BLOOD PARASITES OF PRAIRIE ANATIDS AND THEIR IMPLICATION IN WATERFOWL MANAGEMENT IN ALBERTA AND SASKATCHEWAN

Authors: BENNETT, GORDON F., NIEMAN, DANIEL J., TURNER, BRUCE, KUYT, ERNIE, WHITEWAY, MADONNA, et al.

Source: Journal of Wildlife Diseases, 18(3) : 287-296

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-18.3.287

BLOOD PARASITES OF PRAIRIE ANATIDS AND THEIR IMPLICATION IN WATERFOWL MANAGEMENT IN ALBERTA AND SASKATCHEWAN

GORDON F. BENNETT,[1] DANIEL J. NIEMAN,[2] BRUCE TURNER,[3] ERNIE KUYT,[3] MADONNA WHITEWAY,[1] and ELLIS C. GREINER[1,4]

Abstract: Information on the blood parasites occurring in 3,866 anatids of 14 species collected from five locations in Alberta and Saskatchewan during 1976-80 is summarized. An overall prevalence of 26% with avian hematozoa was recorded. *Leucocytozoon simondi* was the most frequently encountered parasite, occurring in 17% of the ducks; *Haemoproteus nettionis* was observed in 11% of the birds while *Plasmodium circumflexum* and microfilariae (probably of *Splendidofilaria fallisensis)* occurred in only 2% and <1% of the sample respectively. Overall prevalence of infection in both immatures and adults was similar, although the sample was heavily biased in favor of the immature age class. While the overall prevalence of *L. simondi* was similar in both age classes, *H. nettionis* occurred twice as frequently in the adult birds. Infection prevalences of birds in the five geographic areas sampled were different and these differences are discussed. Prevalences also differed from year to year in birds from the various areas and these differences are attributed, in part, to the water levels encountered each year. *Leucocytozoon simondi* is considered a potentially limiting factor for waterfowl production in some areas of northern Alberta and Saskatchewan.

INTRODUCTION

Extensive surveys of the blood parasites of both breeding and overwintering populations of anseriforms have been made in various parts of North America, especially along the Atlantic Flyway (Bennett, 1972; Bennett et al., 1974, 1975; Herman, 1968; Nelson and Gashwiler, 1941; Thul et al., 1980). With the exception of a recent survey of the blood parasites of the anatids from central Alberta and the Mackenzie delta (Williams et al., 1977) and a survey of the blood parasites in Trumpeter swans of Alberta (Bennett et al., 1981), few extensive surveys have been carried out in Canada's Prairie Provinces — a region noted for its waterfowl production. The lack of surveys in this region is somewhat surprising as at least one of the commonly occurring anseriform blood parasites, *Leucocytozoon simondi,* can cause extensive mortality among flocks of domestic ducks and geese (Fallis and Bennett, 1966; Laird and Bennett, 1970; O'Roke, 1934), and has been cited as the major factor limiting the success of Canada Geese in the Seney National Wildlife Refuge in northern Michigan (Herman et al., 1975). It is thus strange that the possible role of this particular parasite as a population

[1] Department of Biology and International Reference Centre for Avian Haematozoa, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X9, Canada.

[2] Prairie Migratory Bird Research Centre, 115 Perimeter Road, Saskatoon, Saskatchewan S7N 0W0, Canada.

[3] Canadian Wildlife Service, Western and Northern Region, #1000, 9942 - 108 St., Edmonton, Alberta T5K 2J5, Canada.

[4] Present address: Department of Preventive Medicine, University of Florida, Gainesville, Florida 32610, USA.

limiting factor in this area of high duck productivity has not been previously investigated as part of a waterfowl management strategy.

The role of other blood parasites as factors limiting anatid survival is less clear, but experimentally, parasites such as *Plasmodium lophurae* and *P. circumflexum* can cause mortality (Garnham, 1966). On the other hand, with the exception of a single report (Julian and Galt, 1980), *Haemoproteus nettionis* is not known to have lethal effects (Bennett et al., 1976) and its presence in an anseriform population, while doing it no conceivable benefit, may only serve to indicate the activity and/or density of the population of its ceratopogonid vectors.

In 1976, cooperative projects were initiated with the Canadian Wildlife Service in both Saskatchewan and Alberta to assess the prevalence of blood parasites in the breeding anatid populations of the two provinces. This report summarizes the findings of the 5-yr study.

MATERIALS AND METHODS

Blood smears were obtained from ducks while they were being handled during normal banding regimes, usually during the month of August, and represented local breeding, moulting and pre-migration populations. The latter were composed of either adults or immature birds 8-10 wk of age. Waterfowl were captured in clover-leaf wire traps with funnel entrances baited with grain. Blood was obtained from the femoral vein along the tarso-metatarsus and the preparation of blood smears in the field followed the protocols previously described (Bennett, 1970a). Following collection, the blood films were sent to the International Reference Centre for Avian Haematozoa (IRCAH) where they were stained with Giemsa's stain prior to examination for blood parasites. The IRCAH accession numbers for these smears are as follows: 55377-56026; 63146-63869; 63963-64140; 64206-64244; 66027-66109; 66292-69358; 70646-71188; 73040-73481; 76768-77218; 77713-78030; 80355-80377.

The ducks were obtained from two localities in Saskatchewan. The first was the Corning-Heward region in the parkland of southern Saskatchewan, approximately 100 km from the United States border. The area does not support a large number of water bodies (lakes, rivers, streams) and is severely affected by periodic drought. The second locality was the Lake Lenore area (St. Brieux, Naicam), some 300 km north of the first region, in the east-central portion of the province. This area supports a much larger number of water bodies than the former, with numerous tributaries of the South Saskatchewan and Carrot Rivers. The Lake Lenore region is one of the most stable in the province with respect to annual water conditions and is rarely affected by periodic drought. Anatid blood smears were obtained from three areas in Alberta. The first was Wood Buffalo National Park in northeastern Alberta. The area is located on the northern edge of the mixed forest adjacent to the Canadian Shield. Lakes, ponds and streams are abundant in the area although the annual water regime can be quite variable. Samples were collected in Wood Buffalo National Park in 1977, 1978 and 1979. The second area was the Vermilion region, located some 160 km east of Edmonton. Vermilion is situated on the northern edge of the central Alberta parkland in an undulating to hilly moraine. The area is dotted with many potholes and lakes and is threaded by two permanent rivers and several seasonal streams. Blood samples were collected in the Vermilion area in 1976 and 1977. The third area sampled was the Grande Prairie region located some 380 km northwest of Edmonton. The region is somewhat unique in that it is an island of parkland isolated within the mixed forests of northern Alberta.

The area consists mainly of the remnants of a former till plain and is characterized by an undulating to gently rolling terrain. Numerous lakes and several permanent rivers and seasonal streams occur within the region. Blood samples were collected in this area in 1979 and 1980. Chi square analyses were done to determine the independence of prevalence in relation to year, age and location (Sokal and Rohlf, 1979).

RESULTS AND DISCUSSION

Approximately 3,870 anatids of 14 species (Table 1) were examined for blood parasites. The sample was primarily composed of mallards (69%), pintails (13%), blue-winged teal (12%) and green-winged teal (3%), together totalling 97% of the sample. A total of 1,015 (26%) ducks harbored one or more species of blood parasites (Table 1). *Leucocytozoon simondi* was the most frequently encountered parasite, seen in 655 (17%) birds; *H. nettionis* was recorded in 442 (11%) of the ducks while *P. circumflexum* was seen in only 63 (2%) of the waterfowl. Microfilariae, probably those of *Splendidofilaria fallisensis* (the only species recorded from Canadian anseriforms [Anderson and Freeman, 1969]), occurred in 18 adult mallards, one adult pintail and an adult green-winged teal. Ten of the adult mallard infections occurred in the Lake Lenore region of Saskatchewan. Trypanosomes were not seen, but their absence was not considered unusual as this parasite is rarely encountered in anseriforms (Bennett, 1970b; Herman et al., 1971). A few parasites were seen that could not be identified. The combined total of the *P. circumflexum*, microfilariae and unidentified parasites was less than 3% of the total infections; as these numbers were so low, these infections were not further considered. Prevalence of blood parasites in the blue-winged teal was significantly lower than that observed in the green-winged teal ($x^2 = 72.1$, df = 1, $p<0.001$) (Table 1). This observation is similar to those made elsewhere (Bennett et al., 1975) and suggests that the blue-winged teal enjoys some sort of behavioral or ecological immunity from blood protozoa (probably through some type of reduction in host-vector interaction) as the birds themselves are physiologically capable of sustaining infection.

The sample was weighted to immature birds (HY—Hatching Year) as this age class best illustrates transmission on the natal areas and indicates the potential of blood parasites as a mortality factor on a susceptible waterfowl population. Among the 2,422 immature birds sampled, 557 (23%) were infected (Table 2); *L. simondi* was recorded from 386 (16%) and *H. nettionis* from 211 (9%); mixed infections of both species were recorded in 40 ducks. Among the 1,394 adults examined, 414 (30%) were infected, with *L. simondi* occurring in 251 (18%) and *H. nettionis* in 209 (15%); mixed infections of both species occurred in 46 ducks.

The immature ducks sampled were unlikely to have travelled far from their natal areas, probably moving at best from the small production ponds to the larger "pre-staging" areas. In Saskatchewan, the immature birds from the Corning-Heward area showed an overall prevalence of 7%, a prevalence similar to that of adults from the same region (9%). Immature birds from the Lake Lenore region had an overall prevalence of 15%, about twice the level in the Corning-Heward birds ($x^2 = 39.2$, df = 1, $p<0.001$). However, the adult birds from the Lake Lenore area had a significantly higher prevalence of 60% ($x^2 = 309.5$, df = 2, $p<0.001$), with all the adults examined in 1977 harboring one or more species of blood parasites. *Leucocytozoon simondi* and *H. nettionis* were present in approximately the same proportions in both age classes of ducks, although there was some variation from year to year (Table 2). *Plasmodium circumflexum* was most commonly encountered in waterfowl from the Lake

TABLE 1. Blood parasites of some prairie anatids. (H.n. = *Haemoproteus nettionis;* L.s. = *Leucocytozoon simondi;* M. = microfilaria; P.c. *Plasmodium circumflexum;* U. = unidentified parasites. Figures in parentheses are percentages).

	Total birds		Number birds infected with				
	examined	infected	*H.n.*	*L.s.*	*M.*	*P.c.*	*U*
Anas acuta - northern pintail	505	120 (24)	68	58	1	15	1
A. americana - American wigeon	28	6 (21)	2	5	-	1	-
A. clypeata - northern shoveler	10	4	2	1	-	-	1
A. crecca - green-winged teal	119	58 (49)	13	45	1	5	-
A. discors - blue-winged teal	446	59 (13)	25	25	-	8	3
A. platyrhynchos - mallard	2667	754 (28)	327	512	18	33	-
A. rubripes - American black duck	1	1	1	-	-	-	-
A. strepera - gadwall	24	2 (8)	1	1	-	-	-
Anser caerulescens - snow goose	6	6	-	6	-	-	-
Aythya affinis - lesser scaup	15	0	-	-	-	-	-
A. americana - redhead	23	3	1	2	-	-	-
A. collaris - ring-necked duck	1	0	-	-	-	-	-
A. valisineria - canvasback	3	0	-	-	-	-	-
Branta canadensis - Canada goose	18	1	1	-	-	-	-
Total:	3866	1014	441	655	20	62	5
Percentage infected:		(26)	(11)	(17)	(0.5)	(2)	-

TABLE 2. *Haemoproteus nettionis* and *Leucocytozoon simondi* infections in anatids from five regions of Saskatchewan and Alberta. (Table captions as in Table 1).

		Total birds			Infections with	
		no. examined	no. infected	% infected	*H.n.*	*L.s.*
Corning-Heward, Saskatchewan						
1977	HY*	99	11	11	2	9
	AHY*	253	11	4	7	4
	Total	352	22	6	9	13
1979	HY	244	14	6	10	5
	AHY	195	25	13	17	11
	Total	439	39	9	27	16
1980	HY	155	9	6	7	2
	AHY	186	19	10	13	6
	Total	341	28	8	20	8
Three-year total						
	HY	498	34	7	19	16
	AHY	634	55	9	37	27
	Total	1132	89	8	56	43
Lake Lenore, Saskatchewan						
1976	HY	151	27	18	11	19
	AHY	88	35	40	17	29
	Total	239	62	26	28	48
1977	HY	11	11	100	1	10
	AHY	120	120	100	62	62
	Total	131	131	100	63	72
1978	HY	176	14	8	4	8
	AHY	165	69	42	36	45
	Total	341	83	24	40	53
Three-year total						
	HY	338	52	15	16	37
	AHY	373	224	60	115	136
	Total	711	276	39	131	173
Wood Buffalo National Park, Alberta						
1977	HY	60	22	37	7	13
	AHY	5	5	100	1	5
	Total	65	27	42	8	18
1978	HY	20	7	35	2	7
	AHY	58	17	30	3	15
	Total	78	24	31	5	22
1979	HY	58	29	50	7	27
	AHY	8	4	50	2	2
	Total	66	33	50	9	29
Three-year total						
	HY	138	58	42	16	47
	AHY	71	26	37	6	22
	Total	209	84	40	22	69

TABLE 2. (continued)

		Total birds			Infections with	
		no. examined	no. infected	% infected	*H.n.*	*L.s.*
Vermilion, Alberta						
1976	HY	303	81	27	23	58
	AHY	67	32	48	5	26
	Total	370	113	31	28	84
1977	HY	430	112	26	26	76
	AHY	47	27	57	8	20
	Total	477	139	29	34	96
Two-year total						
	HY	733	193	26	49	134
	AHY	114	59	52	13	46
	Total	847	252	30	62	180
Grande Prairie, Alberta						
1979	HY	389	152	39	81	103
	AHY	79	26	33	20	12
	Total	468	178	38	101	115
1980	HY	326	68	21	30	49
	AHY	123	24	20	18	8
	Total	449	92	21	48	57
Two-year total						
	HY	715	220	30	111	152
	AHY	202	50	25	38	20
	Total	917	270	29	149	172
GRAND TOTAL						
	HY	2422	557	23	211	386
	AHY	1394	414	30	209	251
					(15)	(18)

*HY = Hatching Year bird — i.e. — immature
*AHY = After Hatching Year bird — i.e. — adult
NOTE: Totals for Saskatchewan regions consist of mallards, blue-winged teals and northern pintails only; totals for Alberta exclude Canada Geese.

Lenore area (21 of the 24 Saskatchewan infections). The observations that the prevalence of blood parasites in the immature ducks of both regions was equal to or less than that in the adults was surprising. In most other areas of North America, the immature birds show the highest prevalence of parasitism (Bennett et al., 1974, 1975; Herman, 1968; Herman et al., 1975; Laird and Bennett, 1970; Nelson and Gashwiler, 1941; Thul et al., 1980; Trainer et al., 1962). Presumably this situation arises from the fact that the immature birds have not as yet developed immunity to parasitic infections and thus are susceptible. In the Lake Lenore area, however, it is possible that the simuliid vectors of *L. simondi* and the ceratopogonid vectors of *H. nettionis* are most active prior to the hatching of the birds of the year (this point should be established by collections of vectors in these areas) so that the ducklings escape the majority of the transmission season. That this may occur in this region is highlighted by the

fact that the hatching peaks of mallards and blue-winged teal can be as much as 2 wk later than their counterparts in the Corning-Heward area. This would imply that in the Lake Lenore area, transmission is most active to 1-yr old and older birds. This situation would be of advantage to the duck population as the older birds are presumably more able to resist the effects of blood parasite infections than newly hatched ones.

In Alberta, however, although *L. simondi* occurred more frequently than *H. nettionis* in all three areas, age class differences in prevalences were not consistent among regions. Immature birds showed slightly higher prevalences in the Grand Prairie and Wood Buffalo National Park samples ($x^2 = 0.6$, d.f. =1, $p>0.05$; $x^2 = 2.74$, d.f. = 1, $p>0.05$ respectively), whereas the adult component was more frequently infected in the Vermilion area ($x^2 = 30.5$, d.f. = 1, $p<0.001$) (Table 2). The results from the Vermilion area are similar to those observed from the Lake Lenore region and suggest again that in these regions, the peak vector abundance precedes the peak duckling hatch. This could be a natural phenomenon, but could also reflect a higher re-nesting rate in zones of intense agricultural activity, i.e. Vermilion and Lake Lenore, than in the less disturbed habitats to the north, i.e. Wood Buffalo National Park and Grand Prairie.

In Saskatchewan, the overall prevalence of blood parasites in the Corning-Heward region during the years 1977, 1979 and 1980 were remarkably similar ($x^2 = 2.1$, d.f. = 2, $p> 0.05$) (Table 2). Variation from year to year was statistically insignificant ($x^2 = 2.1$, d.f. = 2, $p>0.05$). Prevalences in immature versus adult birds during the same years were variable being signficantly different in 1977 ($x^2 = 6.4$, d.f. = 1, $p<0.05$) and in 1979 ($x^2 = 6.7$, d.f. = 1, $p<0.05$). *Haemoproteus nettionis* was the most common parasite, occurring in 56 (63%) of the infected birds, while *L. simondi* occurred in 43 (48%) (Table 2). The low overall prevalence (8%) of blood parasites, particularly *L. simondi*, might be anticipated in this parkland region where the absence of an abundance of ponds and streams, combined with severe periodic drought, would contribute to a low vector population and hence reduced host-vector interaction and transmission. Certainly, the prevalence of blood parasites in the ducks of the extreme southeasterly portion of Saskatchewan is low in comparison to other areas in Canada (Bennett, 1972; Bennett et al., 1975; Fallis and Bennett, 1966; Laird and Bennett, 1970; Williams et al., 1977), with the exception of those in the arctic tundra (Bennett and MacInnes, 1972). Hence blood parasites may have little influence on anatid populations in this part of Saskatchewan, although a study of the blood parasites of 2 and 3 wk-old ducks would be necessary to confirm or refute this hypothesis.

In contrast to the Corning-Heward region, prevalence of blood parasites in anatids from the Lake Lenore region was high (Table 2). In both 1976 and 1978, the overall prevalence of parasitism in adult birds was similar ($x^2 = 0.1$, d.f. = 1, $p>0.05$), but the infection in young birds in 1976 was almost double that in 1978 ($x^2 = 7.4$, d.f. = 1, $p<0.01$). In 1977, all birds sampled were infected. No explanation for these fluctuations is immediately apparent. However, it is possible that either (i) a cold spring in 1976 synchronized emergence of vectors with peak duckling hatch or (ii) there was a greater success in first nest hatching and a reduction in re-nesting, which would have operated to synchronize duckling hatch and peak vector emergence. The high infection rate in the Lake Lenore area is similar to that observed in anatids in eastern North America (Bennett et al., 1974, 1975; Herman, 1968; Nelson and Gashwiler, 1941; Thul et al., 1980) and suggests a high host-vector interaction, presumably through increased vector density. The topography of the Lake Lenore area, with

numerous lakes, ponds and streams, together with a highly stable annual water regime (similar to conditions seen in Vermilion, Alberta), favors the breeding of vectors, especially simuliids. Higher prevalences of blood parasites, especially *L. simondi*, would be anticipated. The results indicate that *L. simondi* is the most frequently encountered blood parasite in this region (Table 2) and it is in this region that one-half of the filarial infections (also transmitted by simuliids if they are *S. fallisensis)* and much of the mosquito-born *P. circumflexum* occurs. This also suggests that the Lake Lenore region has a more diverse vector fauna than in the Corning-Heward region. Some of the high prevalence of infection in birds in the Lake Lenore region is undoubtedly due to birds which hatched in the "forest fringe" ecotone (a typically Canadian Shield boreal forest area with a multitude of fast-flowing streams) and staged slightly further south in Lake Lenore. The immature birds in the Lake Lenore sample had a lower prevalence of blood parasites than the adults from the same region, but were nearly double the rate of the immatures from the Corning-Heward area. Nevertheless, the prevalence of blood parasites in these immatures is still low in comparison to similar birds in eastern North America. Prevalence of infection in the adult ducks of the Lake Lenore region is high in comparison to those from the Corning-Heward area, and is fully comparable to the prevalence levels recorded in this age class of anatids elsewhere on the continent (Bennett, 1972; Bennett et al., 1974, 1975; Herman et al., 1971; Laird and Bennett, 1970; Thul et al., 1980).

In Alberta, the prevalence of hematozoa was highest in waterfowl from Wood Buffalo National Park (Table 2), an area on the fringe of the Candian Shield; 40% of the birds from this region were infected compared to 30% from Vermilion and 29% from Grande Prairie. *Leucocytozoon simondi* was the most frequently encountered parasite, occurring in 33%, 21% and 19% of the birds from Wood Buffalo National Park, Vermilion and Grande Prairie respectively (Wood Buffalo vs. Vermilion $x^2 = 8.4$, d.f. = 1, $p<0.005$; Wood Buffalo vs. Grande Prairie $x^2 = 9.1$, d.f. = 1, $p<0.005$). The prevalence of *H. nettionis* was one-third that of *L. simondi* in both the Vermilion and Wood Buffalo National Park birds, but only marginally lower in the Grande Prairie sample. In all cases, the prevalence of *H. nettionis* was higher in Alberta waterfowl than in those from Saskatchewan.

Annual infection rates were remarkably consistent in the Vermilion area but varied widely in Grande Prairie. In fact, the prevalence of hematozoa in the Vermilion sample varied marginally from 31% in 1976 to 29% in 1977 ($x^2 = 0.2$, d.f. = 1, $p>0.05$), whereas in the Grande Prairie birds the infection rate ranged from 38% in 1979 to 21% in 1980 ($x^2 = 33.2$, d.f. = 7, $p<0.001$). As water levels were comparable in 1976 and 1977 but decreased markedly between 1979 and 1980, variations in the annual infection rate may well reflect the amount of vector breeding habitat available. Hence the 1980 drought conditions in Grande Prairie probably lowered the vector population and reduced the potential for parasite transmission. Though the small sample sizes from Wood Buffalo National Park renders comparisons of annual infection rates somewhat specious, it is noteworthy that fluctuations in prevalence of hematozoa adhere directionally to changes in water levels.

The elevated prevalence of hematozoa in ducks from Wood Buffalo National Park is largely attributable to the high prevalence of *L. simondi* in both age classes. That *L. simondi* occurs frequently in birds from this area, as in the Lake Lenore sample, is not surprising given its proximity to the Canadian Shield environment. In the Grande Prairie region the prevalence of *H. nettionis* and *L.*

simondi did not markedly differ, although in 1980 the infection rate of each species was reduced about 50% from the previous year. As 1980 was an anomalous year of drought conditions, the 1979 results were likely more indicative of the hematozoan patterns in this area. Nevertheless, the low prevalence of *L. simondi* is enigmatic considering the topography of the area and the known occurrence of two proven vectors, *Simulium (Byssodon) ruggelsi* and *Simulium (Eusimulium) anatinum* in watersheds only 100 km from Grande Prairie (Craig and Pledger, 1979). The pattern of hematozoan occurrence in Vermilion is similar to that observed in the Lake Lenore area of Saskatchewan. *Leucocytozoon simondi* was the most frequently encountered parasite and both *L. simondi* and *H. nettionis* occurred more frequently in adult than immature birds. As both areas are located in parkland and topographically similar, the similarity of the results is not surprising.

Though *L. simondi* occurs in a fairly high percentage of the areas studied, with the exception of the Corning-Heward region in Saskatchewan, it is noteworthy that the prevalence of this parasite in hatching-year birds increases with latitude north, as follows: 4% in southern parkland (Corning-Heward); 11% in central parkland (Lake Lenore); 18% in northern parkland (Vermilion); 21% in mixed forest (Grande Prairie); 34% in northern mixed forest (Wood Buffalo National Park). Although this variable prevalence probably reflects the amount and suitability of vector habitat, it is fortunate that this situation exists as the primary waterfowl breeding habitat is located in the southern regions of the prairie provinces.

In general it would appear that ducks in the Canadian Prairie provinces are not subject to as high an attack rate by blood protozoans as their counterparts in the northeastern portion of the continent. Consequently, the impact of these parasites on the waterfowl populations is probably low. Nevertheless hematozoa do occur in increasing numbers in northern areas. In such areas blood parasites, especially *L. simondi*, may be an important but unrecognized cause of mortality in duck populations.

Acknowledgements

We wish to acknowledge the technical and field assistance of R. Isbister, J. Smith, K. Godwin and S. Edmunds. The financial assistance of the Natural Sciences and Engineering Research Council of Canada, initially to E.C. Greiner and subsequently to the first author is gratefully acknowledged.

LITERATURE CITED

ANDERSON, R.C. and R.S. FREEMAN. 1969. *Cardiofilaria inornata* (Anderson, 1956) from woodcock with a review of the *Cardiofilaria* and related genera (Nematoda: Filarioidea). Trans. Am. Microsc. Soc. 88: 68-79.

BENNETT, G.F. 1970a. Simple techniques for making avian blood smears. Can. J. Zool. 48: 585-586.

———. 1970b. *Trypanosoma avium* Danilewsky in the avian host. Can. J. Zool. 48: 803-807.

———. 1972. Blood parasites of some birds from Labrador. Can. J. Zool. 50: 353-356.

——— and C.D. MACINNES. 1972. Blood parasites of geese of the McConnell River, N.W.T. Can. J. Zool. 50: 1-4.

——, E.C. GREINER and W. THRELFALL. 1976. Impact of parasitic diseases on wildlife: Protozoans. In: *Wildlife Diseases*. L.A. Page (ed.). Plenum Press, New York. pp. 25-33.

——, B. TURNER and G. HOLTON. 1981. Blood parasites of Trumpeter Swans, *Olor buccinator* (Richardson), from Alberta. J. Wildl. Dis. 17: 213-215.

——, W.W. BLANDIN, H.W. HEUSEMANN and A.G. CAMPBELL. 1974. Hematozoa of the Anatidae of the Atlantic Flyway. I. Massachusetts. J. Wildl. Dis. 10: 442-451.

——, A.D. SMITH, W. WHITMAN and M.F. CAMERON. 1975. Hematozoa of the Anatidae of the Atlantic Flyway. II. The Maritime Provinces of Canada. J. Wildl. Dis. 11: 280-289.

CRAIG, D.A. and D. PLEDGER. 1979. A contribution to the population dynamics of biting flies in the Swan hills area of boreal forest. Report to the Minister of the Environment, Province of Alberta, April, 1979. 70 pp.

FALLIS, A.M. and G.F. BENNETT. 1966. On the epizootiology of infections caused by *Leucocytozoon simondi* in Algonquin Park, Canada. Can. J. Zool. 44: 101-112.

GARNHAM, P.C.C. 1966. *Malaria Parasites and Other Haemosporidia*. Blackwell Scientific Publications, Oxford, England. 1,114 pp.

HERMAN, C.M. 1968. Blood parasites of North American waterfowl. Trans. N. Am. Wildl. Nat. Resour. Conf. 33: 348-359.

——, J.H. BARROW and I.B. TARSHIS. 1975. Leucocytozoonosis in Canada Geese at the Seney National Wildlife Refuge. J. Wildl. Dis. 11: 404-411.

——, J. O. KNISLEY JR. and G.D. KNIPLING. 1971. Blood parasites of wood ducks. J. Wildl. Manage. 35: 119-122.

JULIAN, R.J. and D.E. GALT. 1980. Mortality in Muscovy Ducks *(Cairina moschata)* caused by *Haemoproteus* infection. J. Wildl. Dis. 16: 39-44.

LAIRD, M. and G.F. BENNETT. 1970. The subarctic epizootiology of *Leucocytozoon simondi*. J. Parasitol. 56 (sect. 2): 198.

NELSON, E.C. and J.S. GASHWILER. 1941. Blood parasites of some Maine waterfowl. J. Wildl. Manage. 5: 199-205.

O'ROKE, E.C. 1934. A malaria-like disease of ducks caused by *Leucocytozoon anatis* Wickware. Univ. Mich. Sch. Cons. Bull. No. 4. 44 pp.

SOKAL, R.R. and F.J. ROHLF. 1969. *Biometry*. W.H. Freeman and Co., San Francisco, California. 776 pp.

THUL, J.E., D.J. FORRESTER and E.C. GREINER. 1980. Hematozoa of wood ducks *(Aix sponsa)* in the Atlantic Flyway. J. Wildl. Dis. 16: 404-411.

TRAINER, D.O., C.S. SCHILDT, R.A. HUNT and J.R. JAHN. 1962. Prevalence of *Leucocytozoon simondi* among some Wisconsin waterfowl. J. Wildl. Manage. 26: 137-143.

WILLIAMS, N.A., B.K. CALVERLEY and J.S. MAHRT. 1977. Blood parasites of mallard and pintail ducks from central Alberta and the Mackenzie delta, N.W.T. J. Wildl. Dis. 13: 226-229.

Received for publication 28 September 1981