were undetectable in pink mice. It should be noted that carotenoids are naturally present in some crustaceans (Simpson et al. 1981) and possibly other lizards. Although carotenoid levels in diets consumed in the wild remain unknown, these types of prey were reportedly consumed by wild kingfishers (Beck and Savidge 1990). While the role of carotenoids in the diet of the Micronesian kingfisher is unknown at this time, the implications cannot be overlooked.

Vitamin D, Calcium and Phosphorus

Vitamin D, calcium (Ca) and phosphorus (P) are nutrients with inter-related functions (Machlin 1984). In general, the function of vitamin D is to elevate plasma calcium and phosphorus to a level that will support normal mineralization of bone as well as other body functions (McDowell 1989). The deficiency symptoms of Ca and vitamin D for domestic poultry include: thin-shelled eggs, lowered egg production, decreased hatchability, and bone deformities. It is believed that birds better utilize vitamin D in the form of vitamin D3 (cholecalciferol; NRC 1994) which primarily originates from animal sources. Maximum tolerance for vitamin D in poultry is 4-10 times the requirement (NRC 1994), with excessive levels of vitamin D and Ca can causing calcification of soft tissues at end stages.

Insects appeared low in calcium regardless of reported insect supplementation (Appendix K). The Ca content for vertebrates appeared adequate, however, an inverse ratio of Ca:P was found in most of the samples analyzed as part of the 1996 survey. These Ca data appeared similar to the published values for the calcium content of feeder rodents but the levels of P were not reported (Dierenfeld *et al.* 1995). The ratio of Ca:P ideally should be 1:1 for adult animals at maintenance. The mean inverse Ca:P ratios of vertebrates were unexpected. This highlights the fact that these food items are biological and fluctuation is common. It is possible that other samples would show ratios consistently nearer 1:1 or above. Regardless, these values point out the importance of analyzing nutrients in the diet and formulating diets based on real analyses. These data may indicate a relationship between the soft-shelled eggs reported in the population and dietary Ca. Large amounts of phosphorus in relation to calcium have been reported to cause bone loss in some animal studies (LaFamme *et al.* 1972, Krook 1968). While the actual Ca content of the vertebrates and manufactured diets was at least adequate compared to domestic poultry requirements (with one analysis for green anoles being very high) if the Ca:P ratio is not at least 1:1, Ca metabolism problems may occur. This would especially hold true for females with multiple clutches or thin shelled eggs.

Vitamin D analysis showed only trace levels (<1 IU/g dry matter basis) in all food items except large mealworms and green anoles which were considerably higher. However, the minimum detectable level for the analysis is higher than the target nutrient levels. Therefore, it is not known whether all food items are adequate in vitamin D. What is evident is that green anoles contain adequate and even high vitamin D. The levels reported for mighty mealworms are based on just one sample so, while high, this one data point is not strong. It must be remembered that the chemical analysis for vitamin D is difficult and results can be variable.

Iron

Iron deficiency causes anemia as well as reduced hatchability of eggs. Birds lose iron through egg and some feather production, therefore, adequate levels of iron are important to maintain in egg-laying birds. The maximum tolerable levels of iron for domestic poultry are 1000 mg/kg (NRC 1980). There have been reports of excessive iron storage in the livers of some Micronesian kingfishers (Chapter 8). The analyzed values for Micronesian kingfisher foods average 150 mg/kg DM (with some meat-based bird diet samples being higher), which should meet requirements without being excessive. Water is another potential source of iron and this should be quantified if iron accumulation continues to be a problem.

Part II: **DIET RECOMMENDATIONS**

Diet Formulation

It is possible to formulate appropriate diets for Micronesian kingfishers using the National Research Council (NRC) guidelines along with historical reports on natural Micronesian kingfisher feeding and nutrient content of food items available in zoos. A range of values for nutrient levels are provided based on NRC requirements for both domestic fowl (NRC 1994) and carnivorous mammals (NRC 1978, NRC 1982) given that these are carnivorous/ insectivorous birds (Appendix L).

Because of individual preferences, weight, exercise, physical condition, environment, and psychological/social considerations as well as food availability; some flexibility is needed when formulating diets for Micronesian kingfishers. Therefore, guidelines for nutrient content and food categories are provided that allow flexibility in diet formulation while assuring that an appropriate nutritious diet is consumed. If consumed in its entirety, the recommended diet should contain the nutrients presented in Appendix L. Levels are expressed in quantity per unit of diet, on a dry matter basis. These should be considered target nutrient levels until more specific nutrient levels are established (Table 9 provides appropriate quantities).

Schedule of Feeding

Care must be taken to schedule feeding to synchronize with the animal's habits, not the care-giver's preferred routine. The quantity fed at any feeding time should correspond to the feeding activity. For example, the morning (or activity period) feed should consist of more food than the afternoon (less active period) feed. The current recommendation is to feed birds twice per day (Chapter 5). It may not be appropriate to leave all food items out at night anticipating feeding in the early morning hours, because of spoilage and nutrient losses as well as pest infestation or competition. It would be preferable to provide fresh food in those early morning hours when the birds begin feeding. Water should be provided at all times (Chapter 5).

Recommended Diet

In zoos, the diet items offered are often restricted to items available commercially. The items most commonly offered and accepted are mice of different age/size categories, insects, green anoles and some commercially available manufactured products (Table 7). The specific diet recommendations are based on these items as well as the nutritional analysis of the prey items (Table 9 and Appendix K). These recommendations should support the target nutrient values with respect to protein, fat and energy (Appendix L).

In the past there have been supply problems with green anoles since they are wild-caught. For this reason green anoles are often purchased in bulk when available and there may be potential nutrient degradation problems resulting with long term storage. Concerns have also been raised regarding the potential for parasite transmission from wild caught green anoles. These concerns have been addressed with a storage protocol for green anoles obtained in bulk that will minimize the risk of parasite transferal. Anoles are frozen using a standard method (Appendix M) and to date, there have been no reports of parasite transmission.

Table 9: Recommended Diet for Micronesian Kingfishers

Food item	**% (as fed) by weight**	**range to feed (in grams) per bird**	**per pair***	**Expected consumption (single birds)****
Pink mice	25-50%	3-6	10-20	77-100%
Green anoles[1]	25-50%	3-6	10-20	100%
Insects[2]	20-30%	2.4-3.6	8-12	>80%
Dry cat food[3]	0-20%	0-2.4	0-8	na[5]
Supplements	see below[4]			
Total Diet		**12 g**	**40 g**	

*For pairs with chicks a portion of the offered pink mice and green anoles should be chopped and total diet amount should be increased by 25% per chick in nest. Care should be taken to keep the ratio of each dietary item offered consistent with the table.

**Actual consumption may differ depending on caloric density of the diet and energy needs of the individual. Foods selected can be based on availability and seasonality.

[1] During courtship, incubation and chick rearing feed green anoles at upper level (50%). The combined quantity of pink mice and green anoles should not exceed 75% of the diet.

[2]Insects (crickets, mealworms, mighty mealworms or waxworms) should be fed a commercial cricket diet which contains at least 8% Ca to improve the Ca:P ratio. Care should be taken to keep crickets at 80 ^{o} F in order to encourage adequate diet consumption (Ward and Crissey 1997). Insects should comprise at least 20% of the diet.

[3]Cat food should be offered, especially during chick rearing and fledging (see text) . It can be soaked or presented in such a way as to encourage consumption. The type of cat food should contain a nutritional content of 30% protein, 8% fat (see Appendix K).

[4]Calcium: For birds consuming 12 grams of a combination of mice, crickets and green anoles; supplement crickets with 0.36 to 0.6 grams of an insect supplement which contains 8% Ca.
Vitamin E: 0.6 mg of vitamin E per day.

[5]Consumption of manufactured diets must be monitored.

Prey Items (mice, lizards and insects)

The intake data collected on this species strongly suggests that these birds will readily accept almost any whole prey item offered. Since prey items are biological organisms, there will be fluctuations in nutrient content between individual items. It appears to be possible to alter the nutrient content of some prey items by manipulating what is fed (e.g., insects, Allen 1989). At this time we are not able to correct all nutrient imbalances of prey through their diets alone. For this reason and because reproductive problems as well as egg quality problems have been recorded for this species, we recommend the inclusion of a manufactured diet and nutrient supplementation of the basic whole prey diet (see below and Table 9).

Not addressed in detail in this chapter is the behavioral component of the diet. It has been suggested that courtship behavior may be stimulated by the presence of whole prey items (Chapter 6). If this proves to be true, seasonal variation in diet composition may be appropriate. Live prey items (e.g., crickets) may also stimulate natural feeding behaviors. Because the goal of captive breeding is the eventual reintroduction of this species to their natural habitat, efforts to stimulate natural feeding behavior are important to consider along with the nutritional aspects of the diet.

Manufactured Diets

A commercial diet which is readily accepted by adult kingfishers has not been identified. If birds are exposed to a manufactured diet at a very early age, however, they may be more inclined to consume these items. Offering items such as moistened dry cat food or a nutritionally consistent meat-based bird diet is recommended at a 20% level, as fed. Please note that the meat-based bird diet analyzed in the study was not nutritionally consistent, particularly for vitamin A (which can be toxic) as well as fat and energy. In fact, fat content was double in some samples compared with others of the same product. These fluctuations were even more dramatic in some cases than was found in the whole prey items. Thus the nutrient consistency of any meat-based bird diet should be monitored. Always compare the label of commercial diets being considered to the nutrient specifications recommended in Appendix L. Care should be taken to monitor consumption of all manufactured diet items and not to assume that the diet is nutritionally complete simply because an acceptable diet is offered.

As development of a more acceptable manufactured diet continues, this may play an increasingly important role in the total diet. In an attempt to develop an acceptable manufactured diet, a 15-week pilot study (18 February - 29 May 1997) was conducted using 1.1 Micronesian kingfishers at the Philadelphia Zoo. The goal of the study was to determine the acceptability of an artificial gelatin diet by the birds and the feasibility of feeding this diet in combination with whole prey items. The results of this study offer some promise that a manufactured diet can be successfully fed to Micronesian kingfishers and therefore allow better control over the supplementation of nutrients deficient or lacking in the whole prey items.

Supplements

Because of potential nutritional inadequacies in the whole prey diet and the marginal acceptance of nutritionally complete commercial diets, supplementation is advisable. The current recommendation is supplementation of Ca and Vitamin E.

Calcium

Calcium supplementation by feeding insects (both mealworms and crickets) a commercial insect diet that contains at least 8% Ca on a dry matter basis, is recommended. Several appropriate products are currently marketed; read the labels to ensure that the correct product is chosen. Feed the diet for 3 days while the insects are held at 80°F and supply water as a source of moisture. Please note that insects kept on an 8% Ca diet will die after approximately 5 days due to accumulation of feed in the gastrointestinal tract, i.e., calcification of the insect. The insects can also be dusted with this same diet to increase Ca levels even more although the amount ingested by the bird will be highly variable with this method and dusting should not be relied upon as the only source of calcium supplementation. In addition to ensuring adequate Ca intake, supplementation will help to keep the Ca:P ratio of the total diet between the target of 1:1 and 2:1.

Use of the recommended diet (Table 9) will assure that proper nutrient levels and ratios are maintained. When there are deviations from the recommended diet items, care must be taken to ensure proper nutrient levels. Adequate Ca intake can be maintained by determining the Ca and P content of the prey items fed and calculating the quantity of insect diet needed to provide at least 0.7 % but not over 2.5% Ca dry matter in the diet. If needed, the other food items can be dusted using this same insect diet. Please note that the use of supplements must be controlled because too little or too much can cause problems. To determine how much supplemental insect diet to add to the whole diet, the Ca and P contents of all ingredients must be calculated; the nutrition advisors can be contacted for help with these calculations.

Vitamin E

Because vitamin E tolerance is high and the levels present in the recommended diet are low, supplemental vitamin E can be provided at the target levels without adverse effects. Vitamin E is available in both a dry powder form and a liquid oil suspension. The appropriate amount of supplement can either be dusted over the diet (with dry) or injected into a food item (oil suspension). When using the recommended diet (Table 9) a daily supplement of 0.6 mg of vitamin E per 12 gram diet will be sufficient. Since vitamin E is a fat-soluble vitamin which can be stored in the body, it can be supplemented periodically at a more practical level. For example the vitamin E supplementation can be given twice per week at about 2 mg. Care should be taken to determine the potency of the supplement administered to ensure dosage is correct.

Diet Reassessment and Adjustment

Because these diet recommendations are based upon preliminary research, continued reassessment of the adequacy and acceptance of the diet will be necessary. In addition, if one food item is substituted for another or if food intake changes, reassessment of the entire diet may also be necessary. Other factors potentially affecting the diet are individual food preferences and weight fluctuations. Weight problems are not uncommon among captive

Micronesian kingfishers; particularly the tendency towards obesity (Chapters 4 and 8). Diets may also be adjusted seasonally; for example green anoles can be increased to 50% of the diet combined with 10% crickets and 40% pink mice, during the breeding season. When green anoles are scarce or it is not breeding season, the proportion of lizards in the diet can be reduced. It is advisable, however, to include green anoles in the diet at least weekly throughout the year because of the carotenoid and vitamin D content.

Any diet changes should begin slowly, starting with a 5% change in the amount of food offered. Increasing or decreasing the calorically dense food can aid in maintaining appropriate body weights. For example, substituting the same quantity by weight of crickets for mealworms will provide the animals with less energy (Appendix K). It is important to monitor weights when any diet alteration is made, although weighing frequency should not exceed once per month (Chapter 4). Please take care not to catch and weigh birds that are reproductively active. Additionally, weight records will provide an indication of possible seasonal weight fluctuations which would be 'normal' for a particular bird. Careful record keeping with respect to any diet alterations is crucial for determining the best captive diet for the Micronesian kingfisher.

Appendix K. Ranges of nutrients for items offered to Micronesian kingfishers as chemically analyzed. Averages are provided with ranges when these differ substantially from the mean.

NUTRIENT*	Pink Mice	Anolis Lizards	Juvenile Mice	Crickets	Meal-worms	Large M. worm	Meat Bird Diet	Cat Food
	n=5**	n=3	n=1	n=5	n=4	n=2	n=3	n=1
dry matter %	23 19-27	27 25-29	27 26-27	35 31-41	39 37-41	38	36 35-38	93
crude protein %	53 47-61	66 65-68	54 52-56	63 60-66	50 47-52	46	48 44-50	30
fat %	29 15-38	9 8-10	23 13-33	12 11-14	31 27-36	37	22 15-31	8
Gross energy Kcal/g	6 5.3-6.3	4.8 4.7-4.8	6 5-6	5.5 5.5-5.6	6 6.1-6.4	6.4	5 4.3-6.2	5
Vitamin A IU/g	17 13-28	13 9-17	130 9-257	0.93 0.9-1.1	0.37 0.3-0.4	nd	33 3-96	10
Vitamin E[1] IU/Kg	7 6-10	9 0-18	6 4-7	25 5-76	16 9-24	0.5 0.3-0.7	23 17-30	137
Vitamin D IU/g	nd	6.5 3.8-8.5	nd	nd	nd	4.7	-	-
Leut+Zeax[2] µg/100g	nd	2635 1882-3299	nd	33 5-138	39 14-74	5.6 5.5-5.7	81 76-96	216
β-Crypt[3] µg/100g	nd	434 362-498	nd	5 3-8	9 4-14	1.8	15 13-18	0.14
α-carotene µg/100g	nd	nd	nd	2	47 3-117	18 9-26	7 3-15	4.3
β-carotene µg/100g	nd	2 1.6-2.4	nd	2 0.07-7.5	0.9 0.08-1.9	0.61 0.23-1	2 1.3-2.3	0.14
Ca %	1.4 1.2-1.6	2.3 2.3-4.7	1.1 0.82-2.3	0.3 0.05-0.44	0.1 0.06-0.16	0.045 0.04-0.05	1 0.7-1.1	1.2
P %	1.7 1.5-1.8	2.6 2.6-2.8	1.8 1.7-2	1 0.9-1.0	0.9 0.84-0.91	0.66 0.58-0.74	1.1 0.9-1.1	0.88 0.85-0.92[4]
Mg %	0.1 0.1-0.13	0.14 0.13-0.18	0.1 0.09-1.3	0.13 0.1-0.15	2092 1282-2487	0.13 0.13-0.14	0.09 0.06-0.1	0.1[4]
K %	1.1 1-1.5	1.0 1-1.2	1.1 1-1.2	1.2 1.2-1.3	0.81 0.67-0.92	0.6 0.59-0.62	0.9 0.6-1.2	0.95 0.89-1[4]
Na %	0.6 0.5-0.9	0.5	0.5 0.4-0.5	0.4	0.13 0.11-0.15	1.4 0.12-1.5	0.4 0.3-0.4	0.23 0.22-0.25[4]
Fe ppm	182 126-258	134 129-151	197 133-319	64 54-68	58 45-66	49 39-58	244 7-507	281 278-283[4]
Zn ppm	60 - 92	24 – 36	70 – 93	75 - 191	142 130-167	90 88-92	94 90-96	208 197-218[4]

Cu ppm	1 – 21	1 – 2	12 - 15	23 21-23	17 14-20	16 13-18	10 8-13	23 22-25[4]
Mn ppm	nd nd-5	3 2-5	10 2-17	40 34-42	12 8-14	7 5-9	42 37-50	68 66-70[4]
Mo ppm	2.3	nd	nd	0.5 0.4-0.6	1 0.8-1.2	.06 0.3-0.8	0.4	1.0 0.3-1.8[4]

*****All values reported on a dry matter basis with the exception of dry matter. ******Number of zoos submitting samples

[1] Alpha-tocopherol [3] Beta-cryptoxanthin

[2] Lutein + Zeaxanthin [4]Represents multiple tests of one sample

nd = not detectable or below minimum detectable level. -Not analyzed

Sample Analysis Protocol

Institutions submitted frozen food samples for analysis. These samples were light protected and placed in a -80 freezer until analyses were performed. Individual food samples from each institution were homogenized by blending the frozen sample with liquid nitrogen. The blended sample was either used immediately for analysis or returned to the freezer. Each sample was analyzed in duplicate for protein, fat, energy and dry matter, Vitamin A, Vitamin E and carotenoids. For other mineral analyses, a single sample of each food item from each institution was sent out to a laboratory. Means and ranges in the Appendix K table represent the results from these analyses, with each institution counted as 1 sample.

"Adult" mice are actually fuzzy or subadult mice approximately 15g each. Three institutions provided samples. The mineral results from all 3 institutions were questionable due to problems with the equipment in the original laboratory. No sample remained for retesting, so a sample from the Brookfield Zoo stock was sent out to another laboratory. These results came back high in copper and zinc when compared to expected values so a second Brookfield sample was sent for confirmation. single values for mice in the Appendix K table represent the second retest value only. The mineral values for mice in this table include the original values as well as both retested samples. Macronutrient and vitamin values for mice are based solely on the original samples.

In the case of cat food, mineral results appeared questionable, thus they were sent to another laboratory for verification. This is represented in the table by the superscript 4. For calcium, the first value was determined to be erroneous so only the results from the retest are reported.

For Vitamin D analysis, sample was limited. In some cases, there was no remaining sample from an institution(s) so only the remaining samples were tested (pink mice, N=3; adult mice, N=2; mealworms, N=2, large mealworms, N=1). For crickets, small amounts remained from most institutions but not enough for individual analysis. These samples were pooled into 2 samples before analysis for Vitamin D.

Appendix L. Nutrient Target Levels.

Nutrient	Concentration in diet (dry matter basis)
Energy, kcal/g	4-7
Crude protein, %	20-25
Fat, %	18-28[1]
Vitamin A, IU/g	1.67
Vitamin D, IU/g	0.22-0.5
Vitamin E, mg/kg	5-50
Carotenoids, mg/kg	Unk[2]
Calcium, %	0.78-2.5[3]
Phosphorus, %	0.33-0.44
Magnesium, %	0.056
Potassium, %	0.333
Sodium, %	0.167
Iron, mg/kg	66.7-80
Zinc, mg/kg	38.9-50
Copper, mg/kg	6.67
Manganese, mg/kg	33.3-44.4
Cobalt, mg/kg	-
Selenium, mg/kg	0.11-0.156

[1]There is no real requirement per se for fat in the diet the requirement will be for fatty acids. However given that the fat content of the kingfisher diets in captivity range from 18-28% on a dry matter basis, this level is thought to be appropriate.

[2]There is no known requirement level for carotenoids however, given that anolis lizards contain quite high levels (a mean of about 2600 µg/100g dry matter basis), these should be considered when feeding kingfishers.

[3]The higher level may only be appropriate for females laying multiple egg clutches and then, only for a very limited period of time. What is possibly more important is a 1.2:1 to 2:1 Ca:P ratio in the diet for all birds.

Appendix M

PROTOCOL FOR THE PRESERVATION OF LIZARDS AS ANIMAL FOOD

Philadelphia Zoo Nutrition Department

1) Obtain live lizards. Discard any which arrive dead.

2) Euthanize lizards with CO_2 gas according to the 1993 AVMA Panel on Euthanasia recommendations (JAVMA, Jan. '93).

3) Immediately remove dead lizards from CO_2 chamber.

4) Place lizards into a plastic bag and add 200 ml of water/lizard.

5) Place bags containing lizards and water in the freezer and allow to freeze. NOTE: Freezer should be maintained at -5° or below.

6) Defrost lizards on an as needed basis in the refrigerator. Allow lizards to become completely clear of ice before removing from the packaging to avoid damage to the lizard.

7) Defrosted lizards should be used within 8 hours. Hold defrosted lizards in the refrigerator until fed out.

RECOMMENDATION: Freeze the number of lizards/bag which will be used at one feeding, e.g., 3 animals to be fed one lizard each, freeze 3 lizards/bag.

Prepared by:

Barbara Toddes
Nutrition Advisor
Micronesian Kingfisher SSP

Appendix N. Recommended Diet for Micronesian Kingfishers

Food item	**% (as fed) by weight**	**range to feed (in grams) per bird**	**per pair***	**Expected consumption (single birds)****
Pink mice	25-50%	3-6	10-20	77-100%
Anolis lizards[1]	25-50%	3-6	10-20	100%
Insects[2]	20-30%	2.4-3.6	8-12	>80%
Dry cat food[3]	0-20%	0-2.4	0-8	na[5]
Supplements	see below[4]			
Total Diet		**12 g**	**40 g**	

*For pairs with chicks a portion of the offered pink mice and anolis lizards should be chopped and total diet amount should be increased by 25% per chick in nest. Care should be taken to keep the ratio of each dietary item offered consistant with the table.

**Actual consumption may differ depending on caloric density of the diet and energy needs of the individual. Foods selected can be based on availability and seasonality.

[1] During courtship, incubation and chick rearing feed anolis lizards at upper level (50%). The combined quantity of pink mice and anolis lizards should not exceed 75% of the diet.

[2]Insects (crickets, mealworms, mighty mealworms or waxworms) should be fed a commercial cricket diet which contains at least 8% Ca to improve the Ca:P ratio. Care should be taken to keep crickets at 80 ^{o} F in order to encourage adequate diet consumption (Ward and Crissey 1997). Insects should comprise at least 20% of the diet.

[3]Cat food should be offered, especially during chick rearing and fledging (see text) . It can be soaked or presented in such a way as to encourage consumption. The type of cat food should contain a nutritional content of 30% protein, 8% fat (see Appendix K).

[4]Calcium: For birds consuming 12 grams of a combination of mice, crickets and anolis; supplement crickets with 0.36 to 0.6 grams of an insect supplement which contains 8% Ca.
Vitamin E: 0.6 mg of vitamin E per day.

[5]Consumption of manufactured diets must be monitored.

SAN DIEGO ZOO

AVIAN PROPAGATION CENTER
HAND-REARING PROTOCOL

Date: 27 April 2000
updated by PWitman

Common: Micronesian Kingfisher
Species Name: *Halcyon c. cinnamomina*
Desired Adult Body Weight: 1.0: 53.0g - 65.0g
0.1: 53.0g - 72.0g

DAY	BROODER/TEMP.	FREQ.	DIET	INTAKE	MISC.
1	94.0°-96.0°F in nest cup w/ tissue in AICU w/ water pan for humidity 80.0°-82.0°F wet bulb	Feed every 2 hrs 7x/day	Chopped pinkies w/Pedialyte	25%	Betadine ys seal 2x/3days CaCO 2x on 3rd & 6th feeding Feed on scale
2	Decrease temp 1°F/day			30%	Apetate @ 1ml/50g food
3	Add Nomad matting to nestcup			35%	
4				40%	CaCO 3x 1st, 4th & 7th feeding
5	Keep brooder covered to simulate nest cavity			45%	
6			**Add** 2 week old crickets	45-50%	
8			**Add** molted or half mealworms **Change** from Pedialyte to distilled water	50%	
9			Feed mix: equal parts by **volume** Chopped pinkies, 2 week old crickets & meal worms		
10	Remove water pan		**Add** Chopped anole		Note when begins casting pellet
11		Feed every 3 hrs 5x/day	**Change** to adult crickets w/o heads		Feed w/ puppet when eyes begin opening
13	Move to Box Brooder w/				

	mirror 86.0°88.0°F				
15	Remove chick from nest cup		**Change** gradually to chopped fuzzies **Change** to whole crickets w/ heads		Change to Dicalcium phosphate
18		Feed every 4 hrs 4x/day	**Add** Soaked cat food Offer live insects Offer food between feedings Add water bowl		
20				Feed Ad Lib	
25		Feed every 5 hrs 3x/day			27-33 Begin weaning
28	Move to covered Howdy Cage w/ heat				perching
30			**Add** Carnivore meat		**Delete** Apetate Watch for “fledge”
31	Outside w/ heat during day. No heat inside @ night				
38-43	Outside day & night w/ heat @ night	Feed every 6 hrs 2x/day			
47-50		Feed 1x/day			

The goal is maintain a 15%-20% daily weight gain.
If too high a weight gain, hold at previous day’s % intake of decrease by 5%.

Apetate (liquid vitamin B complex for children) - Use 1cc/50g food fed
Calcium carbonate - Use 1% of amount fed previous day
Dicalcium phosphate - Use 1% of amount fed previous day

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** Copies on file