EFFECTS OF SALINE WATER ON GROWTH AND SURVIVAL OF MOTTLED DUCK DUCKLINGS IN LOUISIANA

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Abstract: We studied the effects of saline drinking water on the growth and survival of penned mottled duck (*Anas fulvigula*) ducklings at Rockefeller Wildlife Refuge in southwestern Louisiana in 1989. Duckling mortality at different salinities was 100% at 18 ppt, 90% at 15 ppt, and 10% at 12 ppt. No ducklings died within treatments of <12 ppt, but the growth rate of ducklings in the 12-ppt treatment was lower ($P \leq 0.05$) than all lower salinity treatments. When ducklings were given 12-ppt salinity water and exercised, mortality would have exceeded 70%. Initial lethargy shown by ducklings in the 9-ppt treatment, combined with potentially high mortality of ducklings given 12-ppt salinity water and exercised, suggested that the upper salinity threshold tolerated by wild mottled duck broods lies within this range. We advocate creation and management of semi-impoundments in coastal Louisiana and Texas to prevent deterioration and/or loss of marshes of <9-ppt salinity to provide quality habitat for mottled duck broods and other species of flora and fauna dependent on these marshes.

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The mottled duck is a nonmigratory species occupying a restricted range in North and Central America. Isolated populations occur in Florida, central Mexico, and the coastal marshes from Mississippi westward to northern Veracruz, Mexico (Bellrose 1980). However, the greatest number (98%) of mottled ducks occurs in coastal marshes of Louisiana and Texas where there is an estimated breeding population of 110,000 (Stutzenbaker 1988).

There is concern about the mottled duck because annual surveys conducted in Louisiana have indicated a 44% decline from 1971 to 1983 (Stutzenbaker 1988). Stutzenbaker (1988) hypothesized that the loss and deterioration of remaining habitat in both Texas and Louisiana might be responsible.

Saltwater intrusion, in particular, has caused significant habitat changes in Louisiana marshes. From 1968 to 1978, for example, freshwater marsh vegetation decreased and saline vegetation increased, especially in areas transected by large canals (Chabreck and Linscombe 1982). Furthermore, saline drinking water may affect the condition of both adult and juvenile waterfowl (Windingstad et al. 1987, Tiejte and Teer 1988). Ducklings are even less tolerant of salt water than adult birds because their salt glands are poorly developed, especially at <6 days of age (Ellis et al. 1963, Schmidt-Nielsen and Kim 1964, Riggert 1977). Mallard ducklings, for instance, suffered mortality, reduced growth, and a variety of sublethal physiological abnormalities when exposed to high concentrations of sodium sulfate, magnesium sulfate, and saline water occurring in natural wetlands in Saskatchewan (Mitcham and Wobeser 1988*a*,*b*). In North Dakota, wild ducklings concentrated and fed around freshwater seepages on saline lakes (Swanson et al. 1984).

Female mottled ducks often bypass less productive areas of marsh close to the nest while leading ducklings to more productive brood-rearing areas (Baker 1983). Therefore, ducklings traveling through, or remaining in, marshes affected by saltwater intrusion could suffer decreased survivorship.

Our study determined the effects of saline water on the growth and survival of mottled duck ducklings. We hypothesized that survivorship, growth rates, and levels of body mass and carcass components would decrease as salinity levels increased.

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Table 1. Survival of mottled duck ducklings subjected to various salinity treatments.

Salinity treatment (ppt)	n	No. ducklings alive Day 1	Day 2	Day 3	Day 4	Day 5	Day 8	Day 60	Overall mortality (%)
Freshwater control[a]	8	8	8	8	8	8	8	8	0
1.5	7	7	7	7	7	7	7	7	0
4.0	10	10	10	10	10	10	10	10	0
6.0	8	8	8	8	8	8	8	8	0
9.0	9	9	9	9	9	9	9	9	0
12.0	10	10	10	9	9	9	9	9	10
12.0 exercised[b]	7[c]	7	7	2	2				70
15.0	10	10	9	8	5	3	1	1	90
18.0	10	10	10	6	1	0	0	0	100

[a] 0.5-ppt salinity.
[b] Ducklings were exercised until Day 5 and then allowed to recover on freshwater.
[c] Number of ducklings still active in treatment.

H. B. Underwood provided statistical consultation.

STUDY AREA

We conducted our study at the Rockefeller State Wildlife Refuge in southwestern Louisiana. The refuge is composed of about 34,000 ha of saline, brackish, intermediate, and fresh marshes bordered on the south by the Gulf of Mexico and on the north by the Grand Chenier-Pecan Island stranded beach ridge (Joanen and Glasgow 1965). Paulus (1980) provides a detailed description of the study area.

METHODS

Treatments.—We conducted fieldwork from 1 April to 31 July 1989. We collected eggs from wild nests located on Rockefeller Refuge and from mottled ducks held in pens on the refuge. Upon hatching, ducklings were allowed to dry in brooders for 1 day and then were assigned randomly to 1 of 8 salinity treatments (n = 7–10/treatment). Salinity levels reflected natural habitats as classified by Paulus (1980) and were 0.5 ppt (freshwater control), 1.5 ppt (slightly intermediate), 4.0 ppt (intermediate), 6.0 ppt (stongly intermediate), 9.0 ppt (slightly brackish), 12.0 ppt (brackish), 15.0 ppt (strongly brackish), and 18.0 ppt (slightly saline). Trials were of 60 days duration, which is approximately the time required for ducklings to reach flight-stage (Stutzenbaker 1988). Additionally, because wild ducklings probably expend more energy than penned ducklings while searching for food and traveling to a brood-rearing marsh, we initiated an additional treatment whereby ducklings received 12-ppt water and were exercised by swimming and walking for 20 minutes per hour, 12 hours per day.

Because day-old ducklings were not always available at the start of a treatment, some treatments had ducklings of different ages (i.e., ≤3 days difference). We did not separate these ducklings because we did not think the difference in ages would affect their food consumption. In the freshwater control group, however, a greater age difference occurred (i.e., 4–7 days), so we kept the younger ducklings in a separate brooder until Day 14 to measure food consumption more accurately. Each group of ducklings was kept indoors in a standard-size chick brooder (0.9 × 0.6 × 0.3 m) until 14 days of age and then was placed in covered, outdoor pens (3.0 × 3.0 × 2.5 m). The covers on each pen prevented rainfall from entering and diluting the saline drinking water. All procedures relative to care and handling of ducklings were approved by the animal welfare committee at the State University of New York, College of Environmental Science and Forestry.

Saline Water and Diet.—We used a commercial saltwater aquarium concentrate (Fritz Chemical Co., Dallas, Tex.) to mix saline water to desired salinity levels. The chemical constituents in this preparation are identical to those present in sea water (Levinton 1982). The designated salinity level (or the freshwater control) and a standard commercial starter diet for game birds (protein ≥20%, fat ≥3.0%, fiber <5.0%; Purina Mills, Inc., St. Louis, Mo.) were provided ad libitum. Although some salt was present in the diet, salt intake by ducklings was dominated by that present in the drinking water, and dietary salt would have affected all treatments equally. Each day we recorded mortality, food consumption, and clinical signs (i.e., nasal secretions, lethargy, and fecal characteristics.)

Body Mass and Carcass Composition.—

Table 2. Mean food consumed (g/duckling/day) by mottled duck ducklings in salinity treatments for the 60-day experiment.

	Days						
Salinity treatment (ppt)	1–5	6–10	11–15	16–20	21–30	31–40	41–60
Freshwater control[a]	6.6	17.4	30.8	42.4	58.9	62.4	60.1
1.5	9.4	23.2	40.8	47.6	58.0	60.9	57.2
4.0	6.0	19.2	31.8	45.4	69.2	79.8	60.3
6.0	7.8	19.6	35.8	45.6	63.2	68.2	60.8
9.0	5.2	18.6	34.2	43.5	57.2	64.5	68.0
12.0	3.2	14.4	21.8	29.4	44.2	55.4	58.6
12.0 exercised[b]	1.4						
15.0	0.3						
18.0[c]	1.4						

[a] 0.5-ppt salinity.
[b] Represents Days 1–3 only.
[c] Represents Days 1–4 only because all ducklings died by Day 5.

Ducklings exposed to saline water might not suffer mortality, but sublethal effects could occur which would affect survival after individuals attain flight capability. These effects might be reflected in reduced mass or levels of carcass components. Therefore, at 3-day intervals we recorded duckling body mass to the nearest gram; after the ducklings reached 300 g, we determined their body mass to the nearest 5 g. Surviving ducklings were euthanized by thoracic compression at Day 60 and were weighed to the nearest gram. The carcass, excluding bill, feet, plumage, and total ingesta, was ground into a homogenate, and a 100-g (± 2 g) sample was frozen for analysis. We analyzed samples for total fat, protein, ash, and water with techniques described by Alisauskas and Ankney (1985).

Statistical Methods.—We used a Chi-square test to compare differences in proportions of mortality among treatments. Analysis of covariance, with body mass at Day 60 as the covariate, was used to test for differences in carcass composition. We tested for differences in body mass among treatments with an ANOVA. We used regression analysis to plot mass data and determine growth rates.

RESULTS

Duckling Mortality and Clinical Signs

Duckling mortality was 100% at 18 ppt, 90% at 15 ppt, and 10% at 12 ppt; no ducklings died in the other treatments (Table 1). Within the treatments where mortality occurred, most ducklings died by Day 5. We observed no abnormal behavior, and no ducklings died in the freshwater, 1.5-, 4-, and 6-ppt treatments; however, at 9 ppt some eye fatigue and loss of appetite were evident shortly after the trial began. These ducklings appeared to recover by Day 3 but exhibited heavy nasal secretions from Day 18 until the end of the experiment. All ducklings in the 12-, 15-, and 18-ppt treatments suffered lethargy, loss of appetite, and eye fatigue during the first 1–5 days of the experiment. Salt encrustation occurred on the bills of the 18-ppt birds. All 15- and 18-ppt ducklings appeared very hungry for the first 1–2 days but ate negligible amounts of food (Table 2) and became increasingly lethargic. One duckling survived at 15 ppt but was omitted from all further analyses because means and standard errors could not be calculated.

The highest salinity tolerated with minimal mortality (10%) was 12 ppt, but this was in the absence of any physical stress. However, ducklings given 12-ppt water and exercised had eaten very little food (Table 2) and were weak and lethargic by Day 2 of this trial. By the end of Day 2, 5 ducklings had lost from 19 to 39% (6–13 g) of their initial body mass (30–33 g), were too weak to continue exercising, and were removed from the trial (Table 1). The remaining 2 ducklings were beginning to recover lost mass and appetite when the trial was ended after Day 4. We allowed all ducklings in this trial to recover by providing freshwater and food ad libitum.

Growth and Development

The only significant difference ($P < 0.05$) in body mass of surviving ducklings among treatments was between the heaviest (4.0 ppt) and the lightest (12 ppt) ducklings (Table 3). However, comparison of the regression slopes of masses recorded at 3-day intervals during the entire experiment showed that the 12-ppt treatment had a slower ($P \leq 0.05$) growth rate (30.2 g/3 days) than all other treatments. We found

Table 3. Body mass (g) and carcass composition (g) of penned mottled duck ducklings surviving on Day 60 of each salinity treatment.

Variable	Treatment (ppt)											
	Freshwater control[a]		1.5		4.0		6.0		9.0		12.0	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Body mass	712.1AB[b]	28.5	717.5AB	23.4	768.2A	26.8	734.6AB	32.0	737.4AB	21.3	636.2B	25.2
Fat	46.0AB	9.0	51.6AB	7.7	60.8AB	9.6	55.5AB	7.3	69.2A	8.3	39.7B	3.2
Protein	91.6AC	6.7	96.5ABC	5.9	105.4B	6.4	100.6BC	6.8	105.0BC	5.4	89.2A	4.0
Ash	26.7AC	2.7	28.7ABC	2.6	32.1BC	2.9	30.1BC	2.6	35.0B	2.4	23.1A	1.4
Water	457.8A	22.0	448.4A	16.0	471.6A	12.8	456.7A	15.4	35.4AB	12.1	394.4B	17.7

[a] 0.5-ppt salinity.
[b] Means within rows with the same letters are not different ($P > 0.05$).

no difference ($P > 0.05$) in growth rates (34.0–36.8 g/3 days) among any of the remaining treatments. Ducklings in the 12-ppt treatment also consumed less food per duckling per day than did those in the lower salinity treatments, especially during the first 30 days of the experiment (Table 2). However, they were similar ($P > 0.05$) in total fat, protein, and ash to ducklings in some of the lower salinity treatments (Table 3).

Ducklings differed in the time required to reach flight stage: the control, 1.5-, 4-, and 6-ppt treatments began to fly at Day 46, the 9-ppt ducklings at Day 53, and the 12-ppt ducklings at Day 57. The 1 remaining duckling at 15 ppt had not begun to fly when the experiment was ended on Day 60.

DISCUSSION

Duckling Mortality

Mottled duck broods in marshes of ≥15 ppt salinity might not survive unless females could lead broods to less saline marshes within 1–3 days after hatching. Furthermore, wild ducklings would expend more energy in search of food and in moving to brood-rearing areas than penned birds, so mortality in the wild would likely be much higher than that for penned birds at similar salinities.

Other studies have demonstrated slightly lower duckling tolerance to saline water. For example, Krista et al. (1961) reported 43% mortality of Rouen ducklings (*A. platyrhynchos*) at 10,000 ppm NaCl (10 ppt) and 100% mortality at 12,000 ppm NaCl (12 ppt). Additionally, Mitcham and Wobeser (1988*b*) found mortality rates of mallard ducklings to be 60 and 78% at 20,000 and 21,500 umhos/cm (≈12.7 and 13.8 ppt, respectively). Thus, mottled duck ducklings appear to have a higher tolerance to saline water than do ducklings of domestic and wild mallards. Similarly, black duck (*A. rubripes*) ducklings reared in coastal or estuarine environments also may have a higher tolerance to saline water than do mallard ducklings (Barnes and Nudds 1991). Greater salinity tolerance probably is adaptive for species primarily restricted to coastal areas where exposure to saline water is common.

Growth and Development

Although only 1 duckling died at 12 ppt, the growth rate of ducklings was slower throughout the 60-day experiment in comparison to birds in lower salinity treatments. This lends support to the hypothesis that growth rates would be reduced at higher salinity levels (see also Krista et al. 1961, Ellis et al. 1963, Schmidt-Nielsen and Kim 1964, Riggert 1969, Wink and Hossler 1979, Swanson et al. 1984, Mitcham and Wobeser 1988*b*, and Barnes and Nudds 1991). Ducklings in the 12-ppt treatment also consumed less food, especially during the first 30 days when growth is otherwise most rapid (Brody 1945).

Results of the tests of body mass and carcass composition variables were less clear. However, the ducklings in the 12-ppt treatment had lower body mass and lower mean values of carcass components than at least 1 of the lower salinity treatments. Carcass protein and ash in particular appeared to be lower in the 12-ppt treatment, which probably reflects the slower growth rate. Similarities in carcass fat among treatments may be due to inability of ducklings in all treatments to obtain endogenous lipid stores because of high energy demands during growth and development.

Reduced growth rates and some negative effects on body mass and carcass components in the 12-ppt treatment suggest there is a lower threshold of tolerable salinity for wild mottled duck ducklings that is between 9 and 12 ppt. We think this threshold is closer to 9 ppt because, at that level, we noted lethargy, eye fatigue, and reduced food intake by ducklings during the first 3 days of the trial. Mortality of ducklings broods is highest during the first 2 weeks after hatching (Talent et al. 1983, Duncan 1986, Hill et al. 1987), therefore weak and lethargic ducklings during that time would have an increased probability of mortality. The delay in reaching flight stage at 9 and 12 ppt also could decrease survival in the wild.

MANAGEMENT IMPLICATIONS

We think that mottled duck ducklings having access to marshes of <9-ppt salinity within 1–3 days after hatching will survive better than those exposed to higher salinity levels. Because coastal land is lost in Louisiana at an estimated 102–150 km^2/year (Scaife et al. 1983, Templet and Meyer-Arendt 1988) and because fresh and intermediate marshes are disappearing most rapidly in the Louisiana coastal zone (Chabreck and Linscombe 1982), continued semi-impoundment and active management of fresh and intermediate marsh seems warranted to preserve habitat for mottled ducks and other species of flora and fauna dependent on fresh and intermediate salinity marshes (Chabreck 1960, Perry et al. 1970, Chabreck et al. 1975).

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DISTRIBUTION, ABUNDANCE, AND HABITAT USE BY MOTTLED DUCKS IN FLORIDA

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Abstract: We used harvest information and aerial surveys to determine distribution, abundance, and habitat use by mottled ducks (*Anas fulvigula*) in Florida. Harvest estimates, adjusted for hunting effort, suggested that the greatest densities of mottled ducks were in southern Florida near Lake Okeechobee. Aerial surveys in 1984 indicated that only 2 (prairies and the Everglades Agricultural Area) of 7 physiographic regions on the Florida peninsula contained more mottled ducks than expected based on area. In 1985, mottled duck density outside these regions was low, averaging 0.163 ± 0.041 (SE) birds/km^2, compared with 0.376 ± 0.065 birds/km^2 in the prairies and Everglades Agricultural Area. Mottled duck density in these 2 regions varied among years (P = 0.09) and averaged 0.639 ± 0.060 birds/km^2 during 1985–90. Wetlands occupied an estimated 33.6 ± 1.1% or 4,494 km^2 of the area in these 2 physiographic regions. Emergent wetlands and wet prairies were the dominant wetland types and accounted for much of the annual variation in surface water. Mottled ducks avoided most wetland habitats, but emergent wetlands and ditches tended to be occupied by more birds than expected based on abundance.

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Mottled ducks in Florida range from Gainesville (about 29°N) south to Florida Bay, reportedly reaching their greatest abundance in the Lake Okeechobee area (Beckwith and Hosford 1955). Mottled ducks are also common in the St. Johns and Kissimmee River valleys in central Florida, but drainage and disturbance might have decreased use of these areas (Chamberlain 1960). Certain coastal areas, particularly those with impounded marshes, are also used by mot-

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