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HEMATOZOA OF THE ANATIDAE OF THE ATLANTIC FLYWAY. 1. MASSACHUSETTS

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Abstract: A total of 1852 anatids of 14 species from various locales in Massachusetts were examined for hematozoa; 1064 (58%) of 10 species were found to harbour one or more blood parasites. *Haemoproteus* (*P.*) *nettionis* was the commonest parasite, occurring in 90% of the infected birds; *Leucocytozoon simondi* occurred in 27% while *Plasmodium circumflexum* occurred in 14.5% of the infected birds. Prevalence of parasitism was somewhat higher in adult than in immature birds and the rate of infection varied widely from area to area within the state but was fairly stable within any one region during each of the four years of the survey. Seasonal prevalence of the parasites indicated that transmission occurred twice each season suggesting at least two major vectors for each hematozoon.

INTRODUCTION

The fall harvest of waterfowl has been a traditional feature for sportsmen of the Atlantic seaboard for some four centuries and of the indigenous Indian populations for time immemorial before. The impact of civilization and advancing urbanization with the concurrent destruction of traditional breeding grounds and general ecological disturbance, has required the institution of vigorous waterfowl management schemes to maintain waterfowl populations at a harvestable level. Considerable attention has been paid to hunter-take regulations and to intensive management of waterfowl habitat to provide the maximum harvestable yield for an area. However, while the impact of diseases on wildlife populations is generally acknowledged to have some effect, relatively little has been done to clearly quantitate their effects on wild populations or to attempt their control.

Avian hematozoa, particularly *Leucocytozoon simondi,* have been shown to destroy a large proportion of young birds in some areas. At the Seney Refuge in Michigan, Herman[9] and Sherwood[11] reported a maximum figure of 80% mortality among young Canada geese from *L. simondi* in some years and a minimum of 20% mortality in others. Fallis and Bennett[7] reported a 100% mortality among young domestic ducks in May-July in Algonquin Park from the same cause and Laird and Bennett[6] showed that this parasite precluded commercial rearing of domestic anseriforms at Fort Chimo, Ungava Bay, Quebec. In these areas of recorded high mortality due to *L. simondi,* the prevalence of hematozoa in the waterfowl population ranges from 80-100%. It is assumed, therefore, that in any area where the prevalence of hematozoa in a waterfowl population reaches such a level, the hematozoa may well be considered to be a potential limiting factor of the waterfowl population or of particular species composing it. If such losses, reported from these few isolated localities, are indeed general, then a highly significant portion of the potentially harvestable waterfowl production is lost. Some measures to control such losses must then be instituted. However, baseline information on the prevalence of hematozoa

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in waterfowl in various areas, especially those in which large-scale waterfowl management schemes are employed, is required before the impact of hematozoa (or any other disease) on the breeding populations can be assessed.

The survey reported herein is an attempt to remedy this lack of information and provide baseline information for the State of Massachusetts, an area with extensive waterfowl management schemes in the southern portion of the breeding range of anatids of the Atlantic Flyway. The prevalence of various blood parasites in the breeding species of anatids, with particular emphasis on wood and mallard ducks, is reported, together with a comparison of the blood parasites in young and adult birds. The prevalence of the parasties from various areas within the State are compared, as is the prevalence from year to year over a period of 4 years. The seasonal occurrence of the blood parasites over the period March to October is also given.

MATERIALS AND METHODS

Blood smears were obtained from birds variously acquired by trapping, netting, capture by airboat, etc. The smears were air-dried and fixed in 100% methanol or ethanol in Massachusetts and then sent to St. John's where they were stained with Giemsa's stain (1 Giemsa: 9 distilled water buffered to pH 7.2) and examined for blood parasites.

In all tables, the prevalence of the various species of hematozoa is expressed as a percentage of the total infected birds, *not* of the total birds examined. In all tables, the total of the specific infections will be greater than the total number of birds infected as each infection of a multiple infection is recorded individually.

In all tables, the following abbreviations are used:

Leuc. = *Leucocytozoon simondi;* Haem. = *Haemoproteus* (*Parahaemoproteus*) *nettionis*; Plasm. = *Plasmodium circumflexum;* Micro. = microfilaria.

RESULTS AND DISCUSSION

A total of 1852 anatids of 14 species were examined for hematozoa (Table 1) 1064 (58%) birds of 10 species were found to harbour one or more species of blood parasites and the remaining four species of ducks were sampled in too low numbers to be of significance. All hooded mergansers examined (Table 1) were infected with one or more hematozoa but the sample was small. Wood ducks were heavily infected and also showed the highest prevalence of *L. simondi,* the most lethal of the blood parasites involved. It is possible that blood parasites are acting as a factor of population control on wood ducks in this area; prevalence of blood parasites in the other duck species is considerably lower and these parasites are unlikely to be a serious limiting factor of these duck populations. Blue wing teal show a significantly lower prevalence of blood parasites than any other duck species.

Immature birds showed a slightly lower overall prevalence of hematozoa than the adults (Table 2), but the difference is not significant. Generally, the overall prevalence of haemoproteids and *Plasmodium* was about the same in both adults and immatures, although some variation is noted between duck species. Surprisingly, *L. simondi* is not as prevalent in immatures as in adults, and this is in contrast to the expected as leucocytozoonosis is considered to be primarily a disease of young birds.[7,11] However, if young birds are susceptible (either directly by the parasite or through predation or other environmental effects on parasite-weakened birds), they could die before being included in the sampled population and hence the lower rate of infection in the immatures (essentially the survivors) might be expected.

Considerable variation in overall prevalence of hematozoa was noted during the 4 years of the survey (Table 3). In 1969, the sample was small and probably should not be compared with the other years. However, the prevalence in 1972, the largest sample year, was lower than any other year. Much of the fluctuation seems to be the result of the wide variation of the incidence of *Plasmodium* over

TABLE 1. Prevalence of hematozoa in anatids of Massachusetts. Figures in parentheses indicate percentage of total infected birds.

Duck Species	Total Examined	Infected No. (%)	Leuc. No. (%)	Haemo. No. (%)	Plasm. No. (%)	Micro. No. (%)
Black duck *Anas rubripes*	203	104 (51)	29 (28)	85 (84)	15 (14)	4 (4)
Mallard *Anas platyrhynchas*	624	225 (36)	33 (15)	189 (84)	28 (13)	3 (1)
Mallard x Black hybrid	88	36 (41)	7 (19)	31 (86)	1 (3)	1 (3)
Blue-wing teal *Anas discors*	87	15 (17)	2 (14)	12 (80)	2 (14)	
Green-wing teal *Anas carolinensis*	87	35 (40)	8 (23)	27 (77)	1 (3)	1 (3)
Wood duck *Aix sponsa*	730	633 (87)	209 (33)	598 (94)	103 (15)	47 (7)
Hooded merganser *Lophodytes cucullatus*	11	11 (100)	1 (9)	8 (73)	5 (45)	
Widgeon *Mareca penelope*	1	1		1		
Ring-necked duck *Aythya collaris*	1	1		1		
Canada goose *Branta canadensis*	10	3 (30)		3		
Totals (including negative species):	1852	1064 (58)	289 (27)	955 (90)	155(14.5)	56 (5)

Negative species: domestic duck, *Anas boschas* (7); pintail, *Anas acuta* (1); bufflehead, *Bucephala albeola* (1); blue goose, *Chen caerulscens* (1).

TABLE 2. Prevalence of hematozoans in mature and immature anatids of five species. Figures in parentheses indicate the percentage of each species of parasite expressed as a percentage of the total infected birds.

	Mature					Immature				
Species	Total	Infected No. (%)	Leuc. No. (%)	Haemo. No. (%)	Plasm. No. (%)	Total	Infected No. (%)	Leuc. No. (%)	Haemo. No. (%)	Plasm. No. (%)
Black duck	31	18(58)	8(44)	15(83)	8(22)	170	81(48)	16(20)	83(67)	11(14)
Mallard	152	57(38)	15(26)	47(82)	1(2)	90	163(42)	14(9)	143(88)	25(15)
Blue-wing teal	20	6(30)	1(17)	4(67)	1(17)	56	9(16)	1(11)	8(89)	1(11)
Green-wing teal	28	11(39)	2(18)	9(82)		59	24(41)	18(75)	18(75)	1(4)
Wood duck	282	255(90)	139(55)	235(92)	37(15)	397	338(85)	44(13)	223(66)	62(18)
TOTALS:	513	347(68)	165(48)	310(89)	43(12)	1072	615(57)	93(15)	459(89)	100(10)

the 4 years (Table 3). The prevalence of *H.* (*P.*) *nettionis* was extremely high and stable and except for 1969, *L. simondi* was also relatively stable. The variation of the *Plasmodium* is hard to explain but perhaps adverse climatic or control measures successfully reduced the vector populations in some years.

Birds studied in the survey were obtained from a number of localities in Massachusetts (Fig. 1, Table 4). Prevalence of blood parasites from 21 of these areas (i.e.—areas where 10 or more ducks were sampled) showed that the prevalence varied widely from locale to locale. Generally the areas can be

TABLE 3. Prevalence of blood parasites in anatids of Massachusetts in each of four years. Figures in parentheses indicate percentage infection based on total infected birds.

Year	Total examined	Infected No. (%)	Leuc. No. (%)	Haemo. No. (%)	Plasm. No. (%)	Micro. No. (%)
1969	99	55 (56)	9(16)	51(93)	3(5)	
1970	513	363 (71)	86(24)	338(93)	61(17)	11(3)
1971	482	287 (60)	92(32)	248(86)	82(29)	22(8)
1972	748	360 (48)	102(28)	325(90)	3(1)	23(6)
Total	1852	1065 (58)	289(27)	954(90)	153(14)	56(5)

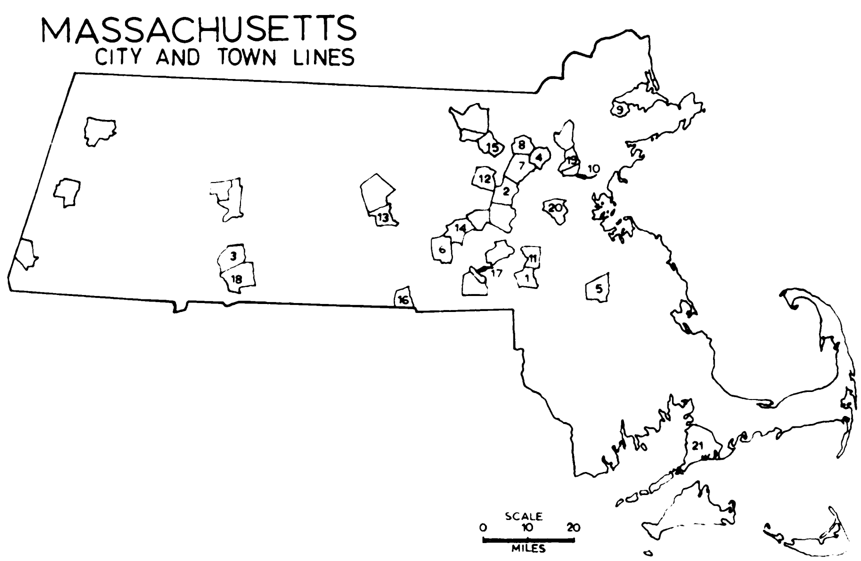

FIGURE 1. Illustrating townships in which anatids were sampled. Townships with numbers (Nos. 1-21) represent areas from which 10 or more birds were sampled and the numbers specifically refer to the numbers (first column) in Table 4.

TABLE 4. Prevalence of hematozoa in anatids from some different locations in Massachusetts (see Fig. 1).

Locality and map reference no.	Total	Infected No. (%)	Leuc. No.	Haemo. No.	Plasm. No.	Micro. No.
MIXED POPULATION OF DUCKS						
1. Bristol Blake, Norfolk	71	54 (76)	16	52	11	2
2. Broad Meadows, Sudbury	118	86 (73)	3	77	21	
3. Chicopee River, Chicopee	66	31 (47)	1	29	4	
4. Concord River, Bedford	101	77 (77)	22	69	9	
5. D. W. Field Park, Brockton	25	2 (8)		2		
6. Fisherville Pond, Grafton	55	12 (25)	1	12		
7. Great Meadows Refuge, Concord	700	451 (64)	81	412	72	13
8. Greenough's Estate, Carlisle	14	14 (100)	8	14	2	5
9. Ipswich River Sanctuary, Topsfield	50	16 (32)	3	13	3	
10. Mill Pond, Winchester	29	4 (14)		4		
11. Stop River, Medfield	16	12 (75)		12		
12. Stow—environs	19	16 (84)	6	11	4	2
13. Turkey Hill Brook, Paxton	41	26 (63)	7	24	5	2
14. Westboro Mgmt. Area, Westboro	33	13 (39)	10	6	1	1
WOOD DUCK ONLY						
15. Beaver Brook, Littleton	19	19 (100)	11	18	5	2
16. Breeding Pond, Webster	16	16 (100)	8	13	1	
17. Fiske Mill Pond, Hopedale	23	20 (87)	15	18	1	4
MALLARD ONLY						
18. Forest Park, Springfield	83	27 (33)	7	22	1	
19. Horn Pond, Woburn	30	7 (23)	1	6		1
20. Norumbega Park, Newton	128	41 (32)	4	37	1	
21. Salt Pond, Falmouth	12	0 (0)				
TOTAL	1649	943 (57)	204	851	141	32

grouped into three categories— heavy infection (75-100%; 8 locales); moderate infection (30-74%; 8 locales); light infection (0-29%; 5 locales). The reasons for this extreme variation are not known but are presumably related to factors such as vector density and behavior, availability of vector breeding areas and host population density. Local trends in climate are also undoubtedly important in this respect. Age of impoundment and, hence, stability of breeding areas for the vectors and a stable vector population, is apparently not a factor. All the areas (Table 4) have been impounded and flooded for at least 25 years. Broad Meadows and Ipswich Sanctuary are natural flood plains, seasonally flooded and an impoundment has existed in the latter region for 30 years. An impoundment of similar age occurs at Forest Park while Fiske Mill pond has existed for 45 years; the Fisherville pond has a 150 year history of impoundment while Bristol Blake was first impounded in 1693 and has gone through a series of earthen and stone dams. Yet of these six areas, two can be classed as high prevalence, one as low, two as medium-low and one as medium-high (Table 4). Whatever the reasons, one fact is clearly demonstrated — generalizations about prevalence of hematozoa in waterfowl in Massachusetts can not be based on samples from only one or two areas.

In 1971, sampling of the anatid population was started in March and continued through October. Much of this sample was composed of wood ducks and the seasonal prevalence of hematozoa in this anatid is compared to that of the total duck population (Fig. 2). The monthly prevalence of the blood parasites in all ducks (Fig. 2 a) indicates a sharp increase in the patent infections in April, persisting at a high level through July and decreasing sharply by October. A similar pattern is observed for the average number of parasite genera/infected bird. The lower prevalence of parasites in the period August-October does not necessarily mean that these birds have lost their parasites, although this is a possibility. It is just as possible that the birds harbour a sub-patent parasitaemia and parasites are not seen on the blood smear. Recrudescence of the infection in March-April as shown (Fig. 2 a), at a time prior to the emergence of the vectors, is due undoubtedly to the relapse phenomenon[1,2,3,5,6] and clearly indicates that many birds must indeed have harboured sub-patent infections.

Although the overall pattern of the prevalence of blood parasites is unimodal, analysis of the prevalence of each of *Leucocytozoon*, *Haemoproteus* and *Plasmodium* show them to be bimodal (Fig. 2 c, d, e), with peaks in May and June for *Leucocytozoon*, May-July for *Plasmodium* and April-August for *Haemoproteus*. The fact that *Haemoproteus* is both the predominant parasite and has its second peak in August destroys the bimodality one would expect in the overall prevalence pattern (Fig. 2 a, b). Bimodal patterns of infection have been demonstrated[3,5] for *Leucocytozoon* and *Plasmodium* in Michigan and Pennsylvania, respectively, but only unimodal patterns (similar to Fig. 2 a) have been shown for *Leucocytozoon* in Northern Michigan[8] and in Algonquin Park.[7] The epidemiology of blood parasites in Massachusetts therefore closely resembles that recorded in Southern Michigan and Pennsylvania. The seasonal prevalence of hematozoa in wood ducks (Fig. 2) is similar to that in the total duck population. However, the prevalence is somewhat higher and the peaks of infection more sharply delineated.

Tarshis[12] has shown that adult simuliid vectors of *L. simondi* occur as early as late March-mid-April in Maryland. If vectors were active in April in Massachusetts, then the combined effect of relapse of infection at the onset of breeding (as shown by Chernin[5]), together with new infection transmitted by early season vectors (such as *Simulium (Eusimulium) anatinum*), could lead to the first peak of infection seen in May-June in adult birds (Fig. 2 c). The second peak, noted in late July, could result from late season vectors (such as *Simulium (Byssodon) ruggelsi*) transmitting the parasite to the young of the year which are now present. Thus a sharp bimodality in parastie prevalence would be seen, resulting from a

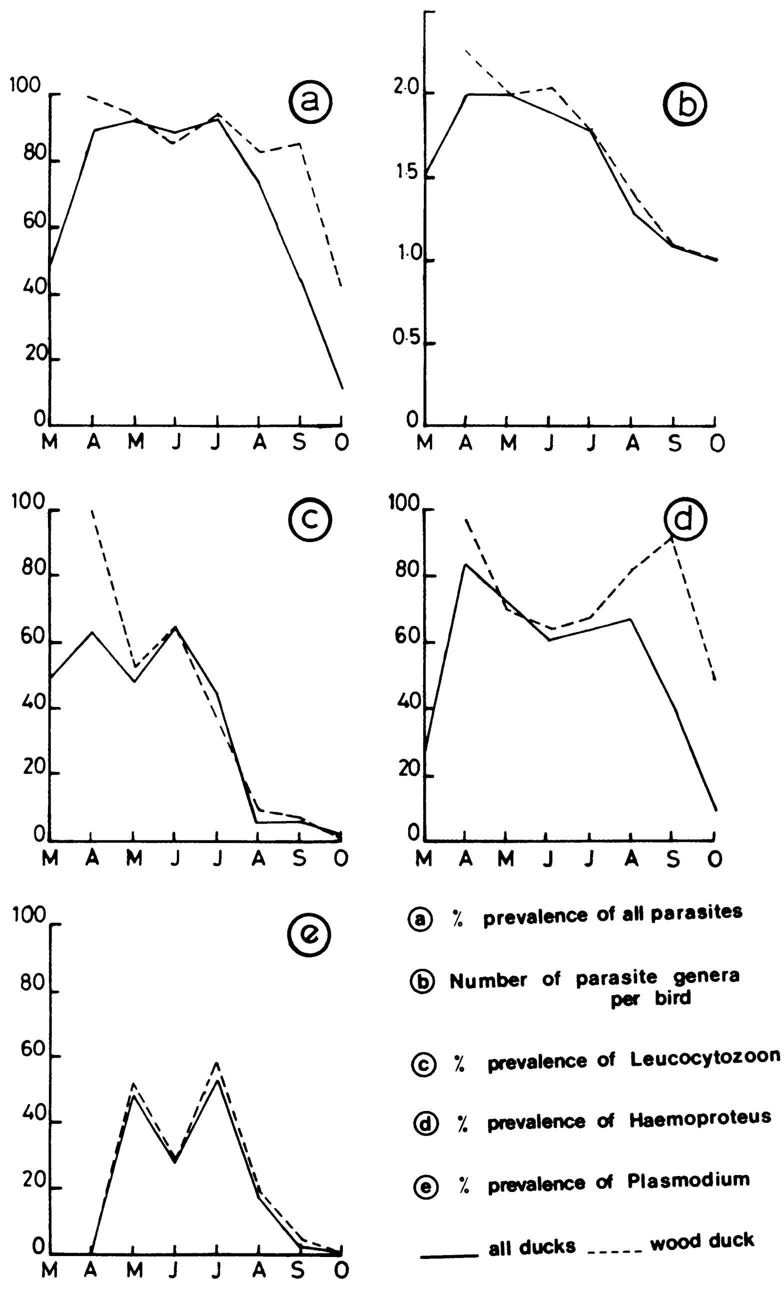

FIGURE 2. Seasonal prevalence of hematozoa in anatids in Massachusetts, 1971.

separation (in time) of the major insect vector populations, this separation leading to the attack by the vectors of two essentially different host populations (adults and adult/immatures). The unimodal curves seen in Michigan and Algonquin Park could well result from climatic factors causing vector populations to overlap, rather than be separated, in time. In Algonquin Park, transmission of *L. simondi* to sentinel birds did not occur until mid-May,[4,7] when *S. anatinum* was the active vector. While the population *S. anatinum* was short-lived, it was still persistent until mid-June, although *S. ruggelsi*, the second major vector of *L. simondi* in the region, became a significant portion of the total vector population by late May-early June and persisted until the end of July-mid-August (extending into September in some years). With no clear separation in time of the two vector populations, a unimodal pattern of infection would thus be anticipated. While this hypothesis applies directly to *L. simondi*, in principle there is no reason that it cannot apply equally to any vector-borne disease and is the substantitive base for malaria-control programs around the world. In Massachusetts it would appear (Fig. 2 c) that transmission of *L. simondi* and *P. circumflexum* ceases by mid-July while a new wave of transmission of *H. nettionis* occurs in mid-August. Transmission of these parasites, of course, occurs some 7-14 days prior to patency. The unexpectedly low prevalence of *L. simondi* in immature birds (Table 2) suggests that either (i) some birds hatch and leave the vector area after the first peak of transmission but before the second or (ii) hatch after the second vector season; probably a combination of both occurs.

In summary it would appear that blood parasites are only moderately prevalent in the Anatidae of Massachusetts, with the wood ducks showing a significantly higher rate of infection than other species. Blood parasites may well be a limiting factor to wood duck production in the state. *Haemoproteus nettionis* is the commonest haematozoan and its rate of infection was stable over a 4 year period. *Leucocytozoon simondi* is particularly prevalent in the wood ducks, and over a 4 year period, the prevalence of this parasite was relatively stable. The prevalence of *Plasmodium circumflexum* appears to vary widely from year to year (as determined by blood smears alone) and the effects of this parasite on wild populations is poorly known. Blood parasites occur somewhat more frequently in adults than in immatures. The occurrence of blood parasites varies widely from area to area within the state, and the evidence suggests that each of the three main hematozoa have at least two vectors, one in the early spring-summer and the other in mid- to late summer.

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