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Duck numbers and duck hunting in southern Alberta, 1975–82, and their implications for waterfowl management

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Abstract

From 1975 to 1982, southern Alberta's estimated May population of ducks fell from 6.5 to 3.6 million, a mean rate of −5.6% annually. Mallard declined more steeply, from 1.4 million to just under 800 000 (−7.4% annually). In the same period, the July index of the US Fish and Wildlife Service (USFWS) for breeding production of all ducks fell from 160.0 to 40.6 (−18.0% annually), while mean brood size fell from 4.6 to 3.8, the lowest yet reported. The late nesting index also fell, from 117.2 to 28.5 for all ducks, and from 30.8 to 7.5 for Mallard. Meanwhile, in 1975–81, estimates of successful duck hunters in southern Alberta fell from 22 400 to 15 700 (−6.4% annually), and to 14 300 in 1982, a further −9.0%. The reported kill of ducks fell from 299 000 to 201 000 (−7.9% annually) and of Mallard from 153 000 to 138 000 (−4.6% annually). The reported kill of all ducks in 1982 was 139 000, including 96 000 Mallard.

Most of the decline in duck numbers and production can be attributed to unfavourable habitat conditions, which are persisting, but the impact of local hunting is also serious under such poor conditions. Any substantial increase in the permitted Alberta kill would put severe pressure on the USFWS to abandon its efforts to hold down the US kill through the 5-year stabilization program for the Pacific and Central flyways.

Introduction

Duck numbers in the prairies show large fluctuations, principally in response to varying amounts of precipitation, especially snowfall, and consequent variations in the numbers and biological productivity of potholes and other small water bodies, and in lake levels. In the last half-century, drainage of wetlands for agriculture or urban and industrial development has been added to this long-term cycle, and has been especially intense in the last decade with the advent of larger machines both for cultivation and for clearing and draining land. Thus we need to look especially closely at the size and success of prairie duck populations in this period of high potential stress.

A second reason for concern, less fundamental in ecological terms but of considerable tactical importance in the context of North America waterfowl management, relates to the current experiment in which the USA and Canada have agreed to leave waterfowl hunting regulations unchanged for at least 5 years, while monitoring duck populations and duck harvests more intensively than before. This is expected to provide a better understanding of the roles of hunting and other factors in regulating duck populations, and hence to improve the international approach to their exploitation. Some hunting organizations in parts of both countries have become increasingly critical of this "program of minimal change", for quite different reasons. Some groups argue that their hunting opportunities are being unnecessarily restricted and that seasons should be lengthened or bag limits increased at once in their regions, whatever may be happening elsewhere. Others fear that the current regulations are dangerously permissive at a time when prairies conditions are unfavourable for ducks, and argue that serious long-term damage to duck stocks must be prevented by abandoning "no change" in favour of further restrictions on hunting, so as to allow increased numbers of ducks to return to potential breeding places. To proponents of both arguments, allowing the 5-year program to run until 1984 before deciding on future directions is a reprehensible example of bureaucrats giving more weight to their own interests than to those of the hunting constituency or of the ducks themselves.

The decision to persist with the current program or to deviate from it in one direction or the other therefore must be justified afresh before Canada and the USA promulgate waterfowl hunting regulations for 1984. This progress note originated in a contribution to the 1983 review process. It highlights events in southern Alberta, where recent reductions in duck numbers and breeding success, and in the activity and success of duck hunters, have been exceptionally large.

We have obtained the data from routine surveys — the USFWS/CWS surveys of waterfowl breeding numbers in May and production in July, the CWS National Harvest Surveys (NHS) based on sales of migratory game bird hunting permits (MGBH permits), and the recoveries of ducks banded pre-season in western Canada and adjacent states. No novel methods of analysis were employed. Many interested people have reservations about the reliability and usefulness of these large-scale surveys, which are not intended to be precise measures. However, we see no reason to suppose that any changes occurring in the surveys' effectiveness would have caused the downward trends in duck numbers and kill revealed in this report.

We have used 1975–82 in analysing population changes, so as to give a sufficient run of years to detect current trends without being led astray by erratic year-to-year variations; 1975 was a good year for prairie ducks, but by no means an exceptional one. For Canadian harvest data, the period of analysis is 1975–81, the results for 1982 not being available at time of preparation.

The principal questions we address are:

(1) How have numbers of breeding ducks in southern

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Alberta changed since 1975, and in relation to changes in other areas sampled in Canada and the USA?
(2) How has duck production varied in southern Alberta since 1975, and in relation to changes in the Canadian and US prairie regions as a whole?
(3) How have duck hunting effort and the reported kill of ducks changed since 1975 in southern Alberta and adjacent states and provinces?
(4) How far is it possible to account for the observed changes in duck numbers in southern Alberta since 1975 in terms of production, local kill, distant kill, and local habitat conditions?
(5) What predictions can be made about the likely numbers of breeding ducks in southern Alberta in May 1983 and in later years?
(6) What effect on the kill of ducks in southern Alberta in 1983 might result from advancing the opening of the duck season to 5 September?

Although there have also been substantial changes in the size of the reported kill of geese in southern Alberta since 1975, including the virtual disappearance of Ross' Geese from the bag, we have not reviewed them here because they would not add significantly to the arguments, while adding considerably to the bulk of this report.

Results: duck populations and production

Numbers of ducks in southern Alberta in May

Southern Alberta is a major breeding place for ducks, with an estimated average of nearly 5 million present on the 166 500 km^2 included in the four strata (USFWS 26–29) making up the region. A density of nearly 30 ducks/km^2 over such a large area is exceeded in few other regions.

The total numbers of ducks (Table 1, Fig. 1) fell from 6.54 million in May 1975 to 3.56 million in May 1982, a decrease of 45.6% at a mean annual rate of −5.56%. The rate of loss was irregular, large gains in 1978 and 1979 offsetting the very large drop from 1976 to 1977, and with a further major fall from 1981 to 1982. After 1977 the greatest fluctuations within the two principal genera, *Anas* (the dabbling ducks) and *Aythya* (the pochards), were found amongst the dabbling ducks other than the Mallard.

In Figure 2, we compare the changes in southern Alberta with those over the entire area covered by the May surveys, from Alaska and the Mackenzie Valley to South Dakota and Wisconsin. Clearly the declines observed in southern Alberta were much steeper than those throughout the sampled range.

Amongst the 16 species of ducks regularly found in the surveys of southern Alberta (Table 1), none showed an increase over the 8-year period and five showed significant declines: Mallard decreased at an average rate of −7.5%, Gadwall −3.6%, Green-winged Teal −6.5%, Redhead −14.4%, and Canvasback −8.0%.

Amongst the diving ducks, the variability of the annual estimates, as indicated by the coefficient of variation (CV), was inversely proportional to population size ($r = -0.553$). For the dabblers, the relationship between size and variability was direct ($r = 0.511$), reflecting the tendency of such species as Pintail, Blue-winged Teal, and Mallard to immigrate and emigrate readily as habitat conditions change.

Duck production in southern Alberta

Although we can convert the number of ducks seen in May to estimates of the population of each species, allowing for differences in their detectability as measured by air/ground comparisons, that degree of detail cannot be achieved in estimating production. The proportion of broods seen at all is much less than that of the adults in May, and many of the broods cannot be identified by species.

Table 1
Mean estimates (in thousands) of ducks in southern Alberta in May 1975–82

Species	Mean	SE	Trend (% pa)
Mallard (*Anas platyrhynchos*)	1025	259.3	− 7.5
Gadwall (*A. strepera*)	314	52.6	− 3.6
American Wigeon (*A. americana*)	303	97.8	—
Green-winged Teal (*A. crecca*)	244	62.1	− 6.5
Blue-winged Teal (*A. discors*)	770	278.7	—
Shoveler (*A. clypeata*)	390	103.4	—
Pintail (*A. acuta*)	943	427.7	—
Total dabblers	3991	912.3	− 5.9
Redhead (*Aythya americana*)	187	108.9	− 8.0
Canvasback (*A. valisineria*)	82	26.2	—
Lesser Scaup (*A. affinis*)	521	105.9	—
Ring-necked Duck (*A. collaris*)	8	4.0	—
Total pochards	785	177.4	—
American Goldeneye (*Bucephala clangula*)	18	13.9	—
Bufflehead (*B. albeola*)	46	11.6	—
White-winged Scoter (*Melanitta deglandi*)	22	12.1	—
Common Merganser (*Mergus merganser*)	7	4.3	—
Ruddy Duck (*Oxyura jamaicensis*)	85	52.0	−16.4
Total ducks	4966	1000.7	− 5.6

The number of broods seen in 1975 extrapolates to 112 300 for southern Alberta as a whole; the corresponding figure in 1982 was only 21 200. The highest estimates were of 131 900 in 1978 and 129 300 in 1979, when May duck numbers (4.43 and 5.44 million respectively) were well below the 6.54 million of 1975. Despite that short-lived boom, the mean annual rate of decline in the estimated numbers of broods was −14.9% (Table 2). The mean size of class II and III broods was 4.8 ± 0.6, range 3.8 (1982) to 5.4 (1978). Although the 1982 broods were the smallest seen, the tendency for broods to decrease over the period as a whole was not statistically significant ($r_{b \cdot t} = -0.401$, $p>0.10$).

Changes in the numbers of single and paired adults seen in July, which are used as an indication of how many ducks may still be attempting to breed, are remarkable for their unanimous downward trend (Fig. 3), which falls short of the conventional level of significance (for $n = 8$, $p = 0.05$, $r = 0.632$) only for Wigeon ($r = -0.581$), Blue-winged Teal (−0.609), and Ruddy Duck (−0.423). The total decline in potential late nesters is dramatic, from 160 000 in 1975 to 40 800 in 1982, a drop of nearly 75%.

We can produce a combined production index by calculating $P = (2B+L)/3$, where B is the brood index and L the late-nesting index. The true form of the relationship of B to L is not known, but in most years the output of young from first broods is likely to exceed that from late broods. Figure 3 shows that the unadjusted values of B and L are closely correlated ($r_{L.B} = 0.821$, $p<0.01$); the correlation remains after the removal of the downward the downward trend ($r_{\Delta L.\Delta B} = 0.536$, $p = 0.10$).

Table 2
Mean brood- and late-nesting indices (in thousands) for ducks in southern Alberta, 1975–82, with their mean annual rates of decrease. The brood index is based on all broods seen, not identified to species. The late-nesting index is based on sightings of single and paired adults during the July survey

	Mean	SE	% decrease
Brood index	86.4	42.5	−14.9
Late-nesting indices			
Mallard	18.7	9.6	−17.3
Gadwall	7.7	5.7	−23.9
American Wigeon	7.2	3.8	−12.6
Green-winged Teal	6.7	3.4	−15.1
Blue-winged Teal	11.6	9.3	−19.9
Shoveler	6.5	4.7	−21.7
Pintail	7.2	4.9	−21.5
All *Anas*	65.8	36.0	−18.3
Lesser Scaup	21.8	14.7	−20.6
Other *Aythya*	3.2	1.5	−13.4
All divers	30.4	17.3	−17.5
All ducks	96.5	52.5	−18.0

Figure 4 shows that production fell more steeply than breeding numbers, although the two were positively correlated ($r_{P.M} = 0.700$, $p<0.05$).

Because of the apparent collapse in production in 1980–82, we extended the review of May duck numbers and production back to 1965. Figure 5 illustrates the following points: (1) the drop in duck numbers since 1974 has been unusually sustained, but is still not enough to suggest that recovery is impossible, with numbers nearly as low as those of 1982 recorded in 1965 and 1968; (2) the low levels of production in 1980–82 were *not* approached in any of the previous years for which comparable records exist, production in 1965 and 1968 having been close to the long-term average; (3) the downward trend in production has been paralleled by a reduction in the ratio of production to population size.

Further analysis of the data summarized in Figure 5 leads to a paradoxical result. Although production in a given year tends to be correlated with population size ($r = 0.558$, $p>0.01$) the total numbers of ducks in May are not clearly related to the numbers present in the previous May ($r = 0.371$, $p>0.10$) and not at all to local production in the previous year ($r = 0.099$). This suggests that the ducks occupying southern Alberta are far from forming closed populations, or that another variable, such as hunting, has a significant effect. That may in turn mean that the recent failure of local production need not be followed by further depletion of the breeding populations. During the period 1965–82, the gains shown from 1968 to 1969 and 1973 to 1974 seem to have been due to immigrations rather than to high local production. Long ago, Dzubin (1969) pointed out that, even in the pothole region regarded as the heartland of Mallard range, immigration may be as important as local production in determining population size.

We acknowledge the weakness in reliance here on indices relating to all ducks, rather than to the performance of individual species, but the crudity of the data available limits the capacity to work out the relationship of production to population size for single species.

Duck hunting and duck kill in southern Alberta

Figure 6 depicts hunters' activity and success in 1975–81 in CWS zone 09 01, which is nearly equivalent in extent to provincial bird game zones 5, 6, and 7. Sales of MGBH permits remained rather steady, averaging 29 800 ± 1420. (Sales in 1982 of 27 780 were similar to the 27 620 in 1981.) They provide a poor index to hunting activity, which by other measures has clearly decreased throughout the period. The number of successful hunters averaged 19 060 (64.0% of permit buyers), but fell at an average rate of −6.4% annually from 79.2% of permit buyers in 1975 to 56.9% in 1981. Estimates of hunting activity (in hunter-days) from the replies of respondents to the NHS gave a similar picture, falling from an average of 6.8 days per permit buyer in 1975 to 5.4 days in 1981, with the total of hunter-days declining at an annual rate of −8.2%.

Table 3
Reported duck hunting activity and duck kill (in thousands) by months within seasons, 1975–81, in relation to numbers of days duck hunting was legally permitted. The hunting of waterfowl on Sundays is not permitted in southern Alberta. Activity and kill are assumed to cease at the end of November, although the open season continues into December

Season	September			October			November			Whole season		
	Duck hunt days	Hunter -days	Rep. kill	Duck hunt days	Hunter -days	Rep. kill	Duck hunt days	Hunter -days	Rep. kill	Duck hunt days	Hunter -days	Rep. kill
1975	11	37.8	68.6	27	106.3	164.4	25	48.1	66.0	63	192.2	299.1
1976	13	46.0	72.6	26	102.5	146.1	26	38.3	44.6	65	186.8	263.3
1977	14	45.5	78.2	26	100.3	134.4	26	28.4	35.9	66	174.2	248.5
1978	15	49.8	63.7	26	100.9	113.8	26	25.7	25.5	67	176.4	203.0
1979	12	31.9	53.1	27	90.0	117.9	26	24.7	28.5	65	146.6	199.4
1980	14	33.3	53.3	27	78.2	100.7	25	26.5	28.5	66	138.0	182.5
1981	15	32.5	49.2	27	79.3	101.2	25	37.1	50.2	67	148.9	200.6
Mean		39.5	62.7		93.9	125.5		32.7	39.9		166.2	228.1
SE		7.4	11.1		11.5	23.9		8.7	14.7		21.4	42.8
r, years		−0.569	−0.849		−0.939	−0.960		−0.533	−0.454		−0.920	−0.913
% change/yr		−4.95	−6.94		−5.31	−8.45		—	—		—	—

In Figure 7, we allocate the reported hunting effort and kill by month. "November" is shorthand for "rest of the hunting season", which legally remained open until 31 December, but in practice probably ended well before 30 November. The way in which late-season data are aggregated by the retrieval programs prevents study of how hunting peters out in response to the departure of the ducks and the onset of cold weather. The interesting point made by Figure 7 is that the mean rates of decline in effort and kill were greater in October than in September: September hunter-days −4.9%, kill −6.9%; October hunter-days −5.3%, kill −8.4%.

There is more hunting in October than in September, chiefly because there are more open days; the mid-September opening date allows only 11–15 hunting days in that month, compared with 26 or 27 in October (depending on the number of Sundays in the month). In Figure 8, averages for 1975 and 1976 show about 3500 active hunters in CWS zone 09 01 each day in September, compared with more than 3900 daily in October. By 1980 and 1981, the corresponding numbers were down to 2800 in September and 2900 in October. Successful hunters took more ducks per day in September (mean 1.59) than in October (1.33), the average number declining by −3.0% a year in October but less, if at all, in September (−2.1% but *r* on years only 0.418, not significant at the 10% level).

The kill in the southern provincial hunting zones is shown in Figure 9. The rate of decrease was greater in zones 5 and 6, from Stettler and Drumheller east to the Saskatchewan border, than in the much larger zone 7, making up the remainder of the south, and including Calgary, Lethbridge, and Medicine Hat.

Mallard populations, production, and kill in Alberta and adjacent provinces and states, 1975–81

In this section, we examine the relative impact of local hunting on different western groups of Mallard by comparing "net P01duction" (P'') with the local kill (K''). "Net production" is obtained from the equation $P'' = F_N - M$ where M is the number of adults in May and F_N, the "net fall flight", $= 0.9\,M\,(1 + P')$. We use the factor 0.9 to reduce the May population by an estimate of adult mortality during the period May–August; with no detailed estimates available, the use of this uniform figure is arbitrary. P' is a production index obtained not from the July production surveys but from the kill in the province or state of interest. $P' = (I/A).V$ where I/A is the ratio of young to adult Mallard wings in the provincial sample of the Species Composition Survey (SCS). V, the vulnerability quotient, is given by $V = (R_1'/B')/(R_1/B)$ where B and B' are the number of adult and young Mallard respectively banded in that province in July–September ("preseason") and R_1 and R_1' are the reported direct (in first season) recoveries from that province. I/A and V vary from place to place and year to year, due to the vagaries of sampling and to biological variability. The provincial and state values of M and I/A, are listed in Table 4.

We obtained the adjusted kill from the NHS estimates of local kill multiplied by $1.1 \times 1.25 = 1.375$. The addition of 10% allows for unreported kill, i.e. that by Indians, who are not required to possess MGBH permits, and who are consequently not sampled by the NHS, and that of other hunters acting illegally, such as those hunting during the closed season or in excess of the daily bag limit. We allow a further 25% for birds hit and not retrieved, but dying from their wounds. Both these adjustments are arbitrary. There are undoubtedly local and seasonal variations in such factors but detailed records do not exist, except from intensive studies in small areas, whose representativeness can always be questioned. The point of a standard upward adjustment of the kill is to avoid underestimating the scale of local losses.

The estimates of net production (Fig. 10) are dominated by the major decreases in Saskatchewan and Alberta. They also show that net output probably fell everywhere from 1975 to 1981, except in the Mackenzie Valley, NWT.

The estimates of adjusted kill in Figure 11 are also dominated by declines in Saskatchewan and Alberta, with the latter markedly less steep (at a mean rate of −2.5% compared with −5.1% in Saskatchewan).

It is the combination of these two sets of figures, the local kill as a percentage of net local production (Fig. 12), that is of greatest interest, showing statistically significant increases for the entire area (at a mean annual rate of 8.1%) and for Alberta (13.9%), South Dakota (11.0%), and Saskatchewan (5.9%), and less certain increases in North Dakota, Manitoba, and Alaska. The Northwest Territories are again distinctive, with the kill as a fraction of net production declining by −7.9% annually. The steep rise in Alberta has brought the kill close to the net production, and even above it in 1981. This means that Alberta is ceasing to be a net exporter of Mallard, a distinction it shares with no other state or province in the sample, though comparable to Minnesota and to many other states further south in which local production is small.

Changes in the recovery rates of Mallard banded and recovered in Alberta, 1965–81

Munro and Kimball (1982) have updated and amplified the study by Geis (1971) of the distribution and derivation of the Mallard kill in North America. Their work is organized with American rather than Canadian readers in mind, and suffers the further limitation in this context of drawing only on banding records for 1961–75. They show that, up to 1975, 47.3% of the Mallard kill in Alberta comprised birds originating in southern Alberta, with a further 31.4% from northern Alberta and the Mackenzie Valley, 14.2% from Saskatchewan, 2.9% from British Columbia and Alaska, 1.1% from Canada east of Saskatchewan, and 3.3% from the contiguous USA. With over 90% of the banded birds taken at that time having originated within or immediately adjacent to Alberta, we get the impression of a nearly

Table 4
May population (M) (in thousands) and immature/adult ratios (I/A) in the local kill of Mallard used in calculating net production from Alaska, the Mackenzie Valley (NWT), the prairie provinces, and the north-central states, 1975–81. r_T = regression on years

Year	Alaska M	Alaska I/A	NWT M	NWT I/A	Alberta M	Alberta I/A	Saskatchewan M	Saskatchewan I/A
1975	101	3.24	494	3.64	2050	3.02	2800	2.56
1976	154	2.76	186	2.96	1848	2.18	3573	2.30
1977	392	2.32	671	2.12	1442	1.56	3338	1.57
1978	270	2.26	430	2.26	1495	1.96	2701	1.56
1979	234	2.06	317	1.06	1868	1.74	2855	1.93
1980	349	2.24	575	2.20	1814	1.24	2646	1.17
1981	411	2.02	476	1.94	1571	1.00	1985	1.20
1975–81 mean	271.7	2.44	458.4	2.31	1726.9	1.81	2842.6	1.76
SE	117.6	0.41	153.8	0.81	224.8	0.67	512.4	0.53
r_T	0.751	−0.823	0.216	−0.731	−0.369	−0.897	−0.720	−0.867
p	<0.02	<0.01	ns	<0.05	ns	⩽0.001	<0.05	<0.01

Year	Manitoba M	Manitoba I/A	Montana M	Montana I/A	North Dakota M	North Dakota I/A	South Dakota M	South Dakota I/A
1975	616	2.42	478	2.6	567	2.4	354	2.4
1976	1035	2.75	480	2.7	459	2.0	332	2.0
1977	746	2.48	333	1.1	375	1.0	267	1.4
1978	829	2.30	283	2.62	507	2.2	537	2.2
1979	893	2.26	389	2.62	685	2.6	483	2.6
1980	816	2.18	256	1.8	485	1.8	339	1.8
1981	895	1.87	246	2.0	309	1.6	187	1.4
1975–81 mean	832.9	2.32	352.1	2.21	483.9	1.94	357.0	1.97
SE	131.2	0.27	99.3	0.60	123.1	0.54	119.9	0.47
r_T	0.321	−0.851	0.845	−0.267	−0.258	−0.172	−0.174	−0.363
p	ns	<0.01	<0.01	ns	ns	ns	ns	ns

closed system. This may be misleading, because the great majority of the Mallard banded pre-season (in July to early September) were adults or freely flying young, rather than "locals" (young birds not yet capable of flight). As many adult males and some females undertake "moult migrations" to large marshes and other secure areas at widely varying distances from their breeding sites, and as most young scatter widely soon after fledging, the population sampled by banding in late summer may be very different from the local breeding population and its progeny. (This inconvenient qualification is often overlooked.)

Our review of direct recoveries in Alberta in 1975–81 of Mallard banded pre-season there and elsewhere shows no significant changes in the origins of the birds shot, the 82 out-of-province specimens having come from Saskatchewan (64), the NWT (14), Montana (3), and South Dakota (1). The recoveries from Saskatchewan represent only 0.092% of the 69 830 banded pre-season in that province in 1975–81, or 2.0% of the total 3199 direct recoveries from the banded sample. The latter represent a drop from the 5.1% found in Alberta up to 1975 as reported by Munro and Kimball (1982).

Direct recoveries within Alberta of Mallard banded there pre-season in 1975–81 amounted to 523 from 43 526 banded (11.9 per 1000), proportionately 13 times as many as from Saskatchewan. This local recovery rate is very low. Figure 13 shows that the rate was declining (−4.6% annually for adults, −4.9% for young) for the period 1965–81, though in 1965–74 the recovery rates fluctuated very widely without the clear trend evident in the dry years after 1975. The corresponding direct recovery rates for young Alberta Mallard reported outside Alberta (Fig. 14) do not show this downward trend, though those of adults do (at −2.1% annually).

These changes in direct recovery rates have led to

some striking changes in the local vulnerability quotient, V_L (Fig. 15), while that calculated from all direct recoveries has fluctuated less. As Figure 13 suggests, the size of the local fluctuations is due mostly to changes in the local direct recovery rate of young birds.

The changes in local direct recovery rates in 1975–81 were not associated with changes in net production or in kill. Nor, though the point will not be pursued in this paper, were they related to the estimated survival of Mallard in Alberta or elsewhere in Canada (Boyd, in prep.). Thus, despite their striking nature, they may reflect nothing more significant than a loss of local interest in reporting bands. As the result of a planned increase in effort, many more Mallard were banded annually in Alberta in 1975–81 (annual average 6000) than in most previous years (average 1962–68, 2200; 1969–74, 3100). There have been many instances in different parts of the world of a decline in local reporting associated with increased banded samples as well as with long-continued banding operations.

On the basis of direct recoveries per 1000 banded, 12.02 Mallard banded in Alberta were reported shot there compared with only 0.39 marked in surrounding areas, so that only 3.1% of the Mallard killed were to be found outside the province immediately prior to the hunting season.

A very different impression is given by the indirect recoveries (Table 5), which are far more numerous. It is impracticable to express these accurately in terms of the numbers of banded ducks at risk 1, 2, 3 or more years after marking, because the annual survival rates are not all known. As a first approximation, we express all indirect recoveries in year t as proportions of the numbers banded in the year $t - 1$, and ignore the effects of varying survival. Assessing the proportion of Alberta-banded Mallard recovered in subsequent years in the same way, the ratio of Alberta-banded to immigrant recovery rates is 4.86:1.83, i.e. immigrants comprise 27.4% of Mallard taken in Alberta in their second or later years. Table 5 shows that the highest rates of immigration were from South Dakota, Montana, and British Columbia. Because of the small numbers of recoveries involved, year-by-year comparisons are unreliable. Grouping the years 1976–78 and 1979–81 separately shows that in several cases the rate of immigration altered considerably.

The important points that emerge from our analysis of recoveries of Mallard banded inside and outside Alberta are that: (1) other states and provinces made a very minor direct contribution to the number of Mallard forming the target population for Albertan hunters; but (2) made a substantial indirect contribution, presumably by supplying immigrants to the breeding population; and (3) the proportion of immigrants increased during 1976–81.

Discussion

We must not lose sight of the important themes that prompted this study in the mass of detail that can readily be generated. The primary concern is what is likely to happen to duck numbers and duck hunting in the immediate future and, more important, when the unusually long dry spell in western Canada and the north-central USA is followed by wetter weather conditions. (Quite rapid alternation of dry and wet conditions has been the rule during the last century, and there is as yet no reason to believe that the prairie climate has changed.)

A second concern is the impact of the deliberate management decisions in 1979, in both Canada and the USA, to hold duck hunting regulations steady during the dry spell, unless confronted by a catastrophic reduction in ducks numbers, instead of tightening the regulations as duck numbers fell, the practice followed in the previous 35 years. As the existing agreement on stabilized regulations stands, the decision to maintain or move on from there has to be made in 1984, after a review of events in 1979–83.

A third question, still hypothetical, is whether immediate changes in regulations so as to encourage a further increase in duck kill, even while unfavourable breeding habitat conditions persist, would bring about the catastrophe that has not yet occurred. The several proponents of immediate relaxation, in several widely separated provinces and states, presumably believe that no damage would be done.

The value of southern Alberta as a testing ground is that it has recently shown greater proportionate reductions in duck numbers and production than elsewhere, together with hunting effort sustained at a high level despite rapidly declining success.

We write this in April 1983, before ducks have returned to the prairies, but when already it is clear that water will again be scarce in Alberta in the summer. One way of testing our understanding of the processes waterfowl managers have to respond to is to make predictions, which we do for the summer and fall of 1983. Table 6 consists of extrapolations to 1983 of the trends in duck numbers, hunting activity, kill, and production observed since 1975. We compare NHS estimates of hunting activity and kill in 1982 with predictions based on 1975–81.

The extrapolations in Table 6 are for the most part unremarkable, but show obvious contradictions in the production indices. The steep rate of decline of the late-nesting index from 1975 to 1982 leads to the prediction that hardly any potential late-nesters will be observed in 1983, and none at all in subsequent years, which is most unlikely to be correct. The production index P' (a combination of the other indices, see "Duck production in southern Alberta") shows a large expected increase in 1983, the 1982 value of 31 having been by far the lowest, because broods and late-nesters (and thus mean brood size) were unusually scarce. Hence the prediction of increased breeding success in 1983 hinges on the interpretation of the 1982 results as aberrant, rather than being determined by population size and habitat conditions (which were in fact less severe in 1982 than in 1981).

A potentially more instructive way of forecasting is to rely on the empirical relationship between parameters

Table 5
Recoveries in Alberta, 1975–81, of Mallard banded in adjacent provinces and states

Where banded	No. banded	Direct no.	Recoveries per 1000 banded	Indirect recoveries No.	Per 1000 banded*	1976–78	1979–81
NWT	5 635	14	2.48	15	2.19	2.71	1.77
BC	722	0	—	8	7.1	11.04	7.69
Sask.	69 852	64	0.92	167	2.55	1.88	3.10
Man.	70 266	0	—	46	0.75	0.50	1.01
Ont.	30 959	0	—	19	0.46	0.45	0.47
Montana	4 286	3	0.70	40	8.96	6.59	12.51
N. Dak.	15 556	0	—	23	1.36	1.24	1.52
S. Dak.	2 457	1	0.41	58	18.93	23.69	13.88
Total	207 733	82	0.39	376	1.83	1.43	2.20

*Approximation assuming all recovered in 2nd and 3rd years after marking.

found in the study, though these are not functional relationships in a strict sense, enabling us to make conditional forecasts in the form "if there are 3.5 million ducks in southern Alberta in May, the production index will be 49". We use point, rather than interval, forecasts in Table 7, as in Table 6, not in the belief that they are reliable, but because at present we know too little to provide satisfactory interval forecasts.

The forecasts in Table 7 differ substantially from those in Table 6. The predicted late-nesting indices look more plausible, because less extreme. The number of broods predicted to be seen is 67% greater than the extrapolation suggests, but the production index is 17% lower. The predicted kills of Mallards and other ducks in both 1982 and 1983 are lower on the basis of the relationship between kill and effort than are the extrapolated values.

It would be a mistake to give much weight to the success of these forecasts. What matters is the picture as a whole, of a (temporarily) declining resource under a hunting attack that is also diminishing, but less rapidly, so that the impact of local (and distant) hunting is growing even though the local kill is falling. In such circumstances, it would surely be misguided to pursue the objective of relaxing regulations so as to increase the kill, unless the manager and the critics might be satisfied with more hunting for less return.

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Munro, R.F.; Kimball, C.F. 1982. Population ecology of the mallard. VII. Distribution and derivation of the harvest. US Fish Wildl. Serv. Resour. Publ. 147. Washington, DC. 127 pp.

Table 6
Estimates (in thousands) by linear extrapolation of trends in 1975–82, of the number of ducks in southern Alberta in May 1983 and of duck production in July 1983; and, from 1975–81, of hunting activity and duck kill (in thousands) in the 1982 and 1983 hunting seasons

Ducks		Mean 1975–81	1982	Forecast 1983	% change from 1982	Reported 1983
Total ducks in May	N_T	5 170	3 560	3 450	−3.1	3181
Mallard in May	N_M	1 060	776	610	−21.4	845
July production indices						
Duck broods seen	$\underline{B}$	95.7	21.2	28.6	+34.9	
Mean brood size	$\bar{b}$	4.9	3.8	4.4	+15.8	
Late nesting index, total ducks	LN	104.5	40.6	0.9	−97.8	
Late nesting index, Mallard	LNM	20.3	7.5	0.9	−88.0	
Production index	P'	110	31	69	+122.6	

Hunting	Mean 1975–81	Forecast 1982	Reported 1982	Forecast 1983
MGBH permit sales	29 790	29 000	27 780	28 800
Hunter-days	166.2	120.6	123.1	111.5
Successful hunters	19.1	14.1	14.3	12.9
Reported kill				
Total ducks	228.1	155.8	137.8	137.7
Mallard	129.5	112.6	95.4	106.3

Table 7
Forecasts (in thousands) of (a) duck production in southern Alberta in 1983 and (b) the kill of ducks in the autumn of 1983 based on empirical relationships between duck numbers and production in 1975–82 and between duck kill and hunting activity in 1975–81

	Equation	Forecast 1983	% change from 1982
Duck broods	$\hat{B} = 0.025N\text{-}39.94$	47.8	+125.5
Late-nesting *Anas*	$\hat{L}_A = 0.032A\text{-}60.86$	31.9	+11.9
Mallard	$\hat{L}_M = 0.031M\text{-}13.42$	7.7	+2.7
Divers	$\hat{L}_D = 0.86D\text{-}54.16$	14.9	+23.1
Total ducks	$L\hat{N}T = 0.050D\text{-}158.33$	29.4	−27.6
Production index		57	+83.9
		1982	1983
Kill of ducks			
Total ducks	$\hat{K} = 1.749HD\text{-}62.54$	148.4	132.4
Mallard	$\hat{K}_M = 20.48 + 0.7140$	106.1	99.7

Figure 1
Estimates (in thousands) of the numbers of ducks in southern Alberta (USFWS strata 26–29) in May 1975–82

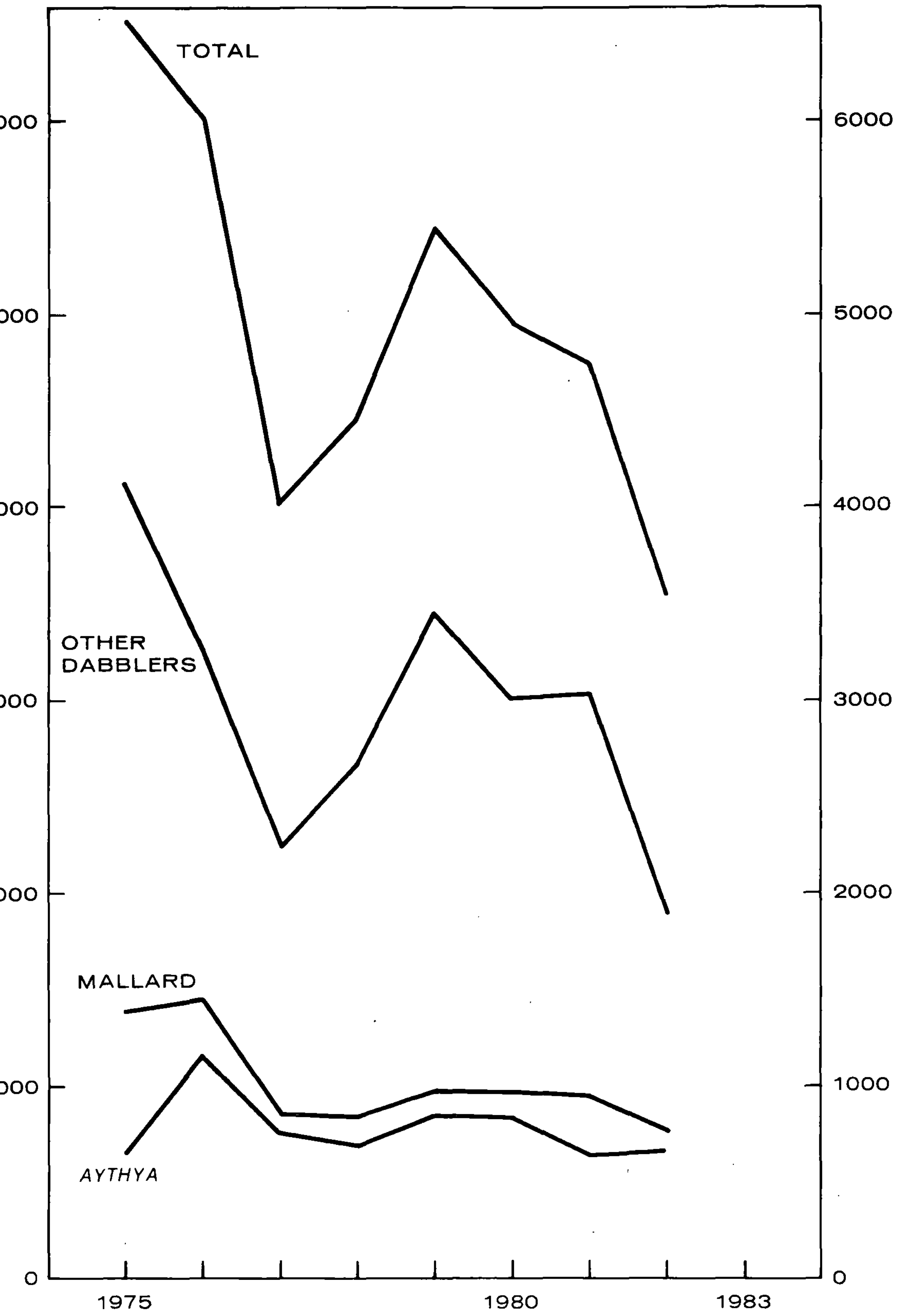

Figure 2
Changes in the estimated numbers of ducks (in millions) in southern Alberta in May 1975–82 compared with those in the entire area of western Canada and the northern USA sampled by USFWS aerial surveys

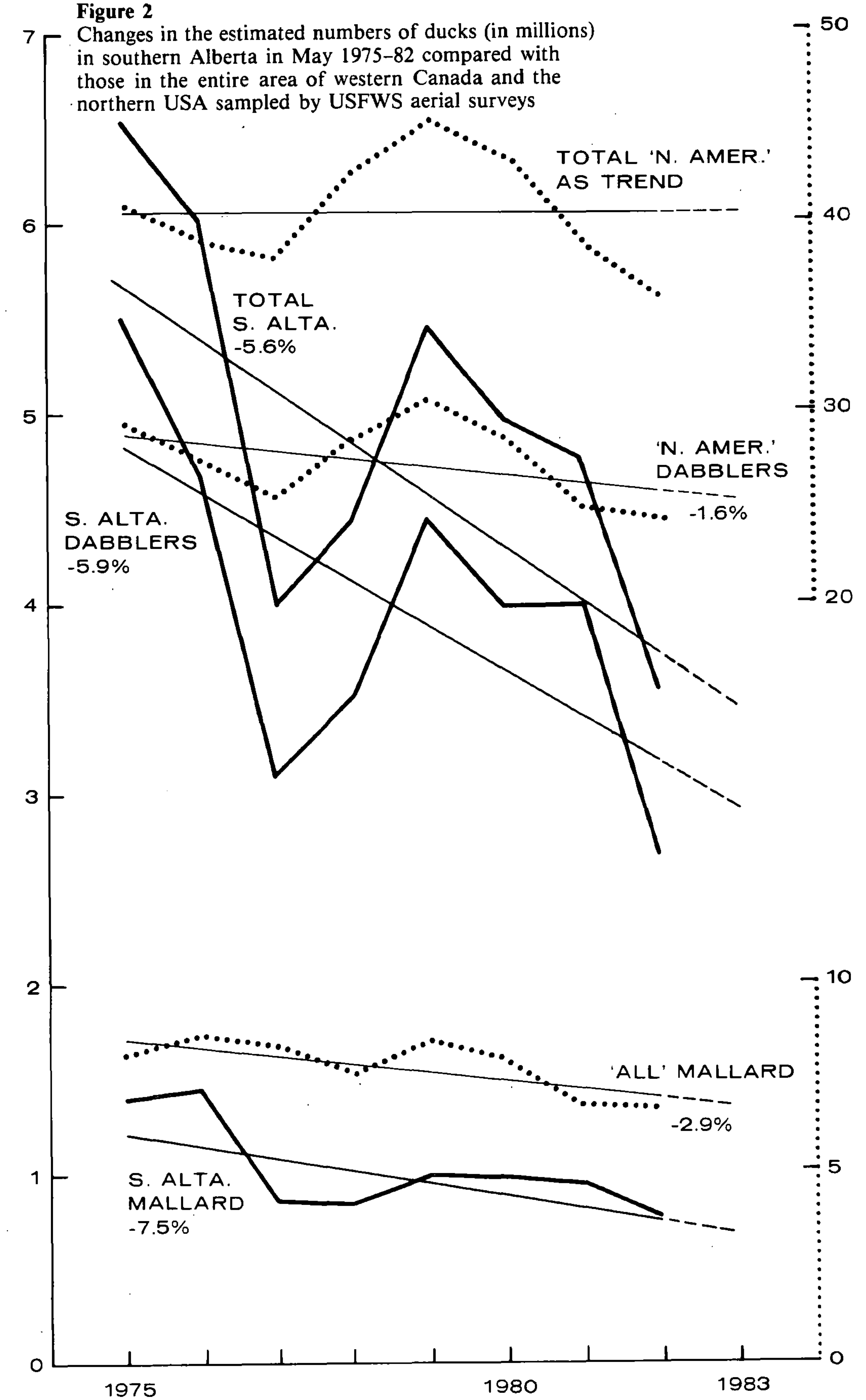

Figure 3
Indices (in thousands) of duck broods seen and of late nesting pairs in southern Alberta, 1975–82

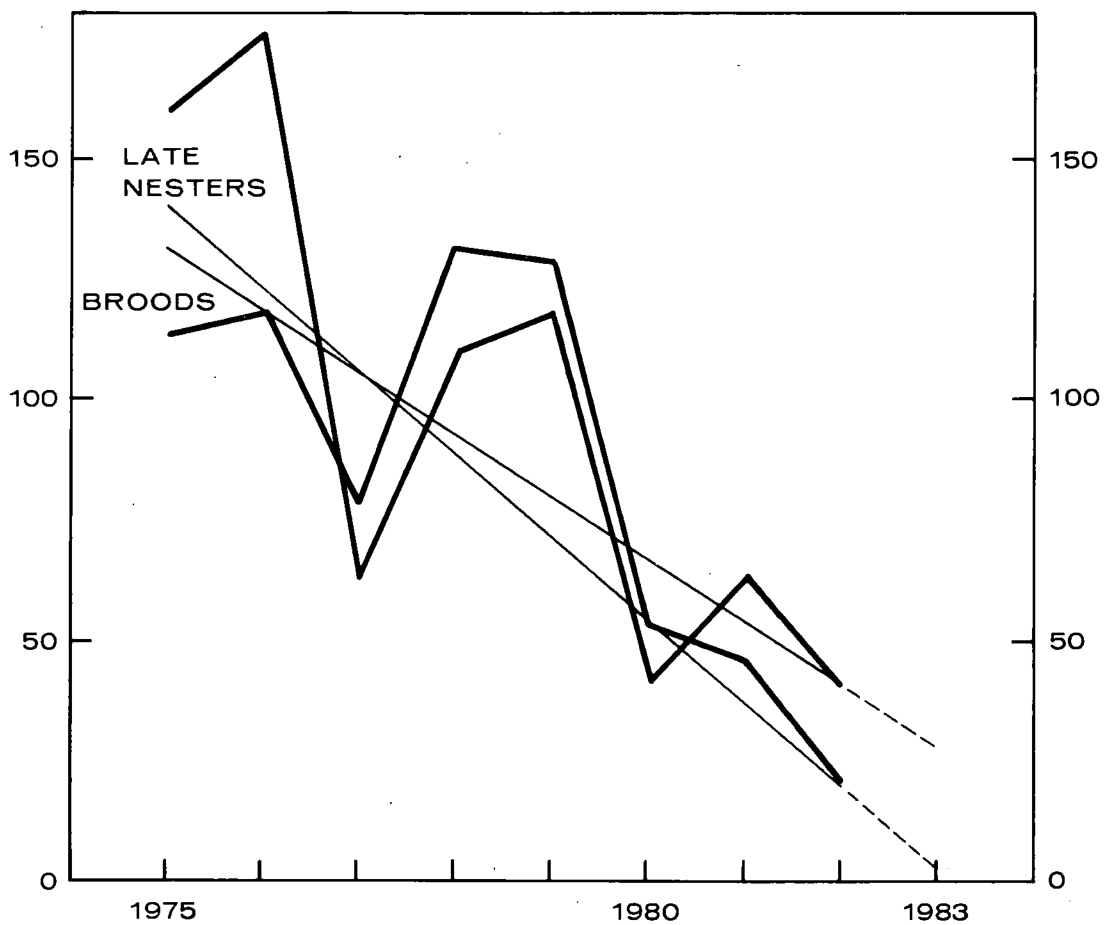

Figure 4
Duck populations (in thousands) in May and production in July, southern Alberta, 1975–82: (a) indices of breeding ducks (M') and of production (P') standardized so that the period mean of each is 100; (b) correlation of indices of population and production

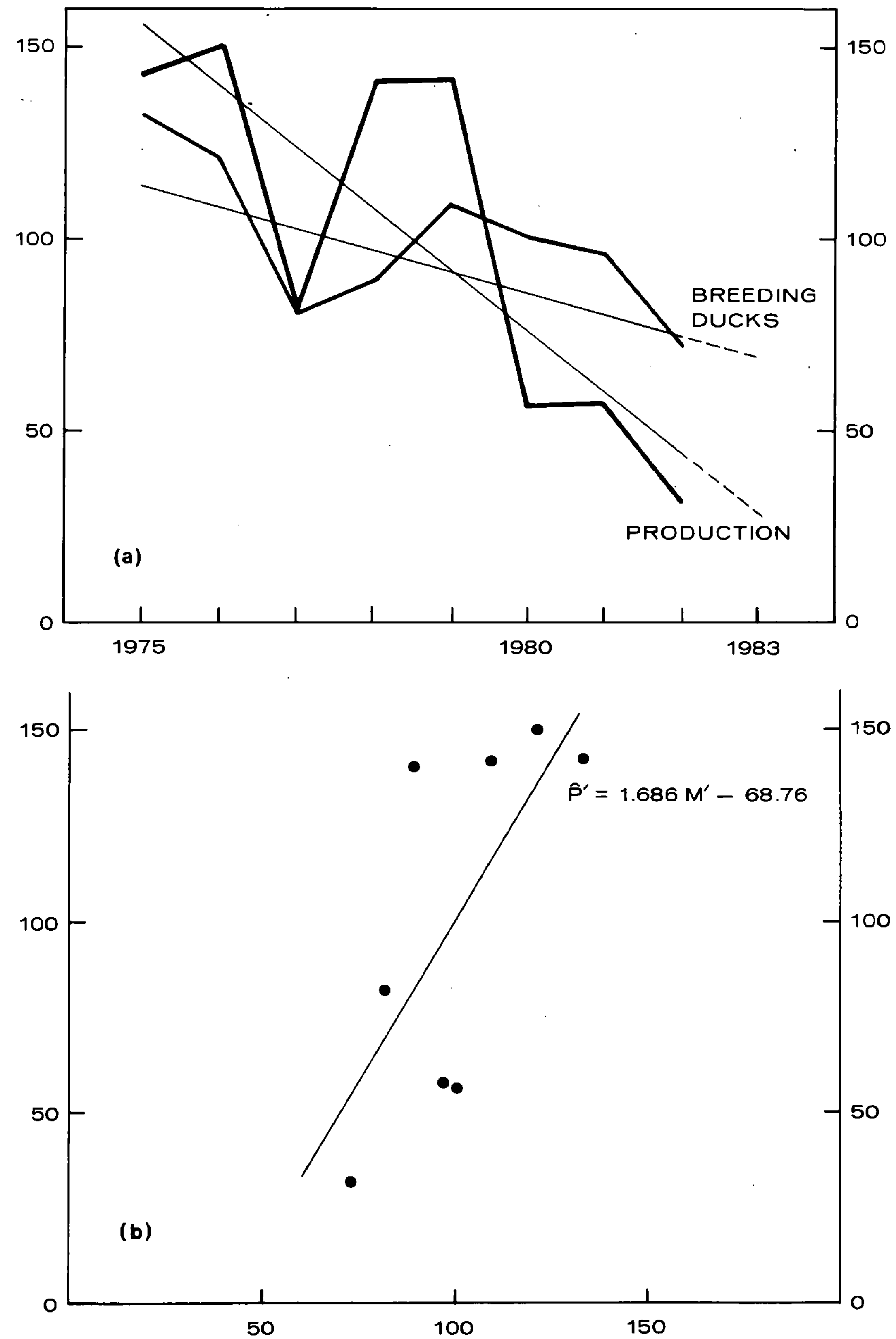

Figure 5
Indices of duck populations (in thousands) in May (M') and production (P') for southern Alberta, 1965–82, based on mean 1975–82 = 100

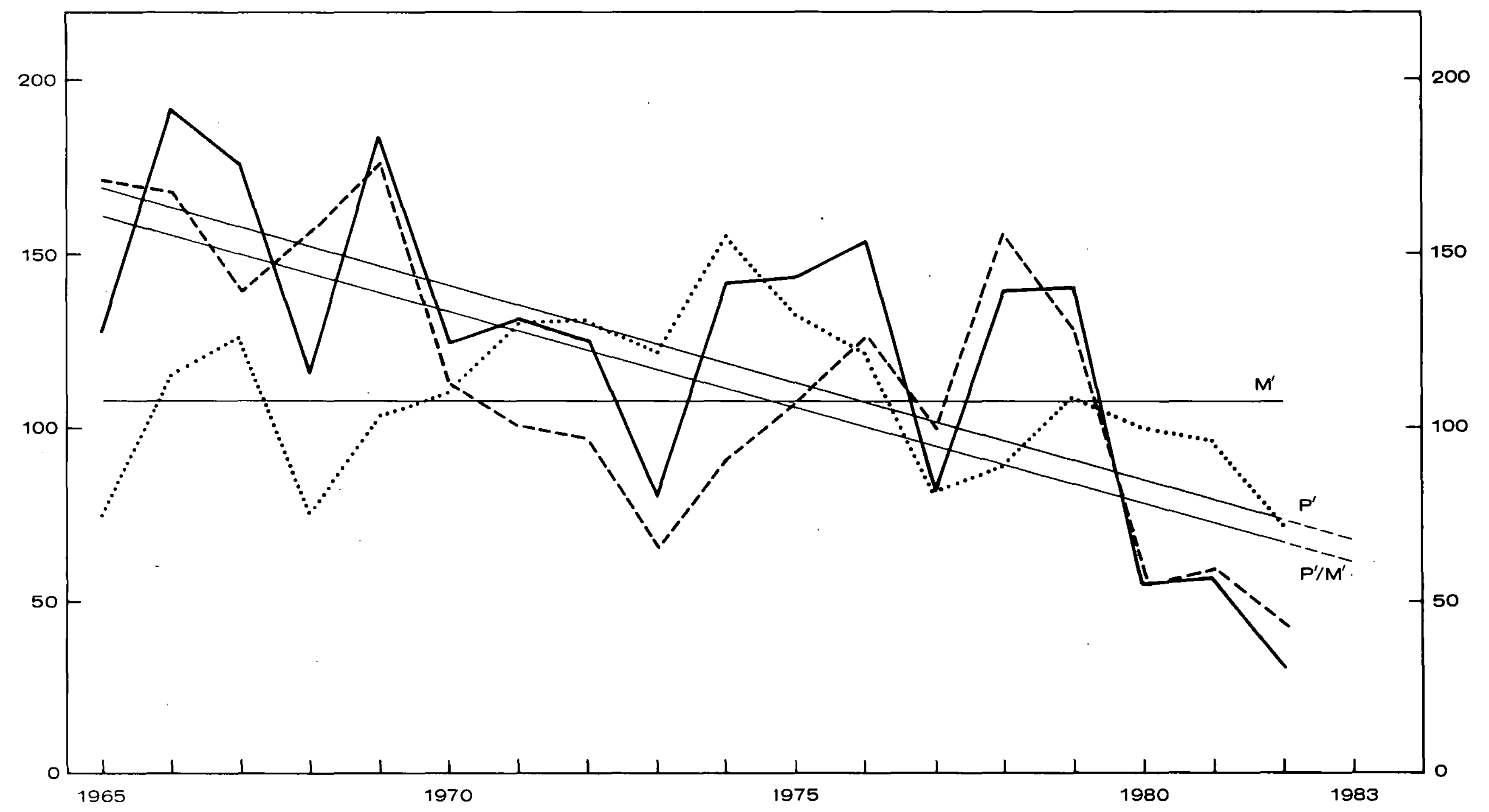

Figure 6
Duck hunting effort and success in southern Alberta (CWS zone 09 01) 1975–81, with projections to 1983

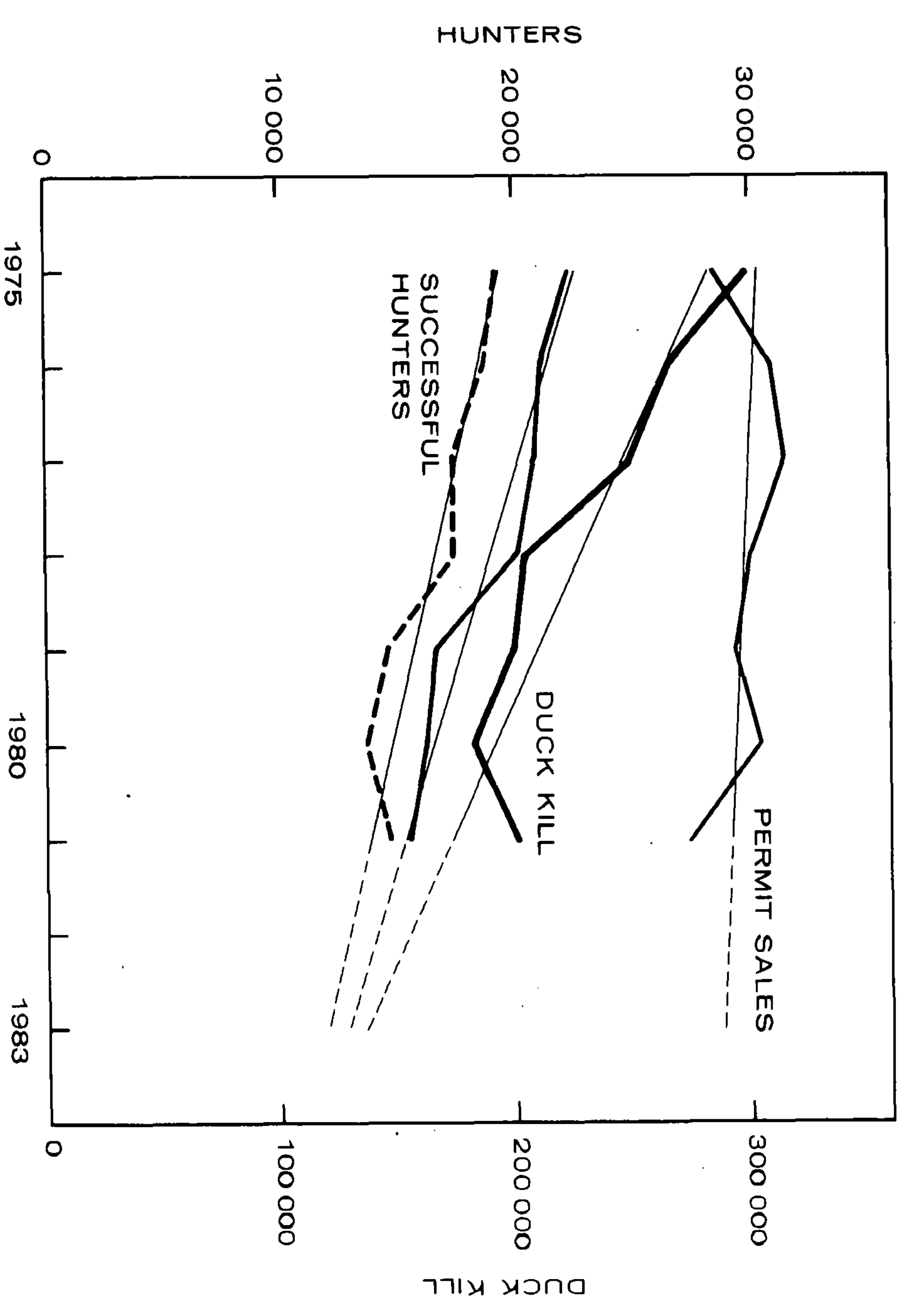

Figure 7
Changes (in thousands) in duck hunting activity and reported kill in southern Alberta in September, October, and November 1975–81: (a) reported kill; (b) reported hunter-days

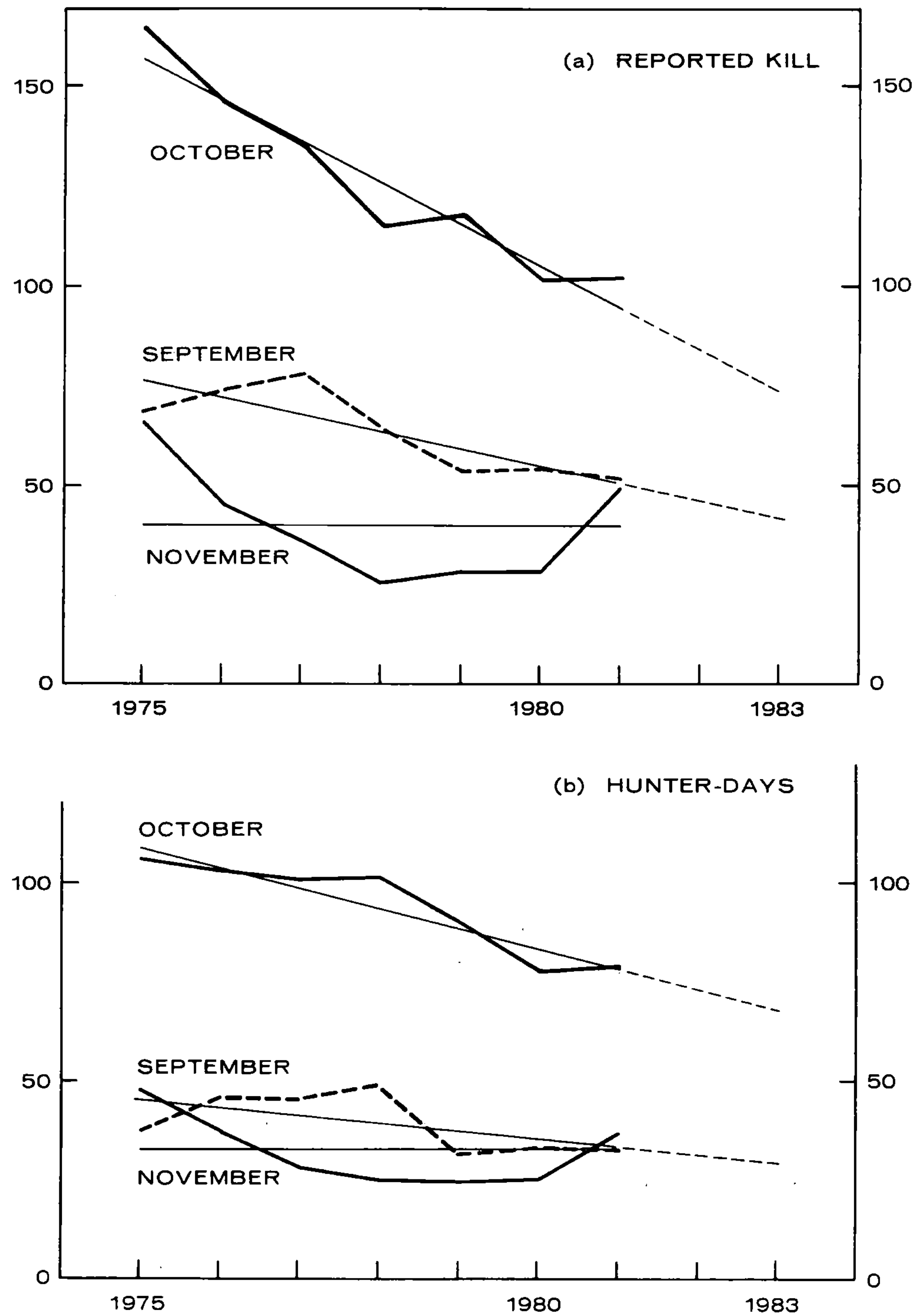

Figure 8
Average numbers of successful duck hunters each day in September and October in southern Alberta, 1975–81, and mean kill per hunter-day

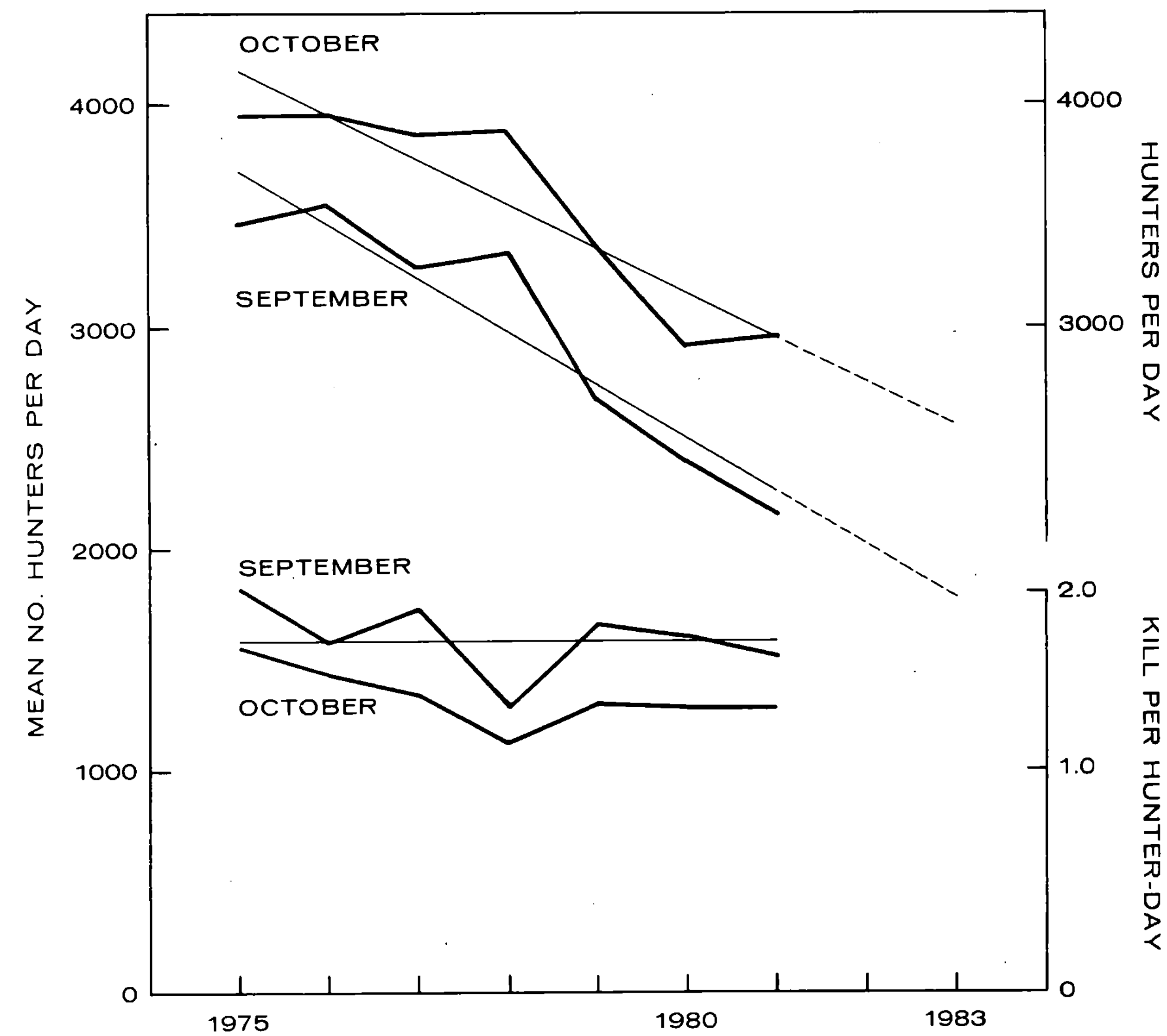

Figure 9
Duck kill (in thousands) reported from southern Alberta provincial bird game zones 5, 6, and 7, 1975-81; data from NHS

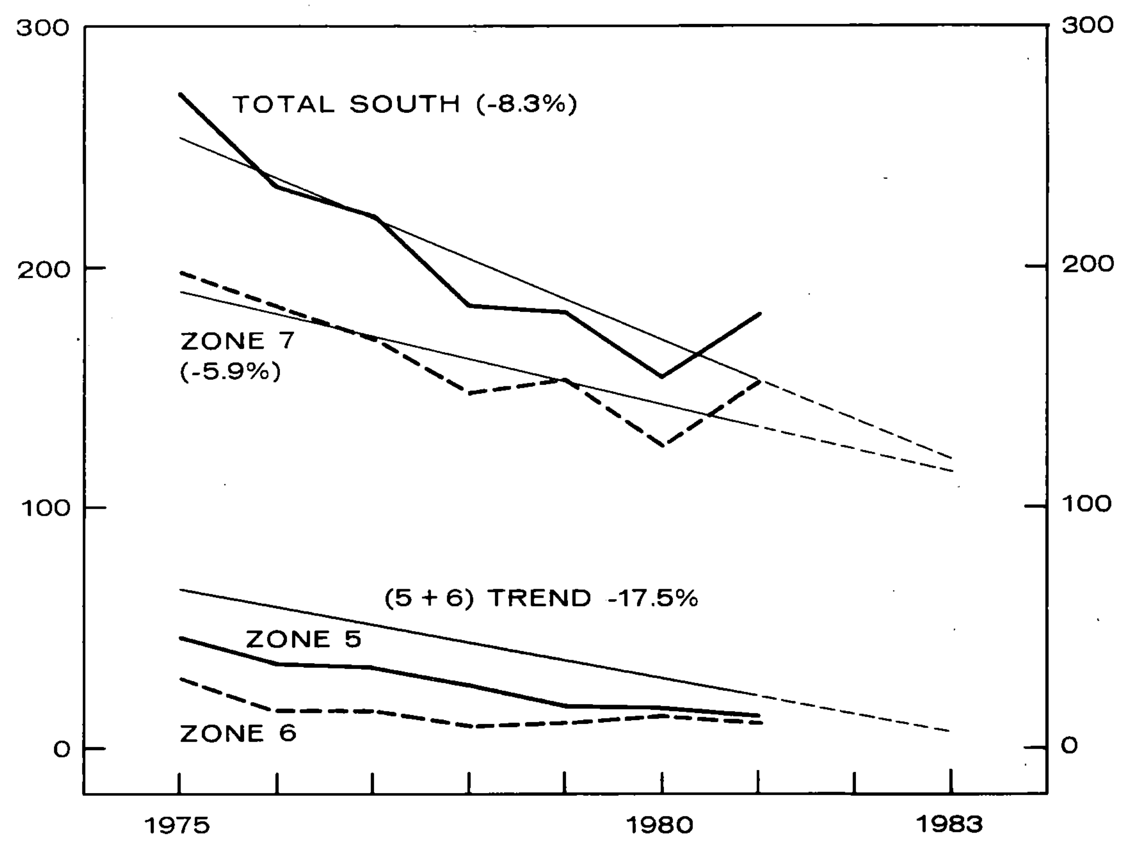

Figure 10
Net production of Mallard (in thousands) in western provinces, NWT, Alaska, and north-central USA, 1975-81

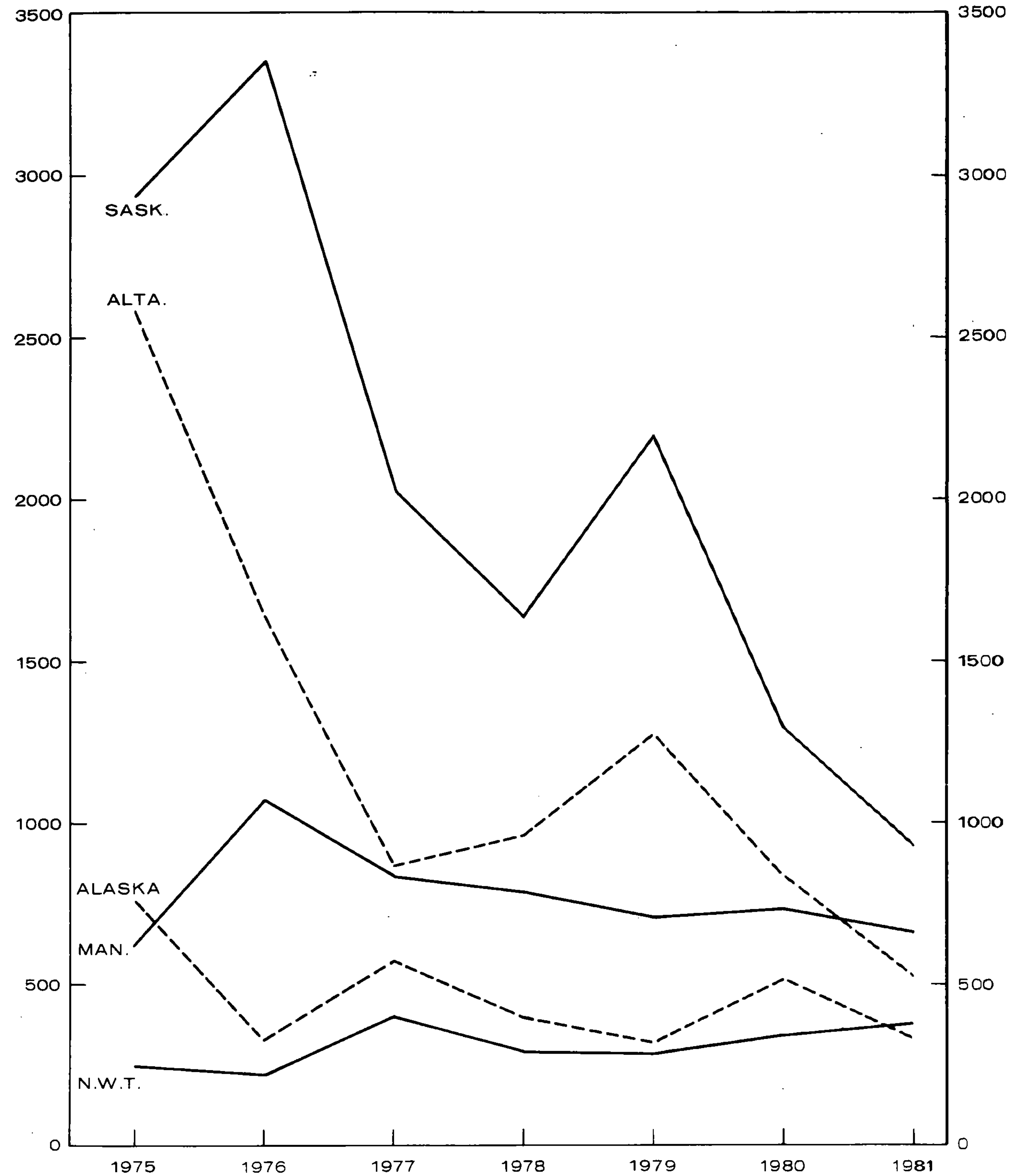

Figure 11
Estimates (in thousands) of Mallard kill in Alberta and adjacent provinces and states, 1975–81, adjusted for unreported hunting and crippling losses

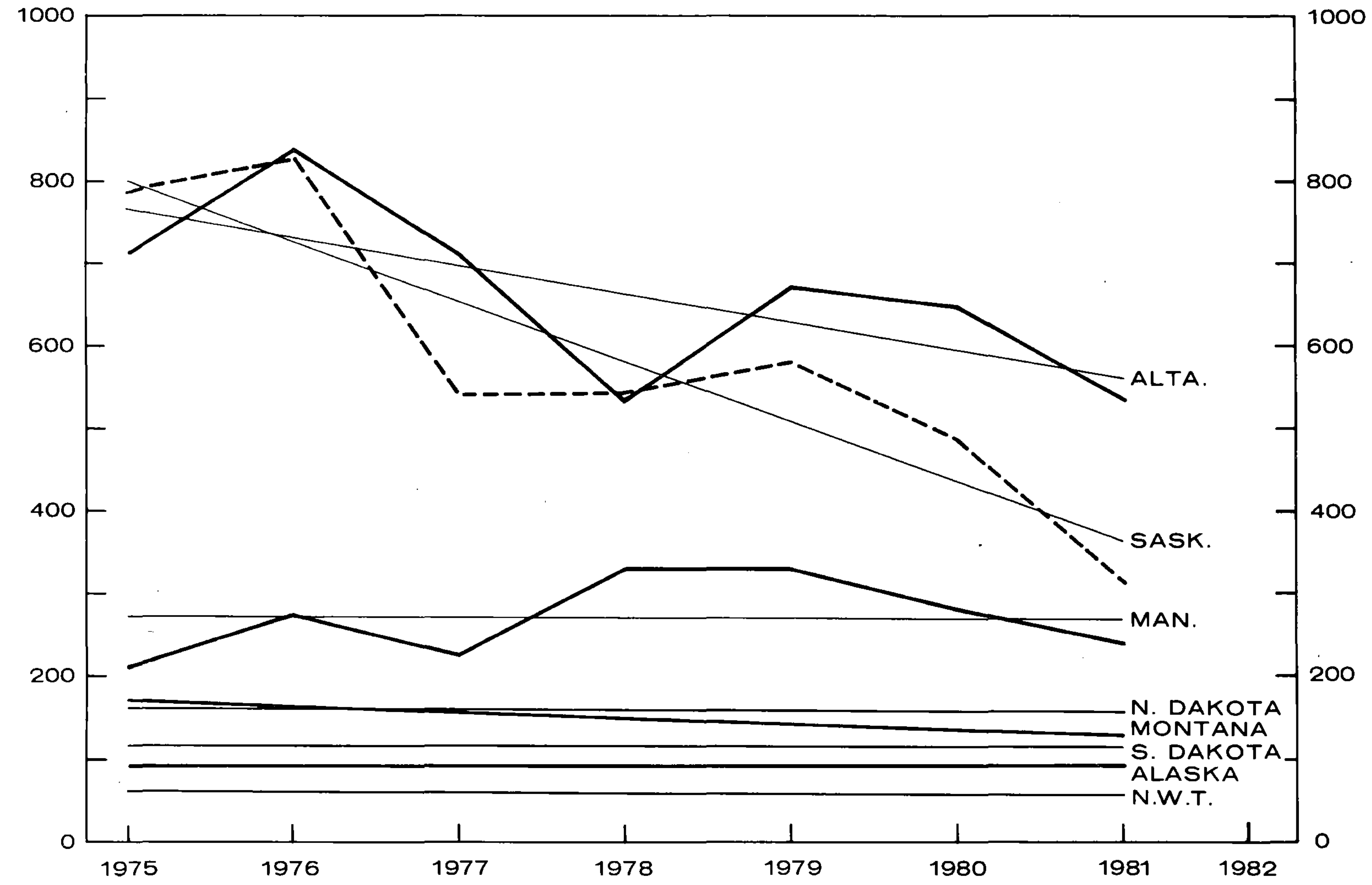

Figure 12
Local kill of Mallards as % of local net production, 1975–81, in Alberta and adjacent areas: linear regressions on years

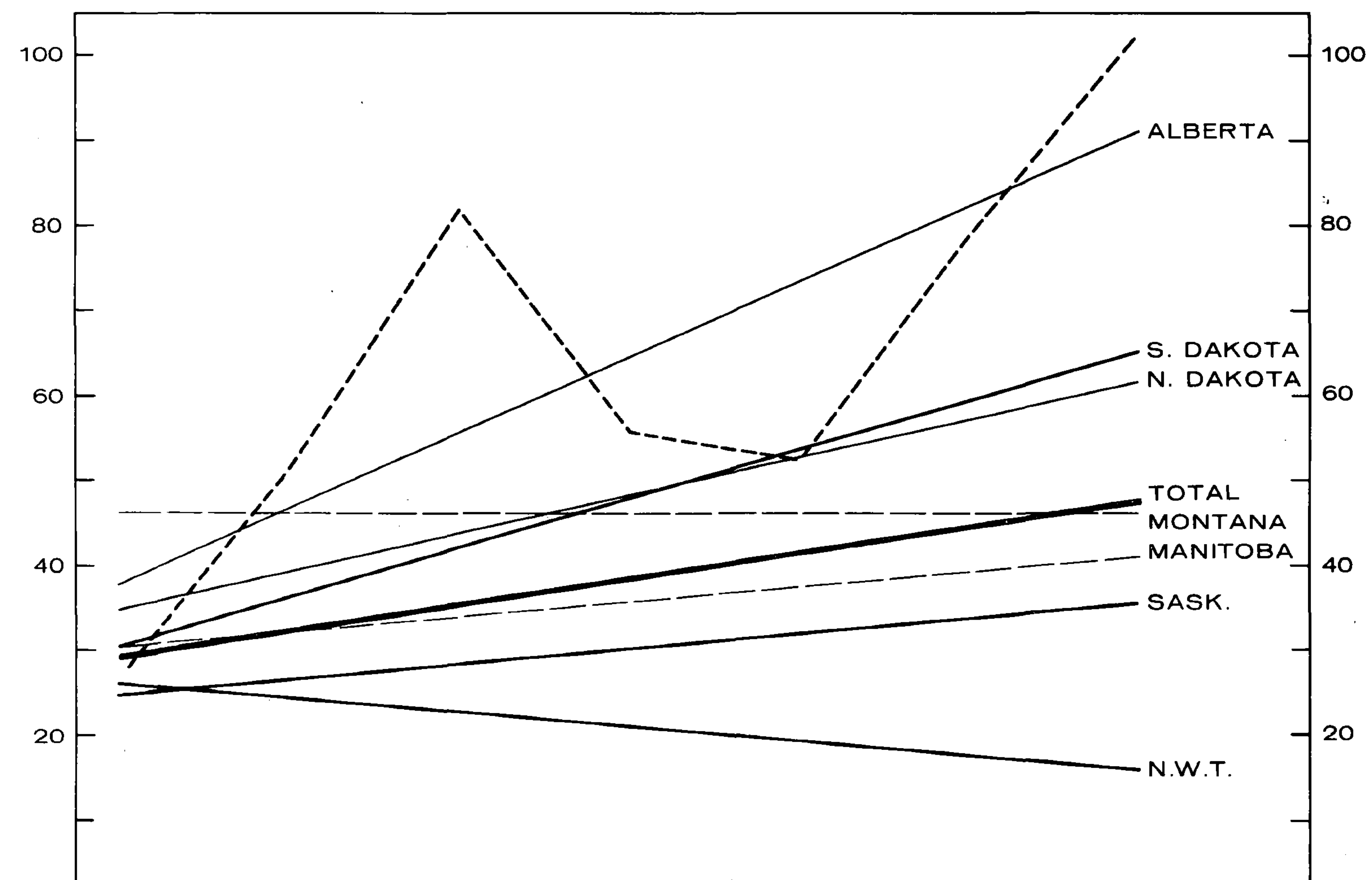

Figure 13
Local direct recovery rates (per thousand banded) of Mallard banded pre-season in Alberta, 1965–81

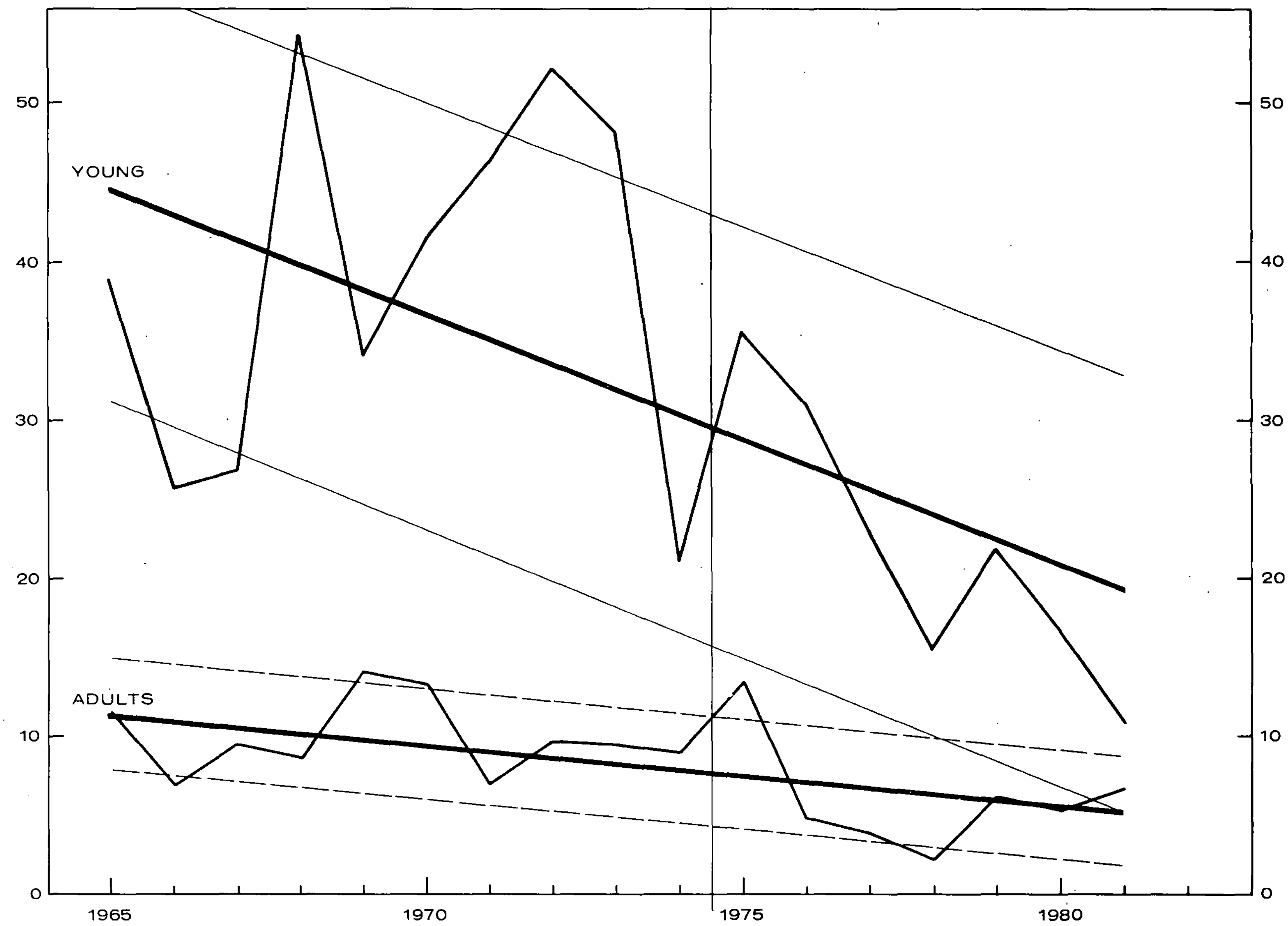

Figure 14
Direct recovery rates (per thousand banded) of Mallard banded pre-season in Alberta and shot outside the province, 1965–81

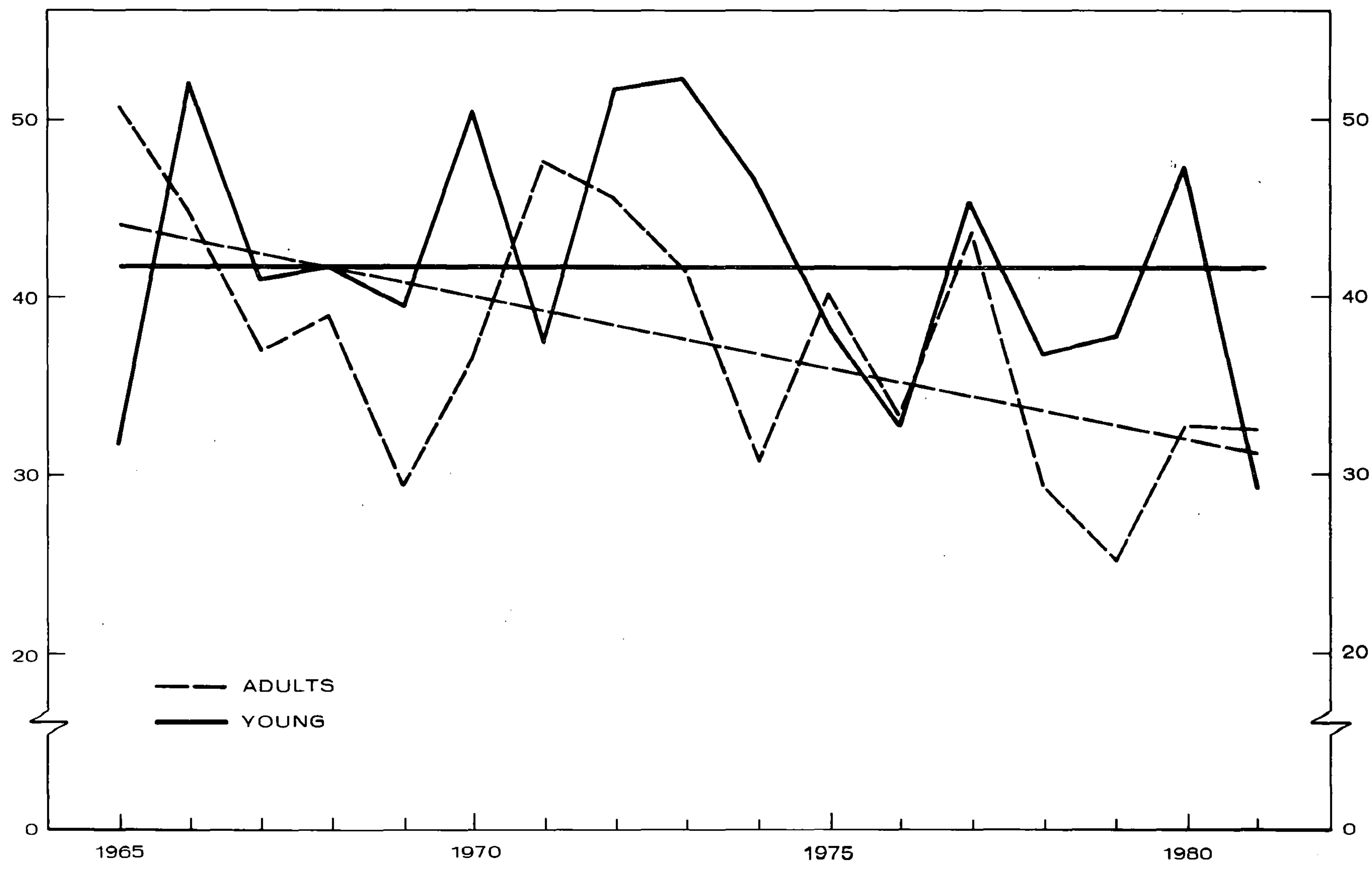

Figure 15
Vulnerability quotients for young Mallard banded pre-season in Alberta, 1965–81: V_L = "local quotient" based on shooting recoveries in Alberta only; $V\ [=(R_1'/M')/(R_1/M)]$ is based on all reported direct recoveries of shot, banded Mallard irrespective of locality