THESIS

ARTIFICIAL INCUBATION, CAPTIVE-REARING AND MAINTENANCE OF PIED-BILLED GREBES IN GUATEMALA

Submitted by

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In partial fulfillment of the requirements

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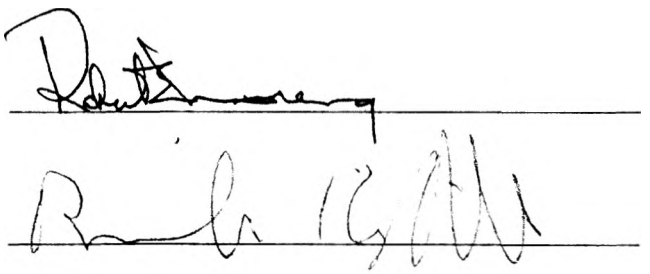
WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY SUSAN RUTH MACVEAN ENTITLED ARTIFICIAL INCUBATION, CAPTIVE-REARING AND MAINTENANCE OF PIED-BILLED GREBES IN GUATEMALA BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

Committee on Graduate Work



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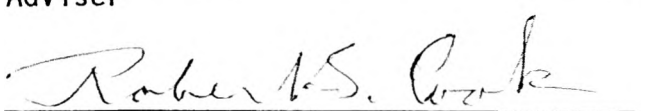

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ABSTRACT

ARTIFICIAL INCUBATION, CAPTIVE-REARING AND MAINTENANCE OF PIED-BILLED GREBES IN GUATEMALA

Pied-billed Grebe (Podilymbus podiceps) eggs (n = 20) were collected in early and mid-incubation stages at 3 lakes in Guatemala. Two factors previously reported to affect hatchability of artificially incubated avian eggs were investigated: egg weight loss during incubation and stage of incubation at collection. Weight loss was lower than reported in the literature and did not differ ($P > 0.05$) for hatched and unhatched eggs. Stage of incubation at the time of collection had an effect ($P < 0.05$) on hatchability and development through pipping. None of the eggs collected in early stages of incubation (n = 13) hatched; all embryos died in early or mid stages of development. Embryos of all eggs collected at mid-incubation (n = 7) developed through pipping and 71% hatched successfully. These data suggested that an initial period of natural incubation increases Pied-billed Grebe egg hatchability.

Captive-rearing and maintenance techniques were developed with common Pied-billed Grebes for implementation with the then-endangered Atitlan Grebe (Podilymbus gigas). Grebes (n = 5) were reared from the artificially incubated eggs. Grebes' diet consisted of live or freshly killed fish (Poecilia butleri and Poeciliopsis gracilis), supplemented by mealworms (Tenebrio sp.) and river shrimp (Panaeus sp.). F were also fed to the chicks until they were regularly observed

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preening and consuming their own. Fish consumption was measured for all chicks through Week 1 and for one chick through Week 7. For the first 10 days, chicks were only hand fed. Thereafter, live fish were provided to encourage independent feeding. Grebes were fed in water but for the first 2-3 weeks spent most of their time in a brood box. By 1 month of age, chicks were spending most of their time in water. Chicks were placed in sequentially larger tubs and water tanks until, at 13 months of age, 2 surviving grebes were released on an artificial pond. Body weight was the only measure of growth used. The period of most rapid growth occurred between Days 10-25. Instantaneous relative growth peaked at 22% to 33% ($\bar{x}$ = 27), Days 3-5. Grebes attained average adult weight by sex at 8-9 weeks of age and asymptotic weight during Weeks 11-14. Growth rate fluctuated widely. Birds tended to undergo spurts of rapid growth separated by periods of slowed growth.

Age of first breeding by Pied-billed Grebes is unknown. The opportunity to document age at first breeding arose during the course of this study. Courtship and breeding calls were first heard from a pair of sibling captive-reared grebes when they were approximately 11 months old. At 13-14 months of age, 2 1/2 weeks after the 2 grebes were released on an artificially-constructed pond, a nest and eggs were found in a patch of reeds (Typha domingensis). No other grebes or waterfowl inhabited the pond. The eggs had been partially destroyed by an unknown predator. Two could be accurately measured and were smaller than other Pied-billed Grebe eggs collected for this study. Fertility

of the eggs could not be determined. These observations indicated that first year Pied-billed Grebes can and will breed.

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I would also like to thank my advisers, Drs. John Ratti and Dale Hein, as well as Steve Rosenstock, for their continued support, and critical review of my work. Thanks to committee members Drs. Rick Knight and Byron Miller for their interest and input to my graduate program. Many thanks to Dr. Robert Moreng for serving on my committee, on last-minute notice.

DEDICATION

To my parents, Bob and Betty, who have always supported and encouraged all of my endeavours.

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I. INTRODUCTION

Origin of study

The common Pied-billed Grebe (Podilymbus podiceps) was the closest relative of the endangered, now extinct, Atitlan Grebe (Podilymbus gigas), endemic to Lake Atitlan, Guatemala. Atitlan Grebe numbers declined from 232 individuals in 1975 to 56 in 1985. This decline was attributed to introduction of Large-mouth Bass (Micropterus salmoides), loss of habitat, and the use of gill nets. Very little work has been done with captive grebes and no literature exists on captive breeding techniques for grebes. In 1986, with support from the International Council for Bird Preservation and the U. S. Fish and Wildlife Service, this project was undertaken to develop artificial incubation and captive techniques with Pied-billed Grebes for implementation with Atitlan Grebes.

Thesis format

This thesis consists of 3 chapters, written as manuscripts to be submitted for publication to The Auk, the International Zoo Yearbook, and the Journal of Field Ornithology. This approach was justified by the difficulty involved in extracting manuscripts from a thesis written in traditional format. Some duplication in content among chapters was unavoidable but minimized.

Description of papers

The papers are organized in chronological order. The first evaluates the effects of incubation stage at collection and water loss during incubation on the hatchability of Pied-billed Grebe eggs. The

second paper describes techniques for rearing and maintaining Pied-billed Grebes in captivity and the third reports on breeding by first year captive-reared Pied-billed Grebes.

II. EFFECTS OF WEIGHT LOSS AND INCUBATION STAGE AT COLLECTION ON HATCHABILITY OF ARTIFICIALLY INCUBATED PIED-BILLED GREBE EGGS

Weight loss of avian eggs during incubation is attributed almost exclusively to the diffusion of water vapor caused by a vapor pressure difference between the outside and the inside of the eggshell (Rahn and Ar 1974). In artificial incubation incubator humidity has been shown to affect hatchability by influencing rates of egg water loss (Lundy 1969, Rahn and Ar 1974, Birchard et al. 1982). Some water loss is necessary for formation of the air cell, which provides air to the embryo when pulmonary respiration initiates (Romanoff and Romanoff 1949). Hatching success is dependent upon "optimal" air cell size (Ar and Rahn 1980:373). At low humidity, eggs may lose too much water and dehydrate. At high humidity, eggs may not lose enough water. Wet shell membranes can obstruct embryo respiration.

In artificially incubated eggs, incubation stage at collection has also been shown to affect egg hatchability (Weaver and Cade 1983). I report the effects of egg weight loss and incubation stage at collection on hatchability of artificially incubated Pied-billed Grebe (Podilymbus podiceps) eggs.

METHODS

Twenty Pied-billed Grebe eggs were collected from 6 nests at 3 lakes in Guatemala, May-July of 1986 and 1987. Eggs were collected at varying stages of incubation. Previous observations (Glover 1953, LaBastille 1974) indicated that Pied-billed Grebes lay 1 egg per day and begin incubating once the clutch is complete. Incubation period for this species is 23 days (Palmer 1962). Based on this information,

stage of incubation at collection was determined by: a) recording the date of the first egg laid in a clutch or b) backdating after the eggs hatched. Eggs were artificially incubated at Club Auto Safari Chapin, a wild animal park, located on Guatemala's Pacific coastal plain. Eggs were incubated in a Humidaire Model 20 incubator at 35.6 C dry bulb and 34.5 C wet bulb, yielding 93% relative humidity. Incubation conditions used were based on techniques developed by Ratti (1977) for Western and Clark's grebes (Aechmophorus occidentalis and A. clarkii) and data on natural incubation conditions of Pied-billed Grebes (Davis et al. 1984).

Eggs were weighed and floated in water at collection and daily thereafter between 0730 and 0930 hours. Weight, angle of flotation, buoyancy and movement were recorded to verify incubation stage and monitor embryo development (Westerskov 1950). Egg position in water was classified into 4 stages. Initial mass of eggs collected after the onset of incubation was calculated by multiplying mean daily weight loss by 23 days (length of incubation period) and adding it to the egg weight on day 23 (or on the day of hatch if different than 23) (Rahn and Ar 1974, Birchard et al. 1982). Eggs which failed to hatch were opened to determine stage of embryo development and possible causes of death.

Differences in egg weight loss of hatched and unhatched eggs were compared with a Mann-Whitney U Test. Independence between incubation stage at collection and hatchability, and between incubation stage at collection and embryo development through pipping were tested with Fisher's Exact Test. Analyses were first conducted using data from all

eggs. In 3 subsequent analyses, potentially infertile (n = 3), damaged (n = 4), and infertile and damaged eggs (n = 7) were deleted.

RESULTS

Egg weight loss and hatchability

Daily weights of individual eggs during incubation are reported in Appendix A. Mean daily weight loss of eggs during incubation was $\bar{x}$ = -0.04 (SD = 0.02, n = 20) (Table 2.1). There were no differences in weight loss for hatched versus unhatched eggs (all P values $\geq$ 0.7).

Weights of fresh (unincubated) eggs ranged from 17.8 g to 24.2 g (n = 20, $\bar{x}$ = 20.9, SD = 1.4). Average weight loss as a percent of initial mass was 4.3 (SD = 1.79).

When placed in water, all eggs that hatched (n = 5) had risen from a horizontal (stage 1) to a vertical position (stages 3 and 4) in water (Fig. 2.1) by Day 12 of incubation. These eggs remained at stages 3 and 4 through hatching. Angle of the eggs fluctuated between 75 (stage 3) and 90 degrees (stage 4). Among the unhatched eggs, 12 achieved a vertical position between Days 11 and 21; 3 never achieved a vertical position and remained at stage 2 through Day 23 and later. None of the eggs achieved a floating stage (i.e., days 15-24, Fig. 2.2).

Fifteen eggs failed to hatch, of which 2 pipped but were dead in the shell 1 day later. Ten eggs were confirmed as fertile; all contained partially developed embryos. It is possible that 4 of these eggs were damaged (jarred) in transport. The fertility of the remaining 3 could not be determined because the eggs were decomposing and no embryo was visible. Estimated age of embryos at death ranged from 1-13 days of incubation (Table 2.2).

Stage of incubation at collection and hatchability

Eggs were collected at estimated ages of 0-11 days of incubation (Table 2.3). Thirteen eggs were collected between Days 0 and 4 (early incubation); all of these failed to pip or hatch. Seven eggs were collected between Days 8 and 11 (mid-incubation); 5 pipped and hatched successfully, 2 pipped only. In all analyses a difference (all P values ≤ 0.016) was found between stage of incubation at collection and hatchability, and between incubation stage at collection and embryo development through pipping (all P values ≤ 0.001).

DISCUSSION

Egg weight loss and hatchability

Egg weight loss was considerably less than expected when compared to reports in the literature. Based on compiled incubation data for 475 species of birds, Rahn and Ar (1974) concluded that eggs, regardless of size, lose approximately 18% of their initial weight during natural incubation. Ackerman and Platter-Reiger (1979) and Davis et al. (1984) found that naturally incubated Pied-billed Grebe eggs lost 13.3% and 16.4%, respectively, of their initial mass during a 23-day incubation period. Boone and Barmore (1965) found that water loss was the same for fertile and infertile eggs; data in this study are consistent with this report.

Generally, gradual growth of the air cell causes an egg to rise from a horizontal position in water, in pre- and early incubation, to a vertical floating position late in incubation (Westerskov 1950, Nuechterlein 1975) (Fig. 2.2). The low weight loss of eggs in this study conforms with the water test results (Fig. 2.1), i.e., air cell growth was not sufficient to cause eggs to float. Thus, these results

indicate that eggs not following the normal flotation pattern (Westerskov 1950) may hatch, and this method should be used with caution. The observed rate of water loss and poor hatchability (25%) suggested that incubator relative humidity was too high. Ar and Rahn (1980) reported that at high humidity hatchlings may die in the egg or during pipping due to inhaling liquid and suffocating, commonly referred to as "drowning" (Romanoff 1930, Ar and Rahn 1980). In this study, 2 chicks died during pipping. However, Ar and Rahn (1980) indicated that early embryo mortality, prior to lung ventilation, could not be caused by "drowning." Most embryo deaths in this study occurred in early and mid stages of incubation (prior to lung ventilation). I am not sure how reduced water loss might have affected embryos in early stages of development.

Poultry scientists have long selected for eggs that hatch successfully under constant artificial incubation conditions (R. E. Moreng, pers. comm.). In wild birds, it is possible that irregularities in natural incubation conditions have been an important selective force and are necessary for successful hatching. The constant conditions provided by artificial incubation may not have been optimal for successful hatching of Pied-billed Grebe eggs.

Stage of incubation at collection and hatchability

Weaver and Cade (1983) reported that Peregrine Falcon (Falco peregrinus) eggs placed in an incubator after receiving less than 3-4 days of natural incubation hatched at a rate of 50-60%. Eggs that were naturally incubated for the first 5-10 days, and then artificially incubated, hatched at a rate of 75-85%.

My results are consistent with Weaver and Cade's (1983) findings. Although Pied-billed Grebe eggs were not collected at all stages of incubation, my results suggested that an initial period of natural incubation increases Pied-billed Grebe egg hatchability. These data, and those of Weaver and Cade (1983) indicated that naturally laid eggs that will be hatched in an incubator should not be collected until the latter 2/3 of the incubation period.

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Table 2.1. Weight loss for hatched and unhatched Pied-billed Grebe eggs (mean, standard deviation and range), Guatemala, 1986-87.

Hatched	n	mean (g)	SD	Range (g)	
Yes	5	-0.04	0.02	-0.01	-0.06
No	15	-0.04	0.02	0.00	-0.07

Table 2.2. Estimated stage of incubation at collection, age of embryos at death, description of egg contents and possible causes of death of unhatched Pied-billed Grebe eggs, Club Auto Safari Chapin, Guatemala, 1986-87.

Egg(s)	Estimated days of incubation at collection	Estimated age (days) of embryo at death	Description of egg contents	Possible causes of death
D	11	24	Fully developed chick	Malpositioned, inadequate incubation conditions
1A	8	27	" "	" "
2A,2B,2D	4	4	Abundant yolk Embryo 1/2 cm long Eyes visible	Embryo damaged in transport
2C	4	4	Embryo 1 cm long Head, eyes, heart discernible	" "
3A	1	1-2	Embryo 1/4 cm long	Inadequate incubation conditions
3B,3D	1	12-13	Embryo 2 1/2 cm long Eyes, bill, wings, feet discernible	" "
3C	1	9-10	Embryo 2 cm long	" "

Table 2.2 (continued).

Egg(s)	Estimated days of incubation at collection	Estimated age (days) of embryo at death	Description of egg contents	Possible causes of death
4A	4	?	Decomposed yolk No embryo visible	Infertile, contaminated or inadequate incubation conditions
4B	4	4	Embryo 1 cm long	Inadequate incubation conditions
4C	4	8-9	Embryo 1 1/2 cm long	" "
5A	0	?	Decomposed yolk No embryo visible	Infertile, contaminated or inadequate incubation conditions
5B	0	?	Abundant yellow yolk No embryo visible	Infertile or inadequate incubation conditions

Table 2.3. Date, location and number of Pied-billed Grebe eggs collected at varying stages of incubation, Guatemala.

Month/Year	Lake[a]	No. eggs collected	Day of incubation at collection
7/87	AM	2	0
6/87	AM	4	1
6/87	AT	4	4
7/87	AM	3	4
5/87	AM	3	8
5/86	LP	4	11

[a]AM = Lake Amatitlan, AT = Lake Atitlan, LP = Laguna del Pino.

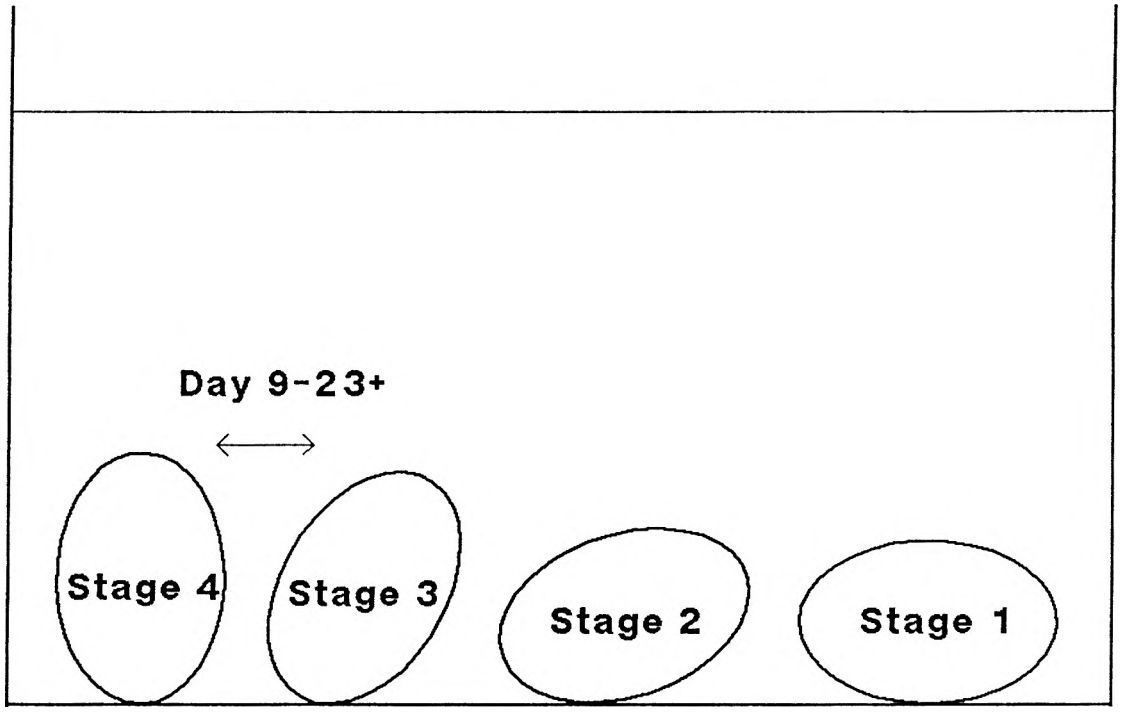

Fig. 2.1. Incubation stages of Pied-billed Grebe eggs by flotation, Guatemala, 1986-87.

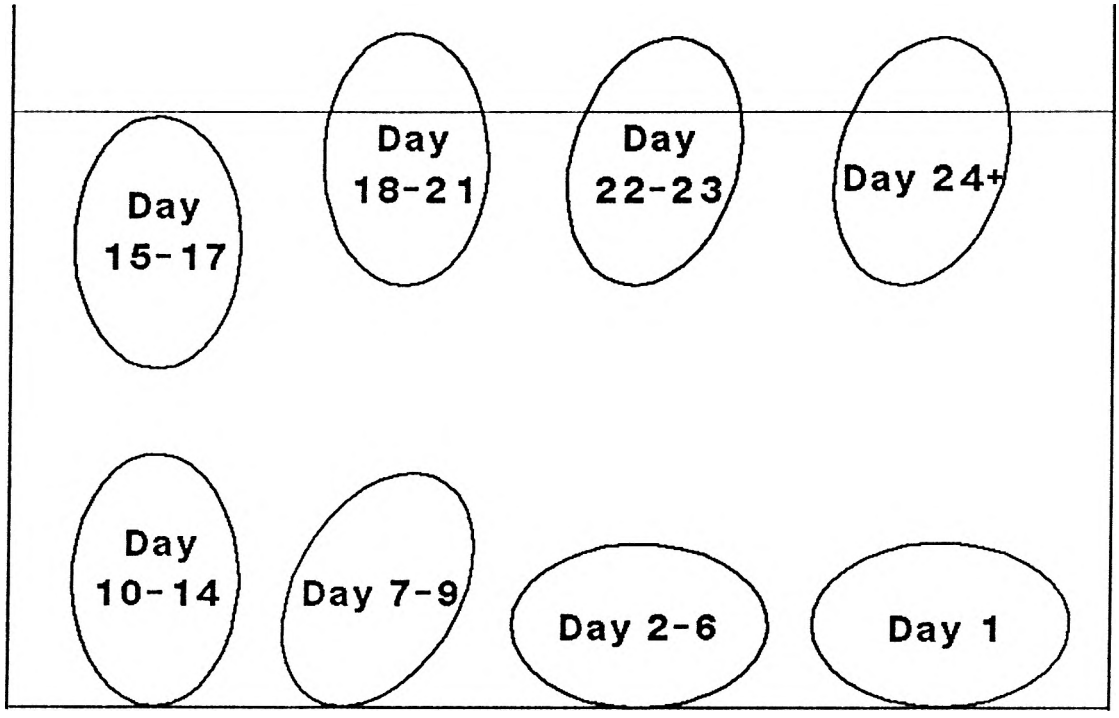

Fig. 2.2. Incubation stages of Western Grebe eggs by flotation (After Nuechterlein 1975).

APPENDIX A

Pied-billed Grebe egg weights during artificial incubation, Club Auto Safari Chapin, Guatemala, 1986-87

Table A.1. Pied-billed Grebe egg weights, days 1-23 of artificial incubation, Club Auto Safari Chapin, Guatemala, 1987.

Day of Incubation	Egg Weight (g)					
	3A	3B	3C	3D	5A	5B
1	20.7	24.2	21.9	22.8	22.6	19.3
2	20.6	24.2	21.9	22.8	22.5	19.1
3	20.6	24.0	21.7	22.6	22.4	18.9
4	20.6	24.0	21.8	22.7	22.5	18.9
5	20.5	23.9	21.7	22.7	22.5	19.0
6	20.5	23.9	21.6	22.5	22.4	19.0
7	20.5	23.9	21.6	22.6	22.5	19.1
8	20.5	23.9	21.7	22.7	22.4	19.0
9	20.4	23.8	21.5	22.5	22.3	18.9
10	20.4	23.8	21.6	22.5	22.2	18.8
11	20.4	23.8	21.5	22.5	22.1	18.8
12	20.2	23.7	21.4	22.4	-	-
13	20.2	23.6	21.4	22.4	22.2	18.8
14	20.2	23.5	21.4	22.3	22.2	18.8
15	20.1	23.4	21.4	22.3	22.1	18.7
16	20.1	23.3	21.3	22.2	22.1	18.7
17	20.1	23.3	21.3	22.1	22.0	18.8
18	20.0	23.3	21.2	22.0	22.0	18.7
19	19.9	23.1	21.1	22.0	22.0	18.7
20	20.0	23.2	21.2	22.1	22.1	18.7
21	19.9	23.1	20.9	21.9	22.1	18.6
22	19.9	23.0	20.9	21.9	22.1	18.8
23	19.8	23.0	20.8	21.7	21.9	18.6

Table A.2. Pied-billed Grebe egg weights, days 4-23 of artificial incubation, Club Auto Safari Chapin, Guatemala, 1987.

Day of Incubation	Egg Weight (g)						
	2A	2B	2C	2D	4A	4B	4C
4	20.2	20.5	20.0	17.7	20.0	20.2	22.0
5	20.2	20.7	20.2	17.7	19.5	20.1	21.8
6	20.2	20.6	20.0	17.8	19.4	20.0	21.7
7	20.1	20.4	19.9	17.6	19.4	20.0	21.8
8	20.1	20.4	20.0	17.6	19.4	20.0	21.8
9	20.0	20.4	19.9	17.6	19.3	20.0	21.8
10	20.0	20.4	19.9	17.6	19.3	20.0	21.7
11	20.1	20.5	20.0	17.6	19.3	19.9	21.7
12	20.1	20.5	19.9	17.5	19.1	19.8	21.5
13	20.0	20.4	19.8	17.4	19.1	19.8	21.4
14	20.0	20.4	19.8	17.4	19.0	19.8	21.4
15	20.0	20.4	19.7	17.4	-	-	-
16	19.9	20.3	19.6	17.3	19.0	19.7	21.3
17	19.8	20.3	19.6	17.2	18.9	19.7	21.4
18	19.7	20.2	19.5	17.1	18.9	19.7	21.4
19	19.7	20.3	19.6	17.1	18.9	19.6	21.3
20	19.7	20.2	19.4	17.1	18.9	19.6	21.3
21	19.6	20.1	19.4	17.0	18.7	19.6	21.2
22	19.5	20.1	19.3	16.9	18.8	19.6	21.2
23	19.5	20.0	19.2	16.9	18.7	19.6	21.2

Table A.3. Pied-billed Grebe egg weights, days 8-23 and 12-23 of artificial incubation, Club Auto Safari Chapin, Guatemala, 1986-87.

Day of Incubation	Egg Weight (g)						
	1A	1B	1C	A	B	C	D
8	22.0	21.3	20.5				
9	22.0	21.3	20.6				
10	21.9	21.1	20.5				
11	21.9	21.2	20.5				
12	21.9	21.1	20.4	20.8	19.5	18.9	19.0
13	-	-	-	20.7	19.4	18.8	18.9
14	21.8	21.0	20.4	20.8	19.4	18.8	18.9
15	21.8	21.0	20.4	20.7	19.3	18.8	18.9
16	21.8	21.0	20.4	20.7	19.3	18.7	18.8
17	21.8	21.0	20.4	20.6	19.2	18.7	18.7
18	21.8	21.1	20.3	20.5	19.1	18.6	18.7
19	21.9	21.2	20.4	20.6	19.1	18.6	18.7
20	-	-	-	20.5	19.1	18.5	18.7
21	22.0	21.4	20.5	-	-	-	-
22	22.0	21.2	20.4	20.3	a	18.3	18.5
23	-	21.3[a]	a	20.2		a	18.5
24				a			

[a]Chick hatched.

III. CAPTIVE-REARING TECHNIQUES FOR PIED-BILLED GREBES

Many podicipediform species are declining (D), threatened (T) or endangered (E) (King 1981, Fjeldsa 1984 and unpubl. data). Among these are the Madagascar Grebe (Tachybaptus ruficollis) (D), the Madagascar Red-necked Grebe (T. rufolavatus) (T), the New Zealand Dabchick (Poliocephalus rufipectus) (T) and the Junin Grebe (Podiceps taczanowskii) (E) of Peru. Over the past 2 decades, captive breeding has become an important strategy used when wild populations are threatened with extinction.

Work with captive podicipediformes has been limited to 3 species. Hick (1966) and Kop (1972) hand-reared Great Crested Grebes (Podiceps cristatus) from artificially incubated eggs. Hick (1966) successfully reared 2 chicks through at least 2 months of age. Kop (1972) reared 5 chicks, 2 chicks through 11 days of age and 3 through 9-11 weeks of age. Herman (1974) artificially incubated and hatched 3 Western Grebe (Aechmophorus occidentalis) eggs and collected 3 Western Grebe hatchlings in the wild. The 6 chicks were reared successfully through at least 4 months of age. Two were released in the wild at an age of 14-15 months. Ratti (1977) successfully reared 7 Western and Clark's grebes (Aechmophorus clarkii) from eggs collected in the field, through 9-12 weeks of age. No literature exists on captive breeding techniques for grebes.

This study was aimed at developing captive-rearing and maintenance techniques with common Pied-billed Grebes (Podilymbus podiceps), to implement with the then-endangered Atitlan Grebe (Podilymbus gigas).

Although a few individuals may still remain, the Atitlan Grebe was recently declared extinct (L. Hunter, pers. comm.). Given the precarious status of several other grebe species, techniques developed in this study may prove useful in future recovery efforts.

METHODS

Pied-billed Grebe chicks (n = 5) were reared from artificially incubated eggs (Chapter II). Chicks were reared at Club Auto Safari Chapin, a wild animal park, located on the Pacific coastal plain of Guatemala, at an elevation of approximately 150 m.

Dry chicks were removed from the incubator and weighed to the nearest 0.1 g. Chick weights were recorded daily, between 0730 and 1000 hours, for the first 2 months of the rearing period, and weekly, biweekly or monthly thereafter. Body weight was the only measure of growth used in this study.

Brooding

Chicks were placed in a plastic brood box, 60 cm x 30 cm x 45 cm, kept at 35-37 C. The bottom of the box was padded with a layer of cotton overlaid by flannel, toweling and thin cotton material. Brood box bedding was washed daily or as often as necessary. Hot water bottles were placed in the padding for the first week. A brood lamp (2-3 60-watt light bulbs) was hung over one end of the box and could be raised and lowered to regulate box temperature. Brooding temperature was gradually lowered to ambient temperature (27-35 C), guided by the chicks' response to heat.

Time and activities in water

Thirty to 60 minutes after leaving the incubator, chicks were offered water and placed in a small tub of lukewarm water to stimulate defecation (Ratti 1977). While chicks were spending most of their time in the brood box, defecation was induced every 2 hours during the day and 1-2 times during the night. On Day 1, drinking was encouraged by dipping the birds' beaks in water. During the first 3 days, chicks were placed in water only long enough to stimulate defecation (15-60 seconds). Beginning on Day 4, chicks were placed in water for part of each feeding session. After the first week, time spent in water was extended to several minutes and gradually lengthened until chicks were spending the entire day in water. During the first 3 weeks, chicks were not left unattended in water.

The first week, chicks were placed in a 38-cm diameter plastic tub. The second week, a 75-cm x 45-cm x 13-cm tub was used. The third week, chicks were introduced into a 2000 l water tank (2 m diameter, 90 cm deep) or a 500 l tank (approximately 0.7 m^2, 0.7 m deep). A screened lid was placed over the tanks to deter predators when chicks were left unattended. At approximately 6-9 weeks of age, the chicks were transferred to a cement pool (5 m x 2 m x 1 m) with water inlets and outlets which insured constant water flow. One third of the pool was roofed to provide cover against rain and wind. Chicken wire fencing enclosed the pool to exclude predators.

Behavior

Behavioral observations were not a major emphasis of this study. However, I recorded chick behavior during the rearing period.

Diet and Feeding

The grebes' diet consisted of fish (Poecilia butleri and Poeciliopsis gracilis), supplemented by mealworms (Tenebrio sp.) and river shrimp (Penaeus sp.). This diet was based on food habits data reported by Palmer (1962) and Borrero (1971). Chicks also received feathers daily until they were regularly observed preening and consuming their own feathers.

Three to 5 hours after leaving the incubator, chicks were offered 1-2 feathers (duck breast down) and small boneless pieces (approximately 0.1 g) of fresh fish. Mealworms (Tenebrio sp.) were raised using methods described by Peterson (1964) and fed to the chicks at least once per day for the first 3-4 weeks, and 3-4 times per week thereafter. When available, river shrimp were fed to the grebes 3-6 times per week.

For the first 7 days, food was offered every 1-2 hours between 0600 and 2200 hours. After the first week, feeding intervals were extended to 1.5-2.5 hours. By the third week, chicks were fed at 2 to 3 hour intervals between 0600 and 2000 hours. Chicks were always fed until satiated.

Except for the first 3 days, when chicks received pieces of freshly killed fish, chicks were fed only live whole fish to avoid problems with thiamin (vitamin B1) deficiencies, commonly associated with feeding dead fish (Robbins 1983). As a preventive measure, a multiple vitamin supplement (Euravit, TAD) was administered in fish, at recommended doses by bird weight, 2 to 3 times per week for the first 2 weeks.

Fish fed to the grebes during the rearing period were grouped into 5 length classes. Fish were weighed to the nearest 0.1 g to obtain mean wet weight of each class. Fish quantities consumed by chicks were recorded for each chick at each meal through Day 7, and for chick #4 through Day 51. Mealworm and shrimp quantities consumed were not measured. For the first 10 days, chicks were hand fed. Thereafter, live fish were provided to encourage independent feeding, supplemented by hand feeding, if necessary. Some hand feeding continued throughout the rearing period.

Release of birds

At 13 months of age, 2 grebes reared in 1986 were released on an artificial pond (approximately 100 m^2) on the ASC. The birds' primary and secondary flight feathers were clipped prior to release. The perimeter of the pond was fenced to help exclude terrestrial predators. Reeds (Typha domingensis and Scirpus californicus) planted in 1985 and 1986 provided cover for resting and nesting. A stream which flows into and out of the pond provided a constant supply of fish. No other grebes or waterfowl inhabited the pond. Although fish were plentiful in the pond, the birds now had to catch fish in a much larger area and in very murky water. In order to ease the transition and supplement the birds' feeding efforts, they were provided with live fish, twice daily. This supplemental feeding was continued throughout their time in the pond.

RESULTS AND DISCUSSION

Brooding and activities in water

For the first 3 weeks, chicks spent most of their time in the brood box. Week 1, box temperature was maintained at 35-37 C, as suggested

by the Humidaire Co. (unpubl. data). Week 2, box temperature was lowered to 32-35 C. Chicks were also able to self-regulate their heat level by approaching or moving away from the brood lamp. By Week 3, chicks could tolerate ambient temperatures. Thereafter, the brood lamp was used only occasionally to warm a wet, chilled chick.

Special care was taken to provide a cushioned brooding area. It is possible for grebes, and other aquatic birds, to develop breast and leg ulcers if maintained out of water for prolonged periods of time without adequate supportive padding (Stoskopf and Kennedy-Stoskopf 1986). Initially, chicks were placed directly on flannel, underlaid by toweling and cotton. On several occasions, however, flannel lint had to be removed from chicks' eyes and chicks were observed pecking at loose strings in the toweling. Henceforth, chicks were placed directly on thin cotton material that did not lint or unravel.

For the first 3-4 weeks, rest periods in the brood box seemed important for proper thermoregulation and feather care. Through Week 3, birds were carefully monitored when in water and removed at any signs of stress (e.g., vocalizations, loss of buoyancy, attempts to jump out, or aggression).

Beginning Week 4, birds became increasingly intolerant of confinement (e.g., the brood box) and began spending most of their time in water. From this point on, chicks were only removed to the brood box to allow them to dry before being weighed.

Behavior

Grebes are considered precocial birds (Nice 1962, Welty 1982). Although grebe hatchlings resemble precocial species (i.e., they are feathered, have their eyes open and some ability to swim or crawl),

behaviorally they more closely resemble altricial species (e.g., grebe hatchlings will drown if left unattended in water (Ratti 1977) and are fed by their parents for several weeks to months). I list a chronology of important behavioral observations in Appendix B.

Diet and Feeding

One to 3 down breast feathers, obtained from a live muscovy duck (Cairina moschata), were fed daily to chicks. It has long been known that grebes ingest feathers (Wetmore 1920, 1924). Lawrence (1950) suggested that in Western Grebes, the feather mass speeds up digestion. Feathers may also comprise the rough material necessary to encase or eject indigestable items (e.g., fish bones and scales) (Simmons 1956). Herman (1974) reported that the initial feeding of feathers increased Western Grebe neonate survival. Ratti (1977) also fed feathers to neonate Western Grebes. On Day 2 (Day 1 = day of hatch), chicks in this study were observed attempting to preen. Day 4, chicks appeared to be preening and consuming feathers regularly. In 1986, feather feeding was discontinued after Week 1. In 1987, as a precaution (J. Ratti, pers. comm.), feather feeding was continued through Week 4. During Week 1, feathers were not easy to administer. Chicks took no interest in eating hand-offered feathers. However, feathers were consumed when wrapped around a piece of fish and moistened.

Days 1-3, chicks were fed boneless pieces of fresh fish or very small whole live fish of length class 1. As chicks matured they consumed larger fish (Table 3.1). Between Days 1 and 7, average daily fish consumption per chick (n = 4) increased from 1.8 g to 13.0 g (Fig. 3.1). Mean daily fish consumption, as a percent of chick body weight, ranged from 12% on Day 1 to 36% on Day 7 (Fig. 3.2). Daily fish

consumption of chick #4, days 8-51, peaked at 129 g on Day 41 (Fig. 3.3). Fish consumption of chick #4, as a percent of body weight, for this period, peaked at 59% on Day 14 (Fig. 3.4). Although relative fish consumption dropped after 14 days of age, absolute fish consumption continued to increase. By Day 30, most chicks were eating largely unaided.

Pellet ejection was observed in 1 chick on Day 17 and in 3 others on Day 80. Hand-reared Great Crested Grebes (Kop 1972) ejected pellets as early as 17 days after hatching. Chitin and vegetable matter, the latter ingested incidentally in fish stomachs or attached to other food items, probably cannot be thoroughly digested by grebes (Storer 1961). Storer (1961) suggested that it is these types of materials that form the bulk of grebe pellets. Grebe pellets in my study consisted primarily of feathers, although chitinous shrimp and mealworm remains were also present; fish bones or scales were never detected. Kop (1972) never observed fish bones in the pellets of Great Crested Grebes raised on fish and insects. From the age of 34 days, Great Crested Grebes ejected pellets approximately every 2 days (Kop 1972). Grebes in my study were not observed to eject pellets on a regular basis. Storer (1961) concluded that pellet-casting is probably more frequent in grebes feeding on insects and other invertebrates than it is in those feeding on fish.

Growth and Development

Weights of chicks throughout the rearing period are presented in Appendix C. Average chick weight at hatching was 14.9 g (Table 3.2). Day 2, chicks #1-4 each lost an average of 1.0 g (range = 0.3-1.9, SD = 0.82); chick #5 gained 0.5 g (chick #5 died on Day 2 and is therefore

excluded from the remainder of this section). On Day 3, chicks #1-4 each gained an average of 2.5 g (range = 0.8-3.6) and more than compensated for the previous weight loss. By Day 7, all chicks had more than doubled their weight at hatching.

The period of most rapid growth, as measured by gross gain in body weight, occurred between Days 10-25 (Fig. 3.5). Instantaneous relative growth, which shows growth at a given time in relation to body weight (Brody 1945:508), peaked at 22% to 33% ($\bar{x}$ = 27, SD = 4.6) on Days 3-5, and then declined (Fig. 3.6).

All grebes required 30 to 48 days ($\bar{x}$ = 39, SD = 7.9), between Days 6 and 55, to increase from 10% of average adult weight (by sex) to 90% of average adult weight. Three of the 4 grebes achieved average adult weight at 8-9 weeks of age. Chick #4 experienced severe weight loss during Weeks 12-14, and achieved average adult weight Week 33 (Table 3.3 and Fig. 3.7).

Grebes #2 and #3 required 51 and 47 days, respectively; between Days 7 and 59, to increase from 10% of asymptotic weight to 90% of asymptotic weight. Asymptotic weight, as used in this discussion, refers to the maximum weight attained during the rearing period. Birds achieved asymptotic weight during Weeks 11-14 (Table 3.3). Following attainment of asymptotic weight, birds lost weight (Fig. 3.7). Weight recession has been documented in many species of birds, including captive-reared Western Grebes (Herman 1974), where the weight of young increases to a peak above average adult weight and then decreases prior to fledging (Ricklefs 1968). Western Grebes (Herman 1974) and Pied-billed Grebes exhibit no obvious fledging. Age of independence in wild Pied-billed Grebes has been documented at 6-8 weeks of age (LaBastille

1974). Weight loss following attainment of asymptotic weight in birds in this study occurred several weeks after documented age of independence. Asymptotic weights of grebes in this study were 7% to 8% higher than average adult weight. Over a period of 45-49 weeks following attainment of asymptotic weight, bird weights averaged 6% lower than average adult Pied-billed Grebe weight (Table 3.3).

Chick growth rate (net daily change in weight) fluctuated widely, ranging from -16.7 to 23.5 g (Fig. 3.8). Grebes tended to undergo spurts of rapid growth separated by periods of slowed growth. Growth rate and absolute fish consumption (Fig. 3.3) peaked on Day 41 for chick #4. Kahl (1972) observed considerable fluctuations in day-to-day food consumption in captive-reared Wood Storks (Mycteria americana) which corresponded to fluctuations in growth rate. Herman (1974) noted that feeding and growth rates of captive-reared Western Grebes fluctuated and cycled within certain limits. In the presence of an unlimited food supply, captive birds in several other studies (Kahl 1962, Junor 1972, Herman 1974), also tended to "overeat" for 1 or 2 days, and then undergo a seemingly compensatory loss of appetite in the following 1 or 2 days (Fig. 3.3). The ability to overeat is probably advantageous in nature because it allows the animal to exploit a temporarily abundant food supply and then survive intervening periods of food scarcity (Kahl 1962). Herman (1974) speculated that an animal evolutionarily unprepared for long term food surpluses (as provided in these studies), but able to exploit a temporarily abundant food source, would likely eat until physiologically sated. The animal would then subsist on stored energy until some threshold of hunger was reached and feeding behavior was again triggered (Herman 1974).

Health

Prior to the attainment of peak weight, all chicks experienced weight losses of varying magnitude (Figs. 3.5 and 3.7). A change in environment was associated with initiation of weight loss. All chicks developed a severe loss of appetite when transferred from the tank to the larger concrete pool. Chicks #1-3 lost 10-13 g each (3-4% of body weight) over the course of a week. Chick #4 lost approximately 100 g (31% of body weight) over a 2-week period. Following the recommendations of an avian pathologist (Elizabeth de Motta, pers. comm.), each chick was administered 50 mg each of tetracycline and a multiple vitamin supplement, daily, for 10 days. The antibiotic and vitamins were dissolved in water, the solution injected into fish, and fed to the chicks. After 2-3 days of undergoing medication, chicks' appetites began to increase. By the eighth day of treatment, chicks #1, #2, and #3 had regained the lost weight. Chick #4 continued to lose weight throughout most of the treatment but had regained the lost weight 3-4 weeks after the treatment ended. Although chicks' appetites increased after initiating the treatment, in general, they consumed less food than prior to transfer to the pool. This period of weight loss occurred after peaks in food consumption and shortly prior to attainment of asymptotic weight. Weight loss at this time may have delayed attainment of asymptotic weight. Bird weights declined after attaining asymptotic weight and then stabilized at a weight somewhat lower than average adult weight by sex.

Survival

Of 5 chicks that hatched, only 1 (chick #5) died at an early age (i.e., $\leq$ 20 days). Day 2, at 1500 hours, approximately 1 hour since

the last meal, chick #5 began to behave abnormally. Up until this time, the chick had been eating as much and acting as energetic as the other chicks. However, it was evident by the frequent cheeping and body convulsions, that the chick was distressed. A mealworm was found caught in the chick's throat and removed. The cheeping and convulsions, now accompanied by fluttering of the wings, became more frequent (approximately every 3-5 sec). At 1830 hours, a low dose of tetracycline and vitamins was administered to the chick in a dropper. The chick became more and more lethargic and died at 1930 hours.

The night of Day 60, chick #1 was killed by an unknown predator. The bird had fallen out of the cement pool due to a heavy rainstorm which caused the water outlet to clog with debris and the pool to overflow.

Chick #3's decapitated carcass was found on Day 407 on the shore of the pond. Chick #2 disappeared from the pond 2 months later, at approximately 16 months of age. His fate is not known.

CONCLUSIONS

I have demonstrated that it is possible to rear and maintain Pied-billed Grebes in captivity. Diet and feeding regimes used seemed appropriate. In general, birds were healthy and behaved normally. Growth patterns were similar to those observed in captive Western Grebes and in several other captive bird studies.

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Table 3.1. Wet weight of fish (mean, standard deviation and coefficient of variation), by length classes used to calculate fish consumption by captive Pied-billed Grebe chicks, and chick age at which length class was first fed, Club Auto Safari Chapin, Guatemala, 1986-87.

Class	Length (cm)	n	Mean wet weight (g)	SD	CV	Age (days) of first feeding
1[a]	≤2.5	32	0.13	0.04	0.3	1
2	2.6-3.5	66	0.30	0.10	0.3	4
3	3.6-4.5	66	0.73	0.22	0.3	8
4	4.6-5.5	52	1.60	0.35	0.2	12
5	5.6-6.5	39	2.35	0.49	0.2	15-18

[a]this category includes whole fish and boneless pieces of fish.

Table 3.2. Pied-billed Grebe chick weights at hatching as a percent of egg and adult weights, Club Auto Safari Chapin, Guatemala, 1986-87.

Egg	Chick	Chick weight at hatching (g)	Percent of egg weight	Percent of adult weight[a]
B	1	14.1	74	4
C	2	13.3	73	3
A	3	15.9	79	5
1C	4	16.2	79	5
1B	5	14.9	70	4
Range		13.3-16.2	70-79	3-5
Mean		14.9	75	4

[a]Mean adult weight for male (443 g) or female (343 g) used if sex of bird known; mean adult weight of 393 g used if sex unknown.

Table 3.3. Number of days to attain adult weight and asymptotic weight, and average weight following attainment of asymptotic weight for 4 captive-reared Pied-billed Grebes, Club Auto Safari Chapin, Guatemala, 1986-87.

Grebe	Sex[a]	No. days to mean adult weight[b]	No. days to asymptotic weight	Asymptotic weight (g)	Mean grebe weight following asymptotic weight (g)
1	F	60	-[c]	-	-
2	M	59	93	480.5	415.0
3	F	55	71	367.5	324.1
4	F	232	232[d]	339.0[e]	-

[a]Sex determined based on weight (Palmer 1962) and/or behavioral observations (LaBastille 1974).
[b]Mean adult female weight = 343 g, mean adult male weight = 443 g (Storer, pers. comm.).
[c]Asymptotic weight not achieved due to chick mortality.
[d]Last day chick weight recorded.
[e]Last weight recorded; may not reflect asymptotic weight. See Fig. 3.7, female (#4) growth curve.

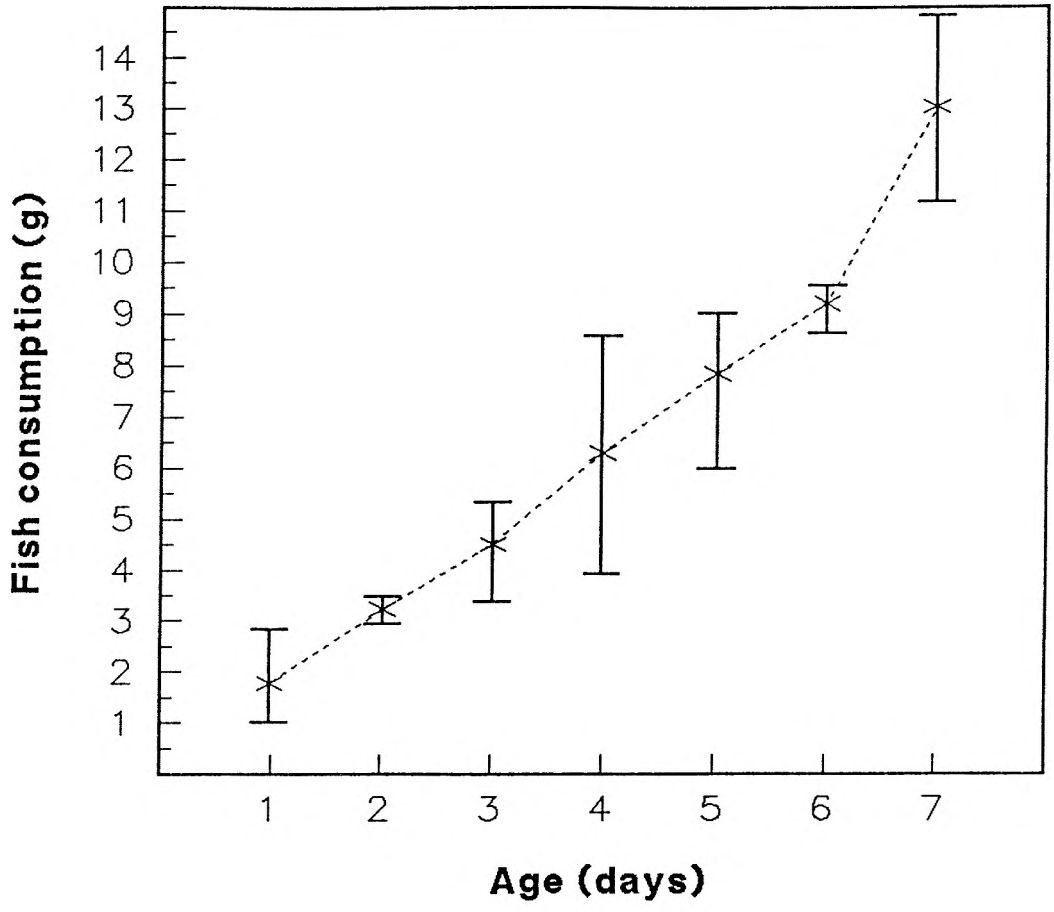

Figure 3.1. Daily fish consumption (mean, range) of 4 captive-reared Pied-billed Grebes, days 1-7, Auto Safari Chapin, Guatemala, 1986-87.

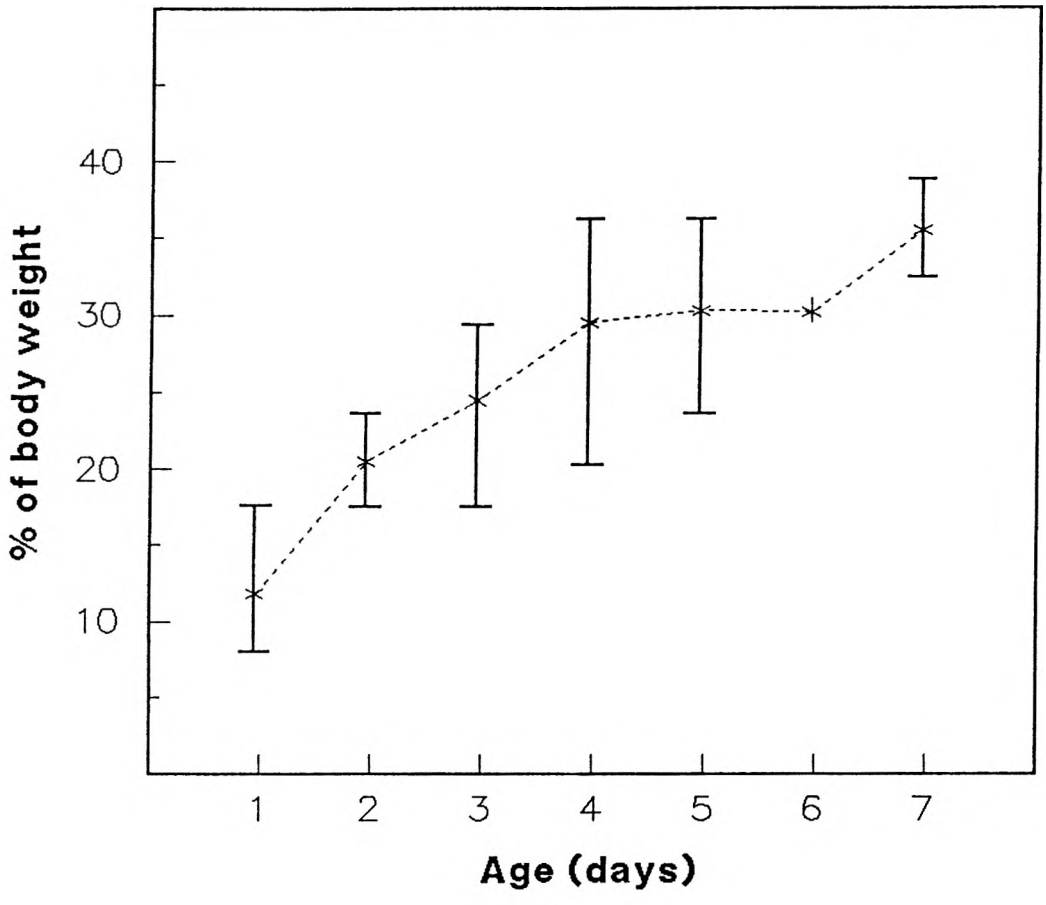

Figure 3.2. Fish consumption (mean, range) as a percent of body weight of 4 captive-reared Pied-billed Grebes, days 1-7, Auto Safari Chapin, Guatemala, 1986-87.

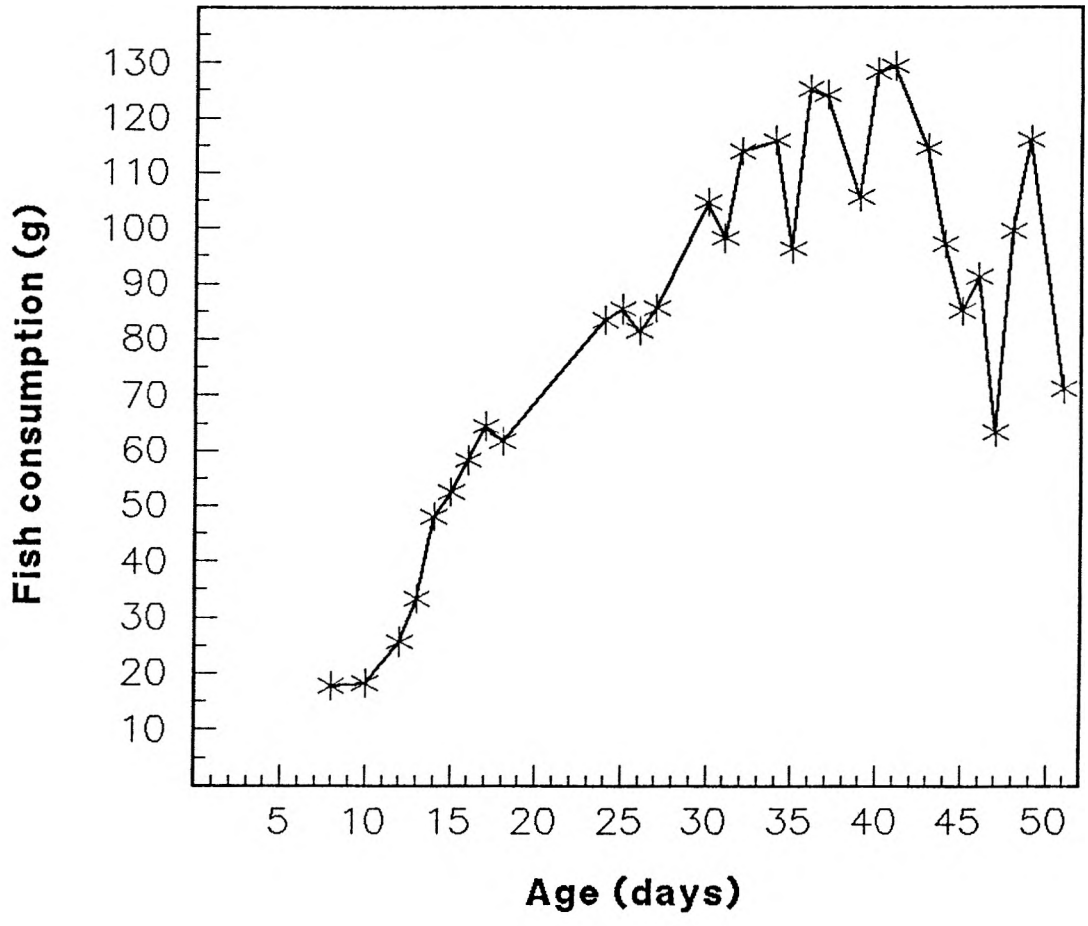

Figure 3.3. Fish consumption of captive-reared Pied-billed Grebe chick #4, days 8-51, Auto Safari Chapin, Guatemala, 1986-87.

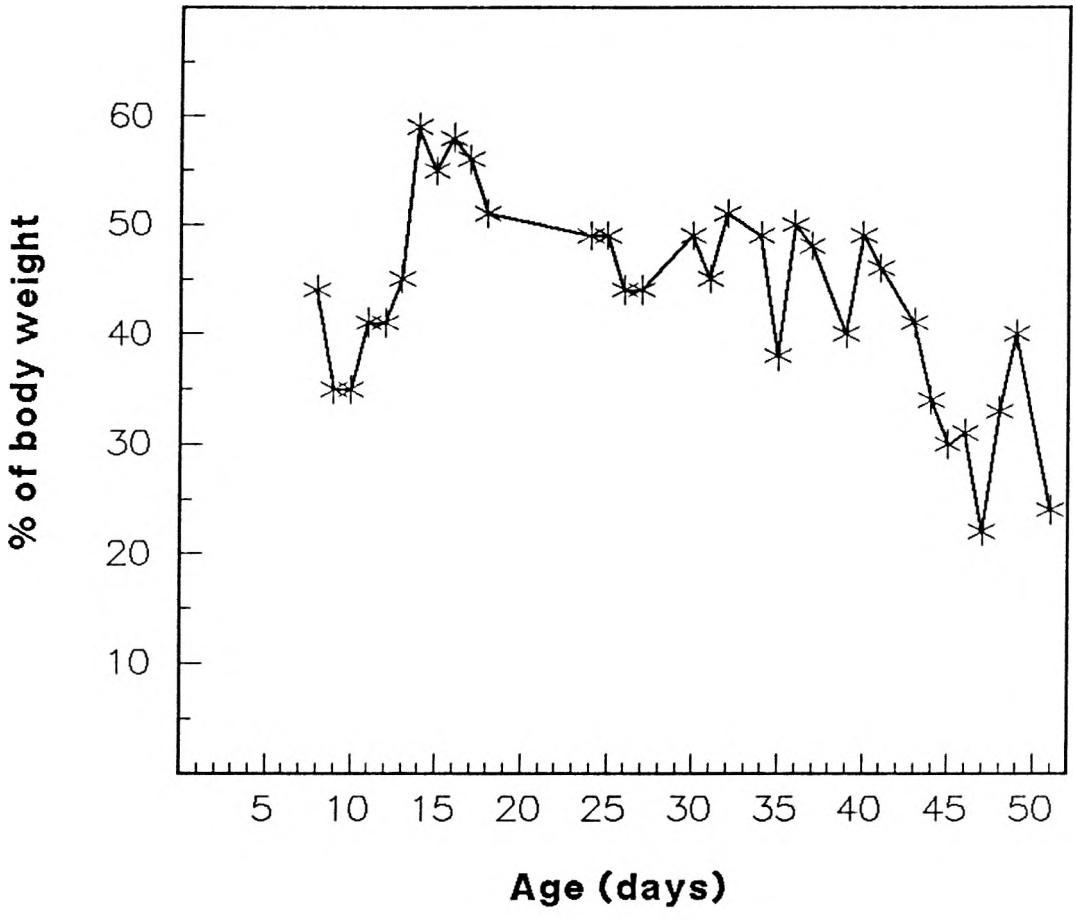

Figure 3.4. Fish consumption, as a percent of body weight, of captive-reared Pied-billed Grebe chick #4, days 8-51, Auto Safari Chapin, Guatemala, 1986-87.

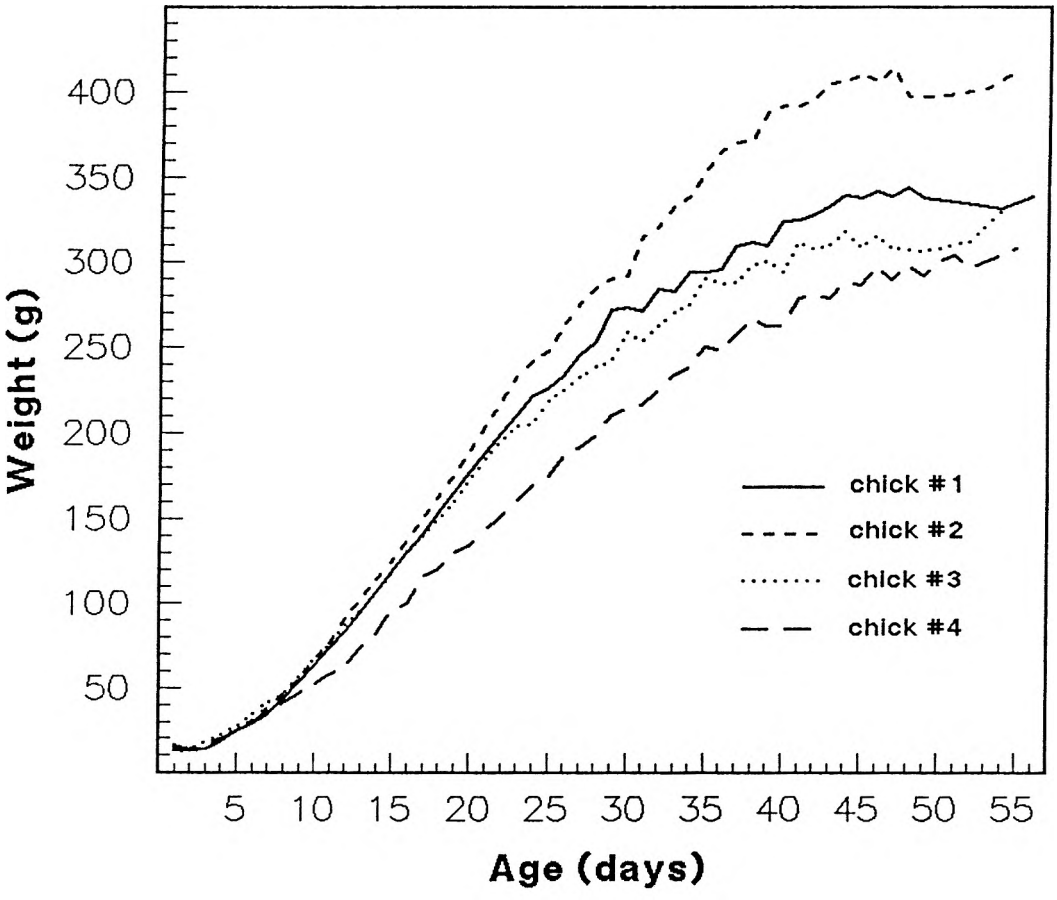

Figure 3.5. Weight growth of 4 captive-reared Pied-billed Grebe chicks, days 1-56, Auto Safari Chapin, Guatemala, 1986-87.

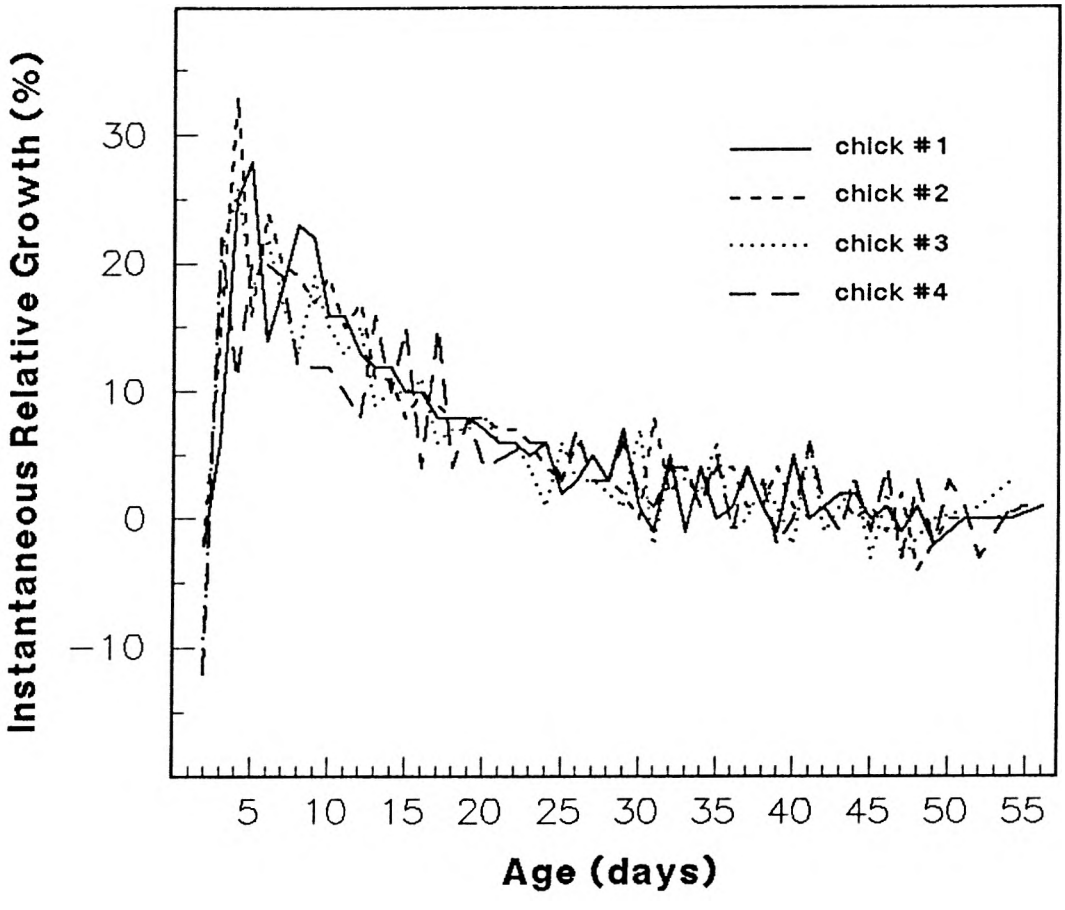

Figure 3.6. Instantaneous relative growth of 4 captive-reared Pied-billed Grebe chicks, days 1-56, Auto Safari Chapin, Guatemala, 1986-87.

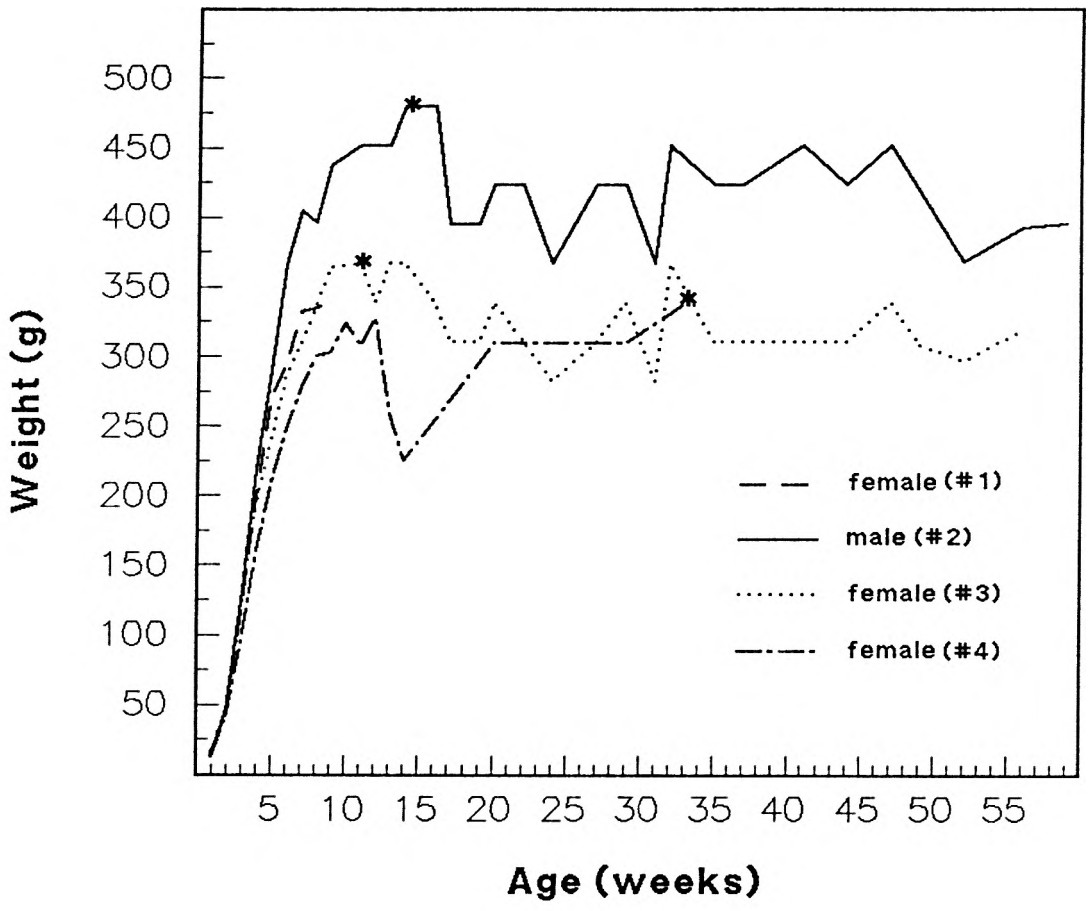

Figure 3.7. Growth curves for 4 captive-reared Pied-billed Grebes, Weeks 1-59, Auto Safari Chapin, Guatemala, 1986-87. Asterisks indicate asymptotic weights for chicks #2, #3 and #4.

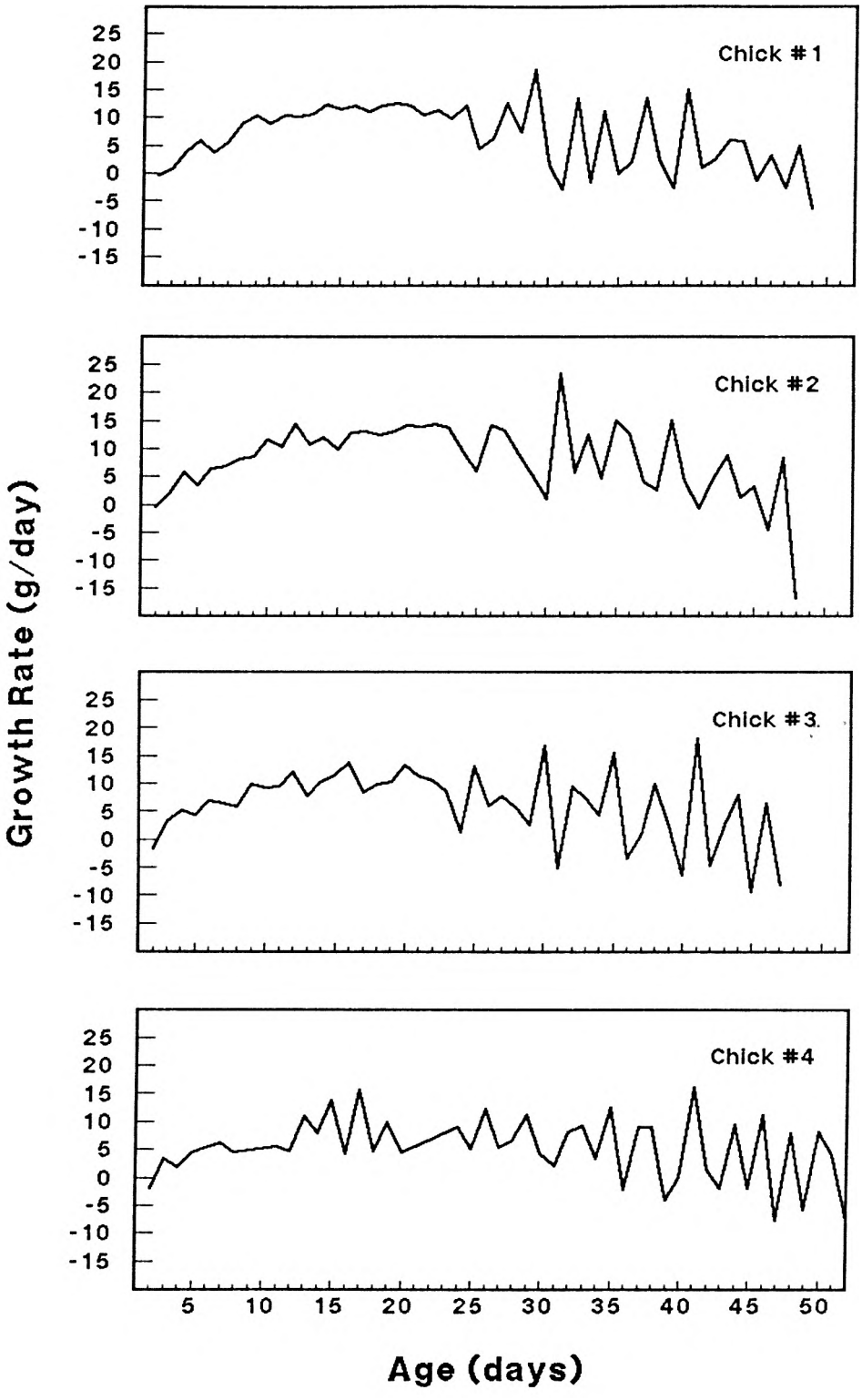

Figure 3.8. Growth rate (daily change in weight) of 4 captive-reared Pied-billed Grebes, days 2-52, Auto Safari Chapin, Guatemala, 1986-87.

APPENDIX B

Chronology of behavioral observations

Table B.1. Behavioral descriptions of captive-reared Pied-billed Grebes, days 1-85, Club Auto Safari Chapin, Guatemala, 1986-87.

Age (Days)	Description of behavior
1	Active and restless in brood box, frequent vocalizations. Poor buoyancy. Difficult to feed, i.e., have poor aim.
2	First attempts at preening. Buoyancy and swimming greatly improved.
3	Consumed first whole fish (2.5-3.5 cm). Time spent in water increased to > 1 minute. First attempts at diving. Easier to feed.
4	Preening regularly. Begin some feeding in water. "Comfort moves"[1] in water.
4-6	Looking for fish in water. Show interest in insects around and on water. Increasing ability to handle whole fish.
6-8	Feeding all meals in water. Diving regularly.
7-9	Spending up to 10 minutes in water at a time.
8-10	Begin chasing live fish and insects.
10-12	First successful attempts at catching live fish and insects in water.

[1]Behavioral terminology (in quotes) after LaBastille (1974).

Table B.1 (continued).

Age (Days)	Description of behavior
12	Chasing fish which won't consume (i.e., for the fun of it).
13	When relaxed or sleeping, in and out of water, chicks tuck their feet up under their wings.
15-16	Spending 20-30 minutes in water at a time. Consuming larger fish (4.5-7 cm). Chicks trying to climb on each other's backs while in water (want to be backbrooded?).
17	First observation of pellet regurgitation.
16-18	All chicks lost egg tooth. Eating feathers regularly.
19-21	Introduced into a larger tank. Deeper diving. Low tolerance for confined spaces. Spending most of the day in water.
26-28	Easily frightened- instinct is to dive; have observed "accordion" (alarm) dives. First serious aggression. Begin leaving in water day and night.
29-31	Capture efficiency improving. Independent feeding increasing. Chicks often decapitate fish before consuming them. Underwater interactions observed: acknowledge each other, chase fish, swim and emerge together.
32-34	All food is administered in water. Stop feeding after 1830 hours (lose interest in food after dusk). Aggression in water- larger chick bullies others.
36-40	Spend most of the day playing- with each other, with leaves, flowers, light reflections, etc. Constantly retrieving things off the bottom.
43-45	Increasingly difficult to catch (e.g., to weigh).
44-46	Transferred to cement pool.

Table B.1 (continued).

Age (Days)	Description of behavior
45-48	Appetites low (eating < 1/2 of normal)- adjusting to a new environment? Will eat shrimp and mealworms but not fish. Have observed chicks "pitter-pattering" across the length of the pool.
47-49	Sleeping a lot, not chasing fish. Begin administering tetracycline and vitamin supplement.
49-51	Appetites improving. Eating fish again.
52	One of the chicks still seems to need some time out of water.
60	All chicks feeding independently.
85	One chick observed attempting to fly.

APPENDIX C

Weights of captive-reared Pied-billed Grebes, days 1-440, Club Auto Safari Chapin, Guatemala, 1986-87

Table C.1. Weights of captive-reared Pied-billed Grebe chicks #1, #2, #3, #4 and #5, days 1-60, 1-440, 1-389, 1-232 and 1-2, respectively, Club Auto Safari Chapin, Guatemala, 1986-87.

Age (Days)	Chick Weight (g)				
	#1	#2	#3	#4	#5
1	14.1	13.3	15.9	16.2	14.9
2	13.8	13.0	14.4	14.3	15.4[a]
3	14.6	15.1	17.7	17.9	
4	18.7	21.0	23.0	20.0	
5	24.7	24.6	27.5	24.5	
6	28.5	31.2	34.4	29.9	
7	34.2	38.1	40.9	36.3	
8	43.2	46.3	46.8	40.8	
9	53.6	54.9	56.8	-	
10	62.6	66.5	66.2	52.2	
11	73.2	76.9	75.7	57.9	
12	83.5	91.4	87.7	62.8	
13	94.3	102.3	95.6	73.8	
14	106.7	114.5	106.1	81.9	
15	118.2	124.5	117.7	95.6	
16	130.3	137.4	131.5	100.0	
17	141.4	150.6	140.0	115.8	
18	153.6	163.1	150.0	120.6	
19	166.3	176.2	160.4	130.6	
20	178.5	190.4	173.9	135.3	
21	188.9	204.4	185.3	-	
22	200.3	218.8	195.9	-	
23	210.2	232.7	204.5	160.5	
24	222.4	242.3	206.0	169.6	
25	227.0	248.5	219.2	174.8	
26	233.4	262.8	225.4	187.0	
27	246.0	276.2	233.2	192.4	
28	253.6	285.4	239.0	199.2	

[a]Last weight obtained for chick.

Table C.1 (continued).

Age (Days)	Chick Weight (g)			
	#1	#2	#3	#4
29	272.2	290.9	241.8	210.5
30	273.8	292.1	258.7	214.9
31	271.1	315.5	253.6	217.1
32	284.6	321.3	263.2	225.4
33	283.1	333.8	270.5	234.7
34	294.2	338.7	275.0	238.2
35	294.2	353.7	290.6	250.7
36	296.3	366.4	287.3	248.6
37	309.7	370.5	288.2	257.7
38	312.1	373.3	298.2	266.7
39	309.5	388.3	300.6	262.7
40	324.4	392.5	294.2	262.8
41	325.5	392.0	312.3	278.9
42	328.1	396.7	307.8	280.5
43	334.1	405.6	310.6	278.7
44	339.8	407.1	318.6	288.3
45	338.6	410.5	309.4	286.5
46	341.8	406.1	315.9	297.8
47	339.3	414.5	307.9	290.1
48	344.3	397.8	-	298.2
49	338.1	-	306.6	292.5
50	-	397.3	-	300.7
51	336.2	-	-	304.8
52	-	-	312.4	297.1
53	-	401.9	-	-
54	332.0	-	330.7	304.6
55	-	413.2	-	308.4
56	338.9	-	-	-
58	-	-	364.7	303.6
59	-	438.1	-	-
60	339.3[a]	-	-	307.9
61		-	-	312.9
62		-	-	317.9
63		-	-	316.8
64		-	-	324.9
66		-	-	318.9
68		-	-	320.0
69		-	-	318.7
70		-	-	325.6
71		-	367.5	-
72		452.3	-	308.4
74		-	-	314.1

[a]Last weight obtained for chick.

Table C.1 (continued).

Age (Days)	Chick Weight (g)		
	#2	#3	#4
78	-	339.3	327.9
79	452.3	-	-
83	-	-	277.4
85	-	367.5	259.5
86	452.3	-	-
92	-	367.5	226.0
93	480.5	-	-
97	-	-	250.8
106	-	339.3	-
107	480.5	-	-
113	-	311.0	-
114	395.8	-	-
120	-	311.0	-
121	395.8	-	-
127	-	311.0	-
128	395.8	-	-
134	-	339.3	-
135	424.0	-	310.8
148	-	311.0	-
149	424.0	-	-
162	-	282.8	-
163	367.5	-	-
166	-	-	310.8
184	-	311.0	-
185	424.0	-	-
198	-	339.3	310.8
199	424.0	-	-
213	-	282.8	-
214	367.5	-	-
222	-	367.5	-
223	452.3	-	-
232	-	-	339.0[a]
241	-	311.0	
242	424.0	-	
257	-	311.0	
258	424.0	-	
285	-	311.0	
286	452.3	-	
301	-	311.0	
302	424.0	-	
327	-	339.3	
328	452.3	-	

[a]Last weight obtained for chick.

Table C.1 (continued).

Age (Days)	Chick Weight (g)	
	#2	#3
340	-	308.5
341	419.5	-
363	-	297.2
364	369.2	-
388	-	320.0[a]
389	393.1	
440	395.5[a]	

[a]Last weight obtained for chick.

IV. BREEDING BY FIRST YEAR CAPTIVE-REARED SIBLING PIED-BILLED GREBES

Age of first breeding by Pied-billed Grebes (Podilymbus podiceps) is unknown (Palmer 1962). Here I document age at first breeding by captive Pied-billed Grebes.

Pied-billed Grebe eggs were collected from nests at 3 lakes in Guatemala (Fig. 4.1) in 1986 and 1987. Eggs were hatched in a Humidaire Model 20 incubator and chicks (n = 4) raised with methods described in detail elsewhere (Chapter III) at Club Auto Safari Chapin, a wild animal park, located on Guatemala's Pacific coastal plain (Fig. 4.1).

Calls associated with courtship and breeding (Deusing 1939, Miller 1942, Kilham 1954, McAllister and Storer 1963, LaBastille 1974) were first heard from 2 of the captive-reared birds when they were approximately 11 months old. The 2 sibling grebes had been reared and maintained together in a concrete pool (5 m x 2 m x 1 m). Grebe sex was determined based on weight (Palmer 1962) and behavioral observations (LaBastille 1974). Male territorial calls (a low throaty "cow-cow-cow") and pair greeting duets (a rapid nasal chatter resembling a series of "na-na-na") (LaBastille 1974) were frequently heard. Aggressive displays were also observed in both birds. On several occasions, the male was seen chasing and then attacking the female by pecking at her head. Aggressive courtship pursuits have also been described by Kilham (1954) and Palmer (1962). Often, when the male swam close to the female, she would turn her head towards him and, without any vocalization, vibrate her bill.

At 13 months of age, the 2 grebes were released at an artificially-constructed pond (approximately 1 ha) on the Club Auto Safari Chapin. Reeds (Typha dominqensis and Scirpus californicus) provided cover for resting and nesting. A stream which flows into and out of the pond provided a constant supply of fish. No other grebes or waterfowl inhabited the pond.

Approximately 2 1/2 weeks after being released on the pond, a Pied-billed Grebe nest and 3 eggs were found in a patch of T. dominqensis reeds, approximately 3 m from shore. Although the grebe pair was never observed building the nest or incubating the eggs, they were frequently seen entering and emerging from that particular patch of reeds. The eggs had been partially destroyed by an unknown predator. Two could be accurately measured (length = 31.5 mm and 34.8 mm, breadth = 25.6 mm and 25.3 mm, respectively); they were smaller than other Pied-billed Grebe eggs collected in Guatemala (n = 20, $\bar{x}$ length = 42.9 $\pm$ 1.9 SD and $\bar{x}$ breadth = 30.1 $\pm$ 0.8 SD). Young birds have been reported to commonly lay smaller eggs than older birds of the same species (Romanoff and Romanoff 1949). Because the eggs were destroyed, it was impossible to determine their fertility. These observations indicate that first year Pied-billed Grebes can and will breed.

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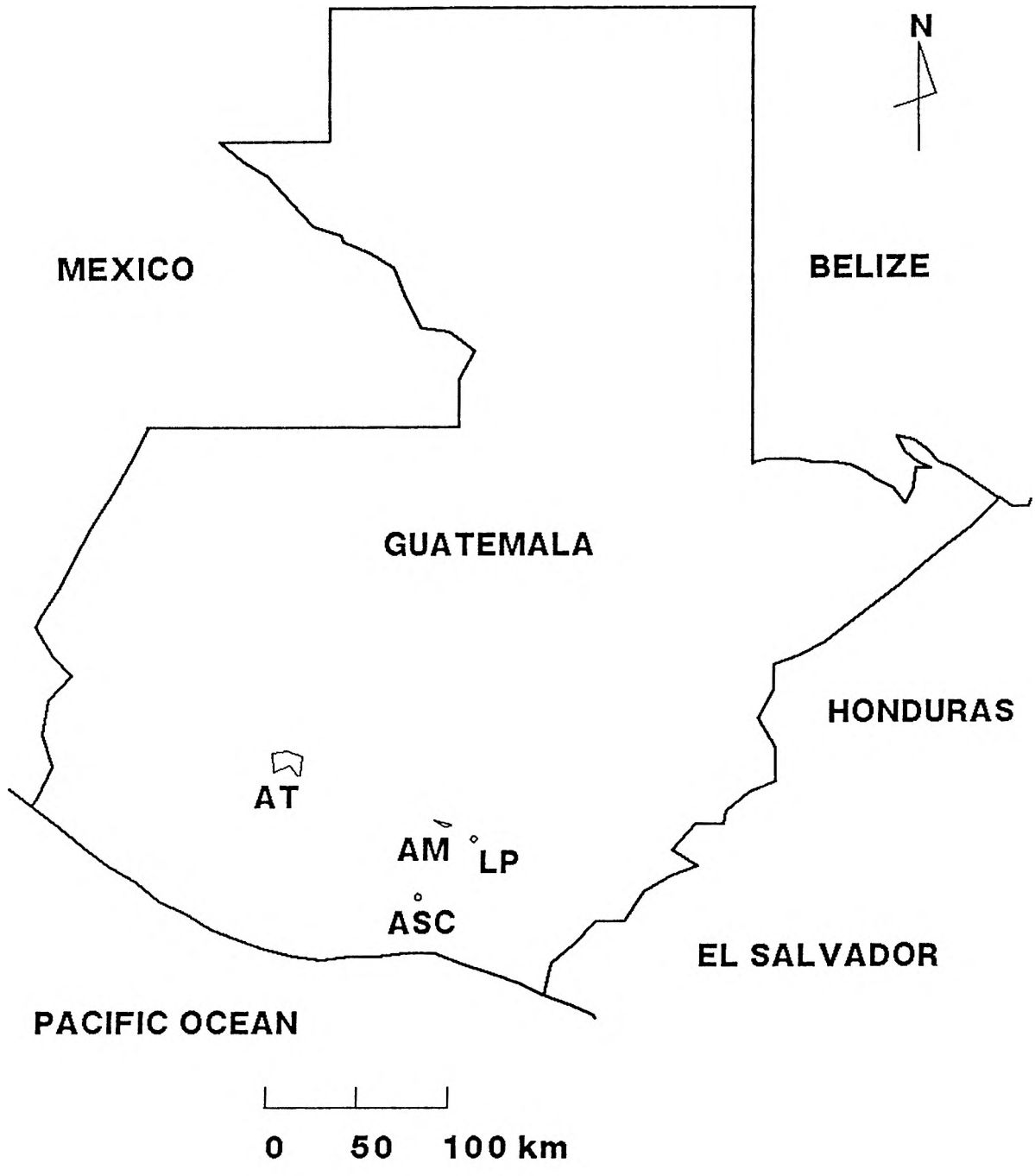


Fig. 4.1. Study site locations, 1986-87, Guatemala, Central America. AT = Lake Atitlan, AM = Lake Amatitlan, LP = Laguna del Pino, ASC = Club Auto Safari Chapin.

THESIS

ARTIFICIAL INCUBATION, CAPTIVE-REARING AND MAINTENANCE OF PIED-BILLED GREBES IN GUATEMALA

Submitted by
Susan Ruth MacVean
Department of Fishery and Wildlife Biology

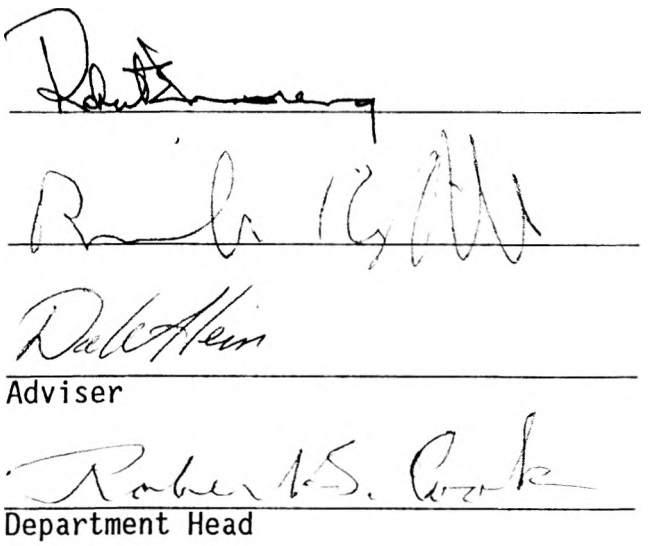
In partial fulfillment of the requirements
for the degree of Master of Science
Colorado State University
Fort Collins, Colorado
Spring 1988

COLORADO STATE UNIVERSITY

April 1, 1988

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY SUSAN RUTH MACVEAN ENTITLED ARTIFICIAL INCUBATION, CAPTIVE-REARING AND MAINTENANCE OF PIED-BILLED GREBES IN GUATEMALA BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

Committee on Graduate Work



Adviser

Department Head

ABSTRACT

ARTIFICIAL INCUBATION, CAPTIVE-REARING AND MAINTENANCE OF PIED-BILLED GREBES IN GUATEMALA

Pied-billed Grebe (*Podilymbus podiceps*) eggs (n = 20) were collected in early and mid-incubation stages at 3 lakes in Guatemala. Two factors previously reported to affect hatchability of artificially incubated avian eggs were investigated: egg weight loss during incubation and stage of incubation at collection. Weight loss was lower than reported in the literature and did not differ ($P > 0.05$) for hatched and unhatched eggs. Stage of incubation at the time of collection had an effect ($P < 0.05$) on hatchability and development through pipping. None of the eggs collected in early stages of incubation (n = 13) hatched; all embryos died in early or mid stages of development. Embryos of all eggs collected at mid-incubation (n = 7) developed through pipping and 71% hatched successfully. These data suggested that an initial period of natural incubation increases Pied-billed Grebe egg hatchability.

Captive-rearing and maintenance techniques were developed with common Pied-billed Grebes for implementation with the then-endangered Atitlan Grebe (*Podilymbus gigas*). Grebes (n = 5) were reared from the artificially incubated eggs. Grebes' diet consisted of live or freshly killed fish (*Poecilia butleri* and *Poeciliopsis gracilis*), supplemented by mealworms (*Tenebrio* sp.) and river shrimp (*Panaeus* sp.). ? … were also fed to the chicks until they were regularly observed

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preening and consuming their own. Fish consumption was measured for all chicks through Week 1 and for one chick through Week 7. For the first 10 days, chicks were only hand fed. Thereafter, live fish were provided to encourage independent feeding. Grebes were fed in water but for the first 2-3 weeks spent most of their time in a brood box. By 1 month of age, chicks were spending most of their time in water. Chicks were placed in sequentially larger tubs and water tanks until, at 13 months of age, 2 surviving grebes were released on an artificial pond. Body weight was the only measure of growth used. The period of most rapid growth occurred between Days 10-25. Instantaneous relative growth peaked at 22% to 33% ($\bar{x}$ = 27), Days 3-5. Grebes attained average adult weight by sex at 8-9 weeks of age and asymptotic weight during Weeks 11-14. Growth rate fluctuated widely. Birds tended to undergo spurts of rapid growth separated by periods of slowed growth.

Age of first breeding by Pied-billed Grebes is unknown. The opportunity to document age at first breeding arose during the course of this study. Courtship and breeding calls were first heard from a pair of sibling captive-reared grebes when they were approximately 11 months old. At 13-14 months of age, 2½ weeks after the 2 grebes were released on an artificially constructed pond, a nest and eggs were found in a patch of reeds (*Typha domingensis*). No other grebes or waterfowl inhabited the pond. The eggs had been partially destroyed by an unknown predator. Two could be accurately measured and were smaller than other Pied-billed Grebe eggs collected for this study. Fertility

of the eggs could not be determined. These observations indicated that first year Pied-billed Grebes can and will breed.

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I would also like to thank my advisers, Drs. John Ratti and Dale Hein, as well as Steve Rosenstock, for their continued support, and critical review of my work. Thanks to committee members Drs. Rick Knight and Byron Miller for their interest and input to my graduate program. Many thanks to Dr. Robert Moreng for serving on my committee, on last-minute notice.

DEDICATION

To my parents, Bob and Betty, who have always supported and encouraged all of my endeavors.

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INTRODUCTION

Origin of study

The common Pied-billed Grebe (*Podilymbus podiceps*) was the closest relative of the endangered, now extinct, Atitlan Grebe (*Podilymbus gigas*), endemic to Lake Atitlan, Guatemala. Atitlan Grebe numbers declined from 232 individuals in 1975 to 56 in 1985. This decline was attributed to introduction of Largemouth Bass (*Micropterus salmoides*), loss of habitat, and the use of gill nets. Very little work has been done with captive grebes and no literature exists on captive-breeding techniques for grebes. In 1986, with support from the International Council for Bird Preservation and the U. S. Fish and Wildlife Service, this project was undertaken to develop artificial incubation and captive techniques with Pied-billed Grebes for implementation with Atitlan Grebes.

Thesis format

This thesis consists of 3 chapters, written as manuscripts to be submitted for publication to *The Auk,* the *International Zoo Yearbook*, and the *Journal of Field Ornithology*. This approach was justified by the difficulty involved in extracting manuscripts from a thesis written in traditional format. Some duplication in content among chapters was unavoidable but minimized.

Description of papers

The papers are organized in chronological order. The first evaluates the effects of incubation stage at collection and water loss during incubation on the hatchability of Pied-billed Grebe eggs. The

second paper describes techniques for rearing and maintaining Pied-billed Grebes in captivity and the third reports on breeding by first year captive-reared Pied-billed Grebes.

II. EFFECTS OF WEIGHT LOSS AND INCUBATION STAGE AT COLLECTION ON HATCHABILITY OF ARTIFICIALLY INCUBATED PIED-BILLED GREBE EGGS

Weight loss of avian eggs during incubation is attributed almost exclusively to the diffusion of water vapor caused by a vapor pressure difference between the outside and the inside of the eggshell (Rahn and Ar 1974). In artificial incubation incubator humidity has been shown to affect hatchability by influencing rates of egg water loss (Lundy 1969; Rahn and Ar 1974; Birchard *et al.* 1982). Some water loss is necessary for formation of the air cell, which provides air to the embryo when pulmonary respiration initiates (Romanoff and Romanoff 1949). Hatching success is dependent upon "optimal" air-cell size (Ar and Rahn 1980:373). At low humidity, eggs may lose too much water and dehydrate. At high humidity, eggs may not lose enough water. Wet shell membranes can obstruct embryo respiration.

In artificially incubated eggs, incubation stage at collection has also been shown to affect egg hatchability (Weaver and Cade 1983). I report the effects of egg weight loss and incubation stage at collection on hatchability of artificially incubated Pied-billed Grebe (*Podilymbus podiceps*) eggs.

METHODS

Twenty Pied-billed Grebe eggs were collected from 6 nests at 3 lakes in Guatemala, May–July of 1986 and 1987. Eggs were collected at varying stages of incubation. Previous observations (Glover 1953; LaBastille 1974) indicated that Pied-billed Grebes lay 1 egg per day and begin incubating once the clutch is complete. Incubation period for this species is 23 days (Palmer 1962). Based on this information,

stage of incubation at collection was determined by: a) recording the date of the first egg laid in a clutch; or b) backdating after the eggs hatched. Eggs were artificially incubated at Club Auto Safari Chapin, a wild-animal park, situated on Guatemala's Pacific coastal plain. Eggs were incubated in a Humidaire Model 20 incubator at 35.6°C dry bulb and 34.5°C wet bulb, yielding 93% relative humidity. Incubation conditions used were based on techniques developed by Ratti (1977) for Western and Clark's Grebes (*Aechmophorus occidentalis* and *A. clarkii*) and data on natural incubation conditions of Pied-billed Grebes (Davis *et al.* 1984).

Eggs were weighed and floated in water at collection and daily thereafter between 0730 and 0930 hours. Weight, angle of flotation, buoyancy and movement were recorded to verify incubation stage and monitor embryo development (Westerskov 1950). Egg position in water was classified into 4 stages. Initial mass of eggs collected after the onset of incubation was calculated by multiplying mean daily weight loss by 23 days (length of incubation period) and adding it to the egg weight on day 23 (or on the day of hatch if different than 23) (Rahn and Ar 1974; Birchard *et al.* 1982). Eggs which failed to hatch were opened to determine stage of embryo development and possible causes of death.

Differences in egg weight loss of hatched and unhatched eggs were compared with a Mann-Whitney *U* Test. Independence between incubation stage at collection and hatchability, and between incubation stage at collection and embryo development through pipping were tested with Fisher's Exact Test. Analyses were first conducted using data from all

eggs. In 3 subsequent analyses, potentially infertile (n = 3), damaged (n = 4), and infertile and damaged eggs (n = 7) were deleted.

RESULTS

Egg weight loss and hatchability

Daily weights of individual eggs during incubation are reported in Appendix A. Mean daily weight loss of eggs during incubation was $\bar{x}$ = −0.04 (SD = 0.02, n = 20) (Table 2.1). There were no differences in weight loss for hatched versus unhatched eggs (all P values 0.7).

Weights of fresh (unincubated) eggs ranged from 17.8 g to 24.2 g (n = 20, $\bar{x}$ = 20.9, SD = 1.4). Average weight loss as a percent of initial mass was 4.3 (SD = 1.79).

When placed in water, all eggs that hatched (n = 5) had risen from a horizontal (stage 1) to a vertical position (stages 3 and 4) in water (Fig. 2.1) by Day 12 of incubation. These eggs remained at stages 3 and 4 through hatching. Angle of the eggs fluctuated between 75 (stage 3) and 90 degrees (stage 4). Among the unhatched eggs, 12 achieved a vertical position between Days 11 and 21; 3 never achieved a vertical position and remained at stage 2 through Day 23 and later. None of the eggs achieved a floating stage (i.e. days 15–24, Fig. 2.2).

Fifteen eggs failed to hatch, of which 2 pipped but were dead in the shell 1 day later. Ten eggs were confirmed as fertile; all contained partially developed embryos. It is possible that 4 of these eggs were damaged (jarred) in transport. The fertility of the remaining 3 could not be determined because the eggs were decomposing and no embryo was visible. Estimated age of embryos at death ranged from 1–13 days of incubation (Table 2.2).

Stage of incubation at collection and hatchability

Eggs were collected at estimated ages of 0–11 days of incubation (Table 2.3). Thirteen eggs were collected between Days 0 and 4 (early incubation); all of these failed to pip or hatch. Seven eggs were collected between Days 8 and 11 (mid-incubation); 5 pipped and hatched successfully, 2 pipped only. In all analyses a difference (all *P* values 0.016) was found between stage of incubation at collection and hatchability, and between incubation stage at collection and embryo development through pipping (all *P* values 0.001).

DISCUSSION

Egg weight loss and hatchability

Egg weight loss was considerably less than expected when compared to reports in the literature. Based on compiled incubation data for 475 species of birds, Rahn and Ar (1974) concluded that eggs, regardless of size, lose approximately 18% of their initial weight during natural incubation. Ackerman and Platter-Reiger (1979) and Davis *et al.* (1984) found that naturally incubated Pied-billed Grebe eggs lost 13.3% and 16.4%, respectively, of their initial mass during a 23-day incubation period. Boone and Barmore (1965) found that water loss was the same for fertile and infertile eggs; data in this study are consistent with this report.

Generally, gradual growth of the air cell causes an egg to rise from a horizontal position in water, in pre- and early incubation, to a vertical floating position late in incubation (Westerskov 1950; Nuechterlein 1975) (Fig. 2.2). The low weight loss of eggs in this study conforms with the water-test results (Fig. 2.1), i.e. air-cell growth was not sufficient to cause eggs to float. Thus, these results

indicate that eggs not following the normal flotation pattern (Westerskov 1950) may hatch, and this method should be used with caution. The observed rate of water loss and poor hatchability (25%) suggested that incubator relative humidity was too high. Ar and Rahn (1980) reported that at high-humidity hatchlings may die in the egg or during pipping due to inhaling liquid and suffocating, commonly referred to as "drowning" (Romanoff 1930; Ar and Rahn 1980). In this study, 2 chicks died during pipping. However, Ar and Rahn (1980) indicated that early embryo mortality, prior to lung ventilation, could not be caused by "drowning". Most embryo deaths in this study occurred in early and mid stages of incubation (prior to lung ventilation). I am not sure how reduced water loss might have affected embryos in early stages of development.

Poultry scientists have long selected for eggs that hatch successfully under constant artificial incubation conditions (R. E. Moreng, pers. comm.). In wild birds, it is possible that irregularities in natural incubation conditions have been an important selective force and are necessary for successful hatching. The constant conditions provided by artificial incubation may not have been optimal for successful hatching of Pied-billed Grebe eggs.

Stage of incubation at collection and hatchability

Weaver and Cade (1983) reported that Peregrine Falcon (*Falco peregrinus*) eggs placed in an incubator after receiving less than 3–4 days of natural incubation hatched at a rate of 50–60%. Eggs that were naturally incubated for the first 5–10 days, and then artificially incubated, hatched at a rate of 75–85%.

My results are consistent with Weaver and Cade's (1983) findings. Although Pied-billed Grebe eggs were not collected at all stages of incubation, my results suggested that an initial period of natural incubation increases Pied-billed Grebe egg hatchability. These data, and those of Weaver and Cade (1983) indicated that naturally laid eggs that will be hatched in an incubator should not be collected until the latter ⅔ of the incubation period.

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Table 2.1. Weight loss for hatched and unhatched Pied-billed Grebe eggs (mean, standard deviation and range), Guatemala, 1986–87.

Hatched	*n*	mean (g)	SD	Range (g)	
Yes	5	−0.04	0.02	−0.01	−0.06
No	15	−0.04	0.02	0.00	−0.07

Table 2.2. Estimated stage of incubation at collection, age of embryos at death, description of egg contents and possible causes of death of unhatched Pied-billed Grebe eggs, Club Auto Safari Chapin, Guatemala, 1986–87.

Egg(s)	Estimated days of incubation at collection	Estimated age (days) of embryo at death	Description of egg contents	Possible causes of death
D	11	24	Fully developed chick	Malpositioned, inadequate incubation conditions
1A	8	27	" "	" "
2A, 2B, 2D	4	4	Abundant yolk Embryo ½ cm long Eyes visible	Embryo damaged in transport
2C	4	4	Embryo 1 cm long Head, eyes, heart discernible	" "
3A	1	1–2	Embryo ¼ cm long	Inadequate incubation conditions
3B, 3D	1	12-13	Embryo 2½ cm long Eyes, bill, wings, feet discernible	" "
3C	1	9–10	Embryo 2 cm long	" "

Table 2.2 (continued).

Egg(s)	Estimated days of incubation at collection	Estimated age (days) of embryo at death	Description of egg contents	Possible causes of death
4A	4	?	Decomposed yolk No embryo visible	Infertile, contaminated or inadequate incubation conditions
4B	4	4	Embryo 1 cm long	Inadequate incubation conditions
4C	4	8–9	Embryo 1½ cm long	" "
5A	0	?	Decomposed yolk No embryo visible	Infertile, contaminated or inadequate incubation conditions
5B	0	?	Abundant yellow yolk No embryo visible	Infertile or inadequate incubation conditions

Table 2.3. Date, location and number of Pied-billed Grebe eggs collected at varying stages of incubation, Guatemala.

Month/Year	Lake[a]	No. eggs collected	Day of incubation at collection
7/87	AM	2	0
6/87	AM	4	1
6/87	AT	4	4
7/87	AM	3	4
5/87	AM	3	8
5/86	LP	4	11

[a]AM = Lake Amatitlan, AT = Lake Atitlan, LP = Laguna del Pino.

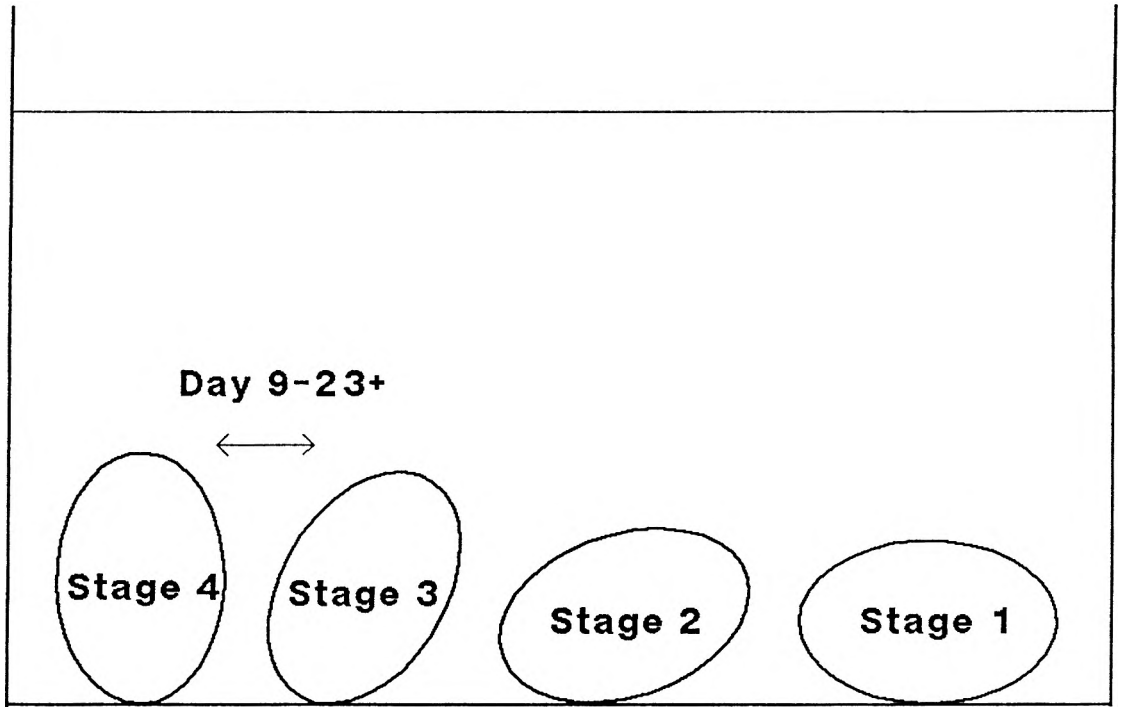

Fig. 2.1. Incubation stages of Pied-billed Grebe eggs by flotation, Guatemala, 1986-87.

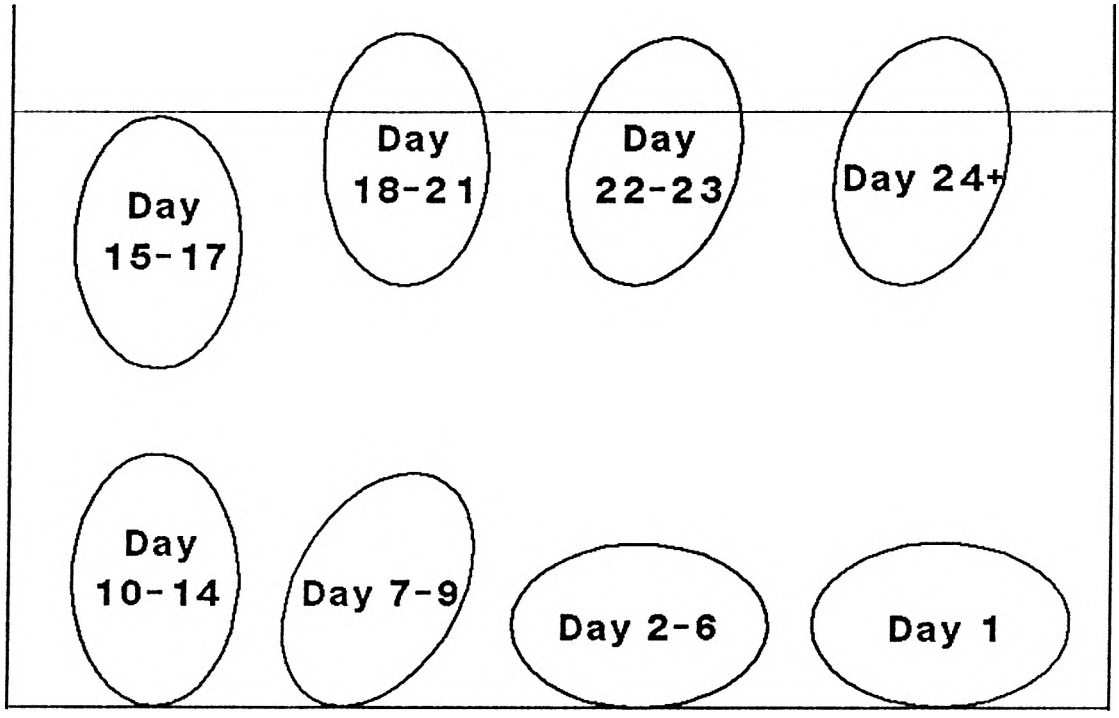

Fig. 2.2. Incubation stages of Western Grebe eggs by flotation (After Nuechterlein 1975).

APPENDIX A

Pied-billed Grebe egg weights during artificial incubation, Club Auto Safari Chapin, Guatemala, 1986–87

Table A.l. Pied-billed Grebe egg weights, days 1–23 of artificial incubation, Club Auto Safari Chapin, Guatemala, 1987.

Day of Incubation	Egg Weight (g)					
	3A	3B	3C	3D	5A	5B
1	20.7	24.2	21.9	22.8	22.6	19.3
2	20.6	24.2	21.9	22.8	22.5	19.1
3	20.6	24.0	21.7	22.6	22.4	18.9
4	20.6	24.0	21.8	22.7	22.5	18.9
5	20.5	23.9	21.7	22.7	22.5	19.0
6	20.5	23.9	21.6	22.5	22.4	19.0
7	20.5	23.9	21.6	22.6	22.5	19.1
8	20.5	23.9	21.7	22.7	22.4	19.0
9	20.4	23.8	21.5	22.5	22.3	18.9
10	20.4	23.8	21.6	22.5	22.2	18.8
11	20.4	23.8	21.5	22.5	22.1	18.8
12	20.2	23.7	21.4	22.4	—	—
13	20.2	23.6	21.4	22.4	22.2	18.8
14	20.2	23.5	21.4	22.3	22.2	18.8
15	20.1	23.4	21.4	22.3	22.1	18.7
16	20.1	23.3	21.3	22.2	22.1	18.7
17	20.1	23.3	21.3	22.1	22.0	18.8
18	20.0	23.3	21.2	22.0	22.0	18.7
19	19.9	23.1	21.1	22.0	22.0	18.7
20	20.0	23.2	21.2	22.1	22.1	18.7
21	19.9	23.1	20.9	21.9	22.1	18.6
22	19.9	23.0	20.9	21.9	22.1	18.8
23	19.8	23.0	20.8	21.7	21.9	18.6

Table A.2. Pied-billed Grebe egg weights, days 4–23 of artificial incubation, Club Auto Safari Chapin, Guatemala, 1987.

Day of Incubation	Egg Weight (g)						
	2A	2B	2C	2D	4A	4B	4C
4	20.2	20.5	20.0	17.7	20.0	20.2	22.0
5	20.2	20.7	20.2	17.7	19.5	20.1	21.8
6	20.2	20.6	20.0	17.8	19.4	20.0	21.7
7	20.1	20.4	19.9	17.6	19.4	20.0	21.8
8	20.1	20.4	20.0	17.6	19.4	20.0	21.8
9	20.0	20.4	19.9	17.6	19.3	20.0	21.8
10	20.0	20.4	19.9	17.6	19.3	20.0	21.7
11	20.1	20.5	20.0	17.6	19.3	19.9	21.7
12	20.1	20.5	19.9	17.5	19.1	19.8	21.5
13	20.0	20.4	19.8	17.4	19.1	19.8	21.4
14	20.0	20.4	19.8	17.4	19.0	19.8	21.4
15	20.0	20.4	19.7	17.4	—	—	—
16	19.9	20.3	19.6	17.3	19.0	19.7	21.3
17	19.8	20.3	19.6	17.2	18.9	19.7	21.4
18	19.7	20.2	19.5	17.1	18.9	19.7	21.4
19	19.7	20.3	19.6	17.1	18.9	19.6	21.3
20	19.7	20.2	19.4	17.1	18.9	19.6	21.3
21	19.6	20.1	19.4	17.0	18.7	19.6	21.2
22	19.5	20.1	19.3	16.9	18.8	19.6	21.2
23	19.5	20.0	19.2	16.9	18.7	19.6	21.2

Table A.3. Pied-billed Grebe egg weights, days 8–23 and 12–23 of artificial incubation, Club Auto Safari Chapin, Guatemala, 1986–87.

Day of Incubation	Egg Weight (g)						
	1A	IB	1C	A	B	C	D
8	22.0	21.3	20.5				
9	22.0	21.3	20.6				
10	21.9	21.1	20.5				
11	21.9	21.2	20.5				
12	21.9	21.1	20.4	20.8	19.5	18.9	19.0
13	—	—	—	20.7	19.4	18.8	18.9
14	21.8	21.0	20.4	20.8	19.4	18.8	18.9
15	21.8	21.0	20.4	20.7	19.3	18.8	18.9
16	21.8	21.0	20.4	20.7	19.3	18.7	18.8
17	21.8	21.0	20.4	20.6	19.2	18.7	18.7
18	21.8	21.1	20.3	20.5	19.1	18.6	18.7
19	21.9	21.2	20.4	20.6	19.1	18.6	18.7
20	—	—	—	20.5	19.1	18.5	18.7
21	22.0	21.4	20.5	—	—	—	—
22	22.0	21.2	20.4	20.3	*a*	18.3	18.5
23	—	21.3[a]	*a*	20.2		*a*	18.5
24				*a*			

[a] Chick hatched.

III. CAPTIVE-REARING TECHNIQUES FOR PIED-BILLED GREBES

Many podicipediform species are declining (D), threatened (T) or endangered (E) (King 1981; Fjelds 1984 and unpubl. data). Among these are the Madagascar Grebe (*Tachybaptus ruficollis*) (D), the Madagascar Red-necked Grebe (*T. rufolavatus*) (T), the New Zealand Dabchick (*Poliocephalus rufipectus*) (T) and the Junin Grebe (*Podiceps taczanowskii*) (E) of Peru. Over the past 2 decades, captive breeding has become an important strategy used when wild populations are threatened with extinction.

Work with captive Podicipediformes has been limited to 3 species. Hick (1966) and Kop (1972) hand-reared Great Crested Grebes (*Podiceps cristatus*) from artificially incubated eggs. Hick (1966) successfully reared 2 chicks through at least 2 months of age. Kop (1972) reared 5 chicks, 2 chicks through 11 days of age and 3 through 9–11 weeks of age. Herman (1974) artificially incubated and hatched 3 Western Grebe (*Aechmophorus occidentalis*) eggs and collected 3 Western Grebe hatchlings in the wild. The 6 chicks were reared successfully through at least 4 months of age. Two were released in the wild at an age of 14–15 months. Ratti (1977) successfully reared 7 Western and Clark's Grebes (*Aechmophorus clarkii*) from eggs collected in the field, through 9–12 weeks of age. No literature exists on captive-breeding techniques for grebes.

This study was aimed at developing captive-rearing and maintenance techniques with common Pied-billed Grebes (*Podilymbus podiceps*), to implement with the then-endangered Atitlan Grebe (*Podilymbus gigas*).

Although a few individuals may still remain, the Atitlan Grebe was recently declared extinct (L. Hunter, pers. comm.). Given the precarious status of several other grebe species, techniques developed in this study may prove useful in future recovery efforts.

METHODS

Pied-billed Grebe chicks (n = 5) were reared from artificially incubated eggs (Chapter II). Chicks were reared at Club Auto Safari Chapin, a wild animal park, situated on the Pacific coastal plain of Guatemala, at an elevation of approximately 150 m.

Dry chicks were removed from the incubator and weighed to the nearest 0.1 g. Chick weights were recorded daily, between 0730 and 1000 hours, for the first 2 months of the rearing period, and weekly, biweekly or monthly thereafter. Body weight was the only measure of growth used in this study.

Brooding

Chicks were placed in a plastic brood box, 60 cm × 30 cm × 45 cm, kept at 35–37°C. The bottom of the box was padded with a layer of cotton overlaid by flannel, toweling and thin cotton material. Brood-box bedding was washed daily or as often as necessary. Hot-water bottles were placed in the padding for the first week. A brood lamp (2–3 60-watt light bulbs) was hung over one end of the box and could be raised and lowered to regulate box temperature. Brooding temperature was gradually lowered to ambient temperature (27–35°C), guided by the chicks' response to heat.

Time and activities in water

Thirty to 60 minutes after leaving the incubator, chicks were offered water and placed in a small tub of lukewarm water to stimulate defecation (Ratti 1977). While chicks were spending most of their time in the brood box, defecation was induced every 2 hours during the day and 1–2 times during the night. On Day 1, drinking was encouraged by dipping the birds' beaks in water. During the first 3 days, chicks were placed in water only long enough to stimulate defecation (15–60 seconds). Beginning on Day 4, chicks were placed in water for part of each feeding session. After the first week, time spent in water was extended to several minutes and gradually lengthened until chicks were spending the entire day in water. During the first 3 weeks, chicks were not left unattended in water.

The first week, chicks were placed in a 38-cm-diameter plastic tub. The second week, a 75 cm × 45 cm × 13 cm tub was used. The third week, chicks were introduced into a 2000-l water tank (2 m diameter, 90 cm deep) or a 500-l tank (approximately 0.7 m^2, 0.7 m deep). A screened lid was placed over the tanks to deter predators when chicks were left unattended. At approximately 6–9 weeks of age, the chicks were transferred to a cement pool (5 m × 2 m × 1 m) with water inlets and outlets which insured constant water flow. One third of the pool was roofed to provide cover against rain and wind. Chicken wire fencing enclosed the pool to exclude predators.

Behavior

Behavioral observations were not a major emphasis of this study. However, I recorded chick behavior during the rearing period.

Diet and Feeding

The grebes' diet consisted of fish (*Poecilia butleri* and *Poeciliopsis gracilis*), supplemented by mealworms (*Tenebrio* sp.) and river shrimp (*Penaeus* sp.). This diet was based on food habits data reported by Palmer (1962) and Borrero (1971). Chicks also received feathers daily until they were regularly observed preening and consuming their own feathers.

Three to 5 hours after leaving the incubator, chicks were offered 1–2 feathers (duck breast down) and small boneless pieces (approximately 0.1 g) of fresh fish. Mealworms (*Tenebrio* sp.) were raised using methods described by Peterson (1964) and fed to the chicks at least once per day for the first 3–4 weeks, and 3–4 times per week thereafter. When available, river shrimp were fed to the grebes 3–6 times per week.

For the first 7 days, food was offered every 1–2 hours between 0600 and 2200 hours. After the first week, feeding intervals were extended to 1.5–2.5 hours. By the third week, chicks were fed at 2- to 3-hour intervals between 0600 and 2000 hours. Chicks were always fed until satiated.

Except for the first 3 days, when chicks received pieces of freshly killed fish, chicks were fed only live whole fish to avoid problems with thiamin (vitamin B1) deficiencies, commonly associated with feeding dead fish (Robbins 1983). As a preventive measure, a multiple vitamin supplement (Euravit, TAD) was administered in fish, at recommended doses by bird weight, 2 to 3 times per week for the first 2 weeks.

Fish fed to the grebes during the rearing period were grouped into 5 length classes. Fish were weighed to the nearest 0.1 g to obtain mean wet weight of each class. Fish quantities consumed by chicks were recorded for each chick at each meal through Day 7, and for chick #4 through Day 51. Mealworm and shrimp quantities consumed were not measured. For the first 10 days, chicks were hand fed. Thereafter, live fish were provided to encourage independent feeding, supplemented by hand feeding, if necessary. Some hand feeding continued throughout the rearing period.

Release of birds

At 13 months of age, 2 grebes reared in 1986 were released on an artificial pond (approximately 100 m^2) on the ASC. The birds' primary and secondary flight feathers were clipped prior to release. The perimeter of the pond was fenced to help exclude terrestrial predators. Reeds (*Typha domingensis* and *Scirpus californicus*) planted in 1985 and 1986 provided cover for resting and nesting. A stream which flows into and out of the pond provided a constant supply of fish. No other grebes or waterfowl inhabited the pond. Although fish were plentiful in the pond, the birds now had to catch fish in a much larger area and in very murky water. In order to ease the transition and supplement the birds' feeding efforts, they were provided with live fish, twice daily. This supplemental feeding was continued throughout their time in the pond.

RESULTS AND DISCUSSION

Brooding and activities in water

For the first 3 weeks, chicks spent most of their time in the brood box. Week 1, box temperature was maintained at 35–37°C, as suggested

by the Humidaire Co. (unpubl. data). Week 2, box temperature was lowered to 32–35°C. Chicks were also able to self-regulate their heat level by approaching or moving away from the brood lamp. By Week 3, chicks could tolerate ambient temperatures. Thereafter, the brood lamp was used only occasionally to warm a wet, chilled chick.

Special care was taken to provide a cushioned brooding area. It is possible for grebes, and other aquatic birds, to develop breast and leg ulcers if maintained out of water for prolonged periods of time without adequate supportive padding (Stoskopf and Kennedy-Stoskopf 1986). Initially, chicks were placed directly on flannel, underlaid by toweling and cotton. On several occasions, however, flannel lint had to be removed from chicks' eyes and chicks were observed pecking at loose strings in the toweling. Henceforth, chicks were placed directly on thin cotton material that did not lint or unravel.

For the first 3–4 weeks, rest periods in the brood box seemed important for proper thermoregulation and feather care. Through Week 3, birds were carefully monitored when in water and removed at any signs of stress (e.g. vocalizations, loss of buoyancy, attempts to jump out, or aggression).

Beginning Week 4, birds became increasingly intolerant of confinement (e.g. the brood box) and began spending most of their time in water. From this point on, chicks were only removed to the brood box to allow them to dry before being weighed.

Behavior

Grebes are considered precocial birds (Nice 1962; Welty 1982). Although grebe hatchlings resemble precocial species (i.e. they are feathered, have their eyes open and some ability to swim or crawl),

behaviorally they more closely resemble altricial species (e.g. grebe hatchlings will drown if left unattended in water (Ratti 1977) and are fed by their parents for several weeks to months). I list a chronology of important behavioral observations in Appendix B.

Diet and Feeding

One to 3 down breast feathers, obtained from a live Muscovy Duck (*Cairina moschata*), were fed daily to chicks. It has long been known that grebes ingest feathers (Wetmore 1920, 1924). Lawrence (1950) suggested that in Western Grebes, the feather mass speeds up digestion. Feathers may also comprise the rough material necessary to encase or eject indigestible items (e.g. fish bones and scales) (Simmons 1956). Herman (1974) reported that the initial feeding of feathers increased Western Grebe neonate survival. Ratti (1977) also fed feathers to neonate Western Grebes. On Day 2 (Day 1 = day of hatch), chicks in this study were observed attempting to preen. Day 4, chicks appeared to be preening and consuming feathers regularly. In 1986, feather feeding was discontinued after Week 1. In 1987, as a precaution (J. Ratti, pers. comm.), feather feeding was continued through Week 4. During Week 1, feathers were not easy to administer. Chicks took no interest in eating hand-offered feathers. However, feathers were consumed when wrapped around a piece of fish and moistened.

Days 1–3, chicks were fed boneless pieces of fresh fish or very small whole live fish of length class 1. As chicks matured they consumed larger fish (Table 3.1). Between Days 1 and 7, average daily fish consumption per chick (n = 4) increased from 1.8 g to 13.0 g (Fig. 3.1). Mean daily fish consumption, as a percent of chick body weight, ranged from 12% on Day 1 to 36% on Day 7 (Fig. 3.2). Daily fish

consumption of chick #4, days 8–51, peaked at 129 g on Day 41 (Fig. 3.3). Fish consumption of chick #4, as a percent of body weight, for this period, peaked at 59% on Day 14 (Fig. 3.4). Although relative fish consumption dropped after 14 days of age, absolute fish consumption continued to increase. By Day 30, most chicks were eating largely unaided.

Pellet ejection was observed in 1 chick on Day 17 and in 3 others on Day 80. Hand-reared Great Crested Grebes (Kop 1972) ejected pellets as early as 17 days after hatching. Chitin and vegetable matter, the latter ingested incidentally in fish stomachs or attached to other food items, probably cannot be thoroughly digested by grebes (Storer 1961). Storer (1961) suggested that it is these types of materials that form the bulk of grebe pellets. Grebe pellets in my study consisted primarily of feathers, although chitinous shrimp and mealworm remains were also present; fish bones or scales were never detected. Kop (1972) never observed fish bones in the pellets of Great Crested Grebes raised on fish and insects. From the age of 34 days, Great Crested Grebes ejected pellets approximately every 2 days (Kop 1972). Grebes in my study were not observed to eject pellets on a regular basis. Storer (1961) concluded that pellet-casting is probably more frequent in grebes feeding on insects and other invertebrates than it is in those feeding on fish.

Growth and Development

Weights of chicks throughout the rearing period are presented in Appendix C. Average chick weight at hatching was 14.9 g (Table 3.2). Day 2, chicks #1–4 each lost an average of 1.0 g (range = 0.3–1.9, SD = 0.82); chick #5 gained 0.5 g (chick #5 died on Day 2 and is therefore

excluded from the remainder of this section). On Day 3, chicks #1–4 each gained an average of 2.5 g (range = 0.8–3.6) and more than compensated for the previous weight loss. By Day 7, all chicks had more than doubled their weight at hatching.

The period of most rapid growth, as measured by gross gain in body weight, occurred between Days 10–25 (Fig. 3.5). Instantaneous relative growth, which shows growth at a given time in relation to body weight (Brody 1945: 508), peaked at 22% to 33% ($\bar{x}$ = 27, SD = 4.6) on Days 3–5, and then declined (Fig. 3.6).

All grebes required 30 to 48 days ($\bar{x}$ = 39, SD = 7.9), between Days 6 and 55, to increase from 10% of average adult weight (by sex) to 90% of average adult weight. Three of the 4 grebes achieved average adult weight at 8–9 weeks of age. Chick #4 experienced severe weight loss during Weeks 12–14, and achieved average adult weight Week 33 (Table 3.3 and Fig. 3.7).

Grebes #2 and #3 required 51 and 47 days, respectively; between Days 7 and 59, to increase from 10% of asymptotic weight to 90% of asymptotic weight. Asymptotic weight, as used in this discussion, refers to the maximum weight attained during the rearing period. Birds achieved asymptotic weight during Weeks 11–14 (Table 3.3). Following attainment of asymptotic weight, birds lost weight (Fig. 3.7). Weight recession has been documented in many species of birds, including captive-reared Western Grebes (Herman 1974), where the weight of young increases to a peak above average adult weight and then decreases prior to fledging (Ricklefs 1968). Western Grebes (Herman 1974) and Pied-billed Grebes exhibit no obvious fledging. Age of independence in wild Pied-billed Grebes has been documented at 6–8 weeks of age (LaBastille

1974). Weight loss following attainment of asymptotic weight in birds in this study occurred several weeks after documented age of independence. Asymptotic weights of grebes in this study were 7% to 8% higher than average adult weight. Over a period of 45–49 weeks following attainment of asymptotic weight, bird weights averaged 6% lower than average adult Pied-billed Grebe weight (Table 3.3).

Chick growth rate (net daily change in weight) fluctuated widely, ranging from −16.7 to 23.5 g (Fig. 3.8). Grebes tended to undergo spurts of rapid growth separated by periods of slowed growth. Growth rate and absolute fish consumption (Fig. 3.3) peaked on Day 41 for chick #4. Kahl (1972) observed considerable fluctuations in day-to-day food consumption in captive-reared Wood Storks (*Mycteria americana*) which corresponded to fluctuations in growth rate. Herman (1974) noted that feeding and growth rates of captive-reared Western Grebes fluctuated and cycled within certain limits. In the presence of an unlimited food supply, captive birds in several other studies (Kahl 1962; Junor 1972; Herman 1974), also tended to "overeat" for 1 or 2 days, and then undergo a seemingly compensatory loss of appetite in the following 1 or 2 days (Fig. 3.3). The ability to overeat is probably advantageous in nature because it allows the animal to exploit a temporarily abundant food supply and then survive intervening periods of food scarcity (Kahl 1962). Herman (1974) speculated that an animal evolutionarily unprepared for long-term food surpluses (as provided in these studies), but able to exploit a temporarily abundant food source, would likely eat until physiologically sated. The animal would then subsist on stored energy until some threshold of hunger was reached and feeding behavior was again triggered (Herman 1974).

Health

Prior to the attainment of peak weight, all chicks experienced weight losses of varying magnitude (Figs. 3.5 and 3.7). A change in environment was associated with initiation of weight loss. All chicks developed a severe loss of appetite when transferred from the tank to the larger concrete pool. Chicks #1–3 lost 10–13 g each (3–4% of body weight) over the course of a week. Chick #4 lost approximately 100 g (31% of body weight) over a 2-week period. Following the recommendations of an avian pathologist (Elizabeth de Motta, pers. comm.), each chick was administered 50 mg each of tetracycline and a multiple-vitamin supplement, daily, for 10 days. The antibiotic and vitamins were dissolved in water, the solution injected into fish, and fed to the chicks. After 2–3 days of undergoing medication, chicks' appetites began to increase. By the eighth day of treatment, chicks #1, #2, and #3 had regained the lost weight. Chick #4 continued to lose weight throughout most of the treatment but had regained the lost weight 3–4 weeks after the treatment ended. Although chicks' appetites increased after initiating the treatment, in general, they consumed less food than prior to transfer to the pool. This period of weight loss occurred after peaks in food consumption and shortly prior to attainment of asymptotic weight. Weight loss at this time may have delayed attainment of asymptotic weight. Bird weights declined after attaining asymptotic weight and then stabilized at a weight somewhat lower than average adult weight by sex.

Survival

Of 5 chicks that hatched, only 1 (chick #5) died at an early age (i.e. 20 days). Day 2, at 1500 hours, approximately 1 hour since

the last meal, chick #5 began to behave abnormally. Up until this time, the chick had been eating as much and acting as energetic as the other chicks. However, it was evident by the frequent cheeping and body convulsions, that the chick was distressed. A mealworm was found caught in the chick's throat and removed. The cheeping and convulsions, now accompanied by fluttering of the wings, became more frequent (approximately every 3–5 s). At 1830 hours, a low dose of tetracycline and vitamins was administered to the chick in a dropper. The chick became more and more lethargic and died at 1930 hours.

The night of Day 60, chick #1 was killed by an unknown predator. The bird had fallen out of the cement pool due to a heavy rainstorm which caused the water outlet to clog with debris and the pool to overflow.

Chick #3's decapitated carcass was found on Day 407 on the shore of the pond. Chick #2 disappeared from the pond 2 months later, at approximately 16 months of age. His fate is not known.

CONCLUSIONS

I have demonstrated that it is possible to rear and maintain Pied-billed Grebes in captivity. Diet and feeding regimes used seemed appropriate. In general, birds were healthy and behaved normally. Growth patterns were similar to those observed in captive Western Grebes and in several other captive bird studies.

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Table 3.1. Wet weight of fish (mean, standard deviation and coefficient of variation), by length classes used to calculate fish consumption by captive Pied-billed Grebe chicks, and chick age at which length class was first fed, Club Auto Safari Chapin, Guatemala, 1986-87.

Class	Length (cm)	*n*	Mean wet weight (g)	SD	CV	Age (days) of first feeding
1[a]	2.5	32	0.13	0.04	0.3	1
2	2.6–3.5	66	0.30	0.10	0.3	4
3	3.6–4.5	66	0.73	0.22	0.3	8
4	4.6–5.5	52	1.60	0.35	0.2	12
5	5.6–6.5	39	2.35	0.49	0.2	15–18

[a] This category includes whole fish and boneless pieces of fish.

Table 3.2. Pied-billed Grebe chick weights at hatching as a percent of egg and adult weights, Club Auto Safari Chapin, Guatemala, 1986-87.

Egg	Chick	Chick weight at hatching (g)	Percent of egg weight	Percent of adult weight[a]
B	1	14.1	74	4
c	2	13.3	73	3
A	3	15.9	79	5
1C	4	16.2	79	5
IB	5	14.9	70	4
Range		13.3–16.2	70–79	3–5
Mean		14.9	75	4

[a] Mean adult weight for male (443 g) or female (343 g) used if sex of bird known; mean adult weight of 393 g used if sex unknown.

Table 3.3. Number of days to attain adult weight and asymptotic weight, and average weight following attainment of asymptotic weight for 4 captive-reared Pied-billed Grebes, Club Auto Safari Chapin, Guatemala, 1986–87.

Grebe	Sex[a]	No. days to mean adult weight[b]	No. days to asymptotic weight	Asymptotic weight (g)	Mean grebe weight following asymptotic weight (g)
1	F	60	_[c]	–	–
2	M	59	93	480.5	415.0
3	F	55	71	367.5	324.1
4	F	232	232[d]	339.0[e]	–

[a]Sex determined based on weight (Palmer 1962) and/or behavioral observations (LaBastille 1974).
[b]Mean adult female weight = 343 g, mean adult male weight = 443 g (Storer, pers. comm.).
[c]Asymptotic weight not achieved due to chick mortality.
[d]Last day chick weight recorded.
[e]Last weight recorded; may not reflect asymptotic weight. See Fig. 3.7, female (#4) growth curve.

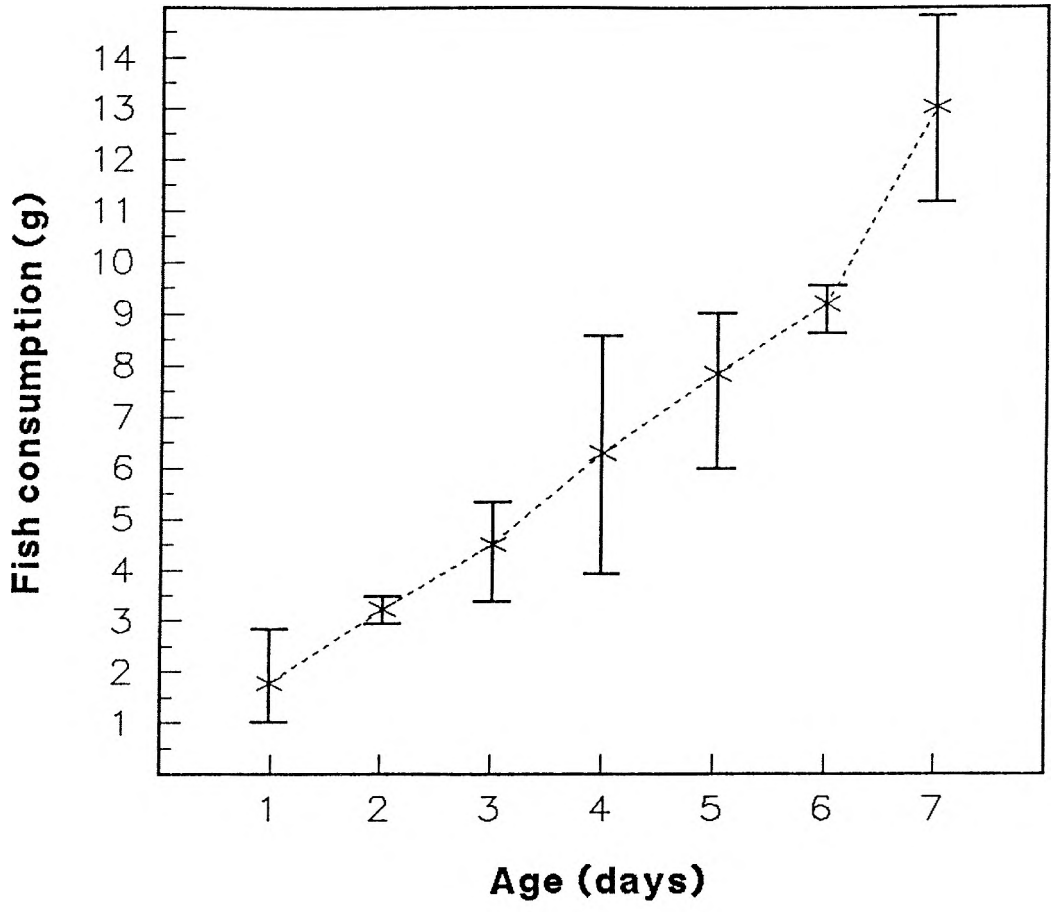

Figure 3.1. Daily fish consumption (mean, range) of 4 captive-reared Pied-billed Grebes, days 1-7, Auto Safari Chapin, Guatemala, 1986-87.

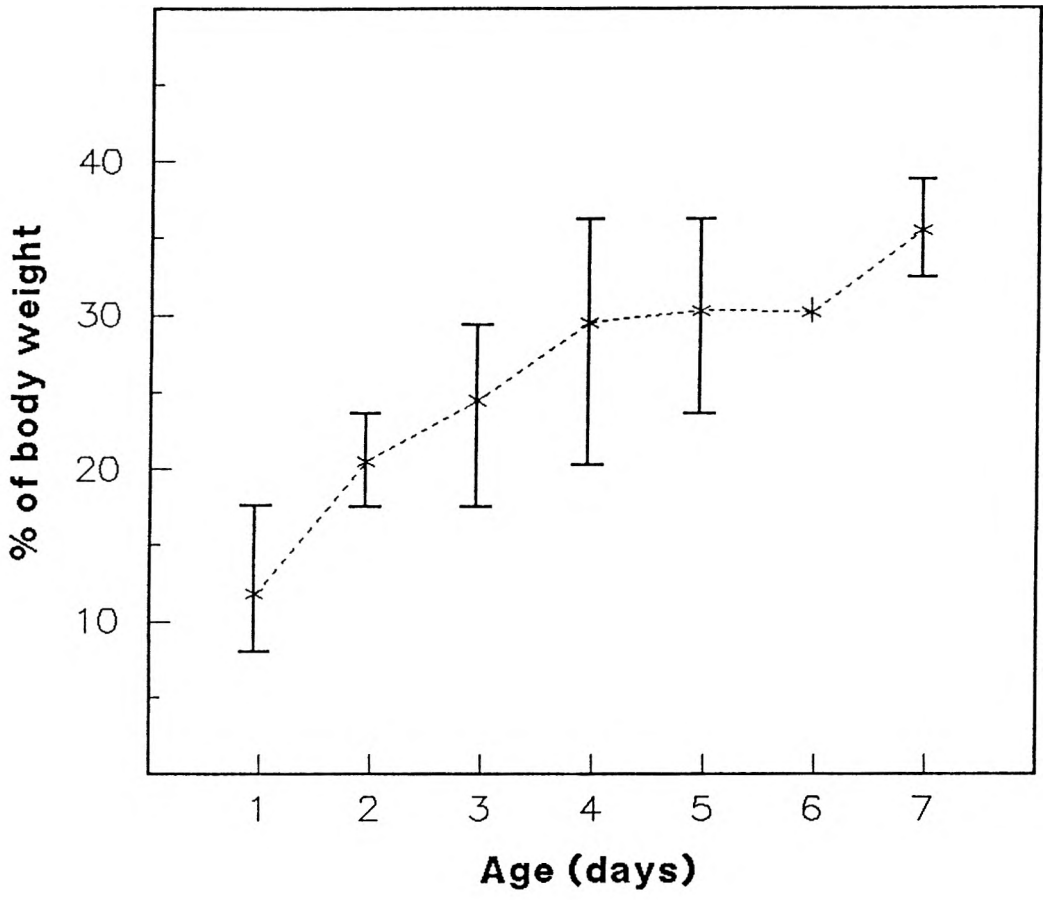

Figure 3.2. Fish consumption (mean, range) as a percent of body weight of 4 captive-reared Pied-billed Grebes, days 1–7, Auto Safari Chapin, Guatemala, 1986–87.

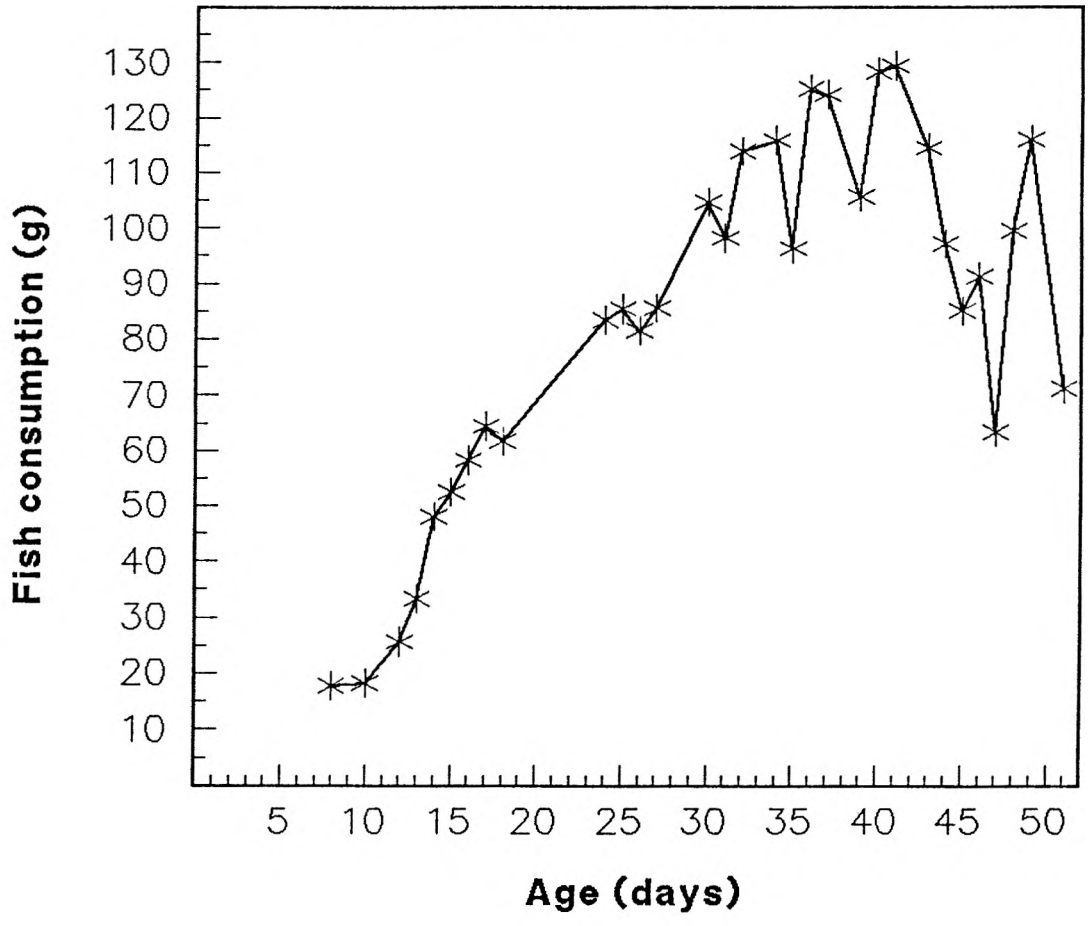

Figure 3.3. Fish consumption of captive-reared Pied-billed Grebe chick #4, days 8-51, Auto Safari Chapin, Guatemala, 1986-87.

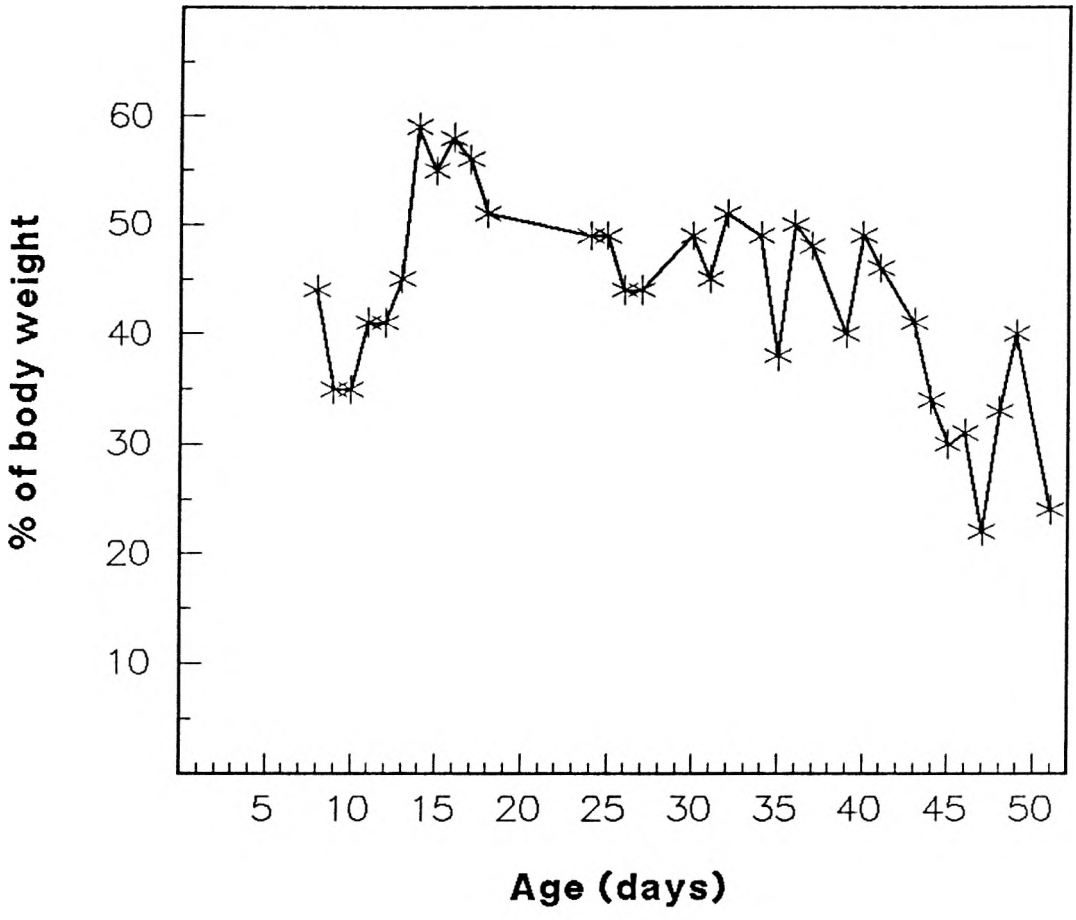

Figure 3.4. Fish consumption, as a percent of body weight, of captive-reared Pied-billed Grebe chick #4, days 8–51, Auto Safari Chapin, Guatemala, 1986–87.

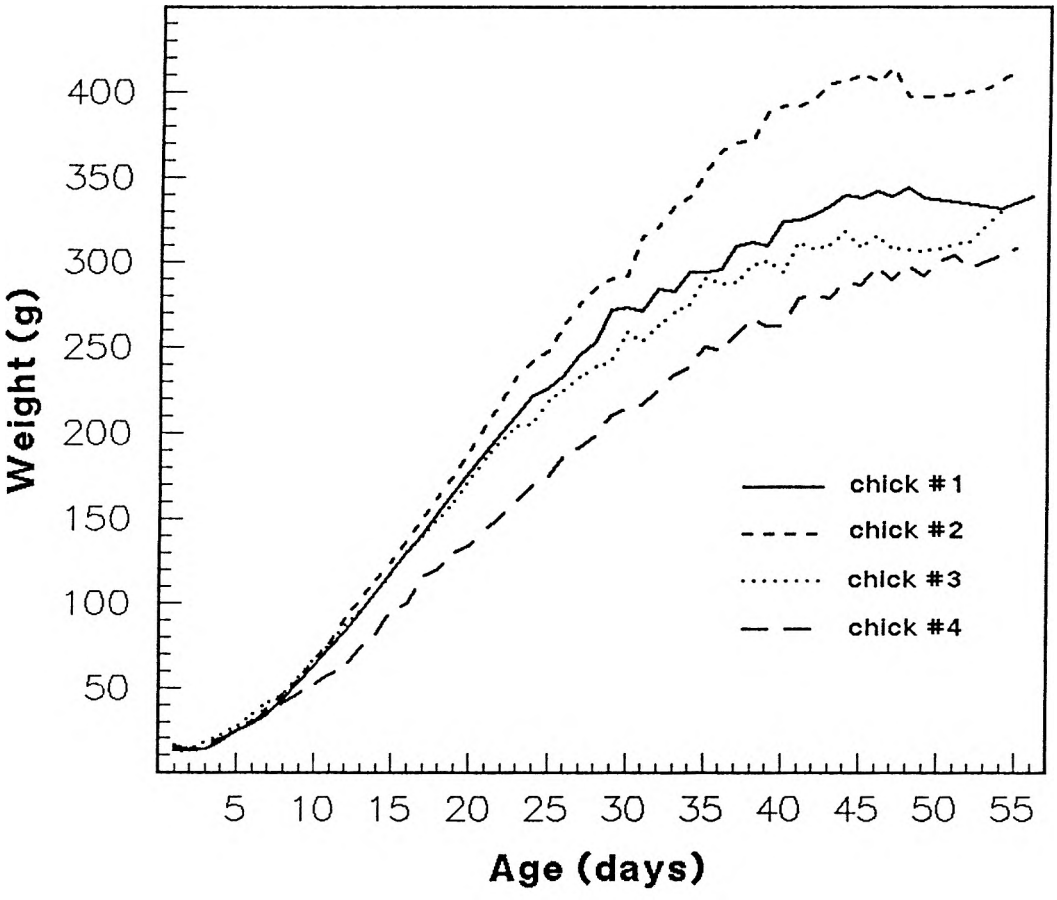

Figure 3.5. Weight growth of 4 captive-reared Pied-billed Grebe chicks, days 1–56, Auto Safari Chapin, Guatemala, 1986–87.

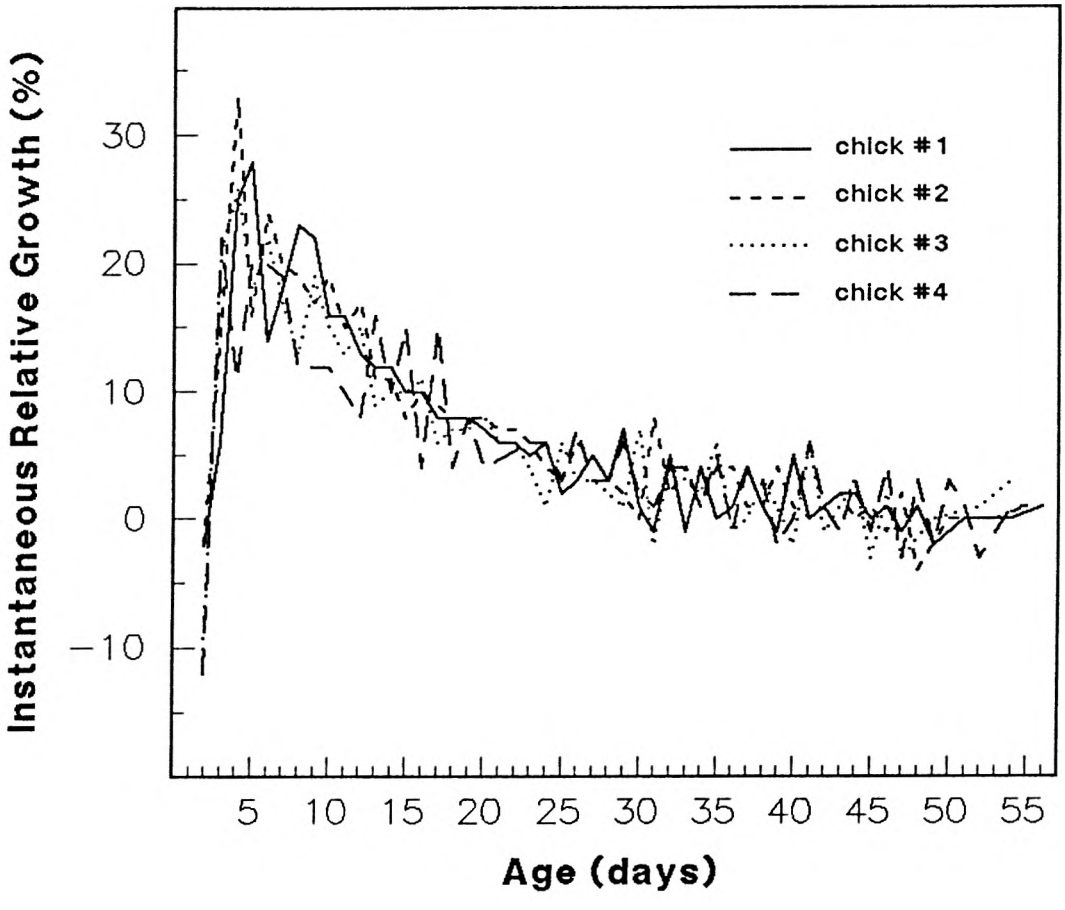

Figure 3.6. Instantaneous relative growth of 4 captive-reared Pied-billed Grebe chicks, days 1–56, Auto Safari Chapin, Guatemala, 1986–87.

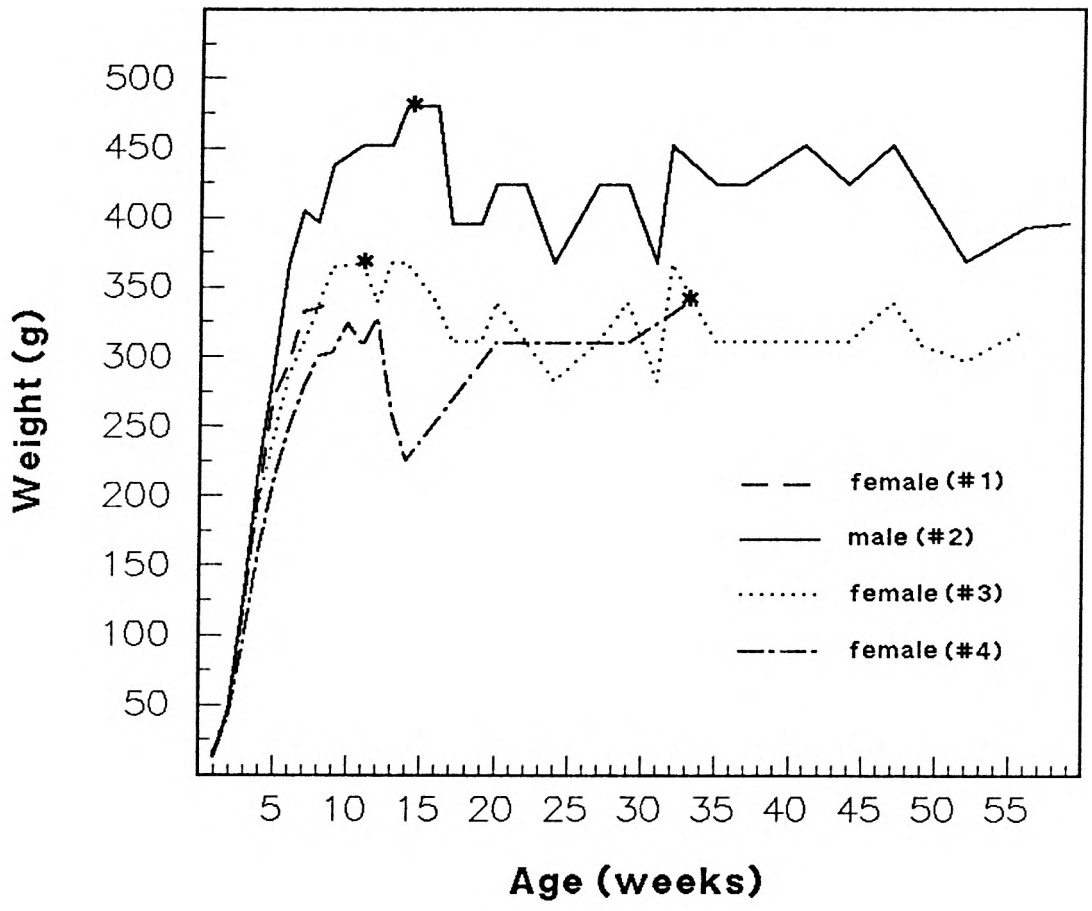

Figure 3.7. Growth curves for 4 captive-reared Pied-billed Grebes, weeks 1-59, Auto Safari Chapin, Guatemala, 1986-87. Asterisks indicate asymptotic weights for chicks #2, #3 and #4.

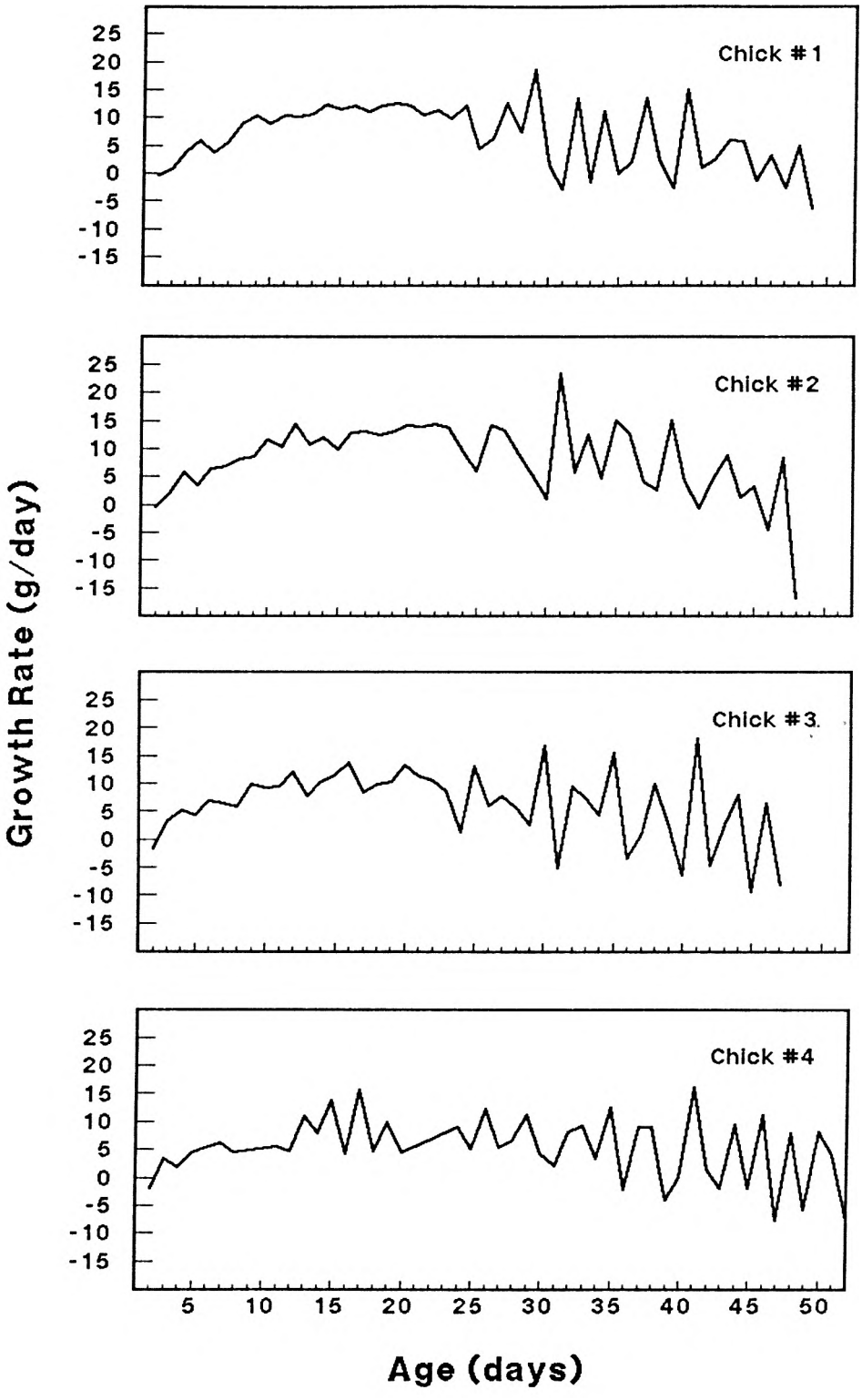

Figure 3.8. Growth rate (daily change in weight) of 4 captive-reared Pied-billed Grebes, days 2-52, Auto Safari Chapin, Guatemala, 1986-87.

APPENDIX B

Chronology of behavioral observations

Table B.l. Behavioral descriptions of captive-reared Pied-billed Grebes, days 1–85, Club Auto Safari Chapin, Guatemala, 1986–87.

Age (Days)	Description of behavior
1	Active and restless in brood box, frequent vocalizations. Poor buoyancy. Difficult to feed, i.e. have poor aim.
2	First attempts at preening. Buoyancy and swimming greatly improved.
3	Consumed first whole fish (2.5–3.5 cm). Time spent in water increased to >1 minute. First attempts at diving. Easier to feed.
4	Preening regularly. Begin some feeding in water. "Comfort moves"[1] in water.
4–6	Looking for fish in water. Show interest in insects around and on water. Increasing ability to handle whole fish.
6–8	Feeding all meals in water. Diving regularly.
7–9	Spending up to 10 minutes in water at a time.
8–10	Begin chasing live fish and insects.
10–12	First successful attempts at catching live fish and insects in water.

[1]Behavioral terminology (in quotes) after LaBastille (1974).

Table B.l (continued).

Age (Days)	Description of behavior
12	Chasing fish which won't consume (i.e. for the fun of it).
13	When relaxed or sleeping, in and out of water, chicks tuck their feet up under their wings.
15–16	Spending 20–30 minutes in water at a time. Consuming larger fish (4.5–7 cm). Chicks trying to climb on each other's backs while in water (want to be back-brooded?).
17	First observation of pellet regurgitation.
16–18	All chicks lost egg tooth. Eating feathers regularly.
19–21	Introduced into a larger tank. Deeper diving. Low tolerance for confined spaces. Spending most of the day in water.
26-28	Easily frightened- instinct is to dive; have observed "accordion" (alarm) dives. First serious aggression. Begin leaving in water day and night.
29–31	Capture efficiency improving. Independent feeding increasing. Chicks often decapitate fish before consuming them. Underwater interactions observed; acknowledge each other, chase fish, swim and emerge together.
32–34	All food is administered in water. Stop feeding after 1830 hours (lose interest in food after dusk). Aggression in water – larger chick bullies others.
36–40	Spend most of the day playing with each other, with leaves, flowers, light reflections, etc. Constantly retrieving things off the bottom.
43–45	Increasingly difficult to catch (e.g. to weigh).
44–46	Transferred to cement pool.

Table B.l (continued).

Age (Days)	Description of behavior
45–48	Appetites low (eating <½ of normal) – adjusting to a new environment? Will eat shrimp and mealworms but not fish. Have observed chicks "pitter-pattering" across the length of the pool.
47–49	Sleeping a lot, not chasing fish. Begin administering tetracycline and vitamin supplement.
49–51	Appetites improving. Eating fish again.
52	One of the chicks still seems to need some time out of water.
60	All chicks feeding independently.
85	One chick observed attempting to fly.

APPENDIX C

Weights of captive-reared Pied-billed Grebes, days 1–440, Club Auto Safari Chapin, Guatemala, 1986–87

Table C.l. Weights of captive-reared Pied-billed Grebe chicks #1, #2, #3, #4 and #5, days 1–60, 1–440, 1–389, 1–232 and 1–2, respectively, Club Auto Safari Chapin, Guatemala, 1986–87.

Age (Days)	Chick Weight (g)				
	#1	#2	#3	#4	#5
1	14.1	13.3	15.9	16.2	14.9
2	13.8	13.0	14.4	14.3	15.4[a]
3	14.6	15.1	17.7	17.9	
4	18.7	21.0	23.0	20.0	
5	24.7	24.6	27.5	24.5	
6	28.5	31.2	34.4	29.9	
7	34.2	38.1	40.9	36.3	
8	43.2	46.3	46.8	40.8	
9	53.6	54.9	56.8	—	
10	62.6	66.5	66.2	52.2	
11	73.2	76.9	75.7	57.9	
12	83.5	91.4	87.7	62.8	
13	94.3	102.3	95.6	73.8	
14	106.7	114.5	106.1	81.9	
15	118.2	124.5	117.7	95.6	
16	130.3	137.4	131.5	100.0	
17	141.4	150.6	140.0	115.8	
18	153.6	163.1	150.0	120.6	
19	166.3	176.2	160.4	130.6	
20	178.5	190.4	173.9	135.3	
21	188.9	204.4	185.3	—	
22	200.3	218.8	195.9	—	
23	210.2	232.7	204.5	160.5	
24	222.4	242.3	206.0	169.6	
25	227.0	248.5	219.2	174.8	
26	233.4	262.8	225.4	187.0	
27	246.0	276.2	233.2	192.4	
28	253.6	285.4	239.0	199.2	

[a]Last weight obtained for chick.

Table C.l (continued).

Age (Days)	Chick Weight (g)			
	#1	#2	#3	#4
29	272.2	290.9	241.8	210.5
30	273.8	292.1	258.7	214.9
31	271.1	315.5	253.6	217.1
32	284.6	321.3	263.2	225.4
33	283.1	333.8	270.5	234.7
34	294.2	338.7	275.0	238.2
35	294.2	353.7	290.6	250.7
36	296.3	366.4	287.3	248.6
37	309.7	370.5	288.2	257.7
38	312.1	373.3	298.2	266.7
39	309.5	388.3	300.6	262.7
40	324.4	392.5	294.2	262.8
41	325.5	392.0	312.3	278.9
42	328.1	396.7	307.8	280.5
43	334.1	405.6	310.6	278.7
44	339.8	407.1	318.6	288.3
45	338.6	410.5	309.4	286.5
46	341.8	406.1	315.9	297.8
47	339.3	414.5	307.9	290.1
48	344.3	397.8	—	298.2
49	338.1	—	306.6	292.5
50	—	397.3	—	300.7
51	336.2	—	—	304.8
52	—	—	312.4	297.1
53	—	401.9	—	—
54	332.0	—	330.7	304.6
55	—	413.2	—	308.4
56	338.9	—	—	—
58	—	—	364.7	303.6
59	—	438.1	—	—
60	339.3[a]	—	—	307.9
61		—	—	312.9
62		—	—	317.9
63		—	—	316.8
64		—	—	324.9
66		—	—	318.9
68		—	—	320.0
69		—	—	318.7
70		—	—	325.6
71		—	367.5	—
72		452.3	—	308.4
74		—	—	314.1

[a]Last weight obtained for chick.

Table C.l (continued).

Age (Days)	Chick Weight (g)		
	#2	#3	#4
78	—	339.3	327.9
79	452.3	—	
83	—	—	277.4
85	—	367.5	259.5
86	452.3	—	—
92	—	367.5	226.0
93	480.5	—	—
97	—	—	250.8
106	—	339.3	—
107	480.5	—	—
113	—	311.0	—
114	395.8	—	—
120	—	311.0	—
121	395.8	—	—
127	—	311.0	—
128	395.8	—	—
134	—	339.3	—
135	424.0	—	310.8
148	—	311.0	—
149	424.0	—	—
162	—	282.8	—
163	367.5	—	—
166	—	—	310.8
184	—	311.0	—
185	424.0	—	—
198	—	339.3	310.8
199	424.0	—	—
213	—	282.8	—
214	367.5	—	—
222	—	367.5	—
223	452.3	—	—
232	—	—	339.0[a]
241	—	311.0	
242	424.0	—	
257	—	311.0	
258	424.0	—	
285	—	311.0	
286	452.3	—	
301	—	311.0	
302	424.0	—	
327	—	339.3	
328	452.3	—	

[a]Last weight obtained for chick.

Table C.l (continued).

Age (Days)	Chick Weight (g)	
	#2	#3
340	—	308.5
341	419.5	—
363	—	297.2
364	369.2	—
388	—	320.0[a]
389	393.1	
440	395.5[a]	

[a]Last weight obtained for chick.

IV. BREEDING BY FIRST YEAR CAPTIVE-REARED SIBLING PIED-BILLED GREBES

Age of first breeding by Pied-billed Grebes (*Podilymbus podiceps*) is unknown (Palmer 1962). Here I document age at first breeding by captive Pied-billed Grebes.

Pied-billed Grebe eggs were collected from nests at 3 lakes in Guatemala (Fig. 4.1) in 1986 and 1987. Eggs were hatched in a Humidaire Model 20 incubator and chicks (n = 4) raised with methods described in detail elsewhere (Chapter III) at Club Auto Safari Chapin, a wild animal park, located on Guatemala's Pacific coastal plain (Fig. 4.1).

Calls associated with courtship and breeding (Deusing 1939; Miller 1942; Kilham 1954; McAllister and Storer 1963; LaBastille 1974) were first heard from 2 of the captive-reared birds when they were approximately 11 months old. The 2 sibling grebes had been reared and maintained together in a concrete pool (5 m × 2 m × 1 m). Grebe sex was determined based on weight (Palmer 1962) and behavioral observations (LaBastille 1974). Male territorial calls (a low throaty "cow-cow-cow") and pair greeting duets (a rapid nasal chatter resembling a series of "na-na-na") (LaBastille 1974) were frequently heard. Aggressive displays were also observed in both birds. On several occasions, the male was seen chasing and then attacking the female by pecking at her head. Aggressive courtship pursuits have also been described by Kilham (1954) and Palmer (1962). Often, when the male swam close to the female, she would turn her head towards him and, without any vocalization, vibrate her bill.

At 13 months of age, the 2 grebes were released at an artificially-constructed pond (approximately 1 ha) on the Club Auto Safari Chapin. Reeds (*Typha domingensis* and *Scirpus californicus*) provided cover for resting and nesting. A stream which flows into and out of the pond provided a constant supply of fish. No other grebes or waterfowl inhabited the pond.

Approximately 2½ weeks after being released on the pond, a Pied-billed Grebe nest and 3 eggs were found in a patch of *T. domingensis* reeds, approximately 3 m from shore. Although the grebe pair was never observed building the nest or incubating the eggs, they were frequently seen entering and emerging from that particular patch of reeds. The eggs had been partially destroyed by an unknown predator. Two could be accurately measured (length = 31.5 mm and 34.8 mm, breadth = 25.6 mm and 25.3 mm, respectively); they were smaller than other Pied-billed Grebe eggs collected in Guatemala (n = 20, $\bar{x}$ length = 42.9 ± 1.9 SD and $\bar{x}$ breadth = 30.1 ± 0.8 SD). Young birds have been reported to commonly lay smaller eggs than older birds of the same species (Romanoff and Romanoff 1949). Because the eggs were destroyed, it was impossible to determine their fertility. These observations indicate that first year Pied-billed Grebes can and will breed.

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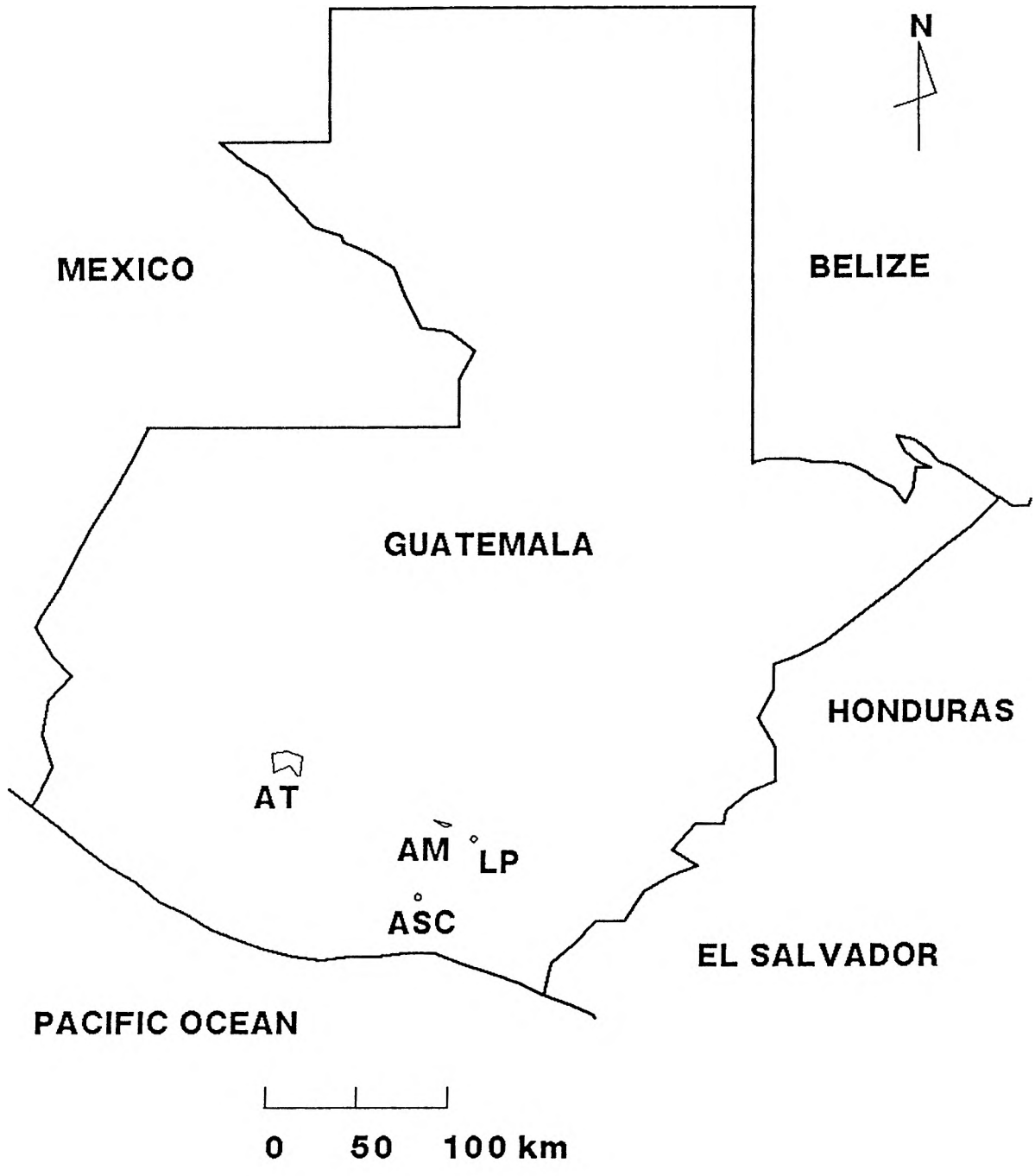

Fig. 4.1. Study site locations, 1986-87, Guatemala, Central America. AT = Lake Atitlan, AM = Lake Amatitlan, LP = Laguna del Pino, ASC = Club Auto Safari Chapin.