Avian Botulism on the Prairies

A Commentary from the Canadian Cooperative Wildlife Health Centre, Western/Northern Regional Centre

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For further information please contact:
Canadian Cooperative Wildlife Health Centre,
Department of Veterinary Pathology,
Western College of Veterinary Medicine,
University of Saskatchewan, Saskatoon
S7N 5B4 Tel. (306) 966-5099 Fax (306) 966- 7439

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Summary

This document is a commentary on avian botulism as it has occurred on the Canadian prairies over the past several years, and as it has been discussed at recent inter-agency meetings in Saskatoon and Brandon in January 1997. Recent outbreaks at Pakowki Lake (AB), Old Wives Lake (SK) and Whitewater Lake (MB) have caused massive mortality, exceeding the total of hunting mortality in Manitoba and the total of duck production on NAWMP lands in Alberta in some years. Hundreds of thousands of dollars have been spent on carcass clean-up operations. The meetings in January were held to seek better ways to manage botulism through sharing experiences and hearing from specialists. It is clear that many outbreaks continued in the face of intensive clean-up efforts. Early preventive surveillance and carcass collection at Pakowki Lake may have reduced mortality in 1996.

Research on botulism has had two different thrusts. One is the ecology of the bacterium and factors that may affect its presence and growth. The other is the role of vertebrate carcasses in the initiation and expansion of outbreaks. No central hypothesis or model of botulism was developed at the January meetings. The carcass-maggot cycle is widely acknowledged to be the major mechanism by which outbreaks are perpetuated and can develop to massive proportions. Much about botulism could be learned from the large outbreaks. However, busy response crews have been overwhelmed with the task of clean-up alone, and relatively little biological information has been collected during these outbreaks. Improved management will require more and different information than is currently available. Seven specific questions are proposed as research topics in this commentary, each of which would have practical application in the management of botulism.

The CCWHC makes five general recommendations to wildlife agencies responsible for waterfowl management on the prairies. These are: 1) that scarce resources not be deployed to review the literature on the disease; 2) that future outbreak management should be focussed on early, preventive surveillance and carcass pickup at major outbreak sites; 3) that agencies pool resources to establish funds to assure collection of detailed biological information before and during major outbreaks; 4) that the feasibility and effectiveness of treatment of sick birds as an additional or alternative response to outbreaks be assessed; 5) that a pool of funds for specific research projects be established.

Botulism is a priority for CCWHC activity on the prairies. If resources are available, and if requested, the CCWHC will expand its activities to include a) coordinating the collection of detailed data before and during outbreaks; b) specific research projects related to the initiation, perpetuation and control of outbreaks.

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Introduction

Large outbreaks of botulism with high mortality of waterfowl have occurred in the prairie provinces during the past three summers. Interagency meetings to deal with the disease have been held in Alberta since 1995, and meetings with broad attendance were held in Saskatoon, January 23 and Brandon, January 28, 1997 to discuss botulism. These were very useful in bringing field personnel and researchers together and in demonstrating the common features of the botulism situation in the three prairie provinces. The reports and discussion also provided a context for assessing the significance of botulism mortality in reference to waterfowl production in the area and the need for research. This document is a synthesis of the current situation by CCWHC personnel and is not intended as a record of those meetings.

Recent Outbreaks

Outbreaks have been recognized on 34 wetlands since 1980, but 4 wetlands- Pakowki Lake (PL), Old Wives Lake (OWL), Whitewater Lake (WL) and Eyebrow Lake (EL)- accounted for 80% of recognized losses. Each of these wetlands has a long history of the disease. It was estimated that, in 1995, 50,000 more ducks died at PL than were produced on all NAWMP wetlands in prairie Alberta that year, and that losses at WL in 1996 exceeded the estimated waterfowl harvest by hunters for the entire province of Manitoba in that year (1).

Although many features have not been examined in detail at each lake, the similarities among PL, OWL and WL are notable. Each is a very large, flat, shallow terminal basin containing somewhat saline water, with considerable wind-generated turbidity and seiches, large beds of dense emergent vegetation and extensive mudflats that are periodically reflooded by wind seiche or precipitation. Each has impoundments or control structures at the inlet streams, and the impression presented was that botulism outbreaks started, or mortality was most severe in the early stages of outbreaks, near the inlets. Because of their physical size, overall surveillance of these lakes is difficult and the effectiveness of cleanups initiated when many carcasses are already present was questioned. Each of these lakes has become completely dry at intervals and the suggestion was made that botulism has been more of a problem in the years following reflooding. Water level manipulation or stabilization currently is not possible on any of these lakes. An engineering feasibility study indicated that water level stabilization on PL would cost about 3 million dollars. The degree of surveillance on the three lakes is quite different, with OWL being the most secluded and difficult of access; consequently much less is known about outbreaks on this lake than on the others. All of the lakes are important moulting and staging areas for both waterfowl and shorebirds.

EL is a smaller wetland and, while the extent of the losses there has been much lower than on the other wetlands (14,473 birds picked up between 1987-96), botulism has been documented there in nine of ten years in the past decade. "*It is possible that the frequency of occurrence observed at Eyebrow is a function of the intensity of monitoring.....However, even if this were the case, we are not less concerned since one could expect a similar frequency at all wetlands included in this analysis, if they were monitored frequently*"(1).

Research Past and Present:

Research on botulism that has been done recently, is underway, or is contemplated, appears to fall into three general subject areas:

1. The first area involves defining the physical and chemical features of wetlands before and during botulism outbreaks, with particular attention to the sediments and water column. In some cases, comparisons have been made between botulism-prone wetlands and others where botulism does not occur. It is hypothesized by some researchers that physical or chemical factors in sediment or water influence vegetative growth and toxin production by *Clostridium botulinum* in some manner, and that this may be a factor in the initiation of certain outbreaks. Associations have been made between individual factors and the occurrence of botulism in some wetlands but it is not clear that there is a cause-effect relationship, and the mechanisms that might be involved are not known. Possibilities include that physical and chemical features might influence:

a) the number of spores that are present in the sediment or water.
b) vegetative growth of the organism in the sediment, water or some unidentified substrate.
c) production of toxin in the environment at large (i.e. outside vertebrate carcasses).

Toxin has not been identified in water, nor has it been found in substrates, other than carcasses, in a concentration or amount required to kill birds. [Waterfowl are relatively insensitive to the toxin, with the reported toxic oral dose for ducks being in the order of 10,000 to 600,000 mouse LD_{50} units (2, 3)].

2. Another broad area of research is related to the population dynamics and epidemiology of the disease and, particularly, the role of vertebrate carcasses. This area of research is based on the hypothesis that vertebrate carcasses are the principal relevant substrate for growth and toxin production by *C. botulinum.* It is known that:

a) spores of *C. botulinum* are very resistant and persist for years in marsh soil.
b) spores are very numerous in marshes with a history of botulism (4,5,6). This might be because massive numbers of spores are deposited from decomposing carcasses during outbreaks, or because spores persist longer in these marshes than in others.
c) animals living in a botulism-prone marsh ingest spores.
d) when an animal dies for any reason with spores in its digestive tract or tissues, the spores may germinate in the anaerobic environment of the carcass, grow and produce toxin.
e) the vertebrate carcass provides a microenvironment for bacterial growth and toxin production that is largely independent of external factors, such as the temperature, oxygen tension and chemical features of the wetland.
f) maggots and other scavenging invertebrates feeding on carcasses contain toxin and cause poisoning if ingested by birds.

Within this general subject area, one question that is being explored at PL is the possible

role played by toxic blue-green algae (cyanobacteria) before and coincident with botulism outbreaks. Toxic algae could be playing two roles: a) as a cause of mortality that provides carcasses within which botulinum toxin might form and/or, b) as an additive mortality factor during botulism outbreaks, i.e., that a portion of the mortality may be due to algal poisoning rather than to botulism.

Research is beginning at the WCVM, to define the factors that determine the extent of spread of botulism among birds through the carcass-maggot cycle. The assumption is that whenever a vertebrate dies in a botulism-prone wetland, there is a potential for toxin to form in its carcass and for toxin-laden maggots produced within the carcass to poison birds. The carcasses of these birds may then, in turn, become substrate for further production of toxin and maggots. Among the factors that may be important in determining if the disease "*spreads*" are the proportion of live vertebrates that have spores of *C. botulinum* in their tissues, the number and type of vertebrates that die in a wetland, the proportion of vertebrate carcasses removed by scavengers before toxin and maggots develop, and the amount and type of contact between live birds and maggot-ridden carcasses. Each of these factors is likely to be site-specific and highly variable, and small changes in any of the factors could influence the probability of an outbreak occurring (7).

3. A third, smaller, area of research is related to treatment of sick birds and the possible use of vaccination as part of the treatment regimen. There may be situations in which treatment of sick birds could be part of the response to outbreaks, but the actual costs and feasibility of such treatment have not been tested in western Canada. Research on the efficacy of treatment may not be practical during major outbreaks on the three largest wetlands (except perhaps for selected species of particular concern, such as female Northern Pintails or endangered shorebirds); treatment might be a desirable part of the response on a highly visible site such as Oak Hammock Marsh. One potential problem in treatment is that birds which recover have no "*resistance*" to the toxin and may become repoisoned if they return to the marsh. Trials are underway at the WCVM to determine if vaccination could be used to protect these birds.

Critical Factors in Botulism Outbreaks

One thing that was not done at either of the meetings held in 1997, was to discuss an overall model of the ecology of botulism. Lack of a central hypothesis or model makes it difficult to determine the relative importance of various types of investigation and research.

At the Saskatoon meeting, it was proposed that botulism is analogous to a forest fire; in that **both** the **spark** that starts the fire and the **factors that determine if the spark dies out or becomes a conflagration** need to be understood, if one hopes to prevent major losses in either a fire or a botulism outbreak.

There are many potential sparks that could start botulism in a wetland. The basic requirement is the presence of sufficient toxin in an accessible form that will be consumed by

birds. Potential sparks can be divided into two general types: a) production of toxin in some substrate other than vertebrate carcasses or, b) production of toxin within vertebrate carcasses. Studies of the chemical and physical features of wetlands are looking predominantly at proliferation of toxin in sites other than vertebrate carcasses. At this point, there is little evidence that this form of spark is important in starting outbreaks. In contrast, it has been known for many years that proliferation of *C. botulinum* in vertebrate carcasses can be the spark that starts outbreaks. This has been verified in experimental trials, e.g., Hunter (8) produced botulism "*at will*" by adding a duck carcass to experimental ponds in a botulism-prone marsh. Reed and Rocke (9) reported that the relative risk of intoxication among sentinel ducks was 4.5 times greater in enclosures to which carcasses were added than in enclosures without carcasses. They suggested that the source of toxin for birds that died in their control enclosures (no carcasses) was "*probably toxic maggots or other invertebrates that floated or dispersed into these areas from adjacent enclosures with carcasses*". Any factor that results in vertebrate deaths, such as a hailstorm, overhead power line, or death of animals from some other disease, could provide carcasses to act as the spark. In California, carcasses of fish, birds, small mammals, and even a cow, have been reported as sources of toxin that initiated outbreaks of botulism in waterfowl (10). Chemical and physical factors, such as those associated with precipitation or reflooding, could play a role in determining the number and availability of spores and in the amount of contact between birds and carcasses.

There is general agreement that the carcass-maggot cycle is the mechanism by which the disease is perpetuated and spreads, after it has started. In other words, carcasses are the "*fuel*" that allows the spark to persist and grow; hence, the commitment of thousands of dollars for carcass collection and disposal.

Investigation of Major Botulism Outbreaks

There has not been any attempt to collect a standard set of information in a systematic manner from botulism outbreaks that have occurred on the prairies. All that is available in most cases is a crude estimate of losses based on carcass collection. Alberta has taken the lead by instituting pre-outbreak surveillance and carcass collection at PL in 1996. Enhanced surveillance and carcass collection beginning in the spring of 1997 on WL and OWL would appear to be a logical action. This would provide an opportunity for uniform and systematic collection of specific common information from the three major sites of botulism mortality on the prairies . This could include:

(a) Information collected prior to a recognized botulism outbreak:

- timing and occurrence of events, such as algal blooms, precipitation and storms.
- extent, timing, location and cause of any vertebrate mortality prior to the onset of anticipated botulism deaths. CCWHC staff believe it is crucial to establish the cause and extent of mortality on these wetlands in the summer. It is important to understand whether low-level mortality prior to large outbreaks is due to botulism,

or if other conditions, such as die-offs of juvenile Franklin's gulls for unknown reasons, algal poisoning of birds, or death of birds in storms, produce carcasses within which toxin forms. This would require surveillance and collection of vertebrates found sick or dead for examination.

- the proportion of carcasses found early in the year that produce maggots laden with botulinum toxin, i.e., how much of a risk do these carcasses represent as a spark. This would require collection of maggots from carcasses for testing.
- weather and water level data
- specific chemical information (if considered to be important)

(b) Information collected during a botulism outbreak:

- the geographical location of mortality within affected wetlands needs to be carefully defined. There was consensus among people who have dealt with outbreaks in the field that mortality usually begins in certain spots on each of the lakes and that carcasses are not uniformly distributed, at least early in outbreaks. The term "*hot-spot*" was used by many people, but what constitutes a hot-spot is not clear. To different people, a hot-spot is where mortality occurs first, where there are dead birds consistently, or where there are many carcasses. The definition should be clarified but, regardless of the precise meaning, if mortality is not randomly or uniformly distributed, areas of early or concentrated mortality deserve special attention. It will be necessary first to identify these areas on each lake, second to confirm that mortality is actually different at these sites than elsewhere, and third to identify features (e.g., spore density, bird usage, vegetative cover, water depth, wind direction, scavenger activity) that distinguish these locations from areas where mortality is less common.

- more detailed information needs to be collected on the species, sex and age of birds that die in outbreaks. This is particularly important for species whose population is of concern, such as the Northern Pintail and threatened species, and also for better definition of the population effect (local and general) of botulism on more plentiful species.

- methods need to be developed for accurate assessment of the actual mortality, i.e. to quantify the relationship between the number of carcasses collected and the actual mortality, to relate this to the population of birds at risk in the area, and to assess the effectiveness of carcass collection.

- routine diagnostic examination of representative samples of dead birds throughout the course of outbreaks would be beneficial to determine the relative importance of causes of mortality other than botulism.

Collection of standardized data of the type outlined above would provide a much clearer

understanding of the factors that lead to outbreaks, the factors that contribute to the spread of the disease, the impact of botulism on waterfowl populations, and the effects of various types of management on the disease. It is recognized that collection of detailed information will require substantial extra effort, personnel and funding but the information gained should provide a much better basis for management of the disease.

Priorities for Future Research

There are a number of research questions that do not fall within the information gathering process outlined above, in that they do not fit well with on-going surveillance and outbreak management programs. Some of the research required could be done at the three major lakes (PL, OWL, WL); other questions could better be addressed on smaller wetlands that have high frequencies of occurrence of botulism, easier access and fewer logistical problems than the large lakes. As noted earlier, EL has botulism mortality almost every year, and is readily accessible. Oak Hammock Marsh in Manitoba might also be suitable for detailed studies.

Questions that should be addressed include:

1) What is the relationship between spore density in the soil and the probability that vertebrate carcasses will develop maggots containing toxin?

Spores are much more frequent in botulism-prone marshes than in wetlands with no history of the disease (4,5,6); this may explain why some wetlands have frequent outbreaks while others do not. However, it is not known if a high density of spores actually results in a greater likelihood that any vertebrate death in botulism-prone marshes will result in production of toxic maggots. One potential management strategy might be to attempt to reduce spore numbers, or to reduce bird use in areas where spores are especially dense. Hence, it is important to understand the relationship between spore density, toxin production, and overall risk.

2) What is the amount, distribution and type of carcass material that is present throughout the summer on a botulism-prone marsh, and what proportion of this material results in toxin production?

Some information of this type could be collected during routine surveillance activities above, but a very detailed search procedure would be required to adequately answer the question. This information is required to assess the potential role of different types of vertebrate mortality as sparks that might start outbreaks.

3) What factors influence the removal of carcasses by scavengers?

Every carcass that is consumed by a scavenger, before maggots are present, is removed as substrate for production of toxin. When only a few carcasses are present, natural scavenging may be a critical factor in preventing development into a large outbreak. It is important to understand the features that determine the rate at which carcasses are removed. Enhancement of scavenging is a potential preventive management technique.

4) What factors influence contact between live birds and maggot-laden carcasses?

This may be another critical factor in determining whether or not an outbreak occurs. Alteration of bird distribution to reduce contact with toxic material might be used both as a preventive management approach prior to outbreaks, and to reduce losses during outbreaks.

5) Can hot-spots be manipulated to reduce botulism mortality, through influencing factors such as bird usage, scavenger activity and effectiveness, occurrence of carcasses, and contact between live birds and carcasses?

If hot-spots can be identified and their features characterized, a logical step would be to modify the areas and measure the effects of the manipulation. Answers to questions 2, 3, and 4 would suggest the type of manipulations most likely to be effective.

6) What is the impact of botulism on the survival of ducks using botulism-prone marshes?

Counts of dead birds collected during outbreaks, together with specific information on the sex and age composition, give one index of the effect of botulism on the population. However, this does not give an indication of the overall effect of the disease, particularly if botulism is occurring at a low level in most botulism-prone marshes in most years, as appears to be the case at EL. Low level continuous mortality at a sub-outbreak level might actually be more important than periodic large die-offs. An intervention trial on a botulism-prone marsh, in which the survival of birds protected from the disease by vaccination is compared with that of unprotected birds, would provide a direct measure of the impact of the disease at a local level. For this study, it would be necessary to identify a vaccine that provides a high level of protection, preferably for more than one year. Resident birds, preferably adult females of species such as Northern Pintails and Mallards, could be trapped, marked with nasal saddles (to improve the resighting rate) and banded. Half of the birds would be vaccinated prior to release. Subsequent survival/mortality of vaccinated and unvaccinated birds could be monitored by systematic searches of the wetland to resight birds, by examining all birds found dead and collected during botulism outbreaks, and by monitoring band returns. This type of study would be well suited to EL or Oak Hammock, and could be coordinated with other studies, particularly #2 above. It is very important to understand the actual impact and significance of botulism, so that funding available for waterfowl management can be allocated appropriately among disease control and other activities.

7. Is treatment of sick birds a feasible adjunct or alternative to carcass collection as a response to botulism outbreaks ?

While it is known that simply providing water and shelter to sick birds will save a considerable proportion (70%±) of those found to be affected with botulism during outbreaks, it is not known how costly or difficult it would be to institute treatment as a form of response. Should vaccination prove effective in providing rapid and long-term protection, treatment would be more attractive as a response option. The feasibility and cost of establishing and operating treatment facilities should be assessed.

Recommendations

1. Detailed review of the literature on avian botulism is not recommended.

The literature on avian botulism is large and diverse, and some older publications are not readily available. However, three volumes [Eklund and Dowell (1987), *Avian Botulism: An International Perspective*; C.C. Thomas, Publisher, Springfield, Illinois; Friend (1987), *Field Guide to Wildlife Diseases*, Vol. 1, *General Field Procedures and Diseases of Migratory Birds* and Wobeser (1997), *Diseases of Wild Waterfowl*, 2nd. ed., Plenum Press, New York] provide extensive coverage of the disease, and most relevant information can be found either in these books or in a relatively small number of papers published since 1990. Commissioning a special review of literature seems unnecessary at this time, but establishment of a central repository of published information on the disease that would be available to those interested in botulism in western Canada would be useful. The library of the Canadian Wildlife Service in Saskatoon, or the CCWHC office in Saskatoon, would be possible locations for such a repository.

2. Outbreak management.

A) Preventive surveillance and carcass removal is recommended.

We recommend establishment of preventive surveillance and carcass collection at OWL and WL and continuation of this program at PL. There are no hard data to prove that carcass collection and disposal during an outbreak alters the course of the disease; however, removal of carcasses that could act as substrate for production of further toxin and maggots seems intuitively correct and makes biological sense. The major questions about the procedure relate to a) the proportion of carcasses that are found and removed before they "contribute" toxin-laden maggots to the environment and spores into the soil and, b) whether or not the proportion removed makes a significant difference when massive amounts of toxic material are present. Intense surveillance with rigorous carcass collection and disposal before an outbreak is established would appear to have the best chance of being successful. This may have been effective in reducing losses at PL in 1996 to a fraction of those in the previous two years. Preventive disease surveillance and carcass collection was described as an accepted methodology on some botulism-prone marshes in the USA by Dr. Rocke (National Wildlife Health Center, U.S. Geological Survey).

B) Expensive alterations for water level stabilization are not recommended.

Water level stabilization and maintenance of deep water levels have been proposed as preventive measures for botulism. There is no firm information that these techniques have a beneficial effect on the occurrence of the disease.

C) New management techniques should be investigated.

Vertebrates die continuously for many reasons in botulism-prone marshes and toxin

undoubtly forms in some of these carcasses, but large-scale outbreaks occur only periodically. As more information becomes available on the factors that influence the carcass-maggot cycle, new management strategies should be developed to limit establishment and spread of the disease. These techniques might include modifying hot-spots, facilitating removal of carcasses by natural scavengers rather than by air-boat crews, and modifying the distribution of birds in relation to known problem areas.

3. Disease investigation at major outbreak sites is recommended.

Unless serious efforts are made to learn as much as possible from outbreaks, there is little hope of improving, verifying or reducing the cost of management responses to botulism.

a) Establish a system for mapping the location of events.

It was clear from the discussion at both meetings that it would be difficult or impossible to collect much additional information during outbreaks without interfering with routine surveillance and carcass collection procedures, unless additional funds and personnel were committed to this task. However, one activity that should be done, and that is a prerequisite for any other data collection steps, is to develop a system for each lake so that the location of events and activities can be defined easily and precisely. Hot-spots can not be defined unless mortality can be mapped; the efficiency of carcass collection can not be assessed unless the areas searched can be identified unequivocally; and year-to-year comparisons can not be made unless the location of shorelines, vegetation beds, and mortality is recorded accurately. A system for dividing WL into segments that are readily identifiable in the field, using permanent markers, is considered a priority for 1997; a similar system should be established on the other lakes. This, in combination with up-to-date maps or aerial photos and use of GPS, would form a base for determining the spatial features of the disease.

b) Collection of detailed information before and during major outbreaks.

Detailed data collection should occur on the botulism-prone wetlands prior to and during any outbreaks. A specific system, with personnel and equipment devoted to the process, should be developed and deployed. There should be close cooperation among the various agencies in developing a data collection system that uses the same methodology in the different wetlands. Because botulism is of concern to several agencies, and not the sole responsibility of any one organization, some method for pooled funding should be developed to support this activity. We estimate that a pool of approximately $30,000 would be necessary, although less might be spent in some years. The concept of pooled responsibility and support across the prairie provinces would be a logical extension from the provincial waterfowl disease contingency plans and from the high degree of interagency cooperation associated with management of recent outbreaks.

In the case of collection of chemical and physical information, Dr. Rocke (National Wildlife Health Center) should be involved in the planning stages, as her program is well

advanced.

4. Treatment as a Response Option should be examined.

Agencies should not discount the potential utility of treatment of sick birds in botulism outbreaks. If vaccination proves to be effective, the view that treatment of birds is not useful because the birds return once again to the population at risk of poisoning when they are released will no longer be valid. Given the high cost of large-scale carcass pick-up operations and the limited number of botulism-prone wetlands that are likely to be subject to intensive preventive surveillance, treatment should be viewed as a possible alternative response when multiple outbreaks make effective clean-up operations impossible at some affected wetlands. Treatment may be the only affordable response option in these cases, and treatment lends itself to the selective incorporation of volunteers into the response effort. Some investment should be made in assessing the cost of establishing treatment facilities in botulism outbreaks

5. Specific research should be funded.

Agencies concerned with botulism on the prairies should support research that addresses important relevant questions. A pool of money from the various agencies to support research should be assembled and efforts made to attract matching funds from other sources. A minimum target budget for such a pool of funds should be $50,000. Research priorities should be identified by the agencies and research proposals should be developed by interested scientists and presented for possible funding.

Roles for the Canadian Cooperative Wildlife Health Centre

Because botulism is a major issue for several agencies that are sponsors of the CCWHC, the Western and Northern Regional Centre of the CCWHC has made a special commitment to help these agencies respond to this disease. The core budget of the CCWHC can accommodate much of the routine diagnostic examinations, general data recording, consultative advice and some field activity with respect to botulism. With additional funds, the CCWHC could and would expand its work on this disease.

To date, the CCWHC has organized and/or participated in two regional, and several provincial, meetings about botulism. Field visits have been made to all three principle sites (PL, OWL, WL), as well as regularly to EL. We have begun to develop field methods to more accurately and statistically estimate bird mortality in prairie wetland environments. We have acquired and established an ELISA (enzyme-linked immunosorbant assay) method for diagnosis of botulism that frees such work from the increasingly unacceptable use of live animals, and we have secured new funds to initiate small research projects that begin to address key questions regarding response options to, and the biology and progress of, botulism outbreaks: one on the effectiveness of a commercially-available vaccine in protecting ducks against the disease, and

another on the relationship between the density of *C. botulinum* spores in marsh soils, the origin of carcasses, and the development of toxin-laden maggots in those carcasses.

Possible future roles for the CCWHC in activities related to avian botulism include:

a) Collection of Detailed Data at Outbreak Sites.

While it is the concensus view that a large amount of information of great practical value is available at outbreak sites, agencies involved in carcass pick-up operations during outbreaks do not believe that their personnel can do this work and also collect detailed data on pre-outbreak and outbreak conditions. Separate personnel and equipment dedicated to this task are required. The CCWHC could facilitate and coordinate the collection of detailed data, thereby assuring that the maximum possible information is extracted from the large-scale, natural occurrences of the disease and the investment made in responding to them. Contributions of funds from all stakeholder agencies could be assembled in a single pool and then used to hire the necessary staff and equipment for a program of data collection agreed to by the sponsoring agencies. Establishment of a disease investigation unit capable of collecting information from outbreak sites across the prairies would require an annual commitment of approximately $30,000, in addition to costs for an air boat and vehicle. Such a unit could also assist with investigation of disease problems other than botulism in waterfowl. The CCWHC would contribute some professional time to this effort, as well as the required accounting and administration, and would work with the agencies to seek support, such as one-time equipment grants, from outside sources.

B. Specific Research Projects:

CCWHC personnel are particularly interested in the conditions that inhibit or favour propagation of botulism to outbreak proportions. We believe that "*sparks*" occur repeatedly in botulism-prone marshes but only a very small proportion of these become established and spread to involve many birds. Should a pool of funds for such research become available, we would propose a series of studies aimed at developing a detailed understanding of the interplay of factors such as the various causes of vertebrate mortality on prairie wetlands, scavenger activity, toxin production by bacteria, availability of toxic maggots and bird populations at risk. Information collected during outbreak investigations will assist in defining areas for detailed research. The CCWHC also is interested in the use of vaccination of birds both as a component of treatment of sick birds during outbreaks and as a tool to assess the effects of botulism on populations.

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