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HUSBANDRY REPORTS

Hand-Rearing, Growth, and Development of Common Loon (*Gavia Immer*) Chicks

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Common loon chicks were reared in captivity in association with studies to evaluate the effects of radiotransmitter implants and to assess the ecological risk of dietary methylmercury. Here we report on hatching and rearing methods used to successfully raise chicks to 105 days of age. We experienced a 91.5% hatch rate, and 89.6% of loon chicks survived to the end of the study at 105 days. Baseline information on observed rates of fish consumption, behavioral development, and growth patterns are provided. Husbandry techniques are provided that should prove valuable to wildlife rehabilitators caring for abandoned or injured loons, and biologists contemplating methods for restoring loons to areas within their former breeding range. Zoo Biol. XX:XX–XX, 2014.

Keywords: behavioral development; captive rearing; common loon; food consumption; growth; husbandry

STATEMENT OF THE PROBLEM

Recent interest in captive-rearing common loons (*Gavia immer*) has arisen among wildlife rehabilitators caring for abandoned or injured loons, and biologists contemplating methods for restoring loons to areas within their former breeding range. An attempt at rearing common loon chicks was first described by Beebe [1907]. Observations over 10 days post hatch provided insights into behavioral development, feeding strategies, and motor skills. Only a couple of accounts of captive-rearing common loons have been published since [Pichner and DonCarlos, 1986; Barr, 1996].

In 1998, we hatched common loon eggs in an incubator and reared chicks while evaluating a subcutaneous radio-transmitter implant technique and its effect on loon chick growth and behavior [Kenow et al., 2003b]. In a subsequent study to inform development of a mercury risk assessment model, we evaluated the effects of dietary methylmercury exposure on growth, behavior, immune function, glutathione metabolism and oxidative stress, and chromosomal damage in captive-reared chicks [Fournier et al., 2002; Kenow et al., 2003a, 2007, 2008, 2010; Karasov et al., 2007]. Over the years we have raised 96 (102 with pilot) common loon chicks in captivity at the USGS Upper Midwest Environmental Sciences Center (UMESC) and maintained records on food consumption, growth and development, and disease issues. Details on incubation and hatching were previously reported in Kenow et al. [2003b]. This paper describes husbandry methods to hand-rear common loon chicks, as well as

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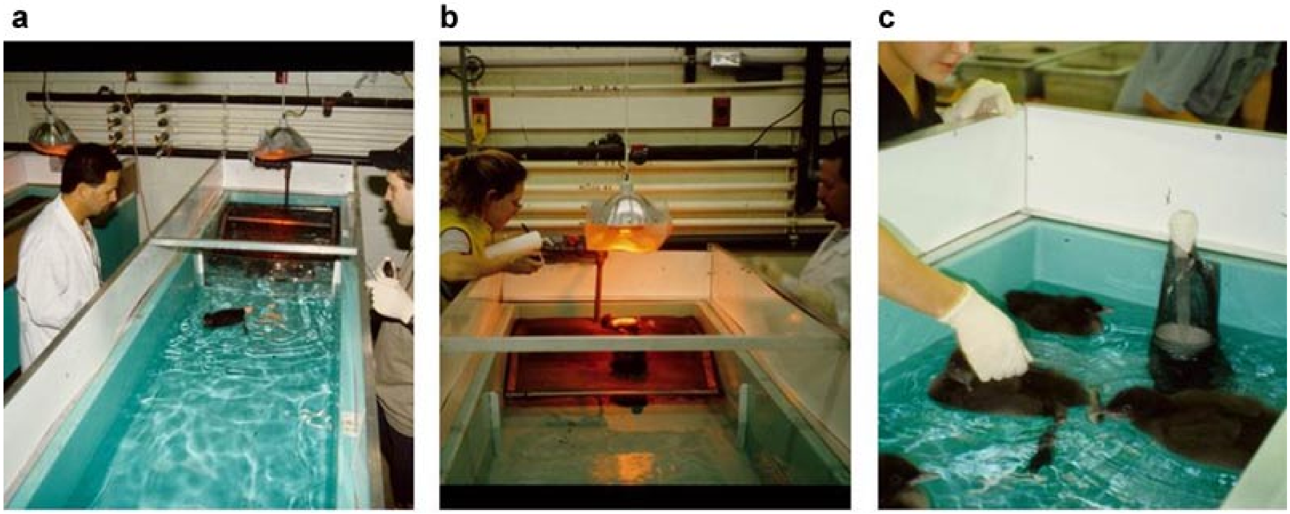

Fig. 1. Indoor raceway used to house common loon chicks at the Upper Midwest Environmental Sciences Center. (a) Interior measurements were 290 cm long, 70 cm wide, and 36 cm deep. An aluminum frame with masonite walls was fitted to each raceway to extend the wall height an additional 20 cm. Indoor raceways were provided with a constant supply of well water at a flow rate of 20–30 L/min and water depth was maintained at approximately 26 cm. (b) At the inflow end of the raceway, we provided a mesh resting platform the width of the raceway and approximately 5 cm above the water level. The front edge was sloped and slightly submerged to facilitate entry to and exit from the water. Centered above each platform was a 250-W infrared heat lamp with reflector and could be raised or lowered to maintain a platform temperature range of 35–38°C. (c) The outflow standpipe was surrounded by a 6 mm plastic mesh shroud to prevent chicks from getting trapped.

information on food consumption, behavioral development, and growth patterns through 15 weeks of age.

DESCRIPTION OF THE PROCESS

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Captive Rearing

Common loon chicks were reared in captivity during late-May through early-October following techniques modified from Pichner and DonCarlos [1986] and Barr [1996]. Chicks were held indoors in groups of 3–4 chicks per raceway/pen in 0.7 m $\times$ 2.9 m raceways until they were about 30 days old (Fig. 1) and then transferred to 49-m^2 outdoor pens (Fig. 2). Facility and environmental conditions are summarized in Table 1. We began transitioning the chicks to the outdoor enclosures at 25–30 days of age. Chicks initially spent about 1 hr in the ponds on the first day and, over a few days, time outside was increased at 4-hr increments until chicks were outside for the entire day, weather permitting. Following acclimation, typically by 35 days of age, they were housed outdoors through the end of the study. Handling and care of chicks were approved by the Animal Care and Use Committee of the UMESC and comply with the Animal Welfare Act.

Feeding

The chicks were fed a diet of rainbow trout (*Oncorhynchus mykiss*). Chicks were fed hourly when very young, but time between feedings increased as the chicks aged. We used forceps to hold and offer fish head first to a chick to simulate the way a wild loon chick is offered food from an adult [Barr, 1996]. Initial feedings required multiple

Fig. 2. The outdoor enclosures to house common loon chicks measured 10 m long, 4.9 m wide, and 1.3 m deep. The complex of 12 ponds was enclosed by fencing with 2.54 cm wire mesh with access gates at either end and covered overhead with polypropylene aviary netting. An electric predator guard wire encircled the top perimeter of the fence and was activated overnight. Fencing separated individual ponds from each other and each raceway had a latching door and concrete-block steps leading into the pond. Each raceway contained an elevated resting platform with sloped ends, approximately 1 square meter in size, constructed from Tenderfoot® matting and supported by cinder blocks. A woven plastic tarp and a 250-W infrared heat lamp were suspended over the platform.

TABLE 1. Description of facilities used in rearing common loons chicks

	Indoor	Outdoor
Description	0.7 m × 2.9 m raceways that contained about 25 cm of water, a resting platform, and a brooder light	48-m^2 outdoor ponds flooded to a depth of approximately 0.6 m and equipped with a resting platform and brooder light. The concrete ponds were enclosed with 2.54 cm wire mesh with access gates and overhead cover of polypropylene aviary netting
Lighting	16L:8D light cycle	Natural lighting
Water supply	Well water (approximately 12°C) was supplied at a constant flow rate of 30–40 L/min. Waste water was discharged and not recirculated	Well water (10–15°C) was supplied at 30–40 L/min. Waste water was discharged and not recirculated
Conditions	Ambient air temperature was 20°C. Raceway water temperature averaged 12.0°C (range 11.1–13.6°C) and indoor platform temperatures were maintained at 29.6°C (18.4–40.3°C). Room lighting was maintained at an approximate 16L:8D light cycle	Outdoor platform temperatures averaged 24.6°C, which was strongly influenced by air temperature as heat lamps were typically off during the day. Outdoor pond water temperature averaged 12.6°C (range 10.2–17.4°C)
Cleaning and disinfecting	Fecal material was removed using a turkey baster as needed. Raceways were drained and rinsed daily and disinfected weekly using chlorhexidine diacetate solution (7.8 ml Nolvasan/L water). Air purifiers equipped with HEPA filters employed to maintain air quality	Outdoor enclosures were drained and power-washed once every 7–14 days to remove buildup of fecal material and algae on the pond floor and walls
Caretaker monitoring period	0600–2200 hr	0600 to sunset

attempts as chicks learned to grasp and manipulate the fish into their mouths. Care was taken to offer chicks appropriately sized fish. Fish were typically stunned before they were offered to a chick, but at about 7–10 days old, chicks were able to pursue and capture live fish. Chicks were fed until satiated, typically signaled by repeated refusals of fish or by exiting the water and resting or preening on the platform. At the first feeding of the day, liquid thiamin (0.2 mg per gram bird weight) and 1 cc of multivitamin solution (LaFebers Vivi 13+; 250 mg in 30 ml distilled water) were injected into fish offered to chicks. Each fish provided to chicks was weighed and recorded. Total number and mass of fish consumed was determined daily for each chick.

Chick Development

Chicks were monitored daily for the occurrence of normal developmental behaviors. Normal and abnormal types of behaviors observed in common loon chicks were developed during a 1998 pilot study and from behaviors observed in wild loon chicks (Table 2).

Chicks were weighed at time of hatch and then daily prior to the first feeding of the day. Growth and plumage measurements were obtained on the day of hatch and then every 3–5 days through age 105 days. Skeletal and structural measurements included culmen, head length, tarsus, wing length, and body length per Baldwin et al. [1931]. Molt intensity and percent of new feathers for the head, body, tail, and wing regions were estimated according to Weller [1957] and Brown and Fredrickson [1983]. The progressive development of the primaries was determined by counting the number of primaries on the right wing in various stages of development (quill color of blue indicating an active growth/blood supply, transitional, or clear).

Measureable effects of mercury toxicosis were limited to chicks receiving a diet containing 1.2 μg Hg/g Hg (as CH_3HgCl)/g wet weight fish and developmental differences were detected between chicks hatched from eggs collected from neutral and low pH lakes [Kenow et al., 2003a]. Consequently, we limited our analyses of chick food consumption and developmental measures to chicks ($n = 32$) dosed at lower Hg treatment levels and which did not exhibit evidence of an infectious process or severe levels of aspergillosis at the conclusion of the study.

Health Monitoring

An individual that exhibited three or more symptoms of bacterial or viral infection (i.e., lethargy, reduced appetite, mass loss, paralysis of one leg, wing droop, listing to one side when floating or swimming) was considered to have likely developed an illness from an unidentified pathogen, and so, a blood sample was drawn and submitted for a complete blood count and serum protein electrophoresis [see Kenow

TABLE 2. Lists of normal and abnormal behaviors developed during observations of captive-reared common loon chicks during the pilot study and from loon chicks in the wild

Normal behaviors	Description	Abnormal behaviors	Description
Accept food	Loon is willing and able to consume fish offered by caretaker	Not eating	Refusal to eat offered fish
Beg/approach caretaker	Swim toward caretaker, peep or other vocalization, light pecks to forceps or caretaker	Reticence	Loon shies away from caretakers and other loons
Float/swim	Loon is able to float upright, high in the water, swim calmly and with purpose	Difficulty swimming	Panics while swimming or has trouble staying afloat
Enter and exit water	Chick able to propel itself down/up platform ramp into/out of water	Listlessness	Lacks energy, does not readily respond to other loons or caretakers
Defecate in water	Bowel movement while floating in water, feces sinks to bottom of pond	Uncontrolled defecation	Defecates in abnormal place, such as on platform
Preen on platform/in water	A series of various behaviors to maintain plumage condition	Not preening	No preening behaviors observed and plumage condition deteriorates
Access oil gland	Loon reaches back with bill to uropygial gland	Excessive preening	Engages in excessive preening behaviors such as wing flaps, foot waggles or bathing
Roll preen	While in water, loon will lean over, exposing its belly to preen it with its bill	Ataxia	Loon lacks total or partial inability to coordinate voluntary bodily movements such as locomotion, feeding or preening
Bathing	Splashes in water with wings	Listing in water	Uncontrolled lean to one side while in the water
Wing flap	Loon raises belly above water and flaps fully extended wings	Hyperactivity/pacing	Constant, purposeless motion
Foot waggle	Loon extends foot backwards and shakes it to remove water before foot tuck	Gasping or wheezing	Loon has labored breathing or makes raspy, gurgling noises while breathing
Foot tuck	Loon places foot between wing and body	Exits water	Crawls up on substrate to leave water as older chick (differs from brooding platform use)
Head tuck	Loon tucks bill between its wings while resting or sleeping	Wing droop	Outer primaries drag in water while floating or swimming
Peer	Loon places bill and face in water to investigate underwater objects	Shiver	Continuous, excessive shivering
Dive/swim underwater	Loon completely submerges itself underwater, propelling itself with its feet	Excessive panting	Noticeably long periods of panting
Capture fish	Capture live, unimpaired free-swimming fish	Leg paralysis or trailing leg	Loon consistently uses only one leg for propulsion, leg trails behind loon with little or no movement
Vocalize	Make typical loon noises	Excessive vocalizations	Hoots, wails or tremolos incessantly, for no apparent reason
Agonistic behavior	Aggressive interaction with another loon chick	Floating or discolored feces	Feces does not sink to bottom of pond, abnormal color
Flight attempt	Loon runs across length of pond while flapping wings		

TABLE 3. Approximate time intervals between feedings of various aged captive-reared common loon chicks

Chick age in days	Average time between feedings (hr)	Time range between feedings (hr)
0–14	1.3	0.5–1.5
15–28	1.75	1.0–2.0
29–40	2.0	1.5–3.0
41–60	3.0	2.0–3.0
60+	3.5	2.0–4.0

et al., 2007]. Elevated white blood cell counts and presence of globulinopathies were used to confirm the presence of an infectious process. Infected chicks were started on a 10-day course of cyprofloxacin at 30 mg per kg body mass twice a day. If a chick failed to recover after the course of antibiotics or continued to decline in health, the chick was euthanized and necropsied.

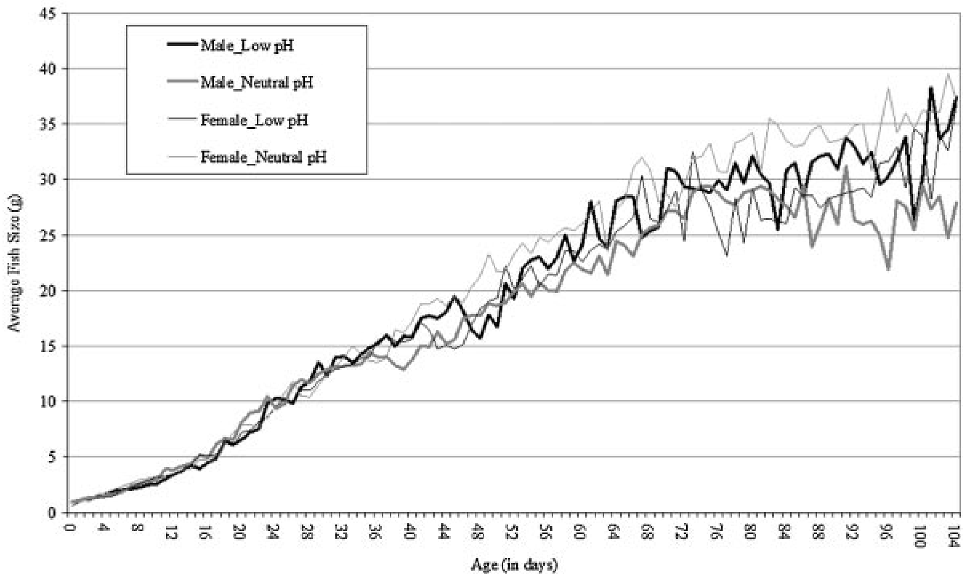

Fig. 3. Average size of rainbow trout fed to captive-raised male and female common loon chicks from low and neutral pH lakes over time. Sample sizes are as follows: males, low pH lake, $n = 6$; males, neutral pH lakes, $n = 8$; Females, low pH lakes, $n = 7$; females, neutral pH lakes, $n = 11$.

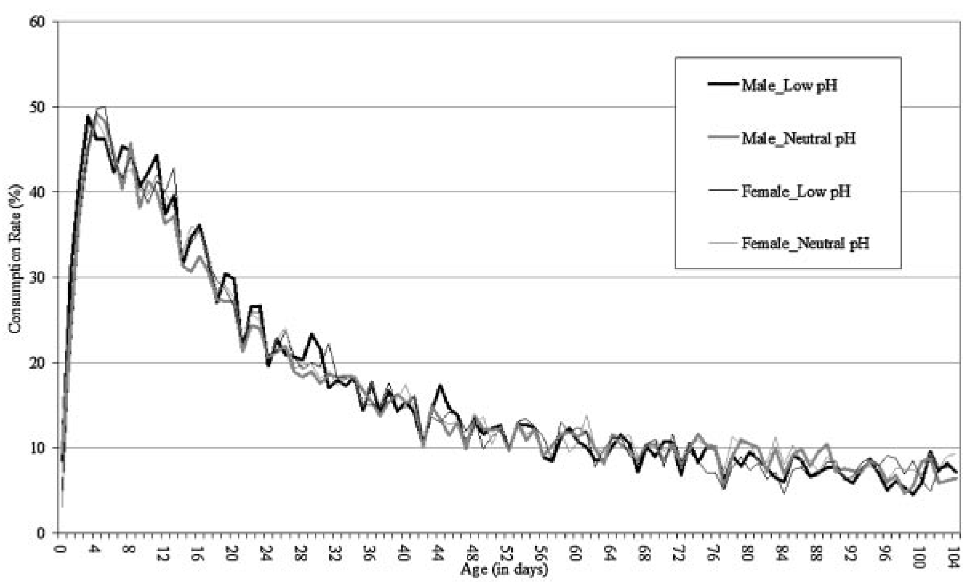

Fig. 4. Average consumption rate (CR) of captive raised male and female common loon chicks from low and neutral pH lakes. Calculated as [(daily total grams consumed/AM weight) × 100]. Sample sizes are as follows: males, low pH lake, $n = 6$; males, neutral pH lakes, $n = 8$; females, low pH lakes, $n = 7$; females, neutral pH lakes, $n = 11$.

TABLE 4. Average age of occurrence of behaviors observed in captive-reared common loon chicks during time-activity budget observation periods

	Age in days			
Behavior	Mean	SD	Median	Range
Accept food	0	0.39	0	0–1
Float/swim	0	0.42	0	0–1
Enter or exit water	0	0.46	0	0–1
Vocalize	1	1.73	0	0–9
Beg	1	0.60	1	0–2
Wing flap	1	0.82	1	0–3
Defecate in water	1	1.96	1	0–8
Preen on platform	1	0.63	1	0–2
Foot waggle	2	1.72	1	0–7
Foot tuck	2	1.04	1	0–4
Preen in water	3	2.52	3	0–10
Dive	3	1.37	2	1–6
Oil	4	2.38	4	1–9
Roll preen	5	2.32	5	1–10
Peer	6	2.67	6	1–11
Head tuck	7	5.69	6	0–18
Capture fish	15	11.49	12	5–59
Bathing	24	15.09	20	3–61
Signs of bacterial/ viral infection	47	12.60	47	29–67
Flight attempt	75	13.90	76	48–107

DEMONSTRATION OF EFFICACY

Disease-Mortality

We hatched 97 of 106 common loon eggs collected for our study in 1999, 2000, and 2003. However, one chick died shortly after hatching due to complications during hatch, leaving 96 that were reared as part of the study. During each year, several chicks contracted an illness from an unidentified pathogen (12 in 1999, 7 in 2000, and 4 in 2003). Most birds recovered after the prescribed course of antibiotics. However, six birds did not respond to antibiotics and were euthanized. Four additional chicks died from accidental causes, including entrapment, head trauma, and infection of a leg injury. Thus, a total of 86 chicks (89.6%) survived to the end of the study.

At the conclusion of the 15-week experiment, necropsy provided evidence of aspergillosis, and included variously sized lesions in the trachea and air sacs. Forty-one (47.7%) of all the birds that were raised to 15 weeks of age exhibited evidence of aspergillosis (17 with minor lesions, 24 with severe lesions and thickened air sac walls).

Feeding

Data in the following sections are summarized by gender and egg lake source (neutral versus low pH lakes) because previous analyses implied differences in chick development related to lake source [Kenow et al., 2003a].

Newly hatched chicks were fed approximately every hour, but feeding frequency decreased with age (Table 3). Loon chicks initially consumed fish <5 g in size until approximately 16 days of age; thereafter, offered fish size steadily increased with age (Fig. 3).

Consumption rate (proportion of body mass), although somewhat variable on a daily basis, peaked at approximately 50% of body mass at 3–5 days old and then declined to under

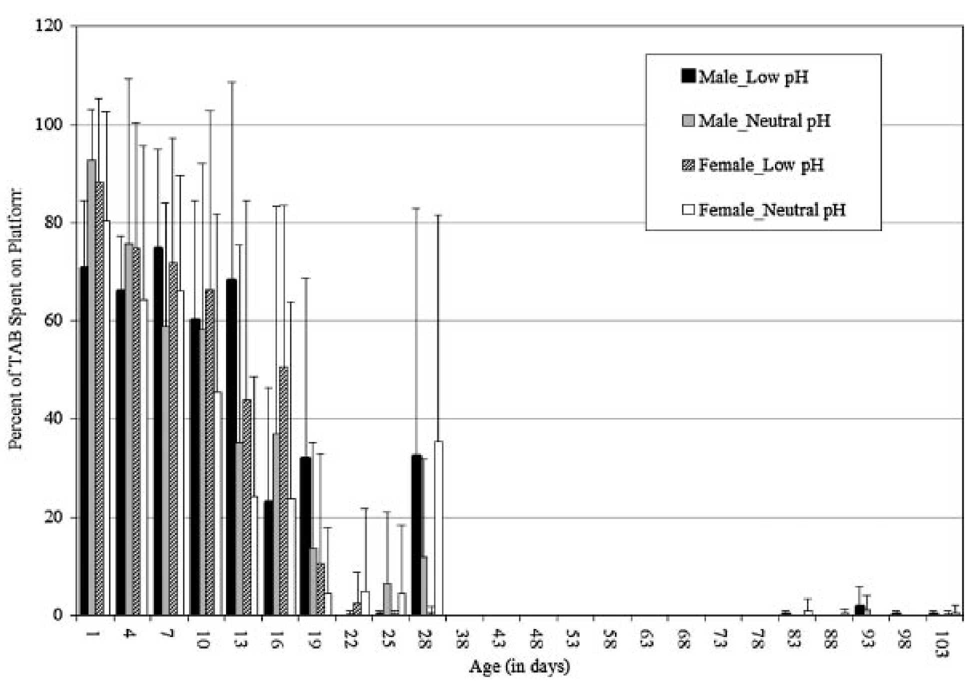

Fig. 5. Average percent of time-activity budgets (TAB) spent on platform by captive-raised male and female common loon chicks from low and neutral pH lakes. Calculated as [(# of observations on platform/total observations) × 100]. Sample sizes are as follows: males, low pH lake, $n=6$; males, neutral pH lakes, $n=8$; females, low pH lakes, $n=7$; females, neutral pH lakes, $n=11$.

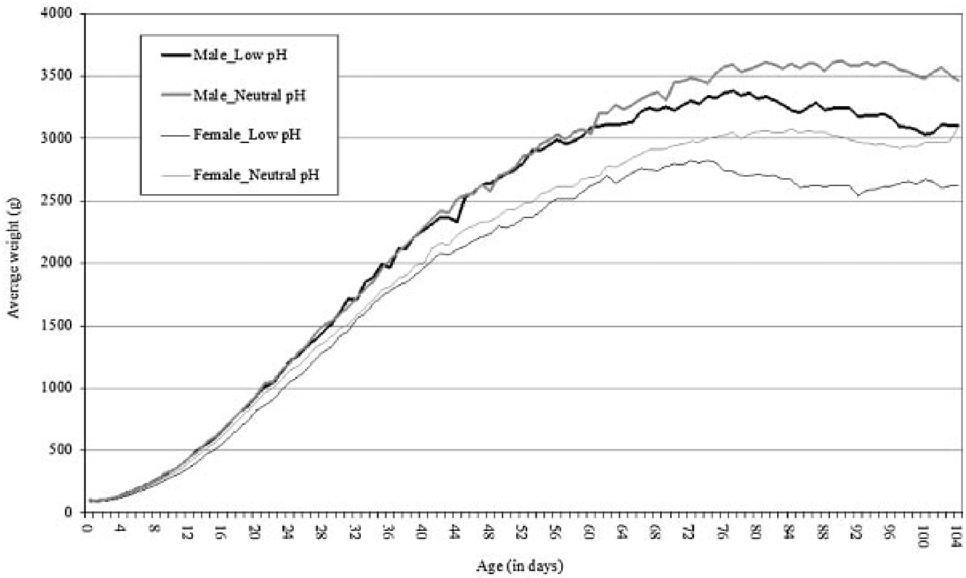

Fig. 6. Average morning weight of captive-raised male and female common loon chicks from low and neutral pH lakes. Chicks were weighed prior to the first feeding each morning. Weight at hatching is indicated at day 0. Sample sizes are as follows: males, low pH lake, $n = 6$; males, neutral pH lakes, $n = 8$; females, low pH lakes, $n = 7$; females, neutral pH lakes, $n = 11$.

10% at approximately 77 days old (Fig. 4). Factors such as molting, blood sampling, and being housed in an unfamiliar raceway (such as during home raceway cleaning) resulted in reduced daily fish consumption of some chicks. As chicks aged, some preferred to capture live fish and refused dead or stunned fish.

Chick Development

Loon chicks were able to perform many behaviors on the day of hatch, including accepting food, entering and exiting the water, and swim/float (Table 4). By 7 days of age, chicks were exhibiting basic behaviors such as preening, vocalizing, diving and swimming underwater, etc. The ability to capture free-swimming fish was observed in chicks as young as 5 days old. While platforms were always available to the chicks, daytime platform use quickly diminished with age, and normal healthy chicks were rarely observed on the platforms provided in the outdoor pens (age >30 days; Fig. 5). The spike in platform use at 28 days coincides with introduction to the outdoor enclosures. Loons began "flight attempts" in the outdoor enclosures at approximately ≥48 days old.

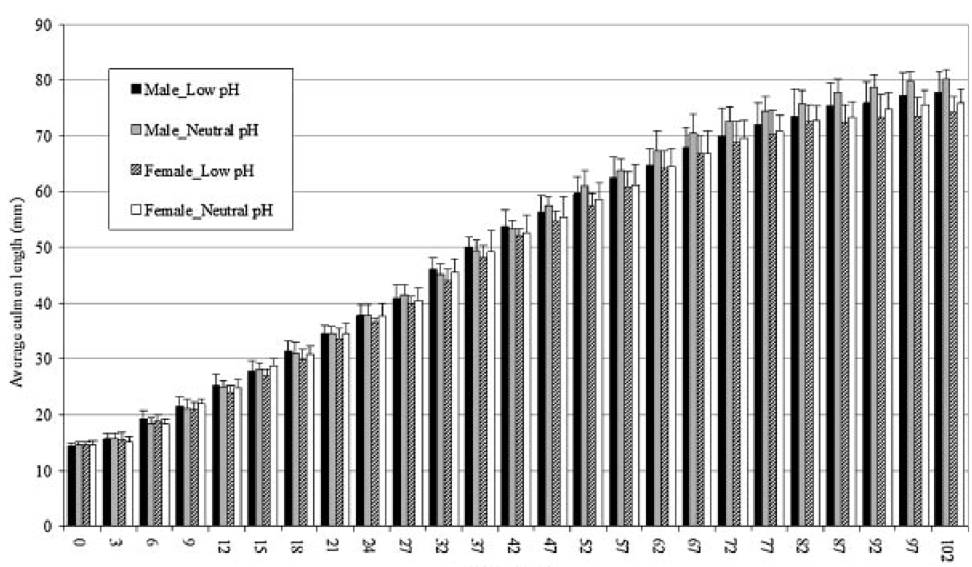

Fig. 7. Average culmen length of captive-raised male and female common loon chicks from low and neutral pH lakes. Sample sizes are as follows: males, low pH lake, $n = 6$; males, neutral pH lakes, $n = 8$; females, low pH lakes, $n = 7$; females, neutral pH lakes, $n = 11$.

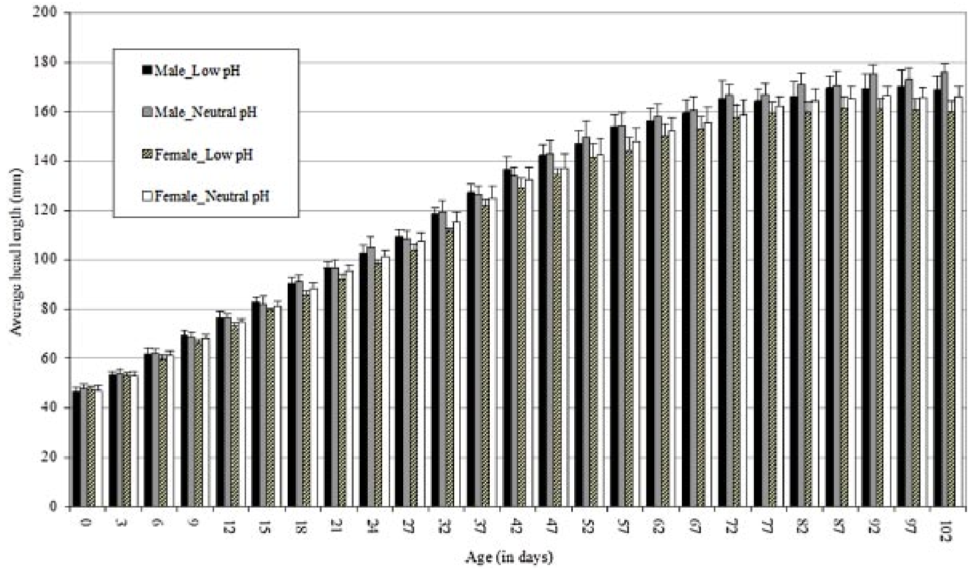

Fig. 8. Average head length of captive-raised male and female common loon chicks from low and neutral pH lakes. Sample sizes are as follows: males, low pH lake, $n=6$; males, neutral pH lakes, $n=8$; females, low pH lakes, $n=7$; females, neutral pH lakes, $n=11$.

Asymptotic measures of body mass and structural size (culmen, head, tarsus, wing, and body lengths) were consistently higher in males (Figs. 6–11). Tarsus development outpaced growth of culmen, head, wing, and body length relative to asymptotic levels.

The transition from down to feathers began at about 12 days old and chicks were completely feathered by 62–67 days old (Fig. 12). The first primaries appeared at 12–15 days of age for all four gender-lake source groups and all primaries appeared by approximately 37 days of age (Fig. 13). The peak of transition from actively growing primaries to clear, fully developed primaries occurred between 67 and 72 days of age. A time-series of photographs in Figure 14a–f depicts a loon at various ages and stages of development.

DISCUSSION

Methods for incubating eggs, hatching, and raising common loon chicks in captivity for our study were considered successful. We experienced a 91.5% hatch rate

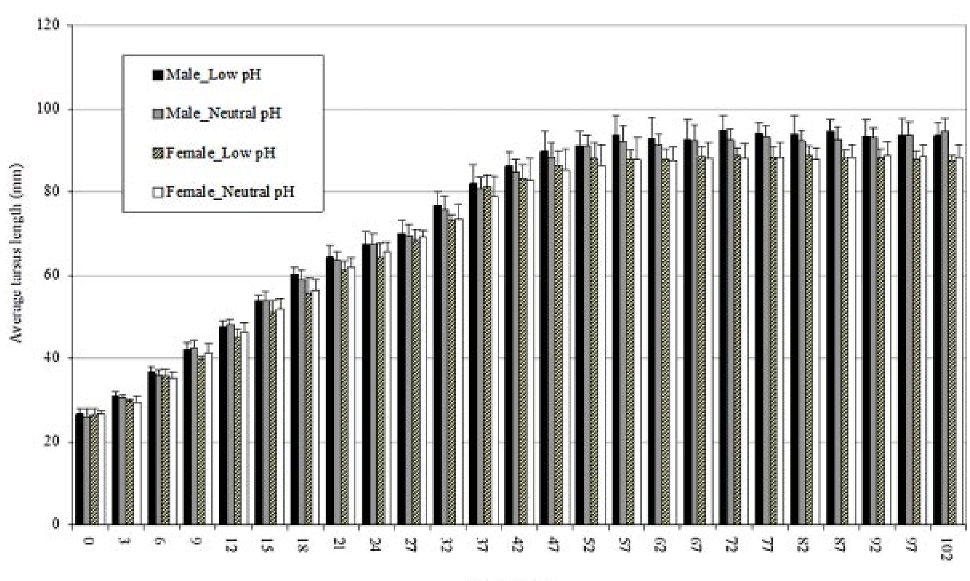

Fig. 9. Average tarsus length of captive-raised male and female common loon chicks from low and neutral pH lakes. Sample sizes are as follows: males, low pH lake, $n=6$; males, neutral pH lakes, $n=8$; females, low pH lakes, $n=7$; females, neutral pH lakes, $n=11$.

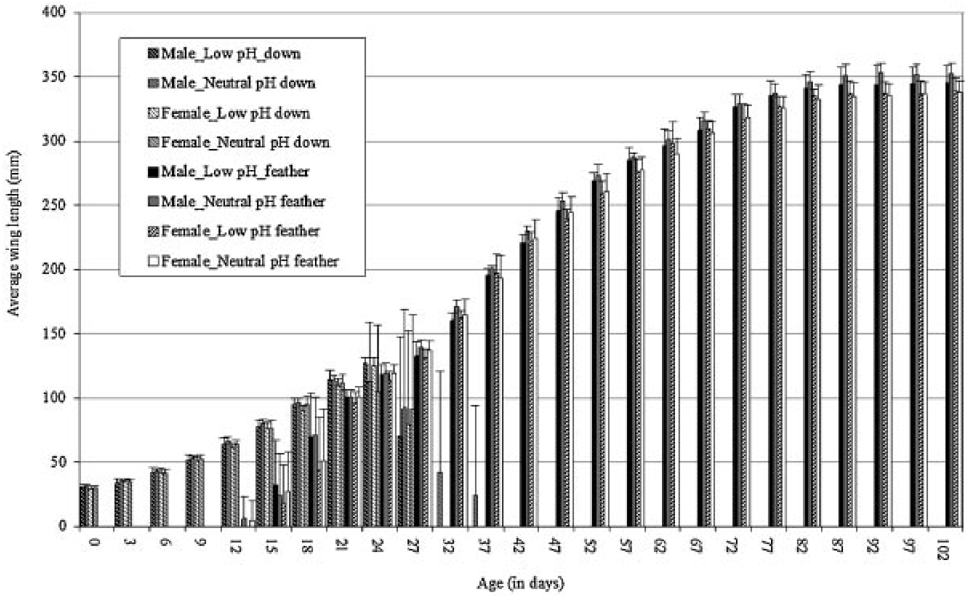

Fig. 10. Average wing length of captive-raised male and female common loon chicks from low and neutral pH lakes. Patterned bars represent wing length in the downy stage; solid bars represent feathered wing length. Sample sizes are as follows: males, low pH lake, $n = 6$; males, neutral pH lakes, $n = 8$; females, low pH lakes, $n = 7$; females, neutral pH lakes, $n = 11$.

and 89.6% of our chicks survived to the end of the study at 105 days. Fish consumption records and growth measurements provide useful baseline information on the dietary needs of rapidly growing chicks and growth patterns.

Rearing loon chicks is a labor-intensive process and requires patience and an understanding of loon behavior. Loons should have access to water at all times and the water needs to have surface movement (i.e., supply flow rates of 30–40 L/min). Chicks should be provided size-appropriate fish, beginning at about 1-g in size for newly hatched chicks, to prevent choking and asphyxiation. It may take several attempts for a newly hatched chick to successfully manipulate and swallow an offered fish so caregivers must be patient. Chicks are capable of foraging on their own by 8 weeks of age [Pichner, 1997], so it is possible to provide free-living forage base in rearing ponds and reduce human contact as chicks mature. During our 1998 pilot study we released six loons to the wild and

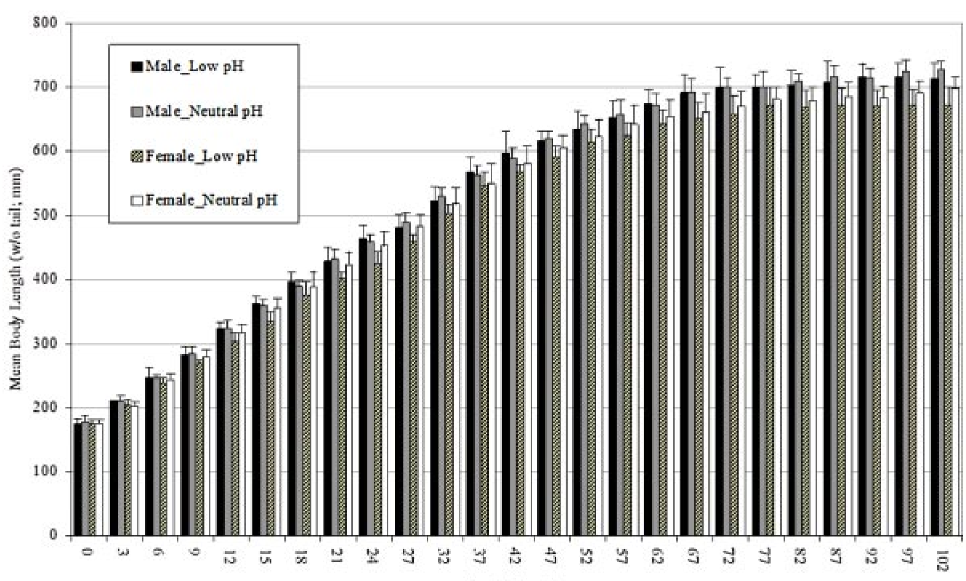

Fig. 11. Average body length of captive-raised male and female common loon chicks from low and neutral pH lakes. Sample sizes are as follows: males, low pH lake, $n = 6$; males, neutral pH lakes, $n = 8$; females, low pH lakes, $n = 7$; females, neutral pH lakes, $n = 11$.

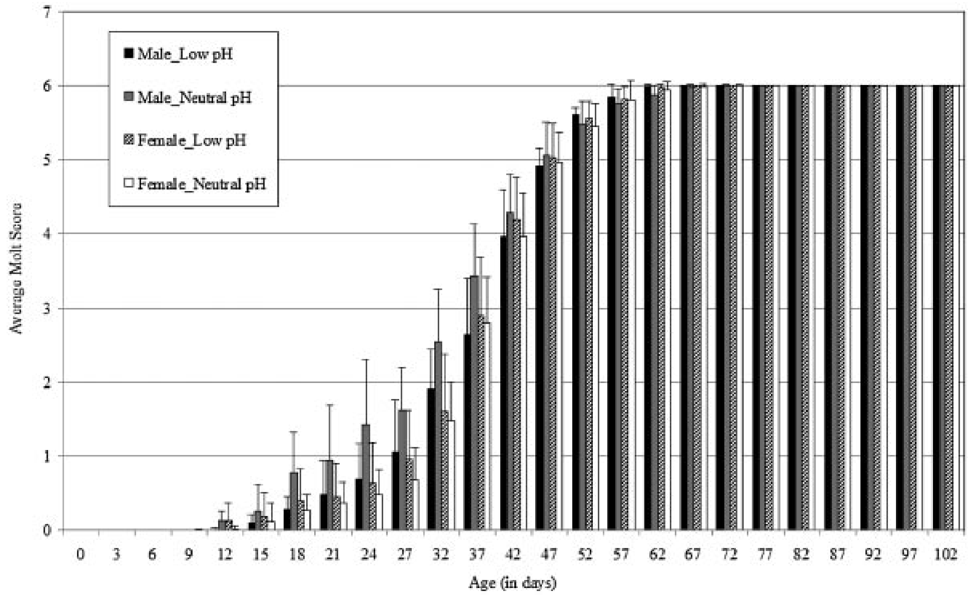

Fig. 12. Average molt scores of captive-raised male and female common loon chicks from low and neutral pH lakes. Molt progress was scored as follows: 0 = 0% feathers; 1 = 1–5% feathered; 2 = 5–25% feathered; 3 = 25–50% feathered; 4 = 50–75% feathered; 5 = 75–95% feathered; and 6 = 95–100% feathered. Molt scores for all feather tracts were combined and averaged to create an overall molt score. Sample sizes are as follows: Males, low pH lake, $n = 6$; males, neutral pH lakes, $n = 8$; females, low pH lakes, $n = 7$; females, neutral pH lakes, $n = 11$.

continued to provide fish to them for a couple of weeks to help them adjust to foraging on their own. We had not anticipated that we would release the captive-reared loons, so 6 weeks prior to the release we limited contact with the penned loons and allowed them to forage on a school of rainbow trout that we maintained in their enclosure. However, upon release, the loons were observed to approach people and beg for food. Limiting human exposure, while allowing chicks to become less reliant on hand-feeding and providing extensive opportunity to forage on their own, should be considered if loons are being reared for release.

Some risk of disease should be expected in captive-rearing situations. We noted that some loon chicks were

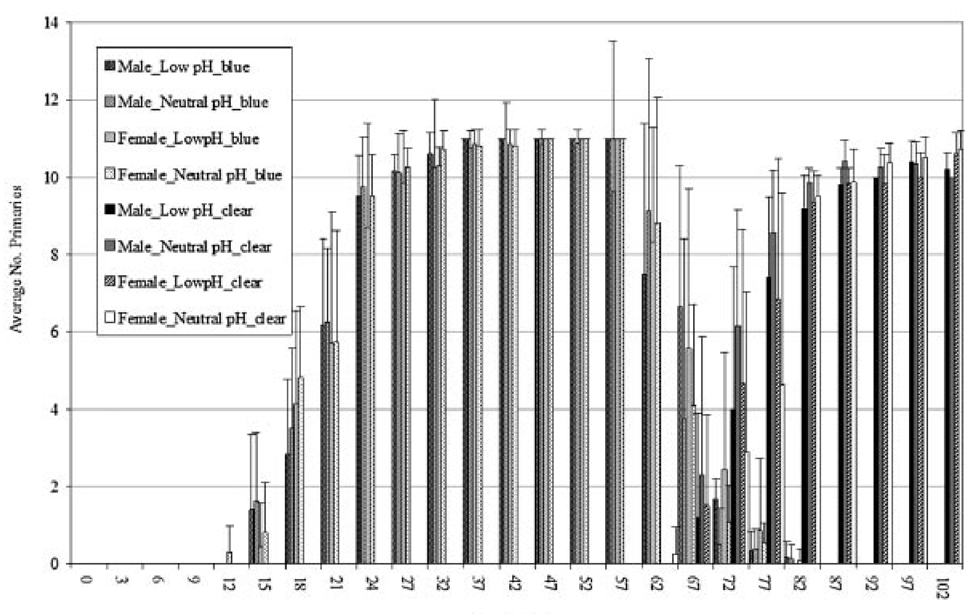

Fig. 13. Average primary development in captive raised male and female common loon chicks from low and neutral pH lakes. Sample sizes are as follows: Males, low pH lake, $n = 6$; males, neutral pH lakes, $n = 8$; females, low pH lakes, $n = 7$; females, neutral pH lakes, $n = 11$.

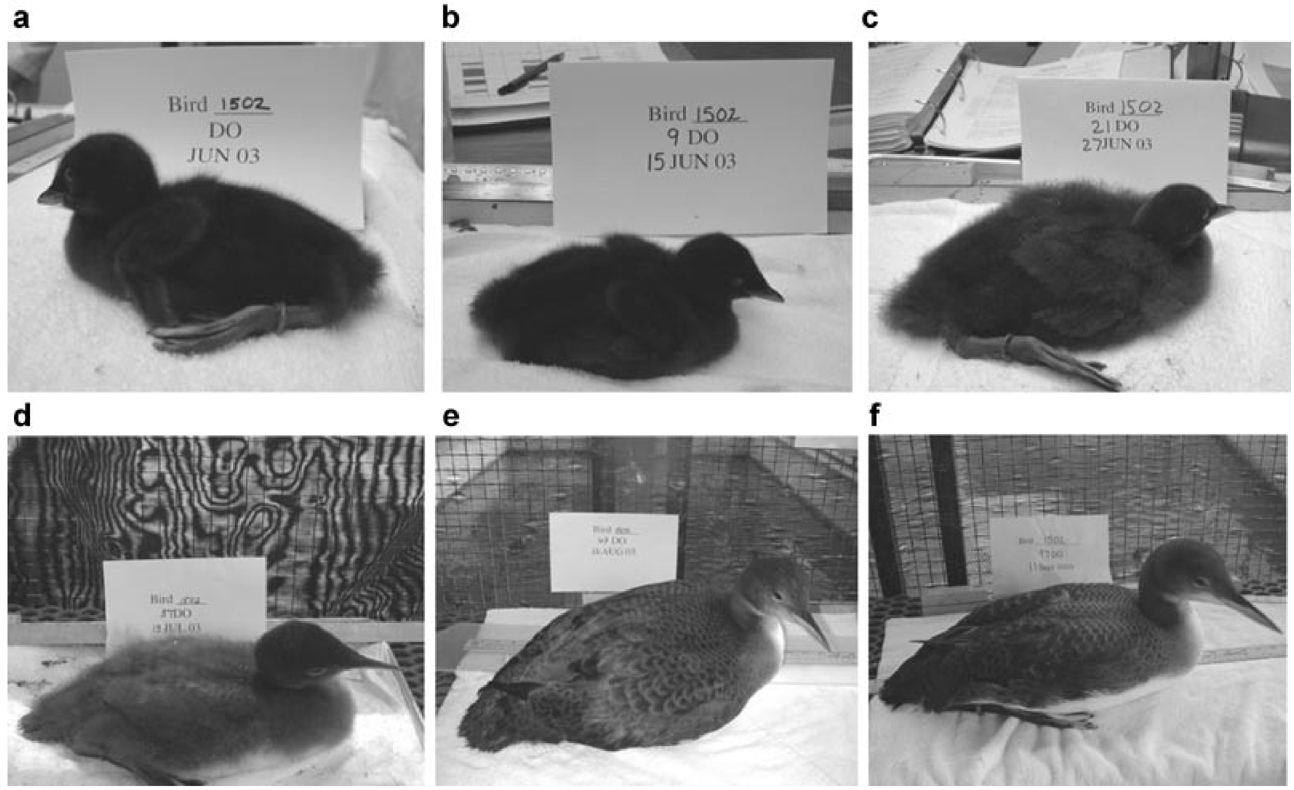

Fig. 14. Photo series of a common loon chick depicting various ages and stages of development: (a) 0 days old (hatch); (b) 9 days old; (c) 21 days old; (d) 37 days old; (e) 67 days old; (f) 97 days old.

susceptible to bacterial infection, but if caught early enough, chicks recovered after a course of antibiotics. Force-feeding was necessary if a chick refused to eat for an extended period of time. We typically force-fed small fish and only when antibiotics were needed and/or to prevent dehydration. Aspergillosis was also a concern. In the indoor lab where loons were housed, we used air purifiers with HEPA filters to maintain air quality. That was not feasible for the outdoor enclosures. Enclosures were drained and cleaned on a regular basis and surfaces were regularly disinfected. However, it is difficult to prevent exposure to airborne *Aspergillus sp*. spores with a facility located within an agricultural region.

After a loon chick hatched, it was introduced to a raceway with 2–3 other chicks. In the wild, a loon chick will aggressively peck its sibling into a submissive posture to exert its dominance [Evers et al., 2010]. We observed this same behavior in captive chicks sharing the same raceway. Once the dominant chick established itself, the aggression toward its raceway-mates ended.

Periods of stress for the loon chicks under our care included the transition to the outdoor enclosures, times of molt, and time spent out of their home raceway (e.g., during raceway cleaning). Loon chicks would typically refuse food, pace, whine, dive repeatedly or make "flight attempts" across their raceway when stressed. The presence of caretakers in the enclosure served as a source of comfort for agitated chicks.

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