THE PREVALENCE OF HEMATOZOAN AND HELMINTH INFECTIONS IN MIGRATORY AND WINTERING WATERFOWL IN OKLAHOMA

By

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Bachelor of Science

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Amherst, Massachusetts

1975

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1978

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PREFACE

Waterfowl, like other birds, serve as definitive hosts for an extensive array of parasite fauna. This research was designed to investigate the prevalence of some specific parasitic infections in waterfowl that migrate through or winter in Oklahoma. In addition, the study focused on the potential for transmission of these parasites among wintering populations of waterfowl.

Research funds and equipment were supplied by the OSU Environmental Institute; the Department of Veterinary Parasitology, Microbiology, and Public Health; and by the Oklahoma Cooperative Wildlife Research Unit at Oklahoma State University.

The author wishes to express his thanks to Dr. A. Alan Kocan and Dr. James H. Shaw for serving as co-advisers and members of the graduate committee. Dr. Kocan provided guidance throughout the research and reviewed the manuscript. Dr. Shaw's assistance in editing the manuscript and his helpful suggestions were appreciated. Special thanks are given to Dr. James C. Lewis for constructive criticism of the manuscript and serving as a member of the committee, and to Dr. Paul A. Vohs who provided additional suggestions in preparing the final manuscript.

Appreciation is expressed to the Max McGraw Wildlife Foundation for supplying ducklings needed for part of the research. A note of thanks is also given to the personnel of Washita and Salt Plains National Wildlife refuges, for their cooperation throughout the project.

Finally, special gratitude is extended to my wife, Laura, for her

help during portions of the research, and her understanding and support throughout the entire study.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

The literature contains numerous reports of parasitism in waterfowl from many areas of North America. The majority of these accounts have been concerned with epizootic outbreaks, individual mortality, new host-parasite records, extension of geographic range, or surveys of easily-sampled species. Although valuable information can be gleaned from such reports, they lend little to understanding the significance of disease in wild populations (Bradshaw and Trainer 1966). Recently, several investigations of broader scale have been undertaken (Bennett et al. 1974, Bennett et al. 1975, Stabler et al. 1975), however, in spite of these efforts, information from the Central Flyway, and specifically Oklahoma, is noticeably absent.

The Central Flyway includes all or parts of Montana, North Dakota, South Dakota, Wyoming, Colorado, Nebraska, Kansas, Oklahoma, New Mexico, and Texas. This flyway comprises more than 33 percent of the area of all the flyways combined, and furnishes 186,000 square miles of waterfowl habitat (Buller 1964). Its importance becomes even more striking under the migration corridor concept developed by Bellrose (1968). Radar tracking, weekly censuses at refuges, and band recovery data show that this flyway, and in particular Oklahoma, supports waterfowl populations that include nearly 10,000,000 ducks and approximately 400,000 geese (Bellrose 1976). These concentrations, and a substantial increase of wintering birds observed in Oklahoma during recent years, make the potential for transmission of parasitic diseases extremely high. For this reason, a seasonal study of parasitic infections in Oklahoma populations is both feasible and warranted.

Studies conducted elsewhere in North America have reported a variety of infections with blood-inhabiting protozoa (Table I), however, comprehensive surveys of helminth infections are less plentiful. Information on the incidence of these infections is needed over a large area before their impact on waterfowl populations can be assessed.

The purpose of this study was to (1) determine the prevalence of hematozoa in waterfowl migrating through and wintering in Oklahoma, (2) determine the prevalence and composition of helminth infections in waterfowl on the wintering ground, (3) examine the potential for transmission of these parasites in wintering populations, and (4) to assess the role of wintering populations in the maintenance and spread of parasitic infections. These objectives were limited to 3 areas in north-central and central-western Oklahoma from which a large number of waterfowl could be sampled.

TABLE I

A SUMMARY OF BLOOD PARASITE STUDIES
IN WATERFOWL OF NORTH AMERICA

Locality	Number examined Individuals	Species	Percent parasitized	Author
Maine	130	9	79.0	Nelson & Gashwiler 1941
California	926	6	3.2	Herman 1951
Horseshoe L., Illinois	353	1	9.1	Levine & Hanson 1953
Maine	753	2	84.0	O'Meara 1956
Saskatchewan and Manitoba, Canada	702	12	0.005	Burgess 1957
Crex Meadows, Wisconsin	179	6	64.0	Trainer et al. 1962
Maryland	90	1	31.0	Kocan & Knisley 1970
Massachusetts	1852	14	58.0	Bennett et al. 1974
Canada, Maritime Provinces	4200	14	30.0	Bennett et al. 1975
Colorado	445	14	27.0	Stabler et al. 1975
Alberta and Northwest Territories, Canada	127	2	28.0	Williams et al. 1977

CHAPTER II

LITERATURE REVIEW

The occurrence of parasitic diseases in waterfowl has been well documented (Halloran 1955, Davis et al. 1971). Although our knowledge concerning the significance and potential impact of disease on waterfowl populations is limited, Bellrose (1976) states that disease is directly or indirectly responsible for the largest proportion of non-hunting mortality. Part of this mortality is a direct result of parasitic infection, while some is indirectly related to parasitic infection as seen in predation on sick or debilitated birds.

Although millions of ducks and geese are lost annually because of disease (Bellrose 1976), many escape notice because sick waterfowl seek heavy cover to avoid detection, and predators soon eliminate any moribund birds. During an epizootic, observers become aware of mortality because scavengers are unable to remove the increased number of dead carcasses.

Many species of parasites have been reported from waterfowl, but not all are considered to be important pathogens. Blood protozoans have been described from many species of waterfowl, and have been implicated, under specific conditions, in annual mortality. This group includes the sporozoans *Leucocytozoon*, *Plasmodium*, and *Haemoproteus*. Of these, *Leucocytozoon* is most frequently responsible for significant mortality, especially at the northern nesting grounds (Herman 1968).

Wickware (1915) was the first to recognize that *Leucocytozoon* was a problem in waterfowl. He noted that it was nearly impossible to raise domestic ducklings due to the prevalence of this disease in certain parts of Canada. The first report of this hematozoan from wild anatids in North America was by O'Roke (1934) who later identified the vector as a blackfly (*Simulium* sp.). The blackflies that transmit *Leucocytozoon* show a strong preference for feeding on birds, and many feed exclusively on waterfowl. Transmission may occur wherever infected waterfowl and the vector occupy the same habitat. Several species of *Leucocytozoon* have been reported from avian hosts, but *L. simondi* seems to be host-specific for waterfowl (Herman 1968).

Leucocytozoon is widespread in Michigan, Ontario, and Wisconsin and severe losses have occurred among young waterfowl in several enzootic areas. In Cheboygan and Presque Isle counties in Michigan, Barrow et al. (1968) studied transmission of *L. simondi* by placing mallard (*Anas platyrhynchos*) ducklings in cages and exposing them to blackflies at 4 locations. At 2 locations, a total of 28 ducklings became infected and 68 percent died. At Seney National Wildlife Refuge in Michigan, evidence indicates that all Canada goose (*Branta canadensis*) goslings become infected with *Leucocytozoon* each year and that severe losses occur every 4th or 5th year (Herman 1968). Sherwood (1965) reported the loss of 500 Canada geese at Seney in 1964, and this represented 80 percent of the goslings hatched that year. In 1960, 690 of 790 goslings at the refuge died from leucocytozoonosis (Sherwood 1965). At a site in Wisconsin, 64 percent of the wild ducks tested carried *L. simondi* (Trainer et al. 1962). Mallards were the predominant species tested, and 100 percent of 102 immature birds were infected. Surveys have been made to determine the distribution of the disease in other parts of North America (Table I), but information on wintering populations and the Central Flyway is scarce.

Another blood protozoan that infects waterfowl is the genus Plasmodium. This organism is the causative agent of avian malaria and many species have been reported from North American birds, however, the species most often found in waterfowl are P. circumflexum, P. relictum, and P. vaughani. The first report of Plasmodium from North American waterfowl was by Herman (1951). Contrary to early reports, recent studies (Herman et al. 1966) have revealed that this parasite is quite prevalent and widespread. Natural transmission occurs through culicine mosquitoes (Herman 1968), but the specific vector species are unknown. Experimental infections have produced mortality (Herman 1968), and Kocan and Knisley (1971) described a bufflehead (Bucephala albeola) found on Chesapeake Bay, that apparently had died from a heavy infection of P. circumflexum. Our knowledge of avian malaria is incomplete, and it is not known whether this disease can have an impact on waterfowl populations.

Haemoproteus is a blood protozoan that has been reported from a variety of North American anatids, and is closely related to Leucocytozoon. H. nettionis was first discovered in the black duck (Anas rubripes) by Herman (1938), and has since been reported from at least 23 waterfowl species. Fallis and Wood (1957) demonstrated that a midge (Culicoides sp.) is a vector for Haemoproteus. As with Leucocytozoon and Plasmodium the occurrence is widespread, but the exact distribution is unknown. At some sites in Wisconsin, 24 percent of the waterfowl were infected with Haemoproteus, and mortality was attributed to this parasite (Fallis and Trainer 1964). Although most evidence indicates that this hematozoan is not pathogenic by itself, it may influence host mortality during a concurrent infection with 1 of the aforementioned parasites, another disease organism, or when the bird experiences severe environmental stress.

The relapse phenomenon is a characteristic shared by the 3 aforementioned blood parasites that favorably affects transmission (Applegate and Beaudoin 1970). After becoming infected, birds may harbor the organisms for long periods of time, perhaps for life. However, the parasites are not present in the blood in uniform concentrations throughout the year (Herman 1968). In winter the infection is generally latent and parasitemia is much reduced. In early spring a relapse occurs and parasitemia is increased. Chernin (1952) demonstrated recrudescence in experimental infections of *Leucocytozoon*, and this phenomenon is known to occur with *Plasmodium* and *Haemoproteus*.

The benefits of recrudescence are obvious in terms of parasite survival. Adult birds, serving as reservoirs of infection, develop increased parasitemias just as the vectors begin to emerge. Applegate and Beaudoin (1969) found that birds were significantly more infective to the vector during this time than during the winter latent period. The vectors are then able to transmit the organism to other adults and eventually to the young. The percentage of infected ducks gradually rises and in some localities it reaches 100 percent. The results of several studies of experimental infections suggest that the relapse is mediated by a physiological change in the host (Applegate and Beaudoin 1970). Most attempts to induce relapse have centered on manipulation of hormone levels, but these experiments have been inconclusive and the exact mechanism or mechanisms that induce relapse remain unknown.

Among the helminth parasites of waterfowl, 1 group of major concern is the filariid worms (Herman 1968). This family of nematodes is characterized by its larval stages known as microfilariae, which are found in the peripheral blood. When ingested by a suitable blood-feeding insect, these larvae develop into mature infective larvae which may then be transmitted to a new host during a subsequent blood meal. The total number of genera that comprise the filariids is too numerous to list here, but 2 deserve special mention. The first is the genus *Sarconema*, which has been reported in swans and geese (Herman 1968). The adult worms live in the muscles of the heart, and the larvae are found throughout the circulating blood. In a study of whistling swans (*Olor columbianus*) on Chesapeake Bay, Holden and Sladen (1968) examined 7 birds and found that all were infected with *Sarconema*, and several suffered severe damage to the heart muscle. Hanson et al. (1956) examined 306 Canada geese wintering at Horseshoe Lake, Illinois, and found 23.9 percent were positive for microfilariae. *Sarconema* was 1 of the genera identified, but myocardial damage was not documented since no birds were necropsied.

Ornithofilaria is another filariid worm that infects wild ducks and Anderson (1956) demonstrated its transmission by ornithophilic blackflies. He speculated that ducklings are more susceptible than adults because they lack full feather protection. *Ornithofilaria* is listed by McDonald (1969) as occurring in a wide variety of waterfowl species, but it is unknown whether this helminth has an impact on wild populations.

In addition to blood parasites, anatids are subject to a vast number of intestinal helminth infections. A large number of worms pass through some stage of their life cycles in or on aquatic animals or plants. Waterfowl serve well as definitive hosts because of their aquatic feeding habits. Gower (1938) stated that ducks are parasitized by more than 100 species of trematodes, and Lapage (1961) compiled an extensive host-species catalogue of anatid helminths. Some of these helminths cause considerable mortality. Cornwell (1963) reported the death of 2 trumpeter swan (Olor buccinator) cygnets at Delta, Manitoba from an infection with the nematode Echinuria uncinata, and estimated the loss of an additional 120 ducks from echinuriasis in late summer, 1961. In Sweden, Persson et al. (1974) described heavy mortality in common eider ducks (Somateria mollissima) that resulted from endoparasitic invasion, and estimated losses among ducklings at 90 percent in some areas.

Although host-parasite reports appear frequently in the literature, little is known about the effects of these infections or the locations where they are acquired. Buscher (1965) studied the intestinal helminth fauna of the gadwall (Anas strepera), shoveler (Anas clypeata), and pintail (Anas acuta) at 3 locations along their migration route in the Central Flyway, and found 27 species of helminths in these 3 species of ducks.

Wehr and Herman discussed age as a factor that influenced acquisition of parasites by Canada geese, and concluded that older birds were generally more refractile to parasitic invasion. Age is an important aspect of the hosts natural defense mechanisms (Barrett 1974). Older birds develop at least some degree of immunity and become resistant to parasitic infection; young ducks are probably slow in developing this immunity, and therefore are more susceptible than adults to parasitic infection. In addition, ducklings ingest a wider variety of foods than adults, including many invertebrates that serve as intermediate hosts for helminths. In some cases, resistance may be the result of certain anatomical changes. The trematode Prosthogonimus usually inhabits the bursa of Fabricius and is lost as the bird ages and the bursa is resorbed (Wehr and Herman 1954).

Although some 260 species of helminths have been recorded from waterfowl (Gower 1938), relatively few have been implicated as important pathogens. Most animals are able to carry a small number of parasites without suffering ill-effects; waterfowl are no exception. However, in certain situations, increased parasite burdens can impair the normal activities of the waterfowl. Individuals or populations may be especially affected when they are living in marginal habitat or on crowded winter quarters where competition is increased. Of course, any parasite is potentially capable of producing disease, particularly in the young or the stressed host.

CHAPTER III

MATERIALS AND METHODS

The Study Area

In an attempt to evaluate migrating and wintering waterfowl for the presence and prevalence of hematozoan and helminth infections, birds were examined from 3 locations in Oklahoma. Two of the 3 locations were national wildlife refuges where permission was granted to obtain samples during winter banding operations. Salt Plains National Wildlife Refuge is located in north-central Oklahoma in Alfalfa County. The refuge contains 12,960 ha including extensive salt flats, uplands habitat, ponds, marshes, and the 3,600 ha Great Salt Plains Reservoir. Washita National Wildlife Refuge is located on the short-grass plains of west-central Oklahoma in Custer County. The upper portion of Foss Reservoir lies within the 3,321 ha refuge, while the remaining area is comprised of shallow marsh, uplands, and bottomland habitat. Much of the suitable upland and bottomland is planted to corn, sorghum, and wheat to provide high quality waterfowl food.

Both refuges serve as important resting and feeding areas for waterfowl in the Central Flyway, and in recent years they have supported increasing populations of wintering birds. During November, December, and January, duck populations at Washita refuge have been estimated at 100,000 birds. Wintering Canada goose populations sometimes peak at 30,000 (B. Giezentanner, Manager, Washita National Wildlife Refuge, pers. comm., 1976)

Ham's Lake, located in north-central Oklahoma in Payne County, was the 3rd study area. All intensive sampling and experimental transmission studies were conducted on this impoundment which is 8 km west of Stillwater. The lake was built in 1965 by the Soil Conservation Service as a flood detention reservoir, and has a surface area of 40 ha. Excellent growths of quality waterfowl foods such as smartweed (*Polygonum* sp.), pondweed (*Potamogeton* sp.), naiad (*Najas* sp.), wild millet (*Echinochloa* sp.), and nutgrass (*Cyperus* sp.) abound in the shallows and along the shoreline of the lake. Dabbling ducks of several species are attracted to the lake during spring and fall, and a few winter there.

Obtaining Wild Waterfowl For Sampling

Two waterfowl swim-traps (Addy 1956) were constructed in late January, 1976 and placed in shallow water at the southwest end of Ham's Lake. Both traps were baited with cracked corn and checked daily. Although ducks used the area regularly during January and February, none were captured. Consequently, a rocket net (Wildlife Materials Inc.) was placed on the southwest shoreline in early March and the area was prebaited with milo, millet, and cracked corn. The initial group of ducks was captured 1 week later. Trapping at this site continued on a seasonal basis from March, 1976 to April, 1977.

Each duck was classified as either juvenile or adult on the basis of feather wear and replacement (Taber 1969). After the sex of the ducks was determined, they were banded with U. S. Fish and Wildlife Service aluminum leg bands which made it possible to identify recaptures and avoid duplicate sampling. Refuge populations were sampled in January, 1976 and 1977, and processed in the same manner as the waterfowl at Ham's Lake except that the ages of geese were not determined.

Examination For Blood Parasites

Waterfowl were bled from the brachial vein or the medial leg vein, using a 3 cc syringe with a 23-gauge, 2.54 cm needle. One to 3 cc of blood were drawn depending on the species of duck. One drop was placed on a clean glass slide and a thin film was prepared; serum from the remaining blood was stored for serologic analysis as part of another study. Blood films were stained with Wright's stain and examined for *Leucocytozoon*, *Plasmodium*, *Haemoproteus*, and microfilariae. Each film was scanned for 20 minutes under oil immersion (1,000 X) to determine the prevalence of parasitic infection. The level of infection was expressed quantitatively as the number of parasites observed per 20-minute period.

Examination For Helminths

A representative sample of birds was retained and examined for helminth endoparasites. Only freshly killed waterfowl were examined. At necropsy, the entire alimentary tract was removed, separated into its component parts, cut open, and examined *in situ*. Readily isolated parasites were removed, and each section was gently rinsed to expose or dislodge any remaining worms. Cestodes, trematodes, and acanthocephalans were fixed in warm alcohol-formol-acetic acid (AFA), stained with Semichon's Acetocarmine stain, cleared in xylene, and mounted in Permount. Nematodes were hot-fixed in 70 percent Ethanol, cleared in lacto-phenol, and left unmounted for identification. Infections were recorded by prevalence (percent of ducks infected) and degree (number of helminths per infected duck).

Natural Transmission of Parasites at the Ham's Lake Study Area

In an effort to determine the presence and extent of natural transmission on the winter quarters, an experimental population of ducks was established at Ham's Lake. Max McGraw Wildlife Foundation of Dundee, Illinois, provided 3 strains of mallard ducklings: incubator-hatched wild, McGraw, and a 1st-generation incubator-hatched wild X McGraw. The birds were shipped from McGraw Foundation as day-old ducklings, and upon arrival at Oklahoma State University they were pinioned and reared under laboratory conditions for 8 weeks. Prior to release, blood films from 10 percent of the ducks were examined for parasites, and 12 ducks were necropsied and their alimentary tracts were examined for helminths.

On 28 June 1976, the 1st group of mallards was selected, banded with numbered aluminum leg bands (National Band and Tag Co.), and released at Ham's Lake. A total of 208 ducks were released periodically during the summer of 1976, and a stable population of approximately 60 birds was established. These pen-reared birds were free to move about Ham's Lake and mingle with free-flying, wild waterfowl, thus serving as sentinels which could be monitored for transmission of parasites. Blood samples were periodically taken from the sentinel mallards to determine if they had acquired hematozoa; others were necropsied to check for helminth endoparasites.

CHAPTER IV

RESULTS

Trapping Wild Waterfowl

Four-hundred and forty-four ducks of 8 species were captured at the Ham's Lake study area. An additional 143 and 277 birds respectively, were captured at the Washita and Salt Plains National Wildlife refuges. Thus, 864 sample were available for examination (Table II).

Prevalence of Blood Parasites in Wild Waterfowl

Blood films from 563 waterfowl of 8 species were examined for hematozoa (Table III). Ninety-nine birds of 5 species harbored 1 or more species of blood parasites. The remaining 3 species were negative, athough the sample size was too small to be representative. *Leucocytozoon*, *Haemoproteus*, and microfilariae were identified. Among the 99 infected ducks, *Leucocytozoon* occurred most frequently (60.6 percent); *Haemoproteus* and microfilariae made up 44.4 percent and 8.1 percent of the respective infections. Concurrent infections of *Leucocytozoon* and *Haemoproteus* occurred in 7.1 percent of the cases.

When the number of infections with each parasite is expressed as a percentage of the total number of birds examined, the same results are apparent. *Leucocytozoon* was the most common, infecting 10.6 percent of the birds, while *Haemoproteus* and microfilariae infected 7.8 percent

TABLE II

RESULTS OF TRAPPING WATERFOWL: WASHITA AND SALT PLAINS NATIONAL WILDLIFE REFUGES, AND HAM'S LAKE, OKLAHOMA

Species	Number trapped	Juvenile		Adult	
		♂	♀	♂	♀
Mallard (*Anas platyrhynchos*)	381	2	1	217	161
Green-winged teal (*Anas crecca*)	175			130	45
Blue-winged teal (*Anas discors*)	131			103	28
American widgeon (*Anas americana*)	74	9	8	36	21
Pintail (*Anas acuta*)	6		3	2	1
Wood duck (*Aix sponsa*)	5			3	2
Canada goose (*Branta canadensis*)	91[a]			32	59
Snow goose (*Anser c. caerulescens*)	1		1		
Total	864				

[a] ages of geese were not determined

TABLE III

PREVALENCE OF HEMATOZOA IN ANATIDS
OF CENTRAL AND WESTERN OKLAHOMA

Species	Number examined	Number infected (%)	Leucocytozoon (%)	Haemoproteus (%)	Microfilaria (%)
Mallard	280	65(23.2)	36(12.8)	34(12.1)	6(2.14)
Green-winged teal	49	14(28.5)	9(18.3)	5(10.2)	1(2.04)
Blue-winged teal	58	5(8.6)	3(5.1)	2(3.4)	
American widgeon	73	13(17.8)	11(15.1)	3(4.1)	
Pintail	6	0			
Wood duck	5	0			
Canada goose	91	2(2.1)	1(1.1)		1(1.1)
Snow goose	1	0			
Totals	563	99(17.6)	60(10.6)	44(7.8)	8(1.4)

and 1.4 percent of the respective birds. Concurrent infections of Leucocytozoon and Haemoproteus were found in 1.2 percent of the birds examined.

Green-winged teal were most frequently infected with hematozoa (28.5 percent); 23 percent of the mallards and 17.8 percent of the American widgeons were infected. Among the ducks, blue-winged teal were least frequently infected (8.6 percent), while Canada geese had the lowest overall percentage of infections (2.1).

The prevalence of infection among the various species of ducks was compared to the average prevalence of infection for all ducks and tested for significance using the chi-square test. Although the prevalence of infection among mallards and American widgeons was not significantly different ($P>0.05$), green-winged teal had a significantly higher prevalence of infection ($P<0.05$) and blue-winged teal had a significantly lower prevalence of infection ($P<0.05$). The prevalence of hematozoan infections in Canada geese was significantly lower than that observed in ducks ($P<0.05$).

When the infected species of ducks were considered separately, Leucocytozoon continued to show the highest prevalence, however there was considerable variation between species of ducks. In mallards and blue-winged teal the prevalence of Leucocytozoon was nearly equalled by Haemoproteus. This similarity was in contrast to the green-winged teal in which Leucocytozoon was almost twice as prevalent as Haemoproteus, and the American widgeon in which Leucocytozoon occurred almost 3 times as often. Low level infections with microfilariae appeared less variable.

Male anatids showed a slightly higher overall prevalence of hematozoa than females (Table IV), and this difference was significant ($P<0.05$). The prevalence of *Haemoproteus* was about the same in males and females of each species, however the prevalence of *Leucocytozoon* differed in male and female American widgeons. Males were infected with *Leucocytozoon* 7 times as frequently as females, and were the only species to exhibit a statistically significant difference ($P<0.05$).

The magnitude of the infections varied considerably. *Haemoproteus* infections typically had higher degrees of parasitemia, with a range of 1 to 95 organisms observed per examination period and a mean of 17.9. The degrees of infection with *Leucocytozoon* and microfilariae were significantly lower ($P<0.05$) than the degrees of infection with *Haemoproteus* when tested with analysis of variance. Infections with *Leucocytozoon* and microfilariae had ranges of 1 to 5 organisms, with means of 1.6 and 2.0 respectively.

Migrants were difficult to trap in fall because of an abundance of natural foods and extreme wariness of the ducks. As a result, very few immature birds were captured and comparisons between juvenile and adult birds were impossible.

Helminth Infections in Wild Waterfowl

Sixty-nine ducks were collected and examined during March and April, 1976 and October, 1976 through April, 1977. Seventeen species of helminths were found in the 4 species of ducks, including 6 genera and 6 species of Cestoda, 5 genera and 5 species of Trematoda, 5 genera and as many species of Nematoda, and 1 species of Acanthocephala (Table V). Nomenclature of the parasites follows McDonald (1969).

Helminths were present in 62 of the 69 ducks (89.8 percent). The

TABLE IV

NUMBER AND (%) OF 5 SPECIES OF MALE AND FEMALE
ANATIDS INFECTED BY HEMATOZOA IN OKLAHOMA

Species	No. examined		No. infected		Leucocytozoon		Haemoproteus		Microfilaria	
	male	female	male	female	male	female	male	female	male	female
Mallard	152	128	41(26.9)	24(18.7)	26(17.1)	10(7.8)	20(13.1)	14(10.6)	2(1.3)	4(3.1)
Green-winged teal	36	13	10(27.7)	4(30.7)	7(19.4)	2(15.3)	4(11.1)	1(7.7)		1(7.7)
Blue-winged teal	44	14	3(6.8)	2(14.3)	1(2.2)	2(14.3)	2(4.5)			
American widgeon	44	29	11(25.0)	2(6.9)	10(22.7)	1(3.4)	2(4.5)	1(3.4)		
Canada goose	32	59		2(3.3)		1(1.7)				1(1.7)
Totals	308	243	65(21.0)	34(14.0)	44(14.2)	16(6.5)	28(9.0)	16(6.6)	2(0.6)	6(2.4)

TABLE V

HELMINTHS COLLECTED FROM 4 SPECIES OF DUCKS IN OKLAHOMA

Helminth species	Duck species, sample size, and (%) infected: Mallard (n=23)	American widgeon (n=9)	Green-winged teal (n=19)	Blue-winged teal (n=18)	Number of infections	Percentage of ducks infected
Cestoda						
Cloacotaenia megalops	17(73.9)	3(33.3)	11(57.9)	13(72.2)	44	63.8
Fimbriaria fasciolaris	3(13.0)		2(10.5)		3	4.3
Diorchis longiovum	1(4.3)				1	1.4
Microsomacanthus compressa	1(4.3)				1	1.4
Dicranotaenia coronula	1(4.3)				1	1.4
Hymenolepis sp.	2(8.7)				2	2.9
Trematoda						
Apatemon gracilis	2(8.7)		2(10.5)		4	5.8
Zygocotyle lunata	6(21.6)	4(44.4)	4(21.0)		14	20.3
Echinostoma revolutum	9(39.1)	2(22.2)		5(27.8)	16	23.1

TABLE V

(CONTINUED)

Helminth species	Duck species, sample size, and (%) infected Mallard (n=23)	American widgeon (n=9)	Green-winged teal (n=19)	Blue-winged teal (n=18)	Number of infections	Percentage of ducks infected
Hypoderaeum conoideum	1(4.3)				1	1.4
Typhlocoelum sisowi	3(13.0)		4(21.0)		7	10.1
Nematoda						
Tetrameres crami	7(30.4)	1(11.1)	4(21.0)	2(11.1)	14	20.3
Echinuria uncinata	3(13.0)	1(11.1)			4	5.8
Amidostomum sp.		1(11.1)			1	1.4
Epomidiostomum uncinatum		1(11.1)		2(11.1)	3	4.3
Microfilariae	6/280(2.1)		1/49(2.0)		7	2.1
Acanthocephala						
Polymorphus sp.	2(8.7)	5(55.5)	3(15.8)	4(22.2)	14	20.3

prevalence of infections among the 4 species examined was: mallard, 95.6 percent; green-winged teal 84.2 percent; blue-winged teal, 83.3 percent; and American widgeon, 100 percent. The chi-square test indicated no significant difference (P>0.05) in the prevalence of infection among the 4 species.

There was considerable variation in the degrees of infection between individuals (range, 1-47). The mean number of worms per duck was 8.4, with infections of the greatest average degree occurring in American widgeons (14.0). The mean number of helminths per mallard was 11.7, while blue-winged teal had a mean of 6.5 parasites. Green-winged teal had infections of the lowest degree (mean, 3.2). Mean levels of infection among the 4 species of ducks were tested for significance using analysis of variance. There was no significant difference (P>0.05) in the levels of infection between mallards, American widgeons, and blue-winged teal, however, green-winged teal had significantly lower levels of infection than the other 3 species (P<0.05).

Cestodes were the most frequently encountered class of helminths, occurring in 72.4 percent of the birds examined (Table VI). Trematodes infected 47.8 percent of the ducks and nematodes were found in 26.1 percent of the hosts. Acanthocephalans showed the lowest overall prevalence (20.3 percent).

Cloacotaenia megalops infected 63.8 percent of the birds, and was the most common cestode, as well as the most common helminth (Table V). This cestode was firmly attached to a pocket in the cloacal lining, with as many as 15 being present in 1 duck. The remaining 5 species of cestodes occurred less frequently and were restricted to either the small or large intestine.

TABLE VI

PREVALENCE OF HELMINTH CLASSES
IN 4 SPECIES OF DUCKS

	Species (sample size) and percent infected			
Helminth class	Mallard (23)	American widgeon (9)	Green-winged teal (19)	Blue-winged teal (18)
Cestoda	86.9	44.4	68.4	72.2
Trematoda	60.9	66.6	42.1	27.8
Nematoda	34.8	33.3	21.0	16.7
Acanthocephala	8.7	55.5	15.8	22.2
All helminths	95.6	100.0	84.2	83.3

Echinostoma revolutum was the most common trematode, although the paramphistome Zygocotyle lunata was also frequently found. Except for Typhlocoelum sisowi which occurred in the trachea and bronchi, all of the flukes were found in the large intestine, caecum, or small intestine.

Adult nematodes were restricted to the proventriculus and the gizzard. Tetrameres crami was the most common, and gravid females occupied the glands of the proventriculus. Echinuria uncinata were found encysted in the submucosa of the same organ. Amidostomum sp. and Epomidiostomum uncinatum were found beneath the lining of the gizzard.

The acanthocephalans were represented only by the genus Polymorphus, which infected 20.3 percent of the ducks. This helminth was found attached to the mucosa of the large and small intestines.

Presence and Extent of Parasite Transmission at the Ham's Lake Study Area

Blood Parasites

All 20 ducks examined for hematozoa prior to release at Ham's Lake were free of infection with blood parasites. The sentinel mallards were monitored from October, 1976 through March, 1977, and 92 samples were taken from 48 individuals. Samples were treated in the same manner as those taken from wild birds. All samples proved negative for hematozoa and microfilariae.

Helminth Transmission

Twelve laboratory-reared mallards were necropsied as controls, and all proved negative for infection with helminths. Fourteen sentinel mallards were collected from the study area from late October, 1976 to mid March, 1977. Seven genera of helminths, comprising 7 species were identified. Twelve (85.7 percent) of the birds were infected with 1 or more species of helminths (Table VII).

TABLE VII

PREVALENCE OF HELMINTH INFECTIONS
IN SENTINEL MALLARDS (N=14)

Helminth species	Number of infections	% of total examined
Trematodes	11	78.6
Zygocotyle lunata	10	71.4
Echinostoma revolutum	2	14.3
Apatemon gracilis	1	7.1
Cestodes	3	21.4
Cloacotaenia megalops	2	14.3
Diorchis bulbodes	1	7.1
Nematodes	7	50.0
Tetrameres crami	7	50.0
Acanthocephalans	1	7.1
Polymorphus sp.	1	7.1

CHAPTER V

DISCUSSION

Prevalence of Blood Parasites in Wild Waterfowl

Ninety-nine (17.6 percent) of the 563 waterfowl examined were positive for hematozoa. Studies conducted in other regions of North America have, with a few exceptions, shown a higher overall prevalence of hematozoa (Table I). In portions of the Atlantic Flyway, up to 84 percent of the waterfowl harbored blood parasites (O'Meara 1956). In Colorado, 27 percent of the anatids were infected with hematozoa (Stabler et al. 1975). Colorado, like Oklahoma, lies in the Central Flyway, and although the prevalence of hematozoa is higher than that observed in Oklahoma, the difference is not appreciable. A majority of the birds examined in Oklahoma were trapped in late fall, winter, and early spring, consequently the Oklahoma data were expected to represent a conservative estimate due to reduced parasitemias during the latent period of the infections.

Greiner et al. (1975), in a discussion of the frequency and distribution of avian hematozoa by host family, categorized the Anatidae as being more frequently infected by *Haemoproteus* than other hematozoa. Ceratopogonid midges are the vectors of *Haemoproteus*, and these dipterans have a widespread distribution and ubiquitous breeding habits.

In contrast, the simuliid blackflies that transmit Leucocytozoon have a restricted breeding habitat, requiring swiftly running water for larval development. Many of the dabbling ducks in this flyway nest in the potholes of the northern prairies. Although water is plentiful in most years, the topography does not produce an abundance of fast-flowing water. Thus, as insect breeding habitat, these areas would appear to favor the midge-Haemoproteus relationship.

Although many of the waterfowl using the Central Flyway nest in areas which would seem to favor the transmission of Haemoproteus, Leucocytozoon was encountered more frequently than Haemoproteus in Oklahoma. Nevertheless, Haemoproteus did form a substantial portion of the infections. These findings are similar to those of Stabler et al. (1975), who found the prevalence of Leucocytozoon and Haemoproteus in waterfowl in Colorado to be 15.5 percent and 13.0 percent respectively. One feasible explanation for the difference between Greiner's findings and the results of both Stabler et al. (1975) and the present study is the hypothesis that parasitemias involving Haemoproteus fall to a lower level than those of Leucocytozoon during the latent period, causing some infected birds to be overlooked. However, when the average levels of parasitemia are examined for both organisms, the data do not support this hypothesis. Haemoproteus infections averaged 10 times greater than those of Leucocytozoon. Although it appears that Leucocytozoon is more prevalent than Haemoproteus in the Central Flyway, these data represent only 2 years of observation and annual prevalence may fluctuate from 1 year to the next.

The apparent low prevalence of microfilariae and the total absence of Plasmodium were not surprising, and these results corresponded well with the findings of most other investigations (Bennett et al. 1974, Bennett et al. 1975, Stabler et al. 1975, Williams et al. 1977). During a study of Canada geese in Illinois, Hanson et al. (1956) found that microfilariae were detected more easily by examining a wet preparation rather than a dry, stained film. However, the difficulty associated with this method precludes its use in large scale studies. Although thousands of anatid blood films have been examined by many investigators in North America, reports of *Plasmodium* infections in waterfowl are infrequent. *Plasmodium* infections are characterized by a relatively short patent period, which limits the number of infections that could be diagnosed by blood film techniques (Greiner et al. 1975). Investigations using subinoculation techniques indicate that this parasite is more prevalent than previous reports suggested (Herman 1966).

When the prevalence of hematozoa among the various species of ducks in Oklahoma is compared to the findings of Stabler et al. (1975), a remarkable similarity can be seen. Among the dabbling ducks Stabler et al. examined, green-winged teal harbored the greatest percentage of hematozoan infections, while blue-winged teal harbored the fewest percentage of infections. Mallards and American widgeons were intermediate between green-winged and blue-winged teal, in the prevalence of hematozoan infection. The ducks in Oklahoma show the same pattern. Many factors could influence the difference in prevalence of hematozoa among various species of ducks, but 2 of the most likely include nest site selection and nesting chronology by the various waterfowl species. *Simulium rugglesi*, an important vector of *Leucocytozoon*, prefers to feed within 15 m of the shoreline, and feeding activity declines rapidly beyond that point (Bennett 1960). Ducks selecting nest sites closer to the water would therefore be selectively exposed to the vector. Green-winged teal, mallards, and American widgeons prefer to nest closer to the water than pintails and blue-winged teal (Bellrose 1976, Sowls 1955), and this choice of habitat may influence the prevalence of hematozoa among the various species of ducks.

Although juvenile and adult birds are considered equally susceptible to hematozoan infections, widespread transmission is dependent upon the presence of young birds. This probably results from the vector feeding preferentially on the young or the ability of fully feathered adults to partially resist feeding attempts by the vector. Therefore, if the young appear during a period when the vector population is at a peak, the potential for transmission is increased.

Among the dabbling ducks, pintails are the earliest nesters, initiating activity in early to mid April. Blue-winged teal begin to nest over a broad part of their range in early May, and are also considered early nesters. Green-winged teal, mallards, and American widgeons begin to nest in mid to late May, the first young appearing in mid June, almost 1 month later than the early nesters. Thus, the hatch of the late nesting species may be better synchronized to the hatch of the vector, causing a larger proportion of these ducklings to become infected. Obviously, local weather conditions influence nesting activities and the number and chronology of vector hatches to a large degree, and this could affect the prevalence of hematozoa both in various areas and in various species.

The low prevalence of hematozoa in Canada geese examined in Oklahoma suggests that they occupy habitat that is unfavorable for contact with large vector populations. Studies of Canada geese that occur on the Salt Plains and Washita National Wildlife refuges indicate that they belong to 3 populations (Grieb 1968). The large races of geese at the Salt Plains refuge belong to the Western Prairie Population, while the small races are from the Tall Grass Prairie Population (Grieb 1968). All geese examined during the present study were small geese trapped at the Salt Plains refuge. The nesting range of this population is largely confined to coastal habitat in the eastern Canadian Arctic. Greiner et al. (1975) refers to this area as the Arctic barrens and found a low overall prevalence of hematozoa in this region. He attributed the low prevalence of hematozoan infections to a lack of vector activity in this area, a hypothesis supported by the results of the present study.

Male anatids were infected more frequently than females. The difference was statistically significant, and these results were not anticipated. Most authors did not report the prevalence of infections by sex; however, Trainer et al. (1962), in a study of Leucocytozoon in Wisconsin waterfowl, presented results that were similar to the findings of the Oklahoma study. The reasons for the difference in prevalence between sexes are not clear, but may be the result of physiological differences or differences in habitat selection on the nesting ground.

Occurrence of Helminth Infections in Wild Waterfowl

Seventeen species of helminths were collected from 69 ducks of 4 species. Buscher (1965) found 27 species of helminths in the pintail, gadwall, and shoveler along their migration route in the Central Flyway. The present study focused on the mallard, American widgeon, green-winged teal, and blue-winged teal. These 4 species of dabbling ducks occur commonly in Oklahoma during migration and limited numbers remain throughout the winter. The 4 species examined in Oklahoma are different from the ones examined by Buscher, therefore, direct comparisons cannot be made. However, the species examined by Buscher, and those examined in Oklahoma, belong to the same genus and have similar habits, therefore indirect comparisons are justifiable. Buscher examined ducks taken from 3 separate geographic areas over 9 months and this explains the larger number of helminth species found. Ducks were collected from the marshes near Delta, Manitoba from April through August, the Cheyenne Bottoms Waterfowl Management Area in Kansas during October and November, and the marshes near Gilchrist, Texas during December and January. Buscher (1965) showed that the magnitude and diversity of helminth infections is greatest on the nesting ground, reaching a peak in August and declining considerably thereafter.

The prevalence of helminth infections in the 4 species of ducks examined in Oklahoma was 89.8 percent. In Buscher's study, during the same months, an average of 85.3 percent of the ducks were infected. Thus, the proportion of infected birds during this period was nearly equal, emphasizing the similarity among members of this genus.

The average number of worms per duck was low (8.4). The infection levels were perhaps most influenced by the season of collection. Eighty percent of the ducks were collected in winter and early spring, a time when parasite loads are probably at an annual low. Seasonal variation is also evident when the levels of infections are examined in different species. Green-winged teal and blue-winged teal were collected only in the spring, while American widgeons were taken in the fall. Mallards were collected during fall, winter, and spring.

Infections of the lowest level were found in the teal, while those of the highest level occurred in American widgeons. Infection levels in mallards were intermediate, thus substantiating the hypothesis that parasite loads vary with season.

Cestodes infected 72.4 percent of the wild ducks and 6 species were found. Trematodes occurred in almost half of the waterfowl examined and were represented by 5 species, which ranked them second in order of prevalence. Similar studies (Buscher 1965, George and Bolen 1975, Broderson et al. 1977) have shown similar results. This is not surprising; as a group, the dabbling ducks feed primarily on vegetative matter on or just beneath the surface of the water. These feeding habits result in the ingestion of many small invertebrates that serve as intermediate hosts for cestodes and trematodes.

Buscher recorded 17 species of cestodes during his study, and attempted to determine their geographic range by noting their presence or absence in the ducks he collected. Only 3 of the species he found were the same as species found in the present study, probably because the prevalence and diversity of this class reaches a peak in early summer and drops rapidly after August (Buscher 1965). The seasonal low occurs in the winter and early spring. Of the 17 cestodes he found, 8 were absent from ducks on the wintering ground, indicating that they were probably acquired on the nesting ground and subsequently lost during fall migration. Seasonal prevalence is, no doubt, related to the seasonally changing food habits of the migratory host.

Mallards, pintails, and American widgeons rely heavily on waste grain and cultivated crops during fall migration and on the wintering ground (Bellrose 1976). This change in diet may cause the natural loss of some helminths, as well as reducing the possibility of acquiring new infections. Other factors having a direct effect on the seasonal prevalence of helminths are the geographic ranges of suitable intermediate hosts and the longevity of the parasites.

Cloacotaenia megalops, in addition to being the most prevalent cestode, was found in all 4 species of ducks over the entire study period. It was also the most common tapeworm in the 3 species of ducks examined by Buscher. Thus, it would appear that *C. megalops* is able to resist changes in diet and is well adapted to remain with the host for long periods. These interpretations are further substantiated by the ample size of this parasite's scolex and its protected site of attachment.

Of the other 5 cestodes that occurred in Oklahoma ducks, *Fimbriaria fasciolaris* was the only 1 that occurred with appreciable regularity. The remaining 4 cestodes comprised such a small portion of the infections that comparisons are not justified. *F. fasciolaris* was found in 5.8 percent of the birds, occurring in both mallards and green-winged teal. Buscher did not find this cestode in the pintail, gadwall, or shoveler on the wintering ground, and he categorized it as 1 of the helminths obtained on the nesting ground, but lost during fall migration. *F. fasciolaris* uses the copepod *Macrocyclops albidus* as an intermediate host (McDonald 1969). It is doubtful that this copepod could survive the northern winters in numbers large enough to account for the extensive infections observed in the spring. Thus, Buscher postulated that *F. fasciolaris* may be brought into the nesting area by species of ducks other than those he examined. Although pintails were not included in the Oklahoma study because of an inadequate sample size, 1 adult male pintail necropsied in October was infected with several immature tapeworms of this species. This bit of evidence supports the claim that this cestode is acquired on the nesting ground. Also, since mallards and green-winged teal were found to be infected in the spring, the arrival of these ducks on the nesting ground could account for a ready source of infection for copepods and subsequently other ducks.

Echinostoma revolutum was the most common of the 5 species of trematodes found. This fluke is an adaptable species, recorded as parasitizing 23 species of birds and 9 species of mammals, including man (Olsen 1974). It is just as diverse in its utilization of intermediate hosts, making it a cosmopolitan parasite (Olsen 1974). This trematode occurred primarily in the large intestine where it was found firmly attached to the mucosa, however a few specimens were found in the caecum.

Zygocotyle lunata occurred in 20.3 percent of the ducks and was the second most abundant trematode. This fluke was restricted to the caecum, a habitat which may afford it protection, and allow a prolonged relationship with the host. Willey (1941) found that individuals of Z. lunata can survive for more than 2 years in the host.

One mallard was infected with Hypoderaeum conoideum. Buscher did not find this fluke in ducks on the wintering ground, and speculated this parasite might be acquired during spring migration. H. conoideum uses lymneid and planorbid snails as intermediate hosts (McDonald 1969). These snails do not become active until early spring, consequently, the presence of several adult flukes in a duck collected in early March indicates that infections can be acquired prior to spring migration, or that the fluke is capable of remaining with the host throughout the year.

Apatemon gracilis infected 2 mallards and 2 green-winged teal in Oklahoma, indicating an overall prevalence of 5.8 percent. Buscher did not find this trematode in ducks at any of the 3 locations he sampled. The true prevalence of *A. gracilis* may be higher, because this strigeid is very small and is easily overlooked.

In Oklahoma, 3 mallards and 4 green-winged teal were infected with *Typhlocoelum sisowi*. In a study of the shoveler in southwest Texas, Broderson et al. (1977) found only 1 bird to be infected with this genus. The higher prevalence in mallards and green-winged teal is probably related to differences in food habits. Among the dabbling ducks, shovelers have the most unique feeding habits, straining large amounts of plankton from the surface of the water with their spatulate bill (Bellrose 1976). This habit may reduce the possibility of exposure to snails of the genus *Lymnaea*, *Helisoma*, and *Planorbis* which the fluke uses as intermediate hosts.

Tetrameres crami, a spiurid nematode, infected all 4 species of ducks in Oklahoma, and occurred in 20.3 percent of the hosts. Broderson et al. (1977) reported it from 8.0 percent of the shovelers in Texas. This worm uses a common amphipod crustacean as an intermediate host, and is known to occur in 9 members of the genus *Anas* (McDonald 1969). Thus, it seems unusual that Buscher did not find this nematode in the pintail, gadwall, or shoveler. He also failed to find it in a later study of blue-winged teal (Buscher 1966). The reasons for the difference in prevalence of *T. crami* are not clear, but may be related to the techniques used in examination.

A second spiurid nematode, *Echinuria uncinata*, occurred in mallards and American widgeons with a low overall prevalence of 5.8 percent. George and Bolen (1975) reported this species from 4.0 percent of the black-bellied tree ducks (Dendrocygna autumnalis) in southern Texas, and Buscher found this worm in 1.0 percent of the blue-winged teal at Delta, Manitoba. Other studies (Buscher 1965, Broderson et al. 1977) failed to detect this nematode.

E. uncinata utilizes several species of water fleas, Daphnia sp., as intermediate hosts. These cladocerans are prevalent and their geographic range is widespread. Thus, a higher incidence of this parasite would be anticipated in waterfowl populations. This worm is a frequent cause of disease and mortality (Cornwell 1963, McDonald 1969). Severe infections resulting in mortality of the host might, therefore, mask the true incidence of this parasite in waterfowl populations.

The prevalence of the remaining 2 nematodes was low, possibly due to the type of life cycle involved. Amidostomum sp. and Epomidiostomum uncinatum both have a direct life cycle. Waterfowl become infected after ingesting the infective larvae. The survival and infectivity of the larvae were found to be greatly decreased by water temperatures below 6 C for 10 days (Cowan 1955). Thus it appears that few eggs or larvae could survive the winter in northern nesting areas. This prevents the build-up of a ready source of infection, and new infections are dependent upon freshly passed eggs which take time to accumulate in the environment.

The acanthocephalans were represented by the genus Polymorphus, which infected 20.3 percent of the ducks. Overall, this genus was the greatest contributor to the levels of infections. Several infections were comprised of 30 or more worms, and 1 American widgeon harbored 46 worms in a 2 cm length of the large intestine. This helminth buries its spine-covered proboscis in the intestinal mucosa, making it quite difficult to dislodge. Infections with this genus were noted throughout the entire study, indicating that this helminth probably remains with the host for long periods of time.

Presence and Extent of Parasite Transmission at the Ham's Lake Study Area

Blood Parasites

The absence of hematozoan transmission can most likely be attributed to the interaction of several factors. Both a source of infection and susceptible birds were available, consequently, the lack of transmission could be interpreted as a result of the absence of suitable vectors. The paucity of information concerning the species of arthropods that can serve as possible vectors makes this interpretation difficult to substantiate.

Because of the impact of *Leucocytozoon* on waterfowl in endemic areas, our knowledge concerning the ecology of this parasite is more advanced than that of the other avian hematozoa. Several species of simuliid blackflies have been known to transmit *Leucocytozoon*. Tarshis (1972) found that *Simulium rugglesi*, *S. innocens*, and *S. anatinum* are all capable of serving as vectors, and another study confirmed transmission by *Cnephia invenusta* (Tarshis and Herman 1965). Other species of *Cnephia* are known to feed on ducks (Bennett 1960), consequently, these arthropods should not be overlooked as possible vectors of *Leucocytozoon*. Unfortunately there is very little information on the simuliids of Oklahoma. The genus *Simulium* is known to occur throughout Oklahoma (R. Wright, Dept. of Entomology, OSU, pers. comm., 1978), but a survey of the species has not been undertaken.

A review of the information on vectors of *Haemoproteus* and *Plasmodium* is even less enlightening. Fallis and Wood (1957) demonstrated that biting midges of the genus *Culicoides* are the intermediate hosts for *Haemoproteus nettionis*, and described the species of midge as belonging to the *piliferus* group. Khalaf (1957) did an extensive survey of the species of *Culicoides* that occur in Oklahoma and found 23 species. *C. piliferus* was 1 of the species he found, but it was one of the less prevalent species. It is unknown whether other species of *Culicoides* are capable of transmitting the parasite.

Plasmodium is known to be transmitted by culicine mosquitoes, but the specific vector species have not been determined. Members of the genus *Culex* typically feed on birds, breed in roadside ditches, stock tanks, ponds, and swampy areas, and are common in Oklahoma (R. Wright, pers. comm., 1978). Although it is possible that suitable vector species do occur in Oklahoma, especially for *Haemoproteus* and *Plasmodium*, 2 other factors probably play a significant role, either by reducing or completely inhibiting natural transmission.

Applegate and Beaudoin (1969) studied the transmission of avian malaria and conducted experiments with English sparrows (*Passer domesticus*), *Plasmodium relictum*, and *Culex pipiens*. They found that gametocytes were significantly more infective during the spring relapse period and hypothesized that latent infections were less infective to mosquitoes. If this hypothesis is true, the predominance of latent infections could limit transmission on the wintering ground and along the migration route, even in the presence of suitable vectors, a reservoir of infection, and susceptible birds. Although it may be possible for natural transmission to occur in Oklahoma, the circumstances are generally unfavorable, making the probability of parasite transmission very low.

Helminth Transmission

Seven species of helminths were acquired by the sentinel ducks during the study period. Six of the seven species were commonly found in wild populations; the cestode *Diorchis bulbodes* did not occur in any of the wild ducks examined. Although this parasite infected only 1 experimental bird, McDonald (1969) lists it as a frequent parasite of waterfowl. The life cycle is unknown, but it is probably similar to *D. nyrocae* which utilizes several genera of copepod crustacea as intermediate hosts.

The most abundant helminth group was the trematodes, and 78.6 percent of the ducks were infected with members of this class. Three species were represented, with *Zygocotyle lunata* and *Echinostoma revolutum* comprising the majority of the infections. This is not surprising when the nature of their life cycles and their frequent occurrence in wild populations are considered. The versatility of *E. revolutum* in its utilization of intermediate and definitive hosts has already been discussed. Although the life cycle of *Z. lunata* is not as flexible, this fluke uses several species of freshwater snails for cercarial development, later encysts on aquatic vegetation, and becomes readily available to most species of dabbling ducks.

Two birds harbored infections with the cestode *Cloacotaenia megalops*. McDonald (1969) lists a freshwater ostracod as the only intermediate host of this common tapeworm, and indicated that *Cypris* *pubera* is active only in the spring. Both infected birds were released on the lake in July, 1976 and were collected in early February, 1977. These circumstances indicate that the intermediate host may be active in late summer or fall as well as spring, or that *C. megalops* is capable of utilizing another intermediate host. In view of the frequency with which this parasite is found in wild birds, the latter seems most likely.

Tetrameres crami occurred in 7 of the 14 birds necropsied and was the only nematode found. This worm uses the amphipod *Gammarus fasciatus* as an intermediate host (McDonald 1969). These invertebrates are common in algae and other vegetation, and Pennak (1953) estimated population densities of 10,000 per m^2 in certain places. As a result of the widespread availability of this crustacean, infections with *T. crami* probably occur over a wide geographic range.

The acanthocephalans were represented by the genus *Polymorphus*, which occurred in 1 duck. Like *T. crami*, *Polymorphus* uses several species of *Gammarus* as intermediate hosts. Due to the abundance of the crustacean intermediate hosts and the frequent occurrence of *Polymorphus* in wild ducks, a higher incidence of this acanthocephalan would be anticipated in sentinel ducks. The reasons for the low prevalence of *Polymorphus* are not clear.

The mean number of worms per experimental duck was 3.6, compared to 8.6 for free-flying birds. The low level of the infections is probably a function of the length of time and the season the birds were on the lake. The first group of sentinels was set free in late July, 1976 and the last releases took place in late September, 1976. No collections were made after March, 1977. Many of the invertebrates which serve as intermediate hosts reach peak population densities during spring or early summer, thus limiting the possibility of the sentinel birds acquiring severe infections.

A survey of the invertebrates that serve as intermediate hosts for the helminths found in Oklahoma ducks shows that several helminth species share the same intermediate hosts. This evidence suggests that the possibility for transmission of helminths is greater than the data indicates. However, low level infections probably prevent serious contamination of the environment and limit the number and species of helminths that are acquired.

Significance of Parasitic Infections in Wintering Waterfowl in Oklahoma

The life cycles of many of the parasites encountered in this study are characterized by discontinuous transmission; transmission is interupted by the migratory habits of the definitive hosts and the seasonal prevalence and geographic distribution of the intermediate hosts. The parasites are thus dependent on a biological reservoir for their survival. An effective reservoir should not be subject to rapid and widespread fluctuation, thus it follows that vertebrate populations are better suited to serve as reservoirs than are invertebrate populations.

Migrating and wintering waterfowl in Oklahoma were found to harbor a variety of hematozoan and helminth infections, including some confirmed pathogens. However, most of the infections were low in magnitude and did not appear to represent a serious threat to wintering waterfowl under normal circumstances. Nevertheless, these infections may be significant; the effects of parasitic infection are usually manifested in subtle ways.

The low levels of the infections are of paramount importance for several reasons. During the annual cycle, waterfowl are likely to experience stress on 2 separate occasions. On crowded winter quarters, increased competition for food and severe weather may cause some degree of environmental stress. Elevated parasite loads during this period could cause the host to succumb, compromising the survival of the parasites. In addition, the presence of a few adult parasites may prevent the acquisition of new infections on the wintering ground by maintaining the immune status of the host. Many factors contribute to the immunity of the host, but it has been shown that the presence of a threshold level of adult parasites can be sufficient to arrest the development or retard the growth of newly acquired larvae (Dobson 1972).

The second period of stress probably occurs on the nesting ground due to competition for nest sites and reproductive activities. If parasite loads were lost during the winter, the immune status of the host could be altered. Upon arrival at the nesting grounds, the host is exposed to increasing invertebrate populations which could result in the rapid acquisition of large numbers of parasites, with possible serious effects. However, the presence of a threshold level of parasites could conceivably protect the host by preventing the rapid acquisition of a superinfection. Instead, parasite loads increase gradually, reaching a peak after reproductive demands are met. Thus, the presence of a few parasites in the host during the winter may be beneficial rather than detrimental.

The manifestations of parasitic infection are most often seen on the nesting ground, where vector and intermediate host populations often reach a peak in synchrony with the hatch of young birds. This factor is responsible for the widespread transmission that is often associated with mortality. However, recent management practices have enhanced the potential for transmission of parasites on the wintering ground by altering wintering areas for many species of waterfowl. Most refuges along the migration route provide an abundance of quality waterfowl foods, and these areas are being utilized by increasing numbers of ducks and geese. Thus, populations that previously dispersed themselves over a wide geographic range now concentrate in localized areas, and remain for longer periods of time. Even though levels of infection are low, overcrowded conditions may cause serious contamination of the environment by parasitic stages, which could contribute to the possibility of disease outbreaks in the future.

CHAPTER VI

SUMMARY

The prevalence and species composition of hematozoan and helminth infections in waterfowl migrating through and wintering in north-central and western Oklahoma were determined. In addition, the potential for transmission of these parasites, and the role of wintering and migrating populations in the maintenance and spread of parasitic infections, was assessed.

Blood films from 17.6 percent of 563 wild waterfowl were positive for hematozoa. *Leucocytozoon simondi* was the most common blood parasite; the second and third most prevalent were *Haemoproteus nettionis* and microfilariae. Green-winged teal harbored the greatest percentage of hematozoan infections, while blue-winged teal were the least frequently infected duck species. Mallards and American widgeons were intermediate in the prevalence of hematozoa. Canada geese displayed the lowest overall prevalence of infections. Low level infections were predominant; *Leucocytozoon* and microfilariae had significantly lower levels of infection than *Haemoproteus*. Low prevalence was probably the result of reduced parasitemias during the winter latent period.

Necropsy of 69 ducks revealed that 89.8 percent were infected with 1 or more species of helminths. Cestodes were the most common helminth class, followed in order of prevalence by trematodes, nematodes, and acanthocephalans. Seventeen species of helminths were

identified, including 6 cestodes, 5 trematodes, 5 nematodes, and 1 acanthocephalan. The species composition of helminth fauna found during the wintering period differed considerably from that found on the nesting ground. This difference is probably a response to changing food habits, which causes the loss of some parasites and the addition of others.

An experimental population of 60 mallard ducks was monitored for 6 months to determine if natural transmission of parasites occurred on the wintering ground. No transmission of hematozoa occurred, however 7 species of helminths were acquired during this period, including 3 trematodes, 2 cestodes, 1 nematode, and 1 acanthocephalan.

Although some parasitic transmission takes place while birds are on their winter quarters, the results of this study indicate that wintering birds maintain parasitic infections at low levels during a period of lapsed transmission. Infections did not appear to constitute a serious threat to wintering waterfowl populations under normal conditions, but may have serious implications on winter quarters that become contaminated through continued overcrowding.

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