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## Optimal Policies for Conservation of Large Mammals, with Special Reference to Marine Ecosystems\*

by

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### INTRODUCTION

In recent years, those concerned with renewable resource management have felt the need for a governing concept that goes beyond the principle of a maximum sustainable yield (MSY). Some aspects of the need are economic and social, but a major concern has had to do with ecological issues that were posed by a single-species maximum-yield approach. This has led to efforts to define an optimum, in the sense of 'best or most favourable', policy with respect to the ecosystem of which the managed species is a component part. While it is now quite widely accepted that Man's well-being depends on that of the biosphere in which he exists, there is as yet insufficient knowledge for the precise design of working rules for 'ecosystem management'. As harvests or other actions affecting particular species continue to require regulation, suitably enlightened interim procedures are essential.

Some such procedures have been defined by various committees and working groups sponsored by the International Whaling Commission and in conferences concerned with the North Pacific Fur Seal, Law of the Sea, and other issues. In the United States, a further impetus towards defining 'optimal' policies results from some pioneering legislation embodied in the Marine Mammal Protection Act of 1972 (Public Law 92-522). Under that Act, it is required that marine mammal population 'stocks should not be permitted to diminish beyond the point at which they cease to be a significant functioning element in the ecosystem of which they are a part, and, consistent with this major objective, they should not be permitted to diminish below their optimum sustainable population' (Sec. 2 (2)). Also, in Sec. 2(6) is the requirement that 'it is the sense of Congress that [such stocks] should be protected and encouraged to develop to the greatest

extent feasible commensurate with sound policies of resource management and that the primary objective of their management should be to maintain the health and stability of the marine ecosystem'.

While the scope of this paper includes large mammals in general, it seems worth while to pay particular attention to marine mammals. Not only have they been oft-neglected in vertebrate ecology, but it is instructive to focus on marine mammals to show the effects of actually requiring, by statute, management on an ecosystem basis. Also, the maximum sustained yield (MSY) principle is beginning to be regarded as insufficiently conservative (Larkin, 1977), so that it seems high time to examine an alternative policy.

### DEFINING AN 'OPTIMUM SUSTAINABLE POPULATION'

Some ambiguity exists in the language defining 'optimum sustainable population' (OSP), as may be expected in an effort to give legislative substance to a concept that is based on limited data and hence insufficient scientific understanding. The specific definition is given (Sec. 3(9) of the Marine Mammal Protection Act) as: 'the number of animals which will result in the maximum productivity of the population or the species...', and thus can be interpreted as being maximum sustainable yield (MSY) or something very near to that level.

The main immediate effect of the Act was a moratorium on the taking of marine mammals (with some exceptions), so it seems clear that Congress had in mind some improvements in present procedures before the moratorium could be removed. Inasmuch as harvests and other forms of utilization are specifically referred to, it is unlikely that the intent is solely to preserve maximal or unmanaged populations. Both interpretations of the Act and procedures developing under its provisions seem to place OSP as above MSY, but less than maximal or 'carrying capacity' stock-levels. Presumably the precise point selected in this

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range might depend on judgements as to the ecological role of the particular species, its impact on other valued species, and possible threats to its well-being from various human activities.

The existing techniques for establishing population levels are subject to many shortcomings. Measurements of historical level (from which judgements about carrying-capacity levels must usually be made) are

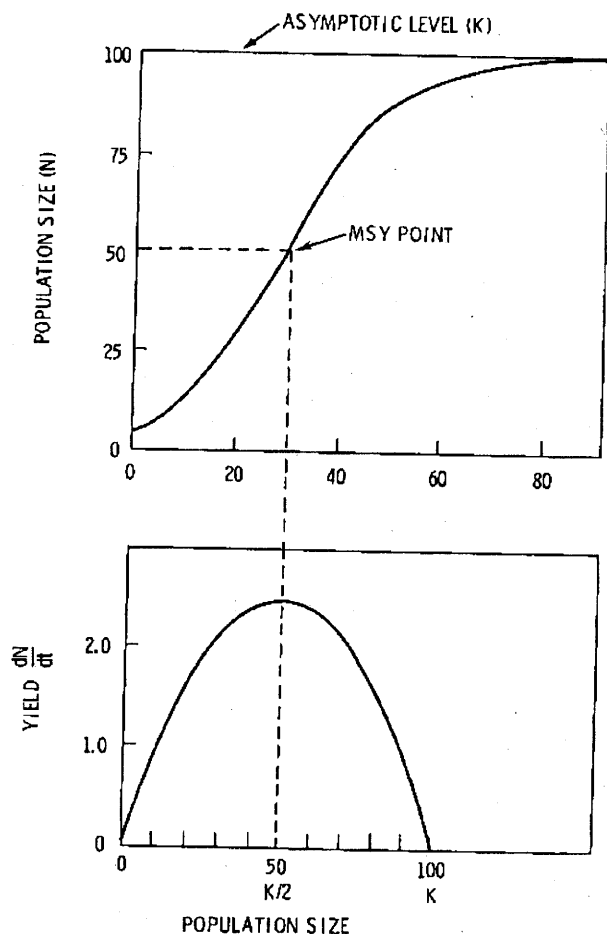


FIG. 1. Location of the maximum sustainable yield (MSY) point and asymptotic level ( $K$ ) for a logistic population growth-curve (upper panel) and the sustainable yields for various population levels (lower panel).

often fragmentary, questionable, or lacking entirely. There are thus some practical reasons for treating OSP as a range of population sizes, with a currently selected target point that is subject to continual refinement as more data become available and techniques are improved. In practical administration of the Marine Mammal Protection Act, a working definition of an optimum sustainable population is emerging as being the range between MSY and carrying-capacity levels. Such a definition has recently been adopted by the National Marine Fisheries Service (U.S. Department of Commerce) as part of its regulations under

the Marine Mammal Protection Act (Federal Register Notice of 21 December 1976, 41FR55536), and thus becomes an official definition of OSP.

There is at present not much evidence as to the precise location of the MSY point for marine mammals. The classical, logistic-curve, MSY point is at one-half of maximal levels (Fig. 1). Some fish species, capable of many-fold increases in population size in a single generation, apparently have MSY points well below the 50% level. Marine mammals, being long-lived and with low reproductive rates, may well have an MSY point somewhere above one-half the maximal level. Eberhardt & Siniff (1977) have suggested that this may be the case for Alaska Fur-seals (*Callorhinus ursinus*) on the Pribilof Islands, and cite data presented by Gulland (1971) showing a similar pattern for Antarctic Blue Whales (*Balaenoptera musculus*). Professor Douglas G. Chapman, Chairman of the U.S. Marine Mammal Commission, in testimony at a 1976 public hearing concerning regulations for taking marine mammals in the course of commercial fishing operations, gave several estimates of MSY level. These include 70% (of unexploited population) for the Blue Whale data of Gulland, a level close to 80% for Antarctic Fin Whales (*Balaenoptera physalus*, data from K. R. Allen, 1972), and 54% for the Fur-seal data. The method used was that of Chapman (1973).

The MSY idea has largely been a product of fisheries research and management, so an extension to marine mammals is not surprising. However, the complications of longevity and the pronounced importance of age-structure in large mammals make for some difficulty in establishing an MSY point, and thus require further consideration.

From the legal point of view, marine mammal management in the United States must be based on the Optimum Sustainable Population concept. But as there are various international ramifications, by way of treaties and other Acts of Congress affecting U.S. trade with other nations, the impact is not limited to the United States alone. Consequently it is important to have reliable measures of the MSY level for marine mammals. As defined in practice, the MSY point corresponds to the inflection point on a population growth-curve. In turn, growth-curves are expressions of the forces regulating the size of a population, so the main issue in determining MSY (and thus OSP) is really that of the very complex and difficult problem of population regulation. Some aspects of this problem will provide the focus for the balance of this paper.

#### OPERATIONAL EXPRESSIONS OF DENSITY-DEPENDENCE

In at least two fields (entomology and fisheries), population regulation through density-dependent mechanisms has been given direct operational expres-

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sions. In fisheries management these are the stock-recruitment curves proposed by Ricker (1954), which give a functional (mathematical) expression of the relationship between parents (stock) and progeny (recruits) forming the next generation. As they prescribe abundance at distinct points in time (generations) these curves are, in effect, models for growth-curves, and thus provide a prescription for location of the MSY point (this is usually provided in the form of a yield-curve). There are two major such curves in use, one being that devised by Ricker while the second is due to Beverton & Holt (1957). These two curves have been treated largely as separate entities, but a relationship suggested by Eberhardt (1977) serves to express the curves in terms of two common parameters, as well as showing a connection to the logistic growth-curve. Paulik (1973) indicates how a wide range of stock-recruitment curves can be constructed, and provides some references to an extensive literature on the subject, while Chapman (1973) provides some further discussion along with a non-parametric approach to finding the MSY point (the entire volume in which these two papers appear is dedicated to studies of stock-recruitment).

In entomology, the same kind of relationship between generations has been utilized as in fisheries, sometimes under the heading of 'reproduction curves' (a term used also by Ricker, 1954). Fujita & Utida (1953), and Utida (1957), give a mathematical development for such a model, obtaining a form very much like that of Beverton & Holt (1957). Considering the substantial history of operational use (i.e. fitting of actual data to reproduction curves) in fisheries and in entomology, it is intriguing to note that 'theoretical' biologists seem to have rediscovered the two curves, without apparent reference to the existing literature in the two fields of application. Thus Southwood *et al.* (1974, Fig. 2) show two curves that are very similar to the Ricker and the Beverton & Holt stock-recruitment curves, but do so without any reference to the fisheries literature.

Wildlife management constitutes a third field of application in which the basic notions of density-dependence have influenced management policies. However, explicit (mathematical) models do not seem to have achieved any prominence in actual applications, and it is thus difficult to identify specific cases. One major principle in wildlife management, fall (autumn) harvests of 'annual surpluses' of small-game species, appears at times to be equated with the MSY principle. It seems to me that this practice has more to do with the ability of populations to 'compensate' for additional mortality factors, than with the MSY notion as such. More precisely, it is generally assumed that the available habitat will support only a limited number of individuals through the winter season, and

that this number is normally substantially exceeded by annual production. There is thus a sizable surplus of 'recruits' (young of the year) that can be harvested without affecting the numbers carried through the winter. This notion is thus quite distinct from the usual interpretation of the maximum sustainable yield (MSY) idea.

Under MSY harvesting, it is usually assumed that the maximum sustainable yield will be achieved at a population level that is well below maximal or carrying-capacity levels (at 50% of that level under the frequently-used logistic model). One can thus visualize the MSY point as somewhere in the mid-range of an S-shaped (sigmoid) growth-curve. Under the 'surplus' idea, the population oscillates around the maximal level, owing to the annual cycle of births and deaths.

It may be noted that a regulatory model, depending on the limitations of winter habitat, does not call for sigmoid growth. A species that is introduced into a new habitat might well expand exponentially up to the level of the winter carrying-capacity. Hence that level may in fact constitute the MSY point. However, the focus of this paper is on long-lived large mammals, and the methods of harvesting such species are often complicated by selective harvests (of males).

#### HYPOTHESES ABOUT REGULATION

Although resource managers may proceed on the basis of some functional realization of a regulatory process—such as a stock-recruitment curve—there does not seem to be any general agreement as to the causes of natural regulation of population size. In a brief paper it is not feasible to review the various hypotheses, but it may be worth mentioning some particular features.

There has been considerable controversy concerning the reality of the basic concept of density-dependence. Probably the major proponent of regulation through density-dependent mechanisms has been Nicholson (1933, 1955). On the other hand, Andrewartha & Birch (1954) attributed little importance to density-dependence, and seemed to believe that regulation might be achieved through a combination of changes in weather conditions, food supplies, and the natural heterogeneity of the environment. In more recent publications these latter authors have emphasized the prospect that both kinds of mechanisms, density-dependent and density-independent, may play a role in regulation. One has only to view a few examples of stock-recruitment curves plotted with actual data, to appreciate the existence of a substantial component of seemingly random fluctuations in such systems.\*

\* Such fluctuations may well be associated with density-independent factors.

Recently, the controversy has seemed to be subsiding into a general acceptance of the reality of density-dependent regulation along with an awareness that density-independent factors may also be responsible for control on many occasions. For the species of main concern here (the larger, long-lived mammals), it seems self-evident that environmental effects will most likely affect young animals—and will do so just after these individuals become dependent on their own resources.

The actual mechanism for density-dependent regulation is a matter of a wide diversity of opinion. The various hypotheses include endocrine function (cf. Christian & Davis, 1964), genetic changes (Chitty, 1960; Krebs, 1964; Krebs *et al.*, 1973), dispersion and territorial behaviour induced socially (Wynne-Edwards, 1962, 1965), resource limitation, and predation—depending on the particular group (Lack, 1954, 1966), and even involving other viewpoints. While not universal, the preponderant opinion seems to be that the physical expression of these factors is largely one of changes in survival rates.

Regulation by predation brings in a good deal of additional complexity by way of the induction of cyclic fluctuations of predator and prey. Certain of the better-studied cases seem now to be accepted as being caused by an inherent mechanism, and not the result of chance phenomena alone. One difficulty in analysis of such data is that randomly fluctuating environmental conditions will not be perfectly reflected in population fluctuations—due to the auto-correlation effect induced by the fact that the level of a mammalian population in any given year is always influenced to some degree by its size in the preceding year. This effect is, of course, much greater in the larger, longer-lived mammals than in others, so that it seems possible to consider the population dynamics of many such species without paying much attention to cyclic effects. Two excellent recent reviews dealing with predation are those of Huffaker (1971) and Keith (1974). These authors discuss in detail the recent theories and present-day understanding of regulatory features of a wide range of species. It seems to me that one avenue for further illumination that has largely been neglected is a study of 'the ecology of invasions' (Elton, 1958), as the translocation of a species to a new environment constitutes an experiment that is not otherwise feasible.

Rather more abstract views of regulation have generally been expressed as mathematical models of one sort or another. Such models have the advantage of being explicit and unambiguous. The great disadvantage of such models is that they are usually much too simple to reflect adequately the complexity of the natural (and real) situation, which may be very difficult to deal with mathematically. This mathematical

complexity has the further effect of discouraging any participation or understanding on the part of most population ecologists, who simply are not trained to handle the necessary mathematics. In spite of these difficulties, I believe there is a need to attempt to formulate more of the present-day understanding of population phenomena in the guise of simple mathematical models.

There have been some attempts to construct far-reaching theoretical structures that are not mathematical models *per se*. One of the currently more popular of such efforts has been called 'r and K selection' (MacArthur & Wilson, 1967), in which one class of species is labelled 'r-selected' to denote an evolved ability to expand very rapidly under temporarily favourable environmental conditions. The other group ('K-selected') is said to be adapted to maintaining population levels very close to the asymptotic level (K)\*. Considering their low reproductive rates, one could hardly suppose marine mammals to be anything but K-selected. However, it seems very likely that the development of existing reproductive patterns in marine mammals is simply a consequence of the adaptation required to permit a warm-blooded species to invade the oceans.

Thus in order to acquire sufficient size and insulation to cope with the temperature differential, new-born individuals must either be quite large and well-insulated at birth, or be born on land or ice and attain a considerable amount of growth before entering the sea. Females are thus likely to produce single young at well-spaced intervals (minimally, one year) in order to accumulate the fat reserves required to provide the nourishment necessary for rapid growth of the young. Under these circumstances, while one can no doubt still use the 'K-selection' label, it does not seem to have any particular utility. Given the low reproductive rate enforced by environmental conditions, high survival rates must necessarily follow. Similarly, one might suppose that a stable population level is most advantageous, as the low reproductive rates make rapid recoveries from low population levels impossible.

#### A GENERAL MODEL FOR SELF-REGULATION IN LONG-LIVED SPECIES

In the situation described just above, it seems self-evident that security of the adult population is the key to persistence of the species. The last parameter to give way to the pressures of over-population may thus be adult survival, and, in particular, survival of adult females. Under this premise, one may suppose that

\* An asymptotic level is one that is maintained by a variety of factors that do not necessarily operate in the same direction.—Ed.

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security of adult females means good health and good physical condition, so that reproductive rates are also likely to remain near maximal levels up to the point where population pressures threaten the security of these females. One might then expect a reduction in reproductive rates.

Assuring survival of adults would seem automatically to require that very young animals would be left to bear the brunt of any unfavourable circumstances, and thus suffer the highest mortality. As the young are both relatively small and inexperienced, it is only to be expected that they will bear the brunt of the forces causing mortality—at least as soon as parental care ceases. This is, of course, a well-established principle. There is also a good deal of evidence to suggest that shifts in the survival of young are the proximate expression of the regulatory mechanism in a wide range of mammalian species. While the basic mechanism may differ appreciably, the expression of its effect tends to appear in juvenile mortality. Both Huffaker (1971) and Keith (1974) give a range of examples, further details, and discussions of the possible underlying mechanisms.

In many circumstances, the same stresses leading to increased juvenile mortality will also act to reduce growth-rates. In most species, reproductive effectiveness depends on the individuals' stage of physical development (some data bearing on this point have been presented for marine mammals by Laws, 1956, 1959). Any force retarding juvenile growth may thus also act to delay the age of sexual maturity, and thus of first reproduction.

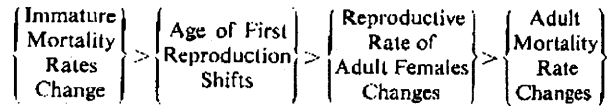
No doubt the simplest and most direct mechanism leading to the above sequence of events is the over-utilization of some essential resource, food-supply being the best-known such instance. Juveniles are the first to be affected; growth-rates are markedly reduced in the survivors, which reach maturity appreciably later than well-nourished individuals and thus show 'delayed' first breeding. If conditions are extreme, adult females may also lose weight and show a consequent reduction in reproductive success. Very likely, conception rates will not be so markedly affected as will the ability to carry a foetus to full-term and nourish the young successfully. This is a particularly serious matter in those marine mammals that depend on utilizing stored fat-reserves (blubber) to carry their young to weaning (in some species the females with young may not feed through most of this time). The ultimate event is the outright death of adults, when conditions have indeed become extreme.

The above scheme is not claimed to be a universal regulatory mechanism. As Keith (1974) and Huffaker (1971) point out in detail, we know very little about the role of predation in many of those circumstances in which Man has greatly altered primeval conditions.

It is now beginning to be believed that some broad groups (e.g. the ungulates) may have been controlled mainly by predation, whilst the top-level predators may have evolved a social mechanism (e.g. territoriality) that served to control their own densities. Neither of these mechanisms need be supposed to preclude the above sequence of events. White-tailed Deer (*Odocoileus virginianus*) demonstrate the sequence very nicely (Eberhardt, 1960). However, in the absence of effective control by predation, they go on increasing until food supplies are greatly reduced, and then the population may decline markedly. I believe the above sequence of events may be observed for virtually all of the large mammals. The crucial point is whether or not that sequence *alone* can constitute a self-regulatory mechanism. Obviously the magnitude of reproductive rates plays an important part here, but other factors also need to be considered.

Parasitism and disease may be considered as further factors in regulation. I am inclined to believe that the more severe instances of either condition may often arise because human intervention has reduced the effect of some other, normally more important, regulatory factor.

The sequence described above can be expressed schematically as follows:



(First → Order of Events as Population Increases → Last)

A somewhat different view of the above sequence of events might be constructed in terms of the simple model used by Eberhardt & Siniff (1977). In that paper, we noted that shifts in the age of first reproduction seem to be equivalent to perhaps two percentage points of adult survival for the most 'prolific' group examined (seals), and that those species with appreciably lower reproductive rates might compensate for perhaps a single percentage point of adult survival by changing the age of first reproduction (cf. Fig. 2 of the paper cited).

We did not attempt a graphic comparison of the effect of changing the reproductive rate of adult females. However, equation 4 of our paper (Eberhardt & Siniff, 1977) can be used to give an indication of the change in reproductive rate (F) required to correspond to a small change in adult survival rate (P). The equation is:

$$F = \frac{1-P}{0.5P^a}$$

where *a* denotes age at first breeding. Using *P* = 0.90 and *a* = 6 (see the discussion on page 187 of the paper cited) gives *F* = 0.376, whereas if *P* = 0.89, then *F* = 0.443—suggesting the rather substantial increase in

reproductive effort (about 18%) required to compensate for a reduction of one percentage point of adult survival. If we use the equation with  $P = 0.90$ , but change  $a$  from 6 to 4, the apparent effect of early breeding is to reduce  $F$  from 0.376 to 0.305.

The example given above pertains to seals, and may also be used to explore the effects of shifts in immature survival rates required to compensate for changing adult survival. The basis for such a comparison is available in Fig. 3 of our paper where, reading from the line for first reproduction at age 6, and equilibrium population ( $\lambda = 1$  on the graph), we find that a shift from immature survival equal to the adult rate down to immature survival of half that of adults corresponds to about 5 percentage points of adult survival (from  $P = 0.84$  to  $P = 0.89$ ). One might thus equate about 40 percentage points of immature survival to 5 percentage points of adult survival, or an 8 to 1 ratio.

The general impression to be obtained from the above numerical results is that of an arrangement like the one outlined but actually based on equivalences with adult survival. Establishing the relative position of age of first reproduction and the reproductive rate of adult females accurately on a numerical basis, would require some more detailed calculations and further analysis, but it seems to me that the preceding, non-numerical argument is to be preferred in the present circumstances.

Components of the model are illustrated in Fig. 2.

The model suggested here falls short of operational needs in several ways. Firstly, we do not currently know how many stages need actually to be invoked for self-regulation in a particular instance. As has already been remarked, ungulates seem to run through the full gamut before coming to a kind of balance in instances where effective predation is lacking. On the other hand, it may be that most marine mammals require only the first two stages. However, even if this is so, choosing an effective management policy calls for knowledge of how the first two stages are invoked. In the classical logistic model, density-dependence is a linear function of population size; no matter how small the population may be, there is always some influence exerted on the rate of increase.

A more realistic point of view seems to me to be that the density-dependent effect is non-linear. Thus for Fur-seals (*Callorhinus ursinus*), it may be that the rate of recruitment to a population may not change much until the population is fairly close to its asymptotic value (cf. Fig. 5 of Eberhardt & Siniff, 1977), though more data and more understanding of population processes will be needed to settle this point. Furthermore, if the regulatory process goes on to the next stage (change in age of first reproduction), another kind of model is needed. This would seem to require both a growth-curve and a functional form (a

mathematical model) for the relationships suggested by Laws (1956, 1959).

One immediate consequence of the above model can be suggested, however. In those cases where animals are taken when still under parental care (the Harp Seal, *Pagophila groenlandica*, provides an example), it would appear that such a harvest may substitute for mortality that would normally operate as the first stage of the regulatory process. Maximum yield from the population might then be obtained at a rather high population-density—possibly very near the carrying capacity or asymptotic population level. Unfortunately, the harvest of Harp Seal pups (and some adults) has apparently reduced the population substantially. It may well be that the mechanism suggested here (regulation by immature mortality) has in fact been responsible for the ability of that population to withstand very heavy harvests for over 20 years—succumbing finally, I suspect, to the impact of an increased harvest of adults in the 1960s (R. L. Allen, 1975, gives the harvest record) \*.

#### SUMMARY

Among the larger mammals, marine types offer some unique insights and problems for management. United States laws require that they be managed 'to maintain the health and stability of the marine ecosystem.' The relevant statute (Marine Mammal Protection Act of 1972) requires maintenance of an 'optimal sustainable population', which is being interpreted as a range between the level giving a maximum sustainable yield (MSY) and asymptotic levels. Emerging evidence pertaining to marine mammals, and perhaps applicable to a larger class of vertebrates, indicates that the MSY point may be well above the logistic-curve 50% point.

'Reproduction curves' of various sorts are used in management as operational representations of population self-regulation (density-dependence). A variety of theories and hypotheses concerning such regulation now exists, though none is adequately supported as yet. A general model for self-regulation in long-lived species is suggested as being comprised of stages of regulation. Immature mortality is postulated as the first stage, followed by age of first reproduction and then reproductive rates of adult females. The fourth and last stage, as populations reach maximum sustainable levels, is assumed to involve changes in adult survival.

Although a model of the kind suggested here offers some useful insights as to harvesting strategies, a more quantitative (functional) basis will be needed for actual management applications.

\* A referee comments that 'uncertainties especially of weather can have a strong influence on marine mammal births and ultimately populations [and that this] should be considered' throughout.—Ed.

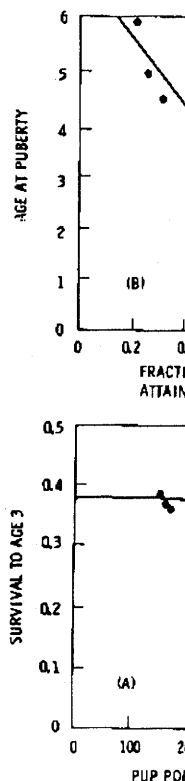


FIG. 2. Components. (A) decreasing juvenile (data on pinniped sp. Eberhardt, 1960 p. 1), at various densities re curve shown exhibits

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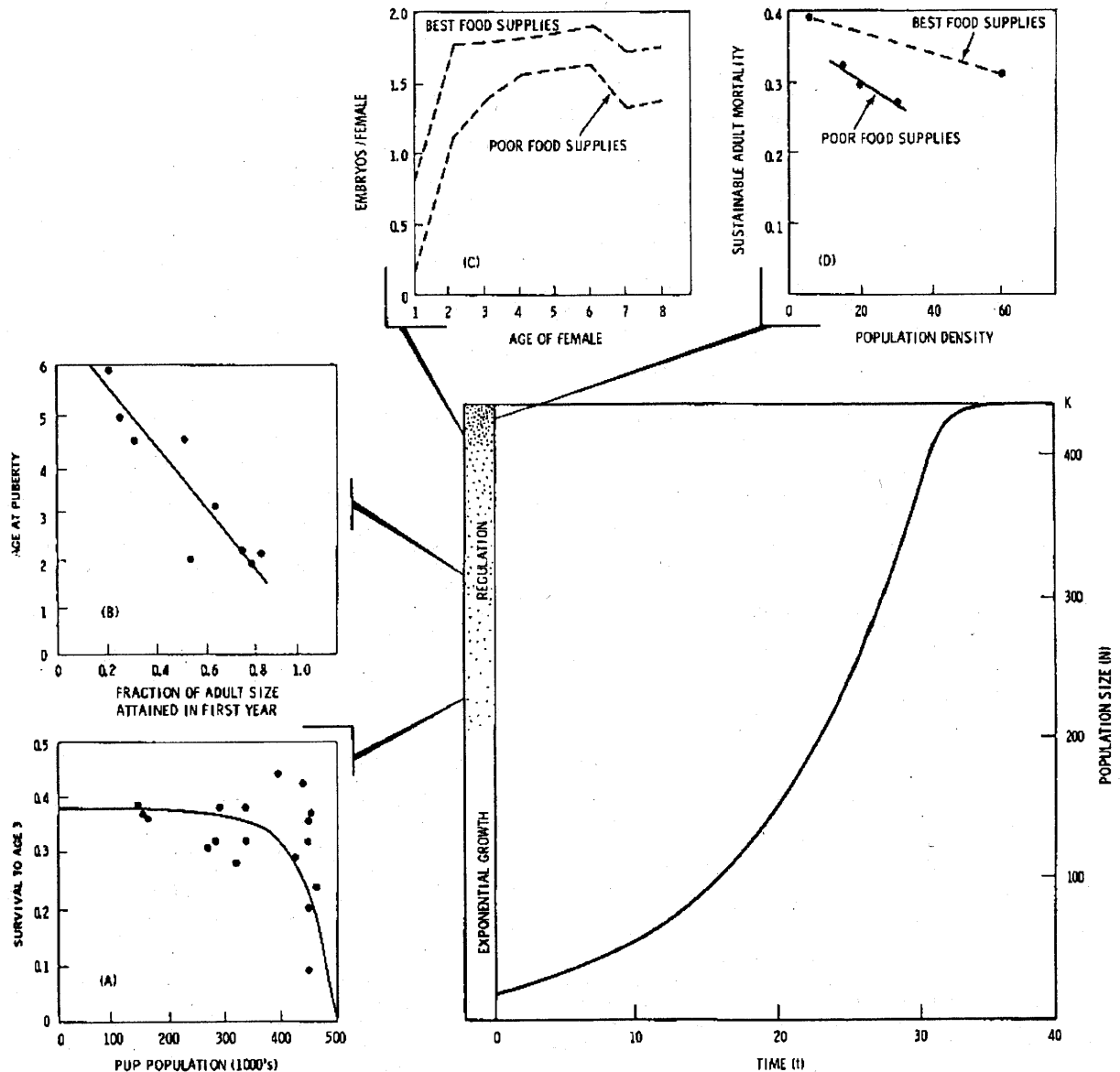


FIG. 2. Components of a population growth model showing the postulated sequence of events that may serve to reduce the growth-rate: (A) decreasing juvenile survival (fur-seal data of Chapman, 1973); (B) age of first reproduction may be delayed if growth-rate is reduced (data on pinniped species—Fig. 1 of Laws, 1956); (C) female reproductive rates are reduced under severe stress (White-tailed Deer: Eberhardt, 1960 p. 178); (D) adult mortality may be increased at very high levels of stress (the illustration indicates sustainable mortality at various densities rather than an actual direct effect on mortality—White-tailed Deer: Eberhardt, 1960 p. 180). The population growth-curve shown exhibits exponential growth up to  $N = 200$ , after which regulation in the form shown in panel (A) is introduced.

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#### United States Starting Intensive Study of Antarctic Krill

The United States' first intensive study of Antarctic Krill, the shrimp-like animal *Euphausia superba* that is considered a potential major source of proteins for humans and livestock, is being started this year in a special laboratory constructed for the purpose in Antarctica. The laboratory, including a new experimental aquarium, has been built at Palmer Station, a small American scientific outpost on Anvers Island off the Antarctic Peninsula.

Dr Mary Alice McWhinnie, Professor of Biology at DePaul University in Chicago, who will head the new project under a National Science Foundation grant, has been studying the small crustacean for several years. The project concentrates on the objectives of BIOMASS, an acronym for Biological Investigations of Marine Antarctic Systems and Stocks, which is a programme drafted by the international Scientific Committee for Antarctic Research (SCAR). One aspect of BIOMASS is to find out how far man can go on harvesting Krill without damaging the delicate marine ecosystem of which it forms an integral part.

Krill, the principal food of whales and seals in the antarctic seas, are pinkish animals that grow no longer than 6.5 centimetres (about 2½ inches). They swim around coastal Antarctica and in the open ocean in such vast numbers that in 1975 a West German ship harvested 260 tons of them in one day. Krill generally rise to near the surface in darkness and sink during the daylight. This vertical migration can be over as much as 200 to 300 metres (ca 219 to 328 yards).

'The Soviets,' Dr McWhinnie says, 'have been harvesting Krill since the mid-1960s. They harvested 20,000 tons in

1975 and have commercial products made from Krill. Also, Japan uses Krill for human and animal protein... and Chile is studying its nutritional value.'

The U.S. study is planned to start at Palmer Station in November of this year, its principal goal being to learn more about the Krill's life (including its reproduction cycle), the number of spawning years it has, how much it eats, and the rate at which it grows at different feeding levels.

In the new aquarium, one 6-foot (1.83 m) high tank is designed to enable the scientists to study the Krills' vertical migration and to determine the light-intensity at which they start to move downwards. A second tank, 11 feet (3.35 m) long, is designed for studies of horizontal migration. Both tanks will have special lights to facilitate simulation of day and night. Water for the tanks will be piped in from the sea and kept at temperatures just above the freezing point.

Dr McWhinnie, a veteran antarctic research worker, was one of the first two women scientists to winter on the Antarctic Continent when she spent the winter of 1974 at McMurdo. One of the few authorities on antarctic Krill, she has suggested an international convention to set limits to the amount that legally may be harvested. She said the United Kingdom is planning a major Krill research programme at South Georgia Island in the Scotia Sea—east of the southern tip of South America—during the 1977-78 season.

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