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Authors: Mitcham, S. A., and Wobeser, G.

Source: Journal of Wildlife Diseases, 24(1) : 45-50

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-24.1.45

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Journal of Wildlife Diseases, 24(1), 1988, pp. 45–50
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TOXIC EFFECTS OF NATURAL SALINE WATERS ON MALLARD DUCKLINGS

S. A. Mitcham[1,2] **and G. Wobeser**[1,3]

[1] Department of Veterinary Pathology, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 0W0
[2] Present address: Box 160, Readlyn, Iowa 50668, USA
[3] Author to whom reprint requests should be addressed

ABSTRACT: Water from 10 saline wetlands in Saskatchewan was provided as drinking water for 1-day-old mallards (*Anas platyrhynchos*). Ducklings given water with conductivity from 3,750 to 7,490 μmhos/cm grew as well as birds on fresh water during a 14-day trial, but birds given water with conductivity of 4,000 μmhos/cm grew poorly during the last 2 wk of a 28-day trial. Ducklings given water with conductivity of 7,720 μmhos/cm grew poorly during a 14-day trial. Six of 10 ducklings given water with conductivity of 20,000 μmhos/cm died, and only two of nine ducklings given water with conductivity of 21,500 μmhos/cm survived 14 days. Survivors were much smaller than controls and had many abnormalities. All ducklings given water with conductivity of 35,000 and 67,000 μmhos/cm died within 60 and 30 hr, respectively. The results indicate that ducklings hatched on many saline wetlands will suffer toxic effects unless they are able to find a source of fresh water shortly after hatching.

Key words: *Anas platyrhynchos*, ducklings, salinity, wetlands, toxicity, growth, pathology, experimental study.

INTRODUCTION

Saline waterbodies comprise a significant proportion of the total wetlands in some parts of the prairie pothole region of North America, but the suitability of these marshes for waterfowl has received little attention. A study by Swanson et al. (1984) of nine wetlands in North Dakota is the only published work that relates usage by ducklings to water chemistry on such wetlands. In that study, ducklings were consistently absent from four lakes (specific conductivity 30,100–67,000 μmhos/cm); four other lakes (conductivity 23,400–65,000 μmhos/cm) had few ducklings, and those present were directly associated with freshwater seeps. Only the least saline lake (conductivity 15,900 μmhos/cm) supported "relatively high" brood use. Water from the more saline wetlands was rapidly fatal for ducklings in the laboratory and water with a conductivity of 17,000 μmhos/cm caused severe growth depression. In an earlier paper we described effects of solutions of Na_2SO_4 and $MgSO_4$ on mallard (*Anas platyrhynchos*) ducklings (Mitcham and Wobeser, 1988). This report describes effects of water from 10 saline wetlands in Saskatchewan on mallard ducklings under laboratory conditions.

MATERIALS AND METHODS

The methods used were similar to those described in an earlier study (Mitcham and Wobeser, 1988); briefly, mallard ducklings received from Whistling Wings (Hanover, Illinois 61041, USA) on the day after hatching were marked with web tags, weighed and assigned randomly to groups of 10 ducklings each. Groups within a trial were held in adjacent indoor pens with an area of 3.3 m^2 equipped with an infrared heat lamp. Commercial duck and goose starter (Federated Cooperatives Limited, Saskatoon, Saskatchewan, Canada S7K 0H2) and water were supplied ad libitum. Within each trial one group received Saskatoon tap water while the other groups were given water from saline wetlands (Table 1). Sufficient water for each trial was collected from the appropriate wetland immediately prior to the trial. The water was held in collapsible 18-liter plastic water containers until used. A sample of this water was submitted for analysis to a private laboratory (Analytic Laboratory, Saskatchewan Research Council, Saskatoon, Saskatchewan, Canada S7N 1Z3). Trials were of 14 days duration, except for Trial D which was continued for 28 days. Food consumption, clinical signs and mortality were recorded daily and ducklings were weighed on alternate days. On day 14, blood samples were collected by cardiac puncture from all surviving

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TABLE 1. Selected characteristics of water used in trials to determine effects of salinity on mallard ducklings.

Trial	Wetland	Class[a]	Major ions (mg/liter)								Conductivity (μmhos/cm)
			Na	Mg	K	Ca	SO_4	Cl	CO_3	PO_4	
A	tap water		22	14	3	32	75	7	ND[b]	ND	357
	1	VI	12,300	5,260	518	456	31,300	8,310	106	>1	67,000
	2	II	815	145	80	42	1,560	191	60	>1	4,640
	3	IV	512	195	64	83	1,440	178	ND	>1	3,750
B	tap water										
	4	IV	911	639	93	425	5,200	86	ND	>1	7,490
	5	IV	8,790	1,310	142	391	20,100	3,360	ND	>1	35,000
	6	IV	3,860	1,300	173	351	12,000	832	ND	>1	21,500
C	tap water										
	7	IV	2,550	1,310	456	256	10,400	804	ND	>1	20,000
	8	IV	1,180	298	51	341	3,860	420	ND	>1	6,890
D	tap water										
	9	VI	821	56	19	44	1,480	45	ND	1.6	4,000
	10	VI	1,980	62	70	15	2,190	778	193	1.5	7,720

[a] As classified by Stewart and Kantrud (1971) (II, temporary pond; IV, semi-permanent pond or lake; VI, alkali pond or lake).
[b] ND, none detected.

ducklings in Trials A–C, and these birds were killed by carbon dioxide overdose.

On day 14, 1 ml of blood was collected from the metatarsal vein of ducklings in Trial D; these birds were then continued on trial until day 28 when they were bled by cardiac puncture and killed by carbon dioxide overdose. Necropsies were performed on all ducklings, and tissues were weighed and fixed in 10% neutral buffered formalin for histologic examination. Preparation and analysis of serum, tissues and statistics were as previously described (Mitcham and Wobeser, 1988).

RESULTS

Ducklings reared on water from the less saline wetlands (2–4, 8, 9) (Table 1) grew as well as control birds and consumed a similar amount of food to day 14. Abnormal clinical signs were not observed in these birds, other than passage of excessively fluid excreta by a few birds within some groups on the first day after exposure to saline water. None was seen to secrete fluid via the salt glands. At day 14, individual groups differed from their respective control in several of the variables measured, but a consistent pattern was not apparent. Ducklings given water from wetland 3 had reduced lymphoid tissue in the spleen, while ducklings on water from wetland 9 had elevated total plasma protein ($\bar{x}$ = 50.5 g/liter, SD = 4.6) compared to that of the control group ($\bar{x}$ = 42.6 g/liter, SD = 2.0). Ducklings given water from wetland 2 had elevated serum osmolality ($\bar{x}$ = 320.1 mmol/kg, SD = 6.6) compared to that of the control group ($\bar{x}$ = 312.6 mmol/kg, SD = 4.6), and enlarged salt glands. Ducklings on water from wetland 8 had significantly lower concentrations of serum phosphorus ($\bar{x}$ = 4.1 mmol/liter, SD = 0.6) and magnesium ($\bar{x}$ = 2.5 mmol/liter, SD = 0.3) compared to $\bar{x}$ = 5.2 mmol/liter, SD = 0.9; $\bar{x}$ = 3.1 mmol/liter, SD = 0.4, respectively, for the control group. Ducklings on water from wetland 4 had shorter culmen length ($\bar{x}$ = 3.08 mm, SD = 1.1) compared to $\bar{x}$ = 3.24 mm, SD = 1.7 for controls and decreased vacuolation of hepatocytes, the latter indicating reduced hepatic glycogen. Lesions were not found at necropsy to explain the death of two ducklings in the group given water from wetland 3 (Table 2). However, because of the relatively low concentration of salt in the water, and the lack of ill effect on others in the group, we feel the deaths were not the result of saline toxicity.

Although the ducklings given water from

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TABLE 2. Survival of mallard ducklings exposed to various types of water in all trials.

Trial	Wetland	Number of ducklings alive on day:												
		0	1	2	3	4	5	6	7	8	9	10	11	14
A	tap water	10												10
	1	10	10	0										0
	2	10												10
	3	10	10	9	8									8
B	tap water	10												10
	4	10												10
	5	10	8	1	0									0
	6	9*	9	7	7	6	6	4	4	3	3	3	3	2
C	tap water	10												10
	7	10	6	6	6	5	5	4						4
	8	10												10
D	tap water	10												10
	9	10												10
	10	10												10

* One duckling died of an accident immediately after the start of the trial.

wetland 9 were not significantly different in terms of average weight from controls at day 14, they were significantly lighter on day 16 and remained so until the trial ended on day 28. At this time the average weight of birds in group 9 was 683 g (SD = 98) compared to 742 g (SD = 93) for controls.

Ducklings given water from wetland 10 were significantly smaller than control birds by day 14 of Trial D and remained so to the end of the trial. On day 28 they weighed on average less than 80% of the weight of control birds (589 g versus 742 g) and during the trial had consumed only 86% as much food as controls. At day 14, these birds had elevated concentrations of sodium ($\bar{x}$ = 147.2 mmol/liter, SD = 2.3) and calcium ($\bar{x}$ = 3.5 mmol/liter, SD = 0.2) in their serum and increased total protein ($\bar{x}$ = 52.1 g/liter, SD = 6.1) in their plasma compared to the controls ($\bar{x}$ = 142.5 mmol/liter, SD = 2.1; $\bar{x}$ = 3.0 mmol/liter, SD = 0.1; $\bar{x}$ = 42.6 g/liter, SD = 2.0, respectively). At necropsy the ninth primary quill and middle retrix feathers of these ducklings were shorter (61% and 83% of length of control birds), and salt glands, kidneys and adrenal glands were significantly larger than those of control birds.

Ducklings on the more saline waters were affected severely, with mortality in all groups (Table 2). Within 1–3 hr after exposure to the saline water the ducklings became inactive, appeared depressed, with ruffled and/or wet down and white salt encrusted on the bill. Birds that survived for more than 2 days passed very fluid excreta. Birds that died became comatose shortly before death. The severity of the effects was related to the salinity of the water. Four ducklings given water from wetland 7 (conductivity 20,000 μmhos/cm) survived the 14-day trial, but their average weight at the end of the trial was only 69% of that of the controls (148 g versus 214 g). Most external body measurements including feather length were significantly smaller than controls. The salt glands and adrenals were enlarged and the thymus was reduced in size proportionate to body weight. Serum electrolytes were not significantly different from those of the control birds.

Only two ducklings survived in the group given water from wetland 6 (conductivity 21,500 μmhos/cm) and on day 14 these weighed only 70 and 86 g, respectively, compared to an average of 214 g for the control group. These survivors differed

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TABLE 3. Serum biochemical values of mallard ducklings reared on various saline waters for 14 days in Trial B.

Wetland	n	Concentration (mmol/liter)										Osmolality (mmol/kg)	
		Sodium		Potassium		Chloride		Calcium		Phosphorus		Magnesium			
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Tap water	10	145.4[b]	3.8	9.1	5.3	105.8[a]	3.4	3.2	0.2	3.3[a]	0.2	2.2	0.3	315.1[b]	5.8
4	10	148.2[b]	3.2	7.0	2.6	106.4[a]	3.0	3.3	0.2	3.3[a]	0.4	2.3	0.4	318.3[b]	6.1
6	2	166.5[a]	4.9	3.8	0.4	86.5[b]	2.1	3.5	0.1	2.2[b]	0.1	2.5	0.4	33.20[a]	0.0

[a,b] Values within columns followed by different superscripts are significantly different ($P \leq 0.05$).

from the control group in concentration of a number of serum electrolytes (Table 3) as well as in having increased total white blood cell count because of an increased number of heterophils, enlarged salt glands and adrenals, reduced thymic weight and reduced trabecular bone in the femur.

All ducklings given water from wetland 5 (conductivity 35,000 μmhos/cm) died within 60 hr. Lesions were not found at necropsy, but the birds had not eaten and weighed an average of 2.1 g less than at the start of the trial.

All ducklings given water from wetland 1 (conductivity 67,000 μmhos/cm) died within 30 hr. Lesions were not found at necropsy, but the birds weighed an average of 5.5 g (17%) less than at the start of the trial.

DISCUSSION

The wetlands chosen for these trials were representative of the saline wetlands that occur in southern Saskatchewan. Wetlands 3, 4, 6, 7, 8, 9 and 10 had been modified specifically for waterfowl use through construction of dams, islands or by periodic introduction of fresher water. The least saline water causing mortality of ducklings in this trial had a conductivity of 20,000 μmhos/cm, which corresponds well with the observation by Swanson et al. (1984) that ducklings were unable to survive saline water with a conductivity >20,000 μmhos/cm. Mortality would likely have been higher under field conditions, and the small ducklings that survived exposure to water from wetlands 6 and 7 in the laboratory probably would not have survived in the wild. Swanson et al. (1984) found that game farm mallards, similar to those used in the present trials, survived longer on saline water than did ducklings of several other species, or than did wild mallard ducklings. Toxicity data derived using game farm birds may underestimate the toxicity of saline water for wild ducklings.

Swanson et al. (1984) observed severe growth depression in ducklings reared to 9 days of age on water with a conductivity

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of 17,000 μmhos/cm. In the present trials ducklings reared on water with a much lower conductivity (7,720 μmhos/cm, wetland 10) grew poorly, whereas ducklings reared on water with conductivity ranging from 3,750 to 7,490 μmhos/cm from five wetlands grew as well to 14 days as did control birds reared on fresh water. However, in Trial D which was continued to day 28, ducklings reared on water from wetland 9 (conductivity 4,000 μmhos/cm) had a significantly lower growth rate during the last 2 wk of the trial than did controls. This suggested that prolonged exposure might have effects not obvious during the 14-day period of the other trials. In prior trials with solutions of Na_2SO_4 and/or $MgSO_4$ we found that ducklings reared on water with conductivity up to 8,000 μmhos/cm usually grew as well as control birds, whereas birds reared on solutions with a conductivity of ≥11,000 μmhos/cm grew poorly (Mitcham and Wobeser, 1988).

The relative toxicity of, and interactions among, the various ions found in saline waters have not been determined, although magnesium salts may be more toxic than sodium salts (Mitcham and Wobeser, 1988). The other ions present in natural saline waters may also be important, and the natural waters used in these trials appeared to be more toxic than solutions containing equivalent amounts of sodium and magnesium used in the previous experiments (Mitcham and Wobeser, 1988). For example, six of 10 ducklings given water from wetland 7 containing 2,550 mg/liter sodium and 1,310 mg/liter magnesium died within 14 days. In the earlier trials all 10 ducklings given a solution containing 3,100 mg/liter sodium and 1,300 mg/liter magnesium survived for 28 days, although they grew very poorly (Mitcham and Wobeser, 1988). In this instance the natural saline water contained higher concentrations of potassium, calcium and chloride and had a conductivity of 20,000 μmhos/cm compared to 15,250 μmhos/cm for the artificial solution.

As we indicated in our earlier study (Mitcham and Wobeser, 1988), the sublethal effects of saline water such as depressed growth and retarded feathering would be difficult to detect in wild ducklings. Ducklings that died shortly after exposure to highly saline water in these trials had no gross lesions, other than emaciation.

The present results, together with those of Swanson et al. (1984) and our earlier study (Mitcham and Wobeser, 1988) provide guidance for assessing the value of saline wetlands for duckling production. However, as pointed out by Swanson et al. (1984), chemical analysis of water, and even experimental exposure of ducklings to water from a wetland are insufficient evidence on which to assess the usefulness of a wetland. The availability of a source of fresh water in or near the wetland appears to be critical. Swanson et al. (1984) found that saline wetlands with no freshwater seepage areas did not support broods. In such wetlands, measurement of conductivity during the brood rearing period may be an adequate method of assessment. Wetlands containing water with a conductivity of ≥20,000 μmhos/cm are probably "death traps" for ducklings, unless fresh water is available. Those with waters with conductivity in the range from about 7,500 to 20,000 μmhos/cm are likely to result in serious sublethal effects on growth, feathering and several other physiologic functions.

Even highly saline wetlands can support brood usage if freshwater seeps are available. Gadwalls (*Anas strepera*) appear to be the species found most commonly in this situation (Duebbert et al., 1983; Swanson et al., 1984). Enhancement of such freshwater sources could be a useful management technique to increase the productivity of saline wetlands. Waterfowl may also use highly saline wetlands for nesting, but then move broods after hatching to adjacent fresh or less saline wetlands (Duebbert et al., 1983). The rapidity with which ducklings became inactive and depressed after drinking water from wet-

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lands 1 and 5 in these trials indicates that movement of broods from such highly saline wetlands must occur very soon after hatching.

ACKNOWLEDGMENTS

This study was supported by a fellowship from the Medical Research Council of Canada and the O'Brien Foundation to the senior author, and by grants from the Natural Sciences and Engineering Research Council of Canada, Ducks Unlimited Canada and the Canadian Wildlife Service.

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Received for publication 6 January 1986.

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