Impoundments for waterfowl

by W. R. Whitman

Environment Canada Environnement Canada

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Contents

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Abstract

Studies were initiated in 1972 to (1) identify factors involved in the aging of freshwater impoundments which affect waterfowl use; (2) evaluate the effect of impoundment upon the nutrient export – import balance within a tidal marsh; and (3) consider undesirable side-effects of parasitism caused by the concentration of waterfowl.

Soil, water, vegetation, and aquatic macroinvertebrates were identified as major factors determining waterfowl use of impoundments, and I have examined the correlations between impoundment age and those factors. Downward trends were particularly evident in dissolved nutrients in the water, while an accumulation of some minerals occurred in the soil as flooding continued. Plant succession in new impoundments progressed toward stable, rooted aquatics which were low in food value for ducks. Invertebrate populations increased rapidly upon flooding in new impoundments, but became nearly stabilized in about two years. Older impoundments and natural marsh areas tended to support a few more taxa. Invertebrates in the families Dytiscidae, Chironomidae, Corixidae, Planorbidae, and Culicidae were most abundant in impoundments less than one year old, while other taxa were more abundant in older marshes. Sparse emergent vegetation containing high quality, waterfowl food plants and invertebrates was most desired. The dramatic increase in waterfowl populations which occurs upon flooding new impoundments was attributed to concurrent increases in invertebrate and vegetable foods. This paper suggests management techniques.

Tidal marsh impoundments were found to be potentially damaging to the coastal zone by reducing plant diversity and preventing the export of fertilizing nitrogen compounds and organic detritus in suspension. Impoundment of tidal marsh to increase waterfowl production may well place waterfowl as competitors with fish for salt marsh productivity. Some compromises are suggested.

Waterfowl impoundments support conditions conducive to increased parasitism. Conditions in those areas provide favourable habitat for mosquito and black-fly vectors of blood parasites. With increased abundance of hosts and vectors, contact between the two becomes more common, thus increasing the opportunities for infection. Prevalence of helminth parasites also increases under the crowded conditions which impoundment management is intended to create. From the evidence accumulated it is obvious that waterfowl management success could be negated by associated increases in parasitism and/or conflicts with other interests such as agriculture and recreation.

Résumé

Des études furent entreprises en 1972 qui visaient à: 1° repérer ceux des facteurs de vieillissement du contenu des retenues d'eau douce qui pourraient en affecter l'emploi par les oiseaux aquatiques; 2° évaluer l'effet de la retenue sur l'équilibre des échanges de substances nutritives au sein d'un marais assujetti à l'action des marées; 3° peser les conséquences secondaires et indésirables du parasitisme qui résulte de la concentration d'oiseaux aquatiques.

Ayant eu lieu de conclure que le sol, l'eau, la végétation et les macro-invertébrés aquatiques étaient au nombre des principaux facteurs déterminants de l'emploi des retenues d'eau douce par les oiseaux aquatiques, j'en ai examiné la corrélation avec l'âge des retenues. Les matières nutritives dissoutes dans l'eau montraient une tendance évidente à précipiter tandis que la continuation de l'inondation s'accompagnait d'une accumulation de certains minéraux dans le sol. La succession des plantes dans les nouvelles retenues évoluait vers l'établissement d'une végétation aquatique stable et enracinée, de faible valeur nutritive pour les canards. Les populations d'invertébrés des nouvelles retenues croissaient rapidement du moment de l'inondation, pour ensuite se stabiliser à peu près, en deux ans environ. Les retenues plus anciennes et les régions marécageuses naturelles tendaient à entretenir quelques formes de plus. Les invertébrés des familles des Dytiscidés, des Chironomidés, des Corixidés, des Planorbidés et des Culicidés étaient des plus abondants dans les retenues d'eau de moins d'un an, tandis que d'autres formes étaient plus abondantes dans les marais plus anciens. Les éléments les plus recherchés consistaient en une végétation émergente éparse comportant des plantes et abritant des invertébrés, les unes et les autres de haute valeur nutritive pour les oiseaux aquatiques. Le remarquable accroissement des populations d'oiseaux aquatiques postérieur à l'inondation de nouvelles retenues a été attribué à l'augmentation simultanée de la quantité d'aliments, invertébrés et plantes, disponible. A la lumière de quoi, le présent article propose des techniques de gestion.

On a trouvé que les retenues d'eau des marais soumis aux marées pouvaient causer des dommages à la zone côtière en réduisant la diversité de la végétation et en empêchant l'élimination des composés azotés fertilisants et des déchets organiques en suspension. Retenir l'eau d'un tel marais en vue d'en accroître la population d'oiseaux aquatiques pourrait bien placer celle-ci en compétition avec les poissons pour ce qui est de la productivité de la saline. Suit l'énoncé de quelques compromis que je propose.

Les retenues destinées aux oiseaux aquatiques entretiennent des conditions susceptibles d'accroître le parasitisme. Ces sites constituent un habitat favorable à ceux des maringouins et mouches noires qui sont vecteurs de parasites sanguins. L'accroissement de l'abondance tant des hôtes que des vecteurs augmente la fréquence de leur contact, donc entraîne une augmentation du risque d'infection.

La gestion des retenues d'eau visant à y promouvoir une densité élevée de population, le succès en accroît d'autant la prédominance des helminthes. Il ressort de toute évidence des données accumulées que le succès apparent de la gestion des oiseaux aquatiques peut être réduit à néant par l'accroissement consécutif du parasitisme, ainsi d'ailleurs que par des conflits avec d'autres intérêts, d'ordres agricole et ludique notamment.

Introduction

A fundamental aim of the Canadian Wildlife Service (CWS) is to manage the migratory bird resource for the maximum benefit of existing and future generations of Canadians and other people having access to the resource (Loughrey, 1975). One aspect of that aim is to preserve habitat for waterfowl through co-operation with other government agencies and private landowners in the acquisition, maintenance, and management of wetlands. Because other human activities continue to encroach on or reduce the quality of wetlands, research is required to develop management techniques which will reduce the amount of space needed by each bird, whether for breeding, migration, or wintering. Government-owned wetlands provide space for that research. However, waterfowl production on government-owned wetlands will probably never make a significant contribution to flyway populations (Munro, 1973). The development of effective management techniques which can be passed on to, and initiated by, private landowners will undoubtedly be a better approach to increasing the number of waterfowl breeding in the settled parts of Canada.

Since 1966 the CWS has established eight National Wildlife Areas in New Brunswick and Nova Scotia for the express purpose of preserving habitat for waterfowl. Those areas total more than 5,260 ha and vary in size from 115 to 1,619 ha. They include both freshwater and tidal marsh habitat, the majority being concentrated near the New Brunswick – Nova Scotia border.

Beginning in 1968, CWS created a series of impoundments on previously drained agricultural marshland and tidal marshes within those National Wildlife Areas, enabling water levels to be closely controlled. Together with adjacent provincial and private marshes, these impoundments present an exceptional opportunity for research and management. Concurrently, studies were initiated to (1) identify factors involved in the aging of a freshwater impoundment which affect waterfowl use; (2) evaluate the effect of impoundment upon the nutrient export – import balance within a tidal marsh; and (3) consider the undesirable side-effects of parasitism caused by the concentration of waterfowl. I discuss these aspects of artificial wetlands in this paper.

Freshwater impoundments

Typically, waterfowl populations in new impoundments increase sharply upon initial flooding, but decline within a few years. The factors responsible for those fluctuations have been the object of a continuing study on a series of freshwater impoundments within the Tintamarre National Wildlife Area and the Missaquash Marsh, a provincially owned waterfowl management area (Whitman, 1973). Both areas are situated on the New Brunswick – Nova Scotia border near Sackville, N.B., and contain impoundments of varying age and size. The factors which I have examined in relation to waterfowl use and the aging of impoundments are soil, water, vegetation, and aquatic macro-invertebrates. All are extensively interrelated and a change in one can generally be correlated with changes in others.

1. Soil and water

Analysis of soil and water samples taken from freshwater impoundments showed some broad correlations between the fertility and age of the impoundment. Downward trends were particularly evident in the water's alkalinity, specific conductance, dissolved chloride, and magnesium as the age of the impoundment increased (Table 1).

The most notable decline occurred between three and four years after the initial flooding. Similar declines in productivity were found by Kadlec (1960) in some Michigan marshes. He attributed the high levels of dissolved nutrients, which occurred shortly after flooding, to a rapid release of soluble nutrients from the substrate and the pre-flood terrestrial vegetation. Subsequent declines resulted as the nutrients were reduced by developing flora and fauna or became trapped by the colloidal content of the substrate.

Soil fertility was highly irregular; however, the oldest impoundments tended to have the highest values for phosphorus, calcium, and potassium. Kadlec's (1960) work in Michigan suggested that the colloid content of the soil increases after flooding due to an accumulation of a partially decomposed organic layer. The exchange capacity in that layer was found to be 10 to 20 times greater than that of mineral soil, and it actively absorbed phosphorus and, to a lesser extent, potassium. The result is a loss of those nutrients from the water and their accumulation in an unavailable form in the soil.

Table 1
Water chemistry data for study areas in ppm, 1972 and 1973

Age–yrs.	pH	Alk.	Sp. cond. umho/cm	Diss. Cl	Ca	Mg	K	Na	SO_4
1972									
0.5	7.0	32.2	260.0	62.0	2.3	6.2	10.7	33.6	6.9
1.5	7.0	23.2	172.0	35.0	4.3	4.9	2.6	19.6	4.3
2.5	6.5	21.1	161.0	36.0	1.7	3.2	1.5	22.8	3.4
3.0	6.5	13.8	112.0	22.0	1.1	2.5	3.2	14.0	5.5
7.0	7.1	15.6	86.0	14.0	3.9	1.6	0.7	10.1	2.9
Natural marsh	6.7	10.7	71.0	12.0	4.9	1.4	0.8	6.6	4.2
1973									
1.5	6.3	25.4	129.0	22.0	2.2	4.3	1.4	16.0	5.0
2.5	6.0	14.0	73.0	12.0	2.6	2.1	0.9	8.2	5.0
3.5	6.5	20.6	135.0	26.0	2.0	2.9	1.9	19.5	5.5
4.0	5.8	8.8	31.0	2.0	2.1	1.2	0.4	2.4	5.0
8.0	6.3	7.7	46.0	7.0	3.6	0.9	0.6	3.9	6.0
Natural marsh	5.9	10.9	73.0	12.0	4.3	1.5	0.8	6.9	5.0

2. Vegetation

Prior to flooding, vegetation within the man-made impoundments was composed primarily of grasses, the dominant species being blue-joint (*Calamagrostis canadensis* [Michx.] Nutt.), couch-grass (*Agropyron repens* [L.] Beauv.) and timothy (*Phleum pratense* L.). Woody plants were absent over large sections, but became increasingly prominent near pre-existing drainage ditches and old river channels, and along the transition zone with peatland areas. Woody plants included spiraea (*Spiraea* spp.), speckled alder (*Alnus rugosa* [DuRoi] Spreng.), and larch (*Larix* spp.). Aquatic vegetation distinguished by a prominence of narrow-leafed pondweeds and arrowhead (*Sagittaria latifolia* Willd.) occurred in drainage ditches and old river channels (Harries, 1968).

Upon flooding with fresh water to average depths of 46 to 61 cm, the pre-flood vegetation was almost immediately affected, with the killing of terrestrial species and rapid initial decomposition. Pre-flood species tolerant of some flooding persisted for a time, depending upon their location and the degree of flooding. Spiraea, blue-joint, and fresh-water cord-grass (*Spartina pectinata* Link) were the dominant pre-flood species in all impoundments. All three were tolerant to some flooding and persisted, especially in the shallow or dry sites along dikes and hummocks.

Conditions favouring the growth of sedge (*Carex* spp.) and cat-tail (*Typha* spp.) predominated following flooding. Both became firmly established by the end of the first year. Competition with blue-joint and spiraea was particularly evident in the wetter sites, for which sedge and cat-tail were better adapted. Cinquefoil (*Potentilla palustris* [L.] Scop.) was either absent or occurred in low densities during the first year. It became one of the most abundant and aggressive species in two- and three-year-old impoundments.

Table 2
Major plant groups and related ecological factors*

Group	Species	Ecol. factor	Opt. conditions
1	*Spartina pectinata* *Spiraea latifolia*	Apparent water content	Moderate to very wet
		Parent materials	High mineral content
2	*Potamogeton pusillus* *Utricularia vulgaris* *Utricularia intermedia* *Lemna minor* *Carex rostrata* *Alisma triviale* *Lysimachia thyrsiflora*	Submersion	Permanent flooding
3	*Calamagrostis canadensis*	Apparent water content	Moderate to very wet
		Parent material	High mineral content
		Submersion	Temporary flooding
4	*Carex lasiocarpa* *Typha* spp. *Calamagrostis neglecta*	Depth of water	Up to 1.2 m
		pH of water	4 to 5.9
		Depth of rooting	Greater than 21.0 cm
		Height of species	Greater than 119.4 cm
		Strength of rooting	Greater than 75%
5	*Potentilla palustris* *Carex limosa*	Micro-relief	Nippled
		Factor responsible for micro-relief	Agricultural practices
		Position of slope	Seasonally flooded

*According to Lamoureux and Zarnovican (1974).

During the early stages of flooding, duckweed (*Lemna* spp.), largely concentrated on the surface of the water, was commonly associated with spiraea. The latter has a low density at the water surface according to Lamoureux and Zarnovican (1973), who also identified five groups of plants based on relationships to ecological factors defined in Table 2. Each group contains species which are commonly associated with each other and are strongly linked to one or more ecological factors operating within the impoundments to determine the presence or absence of each group.

The normal aquatic plant succession within a new impoundment progresses toward stable, rooted aquatics which are low in food value for ducks. As the duration of flooding increased, cat-tail spread over a major part of all impoundments to the exclusion of most other species. Conditions favouring cat-tail included a low pH resulting from decaying organic matter and runoff from surrounding sphagnum bogs. Organic matter accumulating from decaying cat-tail stems assisted in maintaining a low pH. Tall stems and dense rooting systems developed, which were apparently sufficient to exclude most other aquatic plants. Establishment of permanent water levels also favours invasion by cat-tail.

Sedges, particularly *Carex lasiocarpa*, favoured a low pH and permanent flooding, although optimum water levels for them were lower than for cat-tail. Sedges eventually dominated in the shallower spots to the exclusion of both blue-joint and fresh-water cord-grass, which require a higher pH and lower water levels. Desirable waterfowl food plants such as pondweed (*Potamogeton* spp.) and duckweed favoured a pH between 7 and 8. As the pH declined in the years following impoundment, those plants also declined and cat-tail and sedges expanded.

Waterfowl population cycles within artificial wetlands are controlled both directly and indirectly by vegetation succession. In North America the direct influence of the amount, density, and species composition of the emergent vegetation on waterfowl use has long been recognized (Griffith, 1948; DiAngelo, 1953; Sowls, 1955; Harris, 1957). However, the indirect effects of vegetation on waterfowl population cycles are becoming more and more evident.

3. Aquatic macro-invertebrates

In recent years, researchers have identified aquatic invertebrates as potential limiting factors in waterfowl production. Invertebrates, many of which are high in protein, play in important role in the diets of laying females, molting adults and, particularly, young broods (Krapu, 1972; Swanson and Meyer, 1973). Those studies and that by Whitman (1974) suggest that the abundance and availability of invertebrates influence waterfowl populations in northern breeding marshes.

Table 3
Average total numbers of individuals in characteristic taxa of major age classes, 1972 and 1973*

Taxa	Less than 1 year	1 to 4 years	7 + years	Nat. marsh
Dytiscidae	*1,004*	339	504	100
Chironomidae	*125,892*	9,387	11,224	7,197
Corixidae	*14,389*	1,365	2,378	813
Planorbidae	*36,234*	4,985	1,132	1,112
Culicidae	*122*	27	4	14
Subtotal	*177,641*	16,103	15,242	9,236
Gyrinidae	31	*69*	35	14
Physidae	260	*1,432*	284	318
Lymnaeidae	632	*3,842*	194	156
Subtotal	923	*5,343*	513	488
Haliplidae	32	50	*91*	6
Erpobdellidae	36	92	*432*	38
Ostracoda	9,500	3,204	*51,789*	6,934
Copepoda	9,280	3,915	*25,030*	14,828
Talitridae	0	30	*1,436*	832
Libellulidae	7	27	*42*	20
Glossiphoniidae	0	1	*50*	26
Aeschnidae	0	27	*50*	17
Subtotal	18,855	7,346	*78,920*	22,701
Cladocera	16,940	7,523	12,380	*18,388*
Ceratopogonidae	161	151	90	*504*
Sphaeriidae	2	4	40	*233*
Coenagrionidae	13	275	134	*560*
Subtotal	17,116	7,953	12,644	*19,685*
Grand total	214,535	36,745	107,319	52,110

*Italic numbers are the highest average values for the taxa represented.

Samples collected from a series of impoundments of different ages in the Tintamarre National Wildlife Area and Missaquash Marsh in 1972 and 1973 showed a rapid increase in invertebrates during the first and second years of flooding. The number of taxonomic groups of invertebrates became nearly stabilized in less than two years after flooding, with 90% of all taxa appearing by the end of the first full growing season. In impoundments ranging in age from 1.5 to 4 years, the number of taxa remained approximately constant. Natural marshes and impoundments more than seven years old generally contained a few additional taxa.

Most of the invertebrates collected were included in 20 taxa. The relative importance of each taxon varied with the age of the impoundments (Table 3). The number of individuals in the families Dytiscidae, Chironomidae, Corixidae, Planorbidae, and Culicidae increased rapidly after flooding and reached maximum abundance in impoundments less than one year old. Impoundments from one to four years old contained the highest number of individuals in the families Gyrinidae, Physidae, and Lymnaeidae, while older impoundments abounded with ostracods and copepods. Natural marsh areas more commonly supported the taxa Cladocera, Ceratopogonidae, Sphaeriidae, and Cœnagrionidae. I observed three peaks in total abundance of invertebrates in all impoundments during the first halves of May, June, and August. Those peaks generally correspond to critical periods of high protein requirement in the life cycles of waterfowl.

4. Aquatic vegetation and macro-invertebrates

Invertebrate abundance is determined, in part, by the amount, density, and species composition of the aquatic vegetation. I found that zones of submerged and floating-leaf aquatics supported the lowest numbers of invertebrates. That type of vegetation characteristically provides vegetable foods highly preferred by waterfowl and was most common in young impoundments from one to two years old. The initial and temporarily high abundance of invertebrates in impoundments less than one year old is believed to be directly related to the presence of dense pre-flood vegetation and a rapid release of nutrients from decay. McKnight (1969) suggested a similar correlation resulting from flooding of old marsh areas. He attributed the high abundance of corixids and chironomids to the availability of a great supply of organic matter, dead emergent vegetation, and bassia. As plant succession progresses, sparse growths of emergents become inter-mixed with submerged and floating-leaf aquatics, providing abundant vegetable food, good brood cover, and moderate to high densities of invertebrates. In later years, dense emergent vegetation becomes common, while zones of submerged and floating-leaf aquatics are excluded. Dense emergents provide low-quality vegetable foods and thick cover which may have restricted movement by young ducks. Invertebrates were measurably more abundant, but perhaps not as available due to the restrictive action of dense vegetation upon brood movement and vision.

In addition to density, I observed some obvious relationships between plant species and invertebrate abundance in all impoundments. Species such as fresh-water cord-grass and bluejoint, which are intolerant of extensive and prolonged flooding, both supported high numbers of invertebrates. The high invertebrate abundance can again be attributed to a rapid release of nutrients caused by flooding and the subsequent death of extensive areas of both plant species. Spiraea also contained high numbers of invertebrates. It is important to emphasize the strong association of duckweed with spiraea, since Krull (1970) found that duckweed harboured significantly larger numbers of invertebrate taxa than any other species studied. Duckweed may be the controlling factor in this case. I examined several other species (Table 4).

Table 4
Density of invertebrates per sample in relation to some major plant genera, 1972 and 1973

Genera	No. Samples	Veg. Low	Density high	Total
Spartina	13	677	867	1,544
Spiraea	39	386	979	1,365
Carex	121	423	528	951
Calamagrostis	31	440	461	901
Sparganium	40	168	337	505
Typha	28	210	273	483
Potentilla	12	205	270	475
Menyanthes	12	130	192	322
Totals		2,639	3,897	6,536

5. Waterfowl and macro-invertebrates

5.1. Waterfowl production and breeding pairs

Waterfowl and breeding pairs increased sharply in numbers following the flooding of impoundments. Numbers of broods increased from zero prior to flooding to 61 in 1973 on impoundments within the Tintamarre National Wildlife Area, and from zero to 108 on the Missaquash Marsh. Brood numbers declined rapidly on adjacent natural marshes as flooded impoundments became available. Table 5 shows production trends on the Tintamarre National Wildlife Area and the Missaquash Marsh.

Breeding pairs utilized the impounded areas as soon as open water became available in the spring. Extensive feeding began immediately on all impoundments following ice-out and continued throughout the spring and summer. Black Duck (*Anas rubripes* Brewster), Blue-winged Teal. (*A. discors* Linnaeus), American Green-winged Teal (*A. crecca carolinensis* Gmelin), Pintail (*A. acuta* Linnaeus), and Ring-necked Duck (*Aythya collaris* [Donovan]) have been observed repeatedly in the early spring feeding on all impoundments, including those which had been flooded for the first time during the previous winter. The early spring use of impoundments by breeding pairs, together with the change in abundance of broods from natural areas to impoundments, indicates that the composition, abundance, and availability of invertebrate populations may be important factors in determining waterfowl use. Invertebrates are abundant in impoundments immediately following ice-out in early May — a peak corresponding closely to the period of heavy use by breeding pairs. A second peak in invertebrate abundance occurs during the month of heaviest brood use. In brief, critical periods in the life cycles of breeding waterfowl apparently coincide with periods of high density in invertebrate populations.

Table 5
Number of broods on Tintamarre National Wildlife Area and Missaquash Marsh, 1967–73

Area	1967	1968	1969	1970	1971	1972	1973
Tintamarre NWA							
Impoundments				2	50	39	61
Natural marshes	28	31	25	28	9	8	5
Missaquash Marsh	44	62	n.d.	91	108	61	108

5.2. Waterfowl food habits

Impoundments less than four years old support the highest abundance of invertebrates in the families Dytiscidae, Chironomidae, Corixidae, Culicidae, Planorbidae, Gyrinidae, Physidae, and Lymnaeidae. These families have been repeatedly identified as important spring foods of breeding waterfowl; and Sugden (1969) found them to be high in nutritional value based on crude protein content. Older impoundments and natural marsh areas have fewer of the invertebrates that are commonly taken by ducks. Low priority foods in the taxa Erpobdellidae, Glossiphoniidae, and Oligochaeta occur frequently.

New impoundments also appear to provide the most attractive invertebrate diet for waterfowl broods. Low trophic level invertebrates such as chironomids and corixids, which are most abundant in recently flooded impoundments, are most commonly consumed by downy young (McKnight, 1969; Sugden, 1969; Swanson and Meyer, 1973). An analysis of the protein showed that those invertebrates were the most nearly complete in terms of amino acid content of all the invertebrate foods analyzed. Therefore, in the presence of an abundant and highly available supply of those invertebrates, such as exists in new impoundments, ducklings need to expend a minimum of effort to maintain nutritional requirements.

6. Species diversity

Both species diversity and equitability (*sensu* Odum 1971, p. 149) of individuals among invertebrates increased following flooding. Although impoundments flooded for less than one year provided abundant high protein food items, the age class from 1.5 to 4 years is probably most desirable for waterfowl. During those years, impoundments begin to stabilize and are thereby less affected by biological and physical stresses than new impoundments are. The more even distribution of individuals among taxa provides increased assurance that a high protein invertebrate diet will be continually available to waterfowl. Under conditions of high diversity and equitability the loss of one group of invertebrates from the system does not reduce waterfowl use, since several equally abundant groups of invertebrates are available as food. Diversity and equitability declined in older impoundments and natural marsh areas.

7. Management

From our present knowledge of factors influencing waterfowl populations in artificial wetlands, I recommend water-level drawdown and habitat manipulation every five to seven years, when many of the physical and biological factors have changed to the point of being less productive for waterfowl. Soil and water characteristics display a sharp decline in basic fertility after about four years of impoundment. At about the same time, a vegetation type has evolved which is unsuitable for optimum waterfowl use, and invertebrate populations contain a wide variety of taxa that are less abundant and less attractive as waterfowl foods (Whitman, 1973).

Water-level drawdown is an effective management tool which, if applied accurately, will improve soil, water, and vegetation. In addition to drawdown, scarification of the substrate should be carried out wherever possible to mix organic and mineral components and to provide a suitable substrate for terrestrial vegetation. Buckwheat (*Fagopyrum* spp.) and Japanese millet (*Echinochloa frumentacea* [Roxb.] Link) are good crops to encourage. Upon reflooding, those plants will rapidly die and decay, releasing nutrients and providing detritus for invertebrates. Both the timing and duration of drawdown should be complemented by other management tools such as rototilling, cutting, burning, herbicides, and fertilization.

Tidal marsh impoundments

Salt marshes have long been recognized as unusually productive places which act as nutrient recycling mechanisms generated by tidal energy. On the average, a salt marsh produces nearly 9 t of organic matter on every 0.4 ha each year — Teal and Teal (1969) estimated it as 10 times the yield of most agricultural crops. Mann (1972) estimated the productivity of vegetation (macrophytes) in the coastal zone to be 40 times greater than in the open ocean; however, very little of that production is believed to enter the food chain through the herbivore link, since most enters as dissolved or particulate organic matter. The distribution of these nutrients via tidal currents is essential to coastal fisheries resources.

Since 1971, three impoundments have been constructed on salt marshes in Nova Scotia to create waterfowl breeding habitat. Because of the high primary production of salt marshes and the importance of the export of organic detritus to food chains in coastal waters, general concern of marine biologists and ecologists has focused on those impounded areas as being potentially damaging to the coastal zone by reducing productivity and cutting off the supply of organic detritus. Studies to evaluate the effect of impoundment upon nutrient cycles have therefore been started and a moratorium has been imposed upon any further impoundment until the ecological consequences have been fully evaluated.

Two of the impoundments are located within the John Lusby National Wildlife Area on the Bay of Fundy near Amherst, N.S. The third is in the Wallace Bay National Wildlife Area on Northumberland Strait near Pugwash, N.S. The Bay of Fundy and Northumberland Strait have significantly different ecological conditions. On the Bay of Fundy, tides have a large range and carry heavy silt deposits. Tides are much less violent in Northumberland Strait and the subsoil in the Wallace Bay impoundment is less muddy and richer in organic matter, and the fauna and flora appear to be more productive. It has a mature plant community and a wide diversity of species in the ecosystem.

1. Bay of Fundy impoundments

Ducks Unlimited (Canada) constructed two impoundments upon *Spartina* marsh and equipped them with reverse aboiteaux[1] to permit the tide to enter when it reached a water-level higher than the level inside the impoundments. Water depths inside the impoundments vary from 10 cm to 750 cm. The smaller of the two (6.7 ha) was flooded in autumn 1971 and was originally vegetated by fresh-water cord-grass. Studies initiated during the summer of 1973 by David Morantz, under the direction of Dr. K. H. Mann of the Department of Biology, Dalhousie University, showed that emergent macrophytes were absent from the ponded area. They believed this to be partially due either to an insufficient time for colonization by such plants or an abnormally high salinity in the water as a result of evaporation. Scattered throughout the impoundment were stands of submerged macrophytes including widgeon-grass (*Ruppia maritima* L.), horned pondweed (*Zannichellia palustris* L.), and pondweeds. The bottom of the impoundment was covered by a dense mat of green algae.

Water chemistry within the flooded area showed an average salinity over the summer months of 20.5 parts per thousand or about 60% of average sea-water salinity. Between July and September, salinity increased from 9,825 mg/l to 12,900 mg/l as a result of water evaporation and subsequent salt concentration. Values for the major cations increased in a similar fashion.

[1]Aboiteaux – a one way water-control structure commonly used in tidal areas of the Maritime Provinces to permit drainage of reclaimed tidal marshes.

Table 6
Area calculations of Impoundment 2, John Lusby salt marsh, and the proportion occupied by major vegetational species*

Species	Area occ'd (ha)	% of total
Total *Spartina alterniflora*	4.8	50.0
a) shorter *S. alterniflora*	0.6	6.7
b) tall *S. alterniflora*	4.2	43.3
Puccinellia maritima	0.4	4.5
Spartina pectinata	1.7	17.7
Carex paleacea	0.7	7.0
Total area	9.7	
Occupied by water	2.1	20.8

*Morantz (1974)

Table 7
Particulate organic matter content of water at the aboiteaux of an impounded area at various tidal heights*

Time	Tidal ht. (ft above datum)	Particulate organic (mg dry weight/l)
1000 hrs	23.9	< 1.0
1100	34.9	< 1.0
1200	43.7	< 1.0
1300	45.9	14.6
1400	43.7	8.4
1500	34.9	5.8

*Morantz (1974)

The second impoundment (9.7 ha) was flooded in July 1973, drained in September 1973, and exposed to tidal influence until early April 1974. During that time, areas occupied by major plant species were measured (Morantz, 1974). Table 6 shows that salt-water cord-grass (*Spartina alterniflora* Loisel) was the most dominant species in the impoundment, occupying about 50% of the area. It was followed in abundance by fresh-water cord-grass, sedge (*Carex paleacea* Wahlenb.) and alkali-grass (*Puccinellia maritima* Huds. Parl.). Open water occupied about 21% of the area.

Water samples collected at the aboiteaux of the impoundment from mid-flood to mid-ebb tide on October 12, 1973, suggested that a net export of organic matter occurs on the falling tide as well as a net import of nutrients to the marsh (Table 7).

Examination of the particulate organic matter content of ice blocks outside the impounded area showed that ice was important in locking up organic matter and nutrients over the winter months. Concentrations of particulate organic matter as high as 1,494 mg/l were found in ice blocks, together with a phosphorus concentration of 1.08 mg/l. Most of those nutrients were probably contributed to the soil and creeks as the ice melted in the spring (Morantz, 1974). Restriction of water flow by dikes and the aboiteaux prevented the build-up of ice blocks on the impounded area, which will probably reduce the fertility of the impoundment as time progresses.

Plant diversity increases to the seaward of the impounded areas. Beginning at the edge of the upland which forms the inland boundary of both impoundments, dense stands of fresh-water cord-grass and sedge occur. Those species give way to salt-meadow grass (*Spartina patens* [Ait.] Muhl.), salt-water cord-grass, alkali-grass, seaside plantain (*Plantago maritima* L.), and sea-lavender (*Limonium Nashii* [Nash]). Three forms of salt-water cord-grass are found in the marsh — tall, intermediate, and dwarf. The heights of the forms appear to be directly related to the frequency and duration of flooding, which determine the supply of nutrients (Morantz, 1974).

In the larger impoundment and in unimpounded sites, Morantz (1974) measured macrophyte productivity of major vegetational zones. He sampled salt-water cord-grass, alkali-grass, fresh-water cord-grass, and sedge in 400 cm^2 quadrats and determined dry weights per square metre. Total biomass measured at the end of the growing season represents net annual above-ground production, but does not take into account losses due to leaf fall. Table 8 shows biomass results for an impounded area prior to flooding and for a natural salt marsh. According to those results, productivity appears to be higher in the unimpounded area, except in the case of alkali-grass. Comparison of salt-water cord-grass

Table 8
Annual net primary productivity of major plant species in an unflooded impoundment and a natural salt marsh*

Species	Ann. prod. (g/m^2 dry weight) Impoundment	Nat. marsh
Spartina alterniflora		
dwarf		303
intermediate	726	774
tall	913	965
S. patens		501
S. pectinata	769	979
Puccinellia maritima	386	248
Carex paleacea	754	

*Morantz (1974)

production figures with those from other Atlantic coast areas (Teal and Teal, 1969) shows that this area rivals production in any of the North Atlantic marshes.

2. Northumberland Strait impoundment

During the spring and summer of 1973, a 24.3 ha impoundment was created on the Wallace Bay National Wildlife Area by Ducks Unlimited (Canada). Prior to flooding, studies similar to those on the Bay of Fundy impoundments were undertaken to measure productivity and the import – export cycling of nutrients (Martin, 1974) for the purpose of developing a basis upon which to evaluate the effect of impoundment on fertility in a Northumberland Strait ecosystem.

All sampling, conducted prior to impoundment, represented the conditions of a tidal marsh on the Northumberland Strait. Unlike the Bay of Fundy marshes, which are subject to extreme tides, the Wallace Bay area supports both eelgrass (*Zostera marina* L.) and filter-feeding invertebrates. Other dominant primary producers include salt-meadow grass, salt-water cord-grass and sea-lavender.

The study delineated ecotypes of salt-water cord-grass on the basis of elevation and determined productivity as in the Bay of Fundy study. In Wallace Bay, salt-water cord-grass corresponding to the tall, creek-bank variety in the Bay of Fundy had a productivity of 710 g dry weight per m^2 per year, as opposed to 965 in the Bay of Fundy. The greater productivity of the creek-bank variety of salt-water cord-grass on the Fundy coast is attributed to the fact that the creek banks are flooded for shorter periods and are exposed to greater tidal energy. This results in more time for photosynthesis and a greater nutrient subsidy to the plants. Salt-water cord-grass in the intermediate zone appeared to be the most productive variety in Wallace Bay: between 830 and 931 g dry weight per m^2 per year as compared to 774 g in Fundy. Martin (1974) concluded that photosynthesis time and nutrient availability were ideal in this zone.

Primary production of other major macrophytes tended to be notably higher than comparable measurements in the Bay of Fundy; however, the difference may be misleading, since Wallace Bay measurements included a correction factor for losses due to leaf fall. Salt-meadow grass was estimated to contribute 1,070.4 g dry weight per m^2 per year, the highest productivity measured in either region. Sea-lavender was the third most abundant macrophyte in the study area, but its contribution to the production of the marsh as a whole was considered negligible (Martin, 1974). Eelgrass was not abundant in the area, but has been shown to be one of the most productive marine macrophytes (Mann, 1972). Export of eelgrass detritus is believed to be significant to the coastal food web.

3. Preliminary conclusions

These studies suggest that a significant loss to coastal food chains could result from impounding tidal marshes, with the constricting influence of dikes and aboiteaux preventing the export of fertilizing nitrogen compounds and organic detritus in suspension. Both are important to the coastal fishery. Further, productivity is likely to decline over a period of time. With the inflow of fresh water and/or evaporation, salinity can vary violently and irregularly. In time, fresh and brackish water flora of equal productivity may appear; however, it is doubtful that many species can match the productivity of *Spartina*.

The continuation of studies on these experimental salt marsh impoundments will shed further light on long-term changes in productivity. In the meantime, waterfowl biologists must weigh carefully the alternatives to salt marsh impoundment and make compromises between conflicting uses. If productivity is held back by dikes and utilized by waterfowl, it may well be that waterfowl become competitors with fish for salt-marsh productivity (Mann, 1973). One compromise suggested by Mann is to restrict the time for which an impoundment is closed off to allow some of the detritus and nutrients to be exported. He expressed doubt, however, that a productive plant association could be developed which could tolerate changes from standing water to tidal conditions on a regular basis.

Waterfowl parasitism on artificial wetlands

Management programs designed to increase waterfowl production often modify local areas extensively. Although little effort has been made to assess the impact of improved wetlands on populations of helminth, protozoan, arthropod, or other pathogenic agents of waterfowl, it is likely that the success of these management schemes, resulting in increased host population densities, will greatly enhance the transmission of parasites. This could build up a harmful level of parasitism which may well reduce the host population, defeating the initial objective of management.

Studies have been initiated to monitor parasite prevalence before, during, and after the implementation of improved wetland schemes to determine whether the parasites increase and to suggest control measures. The distribution and prevalence of the hematozoan parasites of waterfowl in the Tantramar and surrounding regions of the Maritime Provinces for the period 1969 to 1973 have been examined by Bennett *et al.* (1974*a*), whose reports form the basis for this section.

Blood films were obtained from either the brachial or femoral artery of a variety of ducks and geese. Personnel of the CWS duck-banding program took most of the smears from August 1 to 25 each year. They caught primarily local and hatching-year birds by nightlighting and bait-trapping. All blood films were air-dried, fixed in 100% methanol, and stained with Giemsa's buffered to pH 7.2.

1. Prevalence of blood parasites

The prevalence of blood parasites in a sample of 4,200 waterfowl from the Maritime Provinces — the majority from the improved wetland area of the Tantramar marshes of the New Brunswick – Nova Scotia border — averaged 30.3% over the period 1969 – 73. *Haemoproteus* (*Parahaemoproteus*) *nettionis* was the commonest hematozoan, occurring in 18% of the population (Table 9). *Leucocytozoon simondi* Mathis and Leger, 1911, was found in 14% and *Plasmodium* species, primarily *Plasmodium circumflexum*, in 5% of the birds. Microfilaria, presumably *Ornithofilaria fallisensis* Anderson, were seen in only 52 birds (1.2%), a surprisingly low prevalence in view of the figures reported by Anderson (1956). *Trypanosoma avium* was noted in only two ducks. This parasite is not readily detected by thin film techniques and provides only a transient, evanescent infection in ducks (Bennett, 1970); hence the prevalence indicated is undoubtedly far lower than the true prevalence.

The prevalence of the three commonest species of hematozoa varied widely from year to year, ranging from 19.3% in 1971 to 50.1% in 1969. Different species of haemosporozoans showed different patterns of fluctuation. *Haemoproteus nettionis* occurred in 41.4% of the birds in 1969, but the prevalence dropped sharply over the next four years, ranging from 7.4 to 13.6%. The drop is difficult to explain, but suggests a marked reduction in the *Culicoides* vector population between 1970 and 1973. *Plasmodium* spp. also varied, but less markedly and over a narrower range. In contrast to *Haemoproteus*, the *Plasmodium* prevalence was almost stable. *Leucocytozoon simondi* had a greater year-to-year fluctuation and was the most variable of the three blood parasites.

In the Tantramar region alone, *L. simondi* was the most common parasite but its prevalence was similar to that experienced elsewhere in the Maritimes (Table 10). Similarly, *Plasmodium* spp. occurred with the same frequency in the Tantramar area as in the other regions; however, *H. nettionis* was sharply lower. Overall, birds from the Tantramar marshes showed a lower parasite prevalence than other areas sampled. Of the three most common genera, *Plasmodium* and *Haemoproteus* were least prevalent in the Tantramar area. This was surprising in the case

Table 9
Prevalence of haemosporozoa in waterfowl of the Maritime Provinces, 1969–73

				Waterfowl infected with					
		Infected		*Leucocytozoon*		*Haemoproteus*		*Plasmodium*	
Year	Examined	Total	%	No.	%	No.	%	No.	%
1969	970	486	50.1	146	15.1	402	41.4	93	9.6
1970	745	192	25.8	97	13.0	101	13.6	39	5.3
1971	907	175	19.3	61	6.7	116	12.8	32	3.5
1972	680	217	31.9	174	25.6	50	7.4	9	1.3
1973	898	202	22.5	115	12.8	90	10.0	31	3.5
Total	4,200	1,272	30.3	593	14.0	759	18.0	204	5.0

Table 10
Prevalence of three genera of haemosporozoans in waterfowl of Tantramar Marsh area, 1969–73

				Waterfowl infected with					
		Infected		*Leucocytozoon*		*Haemoproteus*		*Plasmodium*	
Year	Examined	Total	%	No.	%	No.	%	No.	%
1969	332	136	40.9	47	14.0	106	32.0	31	9.0
1970	308	55	17.8	38	12.3	17	5.6	5	1.6
1971	555	64	11.5	26	4.9	42	7.6	8	1.4
1972	633	209	32.0	174	25.5	50	7.9	9	1.4
1973	898	202	22.0	115	12.5	90	10.0	31	3.5
Total	2,726	666	22.2	400	14.4	305	11.0	84	3.0

of *Plasmodium* since the terrain is conducive to production of the mosquito vector, *Culisela morsitans*. The prevalence of *L. simondi* was unexpectedly high. Because of the topography of the area, the simuliid vector of *L. simondi* was not expected to be abundant. In this case, the construction of waterfowl impoundments may have created habitat for ornithophilic simuliids in running water at inlet and outlet structures.

During the five-year sampling period, the number of ducks breeding on the artificial wetlands created within the Tantramar area increased at least fivefold, resulting in a higher potential for host-vector interactions, but the creation of managed wetlands and the concurrent increase in host population has not yet resulted in a demonstrable increase in the prevalence of hematozoa. However, if there are time lags between the increase in host population, increase in vector population, and increase in hematozoa prevalence, the seven years of existence of the managed wetland program in the Tantramar area may be insufficient to encompass the entire process. Continued monitoring would confirm this point.

2. Infection in major waterfowl species

Fourteen species of waterfowl were examined for haemoprotozoa (Table 11). Domestic ducks, as expected, were found to be highly susceptible to *L. simondi*, since they apparently lack the resistance to infection that most wild species appear to possess. Among wild species, the Black Duck was found to harbour blood parasites most frequently, nearly half of the birds sampled showing one or more species of hematozoa. The same high prevalence was noted in Black Ducks from Labrador (Bennett, 1972) and Massachusetts (Bennett *et al.*, 1974*b*). Since those parasites are known to cause mortality in waterfowl (Bennett, *et al.*, 1973), the observed high rate of infection is cause for speculation as to whether the decline in Black Duck numbers recorded over the past decade in eastern North America can be partly attributed to the effect of lethal hematozoa such as *L. simondi*. Certainly, the prevalence of hematozoa in Black Ducks in this region is sufficiently high to act as a limiting factor on the population. In contrast, the prevalence of hematozoa in Mallards (*Anas platyrhynchos* Linnaeus) was only 34.8%. Possibly this closely related species is not as exposed to infection by hematozoa because of basic differences in habitat selection, thus giving it a competitive advantage.

Table 11
Prevalence of hematozoa in 14 species of waterfowl of the Maritime Provinces, 1969–73.
Per cent of birds infected in parentheses

	Total waterfowl			Waterfowl infected with				
Species	exam.	inf.	% inf.	*Leuc.*	*Haemo.*	*Plasm.*	*Trypan.*	*Microf.*
Domestic duck – *Anas boschas*	12	12	100.0	12(100)				
Black Duck – *A. rubripes*	1,750	831	47.8	406(23.2)	541(30.9)	111(6.3)	1	40
Mallard – *A. platyrhynchos*	23	8	34.8	3(13.0)	3(13.0)	3(13.0)		1
Mallard x Black hybrid	6	1		1				
American Green-winged Teal — *A. crecca carolinensis*	387	153	39.5	65(16.8)	86(22.2)	27(7.0)		5
Blue-winged Teal — *A. discors*	1,286	91	7.1	46(3.6)	30(2.3)	20(1.5)	1	
Pintail – *A. acuta*	228	78	34.2	40(17.5)	27(11.8)	16(7.0)		3
Wood Duck – *Aix sponsa*	51	15	29.4	7(13.8)	10(19.6)	3(5.9)		1
Northern Shoveler – *Anas clypeata*	6	0						
Ring-necked Duck – *Aythya collaris*	178	31	17.4	8(4.5)	19(10.6)	7(3.9)		
Common Goldeneye – *Bucephala clangula*	5	5		1	4	2		
Common Eider – *Somateria mollissima*	22	0						
American wigeon – *Anas americana*	180	41	22.8	3(1.7)	35(19.4)	14(17.8)		2
Canada Goose – *Branta canadensis*	66	6	9.1	1	4	1		

Common Eiders (*Somateria mollissima* Linnaeus) sampled during the study did not contain hematozoa. The Eider is normally marine and its behaviour and habitats present ecological barriers to parasite vectors. The prevalence of parasites in Wood Ducks (*Aix sponsa* [Linnaeus]) was surprisingly low. Only 30% of the individuals sampled were infected, in sharp contrast to the prevalence in Massachusetts, where nearly 80% of the population harbours one or more hematozoa (Bennett *et al.*, 1974*b*).

Infections were found to vary greatly between the American Green-winged Teal and Blue-winged Teal. Although both species frequent the same areas, the prevalence of blood parasites in the American Green-winged Teal was 39.5% and in the Blue-winged Teal only 7.1%. The difference is highly significant statistically. Similar differences have been noted between the two species in Ungava (Laird and Bennett, 1970), Labrador (Bennett, 1972), and Massachusetts (Bennett *et al.*, 1974*b*). It is difficult to believe that these two species of ducks have differing susceptibilities to blood parasites. It would be more plausible to assume either (a) a difference in vector preferences for the two species and/or (b) that behavioural characteristics of the Blue-winged Teal impose an ecological barrier to vector attack. There are no data to either support or negate assumption (a). It is known, however, that the American Green-winged Teal migrate to their breeding grounds as much as a month before the Blue-winged Teal. That action may well place them in their breeding areas at the peak of vector abundance, thus maximizing vector contact. In addition, American Green-winged Teal commonly frequent small ponds, the edges of marshes and lakes, and small rivers as breeding and/or feeding habitats. Those areas may well be the preferred feeding habitats of anserophilic vectors (Bennett, 1960, 1963). Blue-winged Teal, on the other hand, prefer larger marshes and tend to avoid small ponds, rivers, and streams, thus minimizing vector contact.

3. Implications of habitat management

Waterfowl impoundments were created in the Tantramar area to increase waterfowl production. Generally, the program has been successful and has increased recreational opportunities for hunters, bird watchers, photographers, and nature-lovers of the region. To achieve that objective, it was necessary to provide water, food, and cover for breeding waterfowl in adequate amounts, through the creation of permanent, shallow water bodies filled with aquatic vegetation. Conditions in those areas, as well as in the attendant water control structures and drainage ditches, also provided favourable habitat for mosquito and black-fly vectors of blood parasites. With increased host and vector abundance, contact between the two became more common, thus increasing the opportunity for infection to occur. An increased incidence of *L. simondi* infection may be particularly imminent, since the introduction of water control systems has created streams which serve as breeding habitat for simuliid vectors where they did not previously exist. A drainage ditch free of simuliids in 1972 was found colonized by three species of them in 1973, one of which was ornithophilic (Bennett, Herman, and Threlfall, 1973).

In addition to being vectors of blood parasites in waterfowl, biting flies are a significant nuisance to both people and livestock. The presence of biting flies at parks, campgrounds, beaches, and other recreational areas raises an outcry from the general public. Therefore, waterfowl managers must understand and appreciate the implications of managed waterfowl areas in the fields of veterinary medicine and public health. This is particularly true where managed marshes are adjacent to agricultural, urban or recreational areas.

Other forms of parasitism associated with the high waterfowl densities which most management projects are intended to create include helminth parasites. Those species having direct life cycles, i.e., through fecal contamination, are most prevalent under crowded conditions. Nematodes and gizzard worms cause mortality, particularly in young birds, and commonly occur in wild waterfowl. Other helminths of waterfowl such as trematodes, tapeworms, and acanthocephalans utilize invertebrates as intermediate hosts. This is highly significant in artificial wetlands, where one of the objectives is to produce abundant aquatic invertebrates as food for young ducks and breeding females. These circumstances are conducive to increased helminth infections (Bennett *et al.*, 1973).

From the evidence accumulated, waterfowl management success obviously could be negated by associated increases in parasitism and/or conflicts with other interests such as agriculture and recreation. As a precaution, all management plans for artificial wetlands should include facilities for control of biting-fly populations, together with a continuing program to monitor vector abundance and distribution. In most cases, water-level manipulation can be used effectively to reduce vector populations as well as to increase them.

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