Nutritional Evaluation of a Hand-Rearing Protocol for the San Clemente Island Loggerhead Shrike (*Lanius ludovicianus mearnsi*)

K.J. Lisi[1], M.S. Edwards[2], and R.E. Bray[1]

Animal and Veterinary Sciences, California State Polytechnic University, Pomona[1] and Zoological Society of San Diego[2]

The San Clemente Island (SCI) Loggerhead Shrike, a subspecies found only on SCI, 80 km off the coast of San Diego, was federally listed as endangered in 1977. The wild population has numbered 12-18 birds for the last 10 years making this one of the most endangered birds in North America. As part of an ongoing, federally funded captive recovery program, 17 chicks (7 ΓΓ, 10 EE) were hand-reared in 1998. Modifications were made to the previous hand-rearing protocol based, in part, on food preferences of adults and projected nutritional needs of growing chicks. Hand-rearing records made available by the Avian Propagation Center of the Zoological Society of San Diego were surveyed to obtain food intake and growth data. Nontraditional food items, including abdomens and guts of adult crickets (*Gryllus* spp.) and whole honeybee larvae (*Apis mellifera*) were sampled and submitted for nutrient analysis. Nutrient content of all other food items was obtained from an existing database. Growth rate data were described by a sigmoid curve. Mean growth rates for days 0-4, 4-16, and 16-29 were 0.60 g/d, 3.29 g/d, and 0.31 g/d, respectively. There was no significant difference in body weight between gender ($P>0.05$). Daily intake of various nutrients, including moisture, crude protein, crude fat, calcium and phosphorus and gross energy were quantified. Mean daily food intake (days 1-9), as a percent of body weight, was 41.42 ± 7.3 % (as-fed basis). Survivability to fledging (day 20) was 100%.

Key words: nutrition, growth curve, altricial birds, endangered species

INTRODUCTION

The San Clemente Island (SCI) Loggerhead Shrike (*Lanius ludovicianus mearnsi)* is found only on SCI, 80 km of the coast of San Diego, California. The subspecies was federally listed as endangered in 1977. Portions of SCI were used for raising domestic livestock (cattle, sheep, and horses) from the late 1800's until 1934 (Scott and Morrison, 1990). Since that time the U.S. Department of the Navy has administered SCI. Official classification as a subspecies was based on differences in body measurements and plumage coloration when compared to other California subspecies (Morrison et al., 1995). The wild population of SCI Loggerhead Shrikes has numbered 12-18 birds for the last 10 years, making this one of the most endangered birds in North America.

Loggerhead Shrikes are medium-sized passerines (adults 45-50g) that inhabit areas of open scrub vegetation and feed on a wide variety of vertebrate and invertebrate prey (Craig, 1978). Scott and Morrison (1990) identified over 88 genera of prey in regurgitated pellets collected in the vicinity of SCI Loggerhead Shrike nesting areas. Craig (1978) found that Loggerhead Shrikes captured prey items in the range of <0.001g to 25g, feeding primarily on small insects (0.5g).

Scott and Morrison (1990) conducted a series of population surveys and natural history studies on SCI during five breeding seasons. The authors estimated that the breeding population declined from 11 pairs in 1984 to 5 pairs in 1988. Forty-nine percent of all nests were depredated, primarily by common ravens, feral domestic cats, and native island foxes. An estimated 55% of fledglings survived to independence (35 days of age). They determined that habitat degradation caused by exotic herbivores and depredation by native and introduced species contributed to the decline of the shrike population and shrike productivity was too low to maintain the wild population. Scott and Morrison (1990) made several management suggestions including the development of techniques to enhance shrike productivity through double clutching, artificial incubation, and captive rearing.

A multifaceted recovery program was initiated in by the U.S. Department of the Navy in 1991 to prevent extinction of the subspecies (Morrison et al., 1995). The Avian Propagation Center of the Zoological Society of San Diego (ZSSD) was contracted for the captive propagation portion of this program. The ZSSD has been instrumental in developing techniques to maintain the captive population of SCI Loggerhead Shrikes. Prior to the 1998-breeding season the captive population consisted of 12 adults. A new hand-rearing protocol was implemented as part of a continual effort to increase chick survivability. Modifications were made to the previous protocol based, in part, on food preferences of adult shrikes and projected nutritional needs of growing chicks.

MATERIALS AND METHODS

Seventeen hatchlings were hand-reared. Dietary components through day 5 consisted of honeybee larvae (BL), cricket guts (CG), pinkie mice (PM), waxworms (WG) and microwaved egg (EG). From day 6 to the beginning of weaning, the modifications of intake levels and individual items fed are provided in Table 1. The hand-rearing protocol is also summarized in Table 1. This protocol required more intensive management of the shrikes than previous efforts. Neonates were fed 9 times/d for the first 6 days, approximately every 1.5h, over 12h period. Detailed records were maintained as part of ongoing efforts toward standardization and improved communication between keepers.

Brooder types varied with neonate age and development. Table 1 provides the type of brooder used relative to the respective stage of growth and their requirements for temperature and humidity. Hatchlings were housed in an AB Newlife Brooder days 0-4 of age. At days 5-18, neonates advanced from the AICU brooder to the Box brooder to allow for more movement and a gradual weaning to environmental temperatures. The Howdy Cage is a small cage placed within a large outdoor enclosure (California Cage). Socialization was the primary goal of this 7-10 day period.

Dietary components were quantified and recorded for each feeding. Total daily intake was determined for individuals and calculated as % body weight (BW), as listed in Table 1. Targeted dietary intakes of neonates were 25% of BW on Day 0 and increased to 50% of BW by day 6.

Samples of whole honeybee larvae (*Apis mellifera*), and guts and abdomens of adult crickets (*Gryllus* spp.) were collected and submitted to a commercial lab for nutrient analysis: gross energy (GE), dry matter (DM)/moisture, crude protein (CP), ether extract (EE), calcium (Ca), and phosphorus (P) (AOAC, 1995). Nutrient contents of all other dietary components were obtained from an existing database of the ZSSD.

TABLE 1. Hand-rearing protocol for neonatal SCI loggerhead shrikes (*Lanius ludovicianus mearnsi*)

Day	Brooder	Freq.	Diet	Intake %BW	Misc.
0	AB Newlife brooder	9X/d, every 1.5h	honeybee larvae (BL) cricket guts (CG) pinkie mice (PM) waxworms (WG) microwaved egg (EG)	25	Dicalcium phosphate with PM
1				25	
2				30	
3				35	Eyes opening
4				40	Feather tracts on belly
5	AICU brooder			45	
6		7X/d, every 2h	Change CG to cricket abdomens (CA) Delete BL	50	
7				50	Eyes open
8		5X/d, every 3h	Feed mix 5.23: 2.19: 0.81: 0.77 PM:EG:CA:WG	50	Mix in grams
9			Delete WG, add mealworms (MW) Feed mix 5.23: 2.19: 1.05: 0.53 PM:EG:CA:MW	50	Pin feathers
10-18	Box brooder		Change to whole crickets Add minced anole Change to fuzzy mice Delete egg Add manufactured mixes	50 - ad lib	Perching on side of cup Casting chitin
19-22	Howdy cage		Add skinned minced mouse	ad lib	Branching
24		4X/d, every 4h	Delete fuzzy mice	ad lib	
27		3X/d, every 6h		ad lib	
29	California Cage	2X/d		ad lib	Beginning Weaning

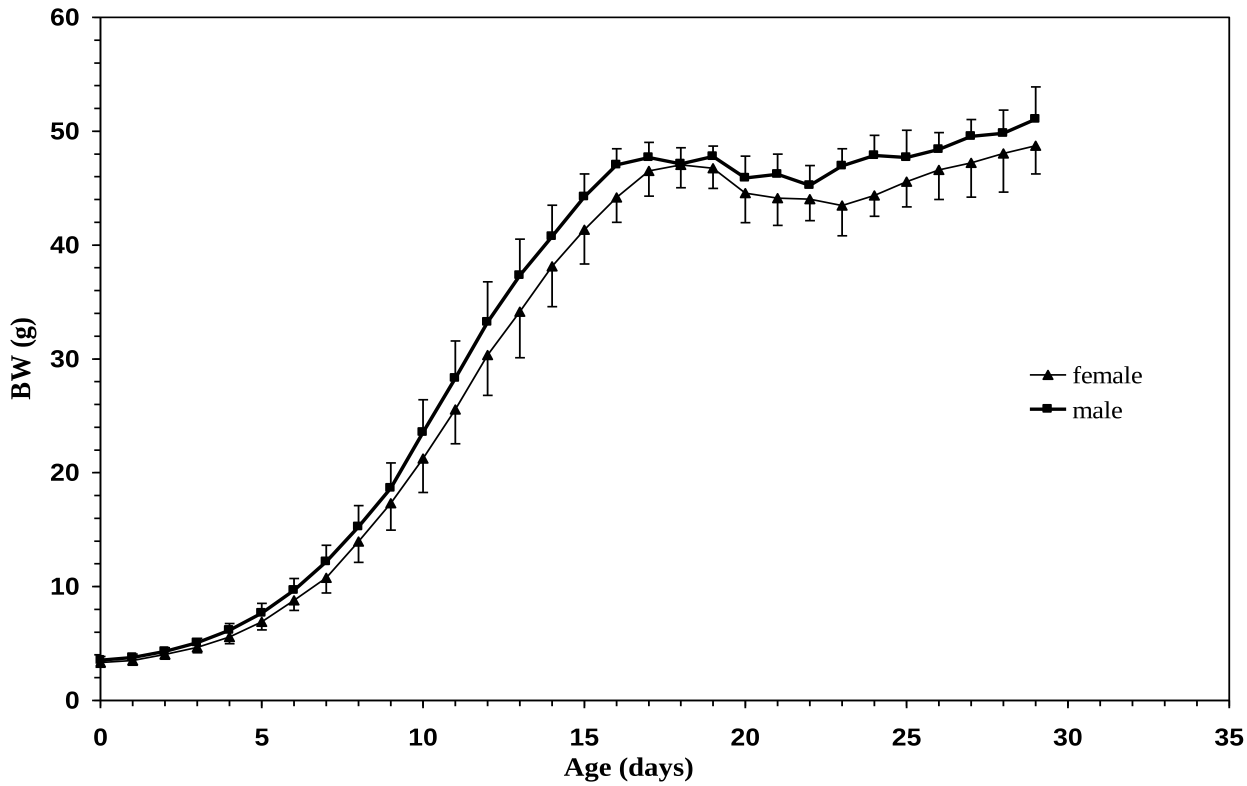

Fig. 1. Average daily weight of SCI Loggerhead Shrikes. No difference (P>0.05) between males (n=7) and females (n=10).

RESULTS

Average daily BW of SCI Loggerhead Shrikes is presented in Figure 1. No difference (P>0.05) in BW was observed between males and females. Subsequently, data for the 17 birds were pooled. Mean growth rates for days 0-4, 4-16, and 16-29 were 0.60 g/d, 3.29 g/d, and 0.31 g/d, respectively.

The average daily intake (%BW) of each item fed through day 9 of age is provided in Table 2. Components of the various mixes fed beyond day 9 could not be quantified with the information provided in the hand-rearing records. The targeted level of intake (Table 1) was similar to actual feed consumption by the birds (Table 2). Mean daily food intake (days 1-9), as %BW, was 41.42 ± 7.3% (as-fed basis). Growth rate, feeding response, fecal output and hydration levels were monitored and recorded for each bird. Exceptions to the protocol were based on nutritional management decisions made by the keepers. For example, one bird received honeybee larvae on day 7 due to signs of dehydration.

TABLE 2. Average daily intake (%BW) of SCI loggerhead shrikes for dietary components from days 0 - 9 of age

Day	BL	EG	CG	CA	WG	MW	PM	Total
0*								
1	6.49	3.09	6.64		6.53		6.50	29.24
2	7.19	3.33	7.19		6.85		7.11	31.67
3	8.49	3.81	8.07		8.02		8.03	36.42
4	8.92	4.38	9.80		8.98		9.49	41.57
5	9.54	4.62	11.19		10.23		10.41	45.99
6		6.43	6.02[a]	10.98	12.78		12.55	44.87
7	2.58[b]	6.94	9.95[b]	14.55	14.31		13.54	50.07
8		11.03		4.07	3.79		26.34	45.23
9		11.58		5.60		2.74	27.76	47.68

*Data inconsistent due to different hatch times: BL = honeybee larvae, EG = microwaved egg, CG = cricket guts, CA = cricket abdomens, WG = waxworms, MW = mealworms, PM = pinkie mice; [a]6 out of 17 birds received CG; [b]1 out of 17 birds received BL and CG

Values for GE, % H_2O, CP, EE, Ca, and P were compiled (DM basis) for the dietary components fed through day 9 (Table 3). Honeybee larvae, microwaved egg, cricket abdomens, waxworms, and mealworms had an inverted Ca-P ratio, range of 0.07:1 to 0.7:1. Pinkie mice and cricket guts contained higher levels of Ca than P (1.1-1.2:1). Cricket guts were removed from the chitinous exoskeleton. Cricket abdomens include the exoskeleton. Dicalcium phosphate was top-dressed on pinkie mice, but the amounts were not quantified or recorded. Values for Ca and P (Table 3) do not reflect supplementation of pinkie mice with dicalcium phosphate. Crickets used for feeding chicks and those submitted for analysis were gut loaded (i.e., fed a high Ca insect diet) for 72 hours prior to use.

TABLE 3. Selected nutrient analysis[a] of dietary components fed to SCI loggerhead shrikes from day 0 - 9 of age

Nutrient	BL	EG	CG	CA	WG	MW	PM
GE (kcal/g)	5.78	6.97	5.51	5.57	7.67	6.49	5.85
% H_2O	79.6	73.1	73.3	70.2	51.3	62.4	74.2
% Crude protein (CP)	44.6	41.3	53.5	57.3	23.6	52.7	59.2
% Ether extract (EE)	17.6	45.5	19.1	22.1	61.5	32.8	23.6
% Calcium (Ca)	0.06	0.26	1.28	0.78	0.05	0.11	2.29
% Phosphorus (P)	0.84	0.63	1.21	1.08	0.40	0.77	1.90
Ca:P	0.07:1	0.4:1	1.1:1	0.7:1	0.1:1	0.1:1	1.2:1

[a]DM except for water; BL = honeybee larvae; EG = microwaved egg; CG = cricket guts; CA = cricket abdomens; WG = waxworms; MW = mealworms; PM = pinkie mice

Mean daily nutrient composition of total diet consumed through day 9 was calculated from laboratory analyses, nutrient database values, and information compiled from hand-rearing records (Table 4). GE consumed increased seven-fold, from 2.09 kcal on day 1 to 14.72 kcal on day 9. During the same interval there was a five-fold increase in average BW, from 3.62g to 17.87g. The Ca-P ratio was inverted days 1-7 (0.8:1) and increased with dietary changes (1:1, on days 8 - 9). The values for %Ca, %P, and Ca:P do not include supplementation of pinkie mice with dicalcium phosphate (which was top-dressed prior to feedings).

TABLE 4. Selected nutrient analysis[a] of diet fed to SCI loggerhead shrikes from days 0 - 9 of age

Day	GE (kcal)	% H_2O	% CP	% EE	% Ca[b]	% P[b]	Ca:P[b]
0*							
1	2.09	69.81	41.23	37.71	0.75	0.94	0.8:1
2	2.54	70.23	41.57	37.10	0.75	0.95	0.8:1
3	3.44	69.89	41.27	37.44	0.74	0.94	0.8:1
4	4.73	69.83	41.55	37.29	0.77	0.95	0.8:1
5	6.52	69.88	41.49	37.39	0.77	0.95	0.8:1
6	9.18	66.50	41.80	41.27	0.76	0.93	0.8:1
7	12.71	66.37	41.94	41.25	0.74	0.92	0.8:1
8	12.24	70.43	49.75	33.99	1.35	1.31	1:1
9	14.72	71.71	54.14	29.40	1.44	1.40	1:1

[a]DM except for water; GE = gross energy; CP = crude protein; EE = ether extract; Ca = calcium; P = phosphorus; *data inconsistent due to different hatch times; [b]values do not reflect dicalcium phosphate added to pinkie mice

DISCUSSION

Due to variable chick survivability the hand-rearing diet and nursery management techniques used for SCI Loggerhead Shrikes have continued to evolve. Seventeen eggs were hatched and successfully hand-reared during the 1998-breeding season. Chick survivorship to fledging was 100%. Loggerhead Shrikes begin fledging 20 days after hatching (Wallace and Mahan, 1975). One chick died due to accidental injury on day 20. Growth rate demonstrated a sigmoid curve (Figure 1), with most of the growth taking place days 4 through 16. Average daily weight increased from 5.82g on day 4 to 45.35g on day 16, with a mean growth rate of 3.29 g/d. Robbins (1983) cites a regression equation for the relatively linear phase of the sigmoid curve relating adult body weight (W in g) and growth rate (Y in g/d) for altricial land birds: $Y = 0.21W^{0.72}$. Using data from this study, W = 46.9 (the average BW on Day 30), then Y = 3.35 g/d. It is interesting to note that the observed growth rate from this study (3.29 g/d) is similar to the calculated growth rate

(3.35 g/d). Therefore, it appears that shrikes fed according to the 1998 hand-rearing protocol grew at a similar rate to the growth rate predicted by the general regression equation for altricial land birds.

The observed 5.6% decrease in BW between days 19 and 22 (Figure 1) corresponds to a change in housing. During this period chicks are moved from a brooder box to a howdy cage. The temporary weight loss may be attributed to a reduction in food intake and/or increased physical activity. Chicks underwent compensatory weight gain after this period.

Neonatal chicks must be provided with a relatively high protein diet in amounts to support adequate growth (Kuehler et al., 1993). Fat provides energy to support the rapid growth of young birds. The contributions of preformed water are of particular concern when developing diets for neonatal altricial birds since water must be provided via food items. The feeding of high dry matter (i.e., low moisture) diets can result in weakness, dehydration, difficulty passing feces, and loss of vitality (Kuehler et al., 1993).

Adequate and properly balanced levels of calcium and phosphorus are needed for growth and skeletal mineralization. Calcium intakes of shrike hatchlings (days 0–9) ranged from 0.74%-1.44% (DM), however these values (Table 4) do not reflect the dicalcium phosphate top-dressed on the pinkie. Based on calcium requirements of comparable aged Japanese quail (0.89%, DM) and chickens (1.11%, DM) (NRC, 1994), these dietary intake levels would be considered marginally deficient to adequate. Phosphorus intake (days 0-9) ranged from 0.94%-1.40% (DM), which exceeded NRC (1994) requirements for Japanese quail (0.33%, DM) and chickens (0.5%, DM).

NRC (1994) recommendations of Ca-P ratios for growing chickens and Japanese quail are 2.2:1 and 2.71:, respectively. Klasing (1998) notes that the rate of skeletal growth in altricial hatchlings is greater than that of precocial species, which may indicate a higher requirement for calcium in developing altricial birds. Honeybee larvae, egg, waxworms, and mealworms contain low levels of calcium (Table 3). In general, insects are a good source of phosphorus but are low in calcium (Klasing, 1998). Supplementation with dicalcium phosphate (Ca:P of 22.0:19.3) increases intake of both minerals without greatly affecting the Ca-P ratio. A more effective strategy may be to review supplementation of insects and/or egg.

All components of the diet fed days 0 - 9 contained approximately 50-80% dietary water (Table 3). Honeybee larvae, containing 79.6% water, is a good source of dietary water for neonate insectivorous birds. The high moisture larvae are contained within a membrane, thus reducing the risk of aspiration. Egg, crickets, honeybee larvae, mealworms, and pinkie mice provided high protein content (41.3-59.2 %CP). Egg and waxworms are good sources of energy to support growth (6.97 and 7.67 kcal GE, respectively). Crude protein in the total diet ranged from 41.23% on day 1 to 54.14% on day 9 (Table 4). Amino acid profiles of the food items have not been determined and would provide useful information. Adequate growth rates and high survivability to adulthood suggest that the blending of protein from several animal and insect sources fulfilled the needs of developing SCI Loggerhead Shrike chicks.

There continues to be many challenges with the SCI Loggerhead Shrike captive recovery program. Current emphasis is on increasing the size of the captive population. Providing proper nutrition to neonatal shrikes, especially during the first few days of life, is a critical component in chick survivability. Nutritional evaluation of hand-rearing records from subsequent breeding seasons will provide additional information. Increasing the database of information pertaining to the SCI Loggerhead Shrike recovery program will have useful application in similar projects worldwide.

CONCLUSIONS

1. Seventeen SCI Loggerhead Shrike eggs were hatched and successfully hand-reared in 1998. Chick survivorship to fledging was 100%.

2. Growth rate data was described by a sigmoid curve. Mean growth rates for days 0-4, 4-16, and 16-29 were 0.60 g/d, 3.29 g/d, and 0.31 g/d, respectively. The growth rate (days 4-16) was similar to that predicted by the general regression equation for altricial land birds.

3. Protein and water content are of particular concern when developing diets for neonatal altricial birds. Honeybee larvae, containing 79.6% water, is a good source of dietary water for neonatal insectivorous birds. Egg, crickets, honeybee larvae, mealworms, and pinkie mice provided high protein content (41.3-59.2%, DM). Adequate growth rates and high survivability to adulthood suggest that the blending of protein from several animal and insect sources fulfilled the needs of developing SCI Loggerhead Shrike chicks.

ACKNOWLEDGMENTS

Special gratitude to Pat Witman, Therese Littlefeather, and the keepers of the Avian Propagation Center of the Zoological Society of San Diego for their assistance in data collection.

REFERENCES

AOAC International. 1995. Official methods of analysis (16th ed.). Methods 2.4.03 and 32.2.03, AOAC, Arlington, Virginia, (modified).

Craig, R.B. 1978. An analysis of the predatory behavior of the Loggerhead Shrike. Auk 95(2): 221-234.

Klasing, K.C. 1998. Comparative Avian Nutrition. CAB International, New York.

Kuehler, C.M., A. Lieberman, B. McIlraith, W. Everett, T.A. Scott, M.L. Morrison, and C. Winchell. 1993. Artificial incubation and hand-rearing of Loggerhead Shrikes. Wildl. Soc. Bull. 21(2): 165-171

Morrison, M.L., C.M. Kuehler, T.A. Scott, A.A. Lieberman, W.T. Everett, R.B. Phillips, C.E. Koehler, P.A. Aigner, C. Winchell, and T. Burr. 1995. San Clemente Loggerhead

Shrike: Recovery plan for an endangered species. In: Shrikes (Laniidae) of the World: Biology and Conservation. Proc. West. Found. Vert. Zool. 6:293-295.

NRC. 1994. Nutrient requirements of poultry. National Academy Press, Washington, DC.

Robbins, C.T. 1983. Wildlife Feeding and Nutrition. Academic Press, New York.

Scott, T.A. and M.L. Morrison. 1990. Natural history and management of the San Clemente Loggerhead Shrike. Proc. West. Found. Vert. Zool. 4:23-60.

Wallace, G.J. and H.D. Mahan. 1975. An Introduction to Ornithology (3rd ed.). Macmillan Publishing Co., New York.