Food preferences and response to novel native berries by captive-reared Nene *Branta sandvicensis* goslings

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Food choice experiments conducted on captive Nene goslings confirmed significant preferences among the food items offered which could not be attributed to protein or water content. Grain (cracked corn and wheat) and Pualele were preferred significantly over all other items offered. Goslings that had been reared on the typical captive diet (Standard Diet) for 40 days did not differ in the average consumption of novel native berries from goslings that had been raised from Day 1 with exposure to berries (Enhanced Diet). From Days 40 to 44, however, gosling groups did differ significantly in their relative preference for different berries, with Standard Diet birds preferring Kukaenene berries and Enhanced Diet birds preferring Ohelo berries. Nene that had remained in captivity until adulthood on a limited diet did not accept novel foods as readily as goslings. Adult Nene that had been captive-reared did not readily try the novel berries whereas wild-caught adult Nene in captivity did recognize and consume the berries. The results of this study indicate that feeding native berries to captive-reared goslings is not likely to influence the diet of Nene released into the wild as fledglings. The length of time in captivity, however, is important in considering the diet to be offered to Nene reared for eventual release.

Keywords: Captive Propagation, Diet, Foraging, Hawaii, Hawaiian Goose, Nene

Unlike the fate of half of Hawaii's native bird fauna, the Nene's *Branta sandvicensis* drastic decline toward extinction was well documented (Baldwin 1945; Smith 1952) and conservation efforts established in the 1950s. Captive propagation programmes were begun both in Hawaii and at The Wildfowl & Wetlands Trust at Slimbridge, England (Smith 1952; Kear & Berger 1980). As a result of the propagation efforts, over 2,200 Nene have been released on Maui and Hawaii since 1960, and recently (1991) on Kauai; however, the wild population today numbers only between 400 and 600 birds (Black *et al.* 1993). The first-year survival of these released birds is low (Banko 1988; Black *et al.* 1993) and wild populations are likely to decline without the continual release of captive propagated birds (Stone *et al.* 1983; Banko 1988; Black & Banko 1993). While predation by introduced mammals (cats, dogs, and Mongooses *Herpestes auropunctatus*) is a major cause of mortality, managers have also cited inadequate food resources in the present Nene sanctuaries (Devick 1981a; 1981b; Stone *et al.* 1983; Banko 1988; Black 1990; Black *et al.* 1994), as well as the possibility of the loss of adaptive behaviour in goslings reared in captivity (Stone *et al.* 1983), as potentially serious problems in the survival of released birds.

Other captive rearing and release programmes have found that the methods used during rearing can result in the absence of important "wild" behaviour in the animals after release. For example, captive-raised Golden Lion Tamarins *Leontopithecus rosalia* were unable to recognize and find native foods after release

but, with a training programme and exposure to natural foods, there was a significant improvement in the foraging behaviour of individuals in the wild (Beck *et al.* 1988; Dietz *et al.* 1988; Kleiman 1989). A study of Sandhill Cranes *Grus candadensis pulla* (Zwank *et al.* 1988) found that the food preferences of released birds reflected the pre-release diet and differed from wild birds, even though native and released Cranes were often seen together within the flocks. This study investigates whether captive-reared Nene would benefit from early exposure to foods that would be found in the sanctuary habitats after release.

Various feeding studies of both captive and wild geese have shown that goslings have preferences among the food items available to them (Lieff *et al.* 1970; Owen *et al.* 1977) and that these preferences may change over the course of development (Madsen & Fox 1981; Sedinger & Raveling 1984; 1986; Buchsbaum & Valiela 1987).

Adult, captive Nene at the State of Hawaii's Endangered Species Propagation Facility (located at Olinda, Maui) were offered novel food items, such as native berries that were separated from branches and offered on a plate, and did not consume them (F. Duvall & A. Marshall, pers. comm.). Nene goslings are reared in captivity with food items not readily available in the high elevation sanctuaries where they have been released in the past. If goslings do not accept novel food items in captivity, then the current diet fed to captive goslings could cause foraging problems for the goslings once they are released. On the other hand, if goslings readily accept novel foods, then the diet used in the current propagation method is unlikely to be contributing to the low survival of Nene in the wild. This study investigates whether captive Nene goslings show preferences for the food items offered to them and tests their ability to accept novel food items.

Methods

Captive site and propagation methods

The study was conducted at the state of Hawaii's Endangered Species Propagation Facility located at Olinda, Maui (OESPF) during two Nene breeding seasons: spring 1992 and winter to spring 1992-93. There were ten pairs of breeding Nene at the facility. Each pair laid from one to three clutches per breeding season, from October to April. Females were induced to lay additional clutches by the removal of either the whole clutch or the eggs two days prior to hatching.

Females laid from one to five eggs (usually four), 48 hours apart, and then began incubation, which lasted 28 days. After hatching, goslings from a single clutch were placed in a brooder box from Days 0-14. These 0.75 m by 0.75 m boxes had a wire screen through which goslings could see one female adult goose. At Day 14, the brood was placed in a larger rearing pen (1.5 m by 1.75 m) for approximately five weeks, during which time they remained out of contact with other geese. Between eight and ten weeks of age, goslings were transferred by air cargo to an open top pen at the release site. The birds were free to fly out of the release pen, and this usually occurred between weeks 10-12 when flight feathers were fully developed.

The diet of captive Nene goslings reared in past years consisted of 80% chopped greens, such as Dandelion *Taraxacum officinale*, Sow Thistle (Pualele) *Sonchus oleraceus*, Clover *Trifolium* sp., Gosmore *Hypochoeris radicata*, Kikuyu Grass *Pennisetum clandestinum*, and a scratch of cracked corn and wheat crumble (ground corn with vitamins and minerals) grain feed; during the first seven days, Alfalfa Sprouts *Medicago sativa* were also provided (F. Duvall, pers. comm.). Young goslings were given straight crumble, with scratch added slowly up to a 50:50 mixture after Day 10. Whereas goslings in past years had occasionally been given berries and other plants growing in the area, this had not been done with any regularity, nor considered part of their daily food requirements (F. Duvall, pers. comm.).

Adult berry selection in captivity

At the time of the study, six of the adult pairs at the OESPF had been in captivity for their entire lives, i.e., "captive-raised";

one pair was brought into captivity as adults, i.e., "wild-caught", from Haleakala Crater, Maui in 1989, and five birds were brought into captivity as adults from the island of Hawaii in the summer of 1992. All these pairs were offered branches with two of the native berries found in release areas, Kukaenene *Coprosma ernodeoides* and Pukiawe *Styphelia tameiameiae* that had been collected in shrubland areas, between 1,800 and 1,900 m in elevation, on Haleakala, Maui.

The experiment was conducted on five different pairs on 1 and 2 June 1993. Pairs could not see one another, and their normal diets were also offered in addition to the berries. The berries, which were left on branches that were placed in cans, were counted before placement of the branches into the pen and after their removal. Any berries on the floor of the pen at the end of the experiment were collected and counted as unconsumed. The difference in berry number before and after the experiment was assumed to be the number consumed.

The first experiment was conducted for 22 hours on 1 June. It involved three pairs of captive-raised pairs and two wild-caught pairs. One of the wild-caught pairs was brought into captivity in 1992; the female of the other pair was raised in captivity, the wild male captured in 1992. The second experiment was conducted for 7.5 hours on 2 June. It involved three captive-raised pairs and two wild-caught pairs, one of which was brought into captivity in 1992, and one of which was brought into captivity (from Haleakala crater) in 1989.

The proportion of each berry type consumed by each pair was calculated and the data were transformed, to stabilize variances in high and low proportions, by using an arcsin square root transformation. The transformed data were analyzed by two sample t-tests, except for one test in which a Mann-Whitney two-sample rank test was used due to the lack of variance in one of the samples. These tests were employed to compare the proportion of Kukaenene and Pukiawe consumed by captive-raised adults *v* adults captured from the wild. All statistical tests were calculated with α=0.05 and were performed using the computer package Minitab (release 8.2; Ryan *et al.* 1985). Power analysis was conducted for the two-sample t-tests because the small sample sizes in the tests made interpretation of statistically non-significant results difficult. The power of the test was calculated as the probability of detecting a true difference in the population means as large as the observed difference in the sample means, in a test with an α=0.05 and sample variances equal to those observed in this study (Zar 1984; Bain & Engelhardt 1987).

Gosling food choice in captivity

Number of goslings observed, diet types, and assignment of diet

At the breeding facility, groups of goslings were randomly assigned to one of two diet types. The groups consisted of two to five individuals that were either siblings or similarly aged birds. The first group to hatch was assigned randomly to either the Standard Diet or the Enhanced Diet. The next group was then assigned to the opposite diet. The third group was again randomly assigned to the Standard or Enhanced diet, with the fourth group then being assigned to the other, etc. This assured that approximately equal numbers of groups were on each diet and that birds with similar hatch dates were on both diets.

In the spring of 1992, 14 goslings, divided into three groups on the Standard Diet and two groups on the Enhanced Diet, were observed. When the experiments were initiated, one group of goslings was 18 days old and another group was 26 days old. These two groups were already on the Standard Diet.

A total of 12 groups and 39 goslings was observed during the second season (1993), with six groups on each diet. Six deaths occurred prior to release: one gosling was on the Standard Diet and five were on the Enhanced Diet. Veterinary necropsy showed the proximate causes of death were yolk sac infection (one

gosling), omphalitis (infection of umbricus or old yolk sac infection, one gosling), necrotic typhlitis (death of tissue in caecum, one gosling), necrotic aspergillous (bacterial infection, one gosling), and a combination of typhlitis and aspergillous (two goslings) (G. Massey, pers. comm.).

Diets were fed to goslings from Day 1 until their placement in the release pen. Goslings assigned to different diets were not in view of one another. The Standard Diet consisted of grain plus the traditional chopped greens fed to captive Nene: Kikuyu Grass, Dandelion, Gosmore, Clover, and Sow Thistle. The Enhanced Diet also included grain and these chopped greens, but was enhanced with three species of berries (offered in bowls or on branches, depending on gosling age) found in the high elevation areas in which captive Nene have been released: Pukiawe, Ohelo *Vaccinium reticulatum*, and Kukaenene.

Plant cuttings and sod trays were provided by the OESPF staff. Berries on branches were collected in shrubland areas at approximately 1,860 m elevation on Haleakala, Maui. All three types of berries were abundant in December, January, and February, but decreased in abundance toward April.

Because the location of the gosling groups, the types of foods offered, and the manner of presentation of the foods changed during the development period, the food choice experiment is explained in relation to the three development phases of the goslings: (i) Phase 1 goslings were 1 to 14 days of age, (ii) Phase 2 goslings were 15 to 39 days of age, and (iii) Phase 3 goslings were 40 to 60 days of age (or until release).

(i) Phase 1 (Days 1 to 14)

Newly hatched goslings were placed in the brooder until approximately 14 days of age. These goslings were in view of, but separate from, an adult female goose housed next to their brooder (Marshall & Black 1992). This "foster mother" received the Standard Diet. For individual identification, goslings were marked with non-toxic coloured magic marker on their foreheads and/or cheeks.

In the brooder box, young birds were given grain and plants chopped into fine pieces and placed in beige or pale blue plastic bowls. Size of the food pieces was increased as the birds grew. Alfalfa Sprouts were offered until Day 7. Live Kikuyu Grass and Clover were offered on a rectangular section of sod. In addition to the greens, Enhanced Diet birds were offered berries, which were removed from branches and presented in small beige bowls (see **Table 1** for food items offered). Several of the Kukaenene and Ohelo berries were cut in half or pieces; Pukiawe could not be cut up.

Table 1. Diets presented to Nene goslings at different phases of development.

Phase	Location	Standard Diet (n = 21)	Enhanced Diet (n = 18)
1	Brooder (gosling age = 1-14 days)	crumble sprouts Dandelion Gosmore Pualele Kikuyu grass Clover	crumble sprouts Dandelion Gosmore Pualele Kikuyu grass Clover Kukaenene Ohelo Pukiawe
2	Rearing pen (gosling age = 15-39 days)	grain Dandelion Gosmore Pualele Kikuyu grass Clover	grain Dandelion Gosmore Pualele Kikuyu grass Clover Kukaenene Ohelo Pukiawe
3	Rearing pen (gosling age = 40-60 days)	same as phase 2 with Kukaenene Ohelo Pukiawe	same as phase 2

Prior to feeding goslings, the food items to be presented were noted and randomly assigned a location within the pen. Food items offered depended on their availability as collected by the OESPF staff and upon availability of ripe berries. Food items were placed within the pen at their

assigned location.

Goslings in both diet groups were monitored daily to determine their food selection, starting from approximately three days of age until their release at approximately 60 days of age. All observations were made at the first morning feeding. Birds were fed additional greens at noon and in the late afternoon by the staff. In the morning, any food left over from the previous day was removed from the pen. The order in which groups were observed was randomized daily, although occasionally activities by the staff at the facility, or illness in a group predetermined some of the group ordering (i.e., if a bird was ill, its group was often observed last to prevent possible contamination of other pens).

Observations for the food choice experiment began after all food items were placed within the pens and the door immediately closed. In the brooder, birds were observed through tinted rectangular windows in the door, through which goslings did not apparently notice observers.

During an observation period, "focal animal sampling" (following one individual at a time) (Martin & Bateson 1986) was used to record the specific food items selected by individuals and the number of pecks on these items. A peck consisted of the lowering of the gosling's head and biting at a food item, followed by a backward movement of the head. Individuals within a group were randomly assigned an order in which they would be watched. During the first year of the study, individuals were watched for five-minute intervals; during the second year, individuals were watched for two-minute intervals. After the first observation interval of two or five minutes, the next individual in the selected order was observed (with the order repeated after all individuals had been observed). This procedure was continued for a total observation time of 20 minutes per pen.

(ii) Phase 2 (Days 15 to 39)

Groups were moved to larger rearing pens after Day 14, and remained in these pens until their release. Goslings were not in view of other groups or other adult Nene. Plastic leg bands, with large engraved numbers on the bands, were used for individual identification of goslings.

In the rearing pen, grain was presented in a stainless steel bowl. Plant cuttings were placed in large coffee cans, and berries (for Enhanced Diet) were left on branches which were placed in cans. These branches had been cut so that all berries were accessible to the goslings. Live Kikuyu Grass and Clover were presented on a rectangular section of sod. The daily placement of food items was randomized as in Phase 1.

Birds were observed for a minimum of 20 minutes per pen and focal animal sampling and data collected were the same as Phase 1.

Doors of the rearing pens contained small, 5 cm by 15 cm, windows which were opened and closed with a sliding panel. The window was kept at the smallest slit possible that allowed observation of the birds; however, birds in the release pen probably were aware of the observer, especially when the window was open wide, and when goslings were close to fledging age.

(iii) Phase 3 (Days 40 to 60 or release)

Groups were observed in rearing pens as in Phase 2 and greens and berries were presented as in Phase 2. During the first season, a food choice experiment was conducted on two groups being fed the Standard Diet, eight days prior to their release. These goslings were offered berries, on branches in cans, as in the Enhanced Diet; and food choices were determined as described in Phase 2. One other Standard Diet group was not offered berries prior to release. Results from the first season were used to modify the experimental method for the second season: all Standard Diet birds in the second season were offered berries on branches for the first time on Day 40 and continued to be offered daily until Day 60 or their release.

Birds were observed for a minimum of 20 minutes per pen and focal animal sampling and data collected were the same as Phase 1 and 2.

Statistical analysis

Pecks by all birds, in each group, for one observation period, were added together for a group total for each food item. This was done for the first ten minutes of observation during the first season and for the first 20 minutes of observation during the second season. The group totals were then summarized as the fraction of total pecks observed on each food item offered for each day. From the first season data, two-sample t-tests were used to compare the average number of pecks on berries by the two Enhanced Diet groups from Days 1 to 14 *v* Days 40 until release, and from Days 15 to 39 *v* Days 40 until release.

To analyze the data from the second season, the proportion of pecks for seven food items given each day from Days 40 to 60 (1993) to each group was transformed using an arcsin square root transformation and then an average (for Days 40 to 60) for each food variable for each group was calculated. The transformation was used to stabilize variances in the error terms and to normalize the distributions which were based on proportions (Zar 1984; Neter *et al.* 1990). The seven food items included in the analysis were Clover, Kikuyu Grass, grain, Pualele, Kukaenene, Ohelo, and Pukiawe. Dandelion and Gosmore were not included, as these plants were rarely offered during Days 40 to 60.

A repeated measures multivariate analysis of variance was employed to determine whether the birds had significant preferences among the seven food items offered, and to determine if these preferences differed between the two diet groups. The significance tests were calculated with an $\alpha = 0.05$. Where statistically significant food effects were found, multiple pairwise comparisons were made and significance was determined using a Bonferroni correction factor for an adjusted overall significance level of $\alpha = 0.05$.

As only three of the seven food items were novel to Standard Diet birds, the analysis was repeated for just the three berry foods from Days 40 to 60. This was done to ascertain whether there were preferences for berry types or preferences for berries based on diet type for just the novel food items alone. Lastly, the analysis was repeated for the three berry foods for the first five days that Standard Diet birds received berries, Days 40 to 44. This analysis was performed to determine whether there was an initial difference in the consumption of berries by the diet groups, which may not have been apparent or differed from the results obtained after Standard Diet birds were exposed to berries for 20 Days.

To determine whether total berry consumption differed between the two diet groups, two-sample t-tests were used, which compared the average proportion of total berries consumed daily from Days 40 to 60, and from Days 40 to 44 between Standard Diet and Enhanced Diet groups during the second season. The arcsin square root transformation was again applied to the data before averages were calculated.

Spearmans rank correlations (Zar 1984) were used to determine if a correlation existed between the goslings preferences for food items and the protein and water content of these food items. Data on the protein content (% dry weight) and water content (% fresh weight) of the plants and berries used in the food choice experiments were based on the analysis of the nutritional content of several plants consumed by wild Nene on Maui and Hawaii by Black *et al.* (1994).

Two statistical computer packages were utilized in the analysis of the data. The repeated measures multivariate analysis of variance and the multiple pairwise comparisons were calculated in SAS, version 6.04, using the PROC GLM statement for repeated measures with "profile" contrasts (SAS Institute Inc. 1989). The two-sample t-tests were performed using Minitab, release 8.2 (Ryan *et al.* 1985).

Results

Adult berry selection in captivity

Nine of the ten adult pairs consumed Kukaenene berries, whereas only six of

the ten consumed Pukiawe berries (**Figure 1**). Four of the six that consumed Pukiawe were wild-caught birds. The results of the two-sample t-test for the five pairs offered berries for 22 hours did not reveal a statistically significant difference in the consumption of Kukaenene berries (t = -1.72, df = 1, P = 0.340) between the captive-raised and wild-caught pairs; however, the power of the test to detect a difference in the true means as large as the difference in the sample means is less than 50%. There was a statistically significant difference between groups in the consumption of Pukiawe berries (t = -6.60, df = 2, P = 0.02), with the wild-caught birds eating significantly more Pukiawe than the captive-raised birds (power between 50 and 80%). In the 7.5 hour experiment, however, differences between captive-raised and wild-caught birds were not statistically significant for either Kukaenene berry consumption (t = -0.84, df = 1, P = 0.56; power less than 50 percent) or Pukiawe berry consumption (Mann-Whitney, W = 9, P = 0.2).

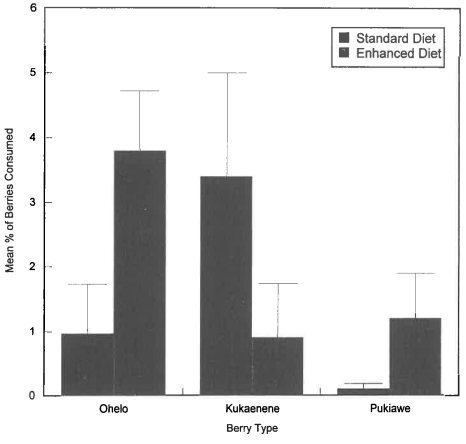

Figure 1. Percentage of berries consumed by pairs of adult Nene at the State of Hawaii's Endangered Species Propagation Facility. Cap = captive-raised birds, Wild = wild-caught birds. A. Berries offered for 7.5 hours. B. Berries offered for 22 hours.

Gosling food choice in captivity

Between gosling comparison

There was a highly statistically significant difference in the proportions of various food items consumed by all goslings in the second season (repeated measures MANOVA, F = 261.37, df = 6,5, P = 0.0001). The goslings preferences for the seven food items differed significantly in 17 out of 21 possible pairwise comparisons, with the 21 comparisons being tested at α = 0.002 to give a Bonferroni adjusted overall significance level of α = 0.05. Grain and Pualele were the most favoured food items and were consumed significantly more than the other food items offered (**Figure 2**). The preference for grain and Pualele was followed by Kikuyu Grass and Clover (not significantly different from each other), and lastly the three berries (which were preferred significantly less than the other foods). Among the berries, Ohelo was preferred, followed by Kukaenene, and then Pukiawe. Overall consumption of Ohelo was not significantly different from Kukaenene, but Ohelo consumption was significantly higher than Pukiawe consumption (Bonferroni-adjusted P = 0.034).

The goslings food preferences were not correlated with either the protein content (Spearman rank, r_s = 0.714) or the water content (Spearman rank, r_s = -0.500) of the seven food items. Protein and water content of the seven food items were also not correlated with each other (Spearman rank, r_s = -0.107).

First season- between group comparison

The first two gosling groups on Standard Diet were offered berries for eight days prior to their release. Goslings in both groups readily tried and ate all three berry types (**Figure 3**). A comparison between the consumption of berries by these two Standard Diet groups and the two Enhanced Diet groups was done using the percentage of pecks on berries during the first ten minutes of observations, as this was the time period in which birds consistently ate for all groups on all days. These results were not compared

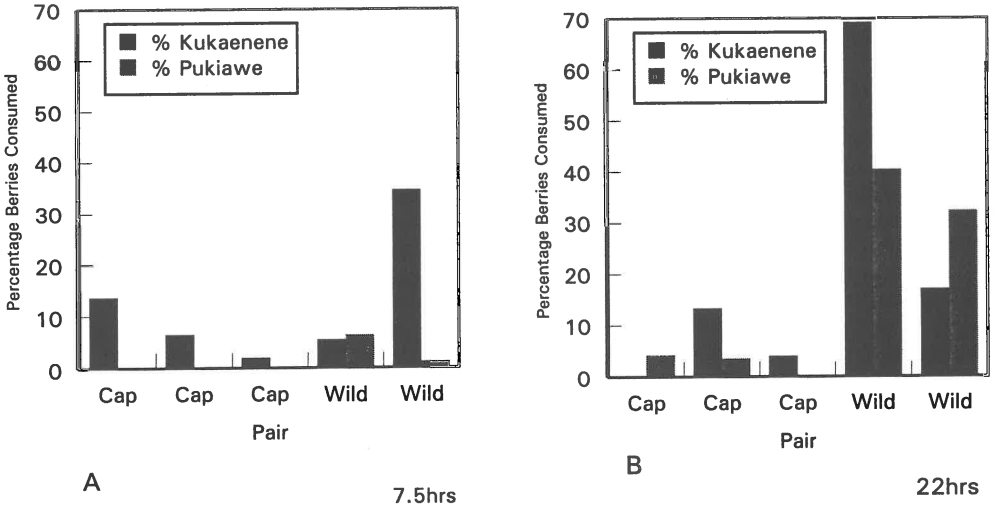

Figure 2. Percentage of pecks on berries during the first ten minutes of observations by first season Standard Diet and Enhanced Diet Nene groups from Days 40 to 60 or release. A. Two Enhanced Diet groups that were offered berries from Day 2 until their release. B. Two Standard Diet groups that were offered berries for the last eight days prior to their release.

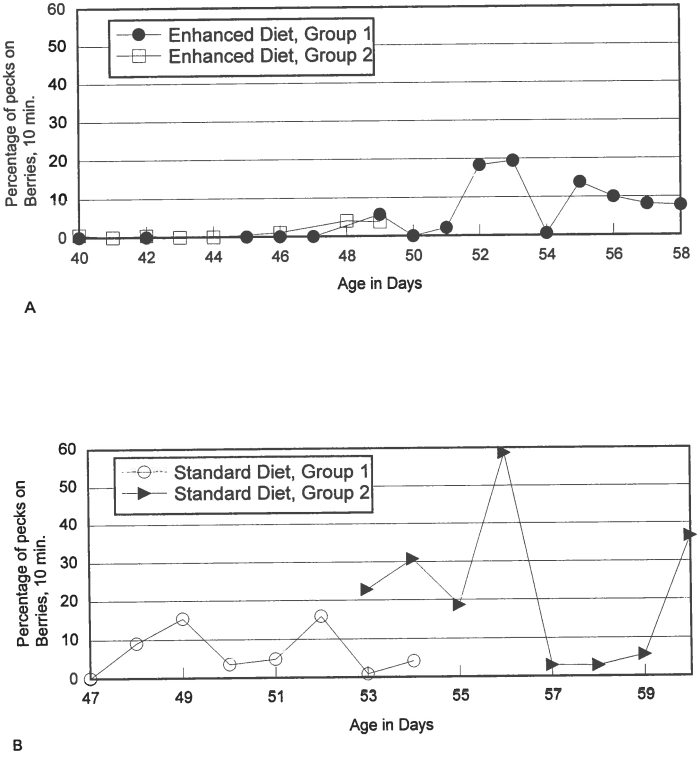

Figure 3. The average percentage of pecks on berries, during the first 20 minutes of observations, by second season Standard Diet and Enhanced Diet Nene groups from Days 40 to 60. Error bars indicate two standard errors of the mean. A. The average of six Standard Diet groups. B. The average of six Enhanced Diet groups.

statistically due to small sample size and varying ages in the groups eight days prior to release.

Age and size, as well as type of food presentation, may be important in the goslings' ability to include berries in the diet. The two Enhanced Diet groups averaged 7.62 (±13.03 SD) pecks on berries (for ten minutes) from Days 1 to 14, which is not significantly different from the average of 4.15 (±5.55 SD) pecks from Days 40 until release (t = 2.09, df = 20.23, P = 0.29). The same groups, however, pecked only an average of 0.67 (±1.56 SD) on berries from Day 15 to 39, which is significantly different from the average pecked from Day 40 until release (t = 2.02, df = 38.59, P = 0.00). The larger numbers of berries initially consumed by Enhanced Diet groups before Day 14 can be explained by the fact that while goslings were in the brooder (until Day 14), berries were available in bowls, with several broken into smaller pieces. Once birds were in the rearing pens, berries may have been more difficult for them to consume, as they had to pull the berries off branches.

Second season- between group comparison

While the results from the first season indicated that perhaps berry consumption gradually increased with age after Day 40, this pattern was not repeated in the second year with a larger sample size. Individuals, within both diets, varied widely in their consumption of berries, but the average proportion of total berries consumed daily from Days 40 to 60 by Standard Diet and Enhanced Diet groups did not differ significantly (t = -0.55, df = 9, P = 0.6) (**Figure 4**). Although Standard diet groups appeared to increase their consumption of berries on Days 59 and 60, the variance in consumption was unusually high on these two days and the averages were calculated from a sample size of four groups (two groups were released prior to Days 59 and 60).

There was no difference in food item preferences between the six Standard Diet groups and the six Enhanced Diet groups from Days 40 to 60 (repeated measures MANOVA, F = 3.33, df = 6,5, P = 0.104).

A repeat of the analysis, considering only the three novel food items offered to Standard Diet birds, i.e., the berries, in the model (to ascertain whether there were preferences for berry types or preferences for berries based on diet type for just the novel food items alone), also resulted in a statistically significant difference in berry preference (F = 13.55, df = 2,9, P = 0.002),

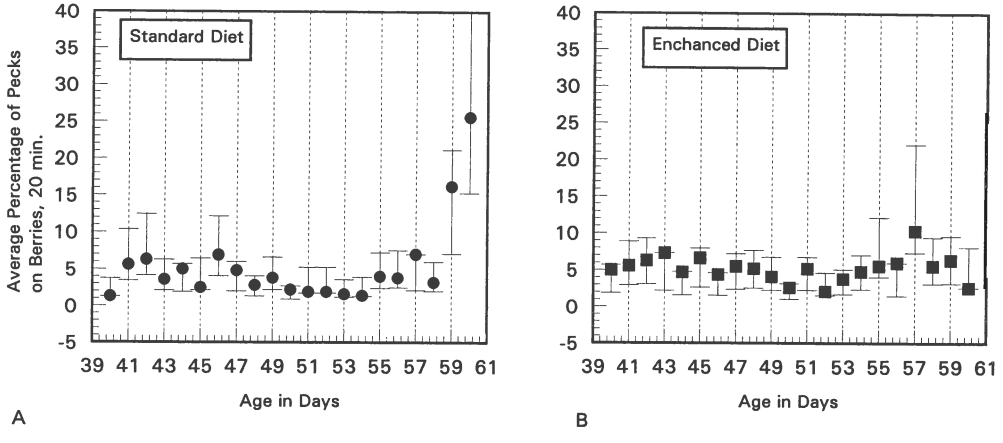

Figure 4. Mean percentage of food types consumed by the 12 second season, Nene gosling groups from Days 40 to 60, with 2 standard errors of the mean, and test-wise significance of the unplanned contrasts between the means of transformed data. Letters indicate means not significantly different at P = 0.002. pua = Pualele, kik = Kikuyu grass, clov = Clover, kukae = Kukaenene, puki = Pukiawe.

and a statistically non-significant effect of diet type on berry preference (F = 3.14, df = 2,9, P = 0.09).

The analysis was repeated for the three berry foods from Days 40 to 44, to determine whether there was an initial difference in the consumption of berries or berry type by the diet groups, which may not be apparent from exposure to berries for 20 days. While the average proportion of total berries consumed from Days 40 to 44 was also not significantly different between Standard Diet and Enhanced Diet groups (t = -0.82, df = 9, P = 0.44), there was a statistically significant effect of diet on the relative preference of berry type between the two diet groups (F = 4.5, df = 2,9, P = 0.04) during this period. Two of the three possible contrasts were statistically significant (Kukaenene v Ohelo, P = 0.04, Kukaenene *v* Pukiawe, P = 0.04; both significance levels are Bonferroni-adjusted for the set of three comparisons). During the first five days that Standard Diet birds received berries, Standard Diet birds preferred Kukaenene, followed by Ohelo, and lastly Pukiawe, while Enhanced Diet birds preferred Ohelo, followed by Pukiawe and Kukaenene (**Figure 5**).

Discussion

Food preferences and nutrition

The Nene goslings in this study did demonstrate preferences among the food items offered to them. While several studies on both captive and wild goslings have shown that the development of preferences can be correlated with the nutritional qualities of the plants consumed by the birds; i.e., water content (correlated with nitrogen) and protein content (Owen *et al.* 1977; Owen 1980; Sedinger & Raveling 1984; Prop 1991; Prop & Vulink 1992), other studies have not correlated nitrogen content with preferences (McFarland & George 1966; Lieff *et al.* 1970; Owen *et al.* 1977; Buchsbaum *et al.* 1984). High protein diets are needed by growing goslings (Owen 1980) and some studies on preferences of wild geese show that goslings consumed and chose plants much higher in protein than parents and other adult birds (Buchsbaum & Valiela 1987). In addition, juvenile herbivores, in general, often show a greater selection for nitrogen than adults of the same species (Janzen 1979).

In this study, grain and the greens were consumed significantly more than the berries, which does correlate with the higher protein contents of grain and the greens relative to berries. The goslings' preferences for individual food items, however, were not correlated with either the protein or water content of these foods. Grain was the most preferred food item (**Figure 2**), yet its protein level is lower than Pualele, Kikuyu Grass, and Clover. In addition, the water content of grain is very low, while all of the greens offered have high and similar percentages of water. Among the greens, Pualele has the highest protein content and was the most preferred plant item. Kikuyu Grass and Clover were significantly less preferred than Pualele, yet the protein content of Clover is very close to than of Pualele, and much higher than Kikuyu Grass. Ohelo and Kukaenene have the highest percentage of water but very low protein, thus the water content of the food items could not be correlated with their nitrogen content.

The experimental methods used in this study may have influenced the preference results which were obtained. For example, Clover was only offered on sod trays, along with Kikuyu Grass. The Clover/Kikuyu ratio on a tray varied from day to day, with Kikuyu usually a higher percentage. Long Kikuyu Grass was also often offered in cans, in addition to being present on the sod. As a result, Clover was often in low abundance and not as visible as all of the other foods on offer. This may partly explain the low preference for Clover in comparison with the other greens offered.

Birds in this study were offered a constant supply of water, and were observed to drink water from these bowls. Thus there is no reason to assume that the captive goslings would choose foods based on their water content. Additionally, water may not have been a factor used by

the goslings in the selection of food items as all of the plant items have similar, high percentages of water. In the current habitats occupied by wild Nene, however, water is often not readily available and therefore may be an important factor in food selection after release.

In terms of the feeding behaviour of the goslings, grain was easy for the birds to consume, while greens required tearing and pulling. Berries were probably more difficult to consume than the other plants offered, as they had to be pulled off branches. It is possible that goslings preferred grain because it was relatively easy to eat, even though it has less protein than greens. By concentrating on grain, goslings may obtain similar amounts of protein from grain as they do from smaller quantities of greens. Measuring preference by number of pecks alone, rather than total amounts consumed and the nutritional content of these amounts, could be misleading.

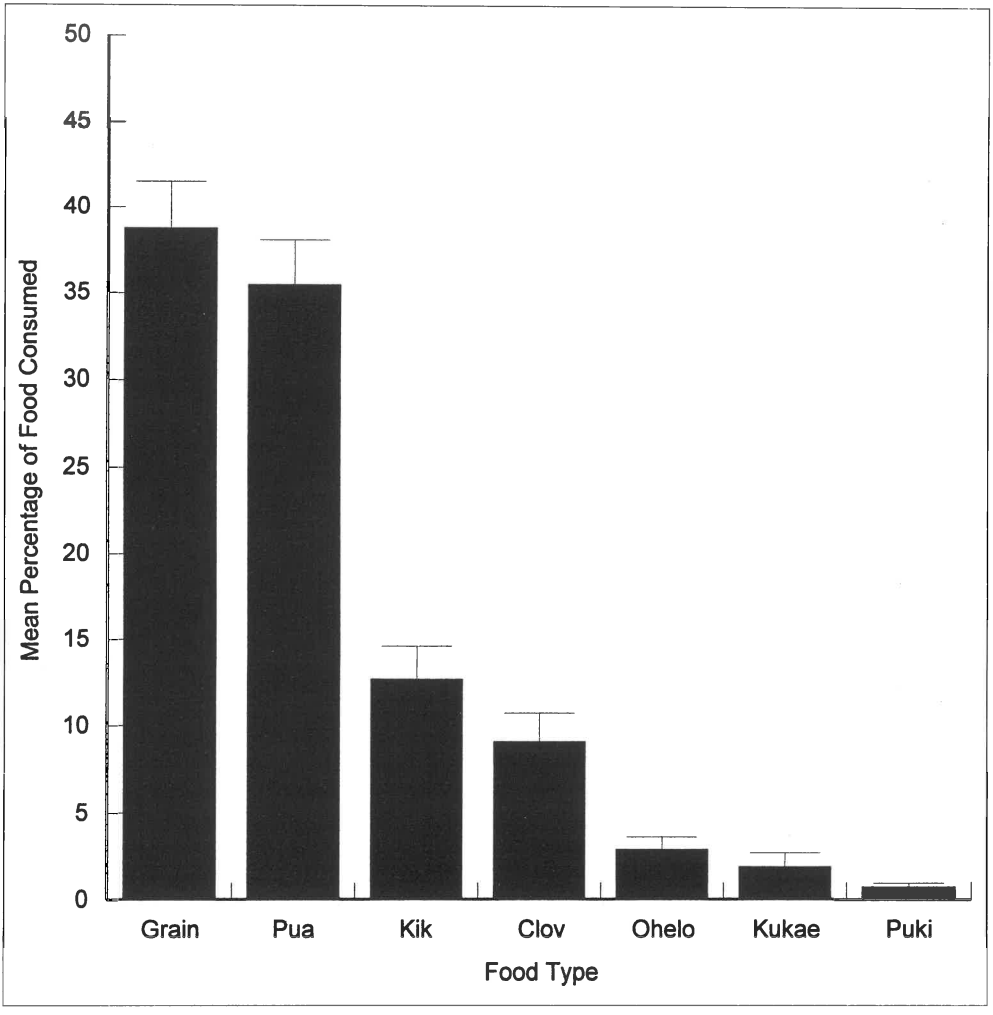

Figure 5. Mean percentage of berry types consumed by second season Standard Diet and Enhanced Diet Nene groups from Days 40 to 44.

Response to novel food items

Most gosling groups on the Standard Diet readily tried and consumed the novel berries after Day 40. The finding that Standard Diet birds consumed, on average, the same number of berries as Enhanced Diet birds indicates that the early exposure to a typical captive diet only does not affect Nene goslings' ability to accept novel food items. The initial differences in the relative preferences of the berry types between the diet groups (from Days 40 to 44), may reflect the ability of Standard Diet birds to consume these berry types by pulling them off branches. Perhaps Kukaenene were the most preferred berry by Standard Diet birds because they are large and conspicuous, fall off branches very easily, and the skin ruptures easily (i.e., easier to remove and eat than the other two berries). Thus, while Standard Diet birds were curious and pecked at all novel berries, they initially consumed more of the easiest to consume type. Enhanced Diet birds also initially consumed Kukaenene more than the other two berry types, earlier in the development period. By Day 40, Enhanced Diet birds had experience with all berry types, and may have preferred the taste of Ohelo over the ease of consuming Kukaenene.

The Nene goslings in this study demonstrated preferences, perhaps based on their early experience with food items. The goslings did not, however, appear to imprint on the diet they received in captivity up to Day 40. Their early experience did not preclude them from consuming novel foods, and in addition, birds on both diets ate a large number of novel food items after release (Rojek 1994). In the wild, Nene goslings stay with their parents until the following breeding season, and learning from parents would occur during this entire period. For goslings, foraging experience with adult geese could be crucial; goslings may learn which foods to eat "food sharing" with parents (Black & Owen 1989a), and also in which areas to forage (Black & Owen 1989a, 1989b). Studies in which goslings diets have switched gradually to the adult diet also indicate that learning is occurring (Madsen & Fox 1981, Buchsbaum & Valiela 1987). The highly social behaviour of geese, with parental association often lasting for a year, and with periods of flocking occurring for most species, indicates that, if a sensitive phase does exist for the development of food preferences, it is likely to be extended. This study did not determine the time frame during which the sensitive phase for learning food preferences by Nene may occur. The finding that Nene that are captive-raised and remain in captivity for several years do not readily try novel food items, while wild-caught adult Nene in captivity immediately recognize and consume these foods, suggests such a phenomenon.

Management implications

All Nene gosling groups in this study demonstrated preferences among the food items offered to them in captivity. Although preferences were present, the early experience of the goslings did not exclude them from accepting novel berries as food. The results of this study indicate that adding native berries to the diet of captive-raised Nene goslings will not increase the likelihood of their eating berries after they are released. The results of the food choice experiment on the adult captive Nene, however, suggests that a longer period of non-exposure to berries could result in a reduced willingness to try novel foods. The length of time in captivity needs to be considered when determining the diet and types of food that are offered to Nene raised in captivity.

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