Progress Notes

Disponible également en français

No. 153, February 1985

Variable versus stable regulatory policies for harvesting waterfowl in prairie Canada: A review of concepts

George S. Hochbaum[1]

Introduction

In 1979, the Canadian Wildlife Service (CWS) and the provincial governments of Manitoba, Saskatchewan, and Alberta initiated a co-operative venture to advance waterfowl management in prairie Canada. Regulations were stabilized for a 5-year period in order to address cause-and-effect relationships between hunting regulations and waterfowl population dynamics. This paper reviews population dynamics and management models, discusses objectives of the 5-year study, and makes recommendations for future programs.

Anderson (1975) suggested that the optimal exploitation of the Mallard (*Anas platyrhynchos*) in North America should be based on regulatory policies determined each year by population size and state of the environment, because policies based on average harvest or plans designed to maintain a constant population size are inefficient: when birds are abundant there is underharvest and in years of scarcity there may be an overharvest.

However, Anderson's recommendations are more applicable in an American context than a Canadian one. Canada and the US have different political systems, environments and harvest opportunities. In Canada there are several advantages to what may be called *stable* or *term* regulations. Stable regulations can be made simple and easily understandable by the hunter; they are thus more readily enforceable. Stabilizing season dates and bag limits may reduce fluctuations in hunter numbers and hunter expectations. Because of our slow-moving system for securing approval of changes and their promulgation by order-in-council, regulations to be published in August must be set not later than early June. Current year production data are not then available, so that fall flight forecasts cannot be made. Regulations agreed to for a period of several years reduce occasions for federal-provincial conflicts, remove the variability associated with constant juggling of zones, season lengths, and bag limits, and allow for a continual evaluation of the effects of hunting on waterfowl. Finally, stable regulations set in Canada at a conservative level over a fairly long period should ensure that no stocks of ducks or geese are jeopardized by *Canadian* overharvest.

Conceptual model and study objectives

The processes and factors involved in regional harvests and population dynamics of waterfowl are outlined in Figure 1. Although largely untested, the relationships among regulations, harvest, survival rate, and population size are critical (Fig. 1). If waterfowl populations are at the carrying capacity of their breeding environment and their different causes of mortality are wholly compensatory, then it is unlikely that hunting regulations and harvest will have any effect on stock size. However, if the population is below the carrying capacity and hunting mortality occurs in addition to natural mortality, populations could be influenced by hunter kill. The limiting effects of habitat and density-dependent mortality affect whether or not birds could be "stockpiled" to increase population size. The logistic model of population growth implies that populations below carrying capacity increase until they attain some limiting environmental threshold.

Other relationships that are also important include those among population size, recruitment, and harvest. Many variables influence these relationships (Fig. 1). Although not all the factors illustrated are included in the present study, we hope to determine key parameters influencing recruitment (to the flying stage), harvest, and subsequent breeding population levels.

The number of hunters may be an important determinant of harvest. Hunters may be influenced by several factors, including waterfowl abundance, both absolute and perceived, and published forecasts of fall flight. Regulations themselves may also play an important role in determining how many hunters will go afield. Many other variables, however, may influence harvest in addition to the number of hunters, including such factors as weather, foraging behaviour, sex ratio, age structure, species composition, and crippling losses (Fig. 1).

The essence of the CWS/provincial co-operative project is to determine what factors influence harvest when hunting regulations are held constant. We must then develop the capability to forecast yields under different management policies. The important state variables, including both biotic and abiotic factors, are listed in Figure 1. The author's analysis concentrates on variables over which managers have most influence and control.

The stabilization of regulations is an adaptive management strategy that forces the system outlined in Figure 1 through natural and uncontrolled changes. The variability associated with bag limit and season length is removed, while other variables lead to a large-scale experimental situation and a host of hypotheses to be tested.

Through the evaluation of the stable framework, the following questions must be answered, at least for those species harvested in large numbers and those seeming to be in difficulties.

1. How many birds are there, where, and why?
2. How many birds are produced, where, and why?
3. How many birds die each year and from what causes?
4. How many do we need to sustain desired harvest levels?
5. What effect do regulations have on harvest?
6. What effect does harvest have on survival and population size?
7. Where, by whom, and how does the harvest occur?

[1] CWS, 501 University Crescent, Winnipeg, Manitoba R3T 2N6

8. How much kill is undocumented?
9. What effects do regulations have on hunter numbers and the level of kill?
10. What interactions occur between birds and hunters and how do these factors affect kill?

Population parameters and management concepts

Two contrary views on the effects of hunting on survival and subsequent population size of waterfowl have received much attention. Hickey (1952) and Geis (1963) suggested that deaths from hunting are additional to natural mortality, which occurs at a constant density-independent rate. Anderson and Burnham (1976) disagreed, arguing that hunting is compensatory and replaces deaths occurring through natural mortality. Anderson and Burnham showed that, prior to 1971, hunting had little effect on survival rates until harvest rates reached a threshold level and argued that ducks cannot be "stockpiled" because if they are not killed by hunters they will die of other causes. They conclude that survival rates could not be increased through restrictive regulations. Restrictive regulations, they maintain, will save few birds and will not increase the size of the breeding population in subsequent years. Their hypotheses suggest that if birds are at carrying capacity of the habitat, death rates are relatively constant.

These opposing views can be expressed in terms of yield models of populations first described for fish by Graham (1935) and later for wildlife populations by Scott (1954) and Gross (1969) and based on the sigmoid growth curve theory. If there is density dependence in birth and death rates (Figs. 2B, C, 3A) a new population initially grows rapidly then levels off asymptotically to some environmental carrying capacity (K) where births equal deaths, giving an S-shaped population growth curve (Fig. 2A). A stock-yield curve can be developed for the compensatory theory by multiplying birth and death rates by the number of animals alive in the population (Figure 2B). Yield or harvest is greatest at intermediate densities where the maximum net production of potential yield occurs (P, Figs. 2B and 3B).

Under the additive theory deaths are largely density independent with constant rate of annual mortality (Fig. 3A). Birth and death rates, where death rate is independent of density, are multiplied by numbers of animals to give functional relationships (Fig. 2C). Maximum yield occurs at an intermediate density (P, Fig. 2C). Harvest occurs as an additive factor (Fig. 2C) and to a certain extent is density dependent (Hochbaum 1980).

Under the compensatory theory, harvest lowers natural density-dependent mortality and, as the population decreases, births and potential yield (Y) increase (Fig. 2B). Under the additive theory, births also increase as the population declines to intermediate levels (P) but the yield is somewhat smaller because natural density-independent mortality does not decrease. Survival rate and population size may be lowered in the additive model because harvests are taken in addition to a constant rate of natural deaths. As a result the level of K, where births equal deaths, will be lowered (Fig. 2C).

A major practical problem is the variable environment and the short period required to reach K. Duck birth rates have recently been reduced in prairie Canada because of intensified agriculture and high predation (Hochbaum and Caswell 1978), and resilience has been reduced by loss of suitable environments both on the breeding and wintering grounds. Mortality, on the other hand, has probably remained constant or has increased due to increased human demands on and conflicts with the ducks.

A major analytical problem is that K is highly variable and yields may be relatively similar under the compensatory (Fig. 2B) and additive theories (Fig. 2C), especially when populations are large. For both there is a critical region (C) where, if harvest is excessive, population small, birth rate constant and yield high, the population may go into a sharp decline (Watt 1955, Walters *et al.* 1974, Peterman 1980): Figure 3C shows that yield per unit effort from the population will decline as the harvest effort increases. Such drastic declines have rarely been documented, but are thought to be related to age structure changes induced by harvesting (see Gulland 1970 for a discussion on marine mammals).

In waterfowl, carrying capacity can be reached in a very few years because of high annual reproductive potential due to early sexual maturity, persistent re-nesting, long life span, large clutch size, and elastic response to environmental conditions (Hochbaum 1970). Examples of where high recruitment rates occur include areas that provide good nest cover, are free from predators (Balser *et al.* 1968, Duebbert and Lokemoen 1980), are on islands (Hammond and Mann 1956, Lokemoen *et al.* 1984), and occupation of ephemeral water areas (Hochbaum and Bossenmaier 1972).

If maximum population size is the management goal and K could be measured (there are many problems, see Dzubin 1969) and maintained, a simple equation could be used to monitor harvests and populations in management modelling and decision-making games.

Let B = number of breeding ducks in May
K = carrying capacity
then $B / K - 1 = A$
where A is a measure of yield at mascimumum population size.
Then if: $B > K$, $A > 0$ and there is underharvesting.
$B < K$, $A < 0$ and there is overharvesting.
When $B = K$, $A = 0$, so that the harvest scheme is optimal for maintaining a maximum population size at the maximum level the habitat will support.

When $A \neq 0$, the degree of effectiveness in the maintenance of the population at K can be measured by multiplying A by 100, yielding the level of underharvest or overharvest of the past years.

As carrying capacity, breeding populations, and production are all highly variable and difficult to predict, attempts should be made to attain maximum birth rates through habitat improvement programs if increased yields are desired. Because of harvest policies in the US, and the controversy over compensatory and additive mortality, coupled with a highly variable environment, harvest policies in Canada should remain at conservative stable yield levels. Level C must never be approached because of lowered growth potential (loss of resilience) due to habitat deterioration and predation. Harvests, populations, and production should be monitored closely. Breeding and wintering habitats are never likely to be stable because of their susceptibility to climatic conditions and to changing human use, most of which seems to be deleterious.

In summary, because of current birth and death rates, and the rapid changes in population size that may occur as a result of changes in these rates or in the environment, it is probably best to adopt a management policy having as its goal the maximum population size.

Management programs and discussion

The progress for evaluating waterfowl hunting in prairie Canada over the past 5 years has consisted of three basic programs:

1. Population inventory
2. Population mortality
3. Hunter performance.

Various aspects of the 10 fundamental questions discussed were investigated under these programs. The population inventory program uses surveys to estimate duck abundance and production. The population mortality program studies survival and harvest, utilizing banding data. The hunter performance program consists of intensive field observations of hunts, bag checks, and the hunter activity and kill data from the National Harvest Survey (NHS) and Species Composition Survey (SCS). The three programs are utilized to study factors and processes regulating births and deaths and to evaluate the interactions that occur between birds and hunters during the fall harvest.

May *et al.* (1978) suggested constant yield as an alternative tactic if the harvest is not to exceed the critical level (C, Figs. 2B and 2C). Yields must never be greater than net production. They suggest constant effort strategies may produce similar equilibrium harvest. However, constant yield may produce strong fluctuations in breeding populations, if this strategy is pursued alone. "Natural" hunting effort levels, varying with changing duck abundance, will achieve stable equilibrium yield rates. Constant yield and constant effort policies should be continually reviewed to ensure that C is never reached.

If hunter activity responds to duck population size, i.e. there is natural control of hunter effort levels, and a constant exploitation rate is maintained, i.e. harvest varies with duck abundance, then stable regulations should be maintained in prairie Canada. Levels of hunting effort and yield must be controlled more by natural variables than by regulations in order that stable regulations can be effective. This being so, policy changes should only be undertaken as a matter of political concern because they probably have little effect on kill. On the other hand, if regulations can be used to control the kill and influence population size, harvest policy should be varied to compensate for population and habitat changes. This situation would occur where harvests and effort levels do not correspond to waterfowl populations. Such a relationship seems to occur on the wintering grounds in the United States, where ducks are concentrated, relatively sedentary, and vulnerable because of courtship and migratory behaviour.

In the US, harvests and harvest rates may be independent of population size, as suggested by Brace and Caswell (1984). Brown *et al.* (1976) stated that the methods of choosing harvest policies for ducks had been more arbitrary than necessary, being based on the "art" of past management experience. Walters and Hilborn (1978) pointed out there are three types of uncertainty in management:

1. Random environments outside the managers' influence, e.g. fluctuations in numbers of May and July ponds;
2. Estimation errors in system states and parameters that cannot be reduced at reasonable cost, e.g. production estimates; and
3. Fundamental misunderstandings about the choice of variables and form of the population models to be used, e.g. compensatory versus additive mortality models.

Walters and Hilborn suggest active planning and judgement (active adaptive management) should be employed where large-scale manipulations or experiments are introduced, such as the stable regulation program, coupled with monitoring and modelling. They prefer this type of management to the "artistic" approach in addressing questions such as those raised here. They believe that increasing the use of scientific methods in the management of ecological systems will improve management performance. During such experiments long-term monitoring and assessment programs should be maintained. Populations, production, harvest, and habitat conditions should be surveyed and the results incorporated into models that will forecast short- and long-term changes in duck abundance and the environmental conditions. Annual review of survey results and projected populations, production, harvests, and habitat conditions will result in refinement and improvement of migratory bird management programs and policies. The result would be the ability to predict duck populations and implement management policies relating to both birth and death rates, which would lead to persistent and relatively stable duck numbers.

Acknowledgements

I wish to thank D. Caswell, K. Brace, G. Cooch, B. Collins, and G. Finney for commenting on an earlier working draft of this paper and A. Kooyman and R. Hutchison for drafting the figures. I am grateful to D. Wilson for typing the manuscript and H. Boyd for his stimulating discussions on yield concepts and his editing of the paper.

References

Anderson, D.R. 1975. Optimal exploitation strategies for an animal population in a Markovian environment. A theory and an example. Ecol. 56(6):1281–1297.

Anderson, D.R.; Burnham, K.P. 1976. Population ecology of the Mallard: VI. The effect of exploitation on survival. USF&WS Ser. Res. Publ. 128.

Balser, D.S.; Dill, H.H.; Nelson, H.R. 1968. Effect of predator reduction on waterfowl nesting success. J. Wildl. Manage. 32:669–682.

Brace, R.K.; Caswell, F.D. 1984. Prairie waterfowl status report: A briefing document. Can. Wildl. Serv. Unpubl. paper. Edmonton. 11 pp.

Brown, G.M.; Hammack, J.; Tillman, M.F. 1976. Mallard population dynamics and management models. J. Wildl. Manage. 40(8):542–555.

Duebbert, H.F. 1969. High nest success and hatching success of ducks on South Dakota CAP land. Trans. N. Am. Wildl. Natl. Resour. Conf. 34:210–224.

Duebbert, H.F.; Lokemoen, J.T. 1980. High duck nesting success in a predator-reduced environment. J. Wildl. Manage. 44: 428–437.

Dzubin, A. 1969. Comments on carrying capacity of small ponds for ducks and possible effects of density on Mallard production. Pages 138–160 *in* Saskatoon Wetlands Seminar. CWS Rep. Ser. No. 6. 262 pp.

Geis, A.D. 1963. Role of hunting regulations in migratory bird management. Trans. N. Am. Wildl. Natl. Resour. Conf. 28:164–171.

Graham, M. 1935. Modern theory of exploiting a fishery and application to North Sea trawling. J. Conseil. Perm. Int. Explor. Mer. 10:264–274.

Gross, J.E. 1969. Optimum yield in deer and elk population. Trans. N. Am. Wildl. and Natl. Resour. Conf. 34:372–386.

Gulland, J.A. 1970. The effect of exploitation on the numbers of marine mammals. Proc. Adv. Study Inst. Dynamics Numbers Popul. Osterbeek.

Hammond, M.C.; Mann, G.E. 1956. Waterfowl nesting islands. J. Wildl. Manage. 20:345–352.

Hickey, J.J. 1952. Survival studies of banded birds. USF&WS Spec. Sci. Rep. Wildl. 15 pp.

Hochbaum, G.S.; Caswell, F.D. 1978. A forecast of long-term trends in breeding Mallard populations on the Canadian prairies. Can. Wildl. Serv. Prog. Note No. 90. 8 pp.

Hochbaum, G.S. 1980. Components of hunting mortality in ducks: a management analysis. Unpubl. PhD. thesis. Univ. of BC.

Hochbaum, G.S.; Bossenmaier, E.F. 1977. Response of pintails to improved breeding habitat in southern Manitoba, Can. Field-Nat. 86:79–81.

Hochbaum, H.A. 1970. Wildfowling and the law. Trans. North Am. Wildl. and Natl. Resour. Conf. 35:313–324.

Lokemoen, J.T.; Duebbert, H.F.; Sharp, D.E. 1984. Nest spacing, habitat selection, and behavior of waterfowl on Miller Lake Island, North Dakota. J. Wildl. Manage. 48:307–321.

May, R.M.; Beddington, J.R.; Horwood, J.W. 1978. Exploiting natural populations in an uncertain world. Math. Biosci. 42:219–252.

Peterman, R.M. 1980. Dynamics of native Indian food fisheries on salmon in British Columbia. Can. J. Fish. and Aquatic Sci. 37:561–566.

Scott, R.F. 1954. Population growth and game management. Trans. N. Am. Wildl. Conf. 19:480–504.

Walters, C.J.; Hilborn, R.; Oguss, E.; Peterman, R.M.; Stander, J.M. 1972. Development of a simulation model of Mallard Duck populations. Can. Wildl. Ser. Occ. Pap. No. 20. 35 pp.

Walters, C.J.; Hilborn, R. 1978. Ecological optimization and adaptive management. Annu. Rev. Ecol. Syst. 9:157–188.

Watt, K.E.F. 1955. Studies in population productivity. I. Three approaches to the optimum yield problem of *Tribolium confusum*. Ecol. Monogr. 25:269–290.

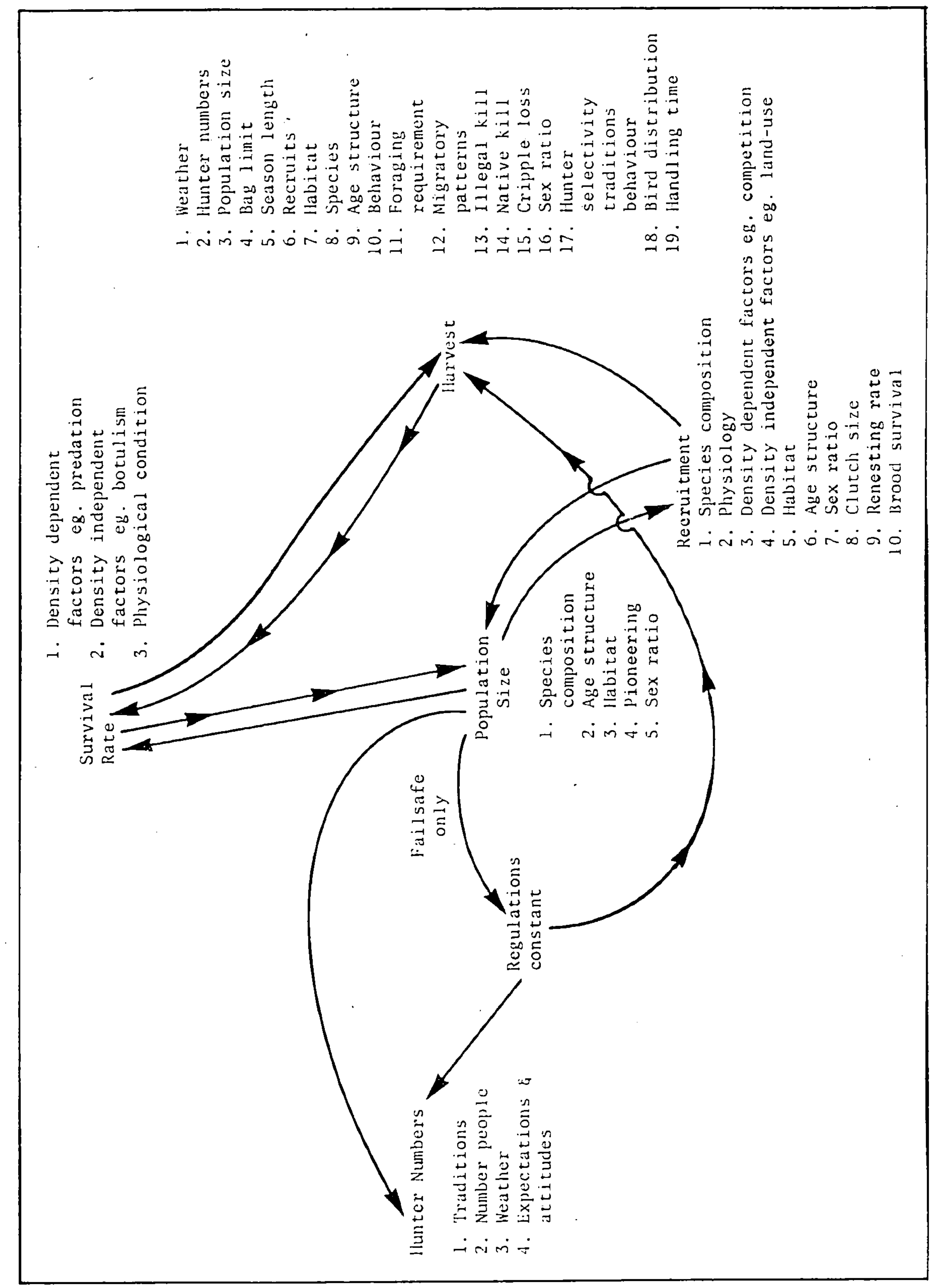

Figure 1
State and independent variables influencing population-regulatory interactions in the absence of policy change

Figure 2
Population growth curve (A), compensatory model of total births and deaths (B), and additive model of total births and deaths (C)

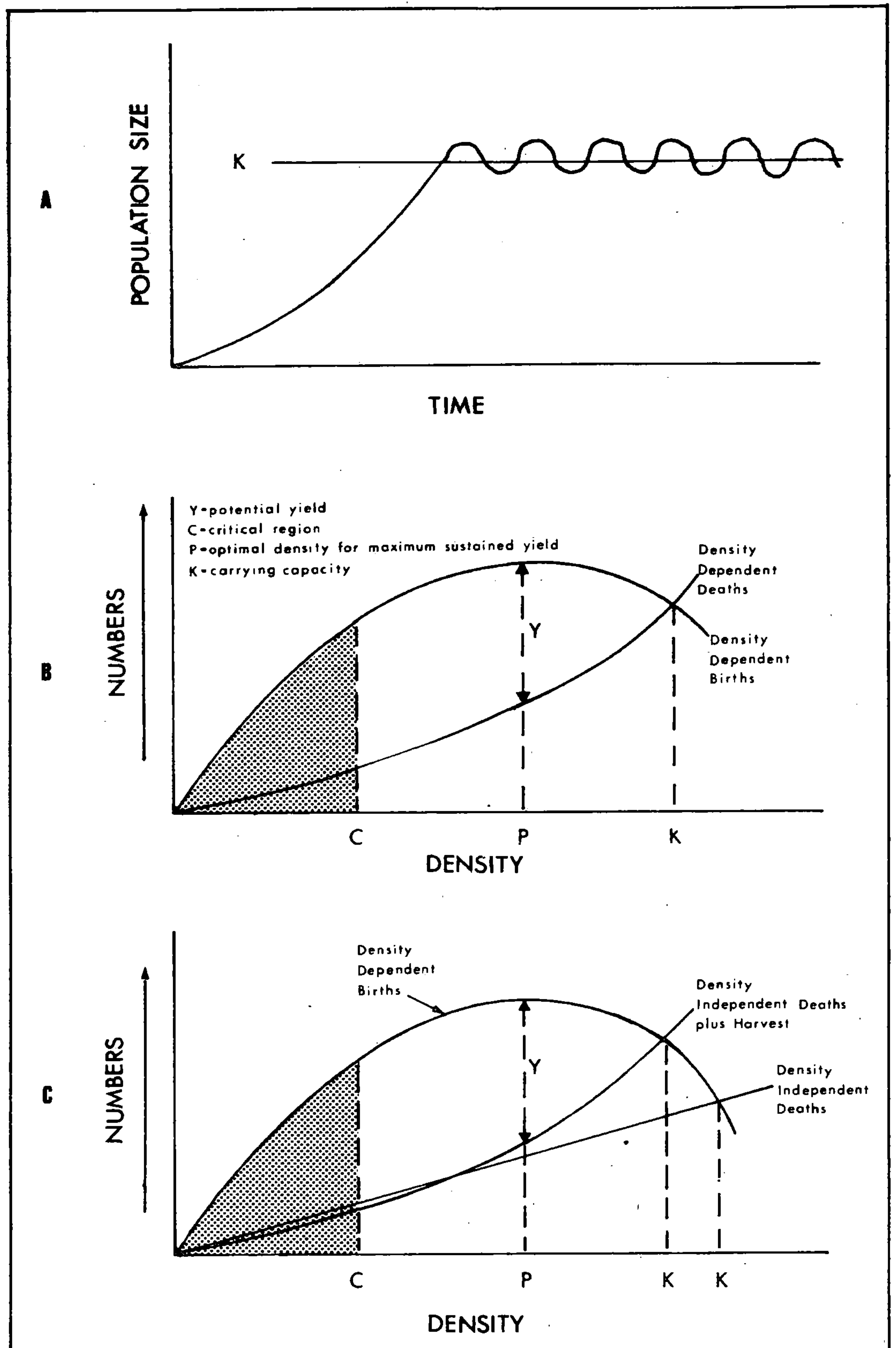

Figure 3
Birth and death rates for population growth in relation to density (A), yield or net gain in relation to density (B), and yield in relation to effort (C)