Fisheries and Environment Canada / Pêches et Environnement Canada
0022722F S
CANADA. WILDLIFE SERVICE. PROGRESS NOTES

Progress Notes

Aussi disponible en français

No. 90, August 1978

A forecast of long-term trends in breeding Mallard populations on the Canadian prairies

by G.S. Hochbaum[1] and F.D. Caswell[2]

Abstract

A simulation model was developed to forecast future trends in Mallard breeding populations on the Canadian prairies, and to evaluate management policies and programs concerning harvest and recruitment. Southern Alberta and southwestern Saskatchewan breeding populations appear to be more stable than those in southeastern Saskatchewan and southwestern Manitoba. Only small population gains can be achieved by unilateral reductions of harvest in Canada.

Substantial increases in breeding Mallard populations were noted under management options selected to improve recruitment.

Introduction

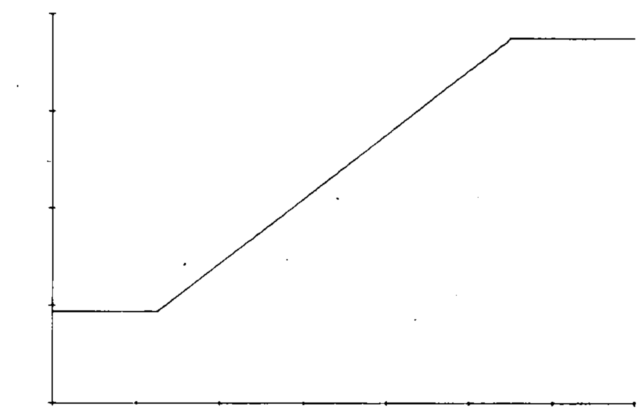
Increased consumptive demands and habitat deterioration have caused declines in breeding populations of some duck species over parts of the breeding range on the Canadian prairies. These trends call for the development of long-range strategies incorporating realistic population goals to ensure the maintenance of sufficient numbers and varieties of waterfowl to meet the needs of all Canadians.

Our objectives have been to develop potential population values for breeding Mallards in prairie Canada and to evaluate management programs that might keep them at the desired abundance levels. This report describes a simulation model used to forecast Mallard numbers in Manitoba, Saskatchewan, and Alberta, and discusses management options and trends in Mallard numbers for these areas.

The population model

The model assumes that all Mallards which survive the winter return to their respective breeding ranges (Anderson and Henney 1972). Thus, emigration is assumed to equal immigration and the populations are treated as closed systems. The model does not account for immigration when ponds are numerous (Hochbaum 1946) or emigration to northern areas during periods of drought (Crissey 1969; Pospahala, Anderson, and Henny 1974). Discrimination is made between adults and juveniles by sex. Carrying capacity is assumed to be related to May ponds by a linear forcing function (Fig. 1). This relationship assumes that the number of May ponds generally affects the ability of the habitat to support breeding Mallards as suggested by Crissey (1969).

Figure 1
Relationship of carrying capacity to May ponds



The simplifying assumption between carrying capacity and May ponds is necessary since May ponds represent the only long-term index to habitat at the regional level. Other factors such as land use and upland cover should be considered when data become available. When the spring adult population exceeds the carrying capacity, only a number of Mallard equalling the carrying capacity are allowed to contribute to reproduction. We assume the lower carrying capacity threshold is controlled by the occurrence of permanent water bodies, and the upper by some optimum open water–upland cover ratio. When this ratio is exceeded, the water may become limiting and actually cause carrying capacity to decline.

Ponds are either read into the model as real data or are generated randomly to fall within the observed range of maximum and minimum ponds from 1955 to the present. Mallard production is calculated by the equation:

$$X_t^{sy} = (X_t^{fa} \cdot P \cdot F)/2$$

where:

X_t^{sy} = number of young (y) in a sex class (s) at time t,

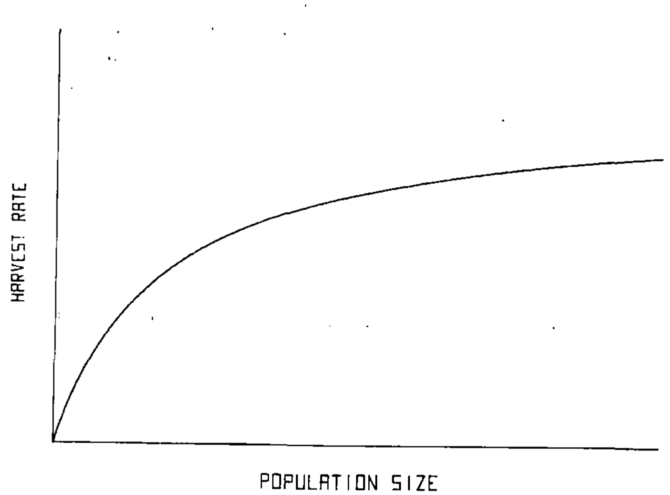
X_t^{fa} = number of breeding females (fa) at time t,

P = hen success (probability that a breeding hen will fledge a brood),

F = fledged brood size for a specific area.

ɛg, Man. R3T 2N6.
ɪf Renewable Resources and Transportation Services,
n. R3C 0V8. Present address: CWS, Winnipeg,
6.

Figure 2
Relationship of harvest rate to population size



Harvest is assumed to be a function of density (Fig. 2) and is calculated by the equation:

$$H_t^{sc} = M^{sc} \cdot X_t^{sc} / (B^{sc} + X_t^{sc})$$

where:

s = male (m) or female (f)

c = adult (a) or young (y)

H_t^{sc} = harvest rate for a specific sex–age class (sc) at time t,

X_t^{sc} = density of a specific sex–age class (sc) at time t,

B^{sc} = density at which H_t^{sc} achieves one-half of its maximum value for a specific sex–age class (sc),

M^{sc} = maximum harvest rate for a specific sex–age class (sc).

This yield equation describes the functional response of predators to prey density as proposed by Holling (1959). We assume that the harvest rate rises as Mallard numbers increase to a maximum, which may be related to physical constraints of hunters and avoidance behaviour of the birds. This relationship was first applied to Mallards by Walters *et al.* (1972) on a continental basis, and was later used in mixed-species models by Hochbaum (1976).

Crippling losses are not monitored in Canada, but are assumed to be similar to the 20% used by Anderson and Burnham (1976). The kill rate is calculated by multiplying harvest rates by 1.25.

The kill is calculated, natural mortality removed, and juveniles aged by the equation:

$$X_{t+1}^{sa} = [X_t^{sa} - (H_t^{sa} \cdot X_t^{sa} \cdot C)] \cdot S_t^s + [X_t^{sy} - (H_t^{sy} \cdot X_t^{sy} \cdot C)] \cdot S_t^s$$

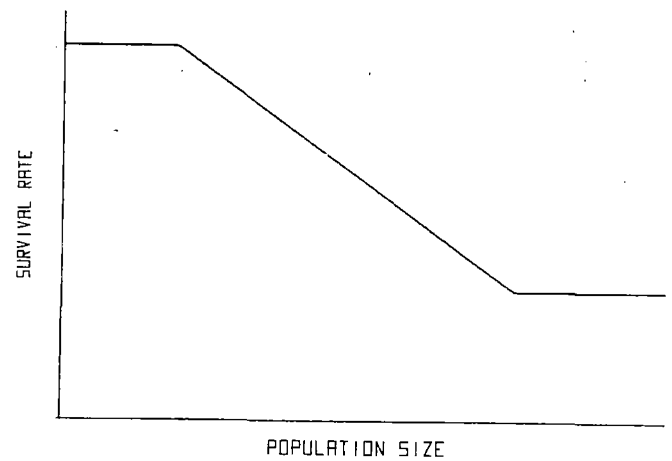
where:

C = crippling loss rate (1.25),

S_t^s = survival outside hunting season at time t;

Survival outside the hunting season is assumed to be a sex-specific negative linear function of post-hunting-season density (Fig. 3). Non-hunting mortality may be attributed to a number of factors including predators, accidents, disease, etc. We suggest a density dependent survival rate in addition to hunting mortality which operates within minimum and maximum population levels. This type of survival relationship may be thought of as compensatory within certain threshold abundance levels and is partially supported by evidence presented for the Mallard by Anderson and Burnham (1976).

Figure 3
Relationship of post-hunting-season survival to population size



Procedures

Mallard breeding population trends were forecast for four management units: southwestern Manitoba (Strata 36, 37, 38, 39, 40), southeastern Saskatchewan (Strata 31, 34, 35), southwestern Saskatchewan (Strata 30, 32, 33), and southern Alberta (Strata 26, 27, 28, 29) (Fig. 4). We tabulated May ponds and Mallard numbers for each unit from data collected between 1955 and 1974 on the spring survey conducted jointly by CWS and the US Fish and Wildlife Service. Estimates of harvest and survival parameters were taken from Anderson (1975), and natural mortality rates were calculated by the equation:

$$N^s = 1 - (H_t^s \cdot 1.25) - S_t^s$$

where:

N^s = natural mortality for a sex class,

H_t^s = harvest rate for a sex class at time t,

For southeastern Saskatchewan and southwestern Manitoba, harvest and survival parameters were estimated from southwestern Manitoba data reference area 061 (Fig. 5). Southern Alberta and southwestern Saskatchewan estimates for these values were taken from reference area 041, which includes southwestern Saskatchewan and southeastern Alberta.

Figure 4
Waterfowl breeding pair survey strata in prairie Canada taken from US Fish and Wildlife Service and Canadian Wildlife Service (1977)

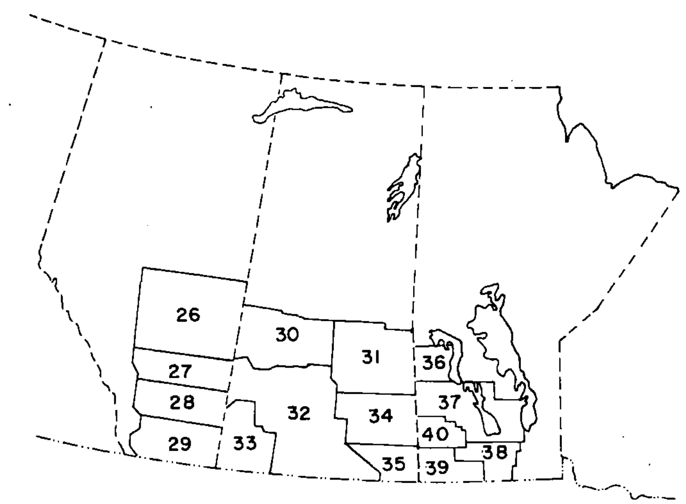
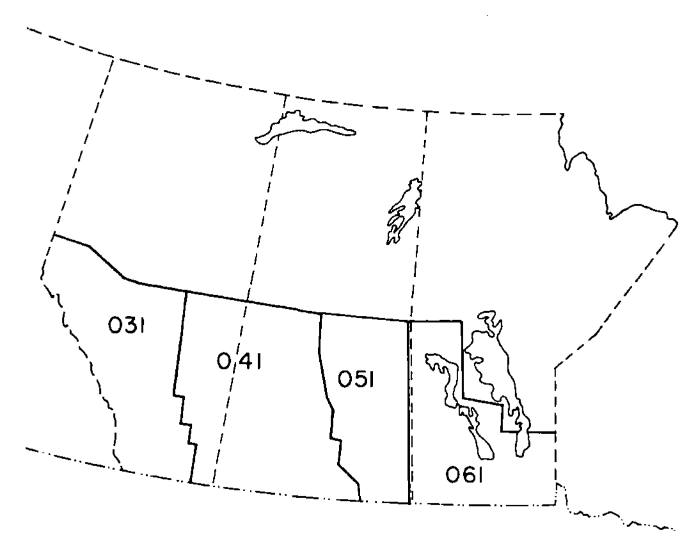


Figure 5
Major Mallard reference areas taken from Anderson and Henny (1972)



Since no recent estimates of hen success are available for the management units, we made simulations using observed pond data to compared predicted and observed populations by ψ^2. The variable, hen success, was varied to drive the model, and a best fit of the predicted values to the observed data was obtained for each area. We then assessed the long-term behaviour of each population by examining the averaged predicted values generated over 25-year periods using random ponds and the best-fit hen success values. Three management options were investigated: (1) no change from present, (2) reduced harvest, and (3) increased hen success. Twenty-five-year trends were then simulated to evaluate realistic management programs.

We based the distribution of the kill between Canada and the USA on direct band recoveries (from J. B. Gollop, CWS, Saskatoon, pers. comm.). Thus, 50% of the young and 25% of the adults are shot in Manitoba and in Alberta, whereas 35% of the young and 20% of the adults are shot in Saskatchewan.

No recent estimates of fledged brood size are available for Mallards on the prairies. The figure of 6.1 reported by Dzubin and Gollop (1972) for the Roseneath Study Area in the mid 1950's was used in all simulations of fledged brood sizes for Manitoba. In Saskatchewan, a mean fledged brood size of 4.9 (A. Dzubin, CWS, Saskatoon, pers. comm.) was used in all simulations. Smith (1971) reported a fledged brood size for Mallards of 5.1 in the Lousana Study Area, and this value was used in all simulations for Alberta.

Results and discussion

The values of hen success exhibiting the best fit by ψ^2 of the predicted to the observed populations were 20% for southwestern Manitoba, 15% for southeastern Saskatchewan, 30% for southwestern Saskatchewan, and 20% for southern Alberta. These differences may be related to climate, habitat conditions, predator levels, farming practices, or genetic variability in each area.

In southwestern Manitoba, with no change in recruitment, or harvest policy, the population will average 320 000 breeding Mallards using random pond values (Table 1 and Fig. 6D). When hen success was increased from 20% to 50%, the long-term average population level of 411 300 remained below the observed 1955 to 1974 average of 432 000 breeders (Table 1).

Harvest reductions of 25% in southwestern Manitoba would stop the decline of this population and Mallards would approach 325 000 breeders under average conditions, if this policy were maintained over a long period (Table 2).

Figure 6
Simulated trend of Mallard breeding populations in southwestern Manitoba under four management options (B, C, and D with best-fit hen success of 20%). A – unlimited ponds and 30% hen success, B – unlimited ponds and 25% reduction in Manitoba harvest, C – unlimited ponds with no management intervention, D – random ponds with no management intervention

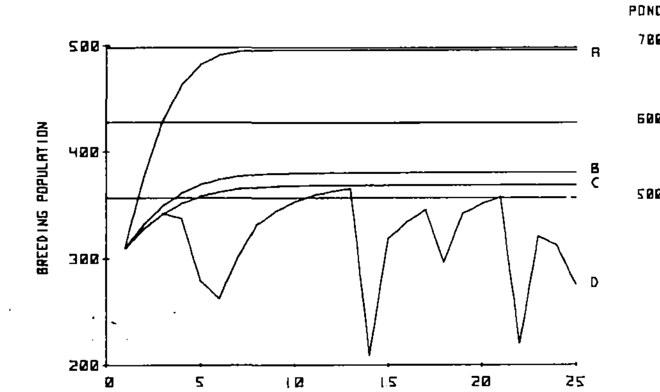


Table 1
Equilibrium (average) population parameters for Mallards in southwestern Manitoba under varying hen successes. Values are 25-year means

	% hen success				
	10	20	30	40	50
Breeding pop.	215 910	318 500	368 500	400 200	411 300
Manitoba kill	7900	23 700	45 600	71 500	96 600
US kill	21 000	50 500	83 100	117 600	144 200
Total kill	28 900	74 200	128 710	189 100	245 800
Harvest rate					
Juvenile male	0.05	0.13	0.18	0.22	0.24
Juvenile female	0.03	0.08	0.11	0.14	0.15
Adult male	0.10	0.12	0.13	0.14	0.14
Adule female	0.09	0.13	0.14	0.16	0.16
Survival rate*					
Male	0.93	0.85	0.80	0.75	0.72
Female	0.83	0.74	0.68	0.64	0.60

*Survival outside hunting season.

Table 2
Equilibrium (average) population parameters for Mallards in southwestern Manitoba with varying harvest reduction in Manitoba. Hen success is 20% for each option. Values are 25-year means

	% reduction in Manitoba harvest				
	0	25	50	75	100
Breeding pop.	318 500	323 700	328 300	332 900	337 600
Manitoba kill	23 700	18 300	12 500	6400	0
US kill	50 500	52 100	53 700	55 300	56 900
Total kill	74 200	70 400	66 200	61 700	56 900

Approximately 66% of the harvest of southwestern Manitoba Mallards occurs in the United States, and as a result, if Manitoba eliminated sport hunting, the population would only average 340 000 (Table 2). The long-range forecast suggests that the habitat could support 500 000 breeding Mallards under optimum conditions. This could only be achieved if there were management programs aimed at increasing recruitment, coupled with reduced harvests in the United States and Canada (Fig. 6). Pond numbers greatly affect the number of breeding Mallards in prairie Canada (Crissey 1969). Populations would increase significantly in southwestern Manitoba if managers could maintain 700 000 ponds and could increase hen success from 20% to 30% (Fig. 6A). Under these water conditions ponds are never limiting. With unlimited ponds and no management policy change, the population stabilizes at about 350 000 (Fig. 6C). The population stabilizes at a slightly higher level if there is a 25% reduction in harvest (Fig. 6B).

In the absence of new management programs, the forecast trend in Mallard numbers of southeastern Saskatchewan suggests the population will average 690 000 breeders (Table 4 and Fig. 7). This number is well below the 1955 to 1974 observed population mean of 1.2 million breeding Mallards. The long-term average breeding population of 1.2 million could be approached if hen success were increased to 50% from the present estimated 15% (Table 3). Approximately 75% of the kill from this population occurs in the United States (Table 4), and as a result population gains will not be rapid if hunting is curtailed in southeastern Saskatchewan alone (Table 4). This population exhibits a rapid increase and stabilizes at near one million breeders when pond numbers are not limiting and hen success is increased from 15% to 25% (Fig. 7A).

The population will increase by less than 10 000 if the southeastern Saskatchewan harvest alone is reduced by 25% with unlimited pond conditions (Fig. 7B). Since the simulated population trends are similar for options B, C, and D (Fig. 6), only showing gains under increased hen success, they suggest that mortality equals recruitment for these populations.

Table 3
Equilibrium (average) population parameters for Mallards in southeastern Saskatchewan under varying hen successes. Values are 25-year means

	% hen success				
	10	20	30	40	50
Breeding pop.	513 600	810 100	953 200	1 042 300	1 097 800
Sask. kill	10 600	34 500	67 800	107 500	149 800
US kill	39 400	108 000	189 800	280 000	377 500
Total kill	50 000	142 500	257 600	387 500	522 300
Harvest rate					
Juvenile male	0.05	0.12	0.18	0.22	0.25
Juvenile female	0.03	0.08	0.11	0.14	0.16
Adult male	0.07	0.09	0.10	0.11	0.12
Adult female	0.07	0.10	0.12	0.13	0.14
Survival rate*					
Male	0.95	0.88	0.83	0.79	0.76
Female	0.85	0.78	0.72	0.68	0.64

*Survival outside hunting season.

Table 4
Equilibrium (average) population parameters for Mallards in southeastern Saskatchewan with varying harvest reduction in Saskatchewan. Hen success is 15% for each option. Values are 25-year means

	% reduction in Saskatchewan harvest				
	0	25	50	75	100
Breeding pop.	691 700	704 300	716 600	728 100	739 800
Sask. kill	21 100	16 300	11 200	5800	0
US kill	71 700	73 800	76 100	78 200	80 500
Total kill	97 800	90 100	87 300	84 000	80 500

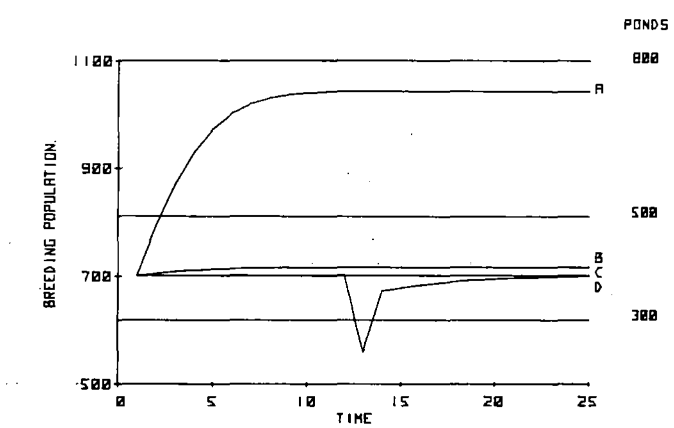


Figure 7
Simulated trend of Mallard breeding populations in southeastern Saskatchewan under four management options (B, C, and D with best-fit hen success of 15%). A – unlimited ponds and 25% hen success, B – unlimited ponds and 25% reduction in Saskatchewan harvest, C – unlimited ponds with no management intervention, D – random ponds with no management intervention

In southwestern Saskatchewan, the long-term average is 1.2 million breeding Mallards with no management intervention (Table 5 and Fig. 8). This predicted value is similar to the 1955–74 observed average of 1.3 million breeders. The observed mean could be achieved by increasing hen success to 40% from the current best-fit level of 30% (Table 5). Approximately 75% of the harvest from this population occurs in the United States, and therefore a reduction in the Canadian harvest alone would result in negligible gains (Table 6).

Southwestern Saskatchewan Mallards would show rapid increases and stabilize at about 1.7 million breeders if ponds were not limiting and hen success were increased from the best fit of 30% to 40% (Fig. 8A). There is only a slight difference in population trends between a 25% reduction in harvest and no management change under unlimited pond values (Fig. 8B and C).

The 1955–74 observed average breeding population of Mallards in southern Alberta is 1.5 million. With 20% hen success, random pond values, and no management change, the long-term predicted average population is about 1.1 million (Table 7 and Figure 9D). If hen success were increased to 40% from the current estimated 20%, the population would average about 1.3 million. About 70% of the kill from southern Alberta Mallards occurs in the United States. Poor population gains are experienced if harvests are reduced only in Canada (Table 8).

Mallards breeding in southern Alberta would stabilize at about 1.5 million if hen success could be increased from the estimated 20% to 30% and ponds were not limiting (Figure 9A). If there is no management change or if harvests are reduced by 25%, the population would remain near 1.3 million provided that there were unlimited pond numbers (Figure 9B and C).

Table 5
Equilibrium (average) population parameters for Mallards in southwestern Saskatchewan under varying hen successes. Values are 25-year means

	% hen success			
	20	30	40	50
Breeding pop.	996 600	1 191 600	1 307 800	1 371 200
Sask. kill	76 900	47 900	69 900	91 000
US kill	89 300	144 400	198 500	248 400
Total kill	116 200	192 300	268 400	339 400
Harvest rate				
Juvenile male	0.06	0.08	0.10	0.11
Junevile female	0.07	0.10	0.11	0.13
Adult male	0.08	0.09	0.10	0.10
Adult female	0.04	0.05	0.05	0.06
Survival rate*				
Male	0.91	0.87	0.83	0.81
Female	0.72	0.66	0.61	0.57

*Survival outside hunting season.

Table 6
Equilibrium (average) population parameters for Mallards in southwestern Saskatchewan with varying harvest reduction in Saskatchewan. Hen success is 30% for each option. Values are 25-year means

	% reduction in Saskatchewan harvest				
	0	25	50	75	100
Breeding pop.	191 600	1 202 100	1 212 600	1 222 500	1 231 800
Sask. kill	47 900	36 300	24 500	12 400	0
US kill	144 400	146 400	148 400	150 300	152 100
Total kill	192 300	182 700	172 900	162 700	152 100

Figure 8
Simulated trend of Mallard breeding populations in southwestern Saskatchewan under four management options (B, C, and D with best-fit hen success of 30%). A – unlimited ponds and 40% hen success, B – unlimited ponds and 25% reduction in Saskatchewan harvest, C – unlimited ponds with no management intervention, D – random ponds with no management intervention

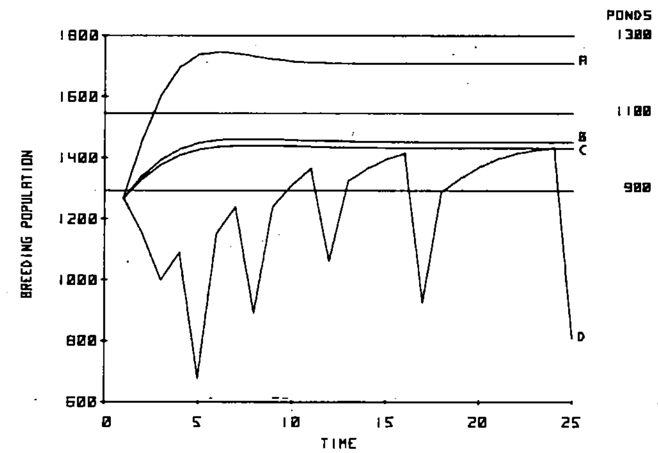


Figure 9
Simulated trend of Mallard breeding population in southern Alberta under four management options (B, C, and D with best-fit hen success of 20%). A – unlimited ponds and 30% hen success, B – unlimited ponds and 25% reduction in Alberta harvest, C – unlimited ponds with no management intervention, D – random ponds with no management intervention

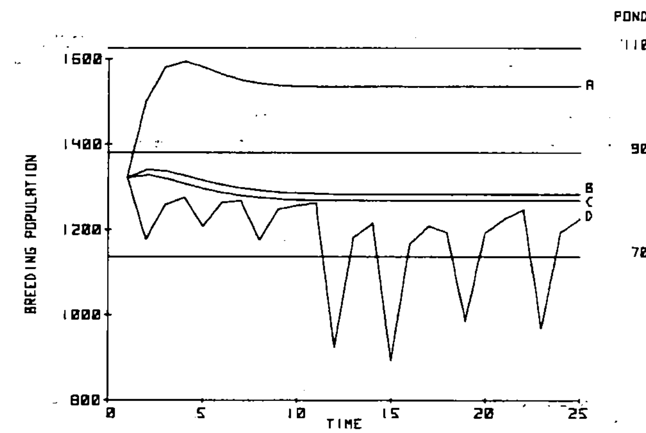


Table 7
Equilibrium (average) population parameters for Mallards in southern Alberta under varying hen successes. Values are 25-year means

	% hen success				
	10	20	30	40	50
Breeding pop.	922 800	1 171 200	1 280 300	1 341 900	1 365 300
Alberta kill	26 400	50 300	76 100	102 400	127 000
US kill	73 300	120 900	163 700	203 200	238 100
Total kill	99 700	171 200	239 800	305 600	365 100
Harvest rate					
Juvenile male	0.03	0.05	0.07	0.08	0.09
Juvenile female	0.03	0.06	0.08	0.10	0.11
Adult male	0.10	0.11	0.12	0.12	0.12
Adult female	0.04	0.05	0.06	0.06	0.06
Survival rate*					
Male	0.98	0.91	0.86	0.83	0.80
Female	0.83	0.72	0.65	0.60	0.56

*Survival outside hunting season.

Table 8
Equilibrium (average) population parameters for Mallards in southern Alberta varying with harvest reduction in Alberta. Hen success is 20% for each option. Values are 25-year means

	% reduction in Alberta harvest				
	0	25	50	75	100
Breeding pop.	1 171 200	1 179 300	1 187 300	1 194 500	1 201 200
Alberta kill	50 300	38 000	35 600	12 900	0
US kill	120 900	122 600	124 200	125 800	127 400
Total kill	171 200	160 600	149 800	128 700	127 400

Conclusions

Simulation results suggest that population gains are small if the Mallard harvest is unilaterally reduced in the Canadian prairie provinces, because the major portion of these population units are harvested elsewhere. The harvest may be increased if hen success is improved, and therefore management strategies aimed at building populations should be directed toward recruitment. Future harvests of prairie Mallards should not be increased in the absence of programs designed to offset this kill by improving production. The long-term forecasts suggest that Mallards in southwestern Manitoba and southeastern Saskatchewan will fall below the 1955 to 1974 observed mean, whereas populations in southwestern Saskatchewan and southern Alberta appear to be more stable under average conditions.

Acknowledgements

We thank J. Patterson of CWS for proposing the project and for his encouragement throughout. We gratefully acknowledge K. Brace, E. Driver, G.E.J. Smith, and S. Wendt for their constructive criticism of this manuscript. This project was jointly funded by CWS and the Research Branch of the Manitoba Department of Renewable Resources and Transportation Services.

References

Anderson, D.R. 1975. Population ecology of the Mallard: V Temporal and geographic estimates of survival, recovery, and harvest rates. US Fish Wildl. Serv. Resour. Publ. 125. 110 pp.

Anderson, D.R., and C.J. Henny. 1972. Population ecology of the Mallard: I A review of previous studies and the distribution and migration from breeding areas. US Fish Wildl. Serv. Resour. Publ. 105. 166 pp.

Anderson, D.R., and K.P. Burnham. 1976. Population ecology of the Mallard: VI The effect of exploitation on survival. US Fish Wildl. Serv. Resour. Publ. 128. 66 pp.

Crissey, W.F. 1969. Prairie potholes from a continental viewpoint. Pages 161–171 *in* Saskatoon Wetlands Seminar. Can. Wildl. Serv. Rep. Ser. 6. 262 pp.

Dzubin, A., and J.B. Gollop. 1972. Aspects of Mallard breeding ecology in Canadian parkland and grassland. Pages 113–151 *in* Population ecology of migratory birds, a symposium. US Fish Wildl. Serv., Rep. 2.

Hochbaum, H.A. 1946. Recovery potentials in North American Waterfowl. Trans. North Am. Wildl. Conf. 11:403–418.

Hochbaum, G.S. 1976. Components of hunting mortality and management options for harvesting ducks. Can. Wildl. Serv. Unpubl. Manuscr. 42 pp.

Holling, C.S. 1959. Some characteristics of simple types of predation and parasitism. Can. Ent. 91:385–398.

Pospahala, R.S., D.R. Anderson, and C.J. Henny. 1974. Population ecology of the Mallard: II Breeding habitat conditions, size of the breeding populations and production indices. US Fish Wildl. Serv. Resour. Publ. 115. 73 pp.

Smith, A.G. 1971. Ecological factors affecting waterfowl production in the Alberta parklands. US Bur. Sport Fish Wildl. Resour. Publ. 98. 49 pp.

US Fish and Wildlife Service and Canadian Wildlife Service. 1977. Standard operating procedures for aerial waterfowl and habitat surveys. Unpubl. Rep. 68 pp.

Walters, C.J., R. Hilborn, E. Oquss, R.M. Peterman, and J.M. Stander. 1972. Development of a simulation model of Mallard duck populations. Can. Wildl. Serv. Occ. Pap. No. 20. 34 pp.