LIMITATION OF SPECIAL REGULATIONS FOR INCREASING THE PROPORTION OF LARGE TROUT IN THE AU SABLE RIVER

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ABSTRACT

Data are reviewed for various time periods relating to the trout fishery of the Au Sable River. A decline in trout growth and a large decline in the proportion of large trout occurred in the 1970's and continues to present. Based on examination of evidence, the most reasonable cause-and-effect relationship producing the decline in the fishery is reduced nutrient input into the river.

In view of present growth and mortality rates, under the present environment, the fishery cannot be restored to its former condition by any form of special regulation, including no-kill or complete prohibition of angling.

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INTRODUCTION

The only salmonine fish species native to the Au Sable River, Michigan, was the grayling. The grayling became extinct soon after brook trout, brown trout, and rainbow trout were introduced into the Au Sable in the late nineteenth century. The non-native trouts thrived and as the brown trout became increasingly dominant in the drainage, the reputation of the river as one of the country's most famous trout streams was established.

A universal phenomenon among anglers is that fishing was always better in the "old days". Such statements can be found in the first report of George Jerome, the first fish commissioner of Michigan, submitted to the legislature in 1873. Mershon (1923) reminiscing on his 50 years as a hunter and fisherman lamented the decline of the Au Sable fishery. Unfortunately no quantitative data on abundance, growth rate, biomass per unit area, etc. are available from the "old days" of the Au Sable trout fishery to document a decline. Data collected over the past 30 years, however, on the 8.7 mile section of the main Au Sable River from Burton's to Wakeley Bridge, does document a decline in growth rate and biomass of the brown trout, especially a decline of large trout of 12-13 inches and larger in this section of the river during the 1970's and continuing to the present.

This documented decline has stimulated several research studies and the implementation of various types of special regulations by the Michigan Department of Natural Resources to better understand the reasons for the decline in the brown trout population and to explore possible ways to reverse the decline. The failure to reverse the decline of larger brown trout in the population has angered and frustrated a segment of the angling public. These anglers generated sufficient public pressure to cause the Natural Resource Commission to declare a five year

catch-and-release (no kill) regulation on the Burton's Landing to Wakeley Bridge section of the main Au Sable River scheduled to begin in 1986.

The purpose of this report is to demonstrate that such a regulation, although well-meaning, is misguided and is not based on biological evidence. It is an example of what might be called the "arrogance of ignorance", by which, "decisions are made loudly and clearly on inadequate and inaccurate data" (Mayer 1984). All of the biological evidence convincingly leads to the conclusion that, under the present environmental conditions which produces a relatively slow growth rate and an extremely high mortality of brown trout between three and four and four and five years of age, any substantial increase of larger, older fish in the population, with or without protection from angler kill, is beyond reasonable expectations.

There may be several types of personal belief which can serve as a basis to argue in favor of a no-kill regulation on the Burton's-Wakeley section of the Au Sable. Some may simply feel strongly against the killing of any animal by man; or, more likely in this case, have strong feelings against the killing of any trout anywhere, under any circumstances. Most anglers currently favoring the no-kill regulation, however, probably do so in the mistaken belief that by avoiding angler removal of any trout, the Au Sable River fishery will return to its former state of excellence, especially with a great proliferation of larger (ca. 14 inches and larger), older trout in the population. I believe that if most of the anglers and the commissioners currently favoring a no-kill regulation critically examined the biological evidence to arrive at an informed and unbiased decision on the matter, they would change their preference to favor one of the alternative regulation options suggested by DNR biologists which would allow a limited take of trout.

In the remainder of this report I will attempt to synthesize, summarize, and interpret the many years of data the Au Sable fishery compiled and published by the DNR, along with other pertinent data from the literature and personal experience with numerous trout populations over a broad geographical area. To those who disagree with any of my conclusions I would request that the particular points of disagreement be

detailed with evidence for the opposing viewpoint. In this way, the final determination of the type of regulation to be implemented on the Au Sable River might be resolved in an atmosphere of reason based on evidence and not entirely on emotion and ego.

First, I should make clear my own record on the matter of special regulation fisheries (regulations designed to reduce or eliminate angler kill to achieve a specified goal). I have favored the greater use of special regulations to maintain the quality of wild trout fisheries in heavily fished waters, especially emphasizing its value in the management of rare native trout (Behnke 1978, 1980, 1981). I have also expressed dismay at the lack of expertise long characterizing the special regulation fisheries of most states (where, historically, special regulations have been considered more in the realm of people management rather than fish management). I have also recommended that special regulations should be applied judiciously and only after the biological evidence is available on which to decide feasibility and to select the best regulations for a particular trout population. Otherwise, the imposition of special regulations on waters where they do not work will create a backlash and act as a setback to progress. Public acceptance of any special regulation by the user group is critical to its success. In relation to this point, I wrote: "except for a relative few fisheries, the 'pure' catch-and-release regulations (no-kill), are not the best type of regulations. No-kill regulations do not allow 'fine-tuning' of population dynamics to optimize both growth and catch-rate. It does not challenge the biologist to learn about recruitment rates, size-age structure and the internal workings of the environmental interactions that determine the potential of a fishery" (Behnke 1980).

In the following sections I will attempt to demonstrate that no-kill regulations will not significantly improve the size-age structure or growth rate of the Au Sable River brown trout population over previous regulations because the major cause of the decline in growth and abundance is attributed to a reduced food supply related to reduced nutrient input into the river. Also, because short term and long term natural factors such as climatic variation will most likely "overpower" any slight negative or positive changes in the trout population which

might be linked to a no-kill regulation, valid conclusions on the efficacy of no-kill regulations will not be possible at the end of the proposed five year trial period (without proper "control" sections).

THE FISHERY

The Burton-Wakeley section of the main Au Sable River is 8.7 miles in length and contains a surface area of about 100 acres (Alexander et al. 1979). The Au Sable River in general (all branches) was early recognized as a fine trout fishery, this was especially true for the main Au Sable in the Burton-Wakeley section. Because of the recognition of its importance as a trout fishery, the Au Sable received some of the first "special regulations" in the state. In 1901, the minimum size limit for trout was increased to 8 inches (6 inches statewide at the time). In 1907, a flies only regulation was imposed on the North Branch. In 1913, the first "backlash" against special regulations was apparent when the flies only regulation was repealed and the size limit reduced to 7 inches. In 1922, the size limit was again increased to 8 inches and the daily bag limit reduced to 20 trout (35 statewide) on the North Branch.

The modern era of scientific studies in the Au Sable drainage began in the 1950's, and it is from this time that changes in the population can be traced. The changes in the population of brown trout in the Burton-Wakeley section of the main Au Sable are apparent in the data of Alexander et al. (1979) comparing statistics, mainly from the 1959-63 period with figures for the 1972-76 period. From 1955 to 1976, six changes in regulations occurred on this section. The major regulation changes were: 1955-63, 10 inch minimum size limit on all trout (brook, brown, and rainbow), five trout per day creel limit, and flies only. In 1969 the size limit on brook trout was reduced to 7 inches. In 1973 the size limit on brown and rainbow trout was increased to 12 inches and the creel limit reduced to three trout (any species). In 1979 a "slot" limit was imposed which allowed the take of trout between 8 and 12 inches, and 16 inches or larger, and required the release of trout between 12 and 16 inches. Fishery data for the 1974-78 and 1980-83 periods are given by Clark and Alexander (1984).

Also: In 1974 the size limit was changed from 7 to 8" on brook trout

The following table summarizes the dynamics of the trout populations in different periods of time.

		Age Group					
		(First year of life) 0	I	II	III	IV	V
Brown trout							
average size (Oct.) (inches)	1959-63	4.0	7.9	10.7	13.6	16.6	19.0
	1974-78	3.6	6.9	9.3	11.2	13.5	15.8
	1980-83	- no change from 1974-78 period -					
numbers (per acre)	1959-63	337	236	101	29	6	0.6
	1974-78	450	164	114	74	4	ca. .5
	1980-83	405	148	80	35	1	trace
Brook trout							
average size	1959-63	3.7	6.4	9.0	10.1	11.5	
	1974-76	3.2	6.4	8.8	10.0	11.2	
numbers	1959-63	324	93	13	0.7	trace	
	1974-76	191	32	3	trace		

The most significant feature demonstrated by these data is the slower growth of brown trout in the 1970's and 80's compared with the 1950's and 60's. In the earlier period, brown trout at ages three and four attained a larger size than age four and five fish did in the later period. The actual number of three-year-old brown trout was greater in the 1974-78 period than in the 1959-63 period (74 vs. 29 per acre), perhaps due in part to the 12 inch minimum size limit in effect at the time, but there were many fewer trout of 12 inches or larger in the population in the 1970's and 80's because they averaged only 11.2 inches in the fall of their fourth year of life (age III+), whereas they averaged 13.6 inches at III+ in the 1950's and 60's. Thus, in the fall of the 1959-63 period there was an average of 36 brown trout per acre of ages III, IV, and V+ whereas in the 1974-78 period there were only about 4 per acre of comparable size at ages IV+ and V+. The proportion of

older trout continued to decline under the slot limit which protected fish between 12 and 16 inches. Also note the extremely high mortality rate between ages III to IV and IV to V. Changes in regulations appear to be very limited in their effectiveness to significantly increase survival to four and five years of age. In the 1959-63 period, under a 10 inch minimum size, brown trout could be taken by anglers beginning at age II. In the 1974-78 period with a 12 inch minimum size, fish would not be harvested until age IV (or faster growing age III+). It might be argued from the figures that the extreme mortality from age III to IV (74 to 4 per acre) was due to angler kill. Angler kill of 12 inch and larger trout in 1976 was 4 per acre -- the rest were lost to natural mortality. Also, about 6 trout of 12 inches or larger were caught and released per acre in 1976. During 1980-84 with the slot limit, 2060 (20.6/acre) "legal" trout between 8 and 12 inches were taken by anglers and 5440 (54/acre) were released. Most of the anglers fishing the Burton-Wakeley section practice catch-and-release angling for legal trout most of the time (release of 60 to 70% or more of total catch of legal trout). The standing crop or biomass per unit area of trout also declined compared to the 1959-63 period. In the 1959-63 period, the Burton-Wakeley section contained an average of 129 pounds per acre of brown trout and 20 pounds per acre of brook trout. This declined to 101 pounds per acre for brown trout and to 7 pounds per acre for brook trout in the 1974-76 period, and evidently continued to decline by an additional 30-40% (to ca. 60-70 pounds per acre) in the 1980's according to the figures on age groups given by Clark and Alexander (1984). Angling pressure on the Burton-Wakeley section averaged 430 hours per acre in the 1960-65 period; 305 hr./acre in 1976; and 345 hr./acre during 1980-83. During this same period, with no changes in regulations, trout in the North Branch Au Sable changed as follows: 1957-60 average of 34 pounds per acre brown trout and 36 pounds per acre of brook trout (total 70 pounds/acre); 1960-67, 45 pounds/acre brown trout and 28 pounds/acre brook trout (total 73 pounds/acre), in 1974-76, 60 pounds per acre brown trout and 24 pounds/acre brook trout (total 84 pounds/acre). In the 1980-83 period, however, the brown trout in the North Branch also declined similar to the decline in the main Au Sable during this same period, which can most

logically be attributed to local climatic variation affecting both the North Branch and main Au Sable, because the decline cannot be well correlated with increased angler kill (or the slot limit on the main Au Sable) (Alexander and Ryckman 1976; Alexander et al. 1979; Clark and Alexander 1984).

Another interesting finding from the North Branch where the brown trout growth rate is similar to the growth rate in the main Au Sable during the 1950's and 60's, is that when two sections were compared, one under statewide regulations and one under special regulations with 10 inch minimum size limit and flies only, the statewide regulation section contained about twice as many brown trout more than 12 inches as did the special regulation section (Alexander and Ryckman 1976). This may be due to the greater density of small brook trout, the major food of large brown trout in the North Branch, in the normal regulation area (Alexander 1977). If the number of trout per acre exceeding 12 inches (sampled in fall) are compared for the Burton-Wakeley section of the main Au Sable in different periods with different regulations the figures are as follows: during 1959-63 (10 inch minimum size limit) there was an average of 50 trout per acre which were 12 inches or larger, 17 of which were 14 inches or more and 5 were 16 inches or more. During 1974-78 (12 inch minimum) there were 19 trout per acre of 12 inches or greater in length, 3 of which were 14 inches or more and only about one-half trout per acre was 16 inches or more (Alexander et al. 1979). During 1980-83 (when slot limit protected all trout between 12-16 inches) trout of 12 inches or greater (which were then protected from angler kill) declined further to 10 per acre (Clark and Alexander 1984).

Thus, a long history of studies and numerous changes in angling regulations in the Au Sable drainage, demonstrate that natural influences determining growth rate and annual survival of age classes, govern the abundance and size of the trout populations. Special regulations, either decreasing, increasing, or eliminating angler kill can do very little to change the situation. The critical question is why has brown trout growth slowed since about 1970?

FACTORS INFLUENCING GROWTH

If the foregoing data syntheses is accepted then it becomes clear that the decline in the fishery of the mainstream Au Sable was not caused by increased angler kill of trout. Actually, the exploitation rate before 1973 was much greater than after more restrictive regulations reduced the annual kill from about 8000 trout per year in the 1960-65 period to about 500 per year after 1973 in the Burton-Wakeley section (Alexander et al. 1979). The angler kill did increase again in 1980's under the slot limit to about 2,100 annually (all but about 30 were in the 8-12 inch size range), but this angling mortality was only about 25% of the 1960-65 mortality when the fishery was considered excellent. The problem centers on changes in growth rate. As discussed, with the 1950's-60's growth rate, Au Sable brown trout average 13.6 inches at age III+ (toward end of fourth growing season), but under the growth rate during 1970's and 80's III+ trout are only 11.2 inches. The high mortality between ages III-IV and IV-V always maintained these older trout as a very small proportion of the total population -- thus, the key to the abundance of 12 inch and larger trout is to have a growth rate which attains this size by age III. Why do the mainstream Au Sable trout now only average 11.2 inches at III+ when they averaged 13.6 inches at this same age 20 years ago?

There has long been a popular belief that angler exploitation of a trout population, by the selective removal of faster growing individuals of each year class, will genetically change a population by favoring the survival of slower growing individuals which are left to reproduce, eventually changing the heredity of the population to slower growth rates. This theory gained particular credence to explain the slower growth of main Au Sable brown trout from a publication by Favro et al. (1979). I suspect that many anglers favoring a no-kill regulation do so because they believe the "genetic" theory of slow growth as expounded by Favro et al. They mistakenly believe that if angler kill is eliminated, a genetic change for faster growth will be favored. For those who favor no-kill regulations for this reason I include Appendix I with a detailed refutation explaining why this genetic theory is not a reasonable

explanation for the slower growth of brown trout in the 1970's and 80's. For now, I will only appeal to common sense and empirical evidence such as: 1. Other brown trout populations with high growth rates have been exposed to greater annual percent angler removal than has the main Au Sable population; for example, the North Branch Au Sable (Shetter 1969; Alexander and Ryckman 1976) and some Wisconsin streams (Avery and Hunt 1981) -- yet their growth rates remain higher than main Au Sable brown trout (also, how can the main Au Sable brown trout remain genetically isolated from North Branch and South Branch Au Sable brown trout where growth rates are higher?). 2. To effectively change the genetics of growth to favor the survival of slower growing individuals, there must be no selection against slower growth. In the Au Sable drainage (studies conducted mainly on North Fork), it was clearly demonstrated by Alexander (1976, 1977) that loss to predators of any year class is much greater than loss to angling, and predators take trout less than 12 inches. Thus, there would be much stronger selection for fast growth (to get out of the predator size range) than for slow growth to avoid angler take. 3. Also, for a genetic change to be effective, the trout must be removed from the population before they reproduce (before they have a chance to pass on any "fastgrowth" genes to the next generation). In the main Au Sable, all trout spawn at least once and some twice by the time they are 12 inches. If such a genetic change for slower growth could be real, it would have appeared in the "old days" under the 8 inch size limit which allowed removal of trout before they spawned and when angling exploitation was much higher than it was after 1973.

they are not isolated, but trout movement between these streams is meager (Shetter 1967)

? Couldn't it occur in theory by reducing only the fastest growers?

After critical examination of all of the available evidence, I must agree with ALEXANDE ET AL 1979 and Clark and Alexander (1984) that the reduction in nutrient input (nitrogen and phosphorous) from the closure of the Grayling Hatchery in the mid 1960's and the diversion of the city of Grayling's sewage effluent away from the river in 1971 is the major cause-effect relationship. This great reduction of nutrient input into the main Au Sable (70% reduction in nitrogen), reduced primary production (vegetation growth) which in turn reduced invertebrate production, leading to a condition of less available food for the trout and a slower growth rate. The study of Merron (1982) comparing nutrient level and trout growth over

different periods of time in the main Au Sable, the North Branch, and the South Branch, clearly defined the correlation between growth of brown trout and nutrient levels. I can conceive of no other reasonable alternative, no other probable cause-and-effect relationships, to explain the reduction in growth and reduction of total biomass of brown trout in the main Au Sable River, and unless nutrient enrichment occurs again comparable to the 1950's and 1960's, the population dynamics of the brown trout will not dramatically change. Thus, I also agree with the conclusion of Clark and Alexander (1984) that special regulations can have only a very limited effect for significantly altering the paucity of large (12 inches and more) trout in the population and therefore the most important aspect of any regulation on the Au Sable is ... "for their influence on satisfying the desires of different factions within the angling community". Obviously, "satisfying" the "different factions" of anglers will not be entirely possible, but those currently favoring no-kill regulations should understand the limitations of any regulation to significantly improve the fishery, as explained in this present report, so they can make an informed and impartial decision based on the biological evidence.

Studies on the relationships between diet and growth of trout in Michigan by Alexander and Gowing (1976) and comparisons of diet and growth of brown trout in the main Au Sable and the South Branch by Stauffer (1977) are of interest for a better understanding of the reasons for the slower growth of Au Sable brown trout. The density of brown trout in the South Branch was less than in the main Au Sable, but the density of benthic invertebrates was about three times greater in the South Branch. Because most aquatic insects are available to trout predation only while they are in the "drift" (in the water column), the higher the invertebrate density in the bottom substrate, everything else being equal, the higher the density in the drift, which makes more food available per unit area per unit time to feeding trout (that is, a feeding strategy for maximum energy gain and minimum energy loss will result in more rapid growth). The average daily diet of South Branch brown trout was about 20% greater than fish of comparable size in the main Au Sable. This increased feeding resulted in significantly faster

growth in South Branch brown trout, similar to main Au Sable growth in the 1950's-60's (attaining 13-14 inches at age III+). An important point for understanding how changes in feeding rate can change growth rate is the relationship between maintenance rations (the amount of food needed to maintain present weight or "status quo") and growth rations (after maintenance requirements are satisfied, additional food it utilized to increase growth). Only a slight increase in the amount of food available for growth can lead to a substantial increase in growth because maintenance rations are constant in relation to body size and water temperature. For example, if a large trout required 90 grams of food per day for maintenance and had an average daily consumption of 100 grams per day, it would have 10 grams of food available for increased growth (after 90 grams were utilized to maintain the "status quo"). If food items became more available and daily food consumption increased to 110 grams per day it would be only a 10% increase in daily diet, but a 100% increase (from 10 to 20 gms.) in food to be utilized for growth.

The study by Warren et al. (1964) enriching a small Oregon stream with sugar (sucrose) created a bloom of bacterial slime (*Sphaerotilus*, which was probably also produced by sewage effluent in the Au Sable), which was fed on by aquatic insects, particularly chironomid larvae. The increased production of insects led to a two fold increase in feeding by a population of cutthroat trout. However, because this increased feeding was above the maintenance requirements of the trout (i.e. it went into growth), the production of the trout population increased more than seven fold!

In view of a consideration on maintenance and growth rations, it can be understood why only a relatively slight increase or decrease in available food can result in substantial changes in trout growth.

Trout in streams, typically have a limited feeding area, circumscribed by their "territory". Their daily feeding is limited to the amount of food available in their feeding area or passing through it (drift) per unit of time. In the East Branch of the Au Sable, Fausch and White (1981) observed that small brook trout (< 8 in.) would feed when the density of invertebrate drift was much less than the threshold needed to stimulate the feeding of 8-12 inch trout. This type of observation

Note: The au Sable had very large population of Isopods and Amphopod which are much reduced since sewage reduction

suggests that larger trout are at a disadvantage when they must compete for a common food supply with smaller trout, especially at reduced food densities. I suspect that in the "old days" there were more abundant large food items such as small brook trout, sculpins, and crawfish in the main Au Sable which allowed larger brown trout to readily switch their diets to larger prey items, avoiding competition with smaller trout for a common food supply and thereby maintain a much higher proportion of 12-16 inch and larger trophy trout in the population than has been possible since the 1970's. The steady decline of brook trout has been a long term event in the Au Sable. A decline of crawfish and sculpins, although not documented, probably occurred when enrichment ceased and bacterial slimes, algae, and macrophyte vegetation declined.

An event that could have influenced growth in the main Au Sable was the installation of about $250,000 worth of "stream improvement" devices in the 1970's in the Burton-Wakeley section. Although this action was taken to improve the abundance of the trout population, the population continued to exhibit slow growth and a decline of larger trout. The number of younger trout (I, II age groups) did increase, which could have resulted from a combination of reduced angler kill on smaller trout and improved habitat which provided areas of cover promoting survival. The increase in suitable habitat sites may have actually reduced the size of feeding territories thereby exacerbating the problem of lower food density.

With lower growth rates, condition factors ("plumpness" or ratio of length to weight) also declined, so that a 10, 12, or 14 inch trout in the 1970's-80s weighs considerably less than 10, 12, or 14 inch trout did in the 1950's-60's. The lower growth, poorer condition and great reduction in trout of 12 inches or larger has resulted in angler dissatisfaction, frustration, and demands for improvement of the situation leading to the commission now grasping for a straw of improvement with the imposition of a no-kill regulation.

LIMITATIONS OF REGULATIONS

It is incumbent on those who act as spokesmen and advocates for better trout fisheries as representatives of conservation organizations

or the news media to have some basic comprehension of the subject matter so that they may be truly effective leaders contributing toward attainment of a worthy goal. To do so, an understanding of the dynamic forces and interactions of a trout population with its environment is necessary to understand the workings of recruitment, growth and mortality governed by natural factors and the limitations imposed by the environment in relation to man's ability to significantly change life history parameters by regulation of angling. A basic text on the subject that I would highly recommend is Allen's (1951) publication on the Horokiwi Stream, New Zealand. There is no doubt that restrictive regulations to reduce or eliminate angler kill can and do work for many wild trout populations. The danger, however, for the well-meaning angling enthusiast concerns the trap of inductive reasoning -- if it works in stream A, therefore it will work in stream B, C, D, etc. The faulty reasoning leading to erroneous conclusions here involves differences between streams in: 1. species of trout, 2. growth rate and mortality rates, 3. age structure (% of population attaining 4, 5, 6 or more years of age), 4. angling pressure (potential angling exploitation rate) and amount of compensatory mortality involved (how much of angling mortality is compensatory to natural mortality rather than additive--for example, if angling mortality is 80% compensatory, a population with an average of 50% total annual mortality would not show improved survival from year to year unless angling mortality exceeded 40%).

Many types of regulations including no-kill have been instituted in the various states for the past 50 years. No dramatic success stories were apparent for many years and the use of special regulations as a fisheries management tool became to be viewed by biologists and administrators as "people management" rather than fish management . Then in the 1970's, substantial increases in trout populations were documented in the St. Joe River and Kelly Creek, Idaho, and in the Yellowstone River in Yellowstone Park after angler kill was drastically reduced by regulation. There was no reasonable doubt that restrictive regulations were working to achieve, their goal of substantial increase (several fold increase of 5-6-7 year-old fish) of larger trout (Behnke and Zarn 1976). The explanation of this phenomenon concerns the species of trout

involved--the cutthroat trout, Salmo clarki, the species most vulnerable to angling exploitation--angling pressure of only 10-12 hours per acre per year can remove 50% of all catchable-size cutthroat trout from a population, whereas, with brown trout, the most resistent species to exploitation, it requires 300 to 800 hours of angling pressure per year to expect a 50% exploitation rate. Another important aspect to understand why some cutthroat trout respond so well to reduced angler kill concerns their size-age structure in large rivers or lakes. In the above mentioned waters, fish of 5, 6, and 7 years are common in the populations and growth averaged about 3 inches per year. For example 6 and 7 year-old Yellowstone cutthroat trout are 17-18 and 19-21 inches. In such populations, only a slight reduction of annual total mortality can lead to substantial increases of older, larger fish. If total annual mortality is reduced from 60% to 50% per year from ages II through VI annual survival changes as follows:

	number surviving at ages				
	II	III	IV	V	VI
60% mortality	100	40	16	6	2
50% mortality	100	50	25	12	6

If average sizes for these age groups are 14 inches (IV), 17 inches (V), and 20 inches (VI), then the reduction in annual mortality from only 60% to 50% would increase the number of 14 inch and larger trout in this example from 24 to 43; the number of 17 inch trout would double and the number of 20 inch trout would triple per unit area. Perhaps 50 years ago, the Au Sable brown trout population reflected age-growth statistics comparable to the above figures. If they did, undoubtedly regulations reducing angler mortality and total mortality would work very well. Under the present environmental regime of slow growth, virtually no fish of age V or older and very high mortality (90-95%), with or without angler kill, of trout from age III to IV to V, it should be obvious that any type of special regulations can only play a very minor role, at best, to change the present situation.

I could go on with 100 or more additional pages discussing examples of where special regulations have worked and where they have not worked and explain the reasons in terms of recruitment and growth rates, annual mortality rates, and angler exploitation rates, but they all would only emphasize a basic agreement that where the existing environment places severe restrictions on growth and survival to older age classes, no amount of protection from angler kill can change the natural factors determining the life history dynamics of the trout population.

Lawrence Creek, Wisconsin, for many years was subjected to several different regulations in attempts to maximize angling quality of its brook trout fishery. A one mile section was completely closed to angling for a five year period -- at the end of which there were fewer trout than when it was open to angling (Hunt 1970).

Theoretically the range of fishery regulations that could be applied to the Au Sable River ranges from none (anything goes) to complete prohibition of angling. I believe that all anglers would prefer something in-between these extremes. The present debate centers on no-kill vs. some form of limited take regulation. A recent poll by the Michigan DNR (Report to the Michigan Natural Resources Commission on Au Sable River Fishing Regulations, Feb. 6, 1986), found 41% of the respondents favored no-kill and 59% favored some form of limited kill, most preferring the present regulations or something equally liberal. The reasons cited for favoring no-kill regulations were, "will improve quality of the fishing" (N=37) and, "will provide more and bigger fish" (N=35). The reasons opposing no-kill mainly focused on the theme that most of the present anglers fishing the Au Sable practice catch-and-release most of the time and they want to be able to take an occasional trout when they want. Also there was a reaction against "elitist" and "purist" special interest imposing regulations on the local anglers. Apparently, no one expressed doubts if a no-kill regulation would achieve the expected goals of its proponents. The information presented in my report raises this issue of doubt--my conclusion is that under the present environmental regime of the Au Sable which dictates the present growth and mortality rates, a no-kill regulation will not significantly improve the fishery with a substantial increase in brown trout of 12

inches and larger. If a five year test period of no-kill was imposed and its success measured by changes in the number of 12 inch and larger trout at the end of five years, three outcomes are possible--increase, decrease, or no change. Without adequate control sections on the river, however, a valid cause-effect relationship between the no-kill regulation and population change would not be possible. The changes could be attributed to uncontrollable variables such as climate, minor fluctuations in invertebrate populations, etc. Because of the regulations governing possession of trout in a no-kill fishery, alternate no-kill sections and limited take regulations, needed for controls do not appear feasible because boaters moving through a no-kill section with a trout would be in violation. An alternative would be to designate about a one mile section of the river for a complete prohibition of angling and compare any change in size-age structure between sections.

The best that could be hoped for to maintain the greatest abundance of older fish in the population would be to protect the age III trout from exploitation. This could essentially be done by lowering the present lower end of the slot limit from 12 to 10 inches. In any event, in a democratic society, regulations should reflect the wishes of licensed anglers--the greatest good for the greatest number. Leaders and spokesmen for angler groups, however, should become informed on the issues involved--in this case, the biological evidence which reveals the constraints which severely limit the response of the trout population to any regulation. Only then can rationale decisions, based on evidence and not emotion, be made.

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APPENDIX I

THE GENETIC BASIS OF GROWTH: WHY SLOW GROWTH OF AU SABLE BROWN TROUT IS NOT DUE TO ANGLING SELECTIVITY

As discussed in the text, I dismiss the theory of a hereditary change in the Au Sable brown trout population which states that due to differential selection by anglers for the fastest growing fish, a genetic basis for slow growth occurs.

I pointed out that the empirical and common sense evidence refutes all of the assumptions necessary to make the "genetic theory" operate on the Au Sable brown trout.

1. Nowhere in the world has this phenomenon been observed (that is, angler exploitation causing a hereditary change for slower growth) and there are many trout populations, especially cutthroat trout, that have been historically exposed to much higher exploitation rates than the Au Sable brown trout.
2. Under the 12 inch minimum size limit, all brown trout had spawned at least once, some twice, before they could have been removed by the fishery. Thus, any "fast growth" genes had already been passed on to the next generation. If a genetic change could have been operating, it would have occurred in "the old days" under an 8 inch size limit when the fastest growing trout could have been removed before they spawned and exploitation rates were much higher than after 1973. The table in the text (p. 6) shows that during 1974-78, under the 12 inch minimum size limit, when this selection against fast growth is assumed to have occurred, there was an average of 74 age III brown trout per acre in the fall of the year (average size of 11.2 inches) but only 4 age IV trout ($\bar{x}$ 13.5 inches). The mortality between ages III and IV (70 of 74 perished for annual mortality of 95%) was extremely high (essentially, the mortality of 12 inch and larger fish). These figures could certainly lead one to the conclusion that under the 12 inch size limit, the anglers were wiping out the large fish. However, the creel census data for 1974-78 reveals that only about 4 fish per acre of 12 inches or larger were harvested by anglers (6 per acre were caught-and-released). That is, of the total annual mortality of 70 trout per acre between

ages III and IV, from one fall period to the next, only 4 can be attributed to angler kill (6%) the other 66 (94%) were lost to natural mortality. In the light of such mortality data, it is nonsensical to attempt to make a case that the 12 inch limit had changed the genetics by selective angling mortality.

3. I also pointed out that natural mortality factors, especially predators, remove many more fish of any year class than do anglers, even under the most liberal regulations of the "old days". Predators take trout less than 12 inches; thus, there would be strong negative selection against slow growth because slower growth would maintain an individual for a longer period in the vulnerable prey size range.

I suspect, however, that the publication of Favro et al. (1979) of computer simulation of the Au Sable brown trout population, is considered my many present proponents of a no-kill regulation as "scientific proof" that a genetic change for slow growth has occurred due to angler selection under the 12 inch minimum size limit and a no-kill regulation is necessary to restore faster growth. Actually the 12-16 inch slot limit completely protected 12 inch trout and "rewarded" the fastest growing fish which attained 12 inches by prohibition of kill. That is, there should have been selection favoring the fastest growing fish to survive from age III to IV whereas slower growing fish, less than 12 inches could be harvested. The mortality statistics for the 1980-83 period under the 12-16 inch protected slot, show that there was an average of 35 age III trout per acre but only one age IV fish. That is, the mortality of age III to age IV from one fall to the next was 34 (of 35) or 97%, despite complete protection of 12 inch trout. Besides the common sense, empirical evidence that there is no basis to establish a case for genetic change due to angler exploitation, I would point out that the assumptions used in the simplistic model of Favro et al. are obviously false: 1. Growth is determined by two alleles (one "fast", one slow") at one gene locus. 2. There is no selection against slow growth 3. Fastest growing fish removed by anglers before they reproduce. These assumptions are simply false to begin with. The model bears no relationship to biological reality.

Another contribution reinforcing the belief that Au Sable brown trout have a genetically determined slow growth rate (which is due to angler exploitation), concerns a "test" of the genetic hypothesis. In this experiment, young brown trout from the Au Sable, Gilchrist Creek, the Pigeon River, and a domesticated hatchery strain were stocked into four lakes in the fall of 1982 and their growth compared after two years in the lakes (Alexander 1985. Mich. DNR Fish. Res. Rep. No. 1929). After two years, the Gilchrist Creek brown trout had exhibited the fastest growth, an average increase of 9 inches, vs. an average growth increase of 8 inches for the Au Sable trout (in weight, the Gilchrist fish gained an average of one ounce more than the Au Sable fish -- 9 oz. vs. 8 ox.). This experiment reveals that there are genetic differences that caused Gilchrist Creek brown trout to grow slightly faster than Au Sable brown trout in the four lakes (but not without qualifications -- the young trout were not uniform when stocked, i.e. they were not raised under identical conditions; no information was provided on the biotic and abiotic conditions in the lakes influencing growth; the study should be continued to follow the growth and survival through older ages). However, if this genetic basis for slower growth is accepted, no valid cause-and-effect relationship can be made connecting the Au Sable growth rate with angler exploitation. As I pointed out in an article on brown trout (Behnke 1986. Trout Magazine vol. 27 no. 1), the diversity of the brown trout first introduced into this country, and different selective pressures in different environments, has resulted in the present situation whereby no two populations could be expected to be genetically identical. Thus, any genetic differences between Gilchrist and AU Sable brown trout are much more likely to be the result of origins from different ancestors and natural selection in each environment. Considering the low angling mortality rates of Au Sable brown trout, no valid conclusion can be made that angling mortality has caused a genetic change in the AU Sable brown trout resulting in slower growth. The slower growth rates in the 1970's and 80's, however, might be expected to select for earlier maturing fish (sexually mature at smaller size) because so few fish survive past age III, it would be expected that early maturation should be favored. If this is true, then the proportion of sexually mature age II+ (and I+) fish should be higher now than it was in

in the 1950's and 60's. I know of no data allowing for such a comparison, however. But in this case the genetic selection would be caused by the reduced nutrients in the river which caused the slower growth.

Another publication often cited to demonstrate the possibility of selective harvest genetically selecting for slow growth (actually the main selection concerns earlier maturation) is Ricker (1981. Can. Jour. Fish. Aquat. Sci. 38:1636-56). Ricker's study deals with Pacific salmon and commercial exploitation (where exploitation on some stocks reached 80-90%). The trend in some stocks of Pacific salmon exposed to heavy exploitation has been for spawning runs to change to higher proportions of young, smaller fish. This selection is due to the fact that when a year-class of salmon is exposed to an intensive ocean fishery, the less time spent in the ocean, the better chance for survival to spawning. What must be remembered here is that Pacific salmon all die after first spawning -- there is no possibility to spawn before being taken in the fishery as was the case with the Au Sable brown trout under the 12 inch size limit (all spawned before any were taken, and the angler "take" was a minor fraction of their total mortality). Thus, any salmon taken in a fishery has had no chance to pass its genotype on to the next generation.

Although I can find no evidence to support the "genetic" theory of slow growth, to those who continue to support the idea, I would point out that a slot limit (or a maximum size limit) could work to favor or reward fastest growing fish and negatively select against slower growing fish by allowing their take in the fishery.

LIMITATION OF SPECIAL REGULATIONS FOR INCREASING THE PROPORTION OF LARGE TROUT IN THE AU SABLE RIVER

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ABSTRACT

Data are reviewed for various time periods relating to the trout fishery of the Au Sable River. A decline in trout growth and a large decline in the proportion of large trout occurred in the 1970's and continues to present. Based on examination of evidence, the most reasonable cause-and-effect relationship producing the decline in the fishery is reduced nutrient input into the river.

In view of present growth and mortality rates, under the present environment, the fishery cannot be restored to its former condition by any form of special regulation, including no-kill or complete prohibition of angling.

Robert Behnke
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LIMITATIONS OF SPECIAL REGULATIONS FOR INCREASING THE PROPORTION OF LARGE TROUT IN THE AU SABLE RIVER

INTRODUCTION

The only salmonine fish species native to the Au Sable River, Michigan, was the grayling. The grayling became extinct soon after brook trout, brown trout, and rainbow trout were introduced into the Au Sable in the late nineteenth century. The non-native trouts thrived and as the brown trout became increasingly dominant in the drainage, the reputation of the river as one of the country's most famous trout streams was established.

A universal phenomenon among anglers is that fishing was always better in the "old days". Such statements can be found in the first report of George Jerome, the first fish commissioner of Michigan, submitted to the legislature in 1873. Mershon (1923) reminiscing on his 50 years as a hunter and fisherman lamented the decline of the Au Sable fishery. Unfortunately no quantitative data on abundance, growth rate, biomass per unit area, etc. are available from the "old days" of the Au Sable trout fishery to document a decline. Data collected over the past 30 years, however, on the 8.7 mile section of the main Au Sable River from Burton's to Wakeley Bridge, does document a decline in growth rate and biomass of the brown trout, especially a decline of large trout of 12-13 inches and larger in this section of the river during the 1970's and continuing to the present.

This documented decline has stimulated several research studies and the implementation of various types of special regulations by the Michigan Department of Natural Resources to better understand the reasons for the decline in the brown trout population and to explore possible ways to reverse the decline. The failure to reverse the decline of larger brown trout in the population has angered and frustrated a segment of the angling public. These anglers generated sufficient public pressure to cause the Natural Resource Commission to declare a five year

catch-and-release (no kill) regulation on the Burton's Landing to Wakeley Bridge section of the main Au Sable River scheduled to begin in 1986.

The purpose of this report is to demonstrate that such a regulation, although well-meaning, is misguided and is not based on biological evidence. It is an example of what might be called the "arrogance of ignorance", by which, "decisions are made loudly and clearly on inadequate and inaccurate data" (Mayer 1984). All of the biological evidence convincingly leads to the conclusion that, under the present environmental conditions which produces a relatively slow growth rate and an extremely high mortality of brown trout between three and four and four and five years of age, any substantial increase of larger, older fish in the population, with or without protection from angler kill, is beyond reasonable expectations.

There may be several types of personal belief which can serve as a basis to argue in favor of a no-kill regulation on the Burton's-Wakeley section of the Au Sable. Some may simply feel strongly against the killing of any animal by man; or, more likely in this case, have strong feelings against the killing of any trout anywhere, under any circumstances. Most anglers currently favoring the no-kill regulation, however, probably do so in the mistaken belief that by avoiding angler removal of any trout, the Au Sable River fishery will return to its former state of excellence, especially with a great proliferation of larger (ca. 14 inches and larger), older trout in the population. I believe that if most of the anglers and the commissioners currently favoring a no-kill regulation critically examined the biological evidence to arrive at an informed and unbiased decision on the matter, they would change their preference to favor one of the alternative regulation options suggested by DNR biologists which would allow a limited take of trout.

In the remainder of this report I will attempt to synthesize, summarize, and interpret the many years of data the Au Sable fishery compiled and published by the DNR, along with other pertinent data from the literature and personal experience with numerous trout populations over a broad geographical area. To those who disagree with any of my conclusions I would request that the particular points of disagreement be

detailed with evidence for the opposing viewpoint. In this way, the final determination of the type of regulation to be implemented on the Au Sable River might be resolved in an atmosphere of reason based on evidence and not entirely on emotion and ego.

First, I should make clear my own record on the matter of special regulation fisheries (regulations designed to reduce or eliminate angler kill to achieve a specified goal). I have favored the greater use of special regulations to maintain the quality of wild trout fisheries in heavily fished waters, especially emphasizing its value in the management of rare native trout (Behnke 1978, 1980, 1981). I have also expressed dismay at the lack of expertise long characterizing the special regulation fisheries of most states (where, historically, special regulations have been considered more in the realm of people management rather than fish management). I have also recommended that special regulations should be applied judiciously and ony after the biological evidence is available on which to decide feasibility and to select the best regulations for a particular trout population. Otherwise, the imposition of special regulations on waters where they do not work will create a backlash and act as a setback to progress. Public acceptance of any special regulation by the user group is critical to its success. In relation to this point, I wrote: "except for a relative few fisheries, the 'pure' catch-and-release regulations (no-kill), are not the best type of regulations. No-kill regulations do not allow 'fine-tuning' of population dynamics to optimize both growth and catch-rate. It does not challenge the biologist to learn about recruitment rates, size-age structure and the internal workings of the environmental interactions that determine the potential of a fishery" (Behnke 1980).

In the following sections I will attempt to demonstrate that no-kill regulations will not significantly improve the size-age structure or growth rate of the Au Sable River brown trout population over previous regulations because the major cause of the decline in growth and abundance is attributed to a reduced food supply related to reduced nutrient input into the river. Also, because short term and long term natural factors such as climatic variation will most likely "overpower" any slight negative or positive changes in the trout population which

might be linked to a no-kill regulation, valid conclusions on the efficacy of no-kill regulations will not be possible at the end of the proposed five year trial period (without proper "control" sections).

THE FISHERY

The Burton-Wakeley section of the main Au Sable River is 8.7 miles in length and contains a surface area of about 100 acres (Alexander et al. 1979). The Au Sable River in general (all branches) was early recognized as a fine trout fishery, this was especially true for the main Au Sable in the Burton-Wakeley section. Because of the recognition of its importance as a trout fishery, the Au Sable received some of the first "special regulations" in the state. In 1901, the minimum size limit for trout was increased to 8 inches (6 inches statewide at the time). In 1907, a flies only regulation was imposed on the North Branch. In 1913, the first "backlash" against special regulations was apparent when the flies only regulation was repealed and the size limit reduced to 7 inches. In 1922, the size limit was again increased to 8 inches and the daily bag limit reduced to 20 trout (35 statewide) on the North Branch.

The modern era of scientific studies in the Au Sable drainage began in the 1950's, and it is from this time that changes in the population can be traced. The changes in the population of brown trout in the Burton-Wakeley section of the main Au Sable are apparent in the data of Alexander et al. (1979) comparing statistics, mainly from the 1959-63 period with figures for the 1972-76 period. From 1955 to 1976, six changes in regulations occurred on this section. The major regulation changes were: 1955-63, 10 inch minimum size limit on all trout (brook, brown, and rainbow), five trout per day creel limit, and flies only. In 1969 the size limit on brook trout was reduced to 7 inches. In 1973 the size limit on brown and rainbow trout was increased to 12 inches and the creel limit reduced to three trout (any species). In 1979 a "slot" limit was imposed which allowed the take of trout between 8 and 12 inches, and 16 inches or larger, and required the release of trout between 12 and 16 inches. Fishery data for the 1974-78 and 1980-83 periods are given by Clark and Alexander (1984).

The following table summarizes the dynamics of the trout populations in different periods of time.

		Age Group					
		(First year of life) 0	I	II	III	IV	V
Brown trout							
average size (Oct.) (inches)	1959-63	4.0	7.9	10.7	13.6	16.6	19.0
	1974-78	3.6	6.9	9.3	11.2	13.5	15.8
	1980-83	- no change from 1974-78 period -					
numbers (per acre)	1959-63	337	236	101	29	6	0.6
	1974-78	450	164	114	74	4	ca. .5
	1980-83	405	148	80	35	1	trace
Brook trout							
average size	1959-63	3.7	6.4	9.0	10.1	11.5	
	1974-76	3.2	6.4	8.8	10.0	11.2	
numbers	1959-63	324	93	13	0.7	trace	
	1974-76	191	32	3	trace		

The most significant feature demonstrated by these data is the slower growth of brown trout in the 1970's and 80's compared with the 1950's and 60's. In the earlier period, brown trout at ages three and four attained a larger size than age four and five fish did in the later period. The actual number of three-year-old brown trout was greater in the 1974-78 period than in the 1959-63 period (74 vs. 29 per acre), perhaps due in part to the 12 inch minimum size limit in effect at the time, but there were many fewer trout of 12 inches or larger in the population in the 1970's and 80's because they averaged only 11.2 inches in the fall of their fourth year of life (age III+), whereas they averaged 13.6 inches at III+ in the 1950's and 60's. Thus, in the fall of the 1959-63 period there was an average of 36 brown trout per acre of ages III, IV, and V+ whereas in the 1974-78 period there were only about 4 per acre of comparable size at ages IV+ and V+. The proportion of

older trout continued to decline under the slot limit which protected fish between 12 and 16 inches. Also note the extremely high mortality rate between ages III to IV and IV to V. Changes in regulations appear to be very limited in their effectiveness to significantly increase survival to four and five years of age. In the 1959-63 period, under a 10 inch minimum size, brown trout could be taken by anglers beginning at age II. In the 1974-78 period with a 12 inch minimum size, fish would not be harvested until age IV (or faster growing age III+). It might be argued from the figures that the extreme mortality from age III to IV (74 to 4 per acre) was due to angler kill. Angler kill of 12 inch and larger trout in 1976 was 4 per acre -- the rest were lost to natural mortality. Also, about 6 trout of 12 inches or larger were caught and released per acre in 1976. During 1980-84 with the slot limit, 2060 (20.6/acre) "legal" trout between 8 and 12 inches were taken by anglers and 5440 (54/acre) were released. Most of the anglers fishing the Burton-Wakeley section practice catch-and-release angling for legal trout most of the time (release of 60 to 70% or more of total catch of legal trout). The standing crop or biomass per unit area of trout also declined compared to the 1959-63 period. In the 1959-63 period, the Burton-Wakeley section contained an average of 129 pounds per acre of brown trout and 20 pounds per acre of brook trout. This declined to 101 pounds per acre for brown trout and to 7 pounds per acre for brook trout in the 1974-76 period, and evidently continued to decline by an additional 30-40% (to ca. 60-70 pounds per acre) in the 1980's according to the figures on age groups given by Clark and Alexander (1984). Angling pressure on the Burton-Wakeley section averaged 430 hours per acre in the 1960-65 period; 305 hr./acre in 1976; and 345 hr./acre during 1980-83. During this same period, with no changes in regulations, trout in the North Branch Au Sable changed as follows: 1957-60 average of 34 pounds per acre brown trout and 36 pounds per acre of brook trout (total 70 pounds/acre); 1960-67, 45 pounds/acre brown trout and 28 pounds/acre brook trout (total 73 pounds/acre), in 1974-76, 60 pounds per acre brown trout and 24 pounds/acre brook trout (total 84 pounds/acre). In the 1980-83 period, however, the brown trout in the North Branch also declined similar to the decline in the main Au Sable during this same period, which can most

logically be attributed to local climatic variation affecting both the North Branch and main Au Sable, because the decline cannot be well correlated with increased angler kill (or the slot limit on the main Au Sable) (Alexander and Ryckman 1976; Alexander et al. 1979; Clark and Alexander 1984).

Another interesting finding from the North Branch where the brown trout growth rate is similar to the growth rate in the main Au Sable during the 1950's and 60's, is that when two sections were compared, one under statewide regulations and one under special regulations with 10 inch minimum size limit and flies only, the statewide regulation section contained about twice as many brown trout more than 12 inches as did the special regulation section (Alexander and Ryckman 1976). This may be due to the greater density of small brook trout, the major food of large brown trout in the North Branch, in the normal regulation area (Alexander 1977). If the number of trout per acre exceeding 12 inches (sampled in fall) are compared for the Burton-Wakeley section of the main Au Sable in different periods with different regulations the figures are as follows: during 1959-63 (10 inch minimum size limit) there was an average of 50 trout per acre which were 12 inches or larger, 17 of which were 14 inches or more and 5 were 16 inches or more. During 1974-78 (12 inch minimum) there were 19 trout per acre of 12 inches or greater in length, 3 of which were 14 inches or more and only about one-half trout per acre was 16 inches or more (Alexander et al. 1979). During 1980-83 (when slot limit protected all trout between 12-16 inches) trout of 12 inches or greater (which were then protected from angler kill) declined further to 10 per acre (Clark and Alexander 1984).

Thus, a long history of studies and numerous changes in angling regulations in the Au Sable drainage, demonstrate that natural influences determining growth rate and annual survival of age classes, govern the abundance and size of the trout populations. Special regulations, either decreasing, increasing, or eliminating angler kill can do very little to change the situation. The critical question is why has brown trout growth slowed since about 1970?

FACTORS INFLUENCING GROWTH

If the foregoing data syntheses is accepted then it becomes clear that the decline in the fishery of the mainstream Au Sable was not caused by increased angler kill of trout. Actually, the exploitation rate before 1973 was much greater than after more restrictive regulations reduced the annual kill from about 8000 trout per year in the 1960-65 period to about 500 per year after 1973 in the Burton-Wakeley section (Alexander et al. 1979). The angler kill did increase again in 1980's under the slot limit to about 2,100 annually (all but about 30 were in the 8-12 inch size range), but this angling mortality was only about 25% of the 1960-65 mortality when the fishery was considered excellent. The problem centers on changes in growth rate. As discussed, with the 1950's-60's growth rate, Au Sable brown trout average 13.6 inches at age III+ (toward end of fourth growing season), but under the growth rate during 1970's and 80's III+ trout are only 11.2 inches. The high mortality between ages III-IV and IV-V always maintained these older trout as a very small proportion of the total population -- thus, the key to the abundance of 12 inch and larger trout is to have a growth rate which attains this size by age III. Why do the mainstream Au Sable trout now only average 11.2 inches at III+ when they averaged 13.6 inches at this same age 20 years ago?

There has long been a popular belief that angler exploitation of a trout population, by the selective removal of faster growing individuals of each year class, will genetically change a population by favoring the survival of slower growing individuals which are left to reproduce, eventually changing the heredity of the population to slower growth rates. This theory gained particular credence to explain the slower growth of main Au Sable brown trout from a publication by Favro et al. (1979). I suspect that many anglers favoring a no-kill regulation do so because they believe the "genetic" theory of slow growth as expounded by Favro et al. They mistakenly believe that if angler kill is eliminated, a genetic change for faster growth will be favored. For those who favor no-kill regulations for this reason I include Appendix I with a detailed refutation explaining why this genetic theory is not a reasonable

explanation for the slower growth of brown trout in the 1970's and 80's. For now, I will only appeal to common sense and empirical evidence such as: 1. Other brown trout populations with high growth rates have been exposed to greater annual percent angler removal than has the main Au Sable population; for example, the North Branch Au Sable (Shetter 1969; Alexander and Ryckman 1976) and some Wisconsin streams (Avery and Hunt 1981) -- yet their growth rates remain higher than main Au Sable brown trout (also, how can the main Au Sable brown trout remain genetically isolated from North Branch and South Branch Au Sable brown trout where growth rates are higher?). 2. To effectively change the genetics of growth to favor the survival of slower growing individuals, there must be no selection against slower growth. In the Au Sable drainage (studies conducted mainly on North Fork), it was clearly demonstrated by Alexander (1976, 1977) that loss to predators of any year class is much greater than loss to angling, and predators take trout less than 12 inches. Thus, there would be much stronger selection for fast growth (to get out of the predator size range) than for slow growth to avoid angler take. 3. Also, for a genetic change to be effective, the trout must be removed from the population before they reproduce (before they have a chance to pass on any "fastgrowth" genes to the next generation). In the main Au Sable, all trout spawn at least once and some twice by the time they are 12 inches. If such a genetic change for slower growth could be real, it would have appeared in the "old days" under the 8 inch size limit which allowed removal of trout before they spawned and when angling exploitation was much higher than it was after 1973.

After critical examination of all of the available evidence, I must agree with Clark and Alexander (1984) that the reduction in nutrient input (nitrogen and phosphorous) from the closure of the Grayling Hatchery in the mid 1960's and the diversion of the city of Grayling's sewage effluent away from the river in 1971 is the major cause-effect relationship. This great reduction of nutrient input into the main Au Sable (70% reduction in nitrogen), reduced primary production (vegetation growth) which in turn reduced invertebrate production, leading to a condition of less available food for the trout and a slower growth rate. The study of Merron (1982) comparing nutrient level and trout growth over

different periods of time in the main Au Sable, the North Branch, and the South Branch, clearly defined the correlation between growth of brown trout and nutrient levels. I can conceive of no other reasonable alternative, no other probable cause-and-effect relationships, to explain the reduction in growth and reduction of total biomass of brown trout in the main Au Sable River, and unless nutrient enrichment occurs again comparable to the 1950's and 1960's, the population dynamics of the brown trout will not dramatically change. Thus, I also agree with the conclusion of Clark and Alexander (1984) that special regulations can have only a very limited effect for significantly altering the paucity of large (12 inches and more) trout in the population and therefore the most important aspect of any regulation on the Au Sable is ... "for their influence on satisfying the desires of different factions within the angling community". Obviously, "satisfying" the "different factions" of anglers will not be entirely possible, but those currently favoring no-kill regulations should understand the limitations of any regulation to significantly improve the fishery, as explained in this present report, so they can make an informed and impartial decision based on the biological evidence.

Studies on the relationships between diet and growth of trout in Michigan by Alexander and Gowing (1976) and comparisons of diet and growth of brown trout in the main Au Sable and the South Branch by Stauffer (1977) are of interest for a better understanding of the reasons for the slower growth of Au Sable brown trout. The density of brown trout in the South Branch was less than in the main Au Sable, but the density of benthic invertebrates was about three times greater in the South Branch. Because most aquatic insects are available to trout predation only while they are in the "drift" (in the water column), the higher the invertebrate density in the bottom substrate, everything else being equal, the higher the density in the drift, which makes more food available per unit area per unit time to feeding trout (that is, a feeding strategy for maximum energy gain and minimum energy loss will result in more rapid growth). The average daily diet of South Branch brown trout was about 20% greater than fish of comparable size in the main Au Sable. This increased feeding resulted in significantly faster

growth in South Branch brown trout, similar to main Au Sable growth in the 1950's-60's (attaining 13-14 inches at age III+). An important point for understanding how changes in feeding rate can change growth rate is the relationship between maintenance rations (the amount of food needed to maintain present weight or "status quo") and growth rations (after maintenance requirements are satisfied, additional food it utilized to increase growth). Only a slight increase in the amount of food available for growth can lead to a substantial increase in growth because maintenance rations are constant in relation to body size and water temperature. For example, if a large trout required 90 grams of food per day for maintenance and had an average daily consumption of 100 grams per day, it would have 10 grams of food available for increased growth (after 90 grams were utilized to maintain the "status quo"). If food items became more available and daily food consumption increased to 110 grams per day it would be only a 10% increase in daily diet, but a 100% increase (from 10 to 20 gms.) in food to be utilized for growth.

The study by Warren et al. (1964) enriching a small Oregon stream with sugar (sucrose) created a bloom of bacterial slime (Sphaerotilus, which was probably also produced by sewage effluent in the Au Sable), which was fed on by aquatic insects, particularly chironomid larvae. The increased production of insects led to a two fold increase in feeding by a population of cutthroat trout. However, because this increased feeding was above the maintenance requirements of the trout (i.e. it went into growth), the production of the trout population increased more than seven fold!

In view of a consideration on maintenance and growth rations, it can be understood why only a relatively slight increase or decrease in available food can result in substantial changes in trout growth.

Trout in streams, typically have a limited feeding area, circumscribed by their "territory". Their daily feeding is limited to the amount of food available in their feeding area or passing through it (drift) per unit of time. In the East Branch of the Au Sable, Fausch and White (1981) observed that small brook trout (8 in.) would feed when the density of invertebrate drift was much less than the threshold needed to stimulate the feeding of 8-12 inch trout. This type of observation

suggests that larger trout are at a disadvantage when they must compete for a common food supply with smaller trout, especially at reduced food densities. I suspect that in the "old days" there were more abundant large food items such as small brook trout, sculpins, and crawfish in the main Au Sable which allowed larger brown trout to readily switch their diets to larger prey items, avoiding competition with smaller trout for a common food supply and thereby maintain a much higher proportion of 12-16 inch and larger trophy trout in the population than has been possible since the 1970's. The steady decline of brook trout has been a long term event in the Au Sable. A decline of crawfish and sculpins, although not documented, probably occurred when enrichment ceased and bacterial slimes, algae, and macrophyte vegetation declined.

An event that could have influenced growth in the main Au Sable was the installation of about $250,000 worth of "stream improvement" devices in the 1970's in the Burton-Wakeley section. Although this action was taken to improve the abundance of the trout population, the population continued to exhibit slow growth and a decline of larger trout. The number of younger trout (I, II age groups) did increase, which could have resulted from a combination of reduced angler kill on smaller trout and improved habitat which provided areas of cover promoting survival. The increase in suitable habitat sites may have actually reduced the size of feeding territories thereby exacerbating the problem of lower food density.

With lower growth rates, condition factors ("plumpness" or ratio of length to weight) also declined, so that a 10, 12, or 14 inch trout in the 1970's-80s weighs considerable less than 10, 12, or 14 inch trout did in the 1950's-60's. The lower growth, poorer condition and great reduction in trout of 12 inches or larger has resulted in angler dissatisfaction, frustration, and demands for improvement of the situation leading to the commission now grasping for a straw of improvement with the imposition of a no-kill regulation.

LIMITATIONS OF REGULATIONS

It is incumbent on those who act as spokesmen and advocates for better trout fisheries as representatives of conservation organizations

or the news media to have some basic comprehension of the subject matter so that they may be truly effective leaders contributing toward attainment of a worthy goal. To do so, an understanding of the dynamic forces and interactions of a trout population with its environment is necessary to understand the workings of recruitment, growth and mortality governed by natural factors and the limitations imposed by the environment in relation to man's ability to significantly change life history parameters by regulation of angling. A basic text on the subject that I would highly recommend is Allen's (1951) publication on the Horokiwi Stream, New Zealand. There is no doubt that restrictive regulations to reduce or eliminate angler kill can and do work for many wild trout populations. The danger, however, for the well-meaning angling enthusiast concerns the trap of inductive reasoning -- if it works in stream A, therefore it will work in stream B, C, D, etc. The faulty reasoning leading to erroneous conclusions here involves differences between streams in: 1. species of trout, 2. growth rate and mortality rates, 3. age structure (% of population attaining 4, 5, 6 or more years of age), 4. angling pressure (potential angling exploitation rate) and amount of compensatory mortality involved (how much of angling mortality is compensatory to natural mortality rather than additive--for example, if angling mortality is 80% compensatory, a population with an average of 50% total annual mortality would not show improved survival from year to year unless angling mortality exceeded 40%).

Many types of regulations including no-kill have been instituted in the various states for the past 50 years. No dramatic success stories were apparent for many years and the use of special regulations as a fisheries management tool became to be viewed by biologists and administrators as "people management" rather than fish management . Then in the 1970's, substantial increases in trout populations were documented in the St. Joe River and Kelly Creek, Idaho, and in the Yellowstone River in Yellowstone Park after angler kill was drastically reduced by regulation. There was no reasonable doubt that restrictive regulations were working to achieve, their goal of substantial increase (several fold increase of 5-6-7 year-old fish) of larger trout (Behnke and Zarn 1976). The explanation of this phenomenon concerns the species of trout

involved--the cutthroat trout, _Salmo clarki_, the species most vulnerable to angling exploitation--angling pressure of only 10-12 hours per acre per year can remove 50% of all catchable-size cutthroat trout from a population, whereas, with brown trout, the most resistent species to exploitation, it requires 300 to 800 hours of angling pressure per year to expect a 50% exploitation rate. Another important aspect to understand why some cutthroat trout respond so well to reduced angler kill concerns their size-age structure in large rivers or lakes. In the above mentioned waters, fish of 5, 6, and 7 years are common in the populations and growth averaged about 3 inches per year. For example 6 and 7 year-old Yellowstone cutthroat trout are 17-18 and 19-21 inches. In such populations, only a slight reduction of annual total mortality can lead to substantial increases of older, larger fish. If total annual mortality is reduced from 60% to 50% per year from ages II through VI annual survival changes as follows:

	number surviving at ages				
	II	III	IV	V	VI
60% mortality	100	40	16	6	2
50% mortality	100	50	25	12	6

If average sizes for these age groups are 14 inches (IV), 17 inches (V), and 20 inches (VI), then the reduction in annual mortality from only 60% to 50% would increase the number of 14 inch and larger trout in this example from 24 to 43; the number of 17 inch trout would double and the number of 20 inch trout would triple per unit area. Perhaps 50 years ago, the Au Sable brown trout population reflected age-growth statistics comparable to the above figures. If they did, undoubtedly regulations reducing angler mortality and total mortality would work very well. Under the present environmental regime of slow growth, virtually no fish of age V or older and very high mortality (90-95%), with or without angler kill, of trout from age III to IV to V, it should be obvious that any type of special regulations can only play a very minor role, at best, to change the present situation.

I could go on with 100 or more additional pages discussing examples of where special regulations have worked and where they have not worked and explain the reasons in terms of recruitment and growth rates, annual mortality rates, and angler exploitation rates, but they all would only emphasize a basic agreement that where the existing environment places severe restrictions on growth and survival to older age classes, no amount of protection from angler kill can change the natural factors determining the life history dynamics of the trout population.

Lawrence Creek, Wisconsin, for many years was subjected to several different regulations in attempts to maximize angling quality of its brook trout fishery. A one mile section was completely closed to angling for a five year period -- at the end of which there were fewer trout than when it was open to angling (Hunt 1970).

Theoretically the range of fishery regulations that could be applied to the Au Sable River ranges from none (anything goes) to complete prohibition of angling. I believe that all anglers would prefer something in-between these extremes. The present debate centers on no-kill vs. some form of limited take regulation. A recent poll by the Michigan DNR (Report to the Michigan Natural Resources Commission on Au Sable River Fishing Regulations, Feb. 6, 1986), found 41% of the respondents favored no-kill and 59% favored some form of limited kill, most preferring the present regulations or something equally liberal. The reasons cited for favoring no-kill regulations were, "will improve quality of the fishing" (N=37) and, "will provide more and bigger fish" (N=35). The reasons opposing no-kill mainly focused on the theme that most of the present anglers fishing the Au Sable practice catch-and-release most of the time and they want to be able to take an occasional trout when they want. Also there was a reaction against "elitist" and "purist" special interest imposing regulations on the local anglers. Apparently, no one expressed doubts if a no-kill regulation would achieve the expected goals of its proponents. The information presented in my report raises this issue of doubt--my conclusion is that under the present environmental regime of the Au Sable which dictates the present growth and mortality rates, a no-kill regulation will not significantly improve the fishery with a substantial increase in brown trout of 12

inches and larger. If a five year test period of no-kill was imposed and its success measured by changes in the number of 12 inch and larger trout at the end of five years, three outcomes are possible--increase, decrease, or no change. Without adequate control sections on the river, however, a valid cause-effect relationship between the no-kill regulation and population change would not be possible. The changes could be attributed to uncontrollable variables such as climate, minor fluctuations in invertebrate populations, etc. Because of the regulations governing possession of trout in a no-kill fishery, alternate no-kill sections and limited take regulations, needed for controls do not appear feasible because boaters moving through a no-kill section with a trout would be in violation. An alternative would be to designate about a one mile section of the river for a complete prohibition of angling and compare any change in size-age structure between sections.

The best that could be hoped for to maintain the greatest abundance of older fish in the population would be to protect the age III trout from exploitation. This could essentially be done by lowering the present lower end of the slot limit from 12 to 10 inches. In any event, in a democratic society, regulations should reflect the wishes of licensed anglers--the greatest good for the greatest number. Leaders and spokesmen for angler groups, however, should become informed on the issues involved--in this case, the biological evidence which reveals the constraints which severely limit the response of the trout population to any regulation. Only then can rationale decisions, based on evidence and not emotion, be made.

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APPENDIX I

THE GENETIC BASIS OF GROWTH: WHY SLOW GROWTH OF AU SABLE BROWN TROUT IS NOT DUE TO ANGLING SELECTIVITY

As discussed in the text, I dismiss the theory of a hereditary change in the Au Sable brown trout population which states that due to differential selection by anglers for the fastest growing fish, a genetic basis for slow growth occurs.

I pointed out that the empirical and common sense evidence refutes all of the assumptions necessary to make the "genetic theory" operate on the Au Sable brown trout.

1. Nowhere in the world has this phenomenon been observed (that is, angler exploitation causing a hereditary change for slower growth) and there are many trout populations, especially cutthroat trout, that have been historically exposed to much higher exploitation rates than the Au Sable brown trout.
2. Under the 12 inch minimum size limit, all brown trout had spawned at least once, some twice, before they could have been removed by the fishery. Thus, any "fast growth" genes had already been passed on to the next generation. If a genetic change could have been operating, it would have occurred in "the old days" under an 8 inch size limit when the fastest growing trout could have been removed before they spawned and exploitation rates were much higher than after 1973. The table in the text (p. 6) shows that during 1974-78, under the 12 inch minimum size limit, when this selection against fast growth is assumed to have occurred, there was an average of 74 age III brown trout per acre in the fall of the year (average size of 11.2 inches) but only 4 age IV trout ($\bar{x}$ 13.5 inches). The mortality between ages III and IV (70 of 74 perished for annual mortality of 95%) was extremely high (essentially, the mortality of 12 inch and larger fish). These figures could certainly lead one to the conclusion that under the 12 inch size limit, the anglers were wiping out the large fish. However, the creel census data for 1974-78 reveals that only about 4 fish per acre of 12 inches or larger were harvested by anglers (6 per acre were caught-and-released). That is, of the total annual mortality of 70 trout per acre between

ages III and IV, from one fall period to the next, only 4 can be attributed to angler kill (6%) the other 66 (94%) were lost to natural mortality. In the light of such mortality data, it is nonsensical to attempt to make a case that the 12 inch limit had changed the genetics by selective angling mortality.

3. I also pointed out that natural mortality factors, especially predators, remove many more fish of any year class than do anglers, even under the most liberal regulations of the "old days". Predators take trout less than 12 inches; thus, there would be strong negative selection against slow growth because slower growth would maintain an individual for a longer period in the vulnerable prey size range.

I suspect, however, that the publication of Favro et al. (1979) of computer simulation of the Au Sable brown trout population, is considered my many present proponents of a no-kill regulation as "scientific proof" that a genetic change for slow growth has occurred due to angler selection under the 12 inch minimum size limit and a no-kill regulation is necessary to restore faster growth. Actually the 12-16 inch slot limit completely protected 12 inch trout and "rewarded" the fastest growing fish which attained 12 inches by prohibition of kill. That is, there should have been selection favoring the fastest growing fish to survive from age III to IV whereas slower growing fish, less than 12 inches could be harvested. The mortality statistics for the 1980-83 period under the 12-16 inch protected slot, show that there was an average of 35 age III trout per acre but only one age IV fish. That is, the mortality of age III to age IV from one fall to the next was 34 (of 35) or 97%, despite complete protection of 12 inch trout. Besides the common sense, empirical evidence that there is no basis to establish a case for genetic change due to angler exploitation, I would point out that the assumptions used in the simplistic model of Favro et al. are obviously false: 1. Growth is determined by two alleles (one "fast", one slow") at one gene locus. 2. There is no selection against slow growth 3. Fastest growing fish removed by anglers before they reproduce. These assumptions are simply false to begin with. The model bears no relationship to biological reality.

Another contribution reinforcing the belief that Au Sable brown trout have a genetically determined slow growth rate (which is due to angler exploitation), concerns a "test" of the genetic hypothesis. In this experiment, young brown trout from the Au Sable, Gilchrist Creek, the Pigeon River, and a domesticated hatchery strain were stocked into four lakes in the fall of 1982 and their growth compared after two years in the lakes (Alexander 1985. Mich. DNR Fish. Res. Rep. No. 1929). After two years, the Gilchrist Creek brown trout had exhibited the fastest growth, an average increase of 9 inches, vs. an average growth increase of 8 inches for the Au Sable trout (in weight, the Gilchrist fish gained an average of one ounce more than the Au Sable fish -- 9 oz. vs. 8 oz.). This experiment reveals that there are genetic differences that caused Gilchrist Creek brown trout to grow slightly faster than Au Sable brown trout in the four lakes (but not without qualifications -- the young trout were not uniform when stocked, i.e. they were not raised under identical conditions; no information was provided on the biotic and abiotic conditions in the lakes influencing growth; the study should be continued to follow the growth and survival through older ages). However, if this genetic basis for slower growth is accepted, no valid cause-and-effect relationship can be made connecting the Au Sable growth rate with angler exploitation. As I pointed out in an article on brown trout (Behnke 1986. Trout Magazine vol. 27 no. 1), the diversity of the brown trout first introduced into this country, and different selective pressures in different environments, has resulted in the present situation whereby no two populations could be expected to be genetically identical. Thus, any genetic differences between Gilchrist and AU Sable brown trout are much more likely to be the result of origins from different ancestors and natural selection in each environment. Considering the low angling mortality rates of Au Sable brown trout, no valid conclusion can be made that angling mortality has caused a genetic change in the AU Sable brown trout resulting in slower growth. The slower growth rates in the 1970's and 80's, however, might be expected to select for earlier maturing fish (sexually mature at smaller size) because so few fish survive past age III, it would be expected that early maturation should be favored. If this is true, then the proportion of sexually mature age II+ (and I+) fish should be higher now than it was

in the 1950's and 60's. I know of no data allowing for such a comparison, however. But in this case the genetic selection would be caused by the reduced nutrients in the river which caused the slower growth.

Another publication often cited to demonstrate the possibility of selective harvest genetically selecting for slow growth (actually the main selection concerns earlier maturation) is Ricker (1981. Can. Jour. Fish. Aquat. Sci. 38:1636-56). Ricker's study deals with Pacific salmon and commercial exploitation (where exploitation on some stocks reached 80-90%). The trend in some stocks of Pacific salmon exposed to heavy exploitation has been for spawning runs to change to higher proportions of young, smaller fish. This selection is due to the fact that when a year-class of salmon is exposed to an intensive ocean fishery, the less time spent in the ocean, the better chance for survival to spawning. What must be remembered here is that Pacific salmon all die after first spawning -- there is no possibility to spawn before being taken in the fishery as was the case with the Au Sable brown trout under the 12 inch size limit (all spawned before any were taken, and the angler "take" was a minor fraction of their total mortality). Thus, any salmon taken in a fishery has had no chance to pass its genotype on to the next generation.

Although I can find no evidence to support the "genetic" theory of slow growth, to those who continue to support the idea, I would point out that a slot limit (or a maximum size limit) could work to favor or reward fastest growing fish and negatively select against slower growing fish by allowing their take in the fishery.

ADDENDA: How many is more?

The main selling point for proponents of no-kill regulations is that such regulations will result in more larger trout. The computer model of the Au Sable trout population by Clark (1984, Mich. DNR Fish. Res. Rep. 1917) is believed by some to offer "scientific proof" for the belief that large trout will increase in the population after no-kill is imposed. (Clark certainly does not imply such reliability of predictive accuracy to his model and clearly emphasizes that, "...caution should be used for extending the modeling results to the real world").

Let us assume, however, that the model prediction is accurate and then examine the question; how many is <u>more</u> large trout?

Graphs of various size groups of trout derived from Clark's computer model and their predicted numbers under several types of regulation are given (12-16 inch slot, 10-16 inch slot [protected group within "slot"], 12 inch minimum, 14 inch minimum, and no-kill). These graphs were part of information given to "Members of the Au Sable River Property Owners Association" (Dec. 3, 1985) by the Michigan DNR for their poll on regulations. These graphs are also contained in a "Report to the Michigan Natural Resources Commission" from the DNR Fisheries Division (Feb. 6, 1986). The predicted outcome from various forms of regulations are shown, in regard to how many trout of 14 inches or larger are expected to result from any particular regulation. If the bar graphs are drawn precisely to scale, I interpret numbers ranging from 22, 14 inch and larger trout per mile of river under 12-16 inch slot (present regs.), to 39 per mile under no-kill. A 10-16 inch slot and 12 inch minimum regulations would result in 28 large (14+ inches) trout per mile according to the simulation model. To make quantitative comparisons with the rest of my report, I converted trout per mile to trout per acre (11.5 acres per mile of the Au Sable), which yields a range of 2.2 to 3.3 trout of 14 inch+ per acre. A 10-16 inch slot or 12 inch minimum produces about 2.4 trout of 14+ inches per acre. That is, the no-kill regulation will result in 0.9 additional larger trout per acre than some of the limited kill regulations (if the computer model is precise--which is impossible, but was ignored for the present). If the average annual fishing pressure on the Au Sable River is 400 hours per acre, and each 14+ inch trout is caught and released, on average, 1.1 times per year, then for each 400 hours of angling, an average increase in the total catch of 1.0 trout of 14+ inch will result. In terms of how this improves the quality for the individual angler, if one fished 8 hours per day, 7 days per week, for 7 weeks (actually 50 days), the angler should, on average, catch one additional trout per year at 14+ inches because of the no-kill regulation. To accomplish this, however, all harvest of any trout must be prohibited and the majority of the anglers who wish to take an occasional trout will be denied their preference. When viewed in quantitative terms, the unfairness of a no-kill regulation on the Au Sable becomes obvious to all except those who firmly believe that anglers should kill no trout anywhere under any circumstances. The foregoing interpretation of the computer simulation graphs should have been provided to the Commission and to the people polled so a more informed decision could be made (but anyone can make these calculations using no more than grammar school arithmetic). The DNR reports to the landowner association and to the Commission attempted to make clear the severe limitations for no-kill regulations to significantly improve the fishery, but they contain such statements as: "no-kill results in an increased catch and standing stock of trout over 14 inches", and "no-kill rules let the trout stocks increase to the limits of their habitat and reach a condition approaching that of an unfished stock."

To many dedicated anglers, desperately hoping for improvement of the Au Sable fishery, such statements would be grasped and held tightly by their minds,--all else ignored. It is time now for the subject of regulations to be reviewed in the light of the evidence presented in my report, and a more reasoned and equitable solution sought.

exh. 2

CURRICULUM VITAE

NAME:	Robert J. Behnke
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BORN:	December 30, 1929, Stamford, Connecticut
MARITAL STATUS:	Married, two children.

EDUCATION:

1957	B.A.	Zoology	Connecticut University
1960	M.A.	Zoology	University of California
1965	Ph.D.	Zoology	University of California

Graduated Connecticut University with distinction and high honors. M.A. thesis on the trouts of the Great Basin; Ph.D. thesis on systematics of family Salmonidae. Fields for Ph.D. qualifying examination: general zoology, ecology, vertebrate zoology, entomology and vertebrate physiology.

EMPLOYMENT:

1947-1952	Yale and Towne Hardware Co.
1952-1954	U.S. Army
1956	Chesapeake Biological Laboratory, Solomons, Maryland, assistant to the late Dr. R. Mansueti; studies on fishes of Chesapeake Bay.
1957-1964	University of California, Research Assistant, teaching assistant and research biologist.
1965	American Academy of Science, Exchange scholar
1966	University of California, Assistant Professor of Zoology, teaching ichthyology course
1966-1974	U.S. Fish and Wildlife Service, Assistant Unit Leader, Colo. Coop. Fishery Unit and Research Biologist
1974-present	Colorado State University, part-time teaching, part-time private consulting and advising.

SPECIAL TRAINING AND EXPERIENCE:

1957-1959	Collected fish specimens in Canada, Alaska, and western United States.
Summer 1960	Collected specimens, visited museums and fisheries institutions in Europe and USSR to gather material for Ph.D. thesis. Sponsored by Department of Zoology, University of California and Woodrow Wilson Foundation.
1964-1965	10-month post-doctoral fellowship studying at the Ichthyological Laboratory of the Zoological Institute, Academy of Sciences, USSR, Leningrad.

June-July 1967 Participated in first Smithsonian Institute for Systematics.
1974 Conducted fishery survey and collections in Iran.

MEMBERSHIP IN HONORARY AND PROFESSIONAL SOCIETIES:

Phi Beta Kappa
Phi Kappa Phi
American Society of Ichthyologists
American Fisheries Society
American Society of Systematic Zoologists
Japanese Society of Ichthyology
Non-game Advisory Council, Colorado Division of Wildlife
Scientific Advisory Board, Trout Unlimited
Technical Advisor for two endangered species recovery teams
First 'Award of Excellent' by the Colorado-Wyoming Chapter American Fisheries Society, 1979.
First A. Starker Leopold Award, Wild Trout Symposium III, Yellowstone National Park, 1984.

SPECIAL EXPERTISE:

Surveys, inventories and identification of fishes. Rare, endangered and threatened fishes. Distribution and speciation of fishes. Environmental factors influencing fish distribution particularly in relation to man-induced environmental changes. Application of intraspecific genetic diversity for fisheries management. Systematics of family Salmonidae.

PRIVATE ACTIVITIES:

Served as fisheries advisor to Iranian government, 1974-1975; fishery studies on the freshwater fishes of Iran and Saudi Arabia; several fishery projects for U.S. Forest Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, Wyoming Department of Game and Fish, New MExico Department of Game and Fish and Colorado Division of Wildlife; fishery related services for the American Sportsman's Club, the law firm of Weissbrodt and Weissbrodt, Thorne Ecological Foundation, Colorado River Water Conservation District, McMillan-Bloedel Ltd., U.S. Justice Department, Ecology Consultants Inc., Woodward-Clyde and other private firms and public agencies; Senior Translations Editor for Scripta Technica for Russian fisheries translations; appeared as an expert witness in court in U.S. and Canada.

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November, 1984

Statement in Rebuttal of Paragraph 4d

Paragraph "4d" is a completely erroneous distortion of the research findings of Michigan DNR fisheries biologists on the Au Sable River fishery and of the output of the computer model developed by Dr. Richard Clark. The statements made in this paragraph are a blatant misrepresentation of the facts of this case. The affidavit of John A. Scott, Chief, Fisheries Divisions, states that he would, as a sworn witness, testify in court that: 4a.) there are no contested biological facts; 4c.) the question of whether to institute a catch and release fishery is a sociological question. I interpret these statements as an admission that no-kill regulations on the Au Sable River concern sociological, not biological issues. Paragraph 4d, however, states that, "catch and release *will* result in a 100 per cent increase in the number of brown trout over 16 inches in length and a 50 per cent increase in the number of brown trout over 8 inches in length compared to the present slotted fishery."

Paragraph 4d states a biological basis for a no-kill regulation in apparent contradiction to the statements given in 4a and 4c. Anyone presenting paragraph 4d. in court as sworn testimony could be exposed as either 1.) the victim of honest ignorance, or 2.) the offerer of perjured testimony.

The phrase "will result" clearly states a certainty and a promise as sworn testimony that there is no reasonable doubt that a 100 per cent increase in 16 inch and larger trout and a 50 per cent increase in trout more than 8 inches would be a reality after no-kill regulations are imposed. Such a statement is completely inconsistent with what Dr. Clark has stated in his publications concerning his computer simulation model. The misrepresentation of Dr. Clark's model presented in paragraph 4d. is potentially damaging to his professional reputation and must be refuted. The refutation is as follows

1. The limitations for accurate predictions of Dr. Clark's fishery simulation model and any model simulating a biological system that attempts to predict the future based on past and present events, concerns limits imposed by natural and uncontrollable variability characteristic of natural biological systems. Accurate predictions based on

observations or data of present and past events are possible only if the system under observation is stable, isolated and highly recurrent--and such systems are extremely rare in nature. For example, long term and precise recordings of tidal fluctuations at a point on a seashore would allow relatively accurate predictions of future tidal variations in time (a tide table) because tides are determined by the constancies of the law of gravity and the motions of the solar system. Even with such a stable, isolated and highly recurrent system, a precise prediction that a certain tidal variation "will" occur in the future is not valid because of unpredictable and uncontrollable wind events.

Natural, uncontrollable variation of biological systems such as a trout population in a river impose severe limitations on the expected accuracy of any predictive model. Hall and Knight (1983. Natural variation in abundance of salmonid populations in streams and its implications for design of impact studies. U.S. E.P.A. 600/3-81-021), produced a compendium of documentation on the natural variation of trout and salmon populations which makes abundantly clear, the problems faced by any predictive simulation model. Any competent biologist with comprehension of model limitations would never use the phrase "will occur" or "will result" in reference to a models predictions. Thus, I am confident that paragraph 4d. was not written by Dr. Clark. The following published statements are what Dr. Clark actually said in relation to his model and fishery regulations on the Au Sable River. "Caution should be used when extending the modeling results to the real world." (Clark, 1984. Mich. DNR Fish. Rep. 1917). "The model was not structured to consider the effects of changing environmental conditions, and even if it was, we could not have predicted the direction of environmental changes." (Clark and Alexander. 1985. Mich. DNR Fish. Rep. 1926).

"With regard to the fishery in the Burton-to-Wakeley study section, it appears that no change in fishing regulations is capable of returning the number of large brown trout observed there in the past. Brown trout growth has declined and short of fertilizing the river with sewage again, we doubt if growth can be returned to former levels." (Clark and Alexander. 1985. Proc. Wild Trout III Symposium p.82).

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"We cannot directly compare the catch predicted with the model to the catch estimated from the creel survey" (Clark and Alexander. 1985. Mich. DNR Fish. Res. Rep. 1926).

Clark's warning that the catch predicted from the model cannot be compared to the catch estimated from creel surveys, relates to the fact that the model for the Au Sable fishery cannot be validly applied to the entire Burton-Wakeley section of the river. This is a critical point in relation to the validity and credibility of paragraph 4d. The fact clearly understood and stated by Dr. Clark is that the data base for the Au Sable model was developed from two sampling sites at Wa Wa Sum and Stephan's Bridge, totalling about three surface acres of the Au Sable River. The entire Burton-Wakeley section of the Au Sable contains about 100 surface acres. The impossibility of extrapolating data and predictions from 3% of the study area to the entire area, with high confidence levels and statistical validity was clearly understood by Dr. Clark and so stated. Paragraph 4d. does indeed extrapolate the model to the entire Burton-Wakeley section in disregard to Dr. Clark's warnings and explanations. I do not believe that paragraph 4d. was written by a competent biologist familiar with the model or with Dr. Clark's publications.

2. The second point of refutation of paragraph 4d. concerns the actual claims of a 100% increase of brown trout over 16 inches and a 50% increase of brown trout over 8 inches that "will result" if no-kill regulations are imposed.

These claims are readily refuted by the defendant's own exhibit 1 and 2 appended to the motion for summary disposition and by data on the Au Sable fishery contained in references cited above.

The defendant's exhibit 1 and 2 are bar graphs entitled, "Predicted size structures of brown trout populations for three different fishing regulations in the Burton-to-Wakeley section of the Au Sable River." To examine the question of predicted increase of trout more that 8 inches from the computer simulation, I calculated the numbers of trout per mile of river for the 9 inch, 10 inch, 11 inch, 12 and 13 inch, and 14+ inch groups for the present slot limit and a no-kill regulation from the graphs. The results of these calculations show 1587 trout per mile from 9 inches to 14+ inches are predicted under the present slot limit and 1988 trout per mile of the same size groups are predicted under a no-kill regulation. If the 8 inch size group is included in the calculations the predicted numbers increase to 2207 per mile under the present slot limit and 2598 per mile under no-kill regulations. The predicted increase of trout more than 8 inches is 1587 to 1988 per mile under no-kill regulations, or an increase of 25%. The predicted increase of trout 8 inches and larger is 2207 to 2598, or 18%. Paragraph 4d. states this increase will be 50%. The defendant's own exhibit refutes their claim.

More thorough refutation is found in the publications of Clark and Clark and Alexander cited above based on actual data from the Au Sable fishery. A comparison of the 1974-1978 period when a 12 inch minimum size limit regulation was in effect with the 1980-83 period under the current slot limit, reveals a decline of 8-12 inch trout from 189 to 128 per acre occurred during the slot limit regulation. However, only 21 8-12 inch trout per acre were harvested by anglers. Thus, if every one of these harvested trout were released and survived to be sampled, the maximum increase of 8-12 inch trout would have been from 128 to 149 per acre under no-kill regulations or an increase of 16%. It is doubtful, however, that the slot limit had more than a very minimal effect on the 1980-83 decline in the Au Sable brown trout population. The North Branch Au Sable, which served as a control, suffered a similar decline from 86 to 65 8-12 inch brown trout per acre with no change in fishing regulations. This indicates that some long-term environmental trend such as lower temperatures during the 1980-83 period was the major factor causing the decline, not angler exploitation. The Au Sable brown trout population suffers enormous natural mortality between age III to the end of age IV (in fourth and fifth years of life). It is the age IV and older trout that attain sizes greater that 12 inches. That is, a trout must reach 12 inches and age IV before it can reach 16 inch at age V or VI. There are so few of these older, larger trout in the population that the possibility of a 100% increase in 16 inch and larger trout is meaningless in relation to the quality of the fishery. During the 1974 to 78 period when 12+ inch trout could be legally taken, there were 74 age III trout per acre, but only 4 age IV per acre. That is, a 95% mortality occurred from age III to age IV, but no more than 4 of the 70 trout lost between age 3-4 could be attributed to angler kill.

During 1980 to 83 when 12 to 16 inch trout were protected under the slot limit, the numbers of age III and age IV trout declined to 35 and 1 per acre respectively. That is, under complete protection against angler take of 12-16 inch trout, the mortality rate from age III to age IV increased to almost 98%.

With such mortality rates and present growth rates it is ridiculous to raise the issue of a possible 100% increase in 16 inch and larger trout in the Au Sable population. The latest published figures on the number of 16 inch and larger trout in the Au Sable River (Clark and Alexander, 1985, cited above) is "less than one per hectare" (one hectare = 2.4 acres). Thus we can assume about .3 or 1/3 16+ inch trout per acre. Considering the limitations imposed on the simulation model by data derived from a limited sampling area (3% of the Burton-Wakeley section) and the limitations due to natural variability, I am sure the statement in paragraph 4d. that no-kill regulations "will result" in a 100% increase in 16 inch and larger trout is not a quote from Dr. Clark. To put this hypothetical 100% increase into perspective in relation to the quality of the Au Sable fishery, the addition of one 16 inch trout per three acres of the Burton-Wakeley section can be hypothesized. At an average angling pressure of 400 hours per acre per year, and assuming that each 16 inch trout in this section would be caught once each year, an additional 16 inch trout would be caught each year in the Burton-Wakeley section for each 1200 hours of angling. The average angler, if he or she fished 10 hours per day, seven days per week from June 1 to September 30 in the Burton-Wakeley section, would, on average, catch one additional 16+ inch trout. In view of these figures, it is ludicrous to claim a 100% increase of 16+ inch trout as a benefit that "will result" from no-kill regulations.

Thus, the data and studies of the Mich. DNR biologists refute the claim that a 50% increase of trout more than 8 inches will result from no-kill regulations as stated in paragraph 4d. The claim of a 100% increase of 16+ inch trout is shown to be meaningless both in relation to problems of extrapolation from the computer model to the "real world" of the entire Burton-Wakeley section and in relation to the insignificance of what 100% would actually mean in quantitative terms. Thus, I find paragraph 4d. to be false, misleading and irresponsible. The distortions of data are an embarrassment to the professional biologists who have done such excellent research on the Au Sable River fishery for many years. The misinformation contained in paragraph 4d. was essentially repeated in a letter from the Fly Fishers Federation published in Rod and Reel Magazine. I recently critiqued this letter and discredited it in a letter dated July 10, 1986 to George Griffith of Grayling (copy appended).

If the Attorney General's office accepts my refutation of paragraph 4d. then we would be in agreement that, "there are no contested biological facts" (that is, there is no biological basis for a no-kill regulation), and we would agree that, "the question of whether to institute a catch-and-release fishery is a sociological question."

I would point out that "sociological" pertains to all aspects of societies. As such, the Au Sable River and its fishery impinges on many aspects of the society of the Grayling area--recreation, pleasure, economics, etc., to a much greater extent than it does on the "societies" of Detroit, Lansing, Grand Rapids or Kalamazoo. Of paramount importance in seeking a "sociological" resolution to the current controversy of the proposed no-kill regulation would be to consider the opinions of the majority of the Grayling society.

LIMITATION OF SPECIAL REGULATIONS
FOR INCREASING THE PROPORTION OF LARGE
TROUT IN THE AU SABLE RIVER

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ABSTRACT

Data are reviewed for various time periods relating to the trout fishery of the Au Sable River. A decline in trout growth and a large decline in the proportion of large trout occurred in the 1970's and continues to present. Based on examination of evidence, the most reasonable cause-and-effect relationship producing the decline in the fishery is reduced nutrient input into the river.

In view of present growth and mortality rates, under the present environment, the fishery cannot be restored to its former condition by any form of special regulation, including no-kill or complete prohibition of angling.

Robert Behnke
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LIMITATIONS OF SPECIAL REGULATIONS FOR INCREASING THE PROPORTION OF LARGE TROUT IN THE AU SABLE RIVER

INTRODUCTION

The only salmonine fish species native to the Au Sable River, Michigan, was the grayling. The grayling became extinct soon after brook trout, brown trout, and rainbow trout were introduced into the Au Sable in the late nineteenth century. The non-native trouts thrived and as the brown trout became increasingly dominant in the drainage, the reputation of the river as one of the country's most famous trout streams was established.

A universal phenomenon among anglers is that fishing was always better in the "old days". Such statements can be found in the first report of George Jerome, the first fish commissioner of Michigan, submitted to the legislature in 1873. Mershon (1923) reminiscing on his 50 years as a hunter and fisherman lamented the decline of the Au Sable fishery. Unfortunately no quantitative data on abundance, growth rate, biomass per unit area, etc. are available from the "old days" of the Au Sable trout fishery to document a decline. Data collected over the past 30 years, however, on the 8.7 mile section of the main Au Sable River from Burton's to Wakeley Bridge, does document a decline in growth rate and biomass of the brown trout, especially a decline of large trout of 12-13 inches and larger in this section of the river during the 1970's and continuing to the present.

This documented decline has stimulated several research studies and the implementation of various types of special regulations by the Michigan Department of Natural Resources to better understand the reasons for the decline in the brown trout population and to explore possible ways to reverse the decline. The failure to reverse the decline of larger brown trout in the population has angered and frustrated a segment of the angling public. These anglers generated sufficient public pressure to cause the Natural Resource Commission to declare a five year

catch-and-release (no kill) regulation on the Burton's Landing to Wakeley Bridge section of the main Au Sable River scheduled to begin in 1986.

The purpose of this report is to demonstrate that such a regulation, although well-meaning, is misguided and is not based on biological evidence. It is an example of what might be called the "arrogance of ignorance", by which, "decisions are made loudly and clearly on inadequate and inaccurate data" (Mayer 1984). All of the biological evidence convincingly leads to the conclusion that, under the present environmental conditions which produces a relatively slow growth rate and an extremely high mortality of brown trout between three and four and four and five years of age, any substantial increase of larger, older fish in the population, with or without protection from angler kill, is beyond reasonable expectations.

There may be several types of personal belief which can serve as a basis to argue in favor of a no-kill regulation on the Burton's-Wakeley section of the Au Sable. Some may simply feel strongly against the killing of any animal by man; or, more likely in this case, have strong feelings against the killing of any trout anywhere, under any circumstances. Most anglers currently favoring the no-kill regulation, however, probably do so in the mistaken belief that by avoiding angler removal of any trout, the Au Sable River fishery will return to its former state of excellence, especially with a great proliferation of larger (ca. 14 inches and larger), older trout in the population. I believe that if most of the anglers and the commissioners currently favoring a no-kill regulation critically examined the biological evidence to arrive at an informed and unbiased decision on the matter, they would change their preference to favor one of the alternative regulation options suggested by DNR biologists which would allow a limited take of trout.

In the remainder of this report I will attempt to synthesize, summarize, and interpret the many years of data the Au Sable fishery compiled and published by the DNR, along with other pertinent data from the literature and personal experience with numerous trout populations over a broad geographical area. To those who disagree with any of my conclusions I would request that the particular points of disagreement be

detailed with evidence for the opposing viewpoint. In this way, the final determination of the type of regulation to be implemented on the Au Sable River might be resolved in an atmosphere of reason based on evidence and not entirely on emotion and ego.

First, I should make clear my own record on the matter of special regulation fisheries (regulations designed to reduce or eliminate angler kill to achieve a specified goal). I have favored the greater use of special regulations to maintain the quality of wild trout fisheries in heavily fished waters, especially emphasizing its value in the management of rare native trout (Behnke 1978, 1980, 1981). I have also expressed dismay at the lack of expertise long characterizing the special regulation fisheries of most states (where, historically, special regulations have been considered more in the realm of people management rather than fish management). I have also recommended that special regulations should be applied judiciously and ony after the biological evidence is available on which to decide feasibility and to select the best regulations for a particular trout population. Otherwise, the imposition of special regulations on waters where they do not work will create a backlash and act as a setback to progress. Public acceptance of any special regulation by the user group is critical to its success. In relation to this point, I wrote: "except for a relative few fisheries, the 'pure' catch-and-release regulations (no-kill), are not the best type of regulations. No-kill regulations do not allow 'fine-tuning' of population dynamics to optimize both growth and catch-rate. It does not challenge the biologist to learn about recruitment rates, size-age structure and the internal workings of the environmental interactions that determine the potential of a fishery" (Behnke 1980).

In the following sections I will attempt to demonstrate that no-kill regulations will not significantly improve the size-age structure or growth rate of the Au Sable River brown trout population over previous regulations because the major cause of the decline in growth and abundance is attributed to a reduced food supply related to reduced nutrient input into the river. Also, because short term and long term natural factors such as climatic variation will most likely "overpower" any slight negative or positive changes in the trout population which

might be linked to a no-kill regulation, valid conclusions on the efficacy of no-kill regulations will not be possible at the end of the proposed five year trial period (without proper "control" sections).

THE FISHERY

The Burton-Wakeley section of the main Au Sable River is 8.7 miles in length and contains a surface area of about 100 acres (Alexander et al. 1979). The Au Sable River in general (all branches) was early recognized as a fine trout fishery, this was especially true for the main Au Sable in the Burton-Wakeley section. Because of the recognition of its importance as a trout fishery, the Au Sable received some of the first "special regulations" in the state. In 1901, the minimum size limit for trout was increased to 8 inches (6 inches statewide at the time). In 1907, a flies only regulation was imposed on the North Branch. In 1913, the first "backlash" against special regulations was apparent when the flies only regulation was repealed and the size limit reduced to 7 inches. In 1922, the size limit was again increased to 8 inches and the daily bag limit reduced to 20 trout (35 statewide) on the North Branch.

The modern era of scientific studies in the Au Sable drainage began in the 1950's, and it is from this time that changes in the population can be traced. The changes in the population of brown trout in the Burton-Wakeley section of the main Au Sable are apparent in the data of Alexander et al. (1979) comparing statistics, mainly from the 1959-63 period with figures for the 1972-76 period. From 1955 to 1976, six changes in regulations occurred on this section. The major regulation changes were: 1955-63, 10 inch minimum size limit on all trout (brook, brown, and rainbow), five trout per day creel limit, and flies only. In 1969 the size limit on brook trout was reduced to 7 inches. In 1973 the size limit on brown and rainbow trout was increased to 12 inches and the creel limit reduced to three trout (any species). In 1979 a "slot" limit was imposed which allowed the take of trout between 8 and 12 inches, and 16 inches or larger, and required the release of trout between 12 and 16 inches. Fishery data for the 1974-78 and 1980-83 periods are given by Clark and Alexander (1984).

The following table summarizes the dynamics of the trout populations in different periods of time.

		Age Group					
		(First year of life) 0	I	II	III	IV	V
Brown trout							
average size (Oct.) (inches)	1959-63	4.0	7.9	10.7	13.6	16.6	19.0
	1974-78	3.6	6.9	9.3	11.2	13.5	15.8
	1980-83	- no change from 1974-78 period -					
numbers (per acre)	1959-63	337	236	101	29	6	0.6
	1974-78	450	164	114	74	4	ca. .5
	1980-83	405	148	80	35	1	trace
Brook trout							
average size	1959-63	3.7	6.4	9.0	10.1	11.5	
	1974-76	3.2	6.4	8.8	10.0	11.2	
numbers	1959-63	324	93	13	0.7	trace	
	1974-76	191	32	3	trace		

The most significant feature demonstrated by these data is the slower growth of brown trout in the 1970's and 80's compared with the 1950's and 60's. In the earlier period, brown trout at ages three and four attained a larger size than age four and five fish did in the later period. The actual number of three-year-old brown trout was greater in the 1974-78 period than in the 1959-63 period (74 vs. 29 per acre), perhaps due in part to the 12 inch minimum size limit in effect at the time, but there were many fewer trout of 12 inches or larger in the population in the 1970's and 80's because they averaged only 11.2 inches in the fall of their fourth year of life (age III+), whereas they averaged 13.6 inches at III+ in the 1950's and 60's. Thus, in the fall of the 1959-63 period there was an average of 36 brown trout per acre of ages III, IV, and V+ whereas in the 1974-78 period there were only about 4 per acre of comparable size at ages IV+ and V+. The proportion of

older trout continued to decline under the slot limit which protected fish between 12 and 16 inches. Also note the extremely high mortality rate between ages III to IV and IV to V. Changes in regulations appear to be very limited in their effectiveness to significantly increase survival to four and five years of age. In the 1959-63 period, under a 10 inch minimum size, brown trout could be taken by anglers beginning at age II. In the 1974-78 period with a 12 inch minimum size, fish would not be harvested until age IV (or faster growing age III+). It might be argued from the figures that the extreme mortality from age III to IV (74 to 4 per acre) was due to angler kill. Angler kill of 12 inch and larger trout in 1976 was 4 per acre -- the rest were lost to natural mortality. Also, about 6 trout of 12 inches or larger were caught and released per acre in 1976. During 1980-84 with the slot limit, 2060 (20.6/acre) "legal" trout between 8 and 12 inches were taken by anglers and 5440 (54/acre) were released. Most of the anglers fishing the Burton-Wakeley section practice catch-and-release angling for legal trout most of the time (release of 60 to 70% or more of total catch of legal trout). The standing crop or biomass per unit area of trout also declined compared to the 1959-63 period. In the 1959-63 period, the Burton-Wakeley section contained an average of 129 pounds per acre of brown trout and 20 pounds per acre of brook trout. This declined to 101 pounds per acre for brown trout and to 7 pounds per acre for brook trout in the 1974-76 period, and evidently continued to decline by an additional 30-40% (to ca. 60-70 pounds per acre) in the 1980's according to the figures on age groups given by Clark and Alexander (1984). Angling pressure on the Burton-Wakeley section averaged 430 hours per acre in the 1960-65 period; 305 hr./acre in 1976; and 345 hr./acre during 1980-83. During this same period, with no changes in regulations, trout in the North Branch Au Sable changed as follows: 1957-60 average of 34 pounds per acre brown trout and 36 pounds per acre of brook trout (total 70 pounds/acre); 1960-67, 45 pounds/acre brown trout and 28 pounds/acre brook trout (total 73 pounds/acre), in 1974-76, 60 pounds per acre brown trout and 24 pounds/acre brook trout (total 84 pounds/acre). In the 1980-83 period, however, the brown trout in the North Branch also declined similar to the decline in the main Au Sable during this same period, which can most

logically be attributed to local climatic variation affecting both the North Branch and main Au Sable, because the decline cannot be well correlated with increased angler kill (or the slot limit on the main Au Sable) (Alexander and Ryckman 1976; Alexander et al. 1979; Clark and Alexander 1984).

Another interesting finding from the North Branch where the brown trout growth rate is similar to the growth rate in the main Au Sable during the 1950's and 60's, is that when two sections were compared, one under statewide regulations and one under special regulations with 10 inch minimum size limit and flies only, the statewide regulation section contained about twice as many brown trout more than 12 inches as did the special regulation section (Alexander and Ryckman 1976). This may be due to the greater density of small brook trout, the major food of large brown trout in the North Branch, in the normal regulation area (Alexander 1977). If the number of trout per acre exceeding 12 inches (sampled in fall) are compared for the Burton-Wakeley section of the main Au Sable in different periods with different regulations the figures are as follows: during 1959-63 (10 inch minimum size limit) there was an average of 50 trout per acre which were 12 inches or larger, 17 of which were 14 inches or more and 5 were 16 inches or more. During 1974-78 (12 inch minimum) there were 19 trout per acre of 12 inches or greater in length, 3 of which were 14 inches or more and only about one-half trout per acre was 16 inches or more (Alexander et al. 1979). During 1980-83 (when slot limit protected all trout between 12-16 inches) trout of 12 inches or greater (which were then protected from angler kill) declined further to 10 per acre (Clark and Alexander 1984).

Thus, a long history of studies and numerous changes in angling regulations in the Au Sable drainage, demonstrate that natural influences determining growth rate and annual survival of age classes, govern the abundance and size of the trout populations. Special regulations, either decreasing, increasing, or eliminating angler kill can do very little to change the situation. The critical question is why has brown trout growth slowed since about 1970?

FACTORS INFLUENCING GROWTH

If the foregoing data syntheses is accepted then it becomes clear that the decline in the fishery of the mainstream Au Sable was not caused by increased angler kill of trout. Actually, the exploitation rate before 1973 was much greater than after more restrictive regulations reduced the annual kill from about 8000 trout per year in the 1960-65 period to about 500 per year after 1973 in the Burton-Wakeley section (Alexander et al. 1979). The angler kill did increase again in 1980's under the slot limit to about 2,100 annually (all but about 30 were in the 8-12 inch size range), but this angling mortality was only about 25% of the 1960-65 mortality when the fishery was considered excellent. The problem centers on changes in growth rate. As discussed, with the 1950's-60's growth rate, Au Sable brown trout average 13.6 inches at age III+ (toward end of fourth growing season), but under the growth rate during 1970's and 80's III+ trout are only 11.2 inches. The high mortality between ages III-IV and IV-V always maintained these older trout as a very small proportion of the total population -- thus, the key to the abundance of 12 inch and larger trout is to have a growth rate which attains this size by age III. Why do the mainstream Au Sable trout now only average 11.2 inches at III+ when they averaged 13.6 inches at this same age 20 years ago?

There has long been a popular belief that angler exploitation of a trout population, by the selective removal of faster growing individuals of each year class, will genetically change a population by favoring the survival of slower growing individuals which are left to reproduce, eventually changing the heredity of the population to slower growth rates. This theory gained particular credence to explain the slower growth of main Au Sable brown trout from a publication by Favro et al. (1979). I suspect that many anglers favoring a no-kill regulation do so because they believe the "genetic" theory of slow growth as expounded by Favro et al. They mistakenly believe that if angler kill is eliminated, a genetic change for faster growth will be favored. For those who favor no-kill regulations for this reason I include Appendix I with a detailed refutation explaining why this genetic theory is not a reasonable

explanation for the slower growth of brown trout in the 1970's and 80's. For now, I will only appeal to common sense and empirical evidence such as: 1. Other brown trout populations with high growth rates have been exposed to greater annual percent angler removal than has the main Au Sable population; for example, the North Branch Au Sable (Shetter 1969; Alexander and Ryckman 1976) and some Wisconsin streams (Avery and Hunt 1981) -- yet their growth rates remain higher than main Au Sable brown trout (also, how can the main Au Sable brown trout remain genetically isolated from North Branch and South Branch Au Sable brown trout where growth rates are higher?). 2. To effectively change the genetics of growth to favor the survival of slower growing individuals, there must be no selection against slower growth. In the Au Sable drainage (studies conducted mainly on North Fork), it was clearly demonstrated by Alexander (1976, 1977) that loss to predators of any year class is much greater than loss to angling, and predators take trout less than 12 inches. Thus, there would be much stronger selection for fast growth (to get out of the predator size range) than for slow growth to avoid angler take. 3. Also, for a genetic change to be effective, the trout must be removed from the population before they reproduce (before they have a chance to pass on any "fastgrowth" genes to the next generation). In the main Au Sable, all trout spawn at least once and some twice by the time they are 12 inches. If such a genetic change for slower growth could be real, it would have appeared in the "old days" under the 8 inch size limit which allowed removal of trout before they spawned and when angling exploitation was much higher than it was after 1973.

After critical examination of all of the available evidence, I must agree with Clark and Alexander (1984) that the reduction in nutrient input (nitrogen and phosphorous) from the closure of the Grayling Hatchery in the mid 1960's and the diversion of the city of Grayling's sewage effluent away from the river in 1971 is the major cause-effect relationship. This great reduction of nutrient input into the main Au Sable (70% reduction in nitrogen), reduced primary production (vegetation growth) which in turn reduced invertebrate production, leading to a condition of less available food for the trout and a slower growth rate. The study of Merron (1982) comparing nutrient level and trout growth over

different periods of time in the main Au Sable, the North Branch, and the South Branch, clearly defined the correlation between growth of brown trout and nutrient levels. I can conceive of no other reasonable alternative, no other probable cause-and-effect relationships, to explain the reduction in growth and reduction of total biomass of brown trout in the main Au Sable River, and unless nutrient enrichment occurs again comparable to the 1950's and 1960's, the population dynamics of the brown trout will not dramatically change. Thus, I also agree with the conclusion of Clark and Alexander (1984) that special regulations can have only a very limited effect for significantly altering the paucity of large (12 inches and more) trout in the population and therefore the most important aspect of any regulation on the Au Sable is ... "for their influence on satisfying the desires of different factions within the angling community". Obviously, "satisfying" the "different factions" of anglers will not be entirely possible, but those currently favoring no-kill regulations should understand the limitations of any regulation to significantly improve the fishery, as explained in this present report, so they can make an informed and impartial decision based on the biological evidence.

Studies on the relationships between diet and growth of trout in Michigan by Alexander and Gowing (1976) and comparisons of diet and growth of brown trout in the main Au Sable and the South Branch by Stauffer (1977) are of interest for a better understanding of the reasons for the slower growth of Au Sable brown trout. The density of brown trout in the South Branch was less than in the main Au Sable, but the density of benthic invertebrates was about three times greater in the South Branch. Because most aquatic insects are available to trout predation only while they are in the "drift" (in the water column), the higher the invertebrate density in the bottom substrate, everything else being equal, the higher the density in the drift, which makes more food available per unit area per unit time to feeding trout (that is, a feeding strategy for maximum energy gain and minimum energy loss will result in more rapid growth). The average daily diet of South Branch brown trout was about 20% greater than fish of comparable size in the main Au Sable. This increased feeding resulted in significantly faster

growth in South Branch brown trout, similar to main Au Sable growth in the 1950's-60's (attaining 13-14 inches at age III+). An important point for understanding how changes in feeding rate can change growth rate is the relationship between maintenance rations (the amount of food needed to maintain present weight or "status quo") and growth rations (after maintenance requirements are satisfied, additional food it utilized to increase growth). Only a slight increase in the amount of food available for growth can lead to a substantial increase in growth because maintenance rations are constant in relation to body size and water temperature. For example, if a large trout required 90 grams of food per day for maintenance and had an average daily consumption of 100 grams per day, it would have 10 grams of food available for increased growth (after 90 grams were utilized to maintain the "status quo"). If food items became more available and daily food consumption increased to 110 grams per day it would be only a 10% increase in daily diet, but a 100% increase (from 10 to 20 gms.) in food to be utilized for growth.

The study by Warren et al. (1964) enriching a small Oregon stream with sugar (sucrose) created a bloom of bacterial slime (Sphaerotilus, which was probably also produced by sewage effluent in the Au Sable), which was fed on by aquatic insects, particularly chironomid larvae. The increased production of insects led to a two fold increase in feeding by a population of cutthroat trout. However, because this increased feeding was above the maintenance requirements of the trout (i.e. it went into growth), the production of the trout population increased more than seven fold!

In view of a consideration on maintenance and growth rations, it can be understood why only a relatively slight increase or decrease in available food can result in substantial changes in trout growth.

Trout in streams, typically have a limited feeding area, circumscribed by their "territory". Their daily feeding is limited to the amount of food available in their feeding area or passing through it (drift) per unit of time. In the East Branch of the Au Sable, Fausch and White (1981) observed that small brook trout (8 in.) would feed when the density of invertebrate drift was much less than the threshold needed to stimulate the feeding of 8-12 inch trout. This type of observation

suggests that larger trout are at a disadvantage when they must compete for a common food supply with smaller trout, especially at reduced food densities. I suspect that in the "old days" there were more abundant large food items such as small brook trout, sculpins, and crawfish in the main Au Sable which allowed larger brown trout to readily switch their diets to larger prey items, avoiding competition with smaller trout for a common food supply and thereby maintain a much higher proportion of 12-16 inch and larger trophy trout in the population than has been possible since the 1970's. The steady decline of brook trout has been a long term event in the Au Sable. A decline of crawfish and sculpins, although not documented, probably occurred when enrichment ceased and bacterial slimes, algae, and macrophyte vegetation declined.

An event that could have influenced growth in the main Au Sable was the installation of about $250,000 worth of "stream improvement" devices in the 1970's in the Burton-Wakeley section. Although this action was taken to improve the abundance of the trout population, the population continued to exhibit slow growth and a decline of larger trout. The number of younger trout (I, II age groups) did increase, which could have resulted from a combination of reduced angler kill on smaller trout and improved habitat which provided areas of cover promoting survival. The increase in suitable habitat sites may have actually reduced the size of feeding territories thereby exacerbating the problem of lower food density.

With lower growth rates, condition factors ("plumpness" or ratio of length to weight) also declined, so that a 10, 12, or 14 inch trout in the 1970's-80s weighs considerable less than 10, 12, or 14 inch trout did in the 1950's-60's. The lower growth, poorer condition and great reduction in trout of 12 inches or larger has resulted in angler dissatisfaction, frustration, and demands for improvement of the situation leading to the commission now grasping for a straw of improvement with the imposition of a no-kill regulation.

LIMITATIONS OF REGULATIONS

It is incumbent on those who act as spokesmen and advocates for better trout fisheries as representatives of conservation organizations

or the news media to have some basic comprehension of the subject matter so that they may be truly effective leaders contributing toward attainment of a worthy goal. To do so, an understanding of the dynamic forces and interactions of a trout population with its environment is necessary to understand the workings of recruitment, growth and mortality governed by natural factors and the limitations imposed by the environment in relation to man's ability to significantly change life history parameters by regulation of angling. A basic text on the subject that I would highly recommend is Allen's (1951) publication on the Horokiwi Stream, New Zealand. There is no doubt that restrictive regulations to reduce or eliminate angler kill can and do work for many wild trout populations. The danger, however, for the well-meaning angling enthusiast concerns the trap of inductive reasoning -- if it works in stream A, therefore it will work in stream B, C, D, etc. The faulty reasoning leading to erroneous conclusions here involves differences between streams in: 1. species of trout, 2. growth rate and mortality rates, 3. age structure (% of population attaining 4, 5, 6 or more years of age), 4. angling pressure (potential angling exploitation rate) and amount of compensatory mortality involved (how much of angling mortality is compensatory to natural mortality rather than additive--for example, if angling mortality is 80% compensatory, a population with an average of 50% total annual mortality would not show improved survival from year to year unless angling mortality exceeded 40%).

Many types of regulations including no-kill have been instituted in the various states for the past 50 years. No dramatic success stories were apparent for many years and the use of special regulations as a fisheries management tool became to be viewed by biologists and administrators as "people management" rather than fish management . Then in the 1970's, substantial increases in trout populations were documented in the St. Joe River and Kelly Creek, Idaho, and in the Yellowstone River in Yellowstone Park after angler kill was drastically reduced by regulation. There was no reasonable doubt that restrictive regulations were working to achieve, their goal of substantial increase (several fold increase of 5-6-7 year-old fish) of larger trout (Behnke and Zarn 1976). The explanation of this phenomenon concerns the species of trout

involved--the cutthroat trout, Salmo clarki, the species most vulnerable to angling exploitation--angling pressure of only 10-12 hours per acre per year can remove 50% of all catchable-size cutthroat trout from a population, whereas, with brown trout, the most resistent species to exploitation, it requires 300 to 800 hours of angling pressure per year to expect a 50% exploitation rate. Another important aspect to understand why some cutthroat trout respond so well to reduced angler kill concerns their size-age structure in large rivers or lakes. In the above mentioned waters, fish of 5, 6, and 7 years are common in the populations and growth averaged about 3 inches per year. For example 6 and 7 year-old Yellowstone cutthroat trout are 17-18 and 19-21 inches. In such populations, only a slight reduction of annual total mortality can lead to substantial increases of older, larger fish. If total annual mortality is reduced from 60% to 50% per year from ages II through VI annual survival changes as follows:

	number surviving at ages				
	II	III	IV	V	VI
60% mortality	100	40	16	6	2
50% mortality	100	50	25	12	6

If average sizes for these age groups are 14 inches (IV), 17 inches (V), and 20 inches (VI), then the reduction in annual mortality from only 60% to 50% would increase the number of 14 inch and larger trout in this example from 24 to 43; the number of 17 inch trout would double and the number of 20 inch trout would triple per unit area. Perhaps 50 years ago, the Au Sable brown trout population reflected age-growth statistics comparable to the above figures. If they did, undoubtedly regulations reducing angler mortality and total mortality would work very well. Under the present environmental regime of slow growth, virtually no fish of age V or older and very high mortality (90-95%), with or without angler kill, of trout from age III to IV to V, it should be obvious that any type of special regulations can only play a very minor role, at best, to change the present situation.

I could go on with 100 or more additional pages discussing examples of where special regulations have worked and where they have not worked and explain the reasons in terms of recruitment and growth rates, annual mortality rates, and angler exploitation rates, but they all would only emphasize a basic agreement that where the existing environment places severe restrictions on growth and survival to older age classes, no amount of protection from angler kill can change the natural factors determining the life history dynamics of the trout population.

Lawrence Creek, Wisconsin, for many years was subjected to several different regulations in attempts to maximize angling quality of its brook trout fishery. A one mile section was completely closed to angling for a five year period -- at the end of which there were fewer trout than when it was open to angling (Hunt 1970).

Theoretically the range of fishery regulations that could be applied to the Au Sable River ranges from none (anything goes) to complete prohibition of angling. I believe that all anglers would prefer something in-between these extremes. The present debate centers on no-kill vs. some form of limited take regulation. A recent poll by the Michigan DNR (Report to the Michigan Natural Resources Commission on Au Sable River Fishing Regulations, Feb. 6, 1986), found 41% of the respondents favored no-kill and 59% favored some form of limited kill, most preferring the present regulations or something equally liberal. The reasons cited for favoring no-kill regulations were, "will improve quality of the fishing" (N=37) and, "will provide more and bigger fish" (N=35). The reasons opposing no-kill mainly focused on the theme that most of the present anglers fishing the Au Sable practice catch-and-release most of the time and they want to be able to take an occasional trout when they want. Also there was a reaction against "elitist" and "purist" special interest imposing regulations on the local anglers. Apparently, no one expressed doubts if a no-kill regulation would achieve the expected goals of its proponents. The information presented in my report raises this issue of doubt--my conclusion is that under the present environmental regime of the Au Sable which dictates the present growth and mortality rates, a no-kill regulation will not significantly improve the fishery with a substantial increase in brown trout of 12

inches and larger. If a five year test period of no-kill was imposed and its success measured by changes in the number of 12 inch and larger trout at the end of five years, three outcomes are possible--increase, decrease, or no change. Without adequate control sections on the river, however, a valid cause-effect relationship between the no-kill regulation and population change would not be possible. The changes could be attributed to uncontrollable variables such as climate, minor fluctuations in invertebrate populations, etc. Because of the regulations governing possession of trout in a no-kill fishery, alternate no-kill sections and limited take regulations, needed for controls do not appear feasible because boaters moving through a no-kill section with a trout would be in violation. An alternative would be to designate about a one mile section of the river for a complete prohibition of angling and compare any change in size-age structure between sections.

The best that could be hoped for to maintain the greatest abundance of older fish in the population would be to protect the age III trout from exploitation. This could essentially be done by lowering the present lower end of the slot limit from 12 to 10 inches. In any event, in a democratic society, regulations should reflect the wishes of licensed anglers--the greatest good for the greatest number. Leaders and spokesmen for angler groups, however, should become informed on the issues involved--in this case, the biological evidence which reveals the constraints which severely limit the response of the trout population to any regulation. Only then can rationale decisions, based on evidence and not emotion, be made.

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APPENDIX I

THE GENETIC BASIS OF GROWTH: WHY SLOW GROWTH OF AU SABLE BROWN TROUT IS NOT DUE TO ANGLING SELECTIVITY

As discussed in the text, I dismiss the theory of a hereditary change in the Au Sable brown trout population which states that due to differential selection by anglers for the fastest growing fish, a genetic basis for slow growth occurs.

I pointed out that the empirical and common sense evidence refutes all of the assumptions necessary to make the "genetic theory" operate on the Au Sable brown trout.

1. Nowhere in the world has this phenomenon been observed (that is, angler exploitation causing a hereditary change for slower growth) and there are many trout populations, especially cutthroat trout, that have been historically exposed to much higher exploitation rates than the Au Sable brown trout.
2. Under the 12 inch minimum size limit, all brown trout had spawned at least once, some twice, before they could have been removed by the fishery. Thus, any "fast growth" genes had already been passed on to the next generation. If a genetic change could have been operating, it would have occurred in "the old days" under an 8 inch size limit when the fastest growing trout could have been removed before they spawned and exploitation rates were much higher than after 1973. The table in the text (p. 6) shows that during 1974-78, under the 12 inch minimum size limit, when this selection against fast growth is assumed to have occurred, there was an average of 74 age III brown trout per acre in the fall of the year (average size of 11.2 inches) but only 4 age IV trout ($\bar{x}$ 13.5 inches). The mortality between ages III and IV (70 of 74 perished for annual mortality of 95%) was extremely high (essentially, the mortality of 12 inch and larger fish). These figures could certainly lead one to the conclusion that under the 12 inch size limit, the anglers were wiping out the large fish. However, the creel census data for 1974-78 reveals that only about 4 fish per acre of 12 inches or larger were harvested by anglers (6 per acre were caught-and-released). That is, of the total annual mortality of 70 trout per acre between

ages III and IV, from one fall period to the next, only 4 can be attributed to angler kill (6%) the other 66 (94%) were lost to natural mortality. In the light of such mortality data, it is nonsensical to attempt to make a case that the 12 inch limit had changed the genetics by selective angling mortality.

3. I also pointed out that natural mortality factors, especially predators, remove many more fish of any year class than do anglers, even under the most liberal regulations of the "old days". Predators take trout less than 12 inches; thus, there would be strong negative selection against slow growth because slower growth would maintain an individual for a longer period in the vulnerable prey size range.

I suspect, however, that the publication of Favro et al. (1979) of computer simulation of the Au Sable brown trout population, is considered my many present proponents of a no-kill regulation as "scientific proof" that a genetic change for slow growth has occurred due to angler selection under the 12 inch minimum size limit and a no-kill regulation is necessary to restore faster growth. Actually the 12-16 inch slot limit completely protected 12 inch trout and "rewarded" the fastest growing fish which attained 12 inches by prohibition of kill. That is, there should have been selection favoring the fastest growing fish to survive from age III to IV whereas slower growing fish, less than 12 inches could be harvested. The mortality statistics for the 1980-83 period under the 12-16 inch protected slot, show that there was an average of 35 age III trout per acre but only one age IV fish. That is, the mortality of age III to age IV from one fall to the next was 34 (of 35) or 97%, despite complete protection of 12 inch trout. Besides the common sense, empirical evidence that there is no basis to establish a case for genetic change due to angler exploitation, I would point out that the assumptions used in the simplistic model of Favro et al. are obviously false: 1. Growth is determined by two alleles (one "fast", one slow") at one gene locus. 2. There is no selection against slow growth 3. Fastest growing fish removed by anglers before they reproduce. These assumptions are simply false to begin with. The model bears no relationship to biological reality.

Another contribution reinforcing the belief that Au Sable brown trout have a genetically determined slow growth rate (which is due to angler exploitation), concerns a "test" of the genetic hypothesis. In this experiment, young brown trout from the Au Sable, Gilchrist Creek, the Pigeon River, and a domesticated hatchery strain were stocked into four lakes in the fall of 1982 and their growth compared after two years in the lakes (Alexander 1985. Mich. DNR Fish. Res. Rep. No. 1929). After two years, the Gilchrist Creek brown trout had exhibited the fastest growth, an average increase of 9 inches, vs. an average growth increase of 8 inches for the Au Sable trout (in weight, the Gilchrist fish gained an average of one ounce more than the Au Sable fish -- 9 oz. vs. 8 oz.). This experiment reveals that there are genetic differences that caused Gilchrist Creek brown trout to grow slightly faster than Au Sable brown trout in the four lakes (but not without qualifications -- the young trout were not uniform when stocked, i.e. they were not raised under identical conditions; no information was provided on the biotic and abiotic conditions in the lakes influencing growth; the study should be continued to follow the growth and survival through older ages). However, if this genetic basis for slower growth is accepted, no valid cause-and-effect relationship can be made connecting the Au Sable growth rate with angler exploitation. As I pointed out in an article on brown trout (Behnke 1986. Trout Magazine vol. 27 no. 1), the diversity of the brown trout first introduced into this country, and different selective pressures in different environments, has resulted in the present situation whereby no two populations could be expected to be genetically identical. Thus, any genetic differences between Gilchrist and AU Sable brown trout are much more likely to be the result of origins from different ancestors and natural selection in each environment. Considering the low angling mortality rates of Au Sable brown trout, no valid conclusion can be made that angling mortality has caused a genetic change in the AU Sable brown trout resulting in slower growth. The slower growth rates in the 1970's and 80's, however, might be expected to select for earlier maturing fish (sexually mature at smaller size) because so few fish survive past age III, it would be expected that early maturation should be favored. If this is true, then the proportion of sexually mature age II+ (and I+) fish should be higher now than it was

in the 1950's and 60's. I know of no data allowing for such a comparison, however. But in this case the genetic selection would be caused by the reduced nutrients in the river which caused the slower growth.

Another publication often cited to demonstrate the possibility of selective harvest genetically selecting for slow growth (actually the main selection concerns earlier maturation) is Ricker (1981. Can. Jour. Fish. Aquat. Sci. 38:1636-56). Ricker's study deals with Pacific salmon and commercial exploitation (where exploitation on some stocks reached 80-90%). The trend in some stocks of Pacific salmon exposed to heavy exploitation has been for spawning runs to change to higher proportions of young, smaller fish. This selection is due to the fact that when a year-class of salmon is exposed to an intensive ocean fishery, the less time spent in the ocean, the better chance for survival to spawning. What must be remembered here is that Pacific salmon all die after first spawning -- there is no possibility to spawn before being taken in the fishery as was the case with the Au Sable brown trout under the 12 inch size limit (all spawned before any were taken, and the angler "take" was a minor fraction of their total mortality). Thus, any salmon taken in a fishery has had no chance to pass its genotype on to the next generation.

Although I can find no evidence to support the "genetic" theory of slow growth, to those who continue to support the idea, I would point out that a slot limit (or a maximum size limit) could work to favor or reward fastest growing fish and negatively select against slower growing fish by allowing their take in the fishery.

ADDENDA: How many is more?

The main selling point for proponents of no-kill regulations is that such regulations will result in more larger trout. The computer model of the Au Sable trout population by Clark (1984, Mich. DNR Fish. Res. Rep. 1917) is believed by some to offer "scientific proof" for the belief that large trout will increase in the population after no-kill is imposed. (Clark certainly does not imply such reliability of predictive accuracy to his model and clearly emphasizes that, "...caution should be used for extending the modeling results to the real world").

Let us assume, however, that the model prediction is accurate and then examine the question; how many is more large trout?

Graphs of various size groups of trout derived from Clark's computer model and their predicted numbers under several types of regulation are given (12-16 inch slot, 10-16 inch slot [protected group within "slot"], 12 inch minimum, 14 inch minimum, and no-kill). These graphs were part of information given to "Members of the Au Sable River Property Owners Association" (Dec. 3, 1985) by the Michigan DNR for their poll on regulations. These graphs are also contained in a "Report to the Michigan Natural Resources Commission" from the DNR Fisheries Division (Feb. 6, 1986). The predicted outcome from various forms of regulations are shown, in regard to how many trout of 14 inches or larger are expected to result from any particular regulation. If the bar graphs are drawn precisely to scale, I interpret numbers ranging from 22, 14 inch and larger trout per mile of river under 12-16 inch slot (present regs.), to 39 per mile under no-kill. A 10-16 inch slot and 12 inch minimum regulations would result in 28 large (14+ inches) trout per mile according to the simulation model. To make quantitative comparisons with the rest of my report, I converted trout per mile to trout per acre (11.5 acres per mile of the Au Sable), which yields a range of 2.2 to 3.3 trout of 14 inch+ per acre. A 10-16 inch slot or 12 inch minimum produces about 2.4 trout of 14+ inches per acre. That is, the no-kill regulation will result in 0.9 additional larger trout per acre than some of the limited kill regulations (if the computer model is precise--which is impossible, but was ignored for the present). If the average annual fishing pressure on the Au Sable River is 400 hours per acre, and each 14+ inch trout is caught and released, on average, 1.1 times per year, then for each 400 hours of angling, an average increase in the total catch of 1.0 trout of 14+ inch will result. In terms of how this improves the quality for the individual angler, if one fished 8 hours per day, 7 days per week, for 7 weeks (actually 50 days), the angler should, on average, catch one additional trout per year at 14+ inches because of the no-kill regulation. To accomplish this, however, all harvest of any trout must be prohibited and the majority of the anglers who wish to take an occasional trout will be denied their preference. When viewed in quantitative terms, the unfairness of a no-kill regulation on the Au Sable becomes obvious to all except those who firmly believe that anglers should kill no trout anywhere under any circumstances. The foregoing interpretation of the computer simulation graphs should have been provided to the Commission and to the people polled so a more informed decision could be made (but anyone can make these calculations using no more than grammar school arithmetic). The DNR reports to the landowner association and to the Commission attempted to make clear the severe limitations for no-kill regulations to significantly improve the fishery, but they contain such statements as: "no-kill results in an increased catch and standing stock of trout over 14 inches", and "no-kill rules let the trout stocks increase to the limits of their habitat and reach a condition approaching that of an unfished stock."

To many dedicated anglers, desperately hoping for improvement of the Au Sable fishery, such statements would be grasped and held tightly by their minds,--all else ignored. It is time now for the subject of regulations to be reviewed in the light of the evidence presented in my report, and a more reasoned and equitable solution sought.

CURRICULUM VITAE

NAME:	Robert J. Behnke
TITLE:	Associate Professor (temporary) Department of Fishery and Wildlife Biology Colorado State University Fort Collins, CO 80523
BORN:	December 30, 1929, Stamford, Connecticut
MARITAL STATUS:	Married, two children.

EDUCATION:

1957	B.A.	Zoology	Connecticut University
1960	M.A.	Zoology	University of California
1965	Ph.D.	Zoology	University of California

Graduated Connecticut University with distinction and high honors. M.A. thesis on the trouts of the Great Basin; Ph.D. thesis on systematics of family Salmonidae. Fields for Ph.D. qualifying examination: general zoology, ecology, vertebrate zoology, entomology and vertebrate physiology.

EMPLOYMENT:

1947-1952	Yale and Towne Hardware Co.
1952-1954	U.S. Army
1956	Chesapeake Biological Laboratory, Solomons, Maryland, assistant to the late Dr. R. Mansueti; studies on fishes of Chesapeake Bay.
1957-1964	University of California, Research Assistant, teaching assistant and research biologist.
1965	American Academy of Science, Exchange scholar
1966	University of California, Assistant Professor of Zoology, teaching ichthyology course
1966-1974	U.S. Fish and Wildlife Service, Assistant Unit Leader, Colo. Coop. Fishery Unit and Research Biologist
1974-present	Colorado State University, part-time teaching, part-time private consulting and advising.

SPECIAL TRAINING AND EXPERIENCE:

1957-1959	Collected fish specimens in Canada, Alaska, and western United States.
Summer 1960	Collected specimens, visited museums and fisheries institutions in Europe and USSR to gather material for Ph.D. thesis. Sponsored by Department of Zoology, University of California and Woodrow Wilson Foundation.
1964-1965	10-month post-doctoral fellowship studying at the Ichthyological Laboratory of the Zoological Institute, Academy of Sciences, USSR, Leningrad.

June-July 1967 Participated in first Smithsonian Institute for Systematics.
1974 Conducted fishery survey and collections in Iran.

MEMBERSHIP IN HONORARY AND PROFESSIONAL SOCIETIES:

Phi Beta Kappa
Phi Kappa Phi
American Society of Ichthyologists
American Fisheries Society
American Society of Systematic Zoologists
Japanese Society of Ichthyology
Non-game Advisory Council, Colorado Division of Wildlife
Scientific Advisory Board, Trout Unlimited
Technical Advisor for two endangered species recovery teams
First 'Award of Excellent' by the Colorado-Wyoming Chapter American Fisheries Society, 1979.
First A. Starker Leopold Award, Wild Trout Symposium III, Yellowstone National Park, 1984.

SPECIAL EXPERTISE:

Surveys, inventories and identification of fishes. Rare, endangered and threatened fishes. Distribution and speciation of fishes. Environmental factors influencing fish distribution particularly in relation to man-induced environmental changes. Application of intraspecific genetic diversity for fisheries management. Systematics of family Salmonidae.

PRIVATE ACTIVITIES:

Served as fisheries advisor to Iranian government, 1974-1975; fishery studies on the freshwater fishes of Iran and Saudi Arabia; several fishery projects for U.S. Forest Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, Wyoming Department of Game and Fish, New MExico Department of Game and Fish and Colorado Division of Wildlife; fishery related services for the American Sportsman's Club, the law firm of Weissbrodt and Weissbrodt, Thorne Ecological Foundation, Colorado River Water Conservation District, McMillan-Bloedel Ltd., U.S. Justice Department, Ecology Consultants Inc., Woodward-Clyde and other private firms and public agencies; Senior Translations Editor for Scripta Technica for Russian fisheries translations; appeared as an expert witness in court in U.S. and Canada.

PUBLICATIONS - R. J. Behnke:

1956. Effects of freshwater on estuarine fishes of Chesapeake Bay. Md. Tidewater News, 13(2):2-4.

1959. A note on Oncorhynchus formosanum and Oncorhynchus masou. Jap. Jour. Ichthyology, 7(5,6):151-152.

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1973. Systematic problems of salmonid fishes endemic to the Mediterranean-Adriatic Province. Fist Int. Cong. Ichthyol., Sarajevo, Yugoslavia.

1973-1974 A series of 24 reports on endangered and threatened fishes of the Southwest (approx. 200 p.) written for U.S. Fish and Wildlife Service, Albuquerque.

1974. Management implications of ecological segregation between two introduced populations of cutthroat trout in a small Colorado lake. Trans. Amer. Fish Soc., 103(3):423-430 (with J. B. Trojnar, sr. author).

1974. Salmoniformes. A major article in the fifteenth edition of the Encyclopedia Britannica.

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1976. Biology and management of threatened western trout. USDA For. Ser., Rocky Mtn. For., Range Exp. Sta., Gen. Tech. Rep. 44 p. (with M. Zarn).

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1983. Acanthobrama hadiyahensis, a new species of cyprinid fish from Saudi Arabia. Nat. Mus. Canada Publ. Nat.Sci. 2:1-6 (with B. W. Coad and H. F. Al Kahem).

1983. A series of articles on various salmonid fishes were written for Trout Magazine including: McCloud River rainbow trout (spring issue), coho salmon (summer), westslope cutthroat trout (autumn) and steelhead trout (winter).

1984. (in press) Organizing the diversity of the Arctic charr complex. In L. Johnson (ed.). proc. Int. Symp. Arctic Charr, Winnipeg, Can.

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1985 (in press) Two new intergeneric cyprinid hybrids from the Bonneville basin, Utah. Copeia (2) (with D. L. Miller).

Approximately 20 reports have been written for state and federal agencies, mainly relating to native trouts. These reports are available to interested persons.

OTHER WORKS - R. J. Behnke

1959. Fishes of the Mianus River. In: The flora and fauna of the Mianus Gorge; mimeographed by the Mianus Gorge Conservation Committee.

1960. Taxonomy of the cutthroat trout of the Great Basin. M.S. Thesis, 98 pp.; Dept.of Zoology, Univ. Calif., Berkeley.

1961. Laboratory Manual for (Fishery Management) course.

1965. A systematic study of the family Salmonidae with species reference to the genus Salmo. Ph.D. thesis, 2722 pp. Dept. Zoology, Univ. Calif., Berkeley.

1966-present. Several mimeographed reports dealing with trout based on particular segments of my studies, designed to answer or pose specific questions. Distributed to interested state, federal and university personnel.

1971. Laboratory manual for ichthyology course.

1974-present. Several consulting reports re. environmental assessments, threatened, endangered and rare species status and probable future impacts for permit applications, Environmental Impact Statement preparation, multiple use land management decisions and potential or actual court cases. Also sport fish management reports for corporation and private clubs.

1982-83. Fishes and endangered species section of Northwest Colorado Wildlife Consortium report (phase I) on potential impacts from energy development in NW Colorado.

November, 1984

APPENDIX I

THE GENETIC BASIS OF GROWTH: WHY SLOW GROWTH OF AU SABLE BROWN TROUT IS NOT DUE TO ANGLING SELECTIVITY

As discussed in the text, I dismiss the theory of a hereditary change in the Au Sable brown trout population which states that due to differential selection by anglers for the fastest growing fish, a genetic basis for slow growth occurs.

I pointed out that the empirical and common sense evidence refutes all of the assumptions necessary to make the "genetic theory" operate on the Au Sable brown trout.

1. Nowhere in the world has this phenomenon been observed (that is, angler exploitation causing a hereditary change for slower growth) and there are many trout populations, especially cutthroat trout, that have been historically exposed to much higher exploitation rates than the Au Sable brown trout.
2. Under the 12 inch minimum size limit, all brown trout had spawned at least once, some twice, before they could have been removed by the fishery. Thus, any "fast growth" genes had already been passed on to the next generation. If a genetic change could have been operating, it would have occurred in "the old days" under an 8 inch size limit when the fastest growing trout could have been removed before they spawned and exploitation rates were much higher than after 1973. The table in the text (p. 6) shows that during 1974-78, under the 12 inch minimum size limit, when this selection against fast growth is assumed to have occurred, there was an average of 74 age III brown trout per acre in the fall of the year (average size of 11.2 inches) but only 4 age IV trout ($\bar{x}$ 13.5 inches). The mortality between ages III and IV (70 of 74 perished for annual mortality of 95%) was extremely high (essentially, the mortality of 12 inch and larger fish). These figures could certainly lead one to the conclusion that under the 12 inch size limit, the anglers were wiping out the large fish. However, the creel census data for 1974-78 reveals that only about 4 fish per acre of 12 inches or larger were harvested by anglers (6 per acre were caught-and-released). That is, of the total annual mortality of 70 trout per acre between

ages III and IV, from one fall period to the next, only 4 can be attributed to angler kill (6%) the other 66 (94%) were lost to natural mortality. In the light of such mortality data, it is nonsensical to attempt to make a case that the 12 inch limit had changed the genetics by selective angling mortality.

3. I also pointed out that natural mortality factors, especially predators, remove many more fish of any year class than do anglers, even under the most liberal regulations of the "old days". Predators take trout less than 12 inches; thus, there would be strong negative selection against slow growth because slower growth would maintain an individual for a longer period in the vulnerable prey size range.

I suspect, however, that the publication of Favro et al. (1979) of computer simulation of the Au Sable brown trout population, is considered my many present proponents of a no-kill regulation as "scientific proof" that a genetic change for slow growth has occurred due to angler selection under the 12 inch minimum size limit and a no-kill regulation is necessary to restore faster growth. Actually the 12-16 inch slot limit completely protected 12 inch trout and "rewarded" the fastest growing fish which attained 12 inches by prohibition of kill. That is, there should have been selection favoring the fastest growing fish to survive from age III to IV whereas slower growing fish, less than 12 inches could be harvested. The mortality statistics for the 1980-83 period under the 12-16 inch protected slot, show that there was an average of 35 age III trout per acre but only one age IV fish. That is, the mortality of age III to age IV from one fall to the next was 34 (of 35) or 97%, despite complete protection of 12 inch trout. Besides the common sense, empirical evidence that there is no basis to establish a case for genetic change due to angler exploitation, I would point out that the assumptions used in the simplistic model of Favro et al. are obviously false: 1. Growth is determined by two alleles (one "fast", one slow") at one gene locus. 2. There is no selection against slow growth 3. Fastest growing fish removed by anglers before they reproduce. These assumptions are simply false to begin with. The model bears no relationship to biological reality.

Another contribution reinforcing the belief that Au Sable brown trout have a genetically determined slow growth rate (which is due to angler exploitation), concerns a "test" of the genetic hypothesis. In this experiment, young brown trout from the Au Sable, Gilchrist Creek, the Pigeon River, and a domesticated hatchery strain were stocked into four lakes in the fall of 1982 and their growth compared after two years in the lakes (Alexander 1985. Mich. DNR Fish. Res. Rep. No. 1929). After two years, the Gilchrist Creek brown trout had exhibited the fastest growth, an average increase of 9 inches, vs. an average growth increase of 8 inches for the Au Sable trout (in weight, the Gilchrist fish gained an average of one ounce more than the Au Sable fish -- 9 oz. vs. 8 oz.). This experiment reveals that there are genetic differences that caused Gilchrist Creek brown trout to grow slightly faster than Au Sable brown trout in the four lakes (but not without qualifications -- the young trout were not uniform when stocked, i.e. they were not raised under identical conditions; no information was provided on the biotic and abiotic conditions in the lakes influencing growth; the study should be continued to follow the growth and survival through older ages). However, if this genetic basis for slower growth is accepted, no valid cause-and-effect relationship can be made connecting the Au Sable growth rate with angler exploitation. As I pointed out in an article on brown trout (Behnke 1986. Trout Magazine vol. 27 no. 1), the diversity of the brown trout first introduced into this country, and different selective pressures in different environments, has resulted in the present situation whereby no two populations could be expected to be genetically identical. Thus, any genetic differences between Gilchrist and AU Sable brown trout are much more likely to be the result of origins from different ancestors and natural selection in each environment. Considering the low angling mortality rates of Au Sable brown trout, no valid conclusion can be made that angling mortality has caused a genetic change in the AU Sable brown trout resulting in slower growth. The slower growth rates in the 1970's and 80's, however, might be expected to select for earlier maturing fish (sexually mature at smaller size) because so few fish survive past age III, it would be expected that early maturation should be favored. If this is true, then the proportion of sexually mature age II+ (and I+) fish should be higher now than it was

in the 1950's and 60's. I know of no data allowing for such a comparison, however. But in this case the genetic selection would be caused by the reduced nutrients in the river which caused the slower growth.

Another publication often cited to demonstrate the possibility of selective harvest genetically selecting for slow growth (actually the main selection concerns earlier maturation) is Ricker (1981. Can. Jour. Fish. Aquat. Sci. 38:1636-56). Ricker's study deals with Pacific salmon and commercial exploitation (where exploitation on some stocks reached 80-90%). The trend in some stocks of Pacific salmon exposed to heavy exploitation has been for spawning runs to change to higher proportions of young, smaller fish. This selection is due to the fact that when a year-class of salmon is exposed to an intensive ocean fishery, the less time spent in the ocean, the better chance for survival to spawning. What must be remembered here is that Pacific salmon all die after first spawning -- there is no possibility to spawn before being taken in the fishery as was the case with the Au Sable brown trout under the 12 inch size limit (all spawned before any were taken, and the angler "take" was a minor fraction of their total mortality). Thus, any salmon taken in a fishery has had no chance to pass its genotype on to the next generation.

Although I can find no evidence to support the "genetic" theory of slow growth, to those who continue to support the idea, I would point out that a slot limit (or a maximum size limit) could work to favor or reward fastest growing fish and negatively select against slower growing fish by allowing their take in the fishery.

ADDENDA: How many is more?

The main selling point for proponents of no-kill regulations is that such regulations will result in more larger trout. The computer model of the Au Sable trout population by Clark (1984. Mich. DNR Fish. Res. Rep. 1917) is believed by some to offer "scientific proof" for the belief that large trout will increase in the population after no-kill is imposed (Clark certainly does not imply such reliability of predictive accuracy to his model and clearly emphasizes that...."caution should be used for extending the modeling results to the real world").

Let us assume, however, that the model prediction is accurate and then examine the question; how many is more large trout?

Graphs of various size groups of trout derived from Clarks computer model and their predicted numbers under ~~four~~ several types of regulation are given (~~8-12~~ 10-16 in. slot, ~~8~~ 10-16 in. slot [protected group within "slot"], 12 in. min., ~~and~~ 14 in. min., and no-kill). These graphs were part of information given to "Members of The Au Sable River Property Owners Association" (Dec. 3, 1985) by DNR for poll on regulations. These graphs are also contained in a "Report to the Mich. Nat. Res. Commission" from DNR Fisheries Div. (Feb. 6, 1986). The predicted outcome from various forms of regulations in regards to how many trout of 14 inches or larger are expected to result from any particular regulation. If the bar graphs are drawn precisely to scale, I interpret numbers ranging from 22, 14 inch and larger trout per ~~under~~ mile of river under 12-16 in slot (present regs.), to 39 per mile under no kill. A 10-16 ~~in~~ slot and 12 in. minimum regulations would result in 28 large (14+ in.) trout per mile according to the simulation model. To make quantitative comparisons with rest of my report, I converted trout per mile to trout per acre (11.5 acres per mile of the Au Sable), which yields a range of 2.2 to 3.3 trout of 14 in.+ per acre. A 10-12 in. slot or 12 in. min. produces about 2.4 trout of 14+ in./acre. That is, the no-kill regulation will result in 0.9 larger trout per acre than some of the limited kill regulations (if computer model is precise--which is impossible, but ignored for present). If the average annual fishing pressure on the Au Sable River is 400 hrs./acre, and each 14+ in. trout is caught and released, on average, 1.1 times/year, then for each 400 hrs. of angling, on average increase in the total catch of 1.0 trout of 14+ in. will result. In terms of how this improves the quality ~~for~~ the individual angler, if ~~one~~ one fished 8 hrs./day, 7 days/week, for 7 weeks (actually 50 days), the angler should, on average, catch one additional trout per year of 14+ inches ~~because of the~~, because of the no-kill regulation. To accomplish this, however, all harvest of any trout must be prohibited and the majority of the anglers who wish to take an occasional trout will be denied their preference. When viewed in quantitative terms, the unfairness of a no-kill regulation on the Au Sable becomes obvious to all except those who firmly believe that anglers should kill no trout anywhere under any circumstances. The foregoing interpretation of the computer simulation graphs should have been provided to the Commission and to the people polled so a more informed decision could be made (but anyone can make these calculations using no more than grammar school arithmetic]. The DNR reports to the landowner asc. and to the Commission attempted to make clear the severe limitations for no-kill regulations to significantly improve the fishery, but they contain such statements as: "no-kill results in an increased catch and standing stock of trout over 14 inches". "No kill rules let the trout stocks increase to the limits of their habitat and reach a condition approaching that of an unfished stock". To many dedicated anglers, desparately hoping for improvement of the Au Sable fishery, such statements would be grasped and held tightly by their minds,--all else ignored. It is time ~~now~~ for the subject of regulations to be reviewed in the light of the evidence presented in my report, and a more reasoned and equitable solution sought.

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The main selling point for proponents of no-kill regulations is that such regulations will result in more larger trout. The computer model of the Au Sable trout population by Clark (1984. Mich. DNR Fish. Res. Rep. 1917) is believed by some to offer "scientific proof" for the belief that large trout will increase in the population after no-kill is imposed (Clark certainly does not imply such reliability of predictive accuracy to his model and clearly emphasizes that...."caution should be used for extending the modeling results to the real world").

Let us assume, however, that the model prediction is accurate and then examine the question; how many is more large trout?

Graphs of various size groups of trout derived from Clarks computer model and their predicted numbers under ~~four~~ several types of regulation are given (~~8-12~~ 12-16 in. slot, ~~8-~~ 10-16 in. slot [protected group within "slot"], 12 in. min., ~~and~~ 14 in. min., and no-kill). These graphs were part of information given to "Members of The Au Sable River Property Owners Association" (Dec. 3, 1985) by DNR for poll on regulations. These graphs are also contained in a "Report to the Mich. Nat. Res. Commission" from DNR Fisheries Div. (Feb. 6, 1986). The predicted outcome from various forms of regulations in regards to how many trout of 14 inches or larger are expected to result from any particular regulation. If the bar graphs are drawn precisely to scale, I interpret numbers ranging from 22, 14 inch and larger trout per ~~under~~ mile of river under 12-16 in slot (present regs.), to 39 per mile under no kill. A 10-16 ~~in.~~ slot and 12 in. minimum regulations would result in 28 large (14+ in.) trout per mile according to the simulation model. To make quantitative comparisons with rest of my report, I converted trout per mile to trout per acre (11.5 acres per mile of the Au Sable), which yields a range of 2.2 to 3.3 trout of 14 in.+ per acre. A 10-12 in. slot or 12 in. min. produces about 2.4 trout of 14+ in./acre. That is, the no-kill regulation will result in 0.9 larger trout per acre than some of the limited kill regulations (if computer model is precise--which is impossible, but ignored for present). If the average annual fishing pressure on the Au Sable River is 400 hrs./acre, and each 14+ in. trout is caught and released, on average, 1.1 times / year, then for each 400 hrs. of angling, on average increase in the total catch of 1.0 trout of 14+ in. will result. In terms of how this improves the quality ~~for~~ the individual angler, if ~~one~~ one fished 8 hrs./day, 7 days / week, for 7 weeks (actually 50 days), the angler should, on average, catch one additional trout per year of 14+ inches, ~~because of the~~ because of the no-kill regulation. To accomplish this, however, all harvest of any trout must be prohibited and the majority of the anglers who wish to take an occasional trout will be denied their preference. When viewed in quantitative terms, the unfairness of a no-kill regulation on the Au Sable becomes obvious to all except those who firmly believe that anglers should kill no trout anywhere under any circumstances. The foregoing interpretation of the computer simulation graphs should have been provided to the Commission and to the people polled so a more informed decision could be made (but anyone can make these calculations using no more than grammar school arithmatic). The DNR reports to the landowner asc. and to the Commission attempted to make clear the severe limitations for no-kill regulations to significantly improve the fishery, but they contain such statements as: "no-kill results in an increased catch and standing stock of trout over 14 inches". "No kill rules let the trout stocks increase to the limits of their habitat and reach a condition approaching that of an unfished stock". To many dedicated anglers, desparately hoping for improvement of the Au Sable fishery, such statements would be grasped and held tightly by their minds,--all else ignored. It is time ~~now~~ for the subject of regulations to be reviewed in the light of the evidence presented in my report, and a more reasoned and equitable solution sought.

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LIMITATION OF SPECIAL REGULATIONS FOR INCREASING THE PROPORTION OF LARGE TROUT IN THE AU SABLE RIVER

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ABSTRACT

Data are reviewed for various time periods relating to the trout fishery of the Au Sable River. A decline in trout growth and a large decline in the proportion of large trout occurred in the 1970's and continues to present. Based on examination of evidence, the most reasonable cause-and-effect relationship producing the decline in the fishery is reduced nutrient input into the river.

In view of present growth and mortality rates, under the present environment, the fishery cannot be restored to its former condition by any form of special regulation, including no-kill or complete prohibition of angling.

LIMITATIONS OF SPECIAL REGULATIONS FOR INCREASING THE PROPORTION OF LARGE TROUT IN THE AU SABLE RIVER

INTRODUCTION

The only salmonine fish species native to the Au Sable River, Michigan, was the grayling. The grayling became extinct soon after brook trout, brown trout, and rainbow trout were introduced into the Au Sable in the late nineteenth century. The non-native trouts thrived and as the brown trout became increasingly dominant in the drainage, the reputation of the river as one of the country's most famous trout streams was established.

A universal phenomenon among anglers is that fishing was always better in the "old days". Such statements can be found in the first report of George Jerome, the first fish commissioner of Michigan, submitted to the legislature in 1873. Mershon (1923) reminiscing on his 50 years as a hunter and fisherman lamented the decline of the Au Sable fishery. Unfortunately no quantitative data on abundance, growth rate, biomass per unit area, etc. are available from the "old days" of the Au Sable trout fishery to document a decline. Data collected over the past 30 years, however, on the 8.7 mile section of the main Au Sable River from Burton's to Wakeley Bridge, does document a decline in growth rate and biomass of the brown trout, especially a decline of large trout of 12-13 inches and larger in this section of the river during the 1970's and continuing to the present.

This documented decline has stimulated several research studies and the implementation of various types of special regulations by the Michigan Department of Natural Resources to better understand the reasons for the decline in the brown trout population and to explore possible ways to reverse the decline. The failure to reverse the decline of larger brown trout in the population has angered and frustrated a segment of the angling public. These anglers generated sufficient public pressure to cause the Natural Resource Commission to declare a five year

catch-and-release (no kill) regulation on the Burton's Landing to Wakeley Bridge section of the main Au Sable River scheduled to begin in 1986.

The purpose of this report is to demonstrate that such a regulation, although well-meaning, is misguided and is not based on biological evidence. It is an example of what might be called the "arrogance of ignorance", by which, "decisions are made loudly and clearly on inadequate and inaccurate data" (Mayer 1984). All of the biological evidence convincingly leads to the conclusion that, under the present environmental conditions which produces a relatively slow growth rate and an extremely high mortality of brown trout between three and four and four and five years of age, any substantial increase of larger, older fish in the population, with or without protection from angler kill, is beyond reasonable expectations.

There may be several types of personal belief which can serve as a basis to argue in favor of a no-kill regulation on the Burton's-Wakeley section of the Au Sable. Some may simply feel strongly against the killing of any animal by man; or, more likely in this case, have strong feelings against the killing of any trout anywhere, under any circumstances. Most anglers currently favoring the no-kill regulation, however, probably do so in the mistaken belief that by avoiding angler removal of any trout, the Au Sable River fishery will return to its former state of excellence, especially with a great proliferation of larger (ca. 14 inches and larger), older trout in the population. I believe that if most of the anglers and the commissioners currently favoring a no-kill regulation critically examined the biological evidence to arrive at an informed and unbiased decision on the matter, they would change their preference to favor one of the alternative regulation options suggested by DNR biologists which would allow a limited take of trout.

In the remainder of this report I will attempt to synthesize, summarize, and interpret the many years of data the Au Sable fishery compiled and published by the DNR, along with other pertinent data from the literature and personal experience with numerous trout populations over a broad geographical area. To those who disagree with any of my conclusions I would request that the particular points of disagreement be

detailed with evidence for the opposing viewpoint. In this way, the final determination of the type of regulation to be implemented on the Au Sable River might be resolved in an atmosphere of reason based on evidence and not entirely on emotion and ego.

First, I should make clear my own record on the matter of special regulation fisheries (regulations designed to reduce or eliminate angler kill to achieve a specified goal). I have favored the greater use of special regulations to maintain the quality of wild trout fisheries in heavily fished waters, especially emphasizing its value in the management of rare native trout (Behnke 1978, 1980, 1981). I have also expressed dismay at the lack of expertise long characterizing the special regulation fisheries of most states (where, historically, special regulations have been considered more in the realm of people management rather than fish management). I have also recommended that special regulations should be applied judiciously and only after the biological evidence is available on which to decide feasibility and to select the best regulations for a particular trout population. Otherwise, the imposition of special regulations on waters where they do not work will create a backlash and act as a setback to progress. Public acceptance of any special regulation by the user group is critical to its success. In relation to this point, I wrote: "except for a relative few fisheries, the 'pure' catch-and-release regulations (no-kill), are not the best type of regulations. No-kill regulations do not allow 'fine-tuning' of population dynamics to optimize both growth and catch-rate. It does not challenge the biologist to learn about recruitment rates, size-age structure and the internal workings of the environmental interactions that determine the potential of a fishery" (Behnke 1980).

In the following sections I will attempt to demonstrate that no-kill regulations will not significantly improve the size-age structure or growth rate of the Au Sable River brown trout population over previous regulations because the major cause of the decline in growth and abundance is attributed to a reduced food supply related to reduced nutrient input into the river. Also, because short term and long term natural factors such as climatic variation will most likely "overpower" any slight negative or positive changes in the trout population which

might be linked to a no-kill regulation, valid conclusions on the efficacy of no-kill regulations will not be possible at the end of the proposed five year trial period (without proper "control" sections).

THE FISHERY

The Burton-Wakeley section of the main Au Sable River is 8.7 miles in length and contains a surface area of about 100 acres (Alexander et al. 1979). The Au Sable River in general (all branches) was early recognized as a fine trout fishery, this was especially true for the main Au Sable in the Burton-Wakeley section. Because of the recognition of its importance as a trout fishery, the Au Sable received some of the first "special regulations" in the state. In 1901, the minimum size limit for trout was increased to 8 inches (6 inches statewide at the time). In 1907, a flies only regulation was imposed on the North Branch. In 1913, the first "backlash" against special regulations was apparent when the flies only regulation was repealed and the size limit reduced to 7 inches. In 1922, the size limit was again increased to 8 inches and the daily bag limit reduced to 20 trout (35 statewide) on the North Branch.

The modern era of scientific studies in the Au Sable drainage began in the 1950's, and it is from this time that changes in the population can be traced. The changes in the population of brown trout in the Burton-Wakeley section of the main Au Sable are apparent in the data of Alexander et al. (1979) comparing statistics, mainly from the 1959-63 period with figures for the 1972-76 period. From 1955 to 1976, six changes in regulations occurred on this section. The major regulation changes were: 1955-63, 10 inch minimum size limit on all trout (brook, brown, and rainbow), five trout per day creel limit, and flies only. In 1969 the size limit on brook trout was reduced to 7 inches. In 1973 the size limit on brown and rainbow trout was increased to 12 inches and the creel limit reduced to three trout (any species). In 1979 a "slot" limit was imposed which allowed the take of trout between 8 and 12 inches, and 16 inches or larger, and required the release of trout between 12 and 16 inches. Fishery data for the 1974-78 and 1980-83 periods are given by Clark and Alexander (1984).

The following table summarizes the dynamics of the trout populations in different periods of time.

		Age Group					
		(First year of life) 0	I	II	III	IV	V
Brown trout							
average size (Oct.) (inches)	1959-63	4.0	7.9	10.7	13.6	16.6	19.0
	1974-78	3.6	6.9	9.3	11.2	13.5	15.8
	1980-83	- no change from 1974-78 period -					
numbers (per acre)	1959-63	337	236	101	29	6	0.6
	1974-78	450	164	114	74	4	ca. .5
	1980-83	405	148	80	35	1	trace
Brook trout							
average size	1959-63	3.7	6.4	9.0	10.1	11.5	
	1974-76	3.2	6.4	8.8	10.0	11.2	
numbers	1959-63	324	93	13	0.7	trace	
	1974-76	191	32	3	trace		

The most significant feature demonstrated by these data is the slower growth of brown trout in the 1970's and 80's compared with the 1950's and 60's. In the earlier period, brown trout at ages three and four attained a larger size than age four and five fish did in the later period. The actual number of three-year-old brown trout was greater in the 1974-78 period than in the 1959-63 period (74 vs. 29 per acre), perhaps due in part to the 12 inch minimum size limit in effect at the time, but there were many fewer trout of 12 inches or larger in the population in the 1970's and 80's because they averaged only 11.2 inches in the fall of their fourth year of life (age III+), whereas they averaged 13.6 inches at III+ in the 1950's and 60's. Thus, in the fall of the 1959-63 period there was an average of 36 brown trout per acre of ages III, IV, and V+ whereas in the 1974-78 period there were only about 4 per acre of comparable size at ages IV+ and V+. The proportion of

older trout continued to decline under the slot limit which protected fish between 12 and 16 inches. Also note the extremely high mortality rate between ages III to IV and IV to V. Changes in regulations appear to be very limited in their effectiveness to significantly increase survival to four and five years of age. In the 1959-63 period, under a 10 inch minimum size, brown trout could be taken by anglers beginning at age II. In the 1974-78 period with a 12 inch minimum size, fish would not be harvested until age IV (or faster growing age III+). It might be argued from the figures that the extreme mortality from age III to IV (74 to 4 per acre) was due to angler kill. Angler kill of 12 inch and larger trout in 1976 was 4 per acre -- the rest were lost to natural mortality. Also, about 6 trout of 12 inches or larger were caught and released per acre in 1976. During 1980-84 with the slot limit, 2060 (20.6/acre) "legal" trout between 8 and 12 inches were taken by anglers and 5440 (54/acre) were released. Most of the anglers fishing the Burton-Wakeley section practice catch-and-release angling for legal trout most of the time (release of 60 to 70% or more of total catch of legal trout). The standing crop or biomass per unit area of trout also declined compared to the 1959-63 period. In the 1959-63 period, the Burton-Wakeley section contained an average of 129 pounds per acre of brown trout and 20 pounds per acre of brook trout. This declined to 101 pounds per acre for brown trout and to 7 pounds per acre for brook trout in the 1974-76 period, and evidently continued to decline by an additional 30-40% (to ca. 60-70 pounds per acre) in the 1980's according to the figures on age groups given by Clark and Alexander (1984). Angling pressure on the Burton-Wakeley section averaged 430 hours per acre in the 1960-65 period; 305 hr./acre in 1976; and 345 hr./acre during 1980-83. During this same period, with no changes in regulations, trout in the North Branch Au Sable changed as follows: 1957-60 average of 34 pounds per acre brown trout and 36 pounds per acre of brook trout (total 70 pounds/acre); 1960-67, 45 pounds/acre brown trout and 28 pounds/acre brook trout (total 73 pounds/acre), in 1974-76, 60 pounds per acre brown trout and 24 pounds/acre brook trout (total 84 pounds/acre). In the 1980-83 period, however, the brown trout in the North Branch also declined similar to the decline in the main Au Sable during this same period, which can most

logically be attributed to local climatic variation affecting both the North Branch and main Au Sable, because the decline cannot be well correlated with increased angler kill (or the slot limit on the main Au Sable) (Alexander and Ryckman 1976; Alexander et al. 1979; Clark and Alexander 1984).

Another interesting finding from the North Branch where the brown trout growth rate is similar to the growth rate in the main Au Sable during the 1950's and 60's, is that when two sections were compared, one under statewide regulations and one under special regulations with 10 inch minimum size limit and flies only, the statewide regulation section contained about twice as many brown trout more than 12 inches as did the special regulation section (Alexander and Ryckman 1976). This may be due to the greater density of small brook trout, the major food of large brown trout in the North Branch, in the normal regulation area (Alexander 1977). If the number of trout per acre exceeding 12 inches (sampled in fall) are compared for the Burton-Wakeley section of the main Au Sable in different periods with different regulations the figures are as follows: during 1959-63 (10 inch minimum size limit) there was an average of 50 trout per acre which were 12 inches or larger, 17 of which were 14 inches or more and 5 were 16 inches or more. During 1974-78 (12 inch minimum) there were 19 trout per acre of 12 inches or greater in length, 3 of which were 14 inches or more and only about one-half trout per acre was 16 inches or more (Alexander et al. 1979). During 1980-83 (when slot limit protected all trout between 12-16 inches) trout of 12 inches or greater (which were then protected from angler kill) declined further to 10 per acre (Clark and Alexander 1984).

Thus, a long history of studies and numerous changes in angling regulations in the Au Sable drainage, demonstrate that natural influences determining growth rate and annual survival of age classes, govern the abundance and size of the trout populations. Special regulations, either decreasing, increasing, or eliminating angler kill can do very little to change the situation. The critical question is why has brown trout growth slowed since about 1970?

FACTORS INFLUENCING GROWTH

If the foregoing data syntheses is accepted then it becomes clear that the decline in the fishery of the mainstream Au Sable was not caused by increased angler kill of trout. Actually, the exploitation rate before 1973 was much greater than after more restrictive regulations reduced the annual kill from about 8000 trout per year in the 1960-65 period to about 500 per year after 1973 in the Burton-Wakeley section (Alexander et al. 1979). The angler kill did increase again in 1980's under the slot limit to about 2,100 annually (all but about 30 were in the 8-12 inch size range), but this angling mortality was only about 25% of the 1960-65 mortality when the fishery was considered excellent. The problem centers on changes in growth rate. As discussed, with the 1950's-60's growth rate, Au Sable brown trout average 13.6 inches at age III+ (toward end of fourth growing season), but under the growth rate during 1970's and 80's III+ trout are only 11.2 inches. The high mortality between ages III-IV and IV-V always maintained these older trout as a very small proportion of the total population -- thus, the key to the abundance of 12 inch and larger trout is to have a growth rate which attains this size by age III. Why do the mainstream Au Sable trout now only average 11.2 inches at III+ when they averaged 13.6 inches at this same age 20 years ago?

There has long been a popular belief that angler exploitation of a trout population, by the selective removal of faster growing individuals of each year class, will genetically change a population by favoring the survival of slower growing individuals which are left to reproduce, eventually changing the heredity of the population to slower growth rates. This theory gained particular credence to explain the slower growth of main Au Sable brown trout from a publication by Favro et al. (1979). I suspect that many anglers favoring a no-kill regulation do so because they believe the "genetic" theory of slow growth as expounded by Favro et al. They mistakenly believe that if angler kill is eliminated, a genetic change for faster growth will be favored. For those who favor no-kill regulations for this reason I include Appendix I with a detailed refutation explaining why this genetic theory is not a reasonable

explanation for the slower growth of brown trout in the 1970's and 80's. For now, I will only appeal to common sense and empirical evidence such as: 1. Other brown trout populations with high growth rates have been exposed to greater annual percent angler removal than has the main Au Sable population; for example, the North Branch Au Sable (Shetter 1969; Alexander and Ryckman 1976) and some Wisconsin streams (Avery and Hunt 1981) -- yet their growth rates remain higher than main Au Sable brown trout (also, how can the main Au Sable brown trout remain genetically isolated from North Branch and South Branch Au Sable brown trout where growth rates are higher?). 2. To effectively change the genetics of growth to favor the survival of slower growing individuals, there must be no selection against slower growth. In the Au Sable drainage (studies conducted mainly on North Fork), it was clearly demonstrated by Alexander (1976, 1977) that loss to predators of any year class is much greater than loss to angling, and predators take trout less than 12 inches. Thus, there would be much stronger selection for fast growth (to get out of the predator size range) than for slow growth to avoid angler take. 3. Also, for a genetic change to be effective, the trout must be removed from the population before they reproduce (before they have a chance to pass on any "fastgrowth" genes to the next generation). In the main Au Sable, all trout spawn at least once and some twice by the time they are 12 inches. If such a genetic change for slower growth could be real, it would have appeared in the "old days" under the 8 inch size limit which allowed removal of trout before they spawned and when angling exploitation was much higher than it was after 1973.

After critical examination of all of the available evidence, I must agree with Clark and Alexander (1984) that the reduction in nutrient input (nitrogen and phosphorous) from the closure of the Grayling Hatchery in the mid 1960's and the diversion of the city of Grayling's sewage effluent away from the river in 1971 is the major cause-effect relationship. This great reduction of nutrient input into the main Au Sable (70% reduction in nitrogen), reduced primary production (vegetation growth) which in turn reduced invertebrate production, leading to a condition of less available food for the trout and a slower growth rate. The study of Merron (1982) comparing nutrient level and trout growth over

different periods of time in the main Au Sable, the North Branch, and the South Branch, clearly defined the correlation between growth of brown trout and nutrient levels. I can conceive of no other reasonable alternative, no other probable cause-and-effect relationships, to explain the reduction in growth and reduction of total biomass of brown trout in the main Au Sable River, and unless nutrient enrichment occurs again comparable to the 1950's and 1960's, the population dynamics of the brown trout will not dramatically change. Thus, I also agree with the conclusion of Clark and Alexander (1984) that special regulations can have only a very limited effect for significantly altering the paucity of large (12 inches and more) trout in the population and therefore the most important aspect of any regulation on the Au Sable is ... "for their influence on satisfying the desires of different factions within the angling community". Obviously, "satisfying" the "different factions" of anglers will not be entirely possible, but those currently favoring no-kill regulations should understand the limitations of any regulation to significantly improve the fishery, as explained in this present report, so they can make an informed and impartial decision based on the biological evidence.

Studies on the relationships between diet and growth of trout in Michigan by Alexander and Gowing (1976) and comparisons of diet and growth of brown trout in the main Au Sable and the South Branch by Stauffer (1977) are of interest for a better understanding of the reasons for the slower growth of Au Sable brown trout. The density of brown trout in the South Branch was less than in the main Au Sable, but the density of benthic invertebrates was about three times greater in the South Branch. Because most aquatic insects are available to trout predation only while they are in the "drift" (in the water column), the higher the invertebrate density in the bottom substrate, everything else being equal, the higher the density in the drift, which makes more food available per unit area per unit time to feeding trout (that is, a feeding strategy for maximum energy gain and minimum energy loss will result in more rapid growth). The average daily diet of South Branch brown trout was about 20% greater than fish of comparable size in the main Au Sable. This increased feeding resulted in significantly faster

growth in South Branch brown trout, similar to main Au Sable growth in the 1950's-60's (attaining 13-14 inches at age III+). An important point for understanding how changes in feeding rate can change growth rate is the relationship between maintenance rations (the amount of food needed to maintain present weight or "status quo") and growth rations (after maintenance requirements are satisfied, additional food it utilized to increase growth). Only a slight increase in the amount of food available for growth can lead to a substantial increase in growth because maintenance rations are constant in relation to body size and water temperature. For example, if a large trout required 90 grams of food per day for maintenance and had an average daily consumption of 100 grams per day, it would have 10 grams of food available for increased growth (after 90 grams were utilized to maintain the "status quo"). If food items became more available and daily food consumption increased to 110 grams per day it would be only a 10% increase in daily diet, but a 100% increase (from 10 to 20 gms.) in food to be utilized for growth.

The study by Warren et al. (1964) enriching a small Oregon stream with sugar (sucrose) created a bloom of bacterial slime (*Sphaerotilus*, which was probably also produced by sewage effluent in the Au Sable), which was fed on by aquatic insects, particularly chironomid larvae. The increased production of insects led to a two fold increase in feeding by a population of cutthroat trout. However, because this increased feeding was above the maintenance requirements of the trout (i.e. it went into growth), the production of the trout population increased more than seven fold!

In view of a consideration on maintenance and growth rations, it can be understood why only a relatively slight increase or decrease in available food can result in substantial changes in trout growth.

Trout in streams, typically have a limited feeding area, circumscribed by their "territory". Their daily feeding is limited to the amount of food available in their feeding area or passing through it (drift) per unit of time. In the East Branch of the Au Sable, Fausch and White (1981) observed that small brook trout ($<$8 in.) would feed when the density of invertebrate drift was much less than the threshold needed to stimulate the feeding of 8-12 inch trout. This type of observation

suggests that larger trout are at a disadvantage when they must compete for a common food supply with smaller trout, especially at reduced food densities. I suspect that in the "old days" there were more abundant large food items such as small brook trout, sculpins, and crawfish in the main Au Sable which allowed larger brown trout to readily switch their diets to larger prey items, avoiding competition with smaller trout for a common food supply and thereby maintain a much higher proportion of 12-16 inch and larger trophy trout in the population than has been possible since the 1970's. The steady decline of brook trout has been a long term event in the Au Sable. A decline of crawfish and sculpins, although not documented, probably occurred when enrichment ceased and bacterial slimes, algae, and macrophyte vegetation declined.

An event that could have influenced growth in the main Au Sable was the installation of about $250,000 worth of "stream improvement" devices in the 1970's in the Burton-Wakeley section. Although this action was taken to improve the abundance of the trout population, the population continued to exhibit slow growth and a decline of larger trout. The number of younger trout (I, II age groups) did increase, which could have resulted from a combination of reduced angler kill on smaller trout and improved habitat which provided areas of cover promoting survival. The increase in suitable habitat sites may have actually reduced the size of feeding territories thereby exacerbating the problem of lower food density.

With lower growth rates, condition factors ("plumpness" or ratio of length to weight) also declined, so that a 10, 12, or 14 inch trout in the 1970's-80s weighs considerably less than 10, 12, or 14 inch trout did in the 1950's-60's. The lower growth, poorer condition and great reduction in trout of 12 inches or larger has resulted in angler dissatisfaction, frustration, and demands for improvement of the situation leading to the commission now grasping for a straw of improvement with the imposition of a no-kill regulation.

LIMITATIONS OF REGULATIONS

It is incumbent on those who act as spokesmen and advocates for better trout fisheries as representatives of conservation organizations

or the news media to have some basic comprehension of the subject matter so that they may be truly effective leaders contributing toward attainment of a worthy goal. To do so, an understanding of the dynamic forces and interactions of a trout population with its environment is necessary to understand the workings of recruitment, growth and mortality governed by natural factors and the limitations imposed by the environment in relation to man's ability to significantly change life history parameters by regulation of angling. A basic text on the subject that I would highly recommend is Allen's (1951) publication on the Horokiwi Stream, New Zealand. There is no doubt that restrictive regulations to reduce or eliminate angler kill can and do work for many wild trout populations. The danger, however, for the well-meaning angling enthusiast concerns the trap of inductive reasoning -- if it works in stream A, therefore it will work in stream B, C, D, etc. The faulty reasoning leading to erroneous conclusions here involves differences between streams in: 1. species of trout, 2. growth rate and mortality rates, 3. age structure (% of population attaining 4, 5, 6 or more years of age), 4. angling pressure (potential angling exploitation rate) and amount of compensatory mortality involved (how much of angling mortality is compensatory to natural mortality rather than additive--for example, if angling mortality is 80% compensatory, a population with an average of 50% total annual mortality would not show improved survival from year to year unless angling mortality exceeded 40%).

Many types of regulations including no-kill have been instituted in the various states for the past 50 years. No dramatic success stories were apparent for many years and the use of special regulations as a fisheries management tool became to be viewed by biologists and administrators as "people management" rather than fish management . Then in the 1970's, substantial increases in trout populations were documented in the St. Joe River and Kelly Creek, Idaho, and in the Yellowstone River in Yellowstone Park after angler kill was drastically reduced by regulation. There was no reasonable doubt that restrictive regulations were working to achieve, their goal of substantial increase (several fold increase of 5-6-7 year-old fish) of larger trout (Behnke and Zarn 1976). The explanation of this phenomenon concerns the species of trout

involved--the cutthroat trout, Salmo clarki, the species most vulnerable to angling exploitation--angling pressure of only 10-12 hours per acre per year can remove 50% of all catchable-size cutthroat trout from a population, whereas, with brown trout, the most resistent species to exploitation, it requires 300 to 800 hours of angling pressure per year to expect a 50% exploitation rate. Another important aspect to understand why some cutthroat trout respond so well to reduced angler kill concerns their size-age structure in large rivers or lakes. In the above mentioned waters, fish of 5, 6, and 7 years are common in the populations and growth averaged about 3 inches per year. For example 6 and 7 year-old Yellowstone cutthroat trout are 17-18 and 19-21 inches. In such populations, only a slight reduction of annual total mortality can lead to substantial increases of older, larger fish. If total annual mortality is reduced from 60% to 50% per year from ages II through VI annual survival changes as follows:

	number surviving at ages				
	II	III	IV	V	VI
60% mortality	100	40	16	6	2
50% mortality	100	50	25	12	6

If average sizes for these age groups are 14 inches (IV), 17 inches (V), and 20 inches (VI), then the reduction in annual mortality from only 60% to 50% would increase the number of 14 inch and larger trout in this example from 24 to 43; the number of 17 inch trout would double and the number of 20 inch trout would triple per unit area. Perhaps 50 years ago, the Au Sable brown trout population reflected age-growth statistics comparable to the above figures. If they did, undoubtedly regulations reducing angler mortality and total mortality would work very well. Under the present environmental regime of slow growth, virtually no fish of age V or older and very high mortality (90-95%), with or without angler kill, of trout from age III to IV to V, it should be obvious that any type of special regulations can only play a very minor role, at best, to change the present situation.

I could go on with 100 or more additional pages discussing examples of where special regulations have worked and where they have not worked and explain the reasons in terms of recruitment and growth rates, annual mortality rates, and angler exploitation rates, but they all would only emphasize a basic agreement that where the existing environment places severe restrictions on growth and survival to older age classes, no amount of protection from angler kill can change the natural factors determining the life history dynamics of the trout population.

Lawrence Creek, Wisconsin, for many years was subjected to several different regulations in attempts to maximize angling quality of its brook trout fishery. A one mile section was completely closed to angling for a five year period -- at the end of which there were fewer trout than when it was open to angling (Hunt 1970).

Theoretically the range of fishery regulations that could be applied to the Au Sable River ranges from none (anything goes) to complete prohibition of angling. I believe that all anglers would prefer something in-between these extremes. The present debate centers on no-kill vs. some form of limited take regulation. A recent poll by the Michigan DNR (Report to the Michigan Natural Resources Commission on Au Sable River Fishing Regulations, Feb. 6, 1986), found 41% of the respondents favored no-kill and 59% favored some form of limited kill, most preferring the present regulations or something equally liberal. The reasons cited for favoring no-kill regulations were, "will improve quality of the fishing" (N=37) and, "will provide more and bigger fish" (N=35). The reasons opposing no-kill mainly focused on the theme that most of the present anglers fishing the Au Sable practice catch-and-release most of the time and they want to be able to take an occasional trout when they want. Also there was a reaction against "elitist" and "purist" special interest imposing regulations on the local anglers. Apparently, no one expressed doubts if a no-kill regulation would achieve the expected goals of its proponents. The information presented in my report raises this issue of doubt--my conclusion is that under the present environmental regime of the Au Sable which dictates the present growth and mortality rates, a no-kill regulation will not significantly improve the fishery with a substantial increase in brown trout of 12

inches and larger. If a five year test period of no-kill was imposed and its success measured by changes in the number of 12 inch and larger trout at the end of five years, three outcomes are possible--increase, decrease, or no change. Without adequate control sections on the river, however, a valid cause-effect relationship between the no-kill regulation and population change would not be possible. The changes could be attributed to uncontrollable variables such as climate, minor fluctuations in invertebrate populations, etc. Because of the regulations governing possession of trout in a no-kill fishery, alternate no-kill sections and limited take regulations, needed for controls do not appear feasible because boaters moving through a no-kill section with a trout would be in violation. An alternative would be to designate about a one mile section of the river for a complete prohibition of angling and compare any change in size-age structure between sections.

The best that could be hoped for to maintain the greatest abundance of older fish in the population would be to protect the age III trout from exploitation. This could essentially be done by lowering the present lower end of the slot limit from 12 to 10 inches. In any event, in a democratic society, regulations should reflect the wishes of licensed anglers--the greatest good for the greatest number. Leaders and spokesmen for angler groups, however, should become informed on the issues involved--in this case, the biological evidence which reveals the constraints which severely limit the response of the trout population to any regulation. Only then can rationale decisions, based on evidence and not emotion, be made.

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APPENDIX I

THE GENETIC BASIS OF GROWTH: WHY SLOW GROWTH OF AU SABLE BROWN TROUT IS NOT DUE TO ANGLING SELECTIVITY

As discussed in the text, I dismiss the theory of a hereditary change in the Au Sable brown trout population which states that due to differential selection by anglers for the fastest growing fish, a genetic basis for slow growth occurs.

I pointed out that the empirical and common sense evidence refutes all of the assumptions necessary to make the "genetic theory" operate on the Au Sable brown trout.

1. Nowhere in the world has this phenomenon been observed (that is, angler exploitation causing a hereditary change for slower growth) and there are many trout populations, especially cutthroat trout, that have been historically exposed to much higher exploitation rates than the Au Sable brown trout.
2. Under the 12 inch minimum size limit, all brown trout had spawned at least once, some twice, before they could have been removed by the fishery. Thus, any "fast growth" genes had already been passed on to the next generation. If a genetic change could have been operating, it would have occurred in "the old days" under an 8 inch size limit when the fastest growing trout could have been removed before they spawned and exploitation rates were much higher than after 1973. The table in the text (p. 6) shows that during 1974-78, under the 12 inch minimum size limit, when this selection against fast growth is assumed to have occurred, there was an average of 74 age III brown trout per acre in the fall of the year (average size of 11.2 inches) but only 4 age IV trout ($\bar{x}$ 13.5 inches). The mortality between ages III and IV (70 of 74 perished for annual mortality of 95%) was extremely high (essentially, the mortality of 12 inch and larger fish). These figures could certainly lead one to the conclusion that under the 12 inch size limit, the anglers were wiping out the large fish. However, the creel census data for 1974-78 reveals that only about 4 fish per acre of 12 inches or larger were harvested by anglers (6 per acre were caught-and-released). That is, of the total annual mortality of 70 trout per acre between

ages III and IV, from one fall period to the next, only 4 can be attributed to angler kill (6%) the other 66 (94%) were lost to natural mortality. In the light of such mortality data, it is nonsensical to attempt to make a case that the 12 inch limit had changed the genetics by selective angling mortality.

3. I also pointed out that natural mortality factors, especially predators, remove many more fish of any year class than do anglers, even under the most liberal regulations of the "old days". Predators take trout less than 12 inches; thus, there would be strong negative selection against slow growth because slower growth would maintain an individual for a longer period in the vulnerable prey size range.

I suspect, however, that the publication of Favro et al. (1979) of computer simulation of the Au Sable brown trout population, is considered my many present proponents of a no-kill regulation as "scientific proof" that a genetic change for slow growth has occurred due to angler selection under the 12 inch minimum size limit and a no-kill regulation is necessary to restore faster growth. Actually the 12-16 inch slot limit completely protected 12 inch trout and "rewarded" the fastest growing fish which attained 12 inches by prohibition of kill. That is, there should have been selection favoring the fastest growing fish to survive from age III to IV whereas slower growing fish, less than 12 inches could be harvested. The mortality statistics for the 1980-83 period under the 12-16 inch protected slot, show that there was an average of 35 age III trout per acre but only one age IV fish. That is, the mortality of age III to age IV from one fall to the next was 34 (of 35) or 97%, despite complete protection of 12 inch trout. Besides the common sense, empirical evidence that there is no basis to establish a case for genetic change due to angler exploitation, I would point out that the assumptions used in the simplistic model of Favro et al. are obviously false: 1. Growth is determined by two alleles (one "fast", one slow") at one gene locus. 2. There is no selection against slow growth 3. Fastest growing fish removed by anglers before they reproduce. These assumptions are simply false to begin with. The model bears no relationship to biological reality.

Another contribution reinforcing the belief that Au Sable brown trout have a genetically determined slow growth rate (which is due to angler exploitation), concerns a "test" of the genetic hypothesis. In this experiment, young brown trout from the Au Sable, Gilchrist Creek, the Pigeon River, and a domesticated hatchery strain were stocked into four lakes in the fall of 1982 and their growth compared after two years in the lakes (Alexander 1985. Mich. DNR Fish. Res. Rep. No. 1929). After two years, the Gilchrist Creek brown trout had exhibited the fastest growth, an average increase of 9 inches, vs. an average growth increase of 8 inches for the Au Sable trout (in weight, the Gilchrist fish gained an average of one ounce more than the Au Sable fish -- 9 oz. vs. 8 oz.). This experiment reveals that there are genetic differences that caused Gilchrist Creek brown trout to grow slightly faster than Au Sable brown trout in the four lakes (but not without qualifications -- the young trout were not uniform when stocked, i.e. they were not raised under identical conditions; no information was provided on the biotic and abiotic conditions in the lakes influencing growth; the study should be continued to follow the growth and survival through older ages). However, if this genetic basis for slower growth is accepted, no valid cause-and-effect relationship can be made connecting the Au Sable growth rate with angler exploitation. As I pointed out in an article on brown trout (Behnke 1986. Trout Magazine vol. 27 no. 1), the diversity of the brown trout first introduced into this country, and different selective pressures in different environments, has resulted in the present situation whereby no two populations could be expected to be genetically identical. Thus, any genetic differences between Gilchrist and AU Sable brown trout are much more likely to be the result of origins from different ancestors and natural selection in each environment. Considering the low angling mortality rates of Au Sable brown trout, no valid conclusion can be made that angling mortality has caused a genetic change in the AU Sable brown trout resulting in slower growth. The slower growth rates in the 1970's and 80's, however, might be expected to select for earlier maturing fish (sexually mature at smaller size) because so few fish survive past age III, it would be expected that early maturation should be favored. If this is true, then the proportion of sexually mature age II+ (and I+) fish should be higher now than it was in

in the 1950's and 60's. I know of no data allowing for such a comparison, however. But in this case the genetic selection would be caused by the reduced nutrients in the river which caused the slower growth.

Another publication often cited to demonstrate the possibility of selective harvest genetically selecting for slow growth (actually the main selection concerns earlier maturation) is Ricker (1981. Can. Jour. Fish. Aquat. Sci. 38:1636-56). Ricker's study deals with Pacific salmon and commercial exploitation (where exploitation on some stocks reached 80-90%). The trend in some stocks of Pacific salmon exposed to heavy exploitation has been for spawning runs to change to higher proportions of young, smaller fish. This selection is due to the fact that when a year-class of salmon is exposed to an intensive ocean fishery, the less time spent in the ocean, the better chance for survival to spawning. What must be remembered here is that Pacific salmon all die after first spawning -- there is no possibility to spawn before being taken in the fishery as was the case with the Au Sable brown trout under the 12 inch size limit (all spawned before any were taken, and the angler "take" was a minor fraction of their total mortality). Thus, any salmon taken in a fishery has had no chance to pass its genotype on to the next generation.

Although I can find no evidence to support the "genetic" theory of slow growth, to those who continue to support the idea, I would point out that a slot limit (or a maximum size limit) could work to favor or reward fastest growing fish and negatively select against slower growing fish by allowing their take in the fishery.