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Intensive regulation of duck hunting in North America: its purpose and achievements

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Abstract

Duck hunting in Canada and the USA is controlled by regulations set annually by the two federal governments, using information on duck numbers obtained by extensive field surveys and on hunting activity by means of mail questionnaires. These activities cost about $12 million annually. The numbers of ducks in northern North America in September were estimated to exceed 100 million from 1955 to 1958. By 1962–65, they had fallen to about 55 million and have since varied between 98 million in 1970 and 64 million in 1980.

Until 1979, the severity of hunting regulations was made to follow the annual variations closely, regulations being more strict in the east, where ducks are scarcer, than in the west. The estimated retrieved kill in the USA was about 13 million in 1955–58, 7 million in 1962–65, and 12–16 million between 1970 and 1980. The reported kill in Canada since surveys began in 1968 has varied between 2.7 (1968) and 4.3 million (1970). In the USA, regulations have substantially affected the amount of waterfowl hunting and the size of the kill. In prairie Canada, the association between regulations, hunting, and kill has been less close. Throughout the years 1955–80, changes in hunting regulations had little effect on duck breeding populations. But, with the reported US kill continuing to increase as a proportion of the total losses of ducks between September and the following May, which amount to rather more than 50%, this happy lack of impact may soon disappear. Since 1979, the regulations in both countries have been kept fixed, even though drought in the prairies has diminished duck numbers and recruitment. This should soon demonstrate whether the hypothesis applies in North America that a threshold exists, above which losses through hunting are added to, rather than substituted for, losses from other causes.

It remains unlikely that the response of ducks to excessive hunting will be catastrophic. Slow declines, like that shown by the Black Duck (*Anas rubripes*), are more likely. US hunting regulations may have been unnecessarily severe in 1959–65, but, in recent years, the regulations have been as liberal as in 1955–58, when ducks were much more plentiful. So far, no lasting harm seems to have been done, though it would be imprudent to encourage even more hunting. The annual surveys of ducks and hunters have made possible a better understanding of the dynamic character of duck populations and of the relationship of hunting to mortality, which is more complicated than had been thought by the framers of US regulations before 1975. This new knowledge should allow continued safe exploitation of ducks, even if the ratio of ducks to hunters cannot return to that prevailing before 1960.

Introduction

For 65 years, the agencies responsible for administering the Migratory Birds Treaty Act in the USA and the Migratory Birds Convention Act in Canada have found it necessary to impose restrictions on duck hunters. These consist chiefly of declaring open seasons far shorter than the upper limit of 3.5 months imposed in the Migratory Bird Convention of 1916, delaying opening dates, and setting daily bag limits, which are the maximum number of ducks that a hunter may legally take in any one day during the season.

Scott (1979), on behalf of the International Waterfowl Research Bureau (IWRB), undertook a review of waterfowl management practices in North America to see whether, for the better conservation of waterfowl in Europe, it would be helpful to introduce some of the monitoring and management activities now being used by the USFWS and CWS, the federal agencies charged with putting the Migratory Birds Convention into effect. Although there is far less quantitative information about ducks and duck hunting in Europe than in North America, Scott (1979) argues that "hunting pressure" must be much greater in Europe than in North America. The numbers of duck hunters in the two continents are fairly similar, about 3 million, but Scott found that in autumn there are about four times as many ducks in North America (100 million) as in Europe and that, although the average annual kill of a successful waterfowl hunter in North America is 6.3 ducks and geese, while in Europe it is only 3.5, the total annual bag of ducks as a proportion of the autumn flight is 44% in Europe, but only 16.7% in North America.

Following on Scott's findings, Matthews (1981) states that, at least for opportunistic species of ducks such as Mallard and Pintail, "the whole complex system, data collection and analysis, would seem to have been a waste of time costing untold millions of dollars and man-hours". The hyperbole of "untold millions of dollars" should not be taken too seriously. About $10 million is being spent annually by governments in the USA on setting and enforcing annual regulations relating to the hunting of migratory birds; about two-fifths of it by the USFWS, and the remainder by the state wildlife agencies (USFWS 1981). In Canada, the figures are much smaller: in 1982–83, the entire budget for the Migratory Birds Program of CWS was only $9.4 million, with administration of the hunting regulations and monitoring of waterfowl hunting allotted less than one-tenth, though generating net revenues of just over $1 million from the sale of migratory game bird hunting permits (MGBH permits).

More serious than the imputation of extravagance are the inferences drawn from the disparity between a kill of 44% in Europe and 16.7% in North America. The first is to the effect that since the kill as a proportion of the supply has been so much less in North America than in Europe, and the European kill has not had catastrophic effects on duck numbers, the North American regulatory agencies have been unnecessarily restrictive. The second inference is that reliance on massive data collection and analysis to monitor the effects of hunting has been a waste of time and money. While it is proper and desirable to question how much effort should be devoted to the administration and enforcement of regulations, and to monitoring the impact of regulations on hunters and hence on ducks, it is less certain that North American waterfowl management should be dismissed so completely.

The case argued in the following pages is that, far from being extravagant or futile, the USFWS and CWS, in collaboration with state and provincial wildlife agencies, have made serious and successful efforts to limit the kill of ducks to levels well below those that might threaten the future of any species. This discussion is confined to ducks to keep the review concise, and because issues raised by goose hunting have been, or are being, dealt with elsewhere (Boyd *et al.* 1982; Boyd, in prep.).

In retrospect, one could argue that some of the regulatory restraints imposed on duck hunters were more severe than necessary. That argument is now being tested as duck numbers decline in response to drought in the principal breeding areas in prairie Canada. In a similar decline from 1958 to 1962, the regulatory agencies successfully reduced the kill to levels commensurate with the reduced numbers of ducks. Since 1979, however, the agencies have agreed not to curtail hunting further unless and until the stocks of ducks decrease so greatly as to threaten their recovery when the state of the habitat in the principal breeding areas again becomes favourable. The existing continental surveys of duck numbers and duck hunting, supplemented by special studies, are essential to measure the success of the experiment and to ensure that no lasting harm is done to ducks by "stabilized regulations".

Objectives of waterfowl management in North America

Because no North American ducks are scarce enough to require special measures to preserve them from the threat of extinction, waterfowl managers have been almost wholly concerned with conservation in the sense of prudent exploitation, chiefly by recreational hunters. For at least 30 years, the management of ducks and duck hunting in the USA, and to a lesser extent in Canada, has been focused on the management of the Mallard (*Anas platyrhynchos*), the largest and most numerous duck sought by hunters (Crissey 1957, 1965, 1969; Geis *et al.* 1969) and the Black Duck (*Anas rubripes*), which replaces the Mallard in the east (Geis *et al.* 1971). The decision to concentrate on the management of a few key species was made in full awareness that other species do not behave in the same ways and may be more or less vulnerable to hunting, land-use changes, pollution, and other human actions, whether intended or accidental (Crissey 1969). Selection was necessary because otherwise the task was too big.

The approach adopted was each year to monitor, as well as could be afforded, the breeding and wintering numbers of the most hunted species and their annual breeding success. Knowledge of the size of the breeding population and of its success permits forecasting the "fall flight", the sum of the number of adults surviving from May to August and the number of young reared to flying age. The estimates of fall flight available at the end of July have been the chief guides in setting annual waterfowl hunting regulations in the USA, a process that must be completed in August. In Canada, corresponding decisions have to be made not later than June, before the output of young is measured, because hunting in parts of Canada begins on 1 September, and because the legal processes involved in issuing regulations take 6–8 weeks to complete. Except in Alaska, the US duck hunting seasons do not open until October or, in recent years, late September. In both countries, the political and legal procedures for securing approval and publication of the annual waterfowl hunting regulations have become more elaborate and lengthy in the last few years, as greater emphasis has been put on the need for public consultation and access to relevant information.

The ways of defining the goals of management have varied over the last 25 years, but the general intent has been to maintain the breeding stocks of Mallard and other ducks at or above the levels they attained in the years 1956–62. In May 1958, the estimated population of Mallard in the principal breeding areas was 12.9 million; in 1962, only 6.1 million. Thus, the target numbers were envisaged as ranges, not single values, allowing for lean years as well as highly favourable ones.

Survey methods

Since each would-be waterfowl hunter has to buy a special waterfowl hunting permit, in addition to any other gun licences or permits that might be obligatory, we can obtain the number of authorized waterfowl hunters each year. In addition, their hunting activities and success are monitored by the use of mail questionnaires, enabling us to estimate the numbers of ducks shot legally in each country each season, for each species as well as in total, from the combination of permit sales and the replies of hunters to questionnaires.

In Canada, Indians and Inuit, as defined in the Indian Act, are exempt from the requirement to possess a MGBH permit and from provincial licensing requirements, so that their hunting of waterfowl is not monitored annually and has never been measured in its entirety. The Cree Indians along the Quebec and Ontario shores of James Bay, which serves as a funnel for very large numbers of migratory geese and ducks, take a great many waterfowl (Boyd 1977, James Bay and Northern Quebec Native Harvesting Research Committee 1980). Elsewhere, native people find it more profitable to hunt and trap mammals and fish than to shoot birds, so that their kill of ducks is probably only a small fraction of the kill by other hunters.

In all, the agencies run seven surveys each year: (1) an aerial transect survey of breeding ducks in May; (2) an aerial transect survey of duck broods covering most of the same survey areas in early July (both surveys comprising large parts of the northern USA and Canada, and being operated by the USFWS with the assistance of CWS): (3) a survey of ducks wintering in the USA, carried out in early January by the USFWS and state wildlife agencies, using a mixture of aerial surveys and counts from boats or the ground; (4) and (5) national harvest surveys (NHS) in the US (from 1952) and Canada (from 1966) yielding estimates of the number of active hunters, how often they hunted (using "hunter-days" as a measure of activity), and how many ducks they claim to have killed; and (6) and (7) species composition surveys (SCS) in the USA and in Canada, by means of which the relative abundance of each species, and of the age and sex classes within each species, can be obtained by sending packets of "wing envelopes" to samples of licensed waterfowl hunters, with instructions to enclose one wing from each duck they shoot in an envelope, recording where and when the bird was taken. Trained biologists and technicians then identify the wings.

Detailed accounts of these surveys, their limitations and uses, have appeared elsewhere. Cooch *et al.* (1978) described the Canadian NHS and SCS in greater detail than any published account of the American mail questionnaire surveys, which use a fundamentally different sampling frame. The Canadian mail surveys use samples drawn from the names and addresses of current purchasers of MGBH permits. In both Canada and the USA, permits can be purchased at post offices. In the USA, a sample of post offices provides the initial sampling frame, and only duck stamp buyers from the selected post offices subsequently receive mail questionnaires. Each country selects different samples of hunters each year for its NHS and its SCS. These mail surveys were designed to provide estimates of kill nationally and in individual states or provinces (and zones within the larger provinces). The accuracy and precision of the estimates derived from the Canadian surveys were improved gradually from 1966, when MGBH permits were introduced, to 1972. They have remained standardized since. Couling *et al.* (1982) investigated the reliability of the estimates of kill and hunting activity in the US survey and suggested that, with the more advanced statistical techniques now available, improvements could be made in the sampling as well as in the subsequent analysis.

Close study of the reliability of the Canadian NHS and SCS at the national, provincial, and zonal levels in 1973–75 has led to bettering the sample allocation, with resulting improvement in estimation (Smith 1975, Cooch *et al.* 1978). In the prairie provinces, the estimates of annual duck harvest in aggregate and per successful hunter since 1973 have had coefficients of variation (CV) of 2.5–4.4%, compared with about 1.5% for the national estimate (G.E.J. Smith, pers. commun.). In Newfoundland, estimates of duck kill by species seem to be complicated by an inaccurate distinction between sea ducks and other species, accompanied by differences in the response rates of different groups of hunters (A.J. Erskine, CWS unpubl. rep.). In the Northwest Territories and other areas where permit sales are sparse, the estimates of kill are probably too low. Yet, despite these local flaws, at the national level the estimates of hunting effort and kill seem to be consistent enough for reliable monitoring.

The general distribution of ducks in North America in both winter and summer is illustrated in Figure 1. The winter inventories, mostly in the southern states, are not carried out according to a strict sampling plan, and could not be so in those parts of the USA where lakes and rivers are liable to be more or less frozen over in early January. The effort has remained large for many years (Table 1) with annual counting of all major concentrations (except some offshore) and a network of sites gradually adjusted in response to the creation of new reservoirs, damage to or destruction of old haunts, widespread ephemeral flooding or freezing, and other untidy characteristics of the winter landscape.

Table 1 indicates a 32% reduction in the numbers of ducks counted from 1958 to 1978, while the numbers of observers were halved. Although the latter partly reflects economy of effort, the apparent reductions in duck numbers recorded in the winter inventories must consequently be used with caution to detect and measure trends. Winter inventories were begun in the 1940s. Here I have used records for only January 1956 onwards, in conjunction with the US NHS and SCS and the aerial surveys. In Canada, several million ducks winter offshore in estuaries and on the Great Lakes, and most of those wintering areas have not been surveyed regularly.

After extensive trials, standardized aerial surveys of the southern prairie provinces were begun in 1955, with additions in the Dakotas and Montana, the northern prairie provinces, the Mackenzie district of the Northwest Territories, and Alaska within the next 5 years. The surveys are carried out and data analysed in accordance with *Standard procedures for waterfowl populations and habitat surveys* (USFWS intern. rep., latest rev. 1977). A brief statistical review was published by Martin *et al.* (1979). A very detailed review undertaken for the USFWS remains unpublished: D.A. Bowden, *Review of evaluation of the May waterfowl breeding ground survey* (USFWS 1974 manuscr. rep. 75 pp. plus append.). The reliability of the estimates varies regionally, by species, and from year to year, as illustrated later.

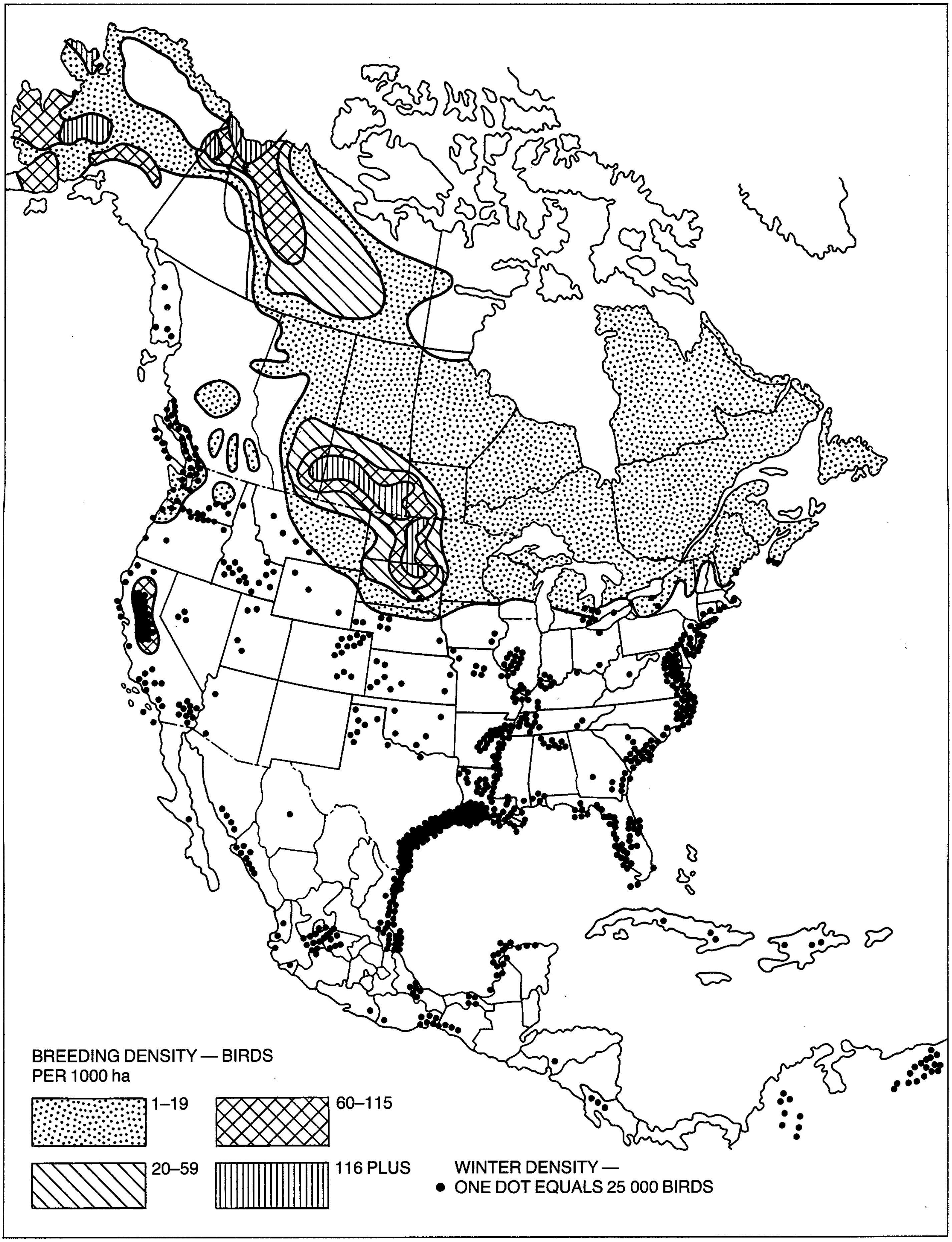
All these surveys collect information on geese as well as ducks, though I have not considered geese here, and have limited the treatment of ducks to eight Canadian-breeding species of dabbling or surface-feeding ducks (genus *Anas*) and five species of the genus *Aythya*, the pochards or diving ducks. This restriction is desirable because information on other ducks, such as eiders, scoters, goldeneyes, mergansers, and Wood Duck (*Aix sponsa*), is less reliable or lacking. One important eastern species of *Anas*, the Black Duck, is scarcely represented in the May breeding survey, and partial estimates for the Ring-necked Duck (*Aythya collaris*), also found chiefly in the east, are available only from 1967 onwards. The surveys also ignore the considerable numbers of some of the other species that breed east of 90°W, or in parts of the USA other than Alaska and the north-central states. While such omissions are regrettable, it has proved impossible to afford continent-wide surveys, with the yield of ducks seen in aerial surveys of the eastern boreal

Table 1
Effort devoted to winter inventory of waterfowl in the USA. Examples from 1958, 1972, and 1978 drawn from USFWS *Waterfowl status reports*. Information on effort has been recorded less completely and consistently than the number of ducks seen. Flyways identified by initial letters: P—Pacific, C—Central, M—Mississippi, and A—Atlantic

						Dist. travelled, km (× 1000)									
	No. observers					By survey aircraft					By car or boat				
Year	P	C	M	A	Total	P	C	M	A	Total	P	C	M	A	Total
1958	348	435	892	185	1860	30.2	36.9	38.2	30.6	135.9	—	72.0	82.5	10.4	—
1972	204	209	502	131	1046	37.0	36.9	—	—	—	13.8	19.3	—	—	—
1978	171	254	427	94	946	30.6	26.7	—	—	—	12.5	29.4	—	—	—

	Ducks counted (millions)					Ducks (thousands) per observer				
Year	P	C	M	A	Total	P	C	M	A	Total
1958	8.59	8.13	6.76	2.22	25.70	24.7	18.7	7.6	12.0	13.8
1972	7.49	6.75	6.41	1.93	22.58	36.7	32.3	12.8	7.1	21.6
1978	6.95	4.04	4.72	1.78	17.49	40.6	15.9	11.1	18.9	18.5

Figure 1
Distribution of Canadian-nesting species of ducks in North and Central America in the breeding season and in winter; after Evans (1964) and Kiel *et al.* (1972)



region too low to justify their continuance (Chamberlain and Kaczynski 1965), although special short-term surveys have produced valuable results (e.g. Gillespie and Wetmore 1974).

A very large area is sampled by the aerial surveys in May (Table 2), over 2.89 million km^2, including more than half of western and northwestern Canada, the parts omitted being mostly mountainous and of little use to ducks. The only comparable aerial surveys elsewhere in the Holarctic took place in the northern parts of Finland, Sweden, and Norway, an area of 333 500 km^2, the surveys being spread over the years 1972–76 (Haapanen and Nilsson 1979). To sample annually in late May a region more than 8.5 times as large as northern Fennoscandia and have the results assembled and analysed within not more than 3 weeks (because the same crews have to fly the July production surveys) poses expensive logistical problems. The aerial line transects cover strips amounting to only 23 700 km^2, about 0.82% of the sampled regions. Careful design, with more intensive sampling in the areas where ducks can be expected in greatest abundance, means nevertheless that useful results can be obtained in May (Martinson and Kaczynski 1967, Martin *et al.* 1979) and from the July production surveys (Henny *et al.* 1972).

The duck numbers used here are from published reports of the USFWS and were computed by the staff of the Office of Migratory Bird Management, who have also provided estimates for the most recent years that have yet to be published. There have been changes from time to time in some of the published estimates, as errors have been corrected and alterations made to some of the factors applied to the field data, such as the visibility factors for each species, which are different in the prairies from those in the boreal regions. I have attempted to use the latest revisions, but may not always have succeeded. It is best to take these numbers as indices rather than unbiased population estimates, because unmeasured biases and errors surely exist. For this reason, I show fewer significant figures than those in the original reports to avoid false impressions of high reliability.

The estimates for May (M) and fall flight (F) refer to the same stock of ducks and so should be comparable, even though the chosen boundaries of the areas surveyed do not coincide with such natural boundaries as may exist. The comparability of the winter inventory numbers (W) with the estimates of M and F is very far from perfect; for all the species included here $\hat{W} < \hat{M}$, which could not occur if identical populations were being sampled at equivalent intensity. Thus, it is impracticable to use the number in January to separate losses in September–January from those in January–May.

Table 2
Extent of major duck breeding areas in northwestern North America sampled annually by aerial transect surveys in May; with data for 1978 used to show how numbers of ducks observed are converted into estimates of regional populations

		Breeding area		Transect area		Duck nos. 1978			
Habitat type	Polit. div.	km^2 (× 1000)	% total surv.	km^2	% breed. area samp.	Count	Extrap. (× 1000)	Extrap. factor	% of total
Tundra	Alaska	118.4		1 159		8 644			
	Mackenzie	12.8		93		497			
	Total	151.3	4.5	1 202	0.92	9 141	370	3 383	7.5
Taiga	Alaska	87.3		1 212		8 153			
	Yukon	5.1		95		1 472			
	Mackenzie	205.2		944		3 454			
	Total	297.6	10.3	2 249	0.76	13 109	363	4 762	10.5
Boreal	Mackenzie	489.6		1 364		4 393			
	N. Alta., BC	428.6		4 209		5 017			
	N. Sask.	319.1		2 296		4 974			
	N. Man.	234.7		1 678		4 796			
	Total	1472.8	50.9	9 547	0.65	19 180	825	15 820	35.0
Prairie	S. Alta.	166.5		927		17 112			
	S. Sask.	287.8		3 287		26 371			
	S. Man.	100.3		1 111		7 863			
	Canadian	554.6	19.2	5 222	0.96	51 345	254	13 025	26.8
	N. Dak.	177.5		2 075		7 167			
	S. Dak.	175.4		1 818		—		7 993	
	Montana	85.2		1 461		5 742			
	USA	438.1	15.1	5 341	1.22	20 952	392	8 222	18.2
	Total prairie	992.7	34.3	10 687	1.08	72 295	294	21 246	47.0
Total surveyed		2894.2		23 635	0.82	113 738	395	45 212	100.0

The scope of this study

I deal here with three principal questions: (1) have changes in duck hunting regulations in Canada since 1967 and in the USA in 1955 brought about changes in the numbers and activities of duck hunters? (2) have duck hunters affected the size and well-being of duck populations and, if so, safely and in the ways intended by the framers of the hunting regulations? and (3) is it necessary to continue detailed monitoring of duck populations and duck hunting in the 1980s?

Before addressing those questions and others arising from them, we need to review the extent to which the ducks sampled in the extensive surveys have changed regionally and from year to year, and see how the distribution of hunting effort has changed.

The Black Duck, breeding almost wholly east of 90°W, is not included in the breeding surveys, so that its status has to be inferred from its occurrence in the kill and in the winter counts. This is unfortunate because the species, though still abundant, has been declining gradually for many years over much of its range, for reasons that remain controversial.

Within Canada, I examine here only the kill of ducks in the three prairie provinces — Alberta, Saskatchewan, and Manitoba. Most of the ducks taken in eastern Canada breed outside the area inspected each May.

The kill of ducks in the USA and the numbers found alive in January are analysed according to the four flyways into which the 48 states have been divided for administering waterfowl hunting regulations for the last 35 years. The numbers of ducks and hunters in these flyways differ substantially, and this proves useful in studying the impact of hunting on duck numbers. In the USA, the Director of the USFWS, for the Secretary of the Interior, sets a "federal framework" of regulations, including opening dates, season lengths, bag limits, and other restrictions not dealt with here (e.g. the points system that has existed since 1972 as an alternative to the bag limit). State wildlife agencies are free to choose their own limits within the flyway framework, subject to the constraint that their regulations must not be more "liberal" (i.e. they may not promulgate earlier openings, longer seasons, or larger bag limits). I am examining only the effects of changes in the flyway framework here, and largely the differing effects of two groups of seasons: "liberal" in 1955–59, 1970–72, and 1974–80, 14 seasons in all; and "strict" in the 11 seasons of 1960–69 and 1973 (with 1973 denoting the hunting season from September 1973 to January 1974).

As Canada does not use a "federal framework" approach (the provinces not being legally free to issue regulations differing from those agreed between them and the federal government) and as the scattering of ducks in Canada prior to the hunting season does not conform well to the USA flyway system, I have used Canadian data here only to establish the size of the duck hunting effort and the reported kill in the three prairie provinces, which provide most of the ducks wintering in the USA.

Results

1. Duck numbers in May

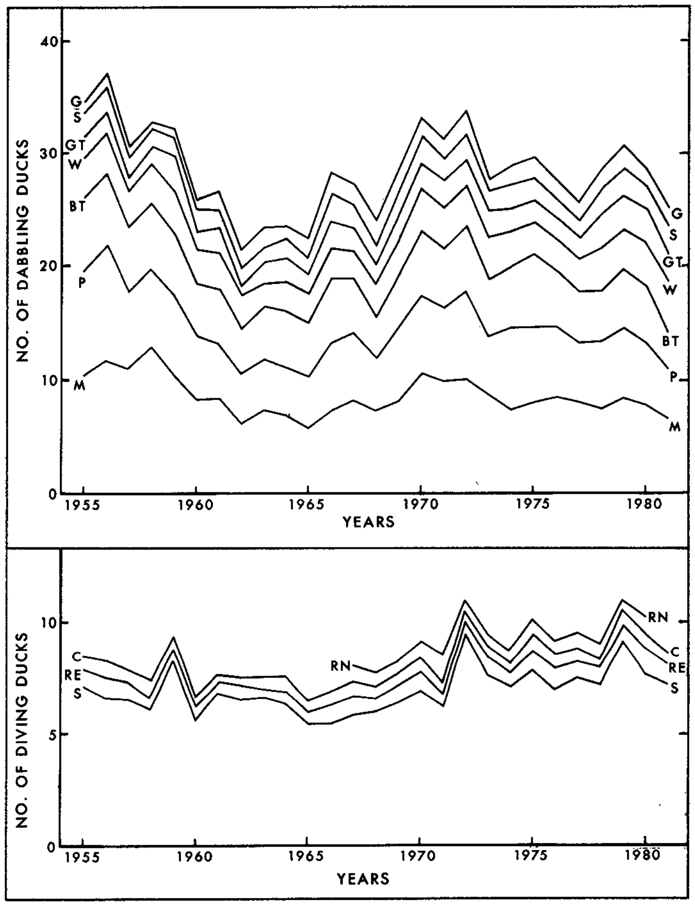
Figure 2 shows the annual May estimates for seven species of *Anas* and five of *Aythya* in the surveyed areas of the prairies and northwest. The pattern for *Anas* is largely determined by changes in the numbers of Mallard and Pintail. In the early peak years, 1955–59, those two species accounted for 33.7 and 24.2% of the total; in the latest 5 years, they represented 28.0 and 19.1%.

The mean annual numbers of dabbling ducks were, in order of decreasing size, Mallard (M) 8.58 ± 1.69 million (with annual coefficients of variation, CV, ranging from 6.0 to 9.0%), Pintail (P) 6.02 ± 1.50 million (CV 7.2–17.3%), Blue-winged Teal (BT) 5.07 ± 0.72 (CV 9.6–20.2), American Wigeon (W) 3.17 ± 0.45 (CV 16.0–23.4), Green-winged Teal (GT) 2.12 ± 0.50 (CV not available), Shoveler (S) 1.96 ± 0.36 (CV 7.5–12.7), and Gadwall (G) 1.47 ± 0.36 (CV 10.3–15.4). The annual coefficients of variation were supplied by R.S. Pospahala, USFWS (pers. commun. April 1983.) Patterson (1979) identified the Blue-winged Teal, Pintail, and Shoveler as the most opportunistic ("*r*-strategists") among the seven species. It is somewhat surprising to find the numbers of Green-winged Teal and Gadwall more variable than those of the Blue-winged Teal and Shoveler. All four species are harder to find and count than the Mallard or Pintail.

Although the general impression is that the numbers of all species tend to vary together, that was often not so. Of the 21 species-pairs amongst *Anas* spp., only eight pairs showed significant correlations over the entire 26-year period at the 0.05 level. The numbers of Mallard and Gadwall varied inversely ($r = -0.49$). There were positive correlations for Pintail with Mallard ($r = 0.729$*), American Wigeon (0.396), and Blue-winged Teal (0.757*); Green-winged Teal with American Wigeon (0.650*) and Shoveler (0.451); Blue-winged Teal with Mallard (0.596*) and Gadwall with Shoveler (0.451) (for values marked with an asterisk, $p < 0.001$).

Among the diving ducks, the scaup (S) play a dominant role, mean 6.62 ± 1.65 million, with Redhead (R) 0.71 ± 0.18 and Canvasback (C) 0.57 ± 0.10 contributing only 16.2% for the whole period. The scaup numbers include *A. marila* as well as *A. affinis*. If the relative numbers in winter surveys and in the kill can be taken as guides, the mean numbers in May should have been about 1.2 million Greater Scaup and 5.4 million Lesser Scaup, the former being a little less numerous than the sum of averages for Redheads and Canvasbacks (1.28 million). Some of the erratic fluctuations in apparent numbers of *Aythya* are attributed to differences in the extent to which they remain together in areas away from their probable nesting areas at the period of the May survey, which is usually flown too early to obtain the most reliable estimates of diving duck abundance and nesting effort.

Figure 2
Annual estimates (in millions) of the May numbers of seven species of *Anas* and five species of *Aythya* in the surveyed areas of the prairies and northwest North America, 1955–81: plotted incrementally from the most numerous species upwards (see Results 1. Duck numbers in May, for key to species labels)



2. Production of young ducks

In determining production from the July surveys, it is impracticable to obtain independent estimates for each species, because a substantial proportion of the broods seen can be identified, at best, only as *Anas* or *Aythya*. The working assumption used here, that all the species in each genus per-form equally well, obscures much that would be of interest. The production indices (P') used for *Anas* and *Aythya* have been calculated (after USFWS 1976) from the equation $P' = P[(LNI + BI)/BP]$, in which BP is the index of brooding pairs, P is the base production rate estimate (for which I have used 1.0 because, on average, the production of young has equalled the size of the adult population), LNI is the late nesting index (of adults seen singly or in pairs and therefore thought still to be involved in a breeding attempt), and BI is the brood index (the number of broods seen).

Aythya start nesting later than most *Anas*, so that relatively few diving-duck broods are seen in most years in the earlier sections of the July survey. The *Aythya* index is therefore constructed only from the late-nesting pairs recorded. The brood surveys for the Canadian prairies provide the longest series. Values for the boreal regions and the north-central states have been interpolated or extrapolated where necessary, using the proportion of the stratum mean values for the numbers of broods or pairs to estimate the missing values for those strata searched incompletely or not at all in a given year. Those mean indices, in thousands, are: southern Mackenzie 19.47 ± 13.02, boreal prairie provinces 42.52 ± 28.20, Canadian prairies 42.27 ± 26.37, Dakotas 3.16 ± 3.17, and Montana 2.11 ± 2.43. I should emphasize that, while 41.3% of reported broods were from the Canadian prairies, 54.1% came from further north, and less than 6% from the north-central states, including Montana. For diving ducks the mean proportion in the Canadian prairies was 38.6%, from the boreal areas 57.9%, and from the north-central USA 3.5%.

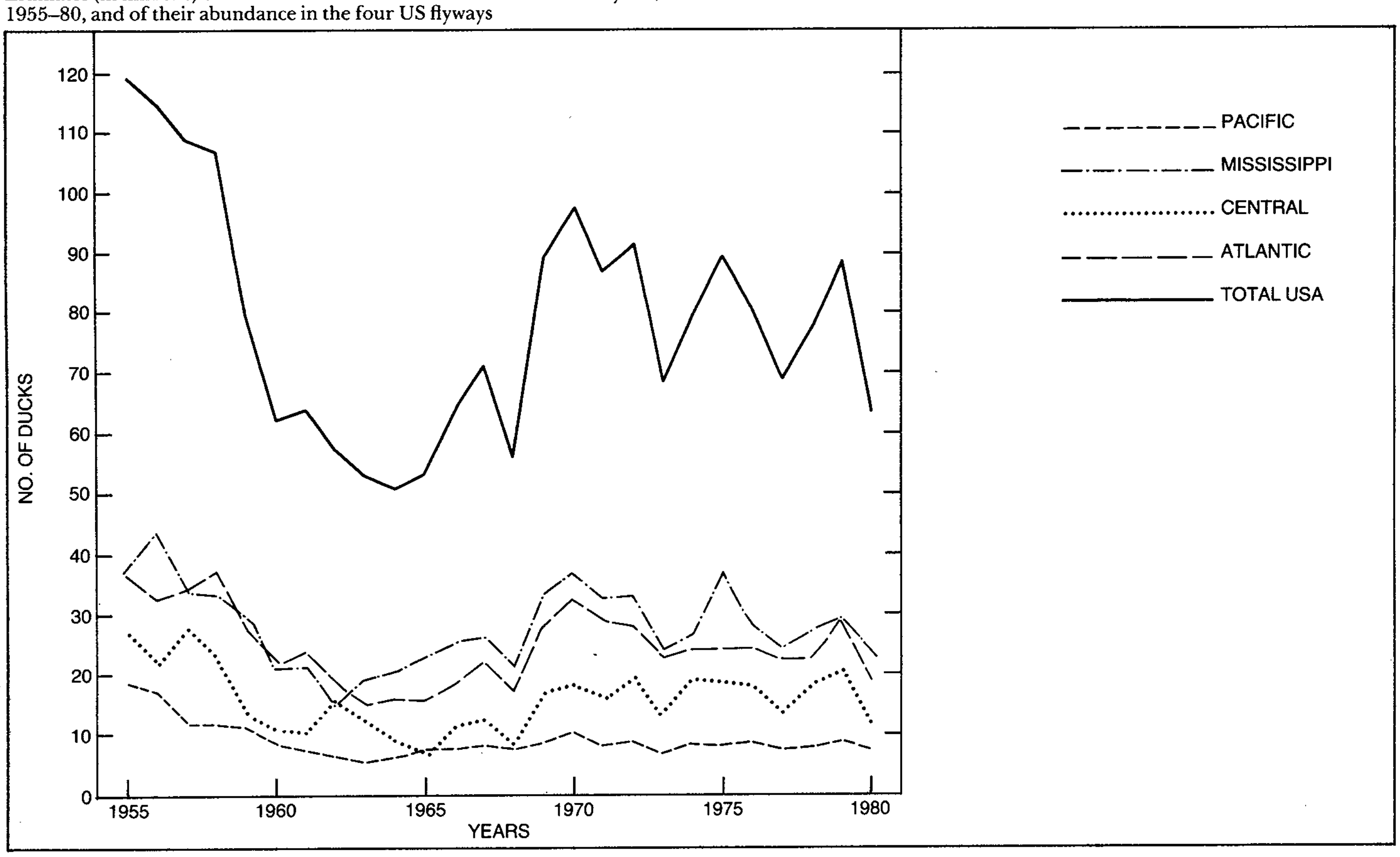
The production index (P') shows some positive correlations with the size of the breeding population (M). The relationship is quite strong for dabbling ducks ($r = 0.687$), and weak for diving ducks ($r = 0.319$). Partly as a consequence of these correlations, fluctuations in the size of the fall flight are greater than those of the breeding population. For most years, the indices for the dabbling and diving ducks are similar ($r = 0.579$), climbing slowly after a steep decline in 1961. I will not explore the reason for these trends and variations here, because only the products, i.e. the size of the fall flight and the proportions of young birds in it, bear on the relationships between hunters and ducks.

The production survey records brood sizes, as well as number of broods. Boyd (1981) noted that the mean brood size in the prairies fell from over 5.8 to less than 5.5 in the later 1950s, rose in the early 1960s to over 5.9, then fell continuously until the late 1970s, when it levelled out at close to 5.0. In the boreal region, from which there were no data for the earliest years, the mean brood size rose from just under 5.0 in the early 1960s to nearly 5.8 in the mid 1970s, falling abruptly in the most recent years, but remaining above the mean for *Anas*.

3. Duck numbers in September

The number of ducks estimated to be on the wing by early September are illustrated in Figure 3. The estimates for September are both larger and less reliable than those for May, from which they are derived. I determined the estimates for the flyways by assuming that the number entering each of them was in proportion to the sum of the kill and the January count in the flyway. These flyway totals, like the September totals for each species, are only crude approximations. Their importance lies in the great disparity between flyways, both in the numbers themselves and in the abundance of ducks in relation to duck hunters.

Figure 3
Estimates (in millions) of total duck numbers in North America in early fall, 1955–80, and of their abundance in the four US flyways



4. Duck hunters

4.1. Sales of migratory game bird hunting permits and hunting activity in Canada

In 1966, the year of their introduction, 380 000 MGBH permits were sold in Canada. Sales increased each year until 1978, except for a minor check in 1974 when the permit fee was raised from $2.00 to $3.50. Peaking at nearly 525 000 in 1975, permit sales have since fallen each year, reaching only 465 000 in 1981 and 1982. In this study, I am focusing attention on the kill reported from the three prairie provinces, because many of the ducks killed in the east (and some in British Columbia) originate from breeding areas that are not surveyed. In the prairies, permit sales were 135 000 in 1966, and rose to 188 600 in 1977 before falling back to 181 750 in 1980, 155 500 in 1981, and 157 500 in 1982. Whether this decline will continue, or has been due to the recent series of dry summers and the associated reduction in duck numbers, remains to be seen.

A surprising number of people buy MGBH permits but do not then hunt (Filion 1980), so that a more useful measure of activity is provided by the respondents to the NHS questionnaire, which includes a question on how many days the hunter was trying to shoot waterfowl. No estimates could be made for 1966. In 1967, prairie hunters reported the equivalent of 865 000 hunter-days. In 1968, the estimate fell by 27% to 630 000 hunter-days. From 1969 onward, the numbers varied around a mean of just under one million hunter-days.

4.2. Sales of US duck stamps and American hunting activity

In 1955, 2.3 million duck stamps were sold. Between 1957 (2.33 million) and 1962 (1.16 million), sales fell by 51%, but by 1970 had reached 2.49 million. They then dropped slowly to 1.92 million in 1980, a fall of nearly 23%. The most interesting feature of the variations in duck stamp sales and in hunting activity was not the large swings between 1955 and 1970, while great changes in duck numbers and hunting regulations were occurring, but the steadying of activity during the 1970s when, nationally, stamp sales declined slowly through a mean of 2.14 ± 0.13 million and waterfowl hunting through a mean of 15.37 ± 0.78 million hunter-days (Fig. 4). The same occurred in all four flyways. In 1980, hunter activity was 24.1% less in the Pacific Flyway than it had been in 1970, 24.3% less in the Central, 15.6% less in the Mississippi, and 10.4% less in the Atlantic. Thus, the greatest changes occurred in the west and the smallest along the Atlantic coast, where opportunities were already least.

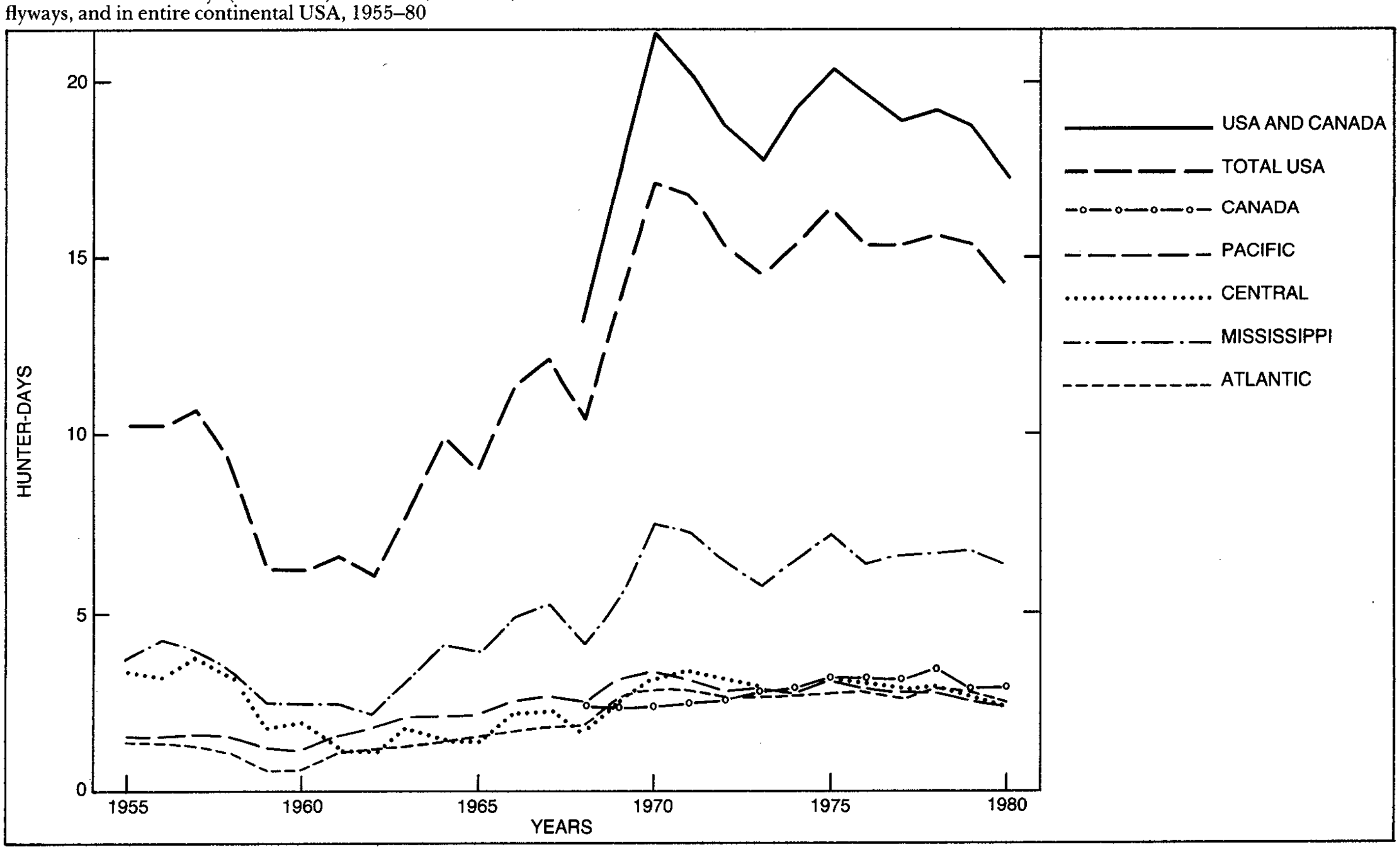
5. Reported kill

5.1. The kill in prairie Canada

The mean kill of *Anas* and *Aythya* in the prairie provinces from 1967 to 1980 was estimated at 1.72 ± 0.32 million ducks, with no trend over the years, the largest kill occurring in 1970 (2.35 million) and the smallest in 1965 (1.05 million). The duck kill in Alberta averaged 773 000, in Saskatchewan 602 000, and in Manitoba 344 000, with no significant time trends overall, but sustained major declines since 1977 in Alberta and Saskatchewan.

Estimates of the kill of individual species in the prairies are available only for the hunting seasons of

Figure 4
Estimates of hunter-days (in millions) in Canada, 1968–80, in the four US flyways, and in entire continental USA, 1955–80



1969–80. Dabbling ducks predominated, with an average kill of all *Anas* of 1.67 ± 0.26 million, compared with only 94 000 ± 34 100 *Aythya*. Mallard accounted for an average of 1.24 million (74%) of the dabbling duck kill, the next most numerous species being Pintail (122 000, 7%). The kills of Mallard, Pintail, Shoveler, and American Wigeon all decreased significantly between 1969 and 1980, as did the breeding numbers of Mallard and Pintail.

There were bag limits of one or two Redheads and/or Canvasbacks in Manitoba throughout the period 1969–80, and in Saskatchewan until 1977. Alberta had no special limits for them, although there had been some a little earlier. Those restrictions may have been partly responsible for the low kill of diving ducks, absolutely and in relation to the breeding populations. However, the kill of Lesser Scaup decreased the most, from 65 000 in 1969–70 to 33 000 in 1979 and 45 000 in 1980, the average kill being about 45 000. The average reported kills of Redheads and Canvasbacks were about 27 000 and 15 000 respectively. The fourth diving duck killed in any quantity in the prairies was the Ring-necked Duck, with a mean of 13 200 ± 4500, 85% taken in Manitoba. The average annual rate of decline in the kill of *Aythya* was 3.8%, compared with 2.4% for the kill of dabbling ducks.

5.2. The kill in the USA

The USFWS publishes its duck kill estimates in two forms — with and without upward adjustment for biases, which include the activity of junior hunters (those under 16 years old who do not have to buy a duck stamp and whose success is low), also memory and prestige bias (exaggerating), and ducks killed but not retrieved. They apply those adjustments only to the total flyway kill, including sea ducks not included in this study. In using figures for individual species, I have made no adjustments here. Unretrieved kill is believed to average one-sixth of the retrieved.

In recent years, the retrieved kill in the Mississippi Flyway (mean 1976–80, 6.2 million) has contributed about 44% of the US national kill (14.1 million), the Pacific Flyway 3.5 million (25%), the Central 2.6 million (18%), and the Atlantic 1.9 million (13%). In 1955–57, when the mean US kill was also 14.1 million, the Pacific Flyway took 3.6 million (26%), the Central 3.2 million (23%), the Mississippi 5.4 million (38%), and the Atlantic 1.6 million (11%). In the 5 lean years, 1959–63, when the mean US kill was only 6.3 million, the Pacific Flyway took 2.3 million (36%), the Central 1.0 million (26%), the Mississippi 2.25 million (36%), and the Atlantic 0.8 million (12%). Thus, the size of the kill in each flyway as a proportion of the US kill has varied much less than the size of the total kill.

The appearance of steadiness is reduced when we look at *Anas* and *Aythya* separately. In the poor years, 1959–63, 39% of *Anas* were taken in the Pacific Flyway, compared with 25% in 1955–57 and 29% in 1978–80. The Central Flyway took proportionately more dabbling ducks (28.7%) in 1955–57 than later (17.9% in 1959–63 and 20.0% later). Among the diving duck kill, only minor changes occurred in the proportions taken in the Atlantic and Pacific flyways; but while, in 1955–57, 25% were killed in the Central Flyway and 42% in the Mississippi, in both 1959–63 and 1978–80 the Central took less than 16%, while the Mississippi Flyway took 54%. Changes in the American kill of individual species can most usefully be discussed in later sections.

6. Effects of regulation changes on hunting activity and kill

6.1. Changes in prairie Canada

To describe changes in the regulations governing duck hunting in the three prairie provinces, I have used an index of (season length) × (daily bag limit) expressed in bag-days. Since few ducks are taken in the latter part of most hunting seasons, most having emigrated before or as soon as winter begins, I prefer using arbitrary cut-offs to the legally designated closing dates. For the northern forested region, where the seasons open in the first week of September, an effective closing is 15 October. Farther south, I have used a cut-off of 30 November, based on the empirical finding that in all years less than 10%, and usually much less, of the reported kill has occurred in December.

I have combined the annual values of the regulation indices for each of the three provinces and the zones within each province into a single figure, R (bag-days), for each province, and have weighted the zone values by the number of successful hunters in each zone. The indices for the provinces overlap considerably: Manitoba mean 454 bag-days, range 306 (1965) to 556 (1980); Saskatchewan mean 562, range 259 (1968) to 722 (1972); and Alberta mean 432, range 236 (1978) to 515 (1969).

In the earliest and latest years of the period 1965–71, the regulation indices for both southern and northern areas of the three provinces show close resemblances. Some wider divergences occurred in 1968–78, with Manitoba imposing greater restrictions than the other two provinces in 1973–77. The duck kill peaked in 1970 and 1976, having been least in 1968. The regulation index was highest in the most recent years, though in Saskatchewan the regulations had been most relaxed in 1970–72.

Although the indices for the three provinces emerge as mostly similar, the resemblances arose in different ways. In Alberta the daily bag limit, five in 1965 and six in 1966, became eight in 1967 and remained so until 1981, except in 1976 when it was lowered to four in response to evidence that the provincial breeding population was low. In Saskatchewan, the bag-day changes resulted more from altering the bag limit than from moving the opening dates, which were uniform throughout the province except in the northernmost zone, while both Alberta and Manitoba had different zone opening dates each year. In Manitoba, with the fewest ducks, bag limits and/or opening dates changed almost every year. In the northern boreal areas of the provinces, with early opening dates, minor divergences appeared in 1969–73 and in 1977.

Neither changes in provincial MGBH permit sales nor hunting activity were significantly associated with the severity of the regulations, except in Saskatchewan, where the number of hunter-days showed moderate correlation with the index ($r = 0.545, p < 0.05$). Yet the reported kills of ducks both in total (K) and as average bag for season ($\bar{K}_s$) correlated with the regulation index (r_{KR} 0.622, $r_{\bar{K}sR}$ 0.682, $p < 0.01$), as well as with the size of the fall flight, F (r_{KF} 0.826, $r_{\bar{K}sF}$ 0.719), the most plausible immediate determinant of hunting activity and success.

These results for the three provinces taken together were matched in each province separately. Partialling out the size of the fall flight reduces the correlations with the regulation index for the prairies as a whole ($r_{KR.F}$ 0.383), for Manitoba (r_{KR} 0.595, $r_{KR.F}$ 0.419) and for Saskatchewan (r_{KR} 0.681, $r_{KR.F}$ 0.373), but not for Alberta (r_{KR} 0.560, $r_{KR.F}$ 0.567), where the regulation index was not associated with the size of the expected fall flight as it was further east:

r_{KF} for Alberta 0.169, Saskatchewan 0.624, Manitoba 0.509. In passing, note that R was more highly correlated with the size of the breeding population in May (M) than with the expected size of the fall flight (r_{RM} 0.759, r_{RF} 0.532), as should be the case, only the size of M being known when the decisions on Canadian regulations were made.

While the prairie kill of ducks fluctuated about the 14-year mean without any sustained trend, the numbers of permit buyers and the days they spent hunting ducks increased. Permit sales in the region were about 136 000 in 1967 and 1968, rose to more than 188 000 in 1977, fell a little in 3 successive dry years to about 182 000 in 1979 and 1980, then more sharply to 155 500 in 1981 (and 159 500 in 1982). The mean annual rate of increase in permit sales was 2.7%, being greatest in Alberta (3.3%), and 2.3% in both Saskatchewan and Manitoba. The corresponding rates of increase in hunter-days were 2.4% in the region, 2.5% in Alberta, 2.1% in Saskatchewan, and 2.8% in Manitoba.

Increased hunting without increased reported kill resulted in declines in the average seasonal bags of successful duck hunters. The mean seasonal bags for the 14-year period were 15.8 in Alberta, 16.7 in Saskatchewan, 11.7 in Manitoba, and 14.7 in the region. The mean annual rates of decrease were 2.2% in Manitoba, 2.1% in Alberta, and 2.1% for the region, the estimated rate of loss of 1.0% in Saskatchewan not being statistically significant.

What is most remarkable about the declines in the seasonal bags is that reported kill by prairie hunters represented on average only 2.2 ± 0.2% of the fall flight from the area covered by the summer surveys. Most of those ducks should have spent some time in the prairie provinces after the end of the breeding season before moving south, although many of the Pintail and Blue-winged Teal doubtless left before the opening of the hunting season. Not surprisingly, there is no indication of a trend in the ratio (ducks killed)/(fall flight), $r = 0.069$.

The decrease in hunting success is reflected also in the mean bag of a successful hunter, 1.76 ± 0.31 ducks per day, reducing by 2.7% annually. The lowest daily bag limit imposed was four, in Alberta in 1976, and the predominant limit was eight. Unfortunately, as Couling *et al.* (1982) demonstrated with respect to the US harvest surveys, estimates of kill and hunting activity show wide departures from normality, resulting in inefficient estimates of the means and their variances, which complicate the use of these results. In relation to the findings on the kill of ducks reported in other sections, the important results seem to be that: (1) in the prairie provinces, duck hunting activity since 1967 has been little influenced by changes in the MBC Act regulations, and (2) the reported local kill has been far below the supply of ducks. Although the stable regulations from 1979 onwards have been "liberal", the reported kill has represented a smaller proportion of the potential permitted take, the product of (no. of MGBH permit sales) × (regulation index); about 1.4% in 1979 and 1980, compared with 2.1% in 1968 and 1969. This seems to indicate that duck hunting in the Canadian prairies is a very inefficient exploitation process, and that the combinations of bag limits and season lengths laid down by the MBC Act regulations affect duck hunting obliquely rather than directly, which seems likely enough.

6.2. Changes in US regulations

I have formed a rough index of the availability of ducks to hunters by dividing the estimated size of the fall flight (F) into each flyway by the number of duck stamp sales (S) (Fig. 5). For the 48 states as a whole the ratio F/S fell from about 50 in 1955–59 to less than 37 in 1976–80, at a mean rate of 1.4%. The Pacific Flyway shows the greatest relative abundance throughout, and its F/S plot follows the changes in fall duck numbers more closely than do the F/S ratios in the other flyways. The plots for the Central and Mississippi flyways are similar (apart from 1962, when the sales of duck stamps in the Central Flyway were exceptionally low). Though the F/S ratio in the Atlantic Flyway was similar to those in the Mississippi and Central flyways for 1955 to 1961, thereafter it remained close to 20 ducks per duck stamp, little more than half as many as in the mid continent.

The Canadian hunting data provide some contrast to the American. The ratio of ducks to hunters was over 100 in 1970, but only 65.8 in 1980. If the ratio continues to fall at the same mean rate of 4.2% per annum, by 1988 it will reach the level of 37 ducks per hunter prevailing in the USA in the late 1970s, which was falling less than in Canada. The kill per 1000 hunter-days has fallen from 1829 in 1970 to 1147 in 1980, at a mean annual rate of 3.7%, while the number of hunter-days has increased from 2.3 million in 1969 to a peak of 3.2 million in 1978, and nearly 3 million in 1980 (mean rate of increase 2.55%).

During 1965–80, the relationship of reported kill to size of fall flight (K/F) rose from about 15% to more than 20% in the Mississippi and Atlantic flyways, while remaining at about 15% in the two western flyways (Fig. 6).

To see how far these observations reflect variations in the restraints imposed on duck hunters by waterfowl hunting regulations, it helps first to establish whether duck stamp sales (S) and hunter-days (D) are affected by regulation changes as well as by the changes in duck numbers that prompted those alterations. For the continental USA, both stamp sales and hunter-days are highly correlated with the US regulation index, R_u ($r_{RuS} = 0.864$, $r_{RuD} = 0.702$). (R_u is a weighted mean of the four flyway indices.) Significant correlations are also registered in the Central, Mississippi, and Pacific flyways, in descending magnitude.

Looking at the relationship between regulations and duck hunting activity in each flyway, I have found it useful to split the regulation index into its components, season length (l, in days) and bag limit (not more than B ducks to be taken in one day). In the Pacific, Central, and Atlantic flyways, increases in season length (l) were strongly associated with increases in duck stamp sales (S) and hunter-days (D) (Table 3). The size of the kill was also associated with season length in the Atlantic and Central flyways and, weakly, in the Pacific. Despite an indication that the amount of hunting in the Mississippi Flyway may have been affected by season length, duck stamp sales and kill did not show such a response.

An increase in bag limit was associated with increased duck stamp sales, strongly in the Pacific Flyway, less so in the Central and Atlantic, and weakly in the Mississippi Flyway. Hunter-days were correlated with bag limit in the Pacific Flyway (strongly) and the Central Flyway, but not in the two eastern flyways. That negative finding becomes more interesting when we note a significant correlation between bag limit and kill in the Mississippi and Atlantic flyways, but not in the Central and Pacific flyways. In testing for these associations, the series in most flyways in recent years are unhelpful because the changes in season length or bag limit were so small that they were unlikely to have had detectable effects.

The general result, that changes in season length usually have greater consequences for duck hunting than changes in the bag limit, is in no way novel. The most thorough study of the effects of hunting regulations on the activity and success of duck hunters in killing Mallard (Martin and Carney 1977) emphasized, however, that the con-

Figure 5
Estimated numbers of ducks in the US fall flight divided by numbers of duck stamps sold, 1955–80

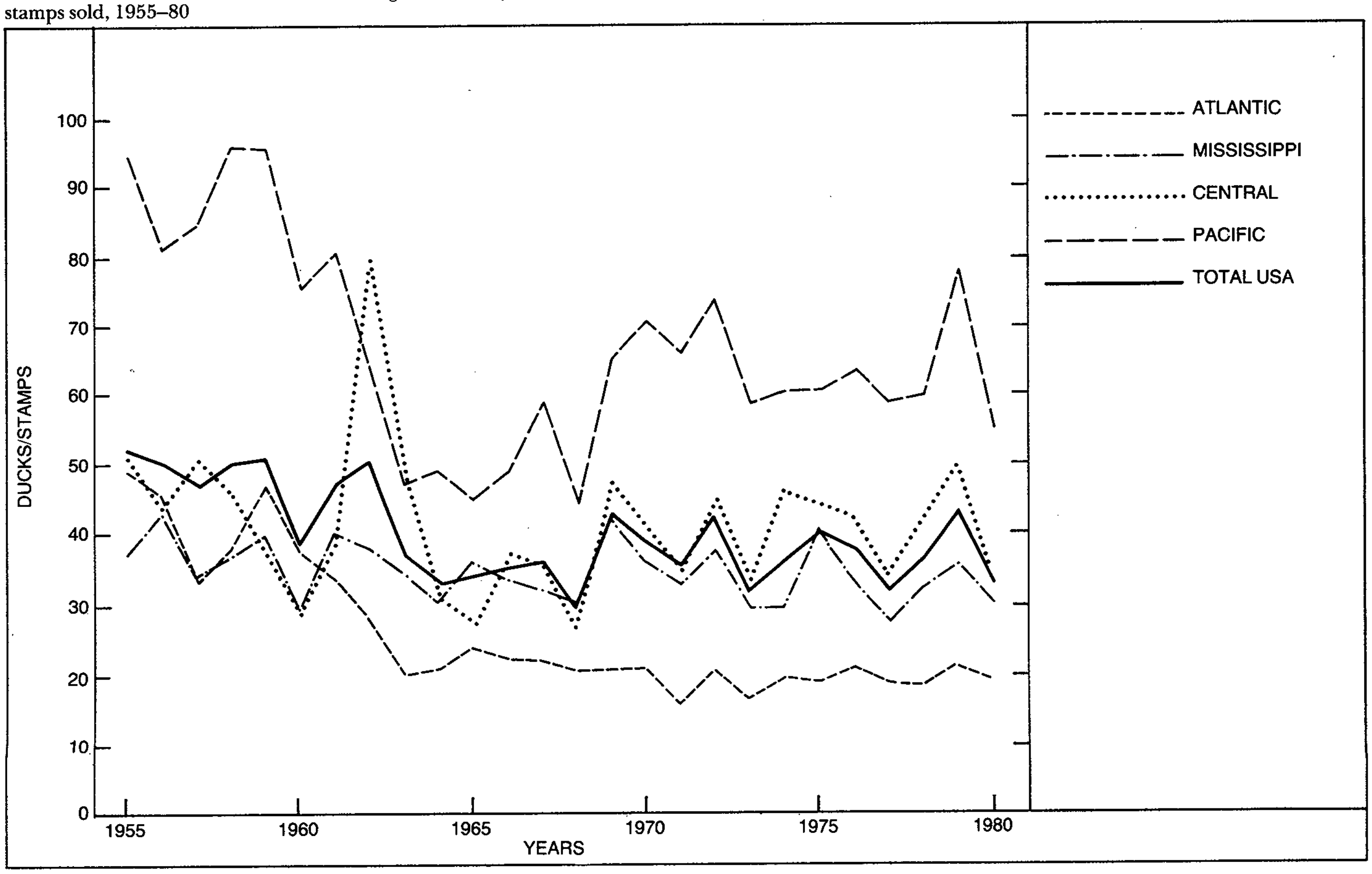


Table 3
Correlation coefficients between US national and flyway regulation indices (R) and reported kill (K) 1955–80, without and with partialling out of size of fall flight (F); and correlation between K, R, and F in the four flyways. Only values of r for which $p < 0.05$ are entered; $*p < 0.01$, $**p < 0.001$

Area	Genus	*KR*	*KF*	*KR.F*	*KR.F*	*KR* 1955–60	*KR* 1961–70	*KR* 1971–80
All USA	*Anas*	0.551	0.746	0.691	0.402	0.820*	0.922**	—
	Aythya	0.642	0.520	0.456	—	0.894*	0.730*	—
	Both	0.828	0.656	0.685	—	0.948	0.854**	0.724**
Pacific		—	0.469					
Central		0.898	0.749					
Mississippi		0.828	0.600					
Atlantic		—	—					

sequences of regulation change may be very different in different parts of the USA, so that wide generalizations on their effects will not often be helpful.

The association between US hunting regulations, as measured by R, and the kill of *Anas* and *Aythya* separately and collectively, are shown for the USA as a whole and for each flyway in Table 3. The correlations are higher for *Anas* than *Aythya* in six of the eight cases in which $p < 0.05$ for one or both genera.

While the effects of hunting regulations on duck kill at the flyway level can be explored in several other ways, the important result is that changes in US hunting regulations seem often to have been followed by changes in the retrieved kill of ducks.

There proves to be a direct, rather than an inverse, relationship between the size of the US kill and the number of ducks in the following May. The correlation between M_t and K_{t-1} is 0.722 and remains positive, at 0.465, after the partialling out of the size of the fall flight. The correlation between M_t and R_{t-1} is also positive and high, 0.748, becoming 0.513 after the partialling out of the kill. These correlations presumably reflect the fact that K_t, as well as M_t, is an index of population size, while the regulatory authorities have tended to adjust R in response to the size of the expected fall flight.

Another way of estimating the effects of restrictive regulations on the number of ducks in the following May is to compare the estimates actually obtained in the years 1959 to 1970 with those expected from the regression of M (in thousands) on year Y (in the form '77' for 1977), derived from the data of 1955–58 and 1971–81, to estimate the relation $\hat{M}_t = 54294 - 212.8Y$, with $n = 15$, $r = -0.614$. Had the restrictive regulations helped to ensure higher adult survival and recruitment, the numbers observed in May in the inter-

Figure 6
The kill (K) as a percentage of the fall flight (F) in the USA, nationally and in each flyway, 1955–80

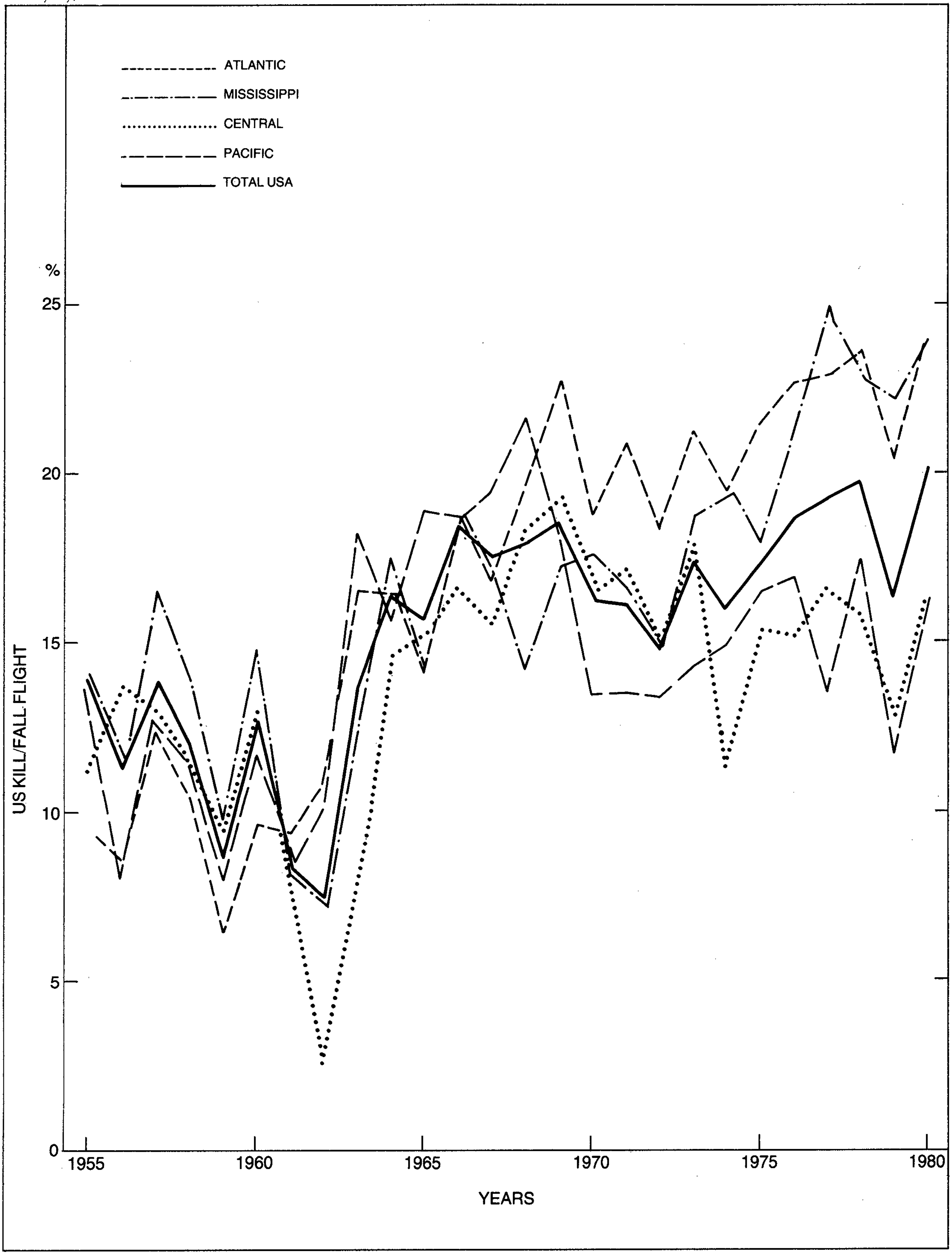


Table 4
Correlation of US regulation index (R) and kill of adult and 1st winter *Anas* and *Aythya*, 1966–80, comparing five seasons with strict waterfowl hunting regulations (R_-) and 10 seasons with liberal regulations (R_+). Values of r significant at 5% level marked with asterisks

Genus	Age	R_- (5)	R_+ (10)	1966–80 (15)
Anas	Adult	0.611	0.179	0.530*
	1st winter	0.769*	0.849*	0.826*
Aythya	Adult	0.303	−0.295	−0.079
	1st winter	0.427	0.019	0.101

vening years of 1959 to 1970, when the regulations were relatively severe, would have been greater than expected from that equation. In practice, they averaged 16% less.

As, with the possible exception of the permit sales record, all the annual statistics are more or less incomplete or biased, I think it useful to look at pooled results from several years, in addition to using the time series. Most of the annual values of the regulation index, R_u, have fallen into two groups, with ranges of 150–225 and 325–362 bag-days. Adding the intermediate value, $R_u = 278$ in 1973, and the two lowest values, each 120, to the first group produces sets of 12 years with strict regulations ($R < 280$ bag days) and 14 years with liberal regulations ($R > 320$). In Table 4 these two groups are compared with respect to the size of the fall flight (F) and breeding population (M) in the following year, the retrieved kill in the US (K), estimates of total losses (L) obtained by subtracting M_{t+1} from F_t, and of losses from causes other than reported hunting (L–K). Losses in seasons of strict regulations were less than losses in liberal seasons due to reductions in the numbers of "other losses", rather than in the kill (a disparity of 1.9% has little weight in this comparison of imprecise estimates).

The relationships of size of fall flight (F), kill (K), and total losses (L) with the regulation index (R) are not what might be inferred from their time trends since 1955. Though L/F increases with R, it has tended to decrease over time. K/L has increased substantially over time but shows no relationship to R. K/F has increased with R and, to a much greater extent, over time.

7. Effects of changing hunting regulations on losses of ducks from September to May

The effects of regulation changes on the kill of ducks are obviously of interest for the management of duck hunting. Their possible effects on survival between one breeding season and the next are potentially of even greater importance, because losses from all causes determine how large the breeding populations will remain. It is worth noting initially that many of the losses over and above the *reported* kill could nevertheless be due to hunting, either illegal or unreported, including the take by subsistence hunters, which is not sampled by the national harvest surveys.

7.1. Effects of regulation changes in prairie Canada

Although the total reported duck kill in the prairie provinces averages only about 2.2% of the continental fall flight, its impact is much greater than that figure suggests. This is best explored initially by concentrating on the Mallard, for which estimates of the provincial and regional numbers are available for the fall flight, as well as for May. Estimates of the kill in the prairie provinces first became available in 1968, providing a 13-year run of data.

The reported kill of Mallard in the prairies is well correlated with the estimated size of the fall flight in each province, the flight in turn being related to the population in the previous May, with only estimates of the latter available to the decision-makers at the date by which Canadian hunting regulations must be set.

As the annual regulation indices in different provinces do not group themselves conveniently, I have used an arbitrary grouping system here. Of the 13 index values for each province, I took the four lowest to represent *strict* regulations, and the four highest *liberal*, with the remaining five grouped as *intermediate*. Pooling the annual estimates of fall flight (F), kill in the prairies (K_c), and total losses from September to May (L) for the three classes in each province, and then expressing K_c/F, L/F, and K_c/L as percentages, yields the results summarized in Table 5 and Figure 7.

I have estimated total loss by subtracting the observed numbers in the next May, M_{t+1}, from the estimate of fall flight, where $F_t = M_t(1 + P_t')$. It is assumed that no immigration or emigration takes place. Though banding has shown that many individual movements do take place, particularly from one year to the next, there is at present no accepted way of determining net gains and losses from one province to the neighbouring provinces or (north-central) states.

The three provinces differ widely in the apparent proportion of the provincial fall flight of Mallard shot in the same province: nearly 39% in Manitoba, 19% in Alberta, and less than 9% in Saskatchewan. The estimated rate of loss from all causes in Manitoba Mallard is extremely high (75%), enough to require sustained immigration to maintain the population at the levels of the latest decade. In contrast, gross overwinter losses of 54% of Saskatchewan and 57% of Alberta Mallard can probably be offset by local production fairly readily, although the situation in Alberta is deteriorating rapidly (Boyd and Cooch 1983). The reported local kill appears to have accounted for just over half the take and winter losses in Manitoba, compared with one-third in Alberta and one-sixth in Saskatchewan.

The secondary grouping into years with strict, liberal, and intermediate Mallard hunting regulations yields some unexpected results. In Manitoba, the ratio K/F was much higher in intermediate than in strict or liberal seasons. In Saskatchewan, the low annual K/F rates varied little. In Alberta, the ratio K/F was highest in the years with strict regulations.

In all three provinces, the ratio L/F% (where L = fall and winter losses from all causes, including reported kill) was least in the seasons with the most restrictive regulations, while the ratio of reported kill to all losses (K/L%) was much higher in years with strict Canadian regulations than in liberal seasons. For the prairies as a whole, K/L was 35% in years with strict prairie seasons, compared with 24% in years with intermediate regulations and less than 20% in liberal years. The spread in the K/L ratio between strict and liberal seasons was much wider in Manitoba, where Mallard were relatively scarce, than in Alberta or Saskatchewan.

The pooled data for *Anas* and *Aythya* show significant correlations between the regulation index and the losses of ducks from September to May ($r = 0.610, p < 0.02$), as well as with the reported kill ($r = 0.622, p < 0.02$), these correlations being greater than those between overwinter losses and the numbers of young in the fall flight.

Because young ducks are easier to shoot than experienced ones, one obvious explanation for year-to-year variations in the prairie kill is that the proportions of young birds in the fall flight have varied. Yet the correspondence of the size of the fall flight with production, expressed as fledged young per 100 adults in the kill, proves to be not very close ($r = 0.509$ in Manitoba, 0.423 in Saskatchewan,

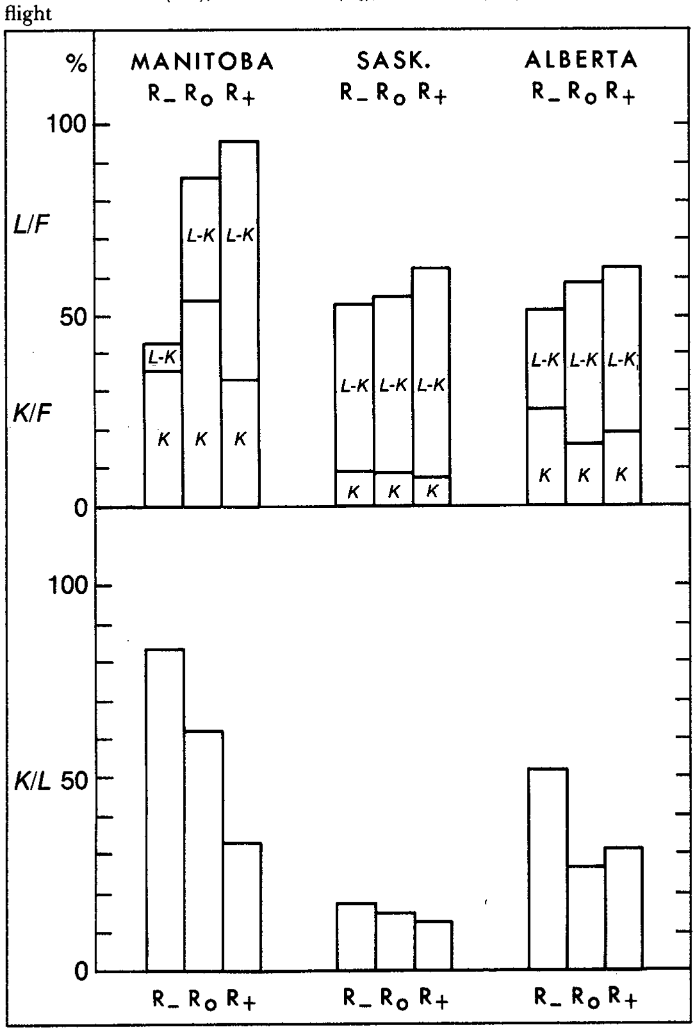
Table 5
Effects of changes in US regulations on rate of loss of ducks from September to May (L/F) on reported kill (K), on ratio of numbers in succeeding January to those in same year (W_{t+1}/W_t), and on ratio of breeding population in following year to that in previous summer (M_{t+1}/M_t). Changes in regulation index of less than 1 SD (standard deviation) are treated as "no change" (R_o), those of more than 1 SD as R_+ = more liberal or R_- = more strict. K and W_{t+1}/W_t are calculable for each flyway, as well as nationally, but L/F and M_{t+1}/M_t only nationally. Responses are shown as +, o and –, using ±1 SD as criterion

Resp. all USA																				
	L/F				K				W_{t+1}/W_t				M_{t+1}/M_t				Total			
Regul. changes	(n)	+	o	–	(n)	+	o	–	(n)	+	o	–	(n)	+	o	–	(n)	+	o	–
R_+	(7)	5	2	–	(7)	5	2	–	(7)	3	4	–	(7)	3	4	–	(28)	16	12	–
R_o	(15)	4	6	5	(15)	2	8	5	(15)	3	6	6	(15)	1	10	3	(60)	11	30	19
R_-	(3)	1	–	2	(3)	–	1	2	(3)	–	2	1	(3)	–	1	2	(12)	1	4	7

Kill changes in flyways																				
	Pacific				Central				Mississippi				Atlantic				Total			
Regul. changes	(n)	+	o	–	(n)	+	o	–	(n)	+	o	–	(n)	+	o	–	(n)	+	o	–
R_+	(5)	2	1	2	(5)	4	–	1	(7)	5	1	1	(3)	1	2	–	(20)	12	4	4
R_o	(17)	4	7	6	(15)	3	7	5	(10)	4	4	2	(19)	5	9	5	(61)	19	25	17
R_-	(3)	1	–	2	(5)	1	–	4	(2)	–	4	4	(3)	1	1	1	(19)	3	5	11

W_{t+1}/W_t in flyways																				
	Pacific				Central				Mississippi				Atlantic				Total			
Regul. changes	(n)	+	o	–	(n)	+	o	–	(n)	+	o	–	(n)	+	o	–	(n)	+	o	–
R_+	(5)	2	2	1	(5)	4	–	1	(7)	5	2	–	(3)	1	2	–	(20)	12	6	–
R_o	(17)	4	7	6	(15)	3	7	5	(10)	4	5	1	(19)	5	9	5	(61)	16	28	1
R_-	(3)	1	1	1	(5)	1	–	1	(8)	–	3	5	(3)	1	1	1	(19)	3	5	1

Figure 7
Relative sizes of the kill (K) and of all losses (L) from September to May among Mallard in the three prairie provinces in years when provincial regulations were strict (R_-), intermediate (R_o), and liberal (R_+) F = size of fall flight



and 0.449 in Alberta, with $0.1 > p > 0.05$). A close relationship between the production index from the July surveys and the proportion of young Mallard in the reported kill was found only in Saskatchewan ($r = 0.718, p > 0.02$). Manitoba showed no evidence of association ($r = 0.048$), and in Alberta it was tenuous ($r = 0.455, 0.10 > p > 0.05$). These are disconcerting findings because, for most species of ducks, we have no annual indices of production other than the proportion of young birds found in the wing samples of the SCS. The proportions of young found in the Canadian SCS differ between species and between years within samples of a single species, so that neither reliance on Mallard data to indicate the output of other species, nor the use of a fixed production ratio for each species, is likely to be satisfactory.

7.2. Effects of changes in US regulations on duck numbers

The estimated total losses of *Anas* and *Aythya*, taken together, between September and May show a close linear relationship to the size of the fall flight: $\hat{L} = 0.837F - 23.52$ (L and F in millions), with $r = 0.985$. The relationship between the reported kill in the USA and the size of the fall flight was not quite so strong: $\hat{K} = 2.61 + 33.5R$ (K in millions, R in bag-day units), $r = 0.828$. In the Mississippi and Central flyways, increases in R were followed by increases in K, but in the Pacific and Atlantic flyways the responses were less clear.

Substantial changes (10%) in US regulations nationally and by flyway can be compared with the responses expected in the kill, with total losses from September to May, and with numbers in the next breeding season. In 14 of 25 years, the changes in R were so small that they could scarcely be expected to yield a measurable reaction (R_o). In those 14 seasons, 28 of 56 entries were zero, with 11 unprompted increases and 17 decreases. In years when the regulations were relaxed (R_+), there were 16 increases in K, L', M', or W', 10 cases without detected changes, and two in which more liberal regulations were followed by reduced losses.

In only four seasons did sharp reductions in the regulations occur nationwide (R_-): 1959, 1960, 1961, and 1973. Nine of 16 responses in those seasons were in the expected direction, only one opposed.

I have found it impracticable to analyse changes at the flyway level between losses and breeding numbers, because there are no simple relationships between the number of ducks wintering in a flyway and those occurring in some readily defined parts of the breeding range. Instead of a May population index, we can use $W' = W_{t+1}/W_t$, the ratio of the number of ducks found in the flyway in January of year $t+1$ to those found in year t, using the convention that t refers to the breeding year, so that the index is one of change from before to after the breeding season t. The rationale for supposing that this ratio may be responsive to changes in R is that relatively little hunting takes place in the late winter and spring, nor are losses in that period from other causes expected to be large, except for a few species in severe winters, so that W_t is a rough substitute for M_t. Although the estimates of K, M', and W' are derived from independent sources, their responses to changes in R_u are alike. Changes in the intended directions occurred in 70 of the 122 responses to regulation changes, with 15 in the opposite direction and 37 cases with no clear response.

Recalling that L' and M' refer respectively to losses from all causes between September and May, and to changes in May numbers from one year to the next, we should note that their responses to changes in R resembled those shown by the reported kill (K): 8 of 11 responses shown by K were in the intended direction, the remaining 3 being null; 7 of 11 responses shown by L' and only 5 of 11 shown by both M' and W' were as intended. For M' and W' together, 10 responses were as intended and only one opposite, with 11 responses too small to be detected. Thanks to the large proportion of minor reactions, this appears to offer poor support for an argument that regulating the US kill affects the size of the breeding population. Nor is that case much strengthened by looking at the responses in each flyway separately: for the reported kill, 23 of 39 responses were as intended, 9 undetectable, and 7 opposed; for the winter count ratio W', 22 responses were as intended, 12 undetectable, and 5 opposed.

The responses of *Anas* and *Aythya* to appreciable changes in regulations separately show that the national kill, (K), moved in the expected direction 8 of 10 times for *Anas* and 7 for *Aythya*. Of the 40 possible flyway responses by *Anas*, 27 were in the anticipated direction. Only 22 of 39 flyway-level responses by *Aythya* were as intended, and 8 were contrary.

The generic changes in the winter count ratio (W') in response to changes in R were inconclusive. For *Anas*, 6 of 10 national changes, but only 10 of 39 at the flyway level, were as intended. For *Aythya*, none of the 10 national changes in W' and only 10 of 39 in the flyways were as expected.

In winters when the kill was large, so was the relative abundance of ducks in January (in 33 of 40 cases). When the kill was small, so was the winter population (in 30 of 40 cases). This indicates that the reported US kill was not the sole, nor even perhaps the principal, determinant of the number of ducks alive in January. It does not, of course, imply that the size of the kill was not important in determining the general level of abundance after the end of the hunting season and in the following season.

Discussion

It will be recalled that Scott (1979) estimated that though Europe has about the same number of waterfowl hunters as North America, the latter's duck population is four times greater, and the average annual kill of ducks and geese by a successful North American hunter is 80% greater than that of a European counterpart. Matthews (1981) interpreted these findings as evidence of the extravagance and redundancy of North American waterfowl management, apparently on the grounds that Europe still has a lot of ducks and successful duck hunters. A contrary interpretation is at least as plausible, that the greater abundance of ducks and the greater success of hunters in North America have been due to the effectiveness of the large-scale and unified system of management that has been operating in North America for nearly half a century.

By successful restraint of demand since 1970 (see Figs. 4 and 5), it has proved possible to sustain both duck numbers and hunters' satisfaction at far higher levels than in Europe, where *laissez faire* prevails. There have, of course, been substantial costs, met in part and involuntarily by the farming community and by taxpayers at large, though predominantly by waterfowl hunters themselves, but those costs are small in relation to the benefits derived by hunters and others who enjoy waterfowl, and by those who cater to them. In Canada, waterfowl hunting alone generates some $230 million of expenditures annually, and economists have estimated that the waterfowl resource is worth at least $1.2 billion (Canadian Wildlife Service, unpubl.).

Although the results in earlier sections suggest that fine tuning of demand by continually modifying hunting regulations to reflect changes in duck numbers has not been very effective, and may have been unnecessary at the past levels of duck abundance and hunting activity, this in no way justifies abandoning annual surveys of duck numbers and production, or of hunting activity and kill. Recent events, e.g. changes in the numbers and survival of Black Ducks in the west of their range and rapid changes in hunters' success in southern Alberta, show that a monitoring system, effective at least down to the provincial level, is necessary to ensure that potentially damaging changes in the relationships between ducks and hunters are detected early enough to put remedial measures in place. Moving from detected high risk to agreed remedies is, of course, a laborious business, involving much argument at several levels, as well as lengthy regulatory processes, so that early warning is a necessary, though not sufficient, prerequisite for effective action. It is likely that, as the kill continues to increase as a proportion of the supply and of death from all causes, some changes in duck numbers will be "catastrophic" rather than gradual. Anderson and Burnham (1976) pointed out that there are likely to be threshold points or areas of rapid transition from one level of abundance to another as the system ceases to be in equilibrium, and that kill in breeding areas is especially likely to bring about such shifts. Thus, Canada has a special responsibility for monitoring local kill in relation to local supply.

A second strong reason for retaining and improving the population and harvest surveys is that they provide a unique long-term monitoring system for waterfowl populations. Large-scale studies of entire populations and subpopulations of many animals are scarce. Yet, for further understanding of ecological systems, we must carry out extensive as well as intensive investigations, and continue these over a wide range of climatic conditions and changing human impacts on lands and waters. With runs of data of 15–28 years now available, we can begin to determine the relative importance, on the continental scale, of different events. These extensive sample surveys may never be precise or accurate enough to provide by themselves convincing evidence of causation, but they will be of great value in sorting out major issues from minor ones, both in biology and in the management of renewable resources. With the aid of locally intensified surveys and other investigations, they can serve as powerful tools for research, as well as for management.

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