promising and deserves support but we must do a better job of identifying who is the real decision maker, how he functions and most important how we can function effectively with him.

SUMMARY

If the problem areas that I have discussed have been real deterrents to success in the past, I am optimistic over the chances for future improvement. I believe we have turned the corner on environmental problems, our knowledge base is improving each year, fishery scientists and managers are becoming more goal-oriented and are working more closely with the legislative process. I personally feel that the new state-federal initiatives and especially the attempts at cooperative regional management hold great promise. If we get the necessary legislation and can give the program our best efforts I feel we have a good chance of solving many of our jurisdictional problems. Furthermore, I see some improvement that could result from the state-federal approach in virtually all of the problem areas referred to.

PROBLEMS AND SOLUTIONS, GOALS AND OBJECTIVES OF FISHERY MANAGEMENT

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ABSTRACT

This summary and discussion covers four papers on current fishery management problems and programs in small ponds and community lakes, reservoirs, streams, and coastal and estuarine environments. Problems are classified in four major categories: economic, political, social, and biological. Biological problems are subdivided as either environmental (physical-chemical) or biotic. In discussing the goals and objectives of fishery management, a distinction is made between the terms harvest, catch and yield, and the goals of maximum sustained harvest and optimum sustained yield. Discussion of management of largemouth bass populations in reservoirs develops the hypothesis that bass biomass may amount to only one half to one sixth of the potential sustained carrying capacity in some waters. Calculations are made to project changes in biomass, production, catch and harvest that may result from the application of various protected-length regulations. The calculations suggest that under conditions as specified in the model, fishing quality and yield values may be much improved and closer to optimum with a minimum length limit as high as 18 inches. Achievement of values approaching optimum sustained yield in sport fishing will require research to test concepts and theories, development and implementation of improved management programs and enhancement of our professional credibility and compentence.

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INTRODUCTION

The speakers on this panel have done an admirable job of identifying problems and reporting or proposing solutions. If this were a contest to see which ecosystem had the most problems identified, and which had the highest variety of solutions or management options, I believe small impoundments and community lakes would be judged the winner. Thinking positively, problems should be considered as challenges and opportunities to practice the art of management. The state of the art is best developed in small reservoirs and is improving in open-ended systems such as streams and rivers, more diverse and complex ecosystems such as lakes and large impoundments, and the most complex ecosystems represented by coastal and estuarine environments.

PROBLEM CLASSIFICATION

In attempting to summarize the problems presented by the panel, I have chosen to classify them in four major categories: Economic, Political, Social, and Biological.

Few economic problems were discussed, which is surprising in view of the rising cost of living. Dr. Davies mentioned the high cost of fish food; Dr. Joseph mentioned the need for improving efficiency and productivity in commercial fisheries in order to meet costs and maintain a profit margin in competitive private industry. Undoubtedly, all speakers could have mentioned the dollar crunch in the public agencies they represent. We are all experiencing a higher percentage of fixed costs in proportion to income or appropriation. Such a problem creates a need for continued evaluation of priorities, benefits, and costs in planning and expediting our programs.

Political problems mentioned include a de-emphasis of some fishery research and management programs by state and federal agencies, jurisdiction over migratory species and the decision-making process in establishment of regulations. Federal-state cooperation was suggested as an important part of a solution to some of these problems. I believe that Mr. Fleener would recommend a bi-partisan commission for a state decision and regulatory body as has been the practice in Missouri for over 35 years.

A primary social problem is the public value and popularity of our aquatic habitats and sport fishing. Our moderator, Mr. Stroud, would be glad to answer questions about the physiological and psychological values that accrue from the planning, anticipation, pursuit, catching, eating and remembering a high-quality fishing experience. Present and projected values for fishing pressure are widely recognized. Research documenting the public use and recreational value of a natural stream system, the Platte River, appears to have carried significant weight in the decision making process of a federal agency.

One of our problems is to maintain or improve the quality and value of the fishing experience for the angling public under conditions of increased popularity and public use. This challenge has and will be met in part by identifying and solving biological problems. The biological problems fall into two categories: habitat or environmental problems (physical-chemical factors); and organism, population or community problems (biotic factors). The physical and chemical problems have stimulated research on pesticides, organic wastes, sedimentation, thermal discharges, and channel "improvements" which is increasing at an apparent geometric rate. Regulations and programs initiated to reduce the rate of deterioration and loss include: water quality guidelines and surveillance; environmental impact statements; land use planning such as coastal zoning; national scenic rivers; and restrictions on the sale and use of control chemicals. Significant progress has been made in a relatively short period of time because of public concern. Dr. Joseph suggested that we may have even solved problems before they have been identified by research.

Biotic or population and community problems are primarily related to the production process. Solutions can be accomplished by manipulation or modification of the form and functions of fish populations and aquatic communities. By form I refer to what can be seen or sampled such as length-frequency distribution, F/C ratios, E and At values (Swingle, 1950). Functions are the rate processes which determine the apparent form. The three primary functions which determine production and the form of a population are the rates of recruitment, growth and/or mortality. The models for balanced and unbalanced bluegill populations serve as an example (Anderson, 1973). Balanced populations exhibit a satisfactory growth rate for fish age III and older; mortality rates are relatively high for young fish and relatively low for age III and older in balanced populations, as compared to unbalanced populations (Figure 1). Management solutions to create more favorable rates include: reduction of recruitment by destruction of small fish; improvement of growth by fertilization or feeding; and/or higher mortality of small and intermediate-sized fish through increased predation. Chemical control of bluegill density is appropriate if predator numbers, biomass or efficiency of predation are less than satisfactory. Fertilization or feeding are appropriate if productivity of the ecosystem is inadequate. Higher predator biomass and a more satisfactory mortality rate of sub-harvestable size bluegill may be achieved with a regulated harvest of bass. An effective fish manager will apply the most appropriate combination of techniques on each ecosystem in order to achieve an optimum sustained yield with the most favorable benefit/cost ratio.

OBJECTIVES AND GOALS OF FISHERY MANAGEMENT

Before discussing population and community problems further, I would like to develop an important point offered by Dr. Joseph: management for reasonable goals. Management by objectives and goals is a relatively new and challenging approach to fishery and natural resource management. Objectives are set in order to achieve goals. Think of the two words as a pyramid with the goals supported by the objectives. The distinction between the two terms can be confusing because one man's objective may be another man's goal.

The highest goal that is being promoted by environmentalists is to maintain or improve the quality of life in our society. This could be a goal of all agencies, institutions, and professions. Our professional society can support this goal by setting as an objective the maintenance or improvement of the quality and value of our aquatic habitats and fishery resources. This should be the goal of our resource agencies. Management biologists can work toward such a goal by improving the state of balance in fish populations. This can be the goal of management biologists with objectives set for harvest, catch rate and size distribution.

A primary goal of the pragmatic fishery manager has been *maximum sustained harvest.* Relationships have been considered as simple and linear with the upper limits set by biological factors. I submit that with the changing values today a better goal might be, *optimum sustained yield.* Optimum implies dome-shaped relationships or relationships that ascend to an optimum level and then decline. The words harvest and yield are usually used synonymously. We have heard still another word today with the same implied meaning, catch. What is needed are words that have three separate and distinct meanings in order to better convey information or ideas: harvest is logically an amount removed; catch can be more than harvest in a catch and release fishery. Yield might better connote a broader concept that includes all the tangible values of catch and harvest such as numbers and weight, and the economic value or contribution to the gross national product, as well as the intangible values of aesthetics and memories. Intangible values may well be a major portion of angling yield. Personally, the memories of fishing with my father and daughters are worth much more than the food or dollar value of the fish we brought home.

Our old simplistic goal of maximum sustained harvest is being challenged by some of the public we serve. It has been challenged for some time by Trout Unlimited and recently by Lee Wulff in the August, 1973 *Sports Afield.* Mr. Wulff is concerned about uniform, low-quality fishing in public waters. He wants a better quality of fishing with quality measured primarily by catch rate and average size rather than harvest. These objectives can be met by appropriate management strategies. A challenge for the future of fishery administration, research and management is to determine where, when, and how to achieve optimum sustained yield. This will inevitably include a multiplicity of programs, species and regulations. Optimum yield may imply maximum harvest well above the normal productivity in environments in or near urban centers or it may dictate a minimum harvest in remote or certain private waters. Most public waters will probably be managed with objectives in between these extremes.

What are some of the concepts and techniques that can be applied to achieve optimum sustained yield? Techniques for maximum harvest as presented by Dr. Davies are well advanced and include fertilization, direct feeding, put-and-take of trout, catfish, carp and bullheads and introduction of exotic or alien species.

An example of high yield with a minimum harvest is on the nearly pristine U.S. Forest Service Sylvania Tract in the Upper Peninsula of Michigan (Anonymous, 1970). The management goal has been to protect the disproportionately high numbers of large predatory fishes in the lakes which were held in private ownership until purchased by the Federal government in 1966. Some lakes are restricted to fishing for sport only (no fish may be kept); others have trophy fish regulations with high minimum length and low bag limits.

MANAGEMENT OF RESERVOIRS AND LARGEMOUTH BASS

Where is the middle road between high exploitation and preservation? What are the strategies for achieving a more optimum yield with higher catch rates and better average size from public waters? According to Jenkins' calculations we are now achieving an equilibrium harvest from some populations of largemouth bass. Important questions for future research and management studies include: are we achieving maximum potential harvest for bass; does maximum bass harvest reduce the potential catch, harvest or yield, or increase the cost of management of other species?

Concept and Theory Related to Carrying Capacity, Biomass, Production, Harvest and Yield

Jenkins defined carrying capacity as calculated spring biomass. But, are the estimated values of 5 to 10 pounds of bass per acre the maximum that can be sustained by these communities? With a total fish biomass of 200 pounds per acre or more, is an E value of 2.5 to 5% a realistic management objective for the species? In lakes with primarily largemouth bass and bluegill, satisfactory E values for bass range from 14 to 25% (Swingle, 1950). In more complex reservoir communities with additional "C" species and some large "F" species such as carp or buffalo, a lower collective E value for the centrarchid bass populations might be expected. Community form should be more satisfactory in reservoirs and a better harvest and yield possible if E values for bass species were maintained at 10 to 15% or 20 to 30 pounds of bass per acre in reservoirs with an average of about 200 pounds of fish per acre. This may represent a two to six-fold increase in the biomass of some bass populations.

Is a greater sustained biomass within the limits of carrying capacity or productivity for average reservoirs? Negative trends in bass biomass from 20 to 30 pounds per acre to 5 to 10 pounds per acre were documented by Jenkins in Beaver Reservoir. It seems unlikely that reduced productivity or carrying capacity for bass is a valid concept since there generally is a positive trend in the biomass of Clupeidae (shad) with reservoir age (Jenkins, 1968).

The data published by Bryant and Houser (1971) make it possible to analyze the three critical functions of growth, recruitment and mortality and the concept of carrying capacity using Beaver Reservoir as an example. The data are based on sampling effort in 1969 and 1970.

Bass in Beaver Reservoir exhibit a rapid growth rate. The average back-calculated lengths at annulus formation are: I, 6 inches; II, 10.9 inches; III, 13.1 inches; IV, 15.6 inches; V, 18.1 inches. Such growth indicates that the bass population in Beaver Reservoir may not be at carrying capacity since populations at carrying capacity might be expected to exhibit a somewhat slower growth rate due to intraspecific competition.

A strong year class of bass was associated with high water level in 1968 in Beaver Reservoir. Recruitment might be more consistent and influenced more strongly by density dependent factors if populations are at carrying capacity. In low water years, recruitment of young bass may not be adequate to maintain populations at carrying capacity.

The average annual mortality of bass age II and older estimated from the data in Bryant and Houser (1971) is 68% or a loss of about two-thirds of each age group each year. For every 100 age-II fish recruited to the population, the numbers of bass in succeeding age groups are calculated to be: III, 32; IV, 12; V, 4; VI, 1. With 10 pounds per acre, the number of bass at annulus formation in each age group in 10 acres would be: I, 187, II, 60; III, 19; IV, 6; V, 2; VI, 0.6, or about one bass per acre larger than 2 pounds. The summer biomass of 7.5-inch and larger gizzard shad has been measured at 140 pounds per acre (Jenkins, personal communication). This forage base must be able to support more than one bass larger than 2 pounds.

BASS MANAGEMENT STRATEGY

Management strategy to create more optimal rate functions in reservoirs could be aimed at improving the rate of recruitment with regulation of water level fluctuations. This concept may be sound but problems may be encountered such as: years of low precipitation; conflicts of interest in water level regulations for other benefits such as flood control; and inadequate annual production of age-0 shad to feed high numbers of young bass as well as crappie and white bass.

An alternative strategy would be to alter the rate of annual mortality by regulating harvest. Harvest mortality must be a large percentage of annual mortality if the estimates of biomass, growth and mortality are accurate. Annual production and theoretical maximum potential sustained harvest of bass can be estimated graphically if a steady-state population is assumed or if estimates represent averages for several years (Anderson, in press). With an average biomass of 10 pounds of bass per acre, the calculated weight of average annual production, mortality and potential sustained harvest for fish age II and older in Beaver Reservoir is 7.9 pounds per acre (Tables 1, 2; Figure 2). The estimate is somewhat conservative since some age-I bass are probably harvested. This calculated weight is close to the annual estimate of largemouth bass harvest reported by Jenkins which indicates a low rate of natural mortality.

In some ecosystems restrictive bass harvest regulations may be a technique to provide better harvest and yields. Minimum length regulations appear to have been successful on the Big Piney River as reported by Mr. Fleener and appear to have imporved sustained yield values on several Missouri impoundments (Redmond, in press).

Harvest Regulations and Potential Yield

Potential changes in biomass, harvest and catch resulting from regulations in Beaver Reservoir can be estimated. Necessary or simplifying assumptions made to enable the calculations include: no change in growth rate; an average rate of recruitment of 60 age-II bass per 10 acres per year; a 30% annual mortality rate for protected size (age) groups; a 70% annual mortality for legal size (age) groups; all legal fish caught are harvested; the number of protected size (age) fish caught and released is equal to 1.5 times the number present at annulus formation for protected age groups (this and higher catch rates have been observed in unpublished catch-and-release bass fishing experiments in Missouri ponds); the average size of protected fish caught and released is equal to an average weight for the age group for the year. For example, with a 13-inch minimum length regulation the calculated number of age-II fish caught and released per 10 acres per year is 1.5 x 60 or 90 fish; the estimated average weight per fish is (0.65 + 1.2) ÷ 2 or 0.9 pounds.

Potential regulations analyzed include minimum lengths of 13, 15.5 and 18 inches in order to protect fish through ages II, III or IV. The effects are also calculated for a protected-length-range regulation of 13 to 18 inches in order to protect age-III and IV bass. In discussing the results of these calculations, biomass values are expressed as pounds per acre; harvest and catch rates are expressed as number or pounds per acre per year.

Calculated spring biomass (biomass at annulus formation) for Beaver Reservoir bass age II and older is 8.6 pounds in the absence of harvest regulations (Table 2). With minimum length limits of 13, 15.5 and 18 inches, the calculated spring biomass values are 13.7, 19.8, and 26.4 pounds. Production and potential sustained harvest for the Beaver Reservoir bass age II and older is calculated to be 7.9 pounds without regulations. Potential harvest is improved to 9.0 to 9.5 pounds with minimum length limits applied; potential harvest is highest with a 15.5-inch minimum length limit. The number of fish to be harvested declines from 6 with no regulations to 2.1 with an 18-inch minimum length limit. With minimum length limits of 13, 15.5 and 18 inches, the calculated numbers of protected size fish caught and released are 9.0, 15.3, and 19.6. With length limits applied, total catch is calculated to increase from 7.9 pounds to 17.6, 28.2, and 39.9 pounds. The number of fish caught increases from 6 to 13.2, 18.2, and 21.7. Average size caught increases from 1.3 pounds with no regulations to 1.8 pounds with an 18-inch minimum length; average size of fish harvested increases to 4.3 pounds. With an 18-inch length limit there is a calculated 10-fold increase in the annual harvest of 3.5 pound and larger bass (two per 10 acres increased to 21 per 10 acres per year).

A protected-length range of 13 to 18 inches provides biomass, harvest and catch values that are better than no regulations yet do not approach the value for the 18-inch minimum length. If the rate of recruitment to age II is doubled, however, it may be desirable to harvest the surplus of young fish in order to avoid intraspecific competition and a calculated biomass that is more than 30 pounds, or the upper limit of the projected sustained carrying capacity in a reservoir with average productivity or standing crop.

The purpose of these theoretical calculations is to predict some magnitude of improved yield for an average midcontinental reservoir. Because of the simplifying or idealistic assumptions and since some values are no more than guesstimates, the calculated values must be viewed with a healthly amount of skepticism. Projected values of harvest or catch are too high if growth is markedly reduced with an increase in biomass, or if 30% is too low a mortality rate for protected age groups or, if 1.5 is too high a factor to estimate catch of protected age groups. However, it is also possible that some values may be conservative. If the trends in the values are valid, the calculations suggest that when bass populations have a low rate of recruitment, good growth rate and high annual mortality rates, yield values may be much closer to optimal with minimum length limits as high as 18 inches. Projected increases are relatively small for total weight of bass harvested but they are considerable for number, average size and total weight of bass caught. The benefits of higher bass biomass, improved size distribution, and greater predation may produce benefits in the quality of fishing for other species as well.

CONCLUDING REMARKS

My discussion has emphasized the potential of restirctive harvest regulations in the future of fishery management. The objectives of such regulations are not to protect young adults so that they can spawn at least once or to prevent the extermination of the species. Regulations are not necessary to achieve these goals. Effective regulations may prove to be most efficient tools for the manipulation and enhancement of community structure, population dynamics, catch, harvest and yield and the quality of fishing.

If regulations are to be effective, however, they must be accepted by a large majority of the public we serve. Enforcement alone cannot lead to acceptance. Acceptance may best be achieved by: 1. Research to test concepts and theories; 2. Development and implementation of improved management programs; and 3. Enhancement of our professional credibility and competence. As our competence, credibility and programs evolve, sport fishermen must also develop a strong conservation (wise use) ethic based on personal values and understanding. Concerned individuals such as Lee Wulff and Ray Scott can make valuable contributions to this end. Professional research and management biologists should be leading the way and setting the trend.

The collected papers in this session have presented a number of problems, solutions, and concepts that will be food for thought as we formulate, evaluate and modify our programs and objectives. We have the management, research and administrative capacity to improve the quality, value and yield of our aquatic habitats and products of interest. These yields can improve the quality of life in our society.

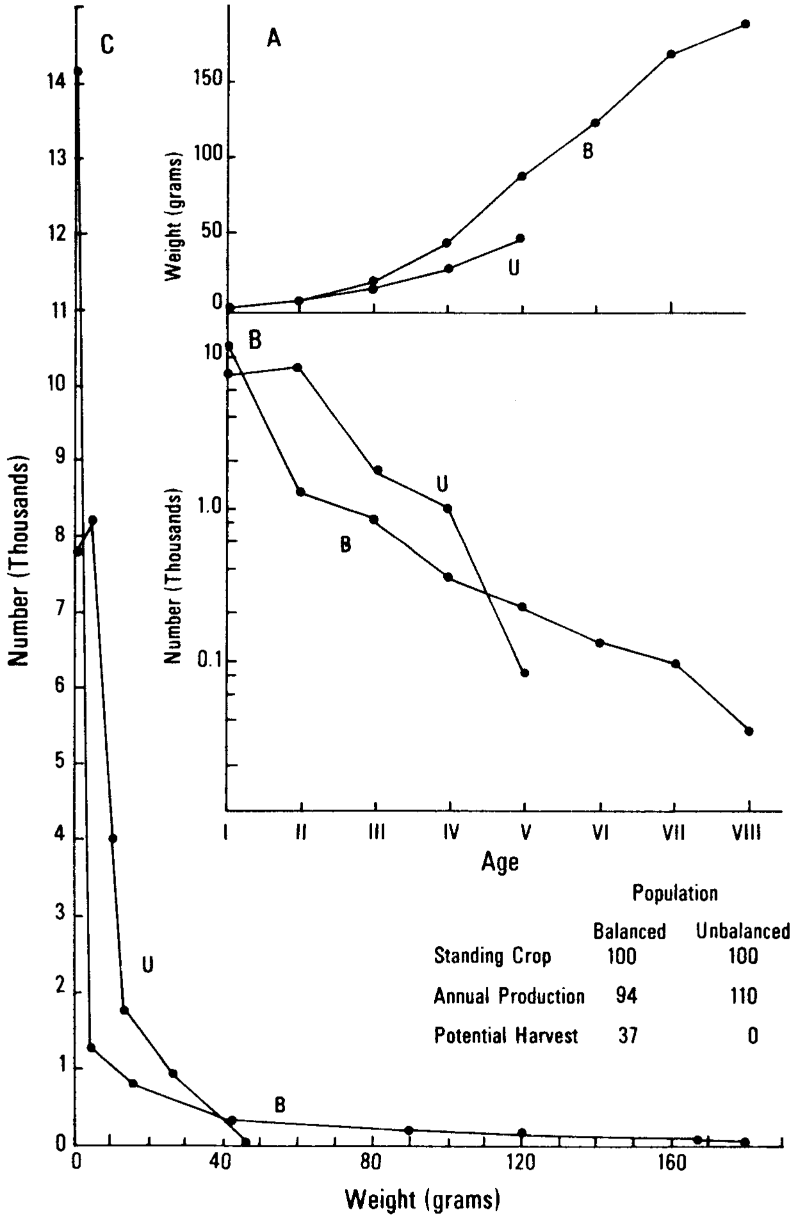

Figure 1. Average growth and survivorship curves for three balanced (B) and two unbalanced (U) bluegill populations. Graphic estimate of annual production per 100 pounds of biomass for bluegill populations with growth and survivorship curves as in A and B. (From Anderson, 1973)

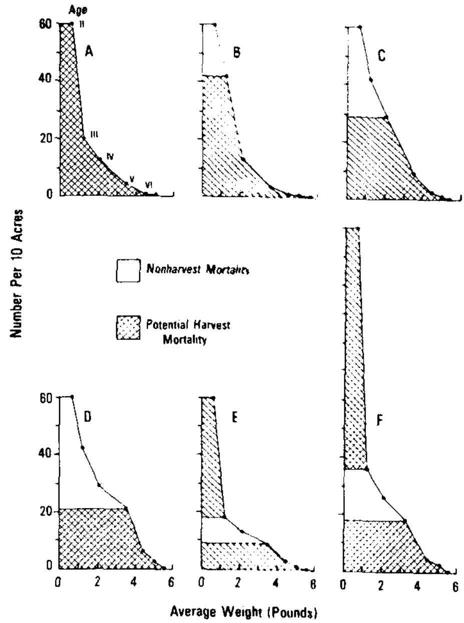

Figure 2. Graphic estimates of annual production and potential sustained harvest of Beaver Reservoir largemouth bass age II and older with various protected size regulations: A, None; B, 13 inches; C, 15.5 inches; D, 18 inches; E, F, 13 to 18 inches. Area of square in legend represents one pound per acre per year.

Table 1. Calculated age distribution of Beaver Reservoir largemouth bass age II and older with various protected size regulations. Number of fish in each age group is number per 10 acres.

	Age Group						
Protected Length (in)	II	III	IV	V	VI	VII	VIII
None	60	19	6.1	2.0	.63	.20	.06
13	60	42	13	3.8	1.1	.34	.10
15.5	60	42	29	8.8	2.6	.80	.24
18	60	42	29	21	6.2	1.9	.56
13-18	60	18	13	8.8	2.6	.80	.24
13-18**	120	36	26	18	5.2	1.6	.48
18**	120	84	59	41	12.3	3.7	1.1
Length(in)	10.9	13.1	15.6	18.1	19.4*	20.3*	20.7*
Weight(lb)	.65	1.2	2.1	3.5	4.4*	5.1*	5.5*

*Assumed data, not in Bryant and Houser (1971)
**Twice the average rate of recruitment

Table 2. Calculated biomass at annulus formation, annual production, theoretical potential sustained harvest, and catch rates for Beaver Reservoir largemouth bass age II and older with various protected length regulations. Numbers and weights (in pounds) are per 10 acres.

Protected Length (in)	Biomass	Production	Potential Harvest		Protected Catch		Total Catch		Average Weight	
			no.	wt.	no.	wt.	no.	wt.	caught	harvested
None	86	79	60	79	0	0	60	79	1.3	1.3
13	137	109	42	93	90	83	132	132	1.3	2.2
15.5	198	133	29	95	153	187	182	292	1.5	3.3
18	264	150	21	90	196	309	217	399	1.8	4.3
13-18	136	97	51	77	46	109	97	186	1.9	1.5
13-18*	272	194	102	154	93	218	195	372	1.9	1.5
18*	525**	-	-	-	-	-	-	-	-	-

*Twice the normal rate of recruitment
**Exceeds assumed sustained carrying capacity

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